Proceedings:

North American Forest Insect Work Conference

Metamorphosis: The Forces of Change

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PREFACE

The North American Forest Insect Work Conference (NAFIWC) is the conclave of the forest entomology community. The conference is scheduled on a five-year cycle and is intended to provide a forum for discussion of contemporary issues in forest entomology. The agenda is broad-based and includes topics relating to research, development, application, and education. The ’06 conference theme was Metamorphosis-forces of change in forests. The goals of the conference were (i) to address the issue of change in the diverse subjects addressed by and associated with forest entomology and (ii) identify the critical issues where emphasis should be directed in the near future.

The NAFIWC draws together forest entomology professionals, practitioners, and students from North America: US, Canada, and Mexico. It serves to integrate and unify the annual regional conferences: the Southern Forest Insect Work Conference, the Western Forest Insect Work Conference, the North Central Forest Pest Management Work Conference, and the North Eastern Forest Insect Work Conference. Participants in the NAFIWC include representatives from the USDA Forest Service, the Canadian Forest Service, State and Provincial forestry organizations, universities, NGOs, and industry. It is the only conference where the full complement of forest entomologists assembles to discuss the state of their enterprise.

The ’06 conference featured plenary sessions in which invited speakers provided their insight into issues of change in forest ecosystems and in the science and practice of forest entomology. The major emphasis of the meeting was moderated concurrent workshops dealing with topics that embrace the scope and bounds of forest entomology. The stakeholder community was asked to identify specific agenda topics. Each workshop concluded with a group discussion of research, development and application needs within the specific topic area. At a final facilitated group session, participants discussed these identified needs within the context of several major topic areas and identify critical issues to be addressed in the near future.

There have been three previous iterations of the NAFIWC: 1991 in Denver, CO, 1996 in San Antonio, TX, and 2001 in Edmonton, Alberta, Canada. Each conference featured a robust agenda that encompassed the traditional subjects entertained in forest entomology but, in addition, considered issues of contemporary importance. The principal benefit of the conferences was information exchange, which was accomplished through plenary addresses, workshop presentations and discussion, and social interaction among the participants. The accomplishments of the conferences were captured in published proceedings. Participation in the conferences has ranged from ca 275 to 375 registrants.

The forest entomology community formulated the program, so the various workshops and plenary addresses *defacto* provide a coarse overview of the issues of contemporary interest and importance. The program consists of 28 workshops which are grouped into six tracks: invasive insects (6), management and silviculture (3), scales and interactions (4), change (5), direct tactics in forest insect management (7), and biodiversity and natural heritage (3). Each workshop had a Moderator who was responsible for organization. Typically, several individuals were asked to make a presentation on an important aspect of the subject at hand. Each workshop speaker identified critical issues associated with the subject of their presentation. The Moderator compiled a list of critical issues identified in the workshop. “Track Coordinators” were designated for each of the six tracks. They compiled, integrated, and synthesized the critical issues identified in the workshops within their track. At the conclusion of the conference, each Track Coordinator presented the results to the meeting at large for discussion and commentary. The results of this activity are presented at the end of these Proceedings. The following Proceedings are organized by the six tracks.

PLENARY ADDRESSES

Forces of Change: One State Agency's Perspective

Ronald F. Billings, Texas Forest Service, College Station, TX 77840

Forest pest management, from the perspective of southern state forestry agencies, has changed in recent years. The author discussed responsibilities and challenges facing a state forest pest specialist, based on his 33 years of experience as principal entomologist with the Texas Forest Service (TFS). Texas, the second largest state in the union, has a diversity of ecological regions, vegetation types, and forest pest challenges. The TFS Forest Pest Management (formerly Forest Pest Control) Section was established in 1962 specifically to address an outbreak of the southern pine beetle (*Dendroctonus frontalis* Zimm.) in the 12 million acres of native pine forests of eastern Texas. Pest problems have grown in number and complexity in the last 24 years to include seed orchard insects, regeneration weevils (*Hylobius* spp., *Pachylobius* spp.), Nantucket pine tip moth (*Rhyacionia frustrana* (Compstock)), leaf-cutting ants (*Atta texana (Buckley)*), various insect defoliators and fusiform rust (*Cronartium fusiforme* Hedg. & Hunt ex Cumm.) in east Texas. In central Texas, the major pest problem affecting live oaks and red oaks in 60 counties is oak wilt, caused by the vascular fungus *Ceratocystis fagacearum (Bretz) Hunt*). Abiotic agents such as wind and ice storms, hail, floods, and drought have also affected forest health in Texas. In response to these increasing challenges, the FPM staff has grown in size, from one forest entomologist in 1962 to three entomologists, one pathologist, and ten multi-program foresters in 2006. Major forces of change affecting all southern forestry agencies include increasing human populations, urbanization and land fragmentation, an influx of invasive non-native plants, insects and diseases, increasing emphasis on urban forestry and the value of urban trees, loss of forest industry lands to timber investment groups (including a reduction in wood-processing mills), reduced levels of state funding, increased pest outbreaks and adverse weather events (due to global warming?), and a large number of experienced forest entomologists and pathologists approaching retirement, with few students to replace them. TFS has addressed these new challenges by means of several innovative approaches. The Western Forest Pest Management Cooperative was established in 1996 to address forest pests in seed orchards and young pine plantations. Membership dues from 8-9 forest industries and government agencies support an applied research program. Partnerships have been established and volunteer groups trained to better manage oak wilt in central Texas and invasive plants throughout Texas. The East Texas Forest Entomology Seminar, initiated in 1973, continues to provide a forum for forest entomology researchers, teachers, graduate students, and pest managers from Texas, Louisiana, Arkansas and Mississippi to present new research and discuss current pest problems. Also in recent years, specific Internet web pages have been established to provide information and increase public awareness of oak wilt (http://www.texasoakwilt.org) and invasive plants (http://www. texasinvasives.org) in Texas. In summary, TFS is meeting increasing forest health challenges through cooperative programs and partnerships. These involve the USDA Forest Service, forest industry, private and government research organizations, non-profit environmental organizations and interest groups, communities, cities and a myriad of urban and rural private landowners.

International Perspective on Forces of Change in North American Forests

Werner A. Kurz, Natural Resources Canada, Canadian Forest Service

Forests in North America have historically been subject to wildfire, insects, windthrow and other natural disturbances. Changes in disturbance regimes (type, frequency and intensity of disturbance) bring about changes in the forest age-class structure and in many ecological processes. There is increasing evidence that global change is already affecting fire and insect disturbance regimes in North America and projections indicate that the impacts of global change will intensify. Forests will be affected by climate change but they can also play a role in mitigating atmospheric greenhouse gas increases.

North American forests are currently acting as carbon sinks, and are thus slowing the rate of increase of greenhouse gas concentrations in the atmosphere. Their future net balance of greenhouse gas emissions and removals will depend to a large extent on future disturbance regimes. Increases in the area and intensity of wildfire, insect range expansions and increases of the severity of insect outbreaks, droughts, and windstorms will diminish the potential of forests to act as carbon sinks and can turn forests into carbon sources. This would provide positive feedback to atmospheric greenhouse gas concentrations. Research and models that project future forest conditions and management impacts upon them can assist land managers in developing mitigation and adaptation strategies to better cope with forces of change in North American forests.

Critical issues include:

1. How will the interaction of climate change, forest management and natural disturbances affect forests?
2. Will forests provide positive feedback to climate change?
3. What role can forest management play in mitigating climate change and in adapting to it? and
4. There is a need for improved systems for monitoring and projecting insect impacts on forest ecosystems.

Global Forestry Issues: Implications for the Future of Forest Entomologists.

Michael R. Wagner, Regents' Professor, School of Forestry, Northern Arizona University

The practice of forestry is undergoing major changes on a global scale. Expectations for an array of environmental services and non-traditional uses of forests are dramatically increasing while traditional wood use remains high. Major international efforts are underway to develop and implement sustainable forestry practices. Legally binding agreements, forest product certification and international trade are forcing the major forest landowners to approach forest management in novel ways. Add to changing societal needs the effects of global climate change and invasive species and many new challenges emerge. Forest entomology, as a discipline long rooted in and essential to successful forestry, must respond to this changing landscape.

Five major global issues affecting forestry are discussed. Each issue is reviewed from the perspective of how it will likely influence the practices of forest entomology. Major global forestry issues include: 1) global climate change, 2) invasive species, 3) sustainable forest management, 4) globalization and 5) societal values and forests. Global climate change may be the environmental issue of the 21st century. Of major concern to forest entomologists is the recognition that global climate change will result in stressed forest ecosystems at the species range boundaries created by elevation and latitude. There will also be significant political and economic impacts of global change including the US participation in Kyoto Protocol and an increase in industrial plantation forests and associated forest insect pests.

Invasive species is a topic that continues to dominate the agenda of many forest entomology conferences. Invading species will cause native species to go extinct, will simplify ecosystems and increase pest problems. Management response may include introducing even more exotic species, including forest plantation species, to compensate for this loss.

Sustainable forest management has emerged as one of the most important new concepts in global forestry. The focus is no longer on the traditional sustainability of forest products but rather establishing criteria and indicators of sustainability to meet international political standards. Implications to forest entomology includes a need for our profession to manage for biodiversity of insects and improve methods to survey pest damage. Additional research on insects as ecological indicators will be needed.

Globalization of the forestry sector means that the US, which is the world's top industrial roundwood producer, will have to meet international standards of sustainable production through forest certification. The global shift to increased wood fiber production from plantations could have profound impacts on where and how wood fiber is produced. Forest entomologists could be increasingly involved in international activities related to enhanced plantation productivity.

A major global issue is the changing societal attitudes about forests. Global society is gradually beginning to recognize that environmental services provided by forests are valuable and mechanisms for assessing that value and making economic transfers from producers to consumers of environmental services is possible.

In summary, many aspects of forestry are changing around the globe. These changes will profoundly impact our profession of forest entomology. Rest assured, however, that there will be plenty of work for our profession. The future of forest entomology may be more international and more focused on the role of insects in impacting non-traditional forest goods than services than any of us have imagined.

Critical Issues Identified in Plenary Lecture

By Michael R. Wagner

1. Global climate change and other factors will increase the area of industrial plantation forests and create a critical need for more training, research and IPM strategy development for intensively grown forest plantations.
2. The adoption of sustainable forest management criteria and indicators requires more emphasis on managing forest insects to enhance biodiversity and the development of more indicator species that can be used in monitoring forest ecosystem function.
3. Globalization will result in increased demand for wood and non-traditional wood products. There is a critical need for better understanding for how forest insects will influence the trade-off in forest uses.
4. Changing societal attitudes and values about forests mean forest entomologists will need to adopt environmental services valuation methods to assess forest insect impacts
5. Forest entomology curricula and training will need to incorporate more international and non-traditional forest products perspectives than has historically been the case.

Forces of Change: Academic Perspective

Fred P. Hain and the Future Directions Committee, NCSU Department of Entomology

Entomology and entomology departments are changing throughout the country. Some of the smaller departments have dissolved or merged with other departments into larger multi-discipline departments. But beyond this all entomology departments are, or will be, undergoing change.

By its nature, entomology is a taxon-based discipline, which has as its unifying element a focus on insects and related arthropods. The roots of entomology lie in the tradition of natural history; however, the identity of entomology as a discipline and the existence of entomology departments as administrative units within land grant universities are related to the importance of insect-related problems and to the land grant mission. Scientifically, entomology is an integrative discipline; it has a rich tradition of contributing to and drawing from many fundamental scientific disciplines. However, the identity and success of entomology as a discipline has been defined primarily by the successful application of science and technology to solving insect-related problems. Solving problems and contributing significantly to fundamental science are defining themes for entomology.

The importance of agriculture as a percentage of US gross domestic product and as a source for employment has declined dramatically over the last 20 years. During that period, the technology, biotechnology, and medical sectors of the economy have grown dramatically. During this period, the proportion of the population living in urban and suburban settings has increased dramatically while the proportion living in rural settings has declined dramatically. Accompanying this shift has been a decline in the political influence of the rural constituencies traditionally served by departments of entomology. In response, state and federal governments and land grant universities have been diverting resources away from traditional areas to fund the basic life science (e.g. biomedical sciences, molecular genetics, and bioengineering) and applied areas that more directly reflect changing constituencies and new funding realities. In conjunction with the aforementioned trends, population growth and the accompanying increase in number of undergraduates is creating the need for greater faculty involvement in undergraduate teaching. All indications are that these trends will continue. Within this context, it seems that for an entomology department to maintain its primary focus on solving agricultural insect problems is a sure path to irrelevance and extinction within the university. Similarly, an exclusive focus on basic research to elucidate fundamental processes is a sure path to loss of departmental identity and with it the justification for maintaining a stand-alone department of entomology within the university. Finally, by actively participating in undergraduate teaching entomology departments have the opportunity to enhance their identity and relevance within the university.

If departments of entomology are to thrive they must:

- Expand the applied mission beyond traditional agriculture to reflect the changing demographic, economic and political realities;
- Enhance their reputation as a vital contributor to the basic research, teaching and outreach mission of the university;
- Maintain a graduate program in entomology to ensure programmatic identity within the university; and
- Participate actively in teaching undergraduate courses, including distance education, courses that meet the needs of the university.

To accomplish this, departments will have to maintain an effective balance in its commitment to fundamental and applied research, extension and teaching, in a way that satisfactorily meet their responsibilities to a diverse array of stakeholders. Core areas of research and teaching should include:

- Agricultural Entomology and Pest management
- Urban and Public Health Entomology (including forensic entomology)
- Biodiversity and Natural Resource Entomology (including forest entomology and aquatic entomology, which are not mutually exclusive).

Forest and water resources are critical to the country's future. Timberlands, in many states, support a large manufacturing industry. Parks and wilderness areas support the large and growing tourism and recreation industries. It should be pointed out that the emphasis in forest management practice is shifting from an emphasis on extraction of forest resources for human consumption to one of maintenance of health and sustainability of the forest environment. In other words, resource extraction is considered in the context of overall forest health and sustainability. Forests are vital to the health of the country's environment, including its fresh water, and wildlife habitat. Healthy aquatic systems are not only vital to maintaining an adequate supply of fresh water but also constitute a valuable resource for tourism and recreation. These systems are being threatened by development and the demands of our growing population. The programmatic areas of forest and aquatic entomology offer great opportunities for departments of entomology to address important stakeholder needs and to address important issues in natural resource management and environmental health. Both areas are rich in opportunities to enhance the graduate program in a number of areas of basic and applied importance.

For example, exotic pest introductions are occurring at an unprecedented rate. Examples of the forest health crisis that we currently face include the Asian longhorned beetle, the emerald ash borer, the hemlock woolly adelgid, the balsam woolly adelgid, gypsy moth, and Sirex wood wasp. In addition, new hosts of endemic pests are also evolving as our forests change and are subjected to various disturbances. The red oak borer, a previously innocuous native insect, has suddenly become a tree killer in the Ozarks. Southern pine beetles and mountain pine beetles may be expanding their host and geographic range, perhaps due to global change.

My take-home message is that natural resource entomology (forest and aquatic entomology) is a critical area of research and teaching in a well-balanced entomology department at a land grant university. A significant group of stakeholders in our society will be looking to departments of entomology for answers to some very serious questions. Too many times, in recent years, I have heard colleagues of my generation (the baby boomers that are about to retire) say that they did not think they would be replaced with another forest entomologist when they retired. My charge to you is don't just walk away from your careers. Convince the decision makers in your respective departments, colleges and universities of the great importance on natural resource entomology (forest and aquatic entomology) to society. The ball is in your court!

National Perspective on Forces of Change in North American Forests and Forestry

Peter J. Roussopoulos, Director, Southern Research Station, US Forest Service

The ground is shifting under our feet. We are currently experiencing dramatic changes, both internally and externally. Globalization and other forces are bringing about many changes in forest industry. We are seeing broad changes in who owns the land and what they want to do with it. Fiscal pressures are causing many changes in government and academia, and changes in our environment are affecting what we need to know. Driven by many of these changes, the Southern Research Station is implementing a major change in how we are organized. In March of this year we began to realign our Work Units and have reduced the number from 28 to 15. The units are now grouped by science areas, one of which is focused on threats to forest health. We intend this new alignment to better enable relevant, credible science that better integrates our efforts across disciplines and institutions to address the large, complex questions surrounding sustainability in a rapidly changing world. Involvement of our customers and research partners will be important to us as the programmatic details of this new order are being designed. We have always valued your collaboration in the forest insect research community. We need you now to help us be even stronger partners in the future.

Forces of Change, CSREES Perspective

Rick Meyer, National Program Leader for Entomology

The future focus on issues and opportunities in forestry research, education and extension with particular implications for forest entomology and ecology are presented within broad areas encompassing the scope of work supported by the Cooperative State Research, Education and Extension Service of the United States Department of Agriculture. Key issues facing forestry and forest entomology include ecosystem fragmentation, and land conversion, a framework for deciding, assessing and evaluating sustainable resource management and methods for valuation of ecosystem services. Detecting, identifying, assessing and responding to invasive and resurgent pests and diseases and development of decision support tools to manage these threats will be an important focus for research, education and extension. A changing natural resources workforce will be addressed through the diversity of our programs designed to reach a diverse public clientele, including underserved groups such as small and limited resource landholders. New or renewed emphasis will be placed on development of forest genomics and biotechnology, development of nutriceuticals and biochemicals including the expansion of efforts directed toward woody biomass conversion and utilization. Research and practical implications of the role of carbon cycles and pools and forest health monitoring continue to be a priority.

A brief overview is provided for CSREES funds by program focus areas for the forestry-related research/extension portfolio. CSREES supports both formula-based and competitively awarded research, education and extension programs and also provides administrative support for congressionally mandated earmarked funds. Major topics with implications for forest entomology highlighted in this presentation included: management and sustainability of forest and range resources, management and control of forest and range fires, urban forestry, agroforestry, aquatic and terrestrial wildlife, and conservation of biological biodiversity.

Administrative and management directions for the future which have high priority for CSREES include an emphasis on multi-state or multi-functional research, education and extension, increased emphasis on competitively awarded grant funding, equitable support for 1890 land grant institutions and full incorporation and inclusion of 1994 institutions (tribal colleges) within our programs. CSREES seeks broad involvement of diverse stakeholders in strategic planning and priority setting, a continued improvement in program accountability and strengthened coordination between FS & CSREES.

Forces of Change: Forest Industry Perspective

R. Scott Cameron, International Paper

Commercial forestland ownership patterns in the United States have changed dramatically in recent years, which will significantly alter land management strategies as well as the impact and management of forest pests. The traditional approach to forest pest management by forest industry companies is to support cooperatives and special projects addressing issues of clear and urgent concern, relying on government agencies and university scientists to conduct more basic research. Relatively few forest entomologists have been hired by forest industry to work exclusively on forest pest problems, and most have had relatively short assignments. International Paper has supported a forest health program for at least 25 years, with fusiform rust, pitch canker, southern pine beetle, and the Nantucket pine tip moth being the primary problems of concern. However, many other forest health related issues have been addressed including seed orchard and nursery pests, seedling mortality, hardwood pests, import/export regulations, invasive species, and pesticide application technology, registrations, and regulations.

Forest industry companies usually do not direct funds towards pest management unless a clean and present economic benefit or threat is perceived. Expenditures must promise an acceptable return on investment and it is difficult to sell prevention of unpredictable damage losses when other programs, such as genetics and silviculture, are justified on the basis of relatively predictable added growth and product value. Pine tip moth management has been recognized as an important opportunity to improve growth in loblolly pine plantations since research has documented significant losses in growth and form, as well as lost opportunities from other silvicultural treatments when damage is heavy.

Traditional forest industry companies have played an important role in the U. S. economy and have contributed significantly to forestry research, establishment of productive timberlands, and they have demonstrated a commitment to good stewardship of the lands they own. However, the global economy, strong off-shore competition, unfavorable tax treatment, declining profitability, and an apparent abundant fiber supply have driven many U. S. forest industry companies to restructure through mergers, consolidation, specialization, land sales, and foreign investments.

There has been an extraordinary shift in industrial timberland ownership in recent years, especially in the U. S. South, from traditional C-corporations to tax-advantaged entities including TIMO's, REIT's, and private landowners. These new landowners have a diversity of land management objectives, often with shorter time horizons, and are prone to reselling land for the "highest and best use," which will lead to further fragmentation of forest timberlands. This change in forestland ownership will undoubtedly lead to even less private investment in forest timberland R&D, especially for pest management.

The massive movement of materials and products associated with our global economy has brought about an escalating invasion of exotic pests. Anther pivotal recent development is the skyrocketing cost of energy and fuel, which together with the rapid development of new technologies has opened the door to future production of biomass and biofuels from wood residues and trees grown in intensively managed plantations.

Fragmentation of forestland ownership, exotic invasive pests, intensive plantation management, clonal forestry, and climate change are creating an onslaught of new and more complex forest pest management challenges, which we are increasingly unprepared to handle. However, this situation will lead to new opportunities for employment, partnerships, and innovative solutions facilitated by scientific discovery.

Key issues for forest pest management from an industrial perspective include:

- Urbanization and fragmentation are serious threats to timber production and the future of forest industry.
- Tax law and other drivers have led industry to divest of most of their timberlands.
- Industry's forest research capacity has been significantly diminished through mergers, consolidation, and land sales.
- Investor ownership will lead to additional fragmentation.
- The global economy and associated commerce will continue to strain our ability to prevent and deal with new pest introductions.
- Biomass and biofuel production have the potential to cause a major resurgence in intensive forest management.

INVASIVE INSECTS

Invasive Insects and Forest Community Structure

Moderator: Tom Coleman, University of Kentucky

A Changing Landscape: Predicting Future Forests Following Catastrophic Losses To Southern Pine Beetle And Associated Disturbance.

Tom W. Coleman and Lynne K. Rieske-Kinney
University of Kentucky, Department of Entomology

Introduction

Mortality events from the endemic southern pine beetle (SPB), *Dendroctonus frontalis* Zimmermann, continue to impact pine forests throughout the southeastern U.S. Unfortunately, the duration between outbreaks has decreased, whereas the scale of outbreaks has increased (Clarke and Billings 2003). Fire suppression, urbanization, and agricultural conversion have altered forest structure and reduced historically dominant longleaf pine communities, leading to an increase in the prevalence and dominance of SPB-susceptible loblolly pine (Landers et al. 1995; Baker and Langdon 1990).

In spite of a wealth of knowledge on SPB biology and ecology, we have only a minimal understanding of the mechanisms by which SPB and associated disturbances influence forest composition and succession. We examined woody vegetation composition following large-scale mortality from SPB in loblolly and shortleaf pine stands in the Western Gulf Coastal Plain and on the Cumberland Plateau. Our research encompassed several aspects of SPB disturbance in multiple geographic locations, including 1) SPB-caused mortality, cut-and-leave suppression, and undisturbed loblolly pine stands in east Texas, 2) cut-and-leave suppression with subsequent wildfire in loblolly pine stands in a Louisiana wilderness area, and 3) SPB-caused mortality coupled with prescribed fire management in shortleaf pine and shortleaf pine/ oak stands of eastern Kentucky.

Methods

Vegetation measurements and plot data followed the Common Stand Exam protocols of the USDA Forest Service. Canonical correspondence analysis was used to assess patterns among woody plant vegetation assemblages, environmental variables, and disturbance regimes (ter Braak 1986, 1988). Current vegetation data was used to depict future forest composition 50 years into the future using the southern variant of the Forest Vegetation simulator (USDA Forest Service 2001).

Results

1) <u>SPB, cut-and-leave, and undisturbed loblolly pine.</u> In east Texas, vegetation composition was primarily explained by plot aspect and elevation, not the disturbance regimes. Species commonly found in mesic areas were associated with northern slopes and low elevation,

Table of Contents

whereas vegetation tolerant to xeric conditions were associated with southern slopes and higher elevations. Loblolly pine was associated with xeric plots. SPB disturbed plots were associated primarily with hardwood regeneration. White oak, red maple, sweetgum, and hophornbeam were related to the SPB disturbance. Undisturbed loblolly pine separated from the SPB disturbance, depicting a shift from initial pine-dominated stands. Vegetation in the cut-and-leave plots were associated with shrubs and vines commonly found in open-canopy forests, including summer grape, American beautyberry, and devil's walking stick, with minimal loblolly pine regeneration. Modeling predicted a shift from pre-disturbance loblolly pine to predominantly mixed upland hardwood communities, comprised of oaks, red maple, hickories, sweetgum, and loblolly pine. Mixed upland hardwood was the major forest type predicted in stands with SPB caused mortality (80%), cut-and-leave suppression (60%), and no disturbance (50%). Undisturbed loblolly pine stands also maintained a dominant and co-dominant pine component (45%) following 50 yr of succession. In Texas, the predicted loblolly pine basal area following SPB and cut-and-leave mortality represent a low hazard to future SPB disturbance (Hicks 1980; Mason et al. 1985).

2) Cut-and-leave with subsequent wildfire in loblolly pine. Vegetation composition in Louisiana followed similar trends; elevation, slope position, and moisture gradients were the primary determinants of woody plant composition. Shrubs, vines, and scrub oaks were related to plots with cut-and-leave suppression and two wildfire events. Shrubs were associated with stands disturbed only by a high-intensity fire two years after cut-and-leave; whereas loblolly pine, longleaf pine, red maple, and southern red oak were associated with plots receiving a low-intensity fire 15 years after cut-and-leave. Stand age at the time of cut-and-leave also influenced plant composition. Loblolly pine, red maple and sweetgum were linked to younger stands, and shade-tolerant hardwoods, including American beech and southern magnolia, were associated with older stands. Loblolly pine dominated the predicted forest types in cut-and-leave suppressed stands (75%), and in pine stands with only wildfire disturbance (77%). In Louisiana, pine stands with cut-and-leave and subsequent fire are predicted to be a moderate hazard to SPB (Hicks 1980; Mason et al. 1985). Fire appears to facilitate loblolly pine seedling establishment and remove competing vegetation for loblolly pine regeneration.

3) SPB-caused mortality and prescribed fire in shortleaf pine. In shortleaf pine and shortleaf pine/ oak stands in Kentucky, hardwood forest types dominated model predictions with and without fire (83% and 92%, respectively). Regardless of the initial forest type, forest composition shifted to white oak/ red oak/ hickory dominance, independent of the use of prescribed fire. However, preliminary results suggest that prescribed fire aids pine regeneration.

Discussion

In all regions, the mix of pine- and hardwood-dominated communities across the landscape resulting from SPB and associated disturbances represents areas of increased biodiversity, and should inhibit future large-scale SPB infestations. It appears that cut-and-leave suppression may initially influence the forest microhabitat much differently than SPB caused mortality, thus causing differences in vegetation succession. The critical issues surrounding revegetation dynamics call for continued research on the extent to which biotic and abiotic factors influence stand succession following catastrophic disturbance, and incorporation of this knowledge into forest management practices.

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Interacting Effects Of Geological Substrate And An Invasive Scale (Beech Bark Disease) On Tree Species Composition And Nitrogen Cycling

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The northeastern U.S. receives high rates of nitrogen (N) deposition, with potential consequences for forests and downstream ecosystems. A 17-fold variability in N concentration in streams of the Catskill Mountains (Lovett et al. 2000), however, do not reflect variability in rates of deposition; rather, differences among watersheds in tree species composition result in varying rates of N cycling and concentrations of N in streamwater

(Lovett et al. 2002). We studied N cycling in single-species stands in the Catskill Mountains and found significantly higher rates of nitrification in stands dominated by sugar maple, compared to stands dominated by other species common in the northern hardwood forest (Lovett et al. 2004). Of particular interest is the difference in N cycling between sugar maple and American beech because of the potential for the exotic pest (the beech scale insect, *Cryptococcus fagisuga)* to infest northern hardwood forests and cause the selective mortality of American beech, whose thin, smooth bark makes it susceptible to the scale and the subsequent invasion by the *Neonectria* sp. fungus. In stands where the beech bark disease (BBD) effectively eliminates American beech, sugar maple may replace beech, resulting in higher rates of nitrification and greater losses of N as nitrate through soil leaching. We established a study with varying levels of beech mortality resulting from BBD. We found that nitrification strongly mirrored sugar maple presence in the leaf litter, corroborating our previous results demonstrating that sugar maple has higher rates of nitrification than beech, and extending our results to show that shifting species composition from beech to sugar maple results in increasing rates of nitrification. The single-species study, described above, also demonstrated that single-species stands of sugar maple tend to occur on sites with higher soil calcium (Ca) than beech stands (Arthur et al., unpublished), suggesting a potential link between soil Ca availability and the successional outcome of BBD infestation. Thus, we have hypothesized that high Ca sites may be more likely to experience a shift in species composition from beech to sugar maple in the face of BBD mortality, whereas low Ca sites may be more likely to regenerate as beech stands. Current research addresses this hypothesis. Ecosystem consequences of forest insect pests and pathogens are likely to depend on a range of factors and reflect complex interactions at the ecosystem scale. Recent advances in our understanding of the linkages between invasions and ecosystem response enabled us to develop a model framework for assessing the key factors of the pest or pathogen and of the host tree species that may be useful in predicting shifts in species and changes in forest ecosystem characteristics (Lovett et al 2006). In developing priority areas for future research, we suggest the need for enhanced understanding of the basic biological functioning of insects, pathogens and trees, including their response in an environment of global change; increased understanding of the interactions between insects/pathogens, their host trees, and ecosystem processes; and increased funding for rapid response to teams of scientists across multiple disciplines.

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Rising From The Ashes: What Might We See After Emerald Ash Borer?

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Emerald ash borer (Coleoptera: Buprestidae) (*Agrilus planipennis* Fairmaire) was identified as the cause of widespread mortality of ash trees (*Fraxinus* sp.) in southeast Michigan and Essex County, Ontario in July 2002. Additional populations of emerald ash borer (EAB) have since been found in other areas of Michigan, Ohio, Indiana and Illinois (www.emeraldashborer.info 2006). Emerald ash borer (EAB) is native to China, Korea and other Asian countries (McCullough and Katovich 2004), but at the time of its discovery, little was known about the biology or behavior of this phloem-feeding insect (Cappaert et al. 2005).

EAB life cycle: Studies in Michigan have shown that adult EAB are active from late May through August. Beetles feed on ash foliage for at least a week before mating, then females typically feed for at least another week before they begin to lay eggs. Each female can lay 50-60 eggs during her 3-6 week life span. Eggs hatch within one to two weeks and larvae tunnel through the bark and feed in the phloem. Tree size does not appear to affect host selection; trees ranging from 1 inch to 60 inches in diameter have been attacked and killed by EAB. Larvae generally begin feeding in late July and continue to feed and develop through September and October. Most overwinter as prepupal fourth instar larvae in cells excavated roughly 0.5 inches into the sapwood or in the thick, outer bark of large trees. Pupation occurs in spring and adults begin to emerge in May. Recent observations have shown that some larvae require two years of feeding for development. This extended development seems to be most common on relatively healthy trees and in areas with low densities of EAB (Cappaert et al. 2005, Siegert and McCullough, unpubl. data).

EAB hosts: Galleries excavated by EAB larvae in the phloem disrupt translocation, leading to canopy dieback and eventually tree mortality. An estimated 15 million ash growing in forested, rural and urban settings in southeast Michigan have been killed by EAB. Studies are underway to evaluate host preference and host selection behavior of adult beetles. All species of ash in southeast Michigan, however, have been colonized and killed by EAB. Green ash (*F. pennsylvanica*) and white ash (*F. americana*) are common hosts of EAB in forest and urban sites, but black ash (*F. nigra*), blue ash (*F. quadrangulata*) and pumpkin ash (*F. profunda*) have also been attacked.

Characteristics of ash species: Ash trees occupy a wide range of soil and site conditions, but their ability to persist and regenerate in areas with high densities of EAB is unknown. Characteristics of ash species described by Burns and Honkala (1990), MacFarlane and Meyer (2005) and Poland and McCullough (2006) are summarized below.

Green ash is distributed across much of the eastern and central U.S. It is often regarded as a pioneer species and is relatively intolerant of shade throughout its life span. Green ash tolerates heavy, poorly-drained soils and is often found in riparian areas or on other periodically wet sites with lowland hardwoods such as American elm (*Ulmus americana*) and cottonwood (*Populus deltoides*). Green ash produces seed crops in most years once trees reach 3-4 inches in diameter (Kennedy 1990). White ash is also widely distributed and is the most economically valuable ash. It is often found in mixed stands on fertile upland soils. Seedlings are tolerant of some shade, but become less tolerant with age and require substantial amounts of light to reach the overstory. Seed years occur at three-year intervals and most seed is produced by trees that are 8-10 inches in diameter or larger (Schlesinger 1990). Black ash occurs occasionally in southern Michigan but is most common in swamps, bogs and riparian areas in northeastern states and Canada. It is highly intolerant of shade and because of its habitat, growth is typically slow. Seed years occur at 7-8 year intervals (Wright and Rauscher 1990). Blue ash is predominantly found in the central Midwest, although some stands and woodlots in southeastern Michigan have a sizeable component of blue ash. It is shade intolerant and grows rapidly. Studies to-date indicate that is may be less preferred by EAB than other native ash species (Anulewicz et al. 2006), but it has been colonized and killed by EAB. Pumpkin ash is a state-listed threatened species in Michigan and is found primarily on wet sites with heavy soils. Like blue ash, it is shade intolerant. Seed is generally not produced until trees are at least ten years old (Harms 1990).

Ash mortality: Results from previous or ongoing studies have shown that EAB can colonize and develop on the native ash species it has encountered (Anulewicz et al. 2006). Density of EAB can build rapidly and once larval densities reach 80 to 100 larvae per m^2, trees are likely to succumb (McCullough and Siegert, unpubl. data). Data collected from 30 forested sites in southeastern Michigan by Ohio State University scientists have shown that ash mortality is largely determined by how long a stand has been infested and the EAB density in the stand (A. Smith and D. Herms, OSU, unpubl. data). Site or stand factors such as ash tree size, age, basal area or related variables appear to have little effect on tree mortality rates. Over time, as ash trees in a given site die, phloem availability drops and the EAB population presumably collapses to a much lower density (Siegert et al. 2006).

Ash seed bank: Whether ash will persist as an overstory component in areas where EAB has become established will depend on the ability of ash to regenerate after the initial wave of EAB-induced mortality. Ash regeneration depends, in part, on the abundance and persistence of ash seed. Based on observations to-date and data collected by OSU scientists, EAB is likely to kill many ash trees before they are old enough or large enough to produce seed. Trees such as black ash, which only produce seed at 7-8 year intervals, may be especially vulnerable to long-term impacts from EAB.

The ash seed bank may contribute to ash regeneration following widespread ash mortality. In August 2005, we cooperated with Dan Herms and other Ohio State University scientists to sample the ash seed bank in nine forested sites with abundant overstory ash. Ash seed generally matures and falls in late summer or autumn, but in 2005, we observed virtually no ash seed on trees in these sites or on trees across most of southern lower Michigan. Therefore, ash seed collected in our samples represented seed produced in previous years.

We used a slide hammer to collect soil samples in 3 white ash, 3 black ash and 3 green ash sites, all located 10 to 30 miles from the core of the EAB infestation in Canton, Michigan. Soil samples were 4 cm in diameter and 10 cm deep and were collected from four locations in each of three plots located in each of the nine sites. At each sample point, we collected one sample from the upper 10 cm of soil (including litter and organic horizons) and a second sample from the next 10 cm down (total of 216 soil samples). Samples were allowed to dry, then sieved. Ash seeds were retrieved and tested for viability using a pressure test and a tetrazolium (TZ) stain.

Overall, there were 52 ash seeds recovered from the 216 soil samples and 46% of the seeds were viable. Nearly all of the seeds (85%) were found in the upper 10 cm samples. Sixty percent of the seeds were collected in white ash sites, but 28 of the 31 white ash seeds came from a single site. Forty-eight percent of the white ash seeds were viable. In the green ash sites, we collected 18 seeds (35% of the total) and 44% were viable. Only three black ash seeds were collected and only one seed was viable. Although we were pleased to see the generally high viability of ash seeds, the patchy distribution of seed of all species and the relatively few seeds collected from the black ash sites warrant concern. These results are, of course, preliminary and additional sampling to characterize the ash seed bank is planned for 2006.

Ash regeneration will also depend on the survival and growth of ash seedlings and saplings. Ash seedlings or saplings can be abundant in some sites, but require a substantial amount of sunlight if they are to be recruited into the overstory. The size of the overstory gap needed for ash recruitment to the overstory, especially in mixed species stands, is not known. The ability of ash regeneration to outcompete invasive plant species may also be problematic. Glossy buckthorn (*Frangula alnus*) and common buckthorn (*Rhamnus cathartica*), for example, often occupy sites where ash trees occur and are likely to rapidly take advantage of canopy gaps as ash mortality progresses. Ash regeneration is also frequently browsed by deer in many areas. The variable production of ash seed, the likelihood that young trees will be killed by EAB before they achieve the size or age to produce seed, and the questionable recruitment of ash regeneration into the overstory, suggest that concern about the future of native ash species in the U.S. is warranted.

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Modeling The Impacts Of Hemlock Woolly Adelgid On The Structure And Composition Of Southern Appalachian Landscapes

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Eastern Hemlock (Tsuga Canadensis) and Carolina Hemlock (Tsuga caroliniana) appear in mesic flats, draws, ravines, coves, and canyons of the southern Appalachian Mountains

(Whittaker 1956). Hemlock populations, which were historically abundant in the area, declined dramatically approximately 5500 years ago due to climatic shift resulting in summer droughts which weakened the hemlocks and left them vulnerable to a subsequent widespread insect outbreak (Davis 1981, Allison et al. 1986, Haas and McAndrews 2000). Canopy gaps were filled by Acer, Betula, Fagus, Pinus, Quercus, and Ulmus Spp. (Fuller 1998). While hemlock did re-establish, it's recovery may have taken up to 2,000 years and it is still is not as prominent as it was before the decline (Fuller 1998, Haas and McAndrews 2000). Now, hemlocks are at risk from the invasive exotic insect pest hemlock woolly adelgid.

The hemlock woolly Adelgid, Adelges tsugae (Annand) (Homoptera: Adelgidae) (HWA), is a non-indigenous invasive species that infests and kills Eastern hemlock (*Tsuga canadensis*), and Carolina hemlock (*T. caroliniana*) throughout their range. In its native Japan, HWA populations are maintained at low densities on hemlocks (*T. diversifolia* and *T. sieboldii*) by a combination of host resistance and natural enemies (McClure 1992, 1995a,b, 2000). The first report of HWA in North America was in the Pacific Northwest in the 1920s, however, western hemlocks were resistant to the adelgid. In the eastern U.S., the first reports of HWA were in 1951 in Richmond, Virginia (Gouger 1971, McClure 1989, 1991). HWA slowly made its way northeast and has subsequently been moving southwest along the eastern side of the Appalachian Mountains. Little is known about stand level characteristics which influence HWA susceptibility in the southeastern United States. However, studies on HWA infestation levels in the northeastern range of this insect noted only latitudinal effects on infestation severity (Orwig and Foster 1998, Orwig et al. 2002). With no natural resistance or natural predators, this would seem to suggest that all hemlock stands have the potentially of being infested and killed, regardless of site and stand factors.

The most pressing concern with HWA is predicting the impact of removing hemlock from the forest environment. The most feasible means of investigating this issue is through a landscape simulation modeling approach. LANDIS is a simulation modeling environment developed to predict forest landscape change over time. It is a spatially explicit, landscape-scale ecological simulation model that incorporates disturbance by fire, wind, biological disturbance (insects & pathogens) and harvesting. Herein, we present a case study using LANDIS to evaluate the impact of herbivory by HWA on forest structure and composition in the southern Appalachians.

Model Description

LANDIS is a spatially-explicit computer model designed to simulate forest succession and disturbance across broad spatial and temporal scales (He et al. 1996, He and Mladenoff 1999a,b, He et al. 1999a,b, Mladenoff and He 1999). While LANDIS was originally developed to simulate disturbance and succession on glacial plains in the upper Midwest (Mladenoff 2004), it has been successfully adapted for use in mountainous areas (Shifley et al. 1998, 2000, He et al. 2002, Xu et al. 2004). LANDIS is raster-based, with tree species (max 30) simulated as the presence or absence of 10-yr age cohorts on each cell. At the site (cell) scale, LANDIS manages species life history data at 10-yr time steps. Succession is individualistic and is based on dispersal, shade tolerance, and landtype suitability.

Disturbances that can be modeled include fire, wind, harvesting, and biological agents (insects, disease) (Sturtevant et al. 2004a).

Fire in LANDIS is a hierarchical stochastic processes based on ignition, initiation, and spread (Yang et al. 2004). Mortality from fire is a bottom-up process whereby low-intensity fires kill young/fire-intolerant species, while fires of higher intensity can kill larger trees and more fire-tolerant species (He and Mladenoff 1999b).

Biological disturbances in LANDIS 4.0 are modeled using the Biological Disturbance Agent (BDA) module. Biological disturbances are probabilistic at the site (cell) level. Each site is assigned a Site Vulnerability (SV) probability value which is checked against a uniform random number to determine if that site has been infected. Site vulnerability can either be directly equated with the Site Resource Dominance (SRD) value which ranges from 0-1 and is based on species and species age. This value however can also be modified by three variables to determine the impact on a given site, Modified Site Resource Dominance (SRDm), Neighborhood Resource Dominance (NRD), and the temporal scale of outbreaks. The functioning of these variables, and of the BDA in general, are described in detail in Sturtevant et al. (2004b).

Results and Discussion

Our goal was investigate the impacts of HWA on species composition in the southern Appalachian Mountains. The results from this study are preliminary, but do show a reduction in hemlock and subsequent replacement by hardwoods. In particular, we see replacement of Hemlocks with Basswood (*Tilia spp.*), Sugar Maple (*Acer saccharum*), Yellow Buckeye (*Aesculus octandra*), Yellow Birch (*Betula alleghaniensis*) and Red Oak (*Quercus rubra*). These results may not be ecologically correct, as we would anticipate rhododendron already present in the understory or several potential non-native invasive species filling many of the gaps created by hemlock removal. Rhododendron, and thick shrub cover in general, has been shown to neutralize tree regeneration in canopy gaps (Beckage et al. 2000). Riparian areas in the southern Appalachians, where we find most hemlocks, have also been shown to contain high exotic species cover and diversity (Brown and Peet 2003). The discrepancies in the landscape approach can be easily corrected by incorporating finer resolution gap models.

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Sirex noctilio in North America – A New Arrival

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In this workshop, the panel gave a presentation on the world distribution of sirex woodwasp (*Sirex noctilio* F.), a summary its biology and ecology, surveys planned for 2006, and management options. The second half of the workshop was moderated discussion on the information presented and identification of critical issues.

Sirex woodwasp is native to Europe, Asia, and northern Africa. It is an established exotic in New Zealand, Australia, Uruguay, Argentina, Brazil, Chile, and South Africa. An established population was discovered during 2005 in upstate New York. Subsequent trapping detected sirex woodwasp in a 40-mile band around Oswego, NY and at six locations in Ontario, Canada, spanning 260 miles.

Pines are the main hosts for sirex woodwasp, including these North American species: Monterey, loblolly, slash, jack, red, ponderosa, lodgepole, and eastern white pine. Sirex woodwasp is likely to have one generation per year over most of the United States. Adult emergence is expected during July through September. A female can lay 25 to 400 eggs. During oviposition, she also injects a fungus (*Amylostereum areolatum*) and mucus into the tree, which together kill the tree. The developing larvae feed only on that specific fungus. During outbreaks in the Southern Hemisphere, up to 80% tree mortality has been recorded in pine plantations, especially in unthinned and overstocked plantations over 12 years of age. More research is needed to determine how sirex woodwasp will interact in the complex North American pine ecosystem compared to the exotic pine plantations of the Southern Hemisphere.

Surveys are needed in 2006 to delimit the sirex population(s) around Lake Ontario and to detect any other established populations in North America. A susceptibility risk map was created by FHTET (www.fs.fed.us/foresthealth/technology/invasives_sirexnoctilio_riskmaps.shtml) as a tool for allocating trapping resources across the United States. Current survey methods include traps (funnel and intercept-panel) baited with alpha- and beta-pinene and trap trees (trees injected with an herbicide). In New York, traps will be placed in the band from 50 to 150 miles from Oswego at 1 trap per 25 square miles (ca. 1800 traps) to delimit the population. In Canada, a delimiting survey is being planned for southern Ontario with about 300 traps radiating out from the six known locations. Detection surveys will be done in other locations in Ontario as well as in Quebec, New Brunswick, and Nova Scotia. In the United States, APHIS and US Forest Service are supporting sirex detection surveys in all the eastern states. Also the exotic bark beetle trapping programs in the United States and Canada will screen any siricids caught in those traps.

Management options for sirex woodwasp include regulatory, silviculture, and biological control. APHIS is currently assessing the need to regulate counties with positive traps and possibly surrounding counties to mitigate the artificial spread of sirex woodwasp. A list of regulated articles is being drafted, along with potential pest mitigations. Silviculture options that promote thinning and increase vigor in residual pines will reduce the potential for an outbreak. Biological control has been effective in the Southern Hemisphere, especially with the parasitic nematode, *Deladenus siricidicola*. This nematode feeds only on *A. areolatum* during its fungus-feeding cycle, and it sterilizes the female sirex woodwasp during its parasitic cycle. This nematode can be easily mass-reared in the laboratory, and inoculated into infested trees as the sirex woodwasp establishes in new areas. Introduction of parasitoids should not be needed, since the parasitoids used in the Southern Hemisphere are native to North America. Research on DNA identification of the woodwasp larvae, fungi, and nematodes is needed. Also better survey tools (traps and lures) need to be developed.

Critical Issues:

1. Improve survey methods.
2. Assess impact and damage in North America.
3. Prepare for long-term management program including monitoring, silviculture guidelines, and nematode introduction.
4. Improve interagency and international cooperation and communication to ensure a unified program for North America.

Pathways of Invasiveness

Moderator: David L. Kulhavy, Stephen F. Austin State University

Potential Pathways For Invasive Forest Pests

Robert Mangold, Director

USDA Forest Service, Forest Health Protection

This paper discusses relevant issues related to the introduction of invasive forest pest species, including biological impacts and regulatory issues.

The biological impact of introductions of exotic organisms can be long-lasting. Initially an introduction to a new area is noticed because it is causing extensive, economic damage. On the other hand, long-established pests (e.g. gypsy moth and white pine blister rust) can also continue to expand onto new hosts or into new ecosystems. The mechanisms of introductions of some of the most notable and costly introductions of exotic forest pests are diverse. Many exotic pest introductions in the past 100-years were via planting stock (chestnut blight, white pine blister rust, Port-Orford Cedar root disease, sudden oak death, hemlock woolly adelgid, and balsam woolly adelgid). The Dutch elm disease fungus was introduced to the US on infected logs. European gypsy moth was accidentally released from an entomologist's home in Massachusetts. More recent exotic pest introductions have occurred in infested solid wood packing material (SWPM). Asian longhorned beetle and emerald ash borer were brought into the US in this manner.

Transportation pathway issues are exacerbated by the exponential growth of world-wide markets for agricultural, forest, and horticultural products. New packaging techniques, along with new modes of transportation also contribute to the potential for these introductions. Transportation related pathways also include military transportation, and items used in the shipping process. An example of a pest introduction via military transportation is the Asian gypsy moth into the port of Wilmington, NC in 1993. Wood packing material has also included intercepted Scolytidae (Coleoptera) at other United States ports of entry.

Regulations are aimed at closing identified invasive biological and transportation pest pathways. Regulatory issues for the Forest Service include coordinating and cooperating with APHIS, PPQ (the lead regulatory agency), foreign governments and scientists, conducting pest risk assessments, helping to develop wood packing material regulations, and initiation of offshore port monitoring and inspections, along with providing technical assessments regarding "Clean Stock" certification programs of inspected plant materials.

The US regulations established by APHIS for plant materials for planting are regulated under imports of living plants 7 CFR 319.37. Current restrictions include a "black list" system—all plants are allowed into this country unless a risk assessment restricts or requires mitigation.

Since the 1970s there are no restrictions on the quantity of acceptable species of plants that can be imported. Most imported plants in soil are not allowed. The exceptions are some bonsai and rhododendron from Europe that are permitted with post-entry quarantine proof by the receiving nursery. Currently there are no fumigation requirements for plants once they enter the United States.

Examples of currently regulated forest insects include:	**Currently regulated forest pathogens include:**
Anoplophora glabripennis - Asian longhorned beetle	*Chrysomyxa abietis* - Spruce needle rust
Curculio elephas - Chestnut weevil	*Chrysomyxa himalensis* - Spruce needle rust
Curculio nucum - Acorn weevil	*Chrysomyxa ledi* var. *rhododendri* - spruce needle rust
Dryocosmus kuriphilus - Gall wasp	*Cronartium flaccidium* - Pine stem rust
Lymantria dispar - Gypsy moth	*Gymnosporangium asiaticum* - Japanese pear rust
Rhynchophorus palmarum - Palm weevil	*Lachnellula willkommii* - European Larch canker
Tomicus piniperda - Pine shoot beetle	*Phacidiopycnis pseudotsuga* - Douglas-fir canker
Xyleborus spp. - Ambrosia beetles	Elm mottle virus
	Horse chestnut variegation agent
	Horse chestnut yellow mosaic agent
	Maple mosaic agent
	Maple variegation agent.

An illustration of current programs designed to close the invasive pest pathways via regulations is useful. Asian gypsy moth was detected nearly simultaneously in North America in the early 1990's in three northwest seaports in Oregon, Washington, and British Columbia and in Wilmington, North Carolina on the Atlantic Coast. To suppress the infestations, the United States and Canada spent $32,000,000 to eradicate the Asian gypsy moth introductions, some of which were traced to Russian ships berthed in west coast ports. This pest suppression program was followed in 1993 by initiation of a monitoring and inspection program located in Russian ports. Initially the program cost $250,000 to implement, but now costs $175,000 annually to maintain.

The Forest Service also does risk assessments in foreign countries using a standing team called WIPRAMET (Wood Import Pest Risk Assessment and Mitigation Evaluation Team). Their purpose is to assess the likelihood of a new pest introduction and establishment, and then estimate the potential economic and environmental impacts. The model the team uses to assess risks is as follows.

Risk assessment = Likelihood of introduction + Potential consequences of introduction

Likelihood of introduction includes presence of a pest in the exporting country, along with estimates of the entry potential, establishment potential, and spread potential into the United States. Potential consequences of introduction include economic damage potential, environmental damage potential, and social and political considerations. To date the USDA Forest Service, at the request of APHIS, has completed risk assessments for wood imports including larch from Siberia and the Russian Far East; Monterey pine and Douglas-fir from New Zealand; Monterey pine and native species from Chile; pine and fir from Mexico; and Eucalypts from South America and Australia.

A new APHIS regulation, ISPM -15, includes standards for heat treatment and fumigation. The international standard for SWPM (Solid Wood Packing Material) is being phased in by NAPPO (North American Plant Protection Organization) countries. After February 1, 2006, all SWPM, except dunnage, is heat treated (56^{o}/30-minutes at core) or methyl bromide fumigated. After July 5, 2006, heat treatment is required on dunnage.

Forest Invasive Species In China

Jianghua Sun, Institute of Zoology, Chinese Academy of Sciences

Currently there are some 20 major forest invasive species causing about 56 RMB losses; this represents almost half of the total economic losses caused by forest pests in China. Timber loss equals 17 million cubic meters over 1.3 million ha annually. The red turpentine beetle, *Dendroctonus valens*, is ranked number 2 important pest and invasive species in China. Native to North America, *D. valens* arrived in China in the 1980s and currently over 6 million pines have been killed. Priority for research and management includes monitoring and monitoring technology; and containing the spread by effective means. Monoterpene baited funnel traps are currently being investigated in China. A mass trapping program was employed since 2002 with over 40,000 funnel traps deployed. Genetic variation and origin of *D. valens* are being investigated. Current work includes *D. valens*, associated fungi, and host tree interactions.

The pinewood nematode, termed pine cancer, is a quarantine pest in more than 40 countries and is the number one invasive species in China. The pinewood nematode has two pathways to damage pines including the propagative nematodes and the dispersal nematodes. Control includes quarantine at ports-of-entry; and field detection and control. The pinewood nematode life cycle is tied to dispersal by its vector, *Monochamus* sawyers. Chinese Academy of Science projects include rapid detection technology; development of an attractant for *Monochamus alternatus*; mechanisms of pinewood nematode aggregation to *Monochamus* chambers and potential distribution in China.

The loblolly pine mealybug project is collaboration between the China and the USDA Forest Service. The loblolly pine mealybug was introduced from Georgia, USA, in 1987. The biological control of kudzu is in the screen process for potential biocontrol agents. This is a joint project with the USDA Forest Service and the Institute of Zoology, Chinese Academy of Science. The emerald ash borer, *Agrilus planipennis*, imported into Michigan in 2002, is being reviewed and a distributional survey completed in China. The coconut leaf beetle, *Brontispa longissima*, reached outbreak levels in southern China causing extensive damage to coconut production. This beetle has the potential for spread and control measures and prevention of spread are high priorities for research. *Hylobitelus xiaoi*, a weevil indigenous to China, has infested more than 80,000 hectares of exotic slash pine in Jianxi Province, China. Damage is most severe in exotic slash and loblolly pines.

Managing Exotic Insects

Moderator Bernie Raimo, USDA Forest Service

Session Overview

Dennis Souto

Many jurisdictions are faced with recognizing newly arrived exotic insects as soon as they appear- at the same time they are faced with decreasing resources to accomplish this task. Early detection is crucial to maintaining a full range of management options. Yet early detection is biologically and logistically difficult to accomplish. Allocating scarce financial and human resources effectively to manage new forest insects can also be difficult to plan and implement. This workshop will cover powerful new technologies- DNA analysis, hyperspectral remote sensing, and GIS decision support- that can assist forest health specialists and land managers to help meet these important problems.

Molecular Methods To Reveal The Introduction History Of Exotic Species

Nathan P. Havill

Department of Ecology and Evolutionary Biology, Yale University

Molecular methods are a powerful way to learn about the history of an exotic species. This knowledge can then be applied to control programs in ways that enhance and accelerate control efforts.

Recent studies using molecular methods have provided insight into the history of the hemlock woolly adelgid, *Adelges tsugae* Annand, and its host plant interactions. *Adelges tsugae* was introduced into eastern North America some time prior to 1951 and is causing serious decline and death of eastern and Carolina hemlocks. Molecular methods were used to clarify the relationships and among hemlock adelgids worldwide and to determine the geographic origin of the introduction to eastern North America (Havill et al. 2006). Approximately 1500 base pairs of mitochondrial DNA were sequenced for hemlock adelgid samples collected in eastern and western North America, China, and Japan. Phylogenetic analyses indicate that there are several distinct evolutionary lineages of adelgids on hemlock worldwide. Adelgids from mainland China and Taiwan are quite diverged from those in Japan and North America and should probably be considered a separate species. In Japan, there appears to be separate lineages associated with each of the two Japanese hemlock (*Tsuga*) species. The adelgids in eastern North America were clearly introduced from the population that is living on *T. sieboldii* Carrière at lower elevations in southern Honshu, Japan. Hemlock adelgids in western North America appear to be a separate lineage that is endemic to that area.

A molecular phylogeny of the family Adelgidae using approximately 2400 base pairs of mitochondrial and nuclear DNA data has revealed the relationship of hemlock adelgids to other adelgid species (Havill et al. in press). This study resulted in a well-resolved phylogenetic tree in which adelgid species group in association with secondary host genera – i.e. adelgid species associated with *Tsuga* form a group with a single common ancestor as do species associated with *Larix, Abies, Pseudotsuga*, and *Pinus.* This suggests that specialization on each secondary host genus occurred only once and there were no subsequent switches among secondary host genera.

Finally, a molecular phylogeny of hemlock (*Tsuga*) was performed to determine its evolutionary and biogeographic history (Havill et al. in preparation). Analysis of approximately 1700 base pairs of ITS and 3500 base pairs of chloroplast DNA provide strong support for a clade that includes the two western North American species, *T. heterophylla* (Rafinesque) Sargent and *T. mertensiana* (Bongard) Carrière, and a clade of Asian species within which the eastern North American species, *T. caroliniana* Engelmann, is nested. The other eastern North American species, *T. canadensis* (L.) Carrière, is sister to the Asian clade. The Taiwanese *T. chinensis* (Franchet) Pritzel *in* Diels did not group with *T. chinensis* from mainland China, and *T. sieboldii* from Ullung Island did not group with the Japanese *T. sieboldii*, suggesting that these distinct island populations should probably be treated as separate species. These results can be used to inform efforts to breed hemlocks resistant to hemlock woolly adelgid.

These results indicate that molecular methods can be used to provide information to inform efforts to control exotic species. They can be used to pinpoint the geographic origin of introduction, to facilitate quarantine efforts by helping to identify other non-native genotypes and prevent their introduction, and to elucidate the evolutionary history insect lineages and the interaction with their host plants.

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New Ways Remote Sensing Can Help Manage Forest Insect Pests

Jennifer Pontius and Richard Hallett, USDA FS Northern Research Station
Mary Martin and Lucie Plourde, Complex Systems Research Center, UNH

In order to aid land managers in monitoring and controlling invasive insect outbreaks, more accurate landscape scale tools are required to accurately locate the host resource, identify new infestations, monitor decline and assess risk. The development and increased availability of hyperspectral remote sensing instruments has greatly increased capabilities to this end. Our experience with NASA's AVIRIS and Specim's AISA Eagle instruments has shown high accuracy in mapping eastern hemlock, beech and sugar maple basal area, mapping foliar chemistry, and tracking detailed changes in forest health across the landscape. Both sensors were able to map a detailed decline scale (0-10) at the plot (AVIRIS) and tree level (AISA Eagle) with greater than 90% accuracy. The ability of these instruments to predict decline below class 4 (when dieback and transparency reach levels first noticeable in the field) is based upon "pre-visual" changes in chlorophyll content and function that are typical of early tree stress. Identifying these early stress stands will help target field surveys for new infestation location. In addition, these sensors can generate foliar chemistry maps that may be useful as input to landscape scale GIS risk modeling. Such technologies will enable land managers to assess, monitor and predict changes in forest health across the landscape so that integrated pest management programs can be effectively implemented. However, it is important to remember that the successful implementation of hyperspectral technologies is dependent upon a high level of user expertise in image acquisition, pre-processing, ground truth calibration data collection, calibration development and accuracy assessment.

Firewalls in the Forest: International Strategies for Combating Invasives

Moderators: Nancy Gillette, USDA Forest Service, PSW and David Cibrián Tovar, Universidad Autonoma Chapingo

Speakers and topic: Rob Mangold, USDA Forest Service, FHP, US strategy
Alain Roques, INRA/Orléans and E.U., European strategy
Jianghua Sun, Chinese Academy Sciences, Chinese strategy
R. Campos Bolaños, Universidad Autónoma Chapingo, Mexican strategy
John Rawlins, Carnegie Museum Caribbean/ Central America strategy

Keith Douce, University of Georgia,Bugwood:Global resource

This workshop will provide a global perspective of strategies for invasives. Representatives from Asia, Europe, and the Americas will present regional strategies for combating invasives. Rob Mangold will describe the challenges and approaches that the US is taking, and Jianghua Sun will describe the current situation in China. Alain Roques will talk about the E.U.'s approach, called DAISIE, "Delivering Alien Species Inventories in Europe. Rodolfo Campos Bolaños will present examples of work in Mexico, and John Rawlins will describe faunal surveys in the Caribbean/Central America to establish baseline data for detection of invasives. Finally, Keith Douce will present an overview of the Bugwood, an example of how a global digital image network can integrate management of invasive species.

Quantitative Approaches to Understanding Insect Invasions in Forests

Moderator: Patrick C. Tobin, USDA Forest Service, NRS

Population Processes That Drive The Gypsy Moth's Invasion Of North America

Andrew M. Liebhold and Patrick C. Tobin
USDA Forest Service, Northeastern Research Station

The process of biological invasion is recognized to be composed of three distinct phases: arrival, establishment and spread. We illustrate the population biology behind these processes using the gypsy moth, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae), as a model system. Given the immense amount of data and research that has focused on this invader, it represents a unique system for understanding invasions. The gypsy moth was accidentally transported from Europe to Medford, Massachusetts in 1868 or 1869, and has subsequently been gradually expanding its range in North America. Analysis of this initial introduction as well as other isolated populations in North America indicates that there is typically a 10-15 year lag between the time of initial colonization and the time at which populations reach densities that cause noticeable damage. In established areas, outbreaks have damaged millions of ha of forest. Traps baited with synthetic gypsy moth pheromone are powerful tools for detecting low-level populations, and hundreds of thousands of traps have been placed along the gypsy moth expanding population front over the last 25 years. From these data we have learned considerably about the population biology of gypsy moth range expansion. Spread occurs through "stratified dispersal" in which isolated colonies are founded ahead of the advancing front; colonies gradually enlarge and eventually coalesce. This phenomenon has been captured in models to develop optimal strategies for retarding the spread of this species. Implementation of this strategy to date indicates that range expansion can be reduced by approximately 50%. The gypsy moth's range still has not reached over 2/3 of its potential range in North America but populations are often accidentally introduced to new areas well beyond the expanding population front. We know that at low densities, these newly colonized populations are strongly influenced by Allee effects and the result is that most very low-density populations go extinct without any intervention. However, when populations become established over large areas, they are more likely to persist. Following detection, these populations can be delimited using pheromone traps and then treated to achieve eradication. The success of these efforts to eradicate isolated gypsy moth populations and to slow it's spread can largely be attributed to the availability of pheromone traps which provide a sensitive, yet inexpensive tool for detecting low density populations.Infestation Dynamics Of

Table of Contents

The Asian Longhorned Beetle In The Urban Forest Landscape

Alan J. Sawyer. USDA-APHIS-PPQ, Pest Survey Detection and Exclusion Laboratory, Bldg. 1398, Otis ANGB, MA 02542.

The Asian Longhorned Beetle (ALB), *Anoplophora glabripennis* (Motschulsky) (Coleoptera: Cerambycidae), is an introduced pest of deciduous trees. Originating in China, this invasive species entered the US and Canada as larvae boring in solid wood packing material. It became established in New York City and Long Island (discovered [d]: 1996), the Chicago Area (d: 1998), Jersey City, NJ (d: 2002), Toronto (d: 2003), Middlesex County, NJ (d: 2004) and Union County, NJ (d: 2006). Evidence suggests that, with the exception of the Jersey City infestation (probably an offshoot of the New York population) these all represent independent introductions. The objective of the research reported here is to develop a qualitative and quantitative understanding of the spatial and temporal dynamics of ALB infestations in urban, suburban and forested areas of North America, and to use this knowledge to provide cooperative ALB eradication programs with improved methods and protocols for survey, control and regulatory efforts and to aid program planning and evaluation.

Infestation dynamics, as a science, is concerned with the origins of infestations, the pathways, mechanisms, distances and rates of spread, the changing numbers of susceptible, infested and dead (or removed) hosts, and the resulting patterns of host damage as they evolve in space and time—in sum, the "behavior" of infestations. The spatial scale of interest might range anywhere from within-tree to large-scale dynamics (on the order of 40 km or more). The focus of the case studies reported here has been on local and medium-scale dynamics, ranging from a few meters to two or three km. The environments studied have included residential neighborhoods, commercial and light industrial zones, urban centers, highway, railroad and utility rights-of-way, and parks, golf courses, marshland, wasteland and woodlands adjacent to urbanized areas. These varied habitats are all characterized by the presence of ALB host trees in close proximity to centers of human habitation and commercial activity; hence the broad term "urban forest landscape."

The data used in these studies have come either directly from the IL, NY and NJ Cooperative (Federal and State) ALB Eradication Programs—in the form of survey, treatment and host-removal records—or were collected in cooperation with these programs. Detailed data collected by my research team have included host identification to the species level, precise locations of trees (obtained by GPS), counts or estimates of the numbers of egg sites and exit holes on infested trees, the date of injury (obtained by growth-ring analysis) and the survival of life stages (obtained by dissecting infested material). Derived estimates include dispersal distances, host preferences, stage-specific mortality rates and rates of population increase. For example, based on records of 1000 infested street and backyard trees in Chicago, approximately 95% of trees bearing only egg sites were located within 200 m of a tree with one or more exit holes, and 99% within 400 m, suggesting that when host trees are abundant, dispersal distances of ovipositing beetles are typically short. Analysis of host inventories and infestation records from Chicago showed that 16% of 6600 maples located within 200 m of an infested (potential source) tree were also infested, while only 9% of 2500 elms and 2% of

2900 ashes were attacked, indicating relative host preferences. Dissection of over 15,000 egg sites on 145 host trees of 15 species yielded an overall estimate of 28% for survival from egg to adult emergence, with differences between host species. The dates assigned to 215 exit holes on a small red maple in NJ showed that, following colonization, the number of emerging adult ALB roughly doubled each year until emergence declined in the fifth year, apparently due to overcrowding and near death of the tree. Gene sequences on mitochondrial DNA of ALB larvae collected from all of the North American infestations have been compared by Maureen Carter (Dept. of Entomology, Cornell Univ., Ithaca, NY). Results suggest that the ALB populations in IL, NY/Jersey City, Toronto and Middlesex Co., NJ are distinct genetically. Larvae from the Union Co., NJ infestation have not yet been analyzed.

Four well-defined infestations of moderate to large size have been studied by these methods (Table 1). The habitats at these sites differed in their physical and biological characteristics, land use, economic value and opportunities for pest management practices. However, there were many similarities in the dynamics of these infestations. In each case the infestation apparently started at a point source and went undetected for five to seven years. During most of this time the ALB population remained highly localized, increasing numerically on a small number of trees. Finally, in just one or two years before discovery the infestation increased greatly in area and number of trees affected. Thus, at the time of discovery, relatively few trees near the point of origin displayed large numbers of exit holes, including some that were several years old, while many more trees, widely scattered from the focal point, bore only recent exit holes or egg sites dating from the previous year (Table 1).

Based on this consistent pattern we hypothesize that newly emerged females typically remain in or stay close to the tree in which they developed, so long as mates, food and oviposition sites are readily available. When a tree becomes over exploited (resulting in declining tree health, a lack of oviposition sites, crowded larvae or negative interactions between adults) there is apparently an increased rate of emigration and dispersal over greater distances (Table 2). This behavior may minimize the risks associated with leaving a proven resource and setting out into a heterogeneous environment while chances of reproductive success at the natal site remain good. Standard models of population spread (often variations of diffusion models, with continuous dispersal) are inappropriate for these "punctuated" dynamics (Table 2).

A consequence of these spatiotemporal dynamics is that there may be a several-year window of opportunity to contain infestations following introduction. Throughout this time the infestation may be confined to just a few trees within a radius of 200-300 m. Even so, a tree bearing 50-100 exit holes may be present, and should be readily apparent. Unfortunately, infestations have generally been discovered "just too late," after the ALB population has spread to a much larger area and number of trees. As a result, the difficulty and cost of survey, host removal, chemical treatment, regulation, final eradication and reforestation have been much greater than they might have been. The environmental and social impacts have also been much greater. The key lesson is that early detection—and, it follows, more efficient detection methods—are vitally important and should be a major goal of research and development.

Acknowledgments
I thank William Panagakos and Suzanne Kreuz for technical assistance and Christine Markham, Michael Stefan, Joe Gittleman, Joan Mahoney, Barry Emens, Tom Denholm and Joe Schafer for cooperation and support.

Table 1. Characteristics of four well-defined infestations of ALB.

	Location			
	Jersey City, NJ	Massapequa, Long Island, NY	Middlesex Co., NJ	Union Co.,NJ
Landscape	Urban center / landscaped commercial	Residential / commercial / school grounds	Residential / commercial / woods / park	Marshland / industrial / woods / cemetery / residential
Discovery date	Oct. 2002	Apr. 2005	Aug. 2004	Apr. 2006
Likely source	Vehicular transport	Remnant from earlier infest.	Warehouse	Construction site
No. trees infested	116	41	517	96
No. trees with ≥ 10 exit holes[a]	11	5	26	24
No. trees with ≥ 25 exit holes[b]	5	4	21	14
No. trees with ≥ 55 exit holes[c]	2	3	8	5
No. trees with ≥ 115 exit holes[d]	0-1	1	5	2

Max. no. exit holes / tree	114	187	800	220
Estimated year of introduction	1997[e] – 1998[f]	1999[f] – 2000[e]	1997[f] – 1999[e]	1998[g] – 2000[f]
Species with max. exit holes	Norway maple	Red maple	Red maple	Red maple
DBH of tree with max. exits	25 cm	33 cm	114 cm (5 trunks)	25 cm
Spatial scale[h]	0.24 km	2.4 km	2.3 km	2.2 km.

[a,b,c,d] estimated to have been infested more than two, three, four and five years, respectively; [e] based on growth ring analysis; [f] based on max. no. exit holes/tree; [g] based on external appearance of healed exit holes; [h] distance from apparent origin to farthest extent.

Table 2. Estimated year of infestation and rate of spread of an ALB population among 102 infested maple trees in Middlesex Co., NJ. Dates are approximate, based on the number of exit holes present and assuming a 2x increase in the number of adults exiting each year after the first emergence (based on growth ring analysis of one tree with 215 exit holes, first attacked in 1999). Mean and maximum distance is from the presumed point of origin of the infestation, a tree with 800 exit holes.

No. Exit Holes	No. Trees	Est. Year of Infest.	Mean distance (m)	Max. distance (m)
0[a]	54	2004	668	2289
1-9	22	2003	455	1873
10-24	4	2002	172	257
25-54	14	2001	115	196
55-114	3	2000	65	104
115-234	3	1999	75	195
235-474	1	1998	85	85
475-954	1	1997	0	0
Total: 2562	Total: 102			

[a] These trees had oviposition sites only

The Relationship Between Forest Landscape Features And The Occurrence Of Imported Fire Ants (*Solenopsis* Spp.) In Mississippi Forests: An Application Of Bayesian Model Averaging.

Menzel, Timothy O., T. Evan Nebeker and Michael Caprio, Department of Entomology and Plant Pathology
Mississippi State University

Within a forested landscape, habitat for imported fire ants (*Solenopsis* spp. Buren) can be found in the form of permanent habitat, such as roadsides and power lines, and ephemeral habitat, where small scale disturbances create temporary opportunities for them to establish colonies. The chances of imported fire ants establishing in one of these islands should be influenced by that location's suitability, the characteristics of the surrounding forest, and the degree to which it is isolated from other areas of suitable habitat. To determine which features of a forest landscape limit the chances of imported fire ants occurring at any location within a forest, a number of locations with and without imported fire ants in the forest were characterized with respect to their local vegetation, soil characteristics, and surrounding landscape features. This data was then analyzed using Bayesian Model Averaging to determine which factors were the best predictors of imported fire ant occurrence. BMA calculates the Bayesian likelihood for every possible model, creates a subset of the best models, and then gives the probability (posterior effect probability) of each variable being in a model that explains presence/absence. Instead of building a predictive model it assumes multiple possible models which allowed us to avoid making a priori decisions in model building which can lead to overlooking important relationships. The occurrence of imported fire ants was positively related to canopy openness and negatively associated with mixed forest cover in the surrounding forest. They also tended to occur closer to maintained open areas and in soils with lower silt content.

Mass-Foraging For Unpredictable Resources: A Possible Explanation For Allee Effects In *Ips typographus*

Jean-Claude Grégoire, Frédéric Piel, Anne Franklin and Marius Gilbert, Biological Control and Spatial Ecology lab, Université Libre de Bruxelles, Belgium

The European Spruce Beetle, *Ips typographus* (Coleoptera, Scolytinae), is a gregarious tree killer which mass-attacks living spruces, inoculates them with pathogenic fungi and breeds in a dying host. It is a very aggressive species, considered as the major forest pest in Europe.

In spite of its aggressiveness, *Ips typographus* never succeeded to establish overseas, although it was trapped many times in the United Kingdom, the US and Canada. Belgian data, where spruce was planted only by the mid-nineteenth century, suggest that even on continental

Europe the spread of *Ips typographus* is very slow, as compared for instance with another species with quite another strategy, the solitary, sib-mating *Dendroctonus micans*.

Data from the literature and from our own research suggest that *Ips typographus*' apparent failure as an invader could be connected to its foraging strategy. The beetles appear to disperse quite widely after emergence, and the revisited results of past release-recapture experiments show that the majority of the catches near the release points are unmarked insects, coming from outside the release-recapture area. New killed trees in the vicinity of an infestation spot are therefore likely to have been mostly attacked by exogenous beetles.

A pattern thus starts to appear, where the insects disperse and form vast aerial "reservoirs", which can rapidly respond to pheromones and concentrate on any resource discovered by pioneer beetles. This could constitute an excellent foraging method for insects dependent upon unpredictible resources. The possible need for such a vast "reservoir" in aggressive, tree-killing bark beetles like *Ips typographus* could also have other implications regarding their capacity to invade new areas across geographic barriers. As they are transported only in limited quantities over these barriers (in view of the species' dispersal capacities, even several thousand insect might be a very limited quantity), they disperse and thin out upon emergence to such an extent that they are unable to reconcentrate in numbers large enough to start a new infestation spot.

MANAGEMENT AND SILVICULTURE

Different Perspectives on Silviculture: Large Scale Applied Silvicultural Assessments Under the Healthy Forest Restoration Act

Moderators: Jim Guldin and Kurt Gottschalk, USDA Forest Service

Applied Silvicultural Assessments Under The Healthy Forest Restoration Act—Southern Pine Beetle

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Outbreaks of the southern pine beetle (*Dendroctonus frontalis*) (SPB) tend to be cyclic within the Southern region, but we cannot anticipate when or where they will occur or predict their severity. Two developments in the past decade have dramatic implications for stands and landscapes of southern pines relative to SPB. The first is a reversion to neoclassical, ecologically-based silvicultural practices that emphasize management of open, naturally-regenerated stands of complex vertical structure for large trees, coupled with open understory conditions maintained using prescribed fire or fire surrogate treatments. These approaches partition stand growth among sawtimber, pulpwood, and regeneration size classes within the stand in ways different from plantations, especially such that individual tree vigor is optimized in the sawtimber component. We hypothesize that this strategy will provide a large measure of hazard reduction to SPB. However, this is balanced with a second trend—wholesale changes in makeup of industry lands that divorce land ownership from mill management and that view standing timber in an investment context, resulting in liquidation of commercial forest stands and replacement with intensively-managed plantations that have rapidly-increasing hazard trajectories for SPB. The questions raised by these developments can be answered through a silvicultural analysis including field treatments and modeling under the Applied Silvicultural Assessment (ASA) authority in Title IV, Section 404 of the Healthy Forest Restoration Act of 2003. Three elements are of special interest in this ASA. First, models used to predict SPB hazard and risk will be proofed against observed and modeled growth of stands with broader structural diversity to develop hazard trajectories over time, coupled with reconstruction of stand structure after future SPB outbreaks that are proofed via modeling. Secondly, model refinement is underway to make existing stand-level SPB models spatially explicit. Thirdly, these platforms will be modified so as to provide a science delivery and technology transfer capability for forest landowners in the region, through existing extension channels as well as through web-based technologies. Through this and other ASAs being conducted in the region, scientists should get a better understanding of what silviculture can and cannot do in the context of control of forest insects.

HFRA Silvicultural Assessments: Gypsy Moth And Oak Decline On The Daniel Boone And Minimizing Gypsy Moth Effects On The Monongahela And Wayne National Forests

Kurt W. Gottschalk, USDA Forest Service, Northern Research Station, Callie Schweitzer and Stacy Clark, USDA Forest Service, Southern Research Station

The Daniel Boone National Forest, Cold Hill Silvicultural Assessment is designed to test the effectiveness of various silvicultural treatments to condition oak (*Quercus* spp.) forests to withstand and recover from gypsy moth, *Lymantria dispar* (L.), and oak decline retaining the composition, structure and function associated with these ecosystems. The Land and Resource Management Plan for the Daniel Boone National Forest provides for a broad range of silvicultural treatments to sustain oak forests and to provide for a variety of structural habitats. Our goal is to assess how the various silvicultural treatments specified in the plan will affect vulnerability to gypsy moth/oak decline in both the near term and long term, as well as whether the treatments will sustain oak forests.

The five silvicultural treatments are: shelterwood with reserves, that creates two-aged stands; specialized shelterwoods that retain a medium density and can be designed to enhance oak regeneration potential (hereafter referred to as the oak shelterwood); thinning, that can alter both stand density and composition; oak woodland treatment, that creates an open habitat through thinning and uses prescribed fire to maintain this condition over extended periods of time; and control (untreated areas). The treatments are replicated three times on each of two site types, dry-mesic (SI 65-80) and dry-xeric (SI 50-65) for a total of 30 treatment units of 16 to 48 acres. The project is being installed during 2005-2007 with cutting in fall 2006 and spring 2007. Evaluations will occur at periodic intervals and modeling of treatment effects on gypsy moth vulnerability will be done.
Another silvicultural assessment is being installed on the Wayne National Forest that will provide research and demonstration areas to test presalvage and sanitation thinning treatments to minimize gypsy moth effects. We are currently in the site selection phase and anticipate having between 10 and 30 stands with paired thinned and unthinned control areas. On the Monongahela National Forest, a set of crop tree release treatments were done in 15-20 year old stands to increase crown vigor of oak trees to enhance future mast production and ability to survive gypsy moth defoliation. We will monitor released and unreleased oak trees for their response to treatment.

Critical issues for this area are: 1) Need to find NFS personnel who are risk takers; 2) Need to find funding for large scale silvicultural assessments, especially on the NFS side; and 3) Need more large scale silvicultural assessments in wider variety of forest types and insect and disease conditions.

Applied Silvicultural Assessments: Section 404, Title IV Of The Healthy Forest Restoration Act Of 2003

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The Healthy Forest Restoration Act of 2003 contained provisions under Section 404 of Title IV, authorizing the establishment of applied silvicultural assessments (ASAs) for insect and disease problems listed in the Act or identified by the Secretary of Agriculture. An ASA is defined as any vegetative or other treatment for information gathering and research purposes, and includes timber harvesting, thinning, prescribed burning, pruning, and any combination to combat damaging insect infestations. Typically, ASAs will be implemented as field studies conducted on Federal land determined to be at risk of infestation by, or infested with, forest-damaging insects. Certain areas are excluded from ASAs, such as lands within the National Wilderness Preservation System or Congressionally-designated wilderness study areas, or other areas in which the removal of vegetation is restricted, prohibited, or inconsistent with applicable land & resource management plans. Certain practices are also prohibited, such as application of insecticides in municipal watersheds or associated riparian areas. A peer-reviewed study plan is required for each ASA, and each ASA must include public notice or comment. The ASA process provides that assessment treatments may be categorically excluded from documentation in EIS or EA under NEPA on not more than 1,000 acres for an individual ASA. Six ASAs are currently being conducted nationally -- southern pine beetle in the west Gulf region, gypsy moth-oak decline in Kentucky, gypsy moth effects in West Virginia, red oak borer in the Arkansas Ozarks, hemlock woolly adelgid on the Allegheny NF, and a now-closed study on pine-feeding insects in Florida. Overall, the ASA provisions in the Healthy Forest Restoration Act of 2003 provide a mandate to conduct applied research and technology transfer regarding forest-damaging insects and associated diseases, allow the use of expertise and resources in both the public and private sector, and offer a streamlining of key procedures under NEPA in order to establish these new studies. Where sufficient knowledge is unavailable to combat these forest pests, the new applied silvicultural assessments represent powerful new tools in the hands of research scientists looking to better manage forests on the nation's public and private forest lands.

Integration Of Silvicultural Strategies For Hemlock Management In Eastern Forests Threatened By Hemlock Woolly Adelgid (*Adelges Tsugae*).

Mary Ann Fajvan, USDA Forest Service

In order to increase hemlock survivability in stands threatened by hemlock woolly adelgid, the objective of this research is to develop silvicultural thinning guidelines to reduce stand densities, reallocate resources, and increase hemlock vigor across a range of stand types and structures. Hemlock is very shade tolerant and can demonstrate growth increases to increased site resources even at advanced ages. Currently, four mixed hardwood-hemlock stands on the Allegheny National Forest in western Pennsylvania are receiving thinnings to reduce relative stand density by 30-40%; half of each stand will not be harvested and serve as controls. Pre- and post-harvest sampling includes measurements of: residual tree stems and crowns; understory vegetation; soil moisture, temperature and nutrients; foliar nutrients; and insect populations (hemlock woolly adelgid and others).

Additional stands on state and federal land in western Massachusetts and southern New Hampshire are being considered for inclusion in the study. Geographically, all of the study areas regularly experience winter temperatures that can be lethal to hemlock woolly adelgid if they are prolonged. The combined effects of climate and silvicultural treatment may serve to moderate adelgid populations and increase survivability of hemlock.

Forest Health and Oak Decline--Setting The Stage For Red Oak Borer

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Forests of the Interior Highlands of Arkansas, Oklahoma and Missouri recently experienced a widespread oak mortality event associated with an outbreak of a native wood-boring beetle, the red oak borer, *Enaphalodes rufulus* (Coleoptera: Cerambycidae). Roughly 33 percent of the area in the Interior Highlands is potentially at risk—stands dominated by oaks (*Quercus* spp.) that are 50 years old or older. According to the recent Ozark-Ouachita Highlands Assessment, the value of oaks at risk from this outbreak exceeds $1.1 billion. This and other insect infestations may be intimately related to forest health, and more research is needed to understand the interactions of insects and diseases in relation to forest site, stand and climatic conditions—especially the degree to which silviculture can be used to increase the health of our forests. These concerns have been codified in a Title IV Section 404 project under the Healthy Forest Restoration Act of 2003—an Applied Silvicultural Assessment (ASA) for red oak borer. A major fundamental advance in our ability to assess this red oak borer outbreak has been the development of within-tree sampling techniques and of a rapid estimation procedure to quickly, non-destructively and economically assess density and duration of within-tree red oak borer populations. But in a practical context, five major gaps continue to exist in our knowledge about how to assess and deal with this widespread ROB infestation. First, the ability to rapidly survey difficult terrain such as that found in the Ozarks suggests that remote sensing technologies have a role to play in assessing the impact of the current outbreak. Second, basic questions about historical ROB population changes and densities across the landscape have yet to be addressed, including documentation of historical changes and elements that are causative to the current outbreak. Third, we do not yet fully understand predisposing and inciting factors of this outbreak, such as tree-insect interactions and mechanisms of tree defense, importance of stand and site variables with respect to distribution and abundance of ROB, the effects of climatic factors including drought, and other insects and associated pathogens such as *Armillaria* spp. Fourth, there is pressing need to better quantify the extent, distribution and repercussions of the outbreak on public and private forestlands in the region. Finally, there is also a critical need to get current information on the scope of and potential for this outbreak into the hands of forest landowners and resource managers in the region. It can be stated conclusively that the authority provided in Section 404 of Title IV of the Healthy Forest Restoration Act of 2003 provided the means and wherewithal to make advances in these and other areas, that otherwise would have been impossible to achieve.

Silviculture and Pest Management: predictions, expectations and consequences

Moderator: Rose-Marie Muzika, University of Missouri-Columbia

Regardless of the objective, any silviculture practice has consequences that may be intended or otherwise. With management objectives specific to minimizing damage from insect pests or directly affecting the insect's reproduction or life cycle, desired outcomes may result. The expected outcomes likely do not occur in isolation, however. Predicted changes in populations of hosts or insects create unintended consequences for other ecosystem components. Modification of stand structure or ecosystem processes may exacerbate stand level damage by positively influencing other problematic insects, or by interfering with cycles of natural enemies. Evidence suggests that silvicultural approaches may have short term successes, but these may lead to longer term problems. Contrary evidence also exists. Furthermore, an assessment of 'successes' of silviculture require years, if not decades.
This session reviews some long term experimental approaches and assessments, as well as unexpected effects of silviculture directed at reducing insect populations. Additional considerations to be addressed include implications for fuel accumulation and wildfire risks, determining appropriate management scale, distinctions among forest insect guilds and corresponding management approaches. Finally, it is critical to consider dramatic differences in silvicultural strategies that may be necessary for native versus non-native forest insect pests.

Fifteen-Year Response Of Oak-Dominated Forests To Gypsy Moth And Thinning

Kurt Gottschalk, USDA-FS, NRS

A replicated study was conducted on the West Virginia University Experimental Forest to evaluate the effectiveness of two silvicultural treatments - presalvage thinning and sanitation thinning - in minimizing gypsy moth, *Lymantria dispar* (L.), effects on forests. The objective of the presalvage thinning treatment is to reduce damage (mortality) by removing trees with higher probabilities of dying and leaving trees with lower probabilities before they are defoliated and die, i.e. to reduce stand vulnerability to gypsy moth damage. The objective of sanitation thinning is to prevent the spread and establishment of gypsy moth by reducing gypsy moth habitat by removing preferred food (host) species, removing structural features or refuges, and by promoting predator and parasite habitat, i.e. to reduce stand susceptibility.

Four stands received each treatment and were split in half with half remaining uncut as a control, resulting in 16 experimental units each 8 to 12 ha in size. The treatments were installed during the winter of 1989-1990. Six of the 16 stands were defoliated in 1990 and

1991. The stands were followed for 15 years post-treatment to evaluate the defoliation effects on mortality and the recovery of the stands.

The presalvage thinning treatment significantly reduced mortality over the uncut control stands. The sanitation thinning treatments reduced mortality but the effect was not statistically significant. High oak (*Quercus* spp.) stands had significantly greater mortality than mixed stands with less oak. By 15 years post-treatment, basal area had recovered but stocking was still lower due to the ingrowth of smaller trees. Thinning and defoliation had a significant interaction: in undefoliated stands, thinning had no effect on mortality but in defoliated stands, it did. Over all trees, thinning increased and defoliation decreased crown diameter growth and the defoliation effect was stronger than the thinning effect. For immune species yellow-poplar, *Liriodendron tulipifera* (L.), thinning had no effect but defoliation increased crown diameter growth. For susceptible species Northern red oak, *Quercus rubra* (L.), thinning increased crown diameter as did defoliation but defoliation was significantly less. For immune species *L. tulipifera*, defoliation and thinning both increased individual tree basal area growth and they had an additive effect. For susceptible species *Q. rubra*, thinning increased individual tree basal area growth and defoliation decreased it and was stronger than the thinning effect.

This was the worst test case for these treatments, as the defoliation occurred immediately after the thinning treatment. There was no growing season for the thinning treatment to result in increased tree growth and vigor. The significant response of the presalvage thinning treatment under these conditions shows the value of using tree vigor as a guide in thinning stands.

Large-Scale Thinning Treatments and Their Unexpected Consequences On Insular Populations Of Eruptive Defoliators

Gaétan Moreau, CFS/AFC/FR

Pre-commercial thinning, whereby tree densities are reduced to diminish competition and maximize tree growth, is one of the most frequently used silvicultural practices in North America. We carried out field surveys in western Newfoundland and in eastern Nova Scotia, Canada, in pre-commercially thinned and unthinned stands of balsam fir (*Abies balsamea* (L.) Mill.) that had been defoliated by the balsam fir sawfly, *Neodiprion abietis* (Harr.), to determine if pre-commercial thinning increased the susceptibility of stands to insect defoliators. Except for stands sampled at the new and increasing stage of an outbreak, both egg densities of, and defoliation by, *N. abietis* were higher in thinned than unthinned stands. Higher levels of defoliation in thinned than unthinned stands were usually associated with higher levels of defoliation on intermediate-aged foliage. An estimate of tree vigor, used to predict future tree growth rate, was only weakly related to defoliation levels and it is, therefore, uncertain if higher defoliation in thinned stands would result in lower future growth rates than for trees in unthinned stands.

Biodiversity vs. productivity and other 'trade-offs' associated with sustainable forest management

Moderators: John R. Spence, University of Alberta, W. Jan A. Volney, Canadian Forest Service & Joshua M. Jacobs, University of Alberta

This workshop session, attended by c. 40 participants, was convened to promote discussion of quantifying and using 'trade-offs' involving insect biodiversity and other forest values. Since the 1991 Earth Summit in Rio, biodiversity has emerged as a central ecosystem value and has been widely adopted as a general measure of non-timber values in forests. Because forest ecosystems are not consciously managed to favor or conserve arthropod species, insects and their relatives have been highly touted as appropriate measures of biodiversity in this context. As a result, there has been a great rush of forest biodiversity studies and forest managers and policy makers are struggling with how to best include such data in the development of forest management. A significant problem results because all forest values cannot be maximized by a single management strategy. Variable retention harvesting, for example, as has been widely adopted to conserve biodiversity in the boreal forests of Canada, leaves potentially harvestable fiber on the ground. Thus, biodiversity has been 'traded-off' against fiber yield. Much present research is devoted to understanding if variable retention actually achieves the biodiversity goals desired, but we still know very little about how to optimize even this straight-forward trade-off. In reality, however, there are other significant values like long-term productivity, nutrient cycling, hydrological function and succession that we would like to factor into management planning. We seek solutions to this problem that allow us to keep all values in the acceptable zone.

The EMEND (Ecosystem Management Emulating Natural Disturbance) project in NW Alberta was discussed to further illustrate the notion of trade-offs. At EMEND four retention harvest systems (10, 20, 50 and 75%) have been applied to 10-ha compartments of forest, each representing one of four cover-types in boreal mixedwood succession (deciduous dominated stands, stands with deciduous canopy and coniferous understory, mixed canopy stands and coniferous dominated stands). Unharvested controls, standard clear-cuts (2% retention) and two fire prescriptions have also been allocated to compartments representing each cover-type. The fire prescriptions are either a whole compartment burn or 15% retention harvest followed by a ground burn of redistributed and cured slash. Each cover-type x disturbance combination has been replicated three times on a landscape that is c. 20 km^2. Details may be reviewed at

http://www.emend.rr.ualberta.ca/english/homepage_e.html.

Our ultimate goal at EMEND is to understand how measures of biodiversity, yield, site productivity, and other forest values behave in relation to natural and anthropogenic disturbance. One possible management outcome would be to adopt the harvesting-regeneration approach that best emulates natural disturbance with respect to behavior of those values. In order to put this into practice, however, we must understand the trade-offs among these variables. After a brief introduction to the topic, we dealt with the potential and pitfalls of this approach and with how the appropriate trade-off analysis could be approached.

The discussion began with identifying critical issues about biodiversity that would require attention in developing the approach outlined above. The following issues were brought forward by the participants:

- Species have highly individual responses; the biodiversity signal will be complex by itself.
- We have focused largely on conservation and preservation but faunal and floral renewal after harvesting is the main issue.
- We require useful approaches for monitoring rare species.
- In order to optimize trade-offs, we need to know how much change is tolerable.
- Should acceptable strategies permit local extirpation of species, if they are retained regionally and adequate provisions are made for their recovery; i.e., what scales are appropriate for performance measures?
- Given the concept of 'extinction debt', how do we establish action thresholds for biodiversity.
- What sorts of actions could we take to ameliorate adverse effects on biodiversity discovered sometime after the disturbances occurred?

We next identified the following critical issues for execution of valid and useful trade-off analyses:

- Some sort of common currencies will be required (e.g., productivity vs. biodiversity).
- We need to develop useful modeling frameworks that reduce trade-offs to decisions about common currencies.
- Realistic alternative scenarios should be developed.
- We need to include forest management as a part of integrated landscape management.
- We need to sort out the contradiction between adaptive management and the concept of policy, unless the policy *is* adaptive management.

The discussion had both a pessimistic and optimistic flavor. The pessimistic view that pervaded flowed from doubts that anything other than dollars on the profit line would be considered in making management decisions. This view, then, justifies the approach taken by many NGO-conservation organizations in winning ecological concessions through market action that force resolution of all trade-offs in the market place without necessary benefit of scientific knowledge. The more optimistic flavor for us flowed from restatement of an interesting old Japanese proverb: "Vision without action is a dream, action without vision is a nightmare". In short, this admonition encourages entomologists who feel that the science of insect biodiversity can provide useful information to support development of forest management to further develop the vision and undertake the actions required to make it happen.

SCALE AND INTERACTIONS

Symbiotic Relationships and Their Role in Forest Insect Invasion and Success

Moderator: Richard Hofstetter, Northern Arizona University

Symbiosis In The Invasive Ambrosia Beetles *Xylosandrus Crassiusculus* And *Xyleborus Glabratus*: Implications For Management

E. P. Ott, Department of Entomology, LSU

Exotic ambrosia beetles are an escalating problem within the United States, with at least one recently-introduced species (*Xyloborus glabratus*) demonstrating the ability to attack living host trees and vector a devastating *Ophiostoma* sp. pathogen. Multiple other ambrosia beetle species (*Xylosandrus compactus* and *X. crassiusculus*), within the Xyloborini tribe, have been found within the *Ophiostoma* infected host along with *X. glabratus*. We therefore performed laboratory experiments in an artificial media to determine whether long-established ambrosia beetles (*X. compactus* and *X. crassiusculus*) might be capable of vectoring the pathogen. Ambrosia beetles maintain a strict obligate mutualism with mycangial fungi that they cultivate in galleries constructed in the xylem. The interactions of the *Ophiostoma* sp. and mycangial fungi involved may affect vectoring capabilities. Therefore, we conducted fungal differential competition experiments to determine competitive effects between the pathogen and the beetle's symbiotic fungus. The differential and primary competition experiments on artificial media indicated a significant advantage for *Ambrosiella xylebori*, the mutualistic fungus of *X. compactus* and *X. crassiusculus* over the *Ophiostoma* sp. Secondary resource utilization was not significant for either fungi. Mycangial isolations showed no evidence of mycangial transfer by *X. crassiusculus* of the *Ophiostoma* sp.. *X. crassiusculus* also showed a decrease of gallery construction behavior in artificial rearing media already inoculated with the *Ophiostoma* sp.

Proteomic And Microscopic Examination Of The Southern Pine Beetle–Fungus Symbiosis

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The southern pine beetle maintains a symbiotic relationship with two fungi via the use of a highly specialized mycangium. This mycangium is surrounded by gland cells and appears to be highly discriminatory in the fungi which it allows to enter and thrive within. We have begun examining the mechanisms (structural and physiological) behind this selective and successful symbiotic partnership. Using scanning electron microscope (SEM) imagery and proteomic comparisons, we are attempting to describe the means by which these fungi enter,

and are maintained within the southern pine beetle mycangium. Preliminary results indicate the differential production of proteins by male and female southern pine beetles. These proteins may play a role in the maintenance of fungal symbionts. Further studies will concentrate on identification of the proteins and further description of mycangial morphology.

The southern pine beetle (SPB), *Dendroctonus frontalis* Zimmermann (Coleoptera; Curculionidae; Scolytinae), is the most economically and ecologically important insect pest of southern forests (Drooz, 1985). These tree killing bark beetles exhibit a mutualistic symbiotic relationship with two species of fungi: *Entomocorticium* sp. *A* (Basidiomycota; Aphyllophorales; Corticiaceae) (Barras and Perry, 1972; Happ et al., 1976), an amber colored basidiomycete (Hsiau and Harrington 2003), and *Ophiostoma ranaculosum* (Ascomycota; Ophio-stomatales; Ophiostomataceae) (syn. *Ceratocystiopsis ranaculosus*; Jacobs and Kirisits, 2003; Barras and Taylor, 1973). The adult female SPB possesses a prothoracic cuticular invagination called a mycangium (Happ et al,. 1971). It is from this structure that *O. ranaculosum* and *Entomocorticium* sp. *A* are cultured, transported, and inoculated into beetle galleries during oviposition. The fungi subsequently proliferate in tree phloem tissues with the resulting hyphal mass providing essential nutrients to larvae (Klepzig et al., 2001). The mycangium apparently favors the growth of only these two fungi through the apparent selective action of its glandular secretions (Happ et al., 1971). *Ophiostoma minus* (Ascomycota; Ophiostomatales; Ophio-stomataceae), a staining fungus which competes with the mycangial mutualists, thereby decreasing beetle reproductive success, is excluded from the mycangium, despite its prevalence on the exterior of the beetle and on associated phoretic mites (Klepzig et al., 2001). Moreover, the two mycangial fungi are not equally beneficial to their symbiotic vector (Barras, 1970; Coppedge et al., 1995; Klepzig and Wilkens, 1997). Due to the complex web of interactions (beetle-fungus, fungus-fungus, mite-fungus, and even beetle-bacteria), and to the incredible economic and ecological impacts of this symbiotic system, we are seeking to identify the molecular basis underlying adaptation of *Entomocorticium* sp. *A* and *O. ranaculosum* to the mycangial environment.

We anticipate that female prothoracic structures and metabolic pathways in mycangial gland cells are key factors in selection, transport, and growth of fungi. SEM and proteomic technologies are powerful tools to understand these processes. We are investigating the mechanism by which fungi are transported from outside to the mycangium. Does the female beetle have a simple transport mechanism by which microorganisms are non-selectively taken from outside through an opening to the mycangium where *Entomocorticium* sp. *A* and *O. ranaculosum* are selectively grown? Or, are there specialized prothoracic structures in the female beetle that aid the entrance of fungi to the mycangium? The latter implies that selection of species that enter to the mycangial lumen possibly occurs on the surface of the mycangium. To answer these questions, thorax section of female beetles at various developmental stages is cryofractured in liquid nitrogen and examined under SEM. We observe yeast-like fungal spores in the mycangium and several hyphae-like structures in the surrounding tubes that presumably carry secreted chemicals from gland cells to the mycangium. Do these tubes secrete chemicals not only to the mycangium but also the surface of the mycangium, and provide a passage to the fungi from outside to the mycangium? The observations in SEM micrographs need to be functionally verified by tagging *Entomocorticium* sp. *A* or *O. ranaculosum* with fluorescent proteins (e.g., green fluorescent protein from the jellyfish *Aequorea victoria*) and/or conducting *in vivo* assays using female beetles to follow the entry of fungi into the mycangium.

Once *Entomocorticium* sp. *A* or *O. ranaculosum* have entered the mycangium, how does the female beetle regulate their proliferation and yeast-like growth form? The mycangium favors the growth of two fungi through the apparent selective action of its glandular chemical secretions (Happ et al., 1971). Because the gland cells differ in morphology, it is suggested that the secretion from one gland cell-type regulates the species composition of the fungi via the biosynthesis of defensive chemicals, whereas the other gland cell-type provides nutrients for fungal growth and reproduction (Happ et al., 1971). However, the nature of these chemicals is unknown. One feasible approach is to identify the metabolic molecular pathways associated with the presumed role of gland cells. Thus, we have taken a proteomic approach to identify proteins involved in these metabolic pathways. This approach is based on the fact that female beetles form true mycangia, whereas males form non-functioning pseudomycangia. Thorax tissues from female and male beetles have been dissected. We have extracted proteins from females (labeled with Cy3, which fluoresces green) and males (labeled with Cy5, which fluoresces red). Labeled proteins were mixed and separated using two-dimensional Difference In-Gel Electrophoresis (2-D DIGE). Differentially expressed proteins from females were seen as green, and male produced proteins as red. Common proteins were seen as yellow. Based on the color mode and statistical analyses, differentially expressed proteins from female tissues were subject to mass spectrometry (MALDI-TOF/TOF) analysis. Due to the unavailability of SPB genome sequence information, we have used genome sequence information from another beetle (*Tribolium castaneum*; http://www.hgsc.bcm.tmc.edu/projects/tribolium/) for protein identification.

The practical application of this research is the possibility of alternative approaches to SPB control based on proteomics and/ or genomics. We anticipate the identification of molecular targets that are essential in the SPB's mutualistic interaction with *Entomo-corticium* sp. *A* and *O. ranaculosum*. Such information may serve as the basis for development of chemicals which might target specific proteins in the mycangium to disrupt the beetle-fungal interaction.

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Morphology of The Mesonotal Mycangium Of *Xylosandrus Mutilatus*

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Xylosandrus mutilatus (Blandford) is an ambrosia beetle from Asia which was first detected in Mississippi in 1999 and has now become established. In China, *X. mutilatus* is one of the major pests attacking the trunk and branches of Chinese chestnut, *Castanea mollissima* Blue. Ambrosia beetles have specialized structures termed mycangia, which consist of pits, sacs, pouches, tubes, or pubescent areas where fungal spores are contained and allowed to proliferate. The mycangia can occur in numerous locations in and on beetles and all are invaginations of the cuticle. Hence, fungi form a symbiotic relationship with the beetle by serving as the primary food resource for larvae and adults. The purpose of this study was to describe the mycangium with light, scanning and transmission electron microscopy. Thirty mycangia were dissected from mature female beetles and prepared by conventional light and electron microscope methodologies. In X. *mutilatus*, the mycangium is found only in females and consists of a double, paired sac-like organ of ectodermal origin which lies in the forward margin of the mesonotum. The inner cuticular structure of the mycangium is formed by the recurved scutellum. The outer secretory cell layer conceals the inner cuticular paired sac. Type-1 secretory cells were identified and observed passing electron dense material into the mycangium via efferent cuticular ductules. Type-2 secretory cells were not observed.

Secretory cells were not observed in association with the nonglandular pit mycangia located on the scutellum. The sceretory and cuticular layers of the mycangium were highly tracheolated. The average length of one inner cuticular sac measured 680µm and height measured 419µm (N=6). The area of cuticle joining both lobes of the sac is termed by this paper as the "mycangial bridge". The average width of the mycangial bridge measured 231µm and height measured 148µm (N=6). Images obtained provide a new understanding of the morphological characteristic of the mesonotal mycangium of *X. mutilatus*. Future research is underway to identify the fungal species.

Symbiosis Between *Sirex Noctilio*, *Amylostereum Areolatum* And *Deladenus Siricidicola*: A South African Perspective

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Sirex noctilio Fabricus was first detected in South Africa in 1994, in the Western Cape. It has since spread to the Eastern Cape and KwaZulu-Natal provinces. The parasitic nematode, *Deladenus siricidicola*, has been released in all three provinces, but with very limited success. Despite the absence of well established biological control agents in South Africa, *S. noctilio* populations remain low in the Western Cape, in contrast to rapidly increasing populations in the Eastern Cape and KwaZulu-Natal. In these two provinces *S. noctilio* causes significant damage to *Pinus* plantations, with some sites having over 50 % mortality. The interactions between *S. noctilio*, its fungal symbiont (*Amylostereum areolatum*), its biocontrol agent (*D. siricidicola*), and its host (*Pinus*), was examined in an effort to understand the differences between provinces and the reason for the low success with *D. siricidicola*. Differences in silvicultural practices between provinces, such as thinning, are likely to be the main factor responsible for differences in *S. noctilio* populations. Moisture content of the tree at time of inoculation, loss of virulence of *D. siricidicola* and incompatibility between *S. noctilio* and *D. siricidicola* strains, or between *D. siricidicola* and *A. areolatum* strains, are important factors that can contribute to the success of *D. siricidicola* as a biocontrol agent. A better understanding of these factors is needed to ensure sustainable control of *S. noctilio* in South Africa and elsewhere.

Multiple-Component Symbioses: Spruce Beetle - Microbe Associations As A Model

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Although insect-microbial symbioses have most commonly been studied as paired species and relatively straightforward interactions, there is now widespread recognition that these relationships can be complex, context-specific, and linking organisms across different biological kingdoms. This presentation provides an overview of one insect system that this complexity.

The spruce beetle, *Dendroctonus rufipennis* (Kirby) is a broadly distributed bark beetle that colonizes most species of spruce within its range. It usually congregates and reproduces on highly stressed or killed trees, but under certain conditions undergoes landscape level eruptions that kill millions of trees (Werner et al. 2006). Under these conditions, its behavior changes and it attacks almost all trees regardless of their physiological condition (Wallin and Raffa 2004). We describe here three sources of complexity to illustrate the overall theme: Bacterial - Beetle - Fungal interactions, Nematode - Beetle - Fungal interactions, and Sources of Variation in the frequencies of association.

Host colonization by spruce beetles leads to gallery invasion by several species of fungi (Cardoza et al. 2006a). These include species carried by the adult insects and environmentally prevalent fungi, close associates and opportunists, and species that may confer some types of benefit as well as strictly antagonistic species. Some of these fungi reduce spruce beetle survival and reproduction in controlled assays. Spruce beetle adults exhibit a behavior by which they exude oral secretions that inhibit fungal growth (Cardoza et al. 2006a). They appear most likely to egest these oral secretions when they encounter fungus-pervaded galleries. Oral secretions contain a variety of bacteria, within the Actinobacteria, Firmicutes, Gamma-proteobacteria and Betaproteobacteria. Some of these bacterial species are responsible for the fungal inhibition, as evidenced by: a) Filter-sterilized secretions do not inhibit fungal growth; and b) Individual bacterial isolates show species-specific inhibitory activity against the four antagonistic fungi. The actinomycete *Micrococcus luteus* shows the strongest fungal inhibition (Cardoza et al. 2006a).

The nematode *Ektaphelenchus obtusus* Massey, and also fungi, occur within special structures on the hindwings of spruce beetles (Cardoza et al. 2006b). These structures are orange-brown with a melanized appearance and apparent leathery consistency. Ultrastructural analysis suggests the walls are composed of a granular matrix that is infiltrated by microbial spores and exuded from the insects' wing veins, through pores. All spruce beetle wings observed were covered with mucilaginous secretions and fungal spores and/or mycelia, but these structures were only found in association with nematodes. This suggests a crucial role of the nematodes in formation of these pockets, which we term "nematangia" (Cardoza et al. 2006b). We identified four predominant microbial species in nematangia: two ophiostomatoid and two yeast morphologies, with sequence matches closest to the following: *Ophiostoma abiocarpum* (82% of beetles), *Ophiostoma penicilliatum* (24% incidence), *Candida spp.* (88% incidence) and *Pichia* (82% incidence). One or both ophiostomatoid fungi were present in all nematangia sampled. Surprisingly, the predominant fungus associated with spruce beetle, *Leptographium abietinum* was not recovered from nematangia, even though similar culturing and sequencing methods recover the same fungus from beetle exoskeletons and galleries (Aukema et al. 2005, Cardoza et al. 2005a). This fungal composition differs substantially from previous isolations from spruce beetles (Six & Bentz 2003, Aukema et al. 2005). The abundance of nematangia varies seasonally, from 60% incidence in spruce beetles overwintering within trees to 17% in beetles flying in late spring (Cardoza et al. 2006b). Incidence does not vary between beetle genders. Nematangia were not found on *Dendroctonus ponderosae* Hopkins or *Ips pini* (Say).

In addition to the added complexity of multiple species, there is also quantitative variation among each of them. Environ-mental influences may affect the distribution of each species of fungus, bacterium, and nematode, and hence their influences on each other and their net impacts on beetle populations. This poses special challenges from both operational and statistical perspectives. We addressed this problem using spruce beetle as a model, by isolating fungi from approximately 1000 beetles from the Kenai Peninsula of Alaska over a three-year period (Aukema et al. 2005). The first year was devoted to comparing results from various isolation methods, culturing conditions, and methods of collecting beetles. We then compared variation in the frequencies of beetle-associated fungi at three levels: among beetles within trees, trees, within sites, and sites within the region. Beetles collected in flight traps and excavated from hosts yielded the same fungi. In this particular system, between-beetle variation within trees is higher than between-tree variation within sites, and between-site variation across the Kenai Peninsula (Aukema et al. 2005). There are three practical ramifications derived from these data. First, experimental designs should include more beetles per tree and more trees per site at the expense of more sites. We found thise results surprising, and would have predicted otherwise. Second, it is valuable to know the tree from which each beetle arose. Obscuring such information reduces the power of subsequent hypothesis testing. Third, the added labor required to keep individual beetles separate throughout all phases of sampling is worth the investment. There is some evidence that two species of fungi, *L abietinum* and *a Pesotum* sp., varied in their frequencies depending on beetle population density (Aukema et al. 2005). There was a strong inverse relationship between frequencies of *L. abietinum* and this *Pesotum* sp. at both the population and individual beetle levels. These results suggest that interpretation of how any one fungus affects its beetle vector or host tree should be considered both alone and in combination with other prevalent fungi.

Areas for future research include: 1) How do multiple interactions among microbial associates affect their net impacts on beetle fitness? 2) How are these multiple interactions and net impacts influenced by the changing template of host tree condition and chemistry across colonization sequence? 3) How are these multiple interactions influenced by, and how do they influence, the changing template of beetle population density at various levels of scale?

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The Roles of Habitat Mosaics and Physical Variables in the Movement of Forest-Dwelling Organisms

Moderator: Brian Strom, USDA Forest Service, Forest Health Protection

Using Reaction-Diffusion Models To Characterize The Landscape-Level Distribution Of Bark Beetles

Reeve, J. D

Bark beetles inhabit a complex landscape including host and non-host stands, clearings, urban areas, and other landscape elements. These insects could potentially disperse at different rates in these elements, and exhibit edge behavior when crossing from one habitat type to another. Reaction-dffusion models provide a useful framework to incorporate these complexities. Methods for estimating the dispersal distance of bark beetles and associates using mark-recapture experiments are reviewed and recent studies presented. It is noted that no studies have examined dispersal in non-host habitat, although this is typically a major component of natural landscapes. Methods of quantifying edge behavior are illustrated using data from the planthopper, *Prokelisia crocea*, an herbivore of prairie cordgrass that inhabits host patches separated by a matrix of mudflat or non-host plants. This herbivore exhibits distinct edge behaviors depending on the matrix type, which in turn affects the persistence of planthopper populations through time. Applications of the same methodology to southern pine beetle are presented.

Impact of Canopy Density On Movement Of A Tracer Gas In A Southern Pine Stand

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The literature on insect semiochemical signaling systems is extensive; this is particularly true for bark beetles that are major pests worldwide. In the trunk space of forests, bark beetles sense their environment largely through olfaction, locating suitable hosts and mates. Semiochemical-based monitoring and control strategies have arisen from this knowledge, and are widely used in forestry to influence bark beetle behavior by strategically releasing synthetic semiochemicals to guide beetles toward a trap or away from a resource.

From a physical point of view, all of these systems have a releaser (mass time^{-1}) and a resulting concentration field of chemical in the surrounding air (mass volume^{-1}). Critical to designing a system from this standpoint are the semiochemical concentrations that influence insect behavior and how they vary in time and space. Obviously, the functioning of the biological sensing system of the insect may be extremely complex. Sampling technology has advanced sufficiently to allow insight into plume microstructure at high frequencies, i.e., conditions more similar to insect olfaction. The focus of this work has been to measure the dynamic concentration and spatial structure of a tracer gas (SF_6) following its release, and to infer semiochemical movement under forest canopies from the results.

Experimental Design

The method used here is a tracer experiment utilizing SF_6 and 30 minute mean samplers (Krasnec et al. 1984), enhanced with high frequency sampling (Benner and Lamb 1985). The basic configuration (Thistle et al. 1995, Thistle et al. 2004) is to surround a point source of SF_6 with three concentric circles of samplers at 5m, 10m, and 30m distance. SF_6 is released at a carefully metered rate from plot center for 4.5 h during each trial day. Approximately 450 mean samples are processed each day; the entire program data base currently consists of over 18000, 30 minute mean samples. In addition, a high frequency sampler is deployed at one point on the sample array, allowing the structure of the plume at high frequency to be compared to the mean plume. SF_6 was chosen because it can be detected at concentrations as low as 10 ppt (even at 1 Hz), is conservative (fairly non-reactive in the environment), and a large body of scientific literature exists utilizing it as a gaseous tracer.

Results and Conclusions

The experiment has been successfully completed in seven canopy types, producing over 18000 mean samples and many high frequency traces of SF_6 concentrations. It is apparent that plume dilution is strongly dependent on canopy density. Closed or relatively dense canopies buffer the trunkspace below, so plumes remain more concentrated with distance. Reduced canopy density promotes coupling with the outside atmosphere, causing plume behavior to be more affected by general atmospheric conditions. This coupling can be viewed as both aerodynamic and radiative. Air flow from above the canopy more easily penetrates lower density canopies, causing more turbulence underneath. An increase in penetrating sunlight causes heating below the canopy, which increases turbulence and plume dilution. This effect reverses at night because exposed surfaces lose heat (to space) more effectively and become colder and mixing is damped. The trunk space environment of closed canopies tends to be low velocity and shaded, an environment that causes plumes to dilute slowly and remain concentrated at greater distances from the source.

The high frequency traces show plumes that are narrow or ‘filamentous’ with discrete edges. These plumes maintain this nature over a range of meteorological conditions so that in the trunkspace below a closed or dense canopy, plumes wander slowly and may impact a single point for a longer period of time. This results in a higher mean concentration at that point. Under the more open canopy, where velocity and mixing can be high, the plumes still exhibit this filamentous nature but move extensively laterally. Although they traverse a wide area, they do not result in high concentrations at a given point in the mean sense. Seemingly a denser canopy promotes trunk space conditions in which an insect can more easily follow a plume to its source.

Effect of Forest Structure On Bark Beetle Response To Pheromone-Baited Traps

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Dispersal of bark beetles in search of breeding habitat is expected to be influenced by the density of forest stands, and this idea underlies the practice of thinning forests to reduce the presence of bark beetles. Thinning increases temperature and wind that in turn affect the behaviour of pheromone plumes. Thinning also influences the clutter through which beetles fly. Consequently, we predicted that beetles would disperse further through thinned stands than through unthinned stands, perhaps in part because their ability to locate pheromone sources is reduced. Using pine engravers, *Ips pini*, we conducted a mark-recapture study in mature lodgepole pine, *Pinus contorta*, stands that were either not thinned or thinned to a third of the initial density (n=4 in each stand type). We released beetles at the centre of an array of pheromone-baited traps at 50 m intervals in the four cardinal directions up to 200 m. Recapture rates (ca. 3%) did not differ between thinned and non-thinned stands. We fit the abundance of recaptured beetles as a function of distance to an area-ratio model (Zolubas and Byers 1995), and found that trap effectiveness was less in thinned stands while the attraction radius tended to be higher in thinned stands. Using a diffusion model (Turchin and Thoeny 1993), we estimated that the mean dispersal distance greater in thinned stands (mean of 377 m) than in non-thinned stands (105 m). However, beetles lost less weight with increasing recapture distance in thinned stands than in non-thinned stands. These results are consistent with the idea that thinning hastens the movement of beetles through stands in part because of a reduced ability to locate pheromone sources and because of reduced flight costs for a given net displacement.

Connecting the Scales

Moderator: Kenneth Raffa, Univ. Wisconsin-Madison

The ability to effectively link pattern and process across multiple scales is a major challenge confronting both forest pest management and basic understanding of insect biology. Emerging issues such as invasive species, global change, and interactions of insects with fire, forest-human interfaces, and wilderness-managed stand interfaces, all share the common problem that information from one level of biological organization is not immediately applicable to another. This session addressed approaches and technologies for improving connections from the biochemical through landscape levels.

We explored this issue using the mountain pine beetle as a model. This insect is highly eruptive, well studied and sensitive to human activities, and thus should serve as a useful model for other forest insects. The speakers addressed this single insect - host tree – fungal - climate system from three perspectives. These perspectives included: Biochemical mechanisms of pine defense (Jorg Bohlman), Population dynamics and transition from endemic to eruptive status (Allan Carroll), and Landscape ecology and weather influences (James Powell). Each speaker also proposed approaches for interfacing their knowledge with that from adjoining scales.

Formal presentations were followed by a panel and open-workshop discussion that included experts on defoliators such as spruce budworm and gypsy moth, and other aspects of the mountain pine beetle system. Panelists included Joe Elkinton, Andrew Liebhold, Rich Fleming, and Dezene Huber, in addition to the above speakers.

Molecular, Biochemical, And Cellular Mechanisms And Genomics Approaches To Coniefr Defense

Jörg Bohlmann, University of British Columbia

Conifer trees display a large array of defenses against insect pests and insect associated pathogens. Insect induced defenses in species of spruce (Picea spp.) include a myriad of combinations of constitutive and induced, chemical and physical, direct and indirect, as well as local and systemic defenses. Among some of the most prominent insect-induced defenses in conifers are terpenoid (traumatic resinosis; terpenid volatile emissions) and phenolic secondary metabolites. Traumatic resinosis involves methyl jasmonate or ethylene-inducible de novo differentiation of specialized anatomical structures (traumatic resin ducts, TRD) for induced terpenoid accumulation in the developing xylem. Phenolic defenses involve the induction of polyphenolic parenchyma (PP) cells of largely unknown chemical contents. Insect induced volatile emissions are based on passive release of resin terpenoids and on the active de novo formation and emission of non-resin monoterpenes and sesquiterpenes. In targeted biochemical characterization of insect-induced secondary metabolite defenses, we have functionally characterized a large family of conifer terpenoid synthase genes as well as cytochrome P450 genes for conifer diterpene resin acid formation and measured their expression in response to real and simulated insect attack. Large-scale genomics resources for species of spruce (>200,000 ESTs; ca. 6,400 FL-cDNA; and a 22k-cDNA microarray) and optimized proteomics tools have been developed in our conifer genomics program (www.treenomix.ca) and applied for a comprehensive analysis of conifer defense response to insect attack. In parallel, we have established an EST resource for a bark beetle associated fungal pathogen representing a large number of CYP450 potentially involved in detoxification of conifer chemical defenses.

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Mountain Pine Beetle Population Dynamics: The Endemic-Epidemic Transition

A.L. Carroll, Canadian Forest Service, Pacific Forestry Centre, B.H. Aukema, Canadian Forest Service, University of Northern British Columbia and K.F. Raffa, University of Wisconsin

The mountain pine beetle is a phloeophagous herbivore native to the pine forests of western North America. Periodically, populations erupt into large-scale epidemics that cause the mortality of mature pine trees over many thousands of hectares. Between epidemics, the mountain pine beetle exists as “endemic” populations that are characteristically scattered and restricted to suppressed and/or damaged pine trees with impaired defences which they colonize in direct competition with an assemblage of “secondary” bark beetle species. We conducted a 4-year study (involving 6 stands at 2 sites in southern British Columbia) in which bark beetle populations were censused and tree and stand characteristics quantified to determine the temporal and spatial changes in trophic interactions that facilitate the eruption of mountain pine beetle populations from the endemic to the epidemic state. During the study, populations in 4 stands erupted from endemic into incipient epidemics. Population eruptions were always preceded by 2-3 years of abrupt increases in attacks by secondary bark beetles correlated with a period of exceptional drought. As each mountain pine beetle population increased, attacks on trees previously colonized by secondary beetles declined, while successful primary attacks of large diameter trees increased, exponentially. The eruptive dynamics of mountain pine beetle arise as a consequence of interactions with bole-infesting secondary bark beetles that restrict their numbers below the threshold required to access healthy, resistant, thick-phloem trees. Eruptions occur when exogenous stress events (i.e. drought, windthrow, pathogens) increase the availability of vigour-impaired host trees within mature pine stands thereby enabling mountain pine beetle populations to build sufficiently to access healthy, large-diameter trees and escape interaction with the secondary beetle assemblage.

Connecting Tree-Level Phenology And Landscape-Level Mountain Pine Beetle Outbreak Dynamics: *Where Did All The Green Trees Go?*

James Powell, Utah State University and Barbara Bentz, USDA Forest Service RMRS

Mountain pine beetle (*Dendroctonus ponderosae* Hopkins) is an outbreak insect infesting pine hosts in western North America. This insect has a historic pattern of outbreak in the western US, and has recently expanded its range into northern British Columbia, where it has impacted millions of hectares of lodegpole pine forest. As with many outbreak insects (e.g. gypsy moth, grasshoppers and southern pine beetle) a phenology model exists which can predict the occurrence of seasonal timing (Gilbert et al. 2004). This model uses hourly phloem temperatures to determine distribution of adult emergence times, using development rates from the literature. Outbreak prediction at the landscape scale depends on predicting population growth rates, and thus upon some demographic model. Certainly there is a long history of demographic population modeling, some of it specific to mountain pine beetle. However, very little of this modeling explicitly includes the interaction between phenology, temperature, and population success as manifested by quantitative dependence of demographic parameters on environmental variables controlling life history traits. In this talk we discuss connecting a distributional model for insect phenology, taking full account of both environmental and genetic variability, with a model for population success. This model bridges the gap between phenology predictions and population viability/growth rates for mountain pine beetle. The model is parameterized and compared with data from an outbreak now finishing in the Sawtooth National Recreation Area of central Idaho, using a variety of temperature models for the phloem in which beetles develop. The model predicts observed landscape-level population growth rates with R-squared of 92% using phloem temperatures from south sides of individual pines in the area. Outbreak seems to be the result of population growth rates above 1 for several years running, suggesting that this model can potentially predict landscape-scale events given local thermal data.

Host Plant-mediated Plant-insect and Insect-insect Interactions

Moderator: L.K. Rieske-Kinney, Department of Entomology, University of Kentucky

Woody Plant Galls Affect Foliar Quality With Potential Consequences For Herbivory

L.K. Rieske-Kinney, Department of Entomology, University of Kentucky

Interactions between spatially or temporally segregated herbivores are complex, particularly when considering different feeding guilds. Response by both herbivores and plants is dynamic, and the cross-effects of these interactions are complex. The role that prior herbivory has in dictating the extent of these responses is not fully understood.

Insect induced plant galls are species-specific with respect to size, shape, relative occurrence, and effects on the host plant. Gallmakers can cause phyto-hormone balances and alter source/sink relations, thereby influencing plant nutrient concentrations and the production of plant defensive compounds. In this talk, I describe research evaluating the extent to which Cynipid gallmakers in two woody plant-gallmaker systems alter the substrate quality for later feeding folivores.

Pin oaks heavily infested with the horned oak gall, *Callirhytis cornigera*, were slower to break bud. Early in the season the foliage from galled trees was denser and had higher tannin levels, and ungalled foliage was preferred by gypsy moth caterpillars. Later in the season the elevated foliar tannins declined, and foliar nitrogen was higher in foliage adjacent to galls. However, gypsy moth growth and development did not differ between galled foliage, foliage adjacent to galls, and ungalled foliage.

In chestnut infested with the Asian chestnut gall wasp, *Drycosmus kuriphilus*, the gallmakers' effects on foliar characteristics were assessed on both American and Chinese chestnut. Foliar suitability to three generalist herbivores (gypsy moth caterpillars, Japanese beetle adults, and fall webworm caterpillars) was evaluated. Gypsy moth caterpillars preferred Chinese chestnut to American chestnut. The gallmaker did not influence caterpillar consumption of Chinese chestnut. However, within American chestnut, caterpillar consumption was lowest on foliage adjacent to galls, and caterpillar development time was shortest on ungalled trees.

For Japanese beetle adults, consumption was greatest on American chestnut, but ungalled American chestnut was least preferred. In contrast, ungalled Chinese chestnut was most preferred by adult beetles. Fall webworm caterpillar consumption was lowest on American chestnut foliage adjacent to galls, but variability was high and separation was poor.

No clear pattern of susceptibility to generalist herbivores emerged between galling categories within a chestnut species; chestnut susceptibility to herbivory varies with the herbivore and with the chestnut species. However, American chestnut appears more susceptible to galling than does Chinese chestnut, and the Asian chestnut gall wasp could pose a threat to restoration efforts for the American chestnut. The implications of this work suggests that gallmakers may indirectly affect later occurring herbivores through physiological changes to the host plant.

Influence Of Intracrown Heterogeneity In Foliage Quality On The Foraging Strategy Of Juvenile Insects

Rob Johns and Dan Quiring, Population Ecology Group, Department of Biology, University of New Brunswick

The foraging behavior of herbivorous insects is shaped by spatial and temporal heterogeneity in the suitability of feeding sites (Denno and McClure, 1983). Many studies have examined how heterogeneity in the distribution of suitable resources, microclimate, and enemy-free space can interact to determine the foraging behavior and performance of herbivorous insects. However, most of these studies have focused on heterogeneity among conspecific plants (Denno and McClure, 1983; Clark and Messina, 1998; Stamp and Bowers, 1990; Quiring and Butterworth, 1994; Alonso and Herrera, 1996; Holland *et al*., 2004) or plant species (Gratton and Welter, 1998; Scheirs *et al*., 2000; Schiers and De Bruyn, 2002; Gottard *et al*., 2005) and do not address increasing evidence that variability within plants, particularly large plants such as trees, can be almost as high as that among plants (Denno and McClure, 1983; Quiring, 1993). If such variability is sufficient to significantly influence the foraging behaviors of insects within plants, then it follows that such behaviors should also have significant implications for how we establish sampling procedures for insect pests within trees.

The role of intraplant heterogeneity in shaping the foraging behaviors of insects has been extensively evaluated for each of two conifer regeneration pests that respond similarly to intratree heterogeneity. Late-instar *Zieraphera canadensis* (Mut. & Free.) (Lepidoptera: Tortricidae) and *Pikonema alaskensis* (Roh.) (Hymenoptera: Tenthredinidae) juveniles disperse acropetally (sensu Quiring, 1993), from lower basal to upper apical shoots, through the crowns of white spruce (*Picea glauca* [Moench] Voss) and black spruce (*Picea mariana* [Mills] B.S.P.), respectively, resulting in significant damage to apically located shoots. For *Z. canadensis* caterpillars, acropetal patterns of shoot development in white spruce are responsible for generating the complimentary acropetal dispersal, thus enabling juveniles to feed almost continuously on foliage of newly burst buds (Carroll and Quiring, 1994). Acropetal dispersal by *P. alaskensis* larvae, in contrast, is sex-biased and appears to represent an adaptation to variations in foliage quality among crown levels, independent of intratree variations in phenology (unpubl. data).

Elucidation of this foraging behavior was necessary to establish robust density-defoliation relationships for both insects (Carroll and Quiring, 1993; Johns *et al*., 2006). To account for acropetal dispersal, these studies used densities of eggs or early-instar juveniles in the mid-crown of trees to predict subsequent damage in the upper crowns of trees. Studies such as these further emphasize the important influence of variability within plants, particularly large plants such as trees, in determining patterns of distribution and abundance of herbivores within plants. Such studies are also critical for constructing management plans (i.e., sampling procedures and density-defoliation relationships) for insect pests.

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Exogenous Application Of Methyl Jasmonate Elicits Defenses In Norway Spruce (*Picea Abies*) And Reduces Host Colonization By The Bark Beetle *Ips typographus*

Nadir Erbilgin, Division of Organisms and Environment, Department of Environmental Science, Policy & Management, University of California, Berkeley, Paal Krokene, Erik Christiansen, Norwegian Forest Research Institute, Gazmend Zeneli, and Jonathan Gershenzon, Max Planck Institute for Chemical Ecology

The terpenoid and phenolic constituents of conifers have been implicated in protecting trees from infestation by bark beetles and phytopathogenic fungi, but it has been difficult to prove these defensive roles under natural conditions. We used methyl jasmonate, a well-known inducer of plant defense responses, to manipulate the biochemistry and anatomy of mature *Picea abies* (Norway spruce) trees and test their resistance to attack by *Ips typographus* (the spruce bark beetle). Bark sections of *P. abies* treated with methyl jasmonate had significantly less *I. typographus* colonization than bark sections in the controls and exhibited shorter parental galleries and fewer eggs deposited. The numbers of beetles that emerged and mean dry weight per beetle were also significantly lower in methyl jasmonate-treated bark. In addition, fewer beetles were attracted to conspecifics tunneling in methyl jasmonate-treated bark. Stem sections of *P. abies* treated with methyl jasmonate had an increased number of traumatic resin ducts and a higher concentration of terpenes than untreated sections, whereas the concentration of soluble phenolics did not differ between treatments. The increased amount of terpenoid resin present in methyl jasmonate-treated bark could be directly responsible for the observed decrease in *I. typographus* colonization and reproduction.

The Nature And Ecological Implications Of Disease Resistance In Pine

Pierliugi Bonello, Dept. of Plant Pathology, The Ohio State University

Conifer trees have evolved to withstand a constant onslaught of attacks by pathogens and insects in the course of their long lifespans. The interface between host and pathogen is often characterized by a hypersensitive response, accompanied by the accumulation of soluble and cell wall-bound secondary metabolites, pathogenesis-related proteins, and induction of the resin system. All of these defenses are inducible both locally and systemically. How do these

pathogen-induced host responses affect insect behavior and performance, particularly from a systemic perspective? I will review the current state of knowledge with specific reference to the Austrian pine-Diplodia pathosystem, a canker model that is amenable to manipulation and should lead to a better understanding of the processes underlying local and systemic induced resistance to pathogens and insects in coniferous trees.

CHANGE

Challenges of Using On-Line Resources to Aid in Forest Entomology Education

Moderators: John McLean, University of British Columbia, and Fred Hain, North Carolina State University

Ten years ago, John McLean, Department of Forest Sciences, University of British Columbia, reported to the second NAFIWC in San Antonio on the establishment of a web site to support his Forest Entomology course. He challenged colleagues in the Work Conferences to develop web sites that report the latest of their work so that students could be directed to the best information sources available. In British Columbia, a Forest Practices Code had been enacted that included several Guidebooks on the management of forest insects. These guidebooks included the best available information of the day and they were made readily available via the world wide web. Over the last 10 years, the growth in electronic resources has been phenomenal. Electronic access to journal papers and research station literature has revolutionized access to the best information available.

The WWW never sleeps. An analysis of UBC's FETCH21 (Forest Entomology Textbook Challenge for the 21st Century) for site usage shows that there is constant access on a 24/7 basis with peaks on Wednesdays and Thursdays during the week and 1700-2400 hours diurnally (PDST). FETCH21 is accessed as much from the USA as it is from Canada. Addresses from more than 85 countries are recorded monthly accessing this site. Information is sought world wide 24/7. The challenge now is to ensure that students are guided to the best of the available information. The general public also accesses these sites and often submits their own digital images for identification.

Research Centers throughout the world are making their excellent publications available electronically. The advent of broad communication allows the ready transmission of high quality images to everyone's desktop. Original images are included in several sites such as FETCH21 and other university based courses. One of the most active developments is The Bugwood Network at www.bugwood.org which is hosted at The University of Georgia's Warnell School of Forest Resources and College of Agricultural and Envronmental Science's Department of Entomology. Keith Douce addressed the challenged of setting up and maintaining this site. The stated mission for the site is "to gather, create, maintain, promote the use of, and economically distribute digital information both as resources and as tools to enhance and complement information exchange and educational activities primarily in the fields of entomology, forestry, forest health and natural resources". The database that he and his team is assembling requires creditable, accurately identified photographs. Every effort is made to acknowledge the photographer and the source of the images. Images are sought for educational purposes and in many cases publication quality images are also available on request. See the web site for more information. Once images are set up on a web site they are also indexed by the major search engines such as Google which leads to greater useage.
The NAFIWC include amongst its members dedicated enthusiasts who bring the world of forest insects to their students. One of the most outstanding of these enthusiasts is David Kulhavy, the Piper Professor of Entomology in the Arthur Temple College of Forestry and

Landscape Ecology at Stephen F. Austin State University. David shared his views on the opportunity to instill into students a real desire to learn through curiosity, enthusiasm and observation. Search David Kulhavy in Google and you will find a record of dedicated teaching that has resulted in several awards including a Distinguished Teaching Award in Entomology from the Entomological Society of America in 1993.

David sees the challenges ahead to include the use of Power Point (rich imagery) for presentations and assignments. Sites such as Bugwood need to be supported so all can use their high quality imagery. Geographical devices such as GIS and GPS make for relevant presentations. We need to add material on invasive insects to our curriculum and to make sure that Forest Entomology stays in the core curriculum of all foresters.

In addition to regular classroom instruction, there is a challenge to try and deliver dynamic on-line courses. Dr, Clyde Sorenson, Department of Entomology, North Carolina State University, addressed several of the challenges that he experienced with asynchronous on-line delivery. It is difficult to for the instructor to learn about the students and engage them in the same way as you can in a laboratory session. There is considerable flexibility for the on-line student and they have greater opportunity to review. For those students who can handle asynchronous delivery, their performance can be comparable to the on-campus lecture course.

Both Clyde and John noted that little academic credit is given in the University systems of the US and Canada for offering distance education courses. John has offered a Distance Education version of his course for more than 25 years. At first it was a paper based course then technology enabled videotapes to be included as a partial compensation for the loss of live lectures. These videotapes have been broken down into a series of videoclips which are now attached to an electronic offering as a WebCT course at UBC. Early efforts with a Classroom emulator called WIMBA were not successful as it requires broad band and voice interaction with Windows XP or better as an operating system. In a short period these resources will be more common place and WIMBA will allow an evening lecture from the course instructor right at the students' desktops in their own study.

"Insects and People": Emulating A Dynamic Classroom Online

Clyde E. Sorenson and Ronald Kuhr, Department of Entomology, North Carolina State University

ENT 201, Insects and People, is a highly interactive lecture course offered to the general undergraduate community at North Carolina State University. The course was developed as a science course for non-science majors. In the lecture hall, we use a range of multimedia tools, including videos, live demonstrations, group assignments, recorded sounds, passed around artifacts, and others to deliver a lively presentation of scientific information to a large section of students largely enrolled in non-science degree programs. This course is in great demand at NCSU; recognizing this, and the potential demand for such a course in the larger community, we developed a web-based, asynchronously delivered section of ENT 201. Our goal was to emulate the classroom experience as much as possible. To do this we, we use narrated Flash presentations generated through Powerpoint and Authorgen; these are supplemented by video demonstrations and movie clips delivered through Quicktime, a Flash interactive on insect diversity, sound files, and downloadable lecture outlines. We utilize internet discussions to emulate the in-class group work, and assign the same course projects as in the lecture section, including a hands-on experiment involving raising insects under different experimental regimens (we mail the insects to students if necessary). Testing is on campus or facilitated by an off-campus proctor.

The distance education section was first offered in the Fall, 2005 semester with an enrollment of 37; enrollment was 57 in the Spring, 2006 semester. Feedback from students taking this distance education offering has been overwhelmingly positive. We will demonstrate some of the tools we use in this course offering and will also discuss the advantages and problems presented by this delivery method.

Global Warming: A Conversation About Management Issues and Responses

Moderators: Tom Eager, USDA Forest Service, FHP, and Bill Mattson, USDA Forest Service, NRS

Managing Forests To Prevent Insect Outbreaks In A Changing World

Darrell W. Ross, Department of Forest Science, Oregon State University

Managing forests and the insects that inhabit them is an inherently risky business with lots of uncertainty. Trees, the dominant feature that define forests, are long-lived. Typical life spans of trees or rotations of managed forests range from several decades to several hundred years. Over those time periods, many aspects of the biophysical and socioeconomic environments change. In addition, management objectives and goals may shift significantly over those same periods. For example, in just the past two decades there has been a dramatic change in forest management on public lands of the Pacific Northwest from a heavy emphasis on timber to more diverse goals of restoration, ecological values, wildlife, recreation, watersheds, and urban-wildland interfaces. Climate change is simply another variable added to the dynamic forest environment.

Forests are complex as well as dynamic. All parts of a forest ecosystem interact with all other parts to some extent. Predicting how these systems will respond to warming temperatures is difficult if not impossible. However, we can use existing knowledge of insect biology and ecology to maintain forest stands and landscapes that are at a low risk of future outbreaks. Practicing good silviculture by matching tree species to the site, maintaining appropriate age and size class distributions, and managing stand density will help to reduce the likelihood of future insect outbreaks. In our efforts to maintain forests that are resistant to future insect outbreaks, we must consider the forest from the individual tree to the landscape scale. As biologists and responsible citizens, we should all practice the concept of "Think Globally, Act Locally" to reduce the impacts of humans on the Earth's environment. Our greatest challenge is to create and maintain healthy, resilient forest ecosystems within the constraints of conflicting management objectives and land ownerships.

Forecasting spruce budworm (*Choristoneura fumiferana*) impacts in the context of climatic change

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Table of Contents

We assembled regional data on forest composition, climate, and spruce budworm (SBW) defoliation in Ontario and generated statistical models that relate the geographical distribution of insect damage to bioclimatic data. These models revealed a number of insights about relationships between the spatial distributions of spruce budworm defoliation and bioclimatic conditions over the landscape. The first model describes where defoliation occurred at least once during the last outbreak of this insect (1967-1998). It relates the northern and southern boundaries of defoliation to the abundance of different host tree species of spruce budworm. The second model describes the frequency of defoliation in areas where defoliation occurred at least once from 1967-1998. It retains 8 variables related to temperature, precipitation and forest composition.

Recent Global Circulation Model (GCM) predictions of future Ontario climate were then used to drive the models. The resulting projections of SBW defoliation for 2011-2040 shows significant changes compared to past outbreaks. The model suggests a northward extension of defoliation to a limit corresponding either to the limit of balsam fir and white spruce distributions or, especially in the northwest, beyond the limit of available vegetation data. Overall, the extent of the total area defoliated at least once increases. The projections also show a latitudinal gradient with defoliation frequencies increasing in the north and decreasing in the south.

Understanding the relations between the geographical distribution of insect outbreaks and bioclimatic conditions has important applied and theoretical applications, particularly in the boreal forests of Canada where insects are considered a major natural disturbance that may be drastically altered by climate change.

Effects of Temperature and Global Warming on Population Ecology of Forest Insects

Moderator: Joseph Elkinton, University of Massachusetts

Global warming has already had measurable effects on winter temperatures and length of growing season with major impacts on many important forest insects. These include expansion of geographic or altitudinal ranges, outbreaks caused by changes in voltinism, changes in synchrony with natural enemies and exposure of tree species previously inaccessible due to climatic limitation. These changes are likely to accelerate in the coming years and will affect many species. Speakers who have agreed to participate include Jeff Hicke(mountain pine beetle), Matt Hansen (spruce beetle), Annie Paradis (hemlock woolly adelgid) and Joe Elkinton (browntail moth).

Monitoring And Forecasting Mountain Pine Beetle Outbreaks In High Elevation Whitebark Pine Forests

Jeffrey A. Hicke, Colorado State Univer. and Jesse A. Logan, USDA Forest Service

Insect outbreaks are significant forest disturbances in the United States. In the western United States, extensive bark beetle outbreaks in recent years have killed thousands of ha of trees. High-elevation whitebark pine forests in the Rocky Mountains have experienced a recent severe infestation of mountain pine beetle (*Dendroctonus ponderosae*). Outbreaks in these ecosystems are associated with unusually high temperatures. Increasing probability of outbreak in these forests may constitute a threat to a keystone species that provides significant services to ecosystems and humans. Here we discuss two studies related to outbreaks in whitebark pine forests. Model results driven by climate change projections suggest that future warming at high elevations will increase the area suitable for mountain pine beetle outbreak across the western United States. We also describe a remote sensing study in central Idaho that quantifies tree mortality using 2.4-m spatial resolution imagery. We will discuss total outbreak area, present landscape patterns, and assess how mortality varies across the landscape with respect to topography.

Spruce Beetle And Climate: Life Cycle Ecology, Population Dynamics, And Spruce Mortality

Matthew Hansen, USDA Forest Service

Although spruce beetle (*Dendroctonus rufipennis*) typically has a semivoltine life cycle, unusually warm temperatures can accelerate development to a univoltine cycle (also, usually cool temperatures can result in a three year cycle). Under laboratory conditions, beetles that developed on the univoltine cycle were found to be reproductively equivalent to beetles with the more typical semivoltine cycle. Thus, beetles with the univoltine cycle have twice the instantaneous rate of population increase relative to beetles with the semivoltine cycle. Recent large spruce beetle outbreaks in western North America have coincided with unusually warm weather. Evidence is discussed regarding the link between these outbreaks and the warming climate.

Effects of Winter Temperatures on The Northern Spread Of Hemlock Woolly Adelgid

Ann Paradis and Joseph Elkinton, University of Massachusetts

The hemlock woolly adelgid, *Adelges tsugae* Annand, was originally introduced to the eastern U.S. in the early 1950's from Osaka, a lowland region of Japan. The insect reached Springfield, Massachusetts in 1989, and currently, inland populations occur as far north as central Massachusetts with some coastal areas infested as far north as Maine. A single town in upstate New York on Lake Ontario became infested this past year (2005). Unlike hemlock stands farther south described by McClure (1987), in which trees die within four to six years, many trees in Massachusetts have been infested for over ten to twelve years. Furthermore, the spread of adelgid across the state has been slower than predicted based on adelgid spread rates occurring further south. By studying adelgid at the edge of the range in southern New England, we hope to document the impacts of cold temperatures on adelgid survival, fecundity, and population growth rate.

We found that overwintering mortality and sistens' fecundity were significantly correlated with daily average mean and minimum winter temperatures, as well as the absolute minimum winter temperature during 2003-04, however this correlation was not found during 2004-05. Overwintering mortality was significantly higher during the first winter the study took place. Finally, based on finite rates of population increase calculated using survival and fecundity data, we predict that the adelgid populations studied should stop expanding if populations experience between 86 to 98% mortality during the winter.

Effects of Winter Temperatures on The Survival And Decline Of The Invasive Browntail Moth

Joseph Elkinton, Evan Preisser, George Boettner, University of Massachusetts and Dylan Parry, State University of New York at Syracuse, Syracuse

Scant attention has been paid to invasive species whose abundance decreases following their initial range expansion. One such species is the browntail moth *Euproctis chrysorrhoea*, ('BTM') which was discovered in the eastern United States in 1897. It had spread throughout the eastern seaboard by 1914; after 1915, however, its invaded range contracted until it reached its current relict distribution, two isolated coastal locations (Cape Cod, MA, and Casco Bay, ME). Although the biological control agent *Compsilura concinnata* has been implicated in this range collapse, cold winter temperatures may also restrict BTM populations. We tested whether BTM mortality is higher in inland versus coastal habitats, and whether low winter temperatures may have contributed to the documented range contraction. We performed experimental manipulations in Cape Cod and conducted field surveys in both Cape Cod and Casco Bay assessing BTM larval density per winter web and both fall and winter mortality rates on multiple host plants in coastal versus inland habitats, and at different larval densities. We also analyzed historical records for whether winter temperatures correlate with changes in the invasive range. Fall mortality was lower in coastal versus inland populations and in low-density aggregations, and there was a host plant*habitat interaction. Larval density was higher in coastal habits in the experiment and in the Cape Cod survey. Overwintering mortality was lower in coastal populations for both the experimental populations and in the Casco Bay survey. Experimental overwintering mortality was affected by host plants and was lower in low-density treatments. There was no difference in mean winter temperature during the expansion and contraction phases of BTM invasion

Status of North American Bark Beetles: Anthropogenic Impacts to Forest Susceptibility

Moderators: Joel McMillin, US Forest Service and Allan Carroll, Canadian Forest Service, Pacific Forestry Centre

During recent decades, the size and severity of bark beetle outbreaks in North America has been unprecedented. There is compelling evidence implicating climate change as a causal factor exacerbating population eruptions and impacts. However, landscape-scale bark beetle epidemics require both favorable climate *and* a profusion of suitable host trees. In many forest types, the distribution and abundance of suitable hosts has been affected by forest management practices including wildfire suppression, selective harvesting and reforestation/afforestation. This session examined the status of eruptive bark beetle populations in North America and explored the potential role of anthropogenic alterations to forest susceptibility in the numerous large-scale bark beetle outbreaks. More than 70 participants attended this session.

Speakers/topics included:

1. Alberto Sediles (Universidad Nacional Agraria de Nicaragua, Nicaragua). Southern pine beetle outbreaks in Central America: role of forest structure and other factors influencing disturbance regimes in subtropical pine forests.

2. Tom Eager (USFS Forest Health Protection, Gunnison, CO). Bark beetle outbreaks in ponderosa pine forests and piñon woodlands: role of forest structure and other factors influencing disturbance regimes in the southwestern US.

3. Steve Taylor (Natural Resources Canada, Canadian Forest Service, Victoria, BC) Effects of altered disturbance regimes on the outbreak dynamics of the primary bark beetles of western Canada.

4. Brian Aukema (Natural Resources Canada, Canadian Forest Service, Prince George, BC) The mountain pine beetle in British Columbia: role of forest structure and land tenure in the current outbreak.

Southern Pine Beetle Outbreaks In Central America The Nicaragua Case: Role Of Forest Structure And Other Factors Influencing Disturbance Regimens In Subtropical Pine Forest

Alberto Sediles Jaén. Universidad Nacional Agraria, Nicaragua

More than 2.1 million out of 4.4 million hectares of pine in Central America have been impacted by bark beetles from 1962–2001. During 2000 through 2001, more than 87 thousand hectares were affected by bark beetles. The main beetles involved during the outbreak were *Dendroctonus frontalis* considered to be the most important species, *D. adjunctus, D. woodi*, a new species declared to be in Belize, *Ips calligraphus, and I.*

grandicollis. Specifically in the case of Nicaragua some 31,747 hectares were affected during the outbreak from 2000 to December 2001. Although there is not yet a proper explanation for these recent large-scale outbreaks, some common factors observed in years prior to attack include: drought periods, frequent forest fires, storm and hurricanes, resin extraction, dense and unmanaged stands, and delayed starting of the control activities; factors that because they impact forest health could be influencing recent observed outbreaks. Three natural factors that could have strongly affected pine forest health came in the middle nineties: severe drought periods caused by El Niño through the years 1994-1995 and 1997-1998, an unusual forest fire season in 1998, and a destructive hurricane season in 1998 – the largest being Hurricane Mitch which reached a category 5 (wind speeds higher than 155 mph). It was detected that the outbreak started and disseminated in dense, unmanaged pine stands with average basal areas higher than 35 square meters/hectare and 900 pine trees per hectare. The time from when the first beetle focus spot of 30 hectares was detected and to when a real control program was implemented was 18 months. More than ? hectares were impacted during this 1.5 year time span. Because improper forest management strategies have occurred through the years, forest susceptibility to pests has likely increased, and as a consequence, bark beetles outbreak will likely occur more frequently and be more destructive to the forests in Central America.

Bark Beetle Outbreaks In Ponderosa Pine Forests And Piñon Woodlands: Role Of Forest Structure And Other Factors Influencing Disturbance Regimes In Southwestern US

Tom Eager, Forest Health Management, Rocky Mountain Region, USDA Forest Service

Within the past five years, widespread and extensive bark beetle outbreaks have occurred throughout western North America. While the onset of these large landscape scale events has been tied to drought conditions that have occurred during the same timeframe, it has also been evident that stand conditions have also played a major role in the initiation and progression of these outbreaks. This phenomenon has been observed in several bark beetle / host interactions, this presentation examined the interactions of the mountain pine beetle / ponderosa pine activity and piñon ips / piñon outbreak.

The central Rocky Mountains have experienced a significant loss of mature ponderosa pine since the year 2000. Cumulatively, several million acres have been impacted; in some cases the mortality has exceeded 90% of the standing volume. While it is apparent that much of this mortality has sparked off by several consecutive years of drought, stand conditions have contributed to the amount of bark beetle activity. Review of the data collected by Forest Inventory and Analysis (FIA) reveals that most of the forested lands throughout the central Rocky Mountains tend to be in the mature to over-mature age/size classes. In addition, in nearly all of the Rocky Mountain States annual growth has exceeded annual losses (due to harvesting, fire, and insects and disease combined) throughout the past several decades. This trend was not reflected in the data representing the state of Utah due to recent severe outbreaks of spruce beetle. It remains to be seen if the recent high levels of mortality due to mountain pine beetle in the other states will reduce the difference between annual growth and annual losses.

An unprecedented outbreak of piñon ips has resulted in the death of millions of piñon trees throughout the Southwest over the past several years. This multivoltine bark beetle's numbers swelled dramatically following a severe drought in 2002 resulting in an outbreak that occurred in six states (New Mexico, Colorado, Arizona, Utah, Nevada and California). Not only was the scale of the outbreak extraordinary, but the intensity was impressive with many areas experiencing mortality exceeding 90%. The public reaction to this mortality was strong, and some lay observers were concerned that the great majority of piñon were being killed throughout their range. Monitoring of the situation by Forest Health Protection units within the affected areas documented the fact that while some locales experienced severe levels of mortality, there would be a substantial living residual throughout most of the distribution of piñon. The second major finding of the monitoring effort was that most of the affected stands were fairly homogeneous, with a significant number of stems in the mature to over mature age classes.

Both the piñon pine and the ponderosa pine situations have highlighted the role of stand conditions in promulgating bark beetle activity. In both cases, there were a substantial number of trees in an "at risk" condition, an adverse weather regime provided the "trigger event" that initiated large scale outbreaks, and bark beetle activity occurred over large areas. Once these large scale events were underway, significant numbers of trees that could be classified as "not susceptible" were killed by bark beetles. This included trees that were smaller than what is considered susceptible, as well as stands with low stocking that would normally be resistant to bark beetle attack. In both cases, it appeared that the sheer number of bark beetle that were produced in susceptible stands were able to overwhelm what were viewed as resistant hosts in nearby stands. In some cases this has led some observers to question the value of stand management and silviculture as a tool with which to manage bark beetles.

However, it is important to point out the demonstrated strength of stand factors with regards to susceptibility of potential hosts to bark beetles. The three factors of stand conditions that can be manipulated by managers are species mix, age distribution and stand density. These factors can be manipulated by managers in order to obtain a high degree of stand and landscape heterogeneity, which is critical to the management of risk of loss due to any one destructive agent. Since scolytids are relatively host specific, host species manipulation can provide strong protection against a given damaging agent. Similarly, because bark beetles tend to concentrate their activity on specific host life stages, a varied distribution of host ages can also provide some measure of protection. Finally, the proven benefits of density management can contribute to the defense of potential hosts by altering stand characteristics as well as increasing individual host defenses. Collectively, these three factors provide not only demonstrated physiological advantages to potentials host, but manipulation of stand characteristics also provides benefits by spreading risk of loss over numerous categories and mixes of stand and host tree characteristics.

Disturbance, Host Age, And Bark Beetle Outbreak Dynamics In British Columbia

Steve Taylor and Allan Carroll
Canadian Forest Service, Pacific Forestry Centre

In British Columbia, four major eruptive bark beetle species occupy distinct but overlapping elevational – latitudinal ranges following an increasing mean annual temperature gradient (and the distribution of their primary hosts) in the series: western balsam bark beetle (WBBB *Dryocoetes confusus)* spruce beetle (SB *Dendroctonus rufipennis),* mountain pine beetle *(*MPB *Dendroctonus ponderosae*) and Douglas-fir beetle (DFB *Dendroctonus ponderosae*). Outbreaks of these species have profound ecological and economic impacts. Between 1960 and 2005, survey records indicate that MPB, WBB, SB, and DFB have affected 66%, 57%, 12%, and 9% of lodgepole pine, subalpine fir, white/Engelmann spruce forest, and Douglas fir forests in B.C., respectively. These forest types are mainly of wildfire origin; historically, the rate of wildfire disturbance controlled their age-class distribution. This has important implications to host availability to bark beetles which preferentially attack larger, older forest stands. Fire disturbance rates were generally higher at warmer southerly low elevations, decreasing with mean temperature to cooler northerly higher elevations. Where wildfires occur independently of stand age, forest age class structure follows a negative exponential distribution (from a waiting time distribution) resulting in more young than old-aged stands.

Wildfire suppression began in B.C., as in much of western North America in about 1900, and is believed to have become increasingly effective over time. This has, in part, along with industrial development, allowed for an increase in forest harvesting. In order to examine whether a changing disturbance regime has affected host availability for bark beetles, we constructed a simple forest stand population age dynamics model. This simulation model incorporated historical stand replacing disturbance rates (wildfire, logging) during 20 year periods from 1920 -2000 for each host species, and was initiated with the current age distribution of host species with ecological zones affected by bark beetles, derived from the complete forest inventory of B.C. and run retrospectively. The results of these simulations indicate that the forests in B.C. are in a transitional state from an unmanaged condition regulated by natural disturbances to a condition regulated by forest harvesting. Annual burn rates declined substantially in interior Douglas fir, lodgepole pine, white/Engelmann spruce and subalpine fir forests between 1920 and 2000 and have not been wholly supplanted by increases in rates of forest harvesting, resulting in an overall reduction in stand-replacing disturbance rates. Reduced disturbance rates appear to have contributed to an increase in the average age of forest stands and the amount of susceptible host for bark beetles in BC, particularly for mountain pine beetle.

Some critical issues that arose from this work were: 1) Can we define statistical hazard rates of bark beetle outbreaks for forest planning purposes or are they inherently unpredictable? 2) Is the spatial contiguity of susceptible stands important for bark beetle population growth? 3) How will current bark beetle outbreaks affect future outbreak potential if susceptible age cohorts are significantly depleted. 4) There is a need to incorporate climate in risk models to account for a potentially warming climate.

Spatiotemporal Dynamics Of The Current Mountain Pine Beetle Outbreak In British Columbia: A Link Between Patterns Of Land Tenure And Insect Spread?

Brian H. Aukema, Canadian Forest Service, University of Northern British Columbia, Allan L. Carroll, Pacific Forestry Centre, Canadian Forest Service, Jun Zhu, Department of Statistics, University of Wisconsin, Kenneth F. Raffa, Department of Entomology, University of Wisconsin, Theodore A. Sickley, Department of Forest Ecology and Management, University of Wisconsin, and Stephen W. Taylor, Pacific Forestry Centre, Canadian Forest Service.

The ongoing outbreak of mountain pine beetle, *Dendroctonus ponderosae* Hopkins now covers an 8.7 million ha area in British Columbia, Canada. We present a landscape-level analysis of the development of the current outbreak using aerial survey assessments of tree mortality. These assessments, projected as polygons onto discrete 12 by 12 km cells, were used as a proxy for insect population density. We had two goals. First, we sought to determine whether the outbreak primarily started in one area, or whether the outbreak began from a series of simultaneous eruptions in spatially disjunct areas. Second, we sought to examine whether the outbreak was associated with land tenures that historically had little management activity directed against mountain pine beetle or other disturbance agents, such as within parks and protected areas. An aspatial cluster analysis of time series from 1990 to 2003 revealed four distinct time series patterns across the province. Each pattern shared a trend of increasing mountain pine beetle populations. Plotting the geographical locations of each temporal pattern on a map revealed that the outbreak occurred first in an area of west-central British Columbia. This area was comprised of three conservation parks and adjacent working forest. However, the map further revealed that many localized infestations erupted in geographically disjunct areas, especially in the southern portion of the province. These southern areas did not have as positive an association with parks as the west-central area of the province. Bark beetle outbreaks are caused by a multitude of biotic and abiotic factors, and it would be incorrect to blame the current outbreak solely on land tenure as an anthropogenic factor.

Effects of Forest Fragmentation and Ownership Change on Forest Pests and Their Management

Moderator: R. Scott Cameron, International Paper

The forests in North America are rapidly becoming more fragmented, especially in areas near high populations, and land ownership patterns are changing at an astounding rate. The physical attributes associated with these changes are affecting forest ecosystems, insect populations, and their hosts in varying ways, which in turn is resulting in more complex management situations. These changes portend major challenges in the future for forest insect research scientists, forest health specialists, and land owners.

The Physical Evidence Of Forest Fragmentation: Geographic Status And Trends

Kurt Riitters, USDA Forest Service
Southern Research Station

Forest parcelization (legal subdivision) and fragmentation (physical subdivision and perforation) increase landscape heterogeneity and the area of interface zones, affecting land management needs, options, and the decision-making process. Recent national land-cover maps derived from remote sensing provide a consistent basis for assessing geographic status and trends of fragmentation. Forest fragmentation is so common that at least one-half of all forest area is within about 100 meters of forest edge, and so pervasive that less than 1% is more than 1000 meters from forest edge. At the same time, three-quarters of all forest exists in mostly-forested landscapes so that forest land is well-connected over very large regions. If forest edge is important to insect population dynamics, then it is potentially important everywhere because of the demonstrated physical exposure to edge. If forest connectivity is important, then it is also important everywhere because of the demonstrated physical connectivity. Forested landscapes are becoming increasingly heterogeneous at local scales and increasingly homogeneous over large regions, yet different regions of the nation are still characterized by different patterns of fragmentation. Landscape management strategies to mitigate and manage fragmentation will need to be tailored to local conditions and applied over large regions.

The Varied Effects Of Habitat Fragmentation On Forest Insect Population Dynamics

Andrew M. Liebhold, USDA Forest Service, Northeastern Research Station

Forest insects exist in spatially heterogeneous environments and considerable interest has focused on the effect of habitat fragmentation on insect dynamics. Here I review both theoretical and empirical approaches to understanding the role of fragmentation. The major theoretical approaches have been theories of island biogeography, metapopulation ecology, and the resource concentration hypothesis. These theories predict that fragmentation can either increase or decrease population stability and/or population levels, and that these population responses depend upon many factors related to the specific population systems e.g., behavior of natural enemies, etc). I also reviewed several studies that focused on the effect of fragmentation on populations of periodical cicadas, forest tent caterpillar and larch budmoth. These field studies confirm the general pattern from theoretical studies, namely that fragmentation can either intensify or diminish forest insect populations via a variety of mechanisms. These types of studies are particularly difficult to design and interpret because of the difficulty in differentiating causation from correlation.

Some Challenges To Managing Forest Health In A Fragmented Landscape

Albert (Bud) Mayfield, Florida Depart. of Agriculture and Consumer Services, Division of Forestry

The ever-increasing fragmentation and parcelization of private forest land in the United States presents a number of challenges to managing for forest health. As forests become fragmented into smaller parcels, health-enhancing treatments (like thinnings) can become more difficult or expensive to conduct, because operators may not be able to recoup their fixed costs from the limited volume harvested on a small tract. In wildland-urban interface (WUI) environments, the creation of which often accompanies fragmentation, traditional forest pest prevention or suppression techniques (such as harvests, prescribed burns, or pesticide applications) can be expensive, dangerous, and/or deemed socially unacceptable. In a highly parceled landscape of multiple ownerships, forest pests can easily spread across property boundaries, raising issues of management liability and sometimes resulting in litigation. Making and implementing management decisions at “landscape” or “ecosystem” scales (as is usually preferable when managing for forest health) becomes more complex as the number of landowning parties involved increases. Examples from Florida that illustrate some of these scenarios are presented.

To deal with these challenges, creative strategies for educating private landowners about forest health (including use of mass media and direct mailings) should be considered. Whenever possible, forest health issues should be presented in the context of management benefits with broad appeal. Strategies for making forest management practices on small or WUI tracts more practical and economical (such as joint contracting or cost-share programs) should be pursued. Also needed are forums that encourage communication between adjacent landowners, and incentives for keeping land in contiguous forest cover.

Chicken Farms, Pine Trees, And Pitch Canker: Fragmentation Spurring Concern And Conflict In The South

James R. Meeker, USDA Forest Service – FHP

Fragmented forestlands coupled with changes in the poultry industry have recently spurred an increased incidence of damaged and dead pines adjoining poultry houses in various areas of the Southeastern Gulf Coastal Plain (e.g., FL, GA, LA, MS). The nature of the tree problems have been due to elevated levels of pitch canker disease, caused by the fungus *Fusarium circinatum* Nirenberg and O'Donnell. Recent research from Florida has demonstrated a direct relationship between nitrogen loading from poultry houses and increased levels of pitch canker infection, severity, and associated tree mortality in adjoining pine stands, with a measurable influence up to 500+ meters (Barnard et al. 2005).

A unique manifestation of this problem has created concern on the Bienville National Forest (NF) in central Mississippi. Within the 357,000 acre proclamation boundary of this forest exists a patchwork of public and private ownerships and various land uses, including the 180,000 ac of forestland managed by the Forest Service, and the municipality of Forest (population 6,000), which is home to a large poultry processing facility. When undesirable levels of pitch canker-related damage and tree mortality became apparent on the Bienville at various locations adjoining chicken farms in 2004, the potential scope and magnitude of this problem was cursorily examined. The 1996 digitized aerial imagery of the area revealed nearly 300 separate poultry farms within or neighboring the bounds of the NF ten years ago, many of which exhibited multiple rearing houses at each location. Poultry houses were/are scattered throughout the forest bounds, surround some disjunctive parcels of NF, and abut pine stands in numerous places. With 140,000 ac of the NF classified as moderate to high hazard for southern pine beetle, serving as an indicator of the resource at risk to pitch canker, the potential for future problems to develop where these two different ownerships and land uses converge is alarming.

In addition, the international corporation that employs approximately 1,700 people at the local processing plants in the city of Forest has initiated improvements to increase production, suggesting the possibility of more poultry houses to come. The economic and associated societal benefits to the community derived from the various facets of this poultry industry makes achievement of the Forest Service's motto of "Caring for the land and serving people.", extremely challenging, particularly if efforts 'to sustain the health, diversity and productivity of the Nation's forests' result in adverse actions/impacts on the local poultry industry. At this juncture, more research is required to better understand the nature and scope of the problem (e.g., impacts to other resources such as water quality), and to develop suitable solutions to mitigate undesirable impacts, before more serious consequences arise.

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The Influence Of Forest Fragmentation And Parcelization On Emerald Ash Borer, *Agrilus Planipennis,* Establishment And Movement

Frank J. Sapio, USDA Forest Service, Forest Health Technology Enterprise Team

Evidence is presented that characterizes the greater Detroit area as an optimal "landing site" for the establishment of Emerald Ash Borer *Agrilus planipennis* (Fairmaire). This exotic pest, first discovered in Canton, Michigan in 2002, has spread successfully to 4 states as a result of a successful establishment in Metro Detroit. The current damaging range of *Agrilus planipennis* (EAB) represents an area larger that the lower peninsula of Michigan. A hypothesis is presented that forest fragmentation promotes EAB habitat and spread and parcelization complicates EAB regulatory and control activities.

After the initial find in Canton Michigan in 2002, the first delimiting survey based upon visual inspection of exit holes tuned up an initial estimate of population range of 1800 square miles. This later turned out to be a significant underestimate of the EAB footprint due to the insufficient and difficult nature of visual EAB survey. Much the area surrounding Metro Detroit is characterized by a mixture of Urban and rural environment and represents to a very large extent an urban rural interface or wildland urban interface.

Ash tree density is relatively high in this interface area characterized by large suburban neighborhoods that penetrate woodland areas. Most back yards back up to mesic wooded areas, many of them riparian, that usually have high densities of native green and black ash. The street tree (planted) of choice is often 1 of 5 varieties of green ash proven to have high vulnerability to EAB. Much of the greater Detroit area was termed the "The Interminable Swamp" in the original land survey notes. This land for the most part has been drained to support suburban development. Ash density remained high in these wooded areas as green ash is able to survive on a wide range of sites from the wettest to the very dry, even after draining. The net result is a highly fragmented landscape with planted green ash and "natural" ash corridors interspersed throughout SE Lower Michigan. Evidence is presented that EAB moves along these "ash corridors" moving from host tree to host tree. Management of EAB is complicated by the large number of forest and shade tree landowners impacting both destructive sampling and tree removal, both "state of the art" EAB management techniques.

DIRECT TACTICS IN FOREST INSECT MANAGEMENT

Hurdling Over Obstacles Toward Implementation of Semiochemical-based Forest Pest Management Tools

Organized by: Christopher J. Fettig (PSWRS), Dezene P. W. Huber (UNBC, moderator) and Darrell W. Ross (OSU)

One of the largest problems with the development of semiochemical-based management tools is that few operational products arise from such efforts, particularly in terms of bark beetle pest management. In this workshop, participants discussed many of the obstacles that impede full registration and utilization of such technology. Items that were discussed included logistic concerns, regulatory and legislative hurdles, proprietary issues, and funding concerns. The intent of this session was to produce recommendations for future research and development efforts that will facilitate more rapid implementation of pheromone-based technologies.

The speakers were:
1. Darrell Ross (Oregon State University, Department of Forest Science), on the topic of research on MCH and its implementation for use in Douglas-fir beetle pest management,
2. Kevin Thorpe (USDA, Agricultural Research Service) on the topic of gypsy moth mating disruption research and its use in operational pest management situations,
3. Jim Heath (Hercon Environmental) on the topic of moving gypsy moth, and other, semiochemical pest management tools from research to full operational implementation, and
4. Russell Jones [Environmental Protection Agency, Biopesticides & Pollution Prevention Division (7511C)] on the meeting regulatory requirements for the marketing and use of semiochemical technologies.

MCH: A Bark Beetle Pheromone Success Story

Darrell W. Ross, Department of Forest Science, Oregon State University

Abstract

Most of the time Douglas-fir beetles infest scattered windthrown, diseased, or otherwise stressed trees. However, periodic disturbances such as windstorms, wildfire, defoliator outbreaks, or drought can create an abundance of breeding sites leading to rapid increases in population density. High Douglas-fir beetle populations can cause tree mortality that interferes with resource management objectives. Large diameter, older trees and densely stocked stands with a high component of Douglas-fir are at highest risk of infestation. Traditional recom-mendations for preventing undesirable Douglas-fir beetle-caused tree mortality included harvesting mature stands, treating or disposing of slash >20 cm diameter, prompt salvage of dead and dying trees, fire prevention, thinning young stands, harvesting or treating infested trees, and felled trap-trees during outbreaks. With recent shifts in resource

management from a predominant emphasis on timber to more diverse sets of resource values, managers need new alternatives for protecting trees and stands from Douglas-fir beetle infestation.

The Douglas-fir beetle pheromone system has been well studied. Early efforts to use pheromones to manage the Douglas-fir beetle focused on the anti-aggregation pheromone, 3-methylcyclohex-2-en-1-one (MCH). An aerially applied plastic bead formulation of MCH was developed and demonstrated to be operationally feasible for preventing the infestation of windthrown trees. Such a treatment could potentially prevent Douglas-fir beetle outbreaks by excluding beetles from breeding in the highly suitable windthrown trees. However, this formulation was never registered with the Environmental Protection Agency (EPA) and has not been available commercially for widespread use.

More recently, a plastic bubble formulation of MCH was shown to be effective in preventing the infestation of live Douglas-fir trees and stands during outbreaks (Ross and Daterman 1994, 1995; Ross et al. 1996). A treatment was developed to be used in high-valued stands such as campgrounds and other recreational sites, special-use areas, old-growth reserves, and residential areas. This treatment involves applying 75 releasers/ha in the spring before beetle flight begins. The bubble capsule formulation was first registered with EPA in the fall of 1999 and became available for use in the U.S. in spring 2000. Currently, two companies have registered formulations of MCH. Since 2000, several thousand hectares of high-valued stands have been treated annually with MCH in the Pacific Northwest and Rocky Mountains with no reports of unsuccessful treatments. An operational user's guide for MCH was published in 2001 and revised in 2006 (Ross et al. 2001). To date, over 6,000 copies of the guide have been distributed. The MCH treatment has been readily implemented by resource managers and landowners throughout the western U.S. This is the first bark beetle pheromone treatment of its kind to be used anywhere in the world.

There are several reasons why the MCH technology development effort was successful. First, there was a strong research basis that provided the framework and support for developing the operational treatment. Research had clearly demonstrated that the Douglas-fir beetle responded consistently in a predictable way to MCH. Second, there was coordinated and focused support for developing the MCH technology within the forest entomology community. Most participants realized the value of developing a successful bark beetle pheromone treatment for obtaining continued support for bark beetle pheromone research and development efforts. Third, the treatment was developed to meet resource management needs. Resource managers were consulted throughout the research and development process to ensure that the treatment was one that would be useful to them in meeting their management goals. Finally, trials with MCH consistently produced unequivocal results. Consequently, the treatment that was developed can be used with confidence.

Several lessons can be learned from the successful development of the MCH treatment for Douglas-fir beetle. First, make sure that existing knowledge supports technology development efforts. Inconsistent or unreliable results suggest the need for more basic research before continuing the technology development efforts. Second, limited resources for applied technology development should be focused on projects most likely to produce useable products. In the long run, it is more valuable to have a few successful projects than many unsuccessful ones. Lastly, treatments must be developed in consultation with resource managers to be certain that the end product will be something that can be readily implemented.

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Gypsy Moth Mating Disruption Research

Kevin Thorpe[1] and Ksenia Tcheslavskaia[2]
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Since its introduction into Medford, MA around 1869, the gypsy moth (*Lymantria dispar* (L.)) infestation has expanded to the west and south at an average rate of 13 miles per year (Liebhold et al. 1992). The generally-infested area currently extends from Wisconsin south to North Carolina (Sharov et al. 2002a). The expansion of its current range is expected to continue until the gypsy moth eventually occupies all areas of the U.S. containing favorable habitat. It has been estimated that the ultimate range of this pest will be three times greater than its current range (Liebhold et al. 1997). To address the economic and environmental impacts caused by the expanding range of the gypsy moth infestation, a national strategy was developed to manage gypsy moth populations along the leading edge of the infestation. The goal of this USDA Forest Service program, known as the Slow the Spread of the Gypsy Moth (STS), is to intensively monitor populations along the leading edge and apply treatments such that the rate of expansion of the infested area is reduced by 50%. The STS program was pilot tested in 1993 and became fully implemented in 2000. Since 2000, 82% of the nearly 2.9 million acres treated in STS used mating disruption (USDA 2006). Mating disruption is a preferred tactic in STS because it is target specific, inexpensive (USDA 2004), and effective (Sharov et al. 2002b). To date the program has exceeded its spread rate reduction goals, resulting in a benefit to cost ratio of 3:1. The program currently includes 10 states and nearly 100 million acres (Sharov et al. 2002b). A sophisticated internet-based data management system and decision algorithm are used to manage the volume of data collected in STS and to assist in decision making (Tobin et al. 2004).

Currently, only one gypsy moth mating disruption formulation, Disrupt II (Hercon Environmental, Emigsville, PA) is registered by the U.S. Environmental Protection Agency and available for commercial use in the U.S. This formulation consists of plastic laminated flakes (1 x 3 x 0.5 mm) with polyvinyl chloride (PVC) outer layers and an inner polymer layer containing racemic disparlure (17.9% active ingredient) (Leonhardt et al. 1996, Reardon et al. 1998). The flakes are mixed with 280 g/ha of sticker (Gelva 2333, Surface Specialties UCB, Smyrna, GA), a multipolymer emulsion used industrially primarily as a pressure-sensitive adhesive. The formulation is applied aerially from specialized pods mounted beneath fixed-wing aircraft. Flakes generally release 30 – 50% or their disparlure content over the 6-week period of male moth flight (Leonhardt et al. 1996; Thorpe et al. 1999). While efficacy with this formulation is greatest when the sticker is used, greater than 85% suppression of mating occurred when flakes were applied without sticker (Thorpe et al. 2000). Early work to establish a dose response indicated that a relatively high rate (75 g/ha) was required to adequately suppress mating (Webb et al. 1988). However, the targeted populations were higher than is now considered appropriate for effective mating disruption. More recent investigations at lower population densities showed that mating is eliminated at application rates of 30 and 15 g/acre, and that trap catch is suppressed by >99% at application rates ≥ 6 g/acre (Tcheslavskaia et al. 2005). In STS, application rates of 6 or 15 g/acre are used operationally depending on the number of moths captured in pheromone traps.

Research efforts to develop mating disruption as an effective tactic to manage gypsy moth populations began in the early 1970s (Cameron 1981). For two decades, progress was limited by the lack of a viable dispenser and because efforts tended to focus on population densities that we now know are too high for effective mating disruption. Operational use of gypsy moth mating disruption, mostly in eradication attempts, was conducted on a limited basis, with variable results (Kolodny-Hirsch and Schwalbe 1990). The implementation of the STS program provided the opportunity for the use of mating disruption on a much larger scale. However, in the early years of STS, most treatments were with the biological insecticide *Bacillus thur-ingiensis* (BT) (USDA 2006). As confidence increased among program managers, the use of mating disruption increased and by 2000 became the predominant tactic. There were a number of sources of this increased confidence, including positive research results demonstrating a reduction in population growth after treatments (Leonhardt et al. 1995; Thorpe et al. 1999) and treatment efficacy of mating disruption treatments equal to or greater than that of BT (Sharov et al. 2002b). As time went on, the cost of mating disruption decreased as a result of improvements in application equipment, reductions in application rates as indicated by the results of dose response experiments in study plots (Tcheslavskaia et al. 2005), and reductions in product costs with larger volume purchases.

As a consequence of these developments, mating disruption has been used to manage gypsy moth populations on an average of nearly 400,000 acres per year over the last 6 years. In terms of land area, this is currently the largest mating disruption program in operation against any insect pest. Research efforts are continuing to develop and evaluate new formulations, especially sprayable formulations that can be applied through conventional hydraulic nozzles, to better define the conditions of gypsy moth population density under which mating disruption will be successful, and to better understand gypsy moth population dynamics at very low population densities, especially those factors that affect mating success and the establishment and growth of isolated colonies.

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Moving Gypsy Moth Mating Disruption Products Into The Marketplace

James H. Heath, Vice President, Hercon Environmental

The process required to move Hercon's gypsy moth, *Lymantria dispar* (Linnaeus), mating disruptant product, DISRUPT® II GM, from the development stage to operational implementation represents a unique case in many respects, but one from which many of the lessons learned may apply to the commercialization of future semio-chemical based forest insect control products, such as bark beetle, *Dendrotonus spp.*, anti-aggregants and spruce budworm, *Choristoneura fumiferana* (Clemens), mating disruptants.

In the case of DISRUPT II GM, the process required to overcome the product development and operational imple-mentation hurdles was greatly facilitated by having the US Forest Service / Gypsy Moth Slow-the-Spread Program (later GMSTS Foundation) function not only as Hercon's primary end-user customer, but also as our principal developmental partner whose constant involvement and feed-back helped speed and assure the successful implementation of mating disruption for gypsy moth control in US forests.

Developmental hurdles included:

- Product development - Hercon successfully adapted its proprietary laminated-polymer controlled-release technology to formulate gypsy moth pheromone, disparlure, to produce a functional gypsy moth mating disruptant product, DISRUPT II GM.

- Application technology development - Aerial applicator cooperators successfully adapted Hercon's aerial application ("pod") system to apply product to large forest areas.
- Use optimization - USDA-USFS / GMSTS successfully experimented with product use rates and application variables to determine most cost-efficient product use method.
- Regulatory requirements - All parties successfully cooperated to satisfy federal, state, and local requirements to permit product use.

Commercialization / operational implementation hurdles included:

- Sourcing economical active ingredient - USDA-USFS / GMSTS successfully procured disparlure on direct bid basis, a function continued by the GMSTS Foundation today.
- Scaling-up production - Hercon successfully met increasing demand for product by up-grading production equipment to increase capacity.
- Assuring availability of application - USDA-USDA / GMSTS successfully contracted directly with suitably-equipped aerial applicators for required product application services. USDA-USFS / GMSTS also provided on-site supervision and monitoring of product applications. USDA-USFS / GMSTS Foundation continue to provide these functions today.
- Training users in novel use methods and modes of action - USDA-USFS / GMSTS continues to function as primary information source for product users and residents in or near application areas.
- Meeting insect-dictated deadlines - A continuing annual challenge for all GMSTS program participants!

Current challenges being addressed in the same cooperative manner include:

- Regulatory
    - Product reformulation and EPA label amendment to allow incidental application to food or feed crops
- Monitoring
    - Characterization/quantification of potential interference from product use with pheromone-based gypsy moth population monitoring programs
- Product improvement
    - "Abrupt shut-off" feature for pheromone release from product to improve efficiency and reduce possibility of interference with established monitoring programs
    - Reformulation of product to improve biodegradability

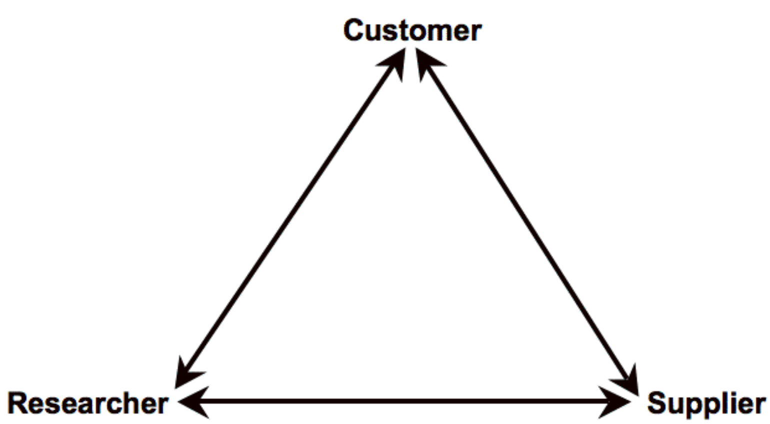
Current challenges of particular concern to Hercon:

- Market variability
    - Uncertainty of annual funding level for Gypsy Moth Slow-the-Spread
    - Natural cyclicality of gypsy moth population
    - Possible market entry of competitor

The DISRUPT II GM development and operational implementation process resulted in significant lessons learned that have potential application to the introduction of similar semio-chemical based products in the future, namely:

- Pursue significant market needs / opportunities
    - Potential to generate at least $500,000 in sales revenue at maturity
        - Other product types may have higher thresholds
    - Potential to initiate sales by the third year of the developmental process
    - Capable of being produced using existing production facilities with minor modification
    - Having some form of proprietary protection
        - *De jure* = Patents, trademarks, contracts, etc.
        - *De facto* = Trade secrets, uniqueness difficult to match, capital investment hurdle, etc.
- The product is more that what's in the box
    - In addition to a "robust" product that reliably meets performance claims, a supplier must also provide:
        - Widely available, reliable product application capability
        - Fulfillment of regulatory requirements
        - End-user training
        - Technical support
    - Do not count on having a USDA-USFS / GMSTS or some other cooperator willing and available to fulfill all these functions for you

Figure 1 - A working three-way partnership provides the best chance for a successful new product introduction into the marketplace.



- Customer / End-User
  - Motivated to purchase new products to satisfy needs not met by existing products
  - Willing to hear suppliers new product sales pitches
  - Willing to purchase on recommendations of researchers
  - Willing to provide real-life/real-time market need information and product use feed-back to researchers and suppliers
- Researcher / Developmental Cooperator (Government, Academic, Private)
  - Willing to act on market need and product use feed-back from end-users
  - Willing to provide new product opportunity leads to suppliers
  - Willing to provide objective evaluations of new products to suppliers and recommendations to end-users
- Supplier
  - Willing to act on market need and product use feed-back from end-users
  - Willing to act on evaluations and recommendations from researchers and developmental cooperators
  - Motivated to invest resources to develop, manufacture, market, and support new products to meet significant market demands

In the case of DISRUPT II GM Gypsy Moth Mating Disruptant, the end-user and researcher / developmental cooperator roles were fulfilled by USDA-USFS / GMSTS, with input from involved aerial applicators.

Table 1 – A working three-way partnership provides the best chance for a successful new product introduction into the marketplace.

	Gypsy moth mating disruption	**Douglas-fir beetle antiaggregant**
Customer	USDA-FS GMSTS Program GMSTS Foundation Private aerial agricultural operators	USDA-FS Regions? State departments of agriculture and forestry? Private arborists?

Researcher/Cooperator	USDA-FS GMSTS Program Private aerial agricultural operators	USDA-FS PSW Research Station
Supplier	Hercon	Hercon

With future products, such as bark beetle anti-aggregants and spruce budworm mating disruptants, this convenient arrangement is unlikely to re-occur. It is more likely that diverse organizations and private companies will be involved in the development and operational implementation process. It is important that the organizations functioning in these roles become involved as early as possible so a working partnership can be established with effective two-way communications between each to give the new product introduction process the best chance for success.

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- Jack Stein, USDA Forest Service, FHTET, Morgantown, WV

Spruce Budworm
- Peter Silk, Canadian Forest Service, Fredericton, NB, Canada
- Ed Katella, Canadian Forest Service, Fredericton, NB, Canada

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Registration Of Biopesticides: Regulatory And Legislative Hurdles

Russell S. Jones, USEPA/OPP/BPPD & Chair, Biochemical Classification Committee

The establishment of the Biopesticides and Pollution Prevention Division (BPPD) in US EPA's Office of Pesticide Programs in 1995 ushered in a new era of regulatory relief for semiochemicals and other biological pesticides. The reduced regulatory burden includes the introduction of tiered toxicological and non-target organism testing, reduced data requirements for arthropod pheromones and other semiochemicals, specific tolerance exemptions, and increased acreage under which certain arthropod pheromone studies may be conducted without need for an Experimental Use Permit. New legislation enacted under the Pesticide Registration Improvement Act (PRIA) of 2004 and proposed revisions in the Subdivision L data requirements for biochemical pesticides further reduce the regulatory burden of bringing semiochemicals into the marketplace.

Forest Protection: Bark Beetles and Woodborers

Moderators: Steve Munson and Brytten Steed, USDA Forest Service, Forest Health Protection

The session covered a general review of suppression and prevention strategies used to address bark beetle outbreaks in the west. Registered insecticides used as preventative treatments and effective pheromone strategies for individual tree and area protection were discussed. Examples of silvicultural treatments used as preventative applications to mitigate bark beetle effects were also highlighted.

Several pyrethroid studies were conducted throughout the west on various host types as preventative treatments for bark beetles. Various formulations were tested and most provided only one year of field efficacy. Onyx™, provided up to two years of field efficacy for some forest types. Carbaryl applications (Sevin® SL), provided two years of field efficacy for ponderosa pine, *Pinus ponderosa* (Laws); lodgepole pine, *P. contorta* (Dougl.); and singleleaf pinyon, *P. monophylla* (Torr. & Frem.).

Combinations of six bark volatiles and three green leaf volatiles were field tested to determine their anti-aggregation effects on western pine beetle, *Dendroctonus brevicomis* (LeConte) in ponderosa pine stands. Preliminary results of this analysis were discussed and further tests will be conducted in 2006.

Single tree injections using systemic insecticide treatments were field tested on a variety of hosts as preventative treatments for several species of western bark beetles and southern pine beetle, *D. frontalis* (Zimm.). Preliminary results indicate treatments were partially effective in reducing successful attacks of southern pine beetle on loblolly pine, *P. taeda* (L.) and western pine beetle attacks in ponderosa pine. Additional analysis of the 2005 applications will be conducted in 2006 to determine treatment effects.

Detection and eradication programs for two introduced woodborers were discussed. Although labor intensive and inefficient, current detection and eradication strategies for the Asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky) seem to be effective. The success of detection and eradication programs for emerald ash borer, *Agrilus planipennis* (Fairmaire) have not been as effective. The current emerald ash borer program operating on a limited budget is focusing on survey, reducing artificial spread of the insect and research on improved methods for managing this introduced pest.

Systemic Insecticide Injections For Protection Of Southern And Western Conifers From Dendroctonus And Ips Bark Beetles

Don Grosman, Western Gulf Forest Pest Management Cooperative & Texas Forest Service, Forest Pest Management

In 2004, it was discovered that injections of the systemic insecticides, emamectin benzoate or fipronil, could prevent the successful attack and mortality of loblolly pine by Ips engraver beetles. This presentation described the establishment of additional trials in 2005 to evaluate the efficacy of these chemicals for protection of trees against more aggressive Dendroctonus spp.: southern pine beetle, *D. frontalis* (Zimm.) on loblolly pine, *P. taeda* (L.) western pine beetle, *D. brevicomis* (LeConte) on ponderosa pine, *Pinus ponderosa* (Laws) mountain pine beetle, *D ponderosae* (Hopkins) on lodgepole pine *P. contorta* (Dougl.), and spruce beetle, *D. rufipennis* (Kirby) on Engelmann spruce, *Picea engelmannii* (Parry).

Preliminary results indicate that both emamectin benzoate and fipronil were at least partially effective in reducing the level of southern pine beetle attack on loblolly pine and mortality of ponderosa pine caused by western pine beetles. Additional trials are planned for 2006 and beyond to refine application rates of emamectin benzoate and fipronil, identify optimal timing of injections, and determine duration of treatment efficacy. The injection of systemic insecticides may 1) provide long-term (3+ years) protection of high-value trees in residential, recreational, or administrative sites; 2) reduce or eliminate problems associated with hydraulic spray applications, such as worker exposure and drift, expense, and impact to non-targets; and 3) allow treatment of trees in environmentally or socially sensitive areas that is not currently permissible with conventional spray equipment.

Developing Methods For Managing Populations Of Exotic Woodborers In North America

D. R. Lance, USDA-APHIS-PPQ Pest Survey

The United States is currently phasing in regulations requiring fumigation or heat-treatment of solid wood packaging materials, but the wood packaging pathway has left us with a legacy of exotic, invasive wood-boring pests. One example is the Asian longhorned beetle (ALB), *Anoplophora glabripennis* (Motschulsky), which has been killing trees in several genera, including maples (*Acer* spp.), following separate introductions from the Orient into New York, Illinois, New Jersey, and Ontario. APHIS-PPQ and cooperating state and local agencies have mounted eradication efforts based on removal and destruction of all trees (>8000) that show signs of ALB infestation. Effective attractants have not been identified for this species, forcing reliance on visual inspection of trees for beetles and beetle damage as the primary survey method. Partially because of the inefficiency of these surveys, another ~19,000 “high-risk” trees have been prophylactically removed in the vicinity of known infestations, and literally hundreds of thousands of hosts in the surrounding areas have been treated with systemic insecticides. These programs are labor-intensive and inefficient but are working – for example, no signs of ALB have been seen in Illinois since 2003.

In 2002, the emerald ash borer (EAB), *Agrilus planipennis* Fairmaire, was determined to be causing the death of ash trees (*Fraxinus* spp.) in the Detroit, MI/Windsor, ON area. Initial surveys indicated that at least six counties were generally infested, with (literally) millions of trees affected. Following subsequent surveys, most of southeastern Michigan is now under quarantine, and numerous additional infestations, products of human transport of ash trees and logs, have been found in Michigan, Ohio, Indiana, Illinois, and Maryland. The current EAB program, operating on a limited budget, is focusing on survey, reducing additional humanaided spread of the beetle, and research on improved methods for managing this pest. Results of semiochemical studies indicate the presence of a potentially useful attractant for EAB, but the size, spread, and destructive ability of the population suggests that host-plant resistance, possibly augmented by biological controls, may be our best hope for maintaining ash as a significant component in North American forests.

Our experience with EAB, in particular, points to the need for development and proper deployment of improved methods for detecting invasive woodborers. Incipient populations must be located when they are small enough that aggressive control methods are viable options and chances of artificial spread remain minimal.

Protecting Trees On High-Value Sites In The West

Ken Gibson, USDA Forest Service, Forest Health Protection

Beginning in the mid-1970s, efforts were expended to prevent bark beetle attacks on trees on high-value sites in the West. By 1977, carbaryl had been proven to be the most effective and efficient means of protecting pine hosts from mountain pine beetle infestations. In the late-1980s, concern over future registration of carbaryl led to the evaluation of alternatives—especially synthetic pyrethroids. Some proved effective for one year protection, but could not provide long-term protection achieved with carbaryl.
Also in the 1970s, research began using bark beetle semiochemicals—some of which proved successful in protecting susceptible trees. The most notable, and still most successful is MCH, which successfully protects Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco from Douglas-fir beetle, *Dendroctonus pseudotsugae* (Hopkins) attacks.

In the late-1980s, we began testing verbenone—an anti-aggregation phero-mone of mountain pine beetle, *D. ponderosae* (Hopkins) that may also affect other western bark beetle behavior. Verbenone applications were administered to protect trees from beetle attacks. Initially, mixed results made its use suspect. More recent tests suggest verbenone may be successful in preventing mountain pine beetle attacks in some hosts.

Protecting trees from attack by other beetle species using pheromones has been only moderately successful. Silvicultural man-ipulations—thinning, sanitation salvage, and trap trees—alone or in conjunction with other strategies; have also been effective in reducing bark beetle-caused mortality. In striving to prevent bark beetle depredations and thereby protect high-value trees; we have shown that, indeed, "an ounce of prevention is worth a pound of cure!"

Critical elements:

- Preventive treatments with carbaryl are effective and economical
- Other chemical treatments may be effective, but generally are not as long-lasting
- MCH is very effective in protecting Douglas-fir from DFB attack
- Verbenone has not yet proven to provide consistent protection from MPB attacks

- Silvicultural manipulations (hazard reduction) can protect trees and stands
- Prevention is almost always less costly than suppression

Single Tree Protection Tools For Western Conifers

Christopher J. Fettig, Pacific Southwest Research Station, USDA Forest Service

High-value conifers, such as those located in residential, recreational, or administrative sites, are particularly susceptible to attack by bark beetles (Coleoptera: Curculionidae: Scolytinae) and other forest insects. Tree losses in these unique environments generally have a substantial impact (Johnson 1981). The value of these individual trees, cost of removal, and loss of aesthetics may justify protection until the main thrust of an infestation subsides. This situation emphasizes the need for assuring that effective tools are available for individual tree protection.

The efficacy of bifenthrin (Onyx™) and carbaryl (Sevin® SL) for protecting: ponderosa pine, *Pinus ponderosa* Dougl. ex. Laws., from western pine beetle, *Dendroctonus brevicomis* LeConte in California, mountain pine beetle, *D. ponderosae* Hopkins in South Dakota, and *Ips* spp. in Arizona; lodgepole pine, *Pinus contorta* Dougl. ex Loud., from *D. ponderosae* in Montana; pinyon, *P. edulis* Engelm. in Colorado and *P. monophylla* Torr. & Frem. in Nevada from pinyon ips, *I. confusus* (LeConte); and Engelmann spruce, *Picea engelmannii* Parry ex. Engelm. from spruce beetle, *D. rufipennis* (Kirby) in Utah was assessed. Few trees were attacked by *Ips* spp. in Arizona and that study was discontinued. Sevin® SL (2.0%) was effective for protecting *P. ponderosa*, *P. contorta* and *P. monophylla* for two field seasons. Estimates of efficacy could not be made during the second field season in *P. edulis* and *P. engelmannii* due to insufficient mortality in untreated, baited control trees. Two field seasons of efficacy was demonstrated in *P. ponderosa*/*D. brevicomis* and *P. monophylla* for 0.06% Onyx™. We conclude that Onyx™ is an effective individual tree protection tool, but repeated annual applications may be required in some systems if multi-year control is desired (Fettig et al. 2006a).

In another study, we assessed the efficacy of permethrin plus-C (Masterline®) and carbaryl (Sevin SL®) for protecting *P. ponderosa*, *P. contorta* and *P. edulis* from bark beetle attack. Masterline® was effective for protecting *P. contorta* from *D. ponderosae* attack for one field season. However, Sevin SL® was efficacious for two field seasons. An insufficient number of *P. ponderosa* and *P. edulis* control trees were killed to make definitive conclusions regarding efficacy in those systems. Masterline® appears to be an effective individual tree protection tool, but repeated applications will be necessary if multi-year control is desired (Fettig et al. 2006b). Based on these results, claims regarding increased efficacy over conventional permethrin formulations, such as Astro®, should be viewed with skepticism until such trials are conducted.

Spruce aphid, *Elatobium abietinum* (Walker), populations have been epidemic in southeast Alaska since 1998. The extended duration of the current outbreak and susceptibility of some

Sitka spruce, *P. sitchensis* (Bong.) Carr., to repeated attacks have resulted in mortality of landmark trees, particularly in urban areas. Treatments available for protecting *P. sitchensis* are currently limited to the use of Acecaps®. Unfortunately, there is a limit to the number of times that an infested tree can be treated with Acecaps® as the procedure requires the drilling of a hole for every 10 cm of tree circumference to facilitate treatment. We are currently examining novel tree injection tools for protecting *P. sitchensis* from *E. abietinum*. Preliminary results were discussed.

Dendroctonus brevicomis is a major cause of *P. ponderosa* mortality in the western US, particularly in California. Under certain conditions, such as extended drought, the beetle can attack and kill apparently healthy trees of all ages and size classes. Verbenone is the primary antiaggregation pheromone of *D. brevicomis*, and is assumed to reduce the negative impacts of intraspecific competition by reducing the overcrowding of developing brood. In 2002-2005, verbenone (2500 mg/24 h/ac hand-applied in pouches) was found to be ineffective for protecting small stands of *P. ponderosa* from *D. brevicomis* infestations (Fettig 2005). These failures led to additional research efforts. In 2004, combinations of six bark volatiles (benzyl alcohol, benzaldehyde, *trans*-conophthorin, guaiacol, nonanal, salicylaldehyde) and three green leaf volatiles [(*E*)-2-hexenal, (*E*)-2-hexen-1-ol, and (*Z*)-2-hexen-1-ol] significantly increased the inhibitory effect of two release rates of verbenone (Fettig et al. 2005). In 2005, we were able to refine release rates, reduce the number of components in our blend, and demonstrated the successful use of nonhost angiosperm volatiles and verbenone for protecting individual *P. ponderosa* from *D. brevicomis* attack in two separate studies. Preliminary results from EAG analyses were also discussed. Additional studies are scheduled for 2006.

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Critical Issues

- Carbaryl is the only single tree treatment with multiple years of efficacy. Further testing of insecticide formulations should be conducted to determine if there are more cost effective treatments that will also increase efficacy and reduce non-target impacts.
- Anti-aggregation pheromones for most bark beetle species are still non-existent or only marginally effective.
- Further research is necessary to determine how or if population density, stand structure or other environmental conditions affects the performance of verbenone.
- Silvicultural treatments designed as preventative measures to mitigate the affects of bark beetles or treatments used as suppression tactics, are effective tools for resource managers if implemented properly. The use of silvicultural treatments that effectively reduces populations or mitigates the affects of western bark beetle outbreaks should be documented in referred Journals.
- Additional research is necessary to determine the effectiveness of systemic insecticide injections to protect individual trees.
- Only one insecticide treatment is currently effective for spruce aphid, however it has limited applications. Other treatment methods must be explored to protect high value Sitka spruce from spruce aphid attack.
- Managing introduced exotic woodborers or bark beetles will require adequately funded research programs to develop improved methods for detecting and suppressing these introduced forest pests. Incipient populations must be located where an aggressive suppression/eradication program provides viable treatment options to limit natural or artificial spread.

Stand Level Tactics to Address Forest Pest Problems

Moderator: Ron Billings, Texas Forest Service

Experienced speakers from across the U.S. will describe current projects related to stand-level manipulations for managing such destructive pests as the emerald ash borer, western bark beetles, and the southern pine beetle. A general discussion of this approach to pest management will follow. The topics and speakers are:

> Modeling the Relationship of Emerald Ash Borer and Ash Phloem, with Management Implications.
>
> Speaker: Andrew J. Storer
>
> The Effects of Mechanical Fuel Reduction Treatments on the Activity of Bark Beetles (Coleoptera: Scolytidae) Infesting Ponderosa Pine
>
> Speaker: Joel McMillian (with Christopher J. Fettig, John A. Anhold, Shakeeb M. Hamud, Robert R. Borys, Christopher P Dabney, Steven J. Seybold)
>
> Red and Dead Trees: Bark Beetle Protection Projects in Idaho
>
> Speaker: Jim Rineholt
>
> Southern Pine Beetle Prevention and Restoration Program: Old Way of Thinking, New Way of Working
>
> Speaker: John Nowak

Living With Emerald Ash Borer: Modeling Phloem Reduction To Reduce Resource Availability

Andrew J. Storer, Tara L. Eberhart and Linda M. Nagel
School of Forest Resources and Environmental Science, Michigan Technological University

The exotic emerald ash borer, *Agrilus planipennis*, (Coleoptera: Buprestidae), is established in Michigan, Indiana and Ohio. At high population densities, all green, black, and white ash trees are apparently susceptible to attack and can be expected to die. Emerald ash borer larvae develop in the phloem of ash trees in stems and branches above approximately 2.5 cm in diameter. One management priority in areas in close proximity to known infested areas is to remove ash trees from forests and woodlots. It is not economically feasible to remove all of the small ash trees from a stand, and some will undoubtedly be left even though timber harvest operators maybe requested to remove them.

It is not yet clear how emerald ash borer will behave in rural forests, especially if host resources limit the size of the beetle population. Removal of ash from high priority areas such as those stands in close proximity to outlier populations will reduce the population density of this insect. Emerald ash borer larvae develop in the phloem of ash trees in stems and branches above approximately 2.5 cm in diameter. Measurements of ash trees suggest a strong relationship between diameter at breast height and calculated surface area of the tree. In addition, relationships between diameter, surface area and volume of phloem are being determined. These relationships, in addition to others involving tree vigor, form, and growing conditions, are being integrated into a model related to the amount of phloem in a forest stand. Using this model it will be possible to determine the size above which all trees should be cut to meet prescribed ash phloem reduction targets. Implementation of the model will enable forest managers to reduce the population potential for emerald ash borer in a stand, remove the larger ash trees from a stand, and retain small individual trees so that genetic diversity of residual ash stands can be optimized. Implementation of the model will also consider tolerable basal area limits. We are currently estimating the amount of phloem available to the insect in a forest stand containing ash and have developed preliminary models of the amount of ash tree removal necessary to reduce the breeding substrate by a target percentage. Forest resource managers will be able to view percent ash phloem volume calculated and find the diameter limit for removal of ash to achieve the phloem reduction target. By reducing emerald ash borer populations through phloem reduction, and decreasing the removal of the smaller trees in a stand, this model will enable the genetic diversity of ash to be optimized in light of ash reduction efforts.

The Effects Of Mechanical Fuel Reduction Treatments On The Activity Of Bark Beetles (Coleoptera: Scolytidae) Infesting Ponderosa Pine

Authors: McMillin, Joel D. Christopher J. Fettig, John A. Anhold, Shakeeb M. Hamud, Robert R. Borys, Christopher P Dabney, Steven J. Seybold

Selective logging, fire suppression, forest succession, and climatic changes have resulted in high fire hazards over large areas of the western USA. Federal and state hazardous fuel reduction programs have increased accordingly to reduce the risk, extent and severity of these events, particularly in the wildland urban interface. In this study, we examined the effect of mechanical fuel reduction treatments on the activity of bark beetles in ponderosa pine, *Pinus ponderosa*, forests located in Arizona and California, USA. Treatments were applied in both late spring (April-May) and late summer (August-September) and included: (1) thinned biomass chipped and randomly dispersed within each 0.4 ha plot; (2) thinned biomass chipped, randomly dispersed within each plot, and raked 2 m from the base of residual trees; (3) thinned biomass lop-and-scattered (thinned trees cut into 1-2 m lengths) within each plot; and (4) an untreated control. The mean percentage of residual trees attacked by bark beetles ranged from 2.0% (untreated control) to 30.2% (plots thinned in spring with all biomass chipped). A three-fold increase in the percentage of trees attacked by bark beetles was observed in chipped versus lop-and-scattered plots. Higher levels of bark beetle colonization were associated with spring treatments, which corresponded with peak adult beetle flight periods as measured by funnel trap captures. Raking chips away from the base of residual trees did not significantly affect attack rates. Several bark beetle species were present including the roundheaded pine beetle, *Dendroctonus adjunctus* (AZ), western pine beetle, *D. brevicomis* (AZ and CA), mountain pine beetle, *D. ponderosae* (CA), red turpentine beetle, *D. valens* (AZ and CA), Arizona fivespined ips, *Ips lecontei* (AZ), California fivespined ips, *I. paraconfusus* (CA), and pine engraver, *I. pini* (AZ). *Dendroctonus valens* was the most common bark beetle infesting residual trees. A significant correlation was found between the number of trees chipped per plot and the percentage of residual trees with *D. valens* attacks. A significantly higher percentage of residual trees were attacked by *D. brevicomis* in plots that were chipped in spring. Engraver beetles produced substantial broods in logging debris, but few attacks were observed on standing trees. At present, no significant difference in tree mortality exists among treatments. A few trees appeared to have died solely from *D. valens* attacks, as no other scolytid attacks in the upper bole were observed. In a laboratory study conducted to provide an explanation for the bark beetle responses observed in this study, monoterpene elution rates from chip piles declined sharply over time, but were relatively constant in lop-and-piled treatments. The quantities of □-pinene, 3-carene, □-pinene, and myrcene eluting from chips exceeded those from lop-and-piled slash during each of 15 sample periods. These laboratory results may, in part, explain the bark beetle response observed in chipping treatments. The implications of these results to sustainable forest management will be discussed.

Red And Dead TreesBark Beetle Protection Projects In Idaho

James F. Rineholt, USDA Forest Service and Idaho Dept. of Lands

The Idaho Department of Lands (IDL) initiated a Mountain Pine Beetle (MPB) Prevention and Restoration Project in the Sawtooth National Recreation Area (Sawtooth NRA) in 2004 with funding provided by the USDA Forest Service, Forest Health Protection, Regions 1 and 4. A partnership between IDL and the Sawtooth NRA was established to administer the program. Grant funds have helped private landowners affected by the current MPB and Douglas-fir beetle (DFB) infestation to implement recommended prevention and restoration practices. The grant program highlights a successful partnership effort to address a widespread condition that crosses private, state, and federal lands.
To be eligible for assistance through the grant, homeowners provided the required match and agreed to implement the following forest management activities:

1. Remove beetle infested trees.
2. Apply Carbaryl and pheromones
3. Thin susceptible stands of trees to increase resistance to bark beetles and fire
4. Restore heavily cutover areas by planting native species appropriate for the site.

Homeowners addressing the MPB outbreak within the Sawtooth NRA and others in the surrounding counties who are trying to protect their Douglas-fir trees have been very grateful for the assistance from IDL and the USFS. Many folks were overwhelmed with the number of dead trees on their properties and lacked the financial means and technical expertise needed to mitigate the problem. The project coordinator and IDL forest entomologist worked with grant recipients to implement appropriate management tactics. Homeowners contracted with local contractors to complete the work.

Positive outcomes of the grant program include:

- Forestry education and awareness to homeowners and local contractors
- Work for local contractors
- Generation of wood products for the homeowner's personal use
- Creation of healthier stands
- Increased IDL profile in south central Idaho
- Inter-agency partnership

Specific Accomplishments since 2004 include:

- Removal/thinning of 20,000 unhealthy trees on 960 acres
- Spraying 17,479 lodgepole pine with Carbaryl
- Deploying 15,968 MCH capsules on 530 acres

The success of this program is reflected in a recent comment by one of the homeowners: "Thanks again for all your help and for the IDL support of this program. It has enabled homeowners in our area to do a lot more to protect and improve the health of the forests on our land than we would have been able to do on our own."

Southern Pine Beetle Prevention And Restoration Program: Old Way Of Thinking, New Way Of Working

John Nowak, Southern Pine Beetle Prevention and Restoration Coordinator, USDA Forest Service, Forest Health Protection, Asheville, NC

The southern pine beetle (SPB) is the most destructive and costly insect pest of pines throughout the South. From 1999 to 2003, SPB caused unprecedented damage in Alabama, Florida, Georgia, Kentucky, North Carolina, South Carolina and Tennessee. More than 1 million acres on private farms and forests, industry lands, State lands, national forests, and other Federal lands were affected (Table 1). The estimated economic cost of the outbreak was $1.5 billion. These losses, from this outbreak and others in the past, severely impact the natural resource base that supports the South's tourism and wood-based manufacturing industries, and also destroys the habitat of threatened and endangered species, such as the red-cockaded woodpecker. In the aftermath of large infestations, dead and downed trees provide abundant fuel for wildfires, and pose additional threats to transportation corridors and public safety. These factors contributed to the creation of the SPB Prevention and Restoration Program in 2003 by the USDA Forest Service and the Southern Group of State Foresters. This program has been implemented by 13 states and 12 national forests in the south. Restoration activities, such as planting longleaf on appropriate sites, are designed to return damaged areas to healthy forest conditions and to create stands that are less susceptible to future SPB infestation. Prevention activities, such as thinning, are designed to improve forest health and therefore reduce SPB hazard, while still providing desired forest values. This program has led to the treatment (restoration and thinning) of more than 250,000 acres since its inception and has set a 10- year target of 2 million acres.

Perspectives on Treatment Tactic Development and Application

Moderators: Andrew Birt, Texas A&M University, and Brian Strom, USDA Forest Service

An Overview of The Discovery, Development, And Registration Of A Pesticide For Use In Forestry

James A. Gagne, BASF Corporation

The process for discovering, developing, and registering a chemical pesticide is discussed mainly from the perspective of the US Environmental Protection Agency (EPA) requirements under the Federal Insecticide, Fungicide, Rodenticide Act (FIFRA). Discovery includes all activities associated with finding a new active ingredient (pesticide), up to the start of development. Development includes all activities that start once a company commits to gaining registration for an active ingredient. (More details will be provided about the discovery and development processes below.) Registration is the review of required studies by a regulatory body. It results in assessments about the risks an active ingredient may pose. Based on these assessments, a regulatory body may grant or deny a registration, which is essentially a license to sell an active ingredient.

The general scope of effort in the pesticide industry is illustrated by a survey of 10 major research and development companies (Phillips McDougal, 2005). In 2004, these companies employed 8890 people full time and spent about 2.25 billion US dollars on research and development. About 40% of the scientists employed worked in biology (entomology, weed science, agronomy, physiology, biochemistry), 30% in chemistry, 19% in human and ecological risk assessment, 14% in regulatory affairs, and 1% in patent law. During 2004, the companies spent about 55% of their budgets trying to discover and develop new active ingredients, 41% of their budgets on expanding uses of, or re-registering, existing products, and about 4% of their budgets on patent-related work. Re-registration refers to the requirement under FIFRA that companies bring the database on older, already registered products up to present day standards. Altogether, the 10 companies spent about 7.5% of their total sales on their research and development activities.

The general scope of investment for a single new product is provided by CropLife International (2005). It typically takes 8 to 10 years from discovery of a new potential active ingredient to registration. Expenditures during this time could range from 180 to 225 million US dollars. Because of the long period with no monetary return, companies typically seek products for major agricultural crops and pests, not forest pests. Therefore, new products for forestry will typically be label expansions of registered agricultural pesticides. During the discovery and development process, companies will seek new active ingredients that approach ideals of biological efficiency (e.g, highly selective, fast acting, optimal residual effect, good plant tolerance), environmental soundness (e.g., low toxicity to nontarget organisms, low application rate, rapid degradation in the environment), user friendliness (e.g., low acute and chronic toxicity to mammals, safe packaging, easy to apply, stable in storage), and economic viability (e.g., good cost to profit ratio for the grower, competitive, patentable). Due to the complexities, all these ideals are not achievable in one active ingredient, so there will have to be trade-offs in satisfying what may be conflicting desiderata. For example, long residual activity on the plant is desirable, but persistence in soil is not. Nonetheless, regulators continue to challenge the pesticide industry by making requirements for acceptable pesticides more and more stringent

Discovery -- The basic components of the discovery process are bioassays known as screens. The process might start with high throughput *in vitro* screens with capacities of thousands or hundreds of thousands of compounds a year. The few compounds that exhibit activity in these screens would be subject to more intensive and expensive *in vivo* screens in the laboratory, greenhouse, and ultimately to testing in the field. Because the aim is to find something new and unique, this part of the process draws most on creativity and "basic" science, such as identification of cellular receptors, structure-activity relationships, and efficient delivery systems.

Development – The basic components of development are the studies required to support a registration under FIFRA. Most of the studies have to be performed under Good Laboratory Practices. EPA has set forth the studies required in the Code of Federal Regulations, Part 158 (2005) and how to perform them in various guidelines, guidance, and policy documents. Literally hundreds of studies are required in areas of: physico-chemical properties, residues in food and feed, environmental fate, hazards to humans and domestic animals, and hazards to nontarget organisms. Because the aim is to fulfill established and rigid data requirements, this part of the process draws more on project management, the ability to follow detailed study protocols, and documenting the results. That is not to say that creativity and "basic' science are not needed during development. Often times it is not straightforward to run a compound through the required tests. Also, results of the individual studies have to be integrated into a cohesive picture of the environmental fate and potential effects of a compound. Once the company completes the required studies, EPA reviews them and has policy-derived standards to assess the potential risks of a pesticide.

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Use of Ecological Modeling For Pesticide Risk Assessment

Andrew Birt, Knowledge Engineering Laboratory, Department of Entomology, Texas A&M University

'Federal law requires that before selling or distributing a pesticide in the United States, a person or company must obtain registration, or license, from EPA (Environmental Protection Agency). Before registering a new pesticide or *new use* for a registered pesticide, EPA must first ensure that the pesticide, when used according to label directions, can be used with a reasonable certainty of no harm to human health and without posing unreasonable risks to the environment'(www.epa.gov). Similar registration is necessary for markets in Canada and the European Union. This regulation process involves the demonstration of acceptable risks to human health, and to ecological systems. This paper discusses the development of models used to assess the risk of a pesticide product to ecological systems – ecosystems, populations and individuals.

It is argued that in order to develop successful ecological models for risk assessment a thorough understanding of standard risk assessment practice is needed. Regulatory authorities provide detailed guidance documents that outline data requirements and models to be used to determine a quantitative risk assessment for ecological safety. Key features of this guidance are a tiered approach and assuming worst-case scenarios. The first step (or tier) is to follow simple models that represent worst-case scenarios for the pesticides intended use and it's potential to impact ecological systems. If safety can be demonstrated using Tier 1 models, no further arguments need to be presented. However, if safety can not be demonstrated, then the risk assessment escalates to the next Tier where inputs to the models are refined according to sensible but conservative ecological principles (i.e. inputs become less worst-case). In some cases, demonstrating the ecological safety of a product requires refinement beyond the models outlined in the guidance documentation. At this stage field studies or semi-field studies are often used to demonstrate safety, but more recently there has been interest in the use of 'higher tier' ecological models.

In this paper it is argued that these higher tier ecological models should extend the tiered approach adopted in the guidance document and work to refine risk rather than trying to predict absolute risk. Working through a number of increasingly refined worst case scenarios is a sensible approach for a number of reasons:

1. The focus of all modeling should be to simplify real world systems to a necessary level of detail - in this case worst case simplifications.
2. Data is usually not available to adequately validate ecological models and will never be available to *fully* validate ecological models.

The paper also demonstrates an important problem of using ecological models for risk assessment. Compounds that reach the higher-tier risk assessment are biased towards those that are potentially unsafe. It follows that ecological models will inevitably show some effect of pesticides to the non-target organism or population of interest. In other words, adding toxicological components (increased mortality, reduced fecundity or development etc) to a population or pharmacological model will always result in some quantifiable effect. Since a stated goal of modeling should be to cut through the variability and complexity encountered in the real world, and because mathematical models work to a high level of precision, these effects are often very apparent in model outputs. It is noted that this situation is opposite to the results from field studies (as an alternative method of refining risk) where effects may be masked by environmental variability and safety is demonstrated by concluding no differences between control and treated experimental results.

As a consequence, this paper argues that two main factors are necessary to make higher tier ecological models useful for risk assessment:

1. A well defined statement about the focus of the risk assessment (individuals, populations, biodiversity etc) and either:
    a. …a definition of an acceptable ecological effect.
    b. …methods that frame the effects shown by the model into a wider context of acceptable risk. For example a demonstration of the ecological effects of a compound versus an alternative management strategy, a cost-benefit analysis using efficacy data for the target species or contextualizing using environmental variability.
2. The models should employ transparent, mechanistic and ecologically intuitive approaches to these higher tier models so that the assumptions of the model can be understood by lay scientists and regulators.

If step 1 (above) has been achieved, then the relevant output of the model should be very simple (i.e. whether safety has or has not been demonstrated). This allows the reviewer to concentrate on whether the assumptions outlined in the model represent an acceptable, worst-case scenario and to argue for amendments where necessary. It is argued that this methodology contrasts with the review of many modeling studies where the primary focuses of attention are complex model outputs rather than the basic, testable assumptions of the model.

Shaping Future Forests: Using Classical Biological Control to Reduce Harm from Invasive Forest Insects

Moderators: Scott Salom, Virginia Tech, Michael E. Montgomery, USDA Forest Service and Roy Van Driesche, University of Massachusetts

Recent invasions into North America show the continued vulnerability of native forests. Future forests could differ greatly from their historical composition if invaders are left uncontrolled. Classical biological control is sometimes the best or only option for reducing the damage to forests caused by non-native insect pests. This workshop focused on a range of systems, starting with two examples of successful classical biological control, the winter moth and Eucalyptus pests. Even these well-documented successes pose new challenges. For the winter moth, it is the establishment of biological controls as it spreads into new locations. For the eucalypts, the issue is the continued introduction of new exotic pests, where the mechanism of their introduction is not well understood. This was followed by the presentation of an active, operational program for the hemlock woolly adelgid, which requires detailed monitoring and evaluation for establishment and success of BC agents released. The last three examples considered biological controls for the newly introduced emerald ash borer, the Asian longhorned beetle, and sirex wood wasp. Several parasitoids have been found in Asia that appear to be good candidates for control of the two former species. Nematodes have successfully controlled the woodwasp in pine plantations; however forest systems where this insect has recently been found in the northeastern U.S are much more complex and pose substantial challenges.

Biological Control of Winter Moth In New England

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The winter moth, *Operophtera brumata*: a leaf-feeding geometrid native to Europe, has recently invaded eastern Massachusetts and is causing widespread defoliation. Previous invasions by this species in Nova Scotia and British Columbia have been suppressed by the introduction of two parasitoids from Europe, the tachinid *Cyzenis albicans* and the ichneumonid, *Agrypon flaveolatum*. As a result of these introductions, low-density populations of winter moth now persist indefinitely in these regions similar to those that exist in Europe. We have introduced *C. albicans* at one location in Massachusetts and we are developing a mass rearing effort for this tachinid and its winter moth host so that we can release large numbers of this parasitoid at many locations in the future. We focus our efforts on *C. albicans* because it specializes on winter moth and it is thought to be the agent primarily responsible for the decline of winter moth densities in Canada, We have established long-term monitoring plots where we will quantify densities of winter moth life stages and document parasitism before and after establishment of *C. albicans.*

We conducted a survey for winter moth across southern and eastern New England with pheromone-baited sticky traps in November and December 2005. The traps attracted both winter moth and the North American congener of winter moth, Bruce spanworm, *Operophtera bruceata*. We used dissection of male genitalia to distinguish between these two species. We recovered winter moths at sites that stretched from the eastern corner of Connecticut, through all of Rhode Island, eastern Massachusetts, coastal New Hampshire, and southern coastal Maine. We caught winter moths in areas that were at least 100 km from any areas known to be defoliated by winter moths. Traps further west and north and south caught exclusively Bruce spanworm. We confirmed these identifications by sequencing the CO1 mitochondrial gene of specimens of these two species. This technique does not distinguish between possible hybrids of these two species, a matter that will require further analyses.

Conflicts Of Interest in Invasive Species: Classical Biological Control In California Eucalypts

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Eucalypts were first planted in California in the mid-19th Century and were free from insect pests and diseases until the mid-1980's. *Phoracantha semipunctata*, a cerambycid native to Australia, was first detected in southern California in 1984. A comprehensive integrated pest management program involving species susceptibility, host plant resistance, cultural control, and classical biological control was developed to limit tree mortality in urban forest settings. Successful biological control was achieved following the introduction of *Avetianella longoi*, an encyrtid egg parasitoid. However, at approximately the same time as biological control was implemented, a second cerambycid, *Phoracantha recurva*, was discovered, again in southern California. In addition, a foliage feeding curculionid, *Gonipterus scutellatus*, was discovered feeding on blue gums. This insect was brought under complete biological control with the introduction of another egg parasitoid, *Anaphes nitens*. A biological control program was attempted against the chrysomelid tortoise beetle, *Glycaspis brimblecombii*, but proved unsuccessful. Professor Donald Dahlsten initiated two classical biological control programs that successfully reduced populations of the blue gum psyllid and the red gum lerp psyllid. A project is currently underway to introduce a parasitoid from Australia to control the spotted gum lerp psyllid, and, hopefully, to consequently reduce populations of the lemon gum psyllid, a commensal species associated with the lerps of the spotted gum lerp psyllid. In total, there have been at least 16 insect herbivores from four different feeding guilds introduced into California since 1984. All but one of these have been discovered first in the southern part of the state. It is unclear why or how the introductions occur, but there is a continuing challenge to implement effective protection of the resource. Biological control is an important component in the management strategy.

Status of Biological Control Efforts For The Hemlock Woolly Adelgid

Scott M. Salom, Department of Entomology, Virginia Tech, Michael Montgomery, USDA Forest Service, Roy Van Driesche, PSIS, Division of Entomology, University of Massachusetts and Carole Cheah, USDA Forest Service and Connecticut Agricultural Experiment Station

The hemlock woolly adelgid (HWA), *Adelges tsugae* Annand, (Hemiptera: Adelgidae) is an introduced pest that was of modest consequence to the native hemlocks (*Tsuga* spp.) of eastern U.S. from the early 1950's to the mid-1980's. It explosive expansion and fatal devastation to eastern and Carolina hemlocks since that time have been sobering to all who have witnessed it. In 1996, the HWA Working Group Coordinating Committee initiated a program using limited available resources to obtain biological control of this pest. This program has continued to date working with several partners and sources of funding. The following is a brief summary of predator releases for biological control.

Sasajiscymnus tsugae, a coccinellid predator imported from Japan was first introduced into Connecticut in 1995. All indications suggested that this would be an excellent biological control agent. It is multi-voltine and relatively easy to rear. As a result it has been the principal biological control agent released over the past decade with over 1,000,000 beetles released throughout the range of HWA in the eastern U.S. Although it has been reported to be established in several areas, the numbers recovered usually are very low and its impact on HWA has been difficult to document.
Laricobius nigrinus is a derodontid predator of hemlock woolly adelgid, native to the hemlock forests of western North America. It is prey-specific, synchronous with the life cycle of HWA, and is active in the winter when HWA sistens are actively feeding and developing. It is difficult to rear because it is univoltine and spends the summer months as pupae and aestivating adults in the soil, limiting its production and release numbers. Three laboratories are currently involved in rearing with more groups getting involved in the near future. Additionally, due to the difficulty in laboratory rearing, field insectaries are being established. Between 2003 and 2005, over 14,000 beetles were released at over 30 locations. We have already documented its establishment at more than 80% of the early release sites, with increasing numbers being recaptured every year post-release. Impact assessment on HWA is planned for the next 3 years.

Three *Scymnus* lady beetles have been imported from China. These are also prey-specific and synchronous with the HWA life cycle, but their larvae are present during mid-late spring, later in the season than *L. nigrinus*. Like *L. nigrinus*, the *Scymnus* beetles are difficult to rear and only small numbers have been released in a few areas. From 2004 to 2005, a total of 4,000 *Scymnus sinuanodulus* were released in 7 states, but to date, this beetle has not been recovered at any of the release sites. Caged studies however have documented good reproduction in the field and dramatic reduction of HWA populations. The cage studies also indicate that pre-release condition of the beetles is critical.

Comprehensive documentation of all new releases is now in place to collect pre- and post-release data for all predator releases sites. This will allow us to better document establishment and impact of the agents over time

In 2004, the HWA Biological Control group decided that an expanded foreign exploration effort was needed to bring in additional biological control agents and to learn more about the pest in its native habitat. This effort was focused on obtaining additional *Laricobius*, coccinellid and hemipteran predators from China. The recent revelation by Havill et al. (2006) that HWA in eastern U.S. is genetically identical to HWA on *T. seiboldii* from southern Japan has encouraged us to focus more in Japan than was previously planned. As a result, a new *Laricobius* sp. has been found and imported into the U.S. where it is currently being studied under quarantine. Early indications are that this predator has great potential as a new biological control agent.

It is still unknown at this time if the continued introduction of biological control agents and the simultaneous expansion of predator complex will suppress HWA populations sufficiently to give the trees a chance to survive. However, it is essential that we keep trying to improve our chances by determining the optimum complex of insects to use through thorough documentation of their establishment and impact, and increase the frequency of their releases through technical and logistical improvements in rearing and release strategies.

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Classical Biological Control Of Emerald Ash Borer And Asian Longhorned Beetle

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The emerald ash borer, *Agrilus planipennis* Fairmaire, and Asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky), are both invasive plant pests recently introduced to North America from the Far East. The emerald ash borer (EAB) is an oligophagous buprestid on *Fraxinus* spp., whereas the Asian longhorned beetle (ALB) is a polyphagous, cerambycid attacking various hardwoods, though it prefers maples, poplars and willows. Classical biological control is indicated for the following reasons: both species arrived in North

America without their habitual natural enemies and appear to be minor pests in the Far East, at least in natural settings, where they are known to be attacked by natural enemies. Parasitism of EAB by native parasitoids in MI is too low (<1%) to suppress EAB populations. Limited ALB samples from NY and IL indicate that parasitism by native parasitoids is likewise low. Therefore, studies on natural enemies of both species have been conducted in the Far East.

Explorations for natural enemies of EAB have been conducted on a limited basis in Japan, Russia and Mongolia, but more extensively in South Korea, and China. To date, the most promising natural enemies of EAB found are from China and include (1) the solitary parthenogenetic egg parasitoid, *Oobius agrili* (Zhang and Huang) (Hymenoptera: Encyrtidae), (2) the gregarious larval ectoparasitoid, *Spathius agrili* (Yang) (Hymenoptera: Braconidae), and (3) the gregarious larval endoparasitoid, *Tetrastichus* sp. (Hymenoptera: Eulophidae). These species have a number of characteristics that increase the likelihood of success as biological control agents such as female-biased sex ratio and > 1 generation per host generation. Data on the host range of these parasitoids are being collected.

Studies on natural enemies of ALB and its congener, *A. chinensis* (Förster), have been conducted in China. Two species from China, both gregarious larval ectoparasitoids, have been studied in depth—*Sclerodermus guani* Xiao and Wu (Hymenoptera: Bethylidae) and *Dastarcus helophoroides* Fairmaire (Coleoptera: Colydiidae). Both parasitoids can be mass-reared and released in large numbers, but are known to attack other cerambycids. It remains to be seen whether natural enemies with a narrow host range attack ALB in Asia. Field exposures of laboratory reared ALB and *A. chinensis* were made near the latter species' initial point of introduction in Italy. One gregarious egg parasitoid *Aprostocetus anoplophorae* Delvare (Hymenoptera: Eulophidae], very likely originating from eastern Asia, was recovered from *A. chinensis* eggs but not from ALB. Six larval ectoparasitoids, *Spathius erythrocephalus* Wesmael (Hymenoptera: Braconidae), *Eurytoma melanoneura* Walker (Hymenoptera: Eurytomidae), *Calosota vernalis* Curtis (Hymenoptera: Eupelmidae), *Cleonymus brevis* Boucek and *Trigonoderus princeps* (Westwood) (Hymenoptera: Pteromalidae), and *Sclerodermus* sp. (Hymenoptera: Bethylidae) were recovered from $1^{st}/2^{nd}$ instars of *A. chinensis*. Five of the latter larval parasitoids (*C. vernalis* excepted) also attacked *A. glabripennis* in the same area.

Host range studies to determine if exotic parasitoids of EAB and ALB will attack beetles native to North America are in progress or planned at U.S. laboratories.

Biological Control of *Sirex Noctilio* In North America

Nathan M. Schiff and A. Dan Wilson, USDA Forest Service, SRS, Center for Bottomland Hardwoods Research

Sirex noctilio F., a woodwasp (Hymenoptera: Siricidae) native to Europe, Asia and North Africa, has been a serious pest of pines wherever they have been planted in the Southern Hemisphere. It was such a problem in Australian pine plantations (*Pinus radiata*) in the

1960's and 1970's that a classical biological control program was developed to manage it. The program used a European nematode, *Deladenus siricidicola* that effectively sterilized *Sirex noctilio* and kept the population below economic injury thresholds.

In March of 2005, *Sirex noctilio* was discovered in New York State. Studies in the summer of 2005 indicated that the population was well established and that eradication was not feasible. A science advisory panel was formed and a classical biological control strategy using *Deladenus siricidicola* was proposed.

We believe that effective control of *Sirex noctilio* using the nematode is possible but we caution that the Southern Hemisphere, pine monoculture, plantation ecosystems where the nematode has been effective are much less ecologically complex than North American, native conifer, ecosystems (see table 1.). We anticipate that further research will be required to adapt the Australian program to North American forest conditions.

Current research on *Sirex noctilio* by us and others addresses; effectiveness of trap trees (a method to detect *Sirex* and release nematodes), development of traps and lures, questions of identification and possible non-target effects.

Table 1. The North American pine ecosystem is more ecologically complex than Southern Hemisphere pine plantations

Northern	Southern
100+ conifers in 12 genera	Single pine monoculture
20 species native Siricidae	Single exotic siricid
Many conifer feeding insects	Few pine feeding insects
Many native wood decay fungi	One exotic fungus
Several native nematodes	One exotic nematode
Many native parasitoids	A few parasitoids introduced from the US.

Challenges to Biological Control

Moderator: Fred P. Hain, NC State University

The face of biological control, especially classical biological control, has changed dramatically in recent years due primarily to concerns about nontarget effects. Therefore, it is reasonable to revisit biological control as a credible strategy for pest management. It is the purpose of my presentation to express specific concerns about the concept of biological control in today's environment so that the speakers, and audience participants, can provide a response. The topics I will cover include foreign exploration and the suitability of the pest for biocontrol, introduction strategies, mass rearing, impact on nontargets, post release evaluation and compatibility with IPM.

Foreign Exploration and the Suitability of the Pest for Biocontrol: Frequently foreign explorations for natural enemies are of relatively short duration and represent only a short period of the pest's life cycle. These trips can be expensive and result in little of practical consequence. If the information that is collected relates only to natural enemies, the main factor regulating the pest population in its native range may be overlooked. A fundamental question that should be addressed in foreign exploration is how is the pest population regulated. This may require a lengthy period of time studying the pest in its native range. Guidelines for determining the minimum duration and the type of information to be collected in foreign exploration for natural enemies should be established.

Introduction Strategy: Release strategies should be employed that maximize the likelihood of natural enemy establishment. Can mathematical models be developed that predict both establishment and impact? Are certain strategies better for certain types of organisms? What life stage should be released? What should be the distribution (clumped, random, uniform) of the release? Is a supplemental food source necessary or desirable for a successful release? What are the criteria that would increase the likelihood of a successful release?

Mass Rearing: Mass rearing of natural enemies requires strict quality control standards that must be maintained throughout the rearing process. What are the criteria that need to be maintained for ensuring the highest quality? Will rearing multiple generations of the natural enemy under laboratory conditions result in an inferior type that will not survive well when released? How can this be avoided? Is a field insectary a reasonable alternative for mass rearing?

Impact on Nontargets: Considering the impact that the introduction of non-native natural enemies may have on nontargets species involves both ethical and ecological considerations. Is augmentation or conservation of native natural enemies a better alternative? Will the natural enemy become a nuisance pest? Will it displace native natural enemies?

General characteristics of a successful natural enemy include strong colonizing ability, temporal persistence, and opportunistic foraging. These factors normally mean a natural enemy that is not host specific. Yet host specificity is currently a trait that is considered desirable. What is the likelihood of finding a host specific natural enemy with all of the other desirable characteristics? According to the IOBC the success ratio of biological control agents tested has been 1:10. In forestry the ratio is closer to 3:10. While this is certainly better than the 1:200,000 ratio for pesticides tested, it still represents a high failure rate. And the failure rate is likely to increase with host specificity added as a criterion.

Post-release Evaluation and Compatibility with IPM: In the past, biocontrol agents have been released without giving adequate thought to post-release evaluation. The strategy apparently was one of looking for a silver bullet: if it works, great; if it doesn't, keep looking. A well thought out post-release evaluation should include more than just impact on the host. What other factors should be included in an evaluation that would help us determine the suitability of the natural enemy in a pest management strategy? In other words, can the natural enemy play a role in an IPM program? What are the criteria that determine whether an introduction of a natural enemy is considered a success or failure?

Compatibility with IPM does not seem to be a major consideration in most classical biological control programs. In fact, biocontrol frequently seems to be presented as an alternative to IPM. Shouldn't biocontrol agents be evaluated for their compatibility with pesticides and other biocontrol agents? While a specific biocontrol agent may not be able to control a pest on its own, it may be an important component to an IPM approach. Shouldn't the resistance or tolerance of the host tree being attacked by the pest be considered when releasing a biocontrol agent? If so, how? The speakers and the audience will address these and other questions during this workshop. The final product will be a list of critical issues that we as a group consider important for maintaining the vigor of the discipline of biological control.

Evaluation Of Biological Control: How Do We Measure Success? Is Biological Control Compatible With IPM?

C. Wayne Berisford, Department of Entomology, University of Georgia

Although we benefit from a great deal of natural biological control for many native forest insects, much of it goes unnoticed when populations are maintained below outbreak levels. However, many of our current and emerging forest pests are foreign introductions which have become established without the full complement of their natural enemies. Parasitoids, predators and pathogens are frequently introduced in attempts to suppress populations and reduce damage. Unfortunately, the follow-up subsequent to such releases is often incomplete, or if there is a perception that an introduction failed to establish, there may be no further evaluation. Failures to establish many promising biocontrol agents, little obvious impact of some successful establishments of natural enemies and/or inadequate follow up after releases, has led to considerable skepticism regarding evaluation of biological control programs. This leads to questions about how biological control efficacy can be measured.
Measurement criteria for success obviously will be different depending on the type of damage caused the pests (tree mortality, degrade of lumber, growth loss, form loss,
etc.). There are logical ways to measure success of at least some biocontrol agents without costly programs to determine population densities or population growth by measuring effects

on tree hosts. There is also some concern that biological control may not be compatible with plans for integrated pest management systems. We provide here some examples of biological control programs for forest insects, with criteria for evaluation of success and observations on their potential compatibility with an integrated control system.

The Hemlock Woolly Adelgid, *Adelges piceae* (Hemiptera: Adelgidae) was introduced into the eastern U. S. during the 1950's and has spread through much of the range of eastern hemlock where it has the potential to essentially eliminate eastern and Carolina hemlock from our forests. A biological control program is under way which consists of releasing predacious beetles in the hope that adelgid populations will be sufficiently reduced to allow infested hosts to survive and resume growth. The obvious criterion for success in this case is simply the survival of the hosts. The introduction of predators is compatible with the other facet of an integrated approach which includes treatment of hemlocks with insecticidal soaps, oils or systemic insecticides which are injected into trees or into the soil beneath the trees. Potential nontarget impact is therefore low and any adverse impact on the biocontrol agents will likely be minimal.

The Nantucket Pine Tip Moth, *Rhyacionia frustrana* (Comstock) is native to the eastern U. S. where populations are regulated by a suite of parasitoids, predators and pathogens. However, it was introduced into the southwestern U. S. in the 1970's and currently infests areas of California, Arizona and New Mexico. Severe damage to ornamental monterry pines, *Pinus radiata D. Don* in California prompted the development of an integrated system which utilizes biological insecticides, certain “hard” pesticides and the introduction of a common parasitoid of the tip moth from its native range. The establishment of *Campoplex frustranae* Cushman (Hymenoptera: Ichneumonidae) reduced tip moth damage sufficientluy to allow infested trees to resume growth and regain lost form. This parasitoid is compatible with the use of biological insecticides and certain “hard” insecticides which may be included in an integrated management system.

The gypsy moth, *Lymantria dispar* L. (Lepidoptera: Lymantriidae) has spread over a large portion of eastern U. S. since its introduction in 1869. Initial impacts were severe as the moth moved into previously uninfested regions. Heavy tree mortality, particularly among favored host species such as oaks, was common. The introductions of several parasitoids, predators and pathogens may have helped to moderate population explosions somewhat, but the reemergence of a fungal pathogen which had been introduced in 1910 caused many infestations to collapse. *Entomophaga maimaiga* has caused a dramatic reduction in the rate of spread into new areas and in the frequency of localized outbreaks. Evaluations of the efficacy of the combined effects of biological control agents can be made by comparing tree mortality, the relative frequency of outbreaks and the rate of spread of new infestations before and after the reemergence of *Entomophaga*. Silvicultural treatments which reduce the frequency of favored gypsy moth hosts in forest stands may be integrated into the current system which relies on biological agents and the judicious application of pesticides.

The southern pine engraver, *Ips grandicollis* (Eichhoff) (Coleoptera: Curculionidae) is native to the U. S. where it is generally considered to be a relatively minor pest. The beetle was accidently introduced into Australia during the 1940's. It was initially established in forests that were not economically viable and therefore no attempts were made to manage populations. However, it eventually moved into valuable monterrey pine plantations where it was considered to be a significant threat. Several hymenopterous parasitoids and two predacious beetles were introduced into Australia from the southeastern U. S. and from bark beetle-infested monterrey pines in California.

Two species of hymenopterous parasitoids from the Southeast (Georgia) were established, initially in the state of South Australia. *Roptrocerus xylophyagorum* (Ratzeberg) (Torymidae) and *Dendrosoter sulcatus* Musebeck (Braconidae) were found to cause *I. grandicollis* mortality which averaged from 12 to 18 percent. Evaluations of success were based on relative losses in plantations of various ages, initially in stands with and without parasitoids and ultimately on losses before and after establishment of these natural enemies. The parasitoids have become part of an integrated system that incorporates rapid salvage of infested trees and timely thinnings to maintain tree vigor to help resist *I. grandicollis* attacks.

Challenges To Biological Control

Scott M. Salom, Department of Entomology, Virginia Tech

Response to Introductory Remarks:
Biological control has always carried inherent risks. While recent debates have centered on the consequences introductions may have on non-targets, such discourses are not new or unique among biological control practitioners. I would argue that with careful screening and strict host-range testing, the risks are minimized. It is not the concept of biological control that is at risk, but the desire of practitioners/sponsors to expedite the release of natural enemies by curtailing the duration of host specificity testing to reduce costs that places the concept at risk.

It should also be acknowledged that not all NEs imported for testing should be released. Additionally, with the increased frequency of introduction of destructive, invasive, exotic pests, alternative pest management tools are often not available to respond with. In these cases it is completely reasonable to consider biological control as an option.

Response to Foreign Exploration Issues:
In planning for foreign exploration, considerable effort first goes into gathering and studying all the background information that can be assembled (ie. taxonomic and life history information on pest, its economic status, host plant distribution, native and current geographic distribution, probable center of origin of pest and related species, and climatic range of native area compared with new area). So viability of BC is greatly considered and possibility of success evaluated before initiation of foreign exploration.

Now if time is not an issue (and it always is), by all means study the system abroad as deeply as possible, then choose natural enemies that appear to be key factors in population regulation. But because time is always an issue, we need to ID areas for exploration, make appropriate contacts and arrangements, determine whether potential prey-specific agents are available, study them short-term, and if possible ship to quarantine in the US for further study. Sometimes the infrastructure at a foreign location does not lend itself to long-term study, (ie. lack of trained personnel, equipment, and facilities).

Predicting success of introducing NEs in new habitats is extremely difficult because often the introduced pest starts feeding on new hosts, perhaps with less resistance. This can change the dynamics of the predator-prey / parasitoid-host system.

Response to Introduction Strategy Issues:
Development of an optimal release strategy is critical. But again, when time is limited, sometimes one needs to start by best-guessing based on knowledge of the pest's distribution, and the natural enemy's ability to disperse and establish itself. The key is to try to get the natural enemy established. If it is a good BC agent, it will search out and find the pest.

Another issue is how many BC agents do you have to release? This may dictate how many are released.

Do the BC agents aggregate or feed singly, competing where conspecifics are dense?

The bottom line is to get BC agents out into the environment quickly and then refine release procedures over time, conducting appropriate systematic studies to optimize release.
Response to Mass Rearing Issues:
Mass rearing operations can be enormously variable depending on the NE and its biological requirements. Issues to consider include:

1. <u>Nutritional Requirements of the NE</u>
   a. Quality of the host can affect NE development and reproductive capacity.
      1. Preferred vs. alternative host?
      2. What kind of shape is host in? – maintenance of a healthy host colony can be a challenge.
   b. Diets have been developed for parasitoids – mostly idiobionts, rare for predators. Still a work in progress!!
      1. For parasitoids, diets include chicken yolk, powdered milk, insect hemolymph, and bovine serum.
      2. Physical or chemical cues may be needed to get the NE to feed.

2. <u>Environmental requirements</u>
   a. It is hard to simulate field environment (ie. Temperature, photoperiod, humidity, developmental substrate, etc.)
      1. NE Life cycle may become asynchronous with field phenology of target host/prey

3. <u>Minimizing contamination</u>
   a. Keep facilities clean and free of entomopathogenic microorganisms.

b. If introducing wild insects, screen for possible pathogens that may accompany insects to be incorporated into the colony…especially if you notice the colony dying off.

4. Infusing wild NEs into the rearing process
   a. It is well documented that continuously rearing labs insects reduces colony fitness. Inbreeding and lost of hybrid vigor may be avoided by periodic infusion of wild populations into the lab colony. It is important to start with as large a genetic base as possible.
   b. Wild insects are often larger and lay more eggs than their lab-reared counterparts.

5. Field Insectaries can supplement the lab
   a. Wild NEs should supplement a lab colony or release in the field if lab rearing becomes too difficult. Over the long term, field insectaries should be preferred over lab rearing.

Response to Impacts on Nontargets:
The days of introducing generalists as BC agents are over. Host-specificity is preferred, however mono-specific organisms are not necessarily the best choice. If BC agent is too host-specific then the question arises, what happens to it if the population of its prey crashes? Ideally, a BC agent should have some adaptability, and can feed on closely related species of the target. Thus, genus-specific organisms may be more desirable. Perhaps it can feed on congeneric species. In many cases, the congeners are also pests. In some cases they are not. So yes there is a risk.

Just like any management decision, cost-benefit or risk analysis may be warranted. While in recent years cases have been cited where BC agents have not only suppressed introduced pests, but also native species that had some ecological value. A good example is the introduction of the head-thistle weevils to control musk thistle. They have done a great job controlling a noxious invasive weed that was causing millions $$ of loss per year to the cattle industry. The negative side of this is that a few native thistles were also impacted. Choices had to be made. If we wait until we have completely "risk-free" IPM options, we'd never get anything done.

Response to Post-release Evaluation Issues:
Post-release evaluation is essential, not only to learn and improve, but also to justify effort and expense. What is needed?
1. Pre-release and post-release data to develop an understanding of why released agents become successfully or unsuccessfully established.
2. Monitor establishment and spread closely.
3. Assess impact only after the BC agent is deemed established.
4. It is useful to learn as much about the relationship of the BC agent and its prey/ host.
5. After BC agents are established and have had time to become part of the plant-pest system, life table analysis can be attempted to assess the role of different mortality factors,

especially when multiple agents have been released and pest populations do appear to be suppressed.

Response to Compatibility with IPM and Host-Resistance:
Sometimes one tactic dominates over others, either due to efficacy or to socio-economic considerations.

Some resistance in a host would be ideal and is important for the success of biological control agents. Resistance may be due to many factors. These should be studied to better understand why invasive pests sometimes have varying impacts on the host.

Challenges To Biological Control

Fred Stephen, Dept. of Entomology, Univ. of Arkansas

Answers and discussion was generated in response to Fred Hain's challenges to speakers, which, for the topic of "Introduction strategies" were:
Hain 'Challenges' related to "Introduction Strategies":

I. Release strategies should be employed that maximize the likelihood of natural enemy establishment.
   A. Yes --- and these are determined by detailed knowledge of NE and host biology. Eg. caged release of NE is one of the oldest techniques (eg. *Vedalia* beetle), but can be important.
II. Can mathematical models be developed that predict both establishment and impact?
   A. Sure --- but without incredibly detailed biological studies, we won't know enough to create models that have meaning.
III. Are certain strategies better for certain types of organisms?
   A. Yes --- but again this is dependent on the species. Eg.With *Vedalia* beetle 10 males/ females yielded success / contrasted with Canadian releases of 10,000 *Dahlbominus fuscipennis* parasitoids against the spruce sawfly.
IV. What life stage should be released?
   A. Needs to be tailored to the biology of the NE (and the host)
V. What should be the distribution (clumped, random, uniform) of the release?
   A. Again, this needs to be tailored to the biology of the NE (and the host)
VI. Is a supplemental food source necessary or desirable for a successful release?
   A. Certainly may be desirable for some species, and maybe essential during transport to field.
VII. What are the criteria that would increase the likelihood of a successful release?
   A. Having an excellent research base on NE and host.
   B. Although a generalization, Hagen 1976 points out --- attributes common to most effective predators are: multivoltinism (non-diapausing), narrow prey specificity, and high search efficiency by long-lived adults, temperature thresholds similar to prey, plus more generations than prey. (And these characteristics are similar to those of the most effective parasitoids).

It was stressed that we must consider the fundamentals of biological control: eg. Although biological control can be considered an applied discipline, it also has its very foundations in ecological theory. The implications of this are that knowledge is often the key to success.

CRITICAL ISSUES

- Successful biological control programs depend on knowledge of biology and ecology of target hosts, natural enemies and the ecosystems in which they will exist.

- In forests, classical biological control remains important, but additional emphasis should be given to augmentation and conservation of natural enemies.

Foreign Exploration And Suitability Of A Pest For Biological Control

Roy Van Driesche, Univ. of Massachusetts

At the earliest stage in consideration of an invasive species as a potential target for classical biological control two questions need to be asked: (1) is the pest intrinsically suitable for control by this method and (2) what approach should be taken to seek natural enemies. Invasive arthropods become pests by several mechanisms, which include potentially their escape from controlling specialized natural enemies, their attack on a new, more susceptible host plant, or movement into a more permissive climatic zone. All three factors may apply, but the importance of natural enemy escape versus the others must be assessed since only species that truly are natural enemy limited will respond favorably to natural enemy introductions. Suitability of pests for classical biological control varies from groups that are known to usually be highly suitable (mealybugs, armored scales, leafminers, beetles with foliar feeding larvae, conifer feeding sawflies, and multivoltine species) to groups with lower suitability (groups with no precedents of classical biological control, pests in soil or concealed in fruits or other plant parts, spider mites, rust mites). While the later are not impossible targets, they will be more difficult and the odds of success are lower. Projects that seek to break new grounds (e.g., control of fire ants or adelgids) will face inherently greater difficulties than projects against species in commonly controlled groups (mealybugs, whiteflies). However even within groups considered highly suitable targets, individual species may pose greater or fewer difficulties depending on several factors, including (1) is the pest a well know species taxonomically, and in terms of its distribution and host plants, (2) is the pest part of a large cosmopolitan complex of populations or a well defined, localized one, (3) are there known natural enemies of the pest, (4) has the pest been successfully controlled by classical biological control previously in other locations, (5) are the logistics of travel easy or difficult in the area from which natural enemies are to be collected and (6) is the government of the country from which natural enemies are to be taken cooperative and friendly, hostile, or requiring of complex and inefficient export procedures. When these conditions are favorable, a single short collecting trip may suffice. For example, collections of ash whitefly parasitoids in Europe for control of *Siphoninus phillyreae* (Haliday) in California were made rapidly and with ease in Italy, France and Israel because the pest and its key natural enemy were well known and the locations to be searched were well developed and friendly to such work. In contrast collections of parasitoids of cassava mealybug (*Phenacoccus manihoti* Matille-Ferrero) for introduction in Africa were more difficult because the species was new to science, from an unknown location in a large continental area, with more travel difficulties, and had no known natural enemies. In cases resembling ash whitefly, short collecting trips to a well defined location may suffice, but in the latter case, more effort will be required. Depending on the needs, collection trips for more difficult targets may be lengthy efforts to cover many diverse areas, or may be long collection efforts in a few locations for the purpose of better understanding the natural enemies associated with the pest in its native range for the purpose of recognizing which natural enemies are most valuable for importation.

Decision Support Tools

Moderator: Randy Hamilton, USDA Forest Service, RSAC

The Use Of Remote Sensing Techniques To Survey Forest Pest And Diseases Of Mexico

Jaime Villa Castillo and David Quiroz Reygadas, CONAFOR Mexico

Background

Since the new federal administration took place in 2001 one of the major goals related to forest health issues was to improve the information about the status of major insect and disease problematic causal agents in Mexico. In the past information databases and thematic maps were seldom produced.

One of the major inputs was to define the specific general information needed for administrative purposes. Diagnostic of a specific area including the identification of causal agents of tree damage, the estimation of the affected area and the effectively treated area were the three variables being considered.

To get the information required to assess the diagnostic of a specific area The Forest Health Program at the Mexican Forestry Agency (CONAFOR) began with a two layered approach: first to get a general survey of main ranges on a per State basis and second to perform ground checking over the suspected spots to verify the causal agent. The general survey is performed mainly by using aerial survey techniques, however in 2003 we began using remote sensing techniques to try to locate potentially dangerous spots. We wanted to explore the feasibility of using remote sensing techniques with satellite imagery as a routinary practice as an alternative to aerial survey because of some local problems to operate the last one technique. We also wanted to test the usefulness of this technique in two other approaches.

Objectives

We conducted an experimental program to evaluate the potential use of satellite imagery on 1) Estimating potential current damages by pest and/or diseases 2) to asses mortality patterns over the time and 3 to perform risk assessment.

Procedures

To cover the first objective the Forest Health Program at CONAFOR contracted a research institute to conduct a project to identify spectral signatures of bark beetle infested areas from LANDSAT images, also to generate a supervised classification and to perform statistical testing over such a classification.

To cover the second objective there was another contract for a local university to evaluate on a specific area changes over the time in forest vegetation cover due to a suspected (unidentified) oak tree disease using LANDSAT imagery.

To cover the third objective Forest Health Program technicians performed a non statistical supervised classification on oak mortality due to an identified tree disease using relatively more precise SPOT imagery.

Results

The test for generating spectral signatures to estimate current damages used the class of susceptible trees (bark beetle infested areas) three other spectral signatures as reference conditions: 1) non susceptible trees (non-pine species on site), 2) non forested areas and 3) water catchments. The class of susceptible trees resulted with the lower percentage of precision out of the other three classes as indicated in table 1.

TABLE 1. Evaluation of the verified classification for bark beetle infested areas

CLASS	TOTAL OF PIXELES VALIDATED	NUMBER OF ACCURATED PIXELS WITHIN THE CLASS	PRECISION OF CLASS %
1	7	4	66.67
2	15	11	75.00
3	4	4	100.00
4	6	5	83.33
TOTALS	**32**		

Class 1= areas of susceptible trees (pine)
Class 2= areas of non susceptible trees (other tree species).
Class 3= non-forest areas
Class 4= water catchments

The test to evaluate the potential use of satellite imagery on estimating damages over the time yielded interesting results. We wanted to estimate the oak tree mortality on a retrospective approach in a specific range in central Mexico. In year 2000 it was suspected the presence of a pathogenic fungi strain (*Phytophthora cinnamomi*) as the causal agent of oak mortality. The study initiated in year 2003 used satellite imagery of years 1997, 2000 and 2002. We were specifically interested in knowing the increase on damaged area if fungi was present, although no positive identification was obtained whatsoever. The results indicated that a raise in tree mortality occurred from 1997 to 2000 but it did not continue over 2002 (table 2).

TABLE 2. CHANGES IN FORESTED AREA IN GUANAJUATO MÉXICO FROM 1997 TO 2002

Total Area (ha)	1997			2000			2002		
	Forested area (ha)	Affected Area (ha)	Affected Area (%)	Forested area (ha)	Affect Area (ha)	Affect Area (%)	Forested area (ha)	Affected Area (ha)	Affected Area (%)
10573	40710	587	1.44	37216	4 310	11.58	35248	2 213	6.28

Further analysis on this research allowed us to sustain the hypothesis that tree mortality between years 1997 to 2000 was due to abnormal low temperatures particularly critical in year 1998 and then to discard any disease effect.

The third test was designed to evaluate the feasibility of using more precise SPOT imagery to assess the risk of *Phythophthora cinnamomi* fungi spread out of an identified location, based upon its spectral signature. Once the verified classification was obtained the extrapolation over the area showed us that the spectral signatures generated in the spots were the disease was present the first year of the study correctly reflected the condition observed the following year, but this time in an area 5 times larger than the original one. Although this is an ongoing test, preliminary result allowed us to pay specific attention to over 100,000 hectares of oak on the southern portion of Jalisco state since there is some evidence that they could be at risk of infection by *P. cinnamomi*

Conclusions

The recent experiences on the use of remote sensing techniques by the Forest Health Program in Mexico allowed us to conclude that these techniques could be useful in several ways to get specific informative products. However there are limitations to the use of remote sensing techniques to be used as we originally expected. For instance we expected to be able of using satellite imagery for identifying current potentially dangerous spots from above as surrogate of observers riding in an aircraft. We found out this is not feasible until we advance in more precise spectral signatures. This could be a serious drawback when a survey program is planned in relatively wide and diverse geographic areas.

Nonetheless we found out that remote sensing techniques could be useful to have information of events that occurred in the past. In our example of evaluating changes of vegetation over the time we could be able of gathering information from previously taken photos from above. This ability is particularly important when there is a delay in identifying specific causal agents of tree damage.

From our third example, we find out that remote sensing techniques have promissory tools to perform risk assessment on potentially dangerous identified causal agents of tree mortality.

Additional restrictions though are imposed by the costs of satellite imagery. More precision of imagery is generally accompanied with escalated price.

Statistical Tools For Examining The Influence Of Landscapes On Forest Insects

Jeffrey D. Holland, Carolyn Foley, and Shulin Yang. Department of Entomology, Purdue University

The large scale spatial pattern of forest across a landscape can affect the ability of both forest insect pests and ecologically valuable species to colonize forest patches and maintain metapopulations. An understanding of how different species are affected by forest connectivity and the relevant spatial scales is necessary to balance control of pest species and biodiversity conservation. Further, an understanding of how large continuous forest patches contribute to connectivity is important in many landscapes such as riparian networks of forest. We used the Focus 2 program to deal with spatial non-independence in determining ecologically relevant spatial scale for *Neoclytus acuminatus acuminatus* (Fabricius). *N. acuminatus* responded most strongly at 1200 m. We detail a method of scaling a measure of functional connectivity, the Incidence Function Model method, using this scale of response. Further, we detail how to use this value to account for the contribution of large forest patch networks to a biologically meaningful measure of habitat connectivity. By using the spatial scale of response and measuring connectivity in this way, we were able to show that *N. acuminatus* is present in all of our 43 surveyed forest patches when connectivity is high, and present in about half of these when connectivity is low. A second species, *Glycobius speciosus* (Say), appears to have its occurrence limited by a critical distance to large source patches of forest.

Data Life-Cycle And Decision Support Framework For Large-Scale Pest Management

Amos H. Ziegler, Computational Ecology and Visualization Laboratory, Department of Entomology, Michigan State University, E. A. Roberts, Department of Entomology, Virginia Tech, and Patrick C. Tobin, USDA Forest Service, Northeastern Research Station - Forestry Sciences Laboratory

Introduction

With an ever increasing threat of invasive species due to globalization, there is a need for greater emphasis to be placed on the development of data life-cycle and decision support strategies during the early stages of emergency program development and deployment. The implementation of a well thought out data life-cycle and decision support framework will allow quality data to feed the decision making and planning processes of an emergency program resulting in a more effective program.

This overview of the data life-cycle and decision support framework of the National Slow the Spread (STS) of the Gypsy Moth trapping program illustrates the various tabular, geospatial, and informational management technologies applied to the monitoring and management of an invasive species. Over the past 17 years the lessons learned, having spanned the pre- and post- “mini-boom” eras of geospatial and internet technologies, provides the STS project with a unique perspective on the design, deployment, and management of wide-area pest management programs.

The National Slow the Spread of the Gypsy Moth Project is a national U.S.D.A strategy for the management of European Gypsy Moth, *Lymantria dispar* (L.), in the United States. This cooperative project crosses several state and federal administrative and jurisdictional boundaries which include as cooperators 10 state agencies, 2 federal agencies, and 2 land grant universities.

Data Life-Cycle Framework

The survey and treatment structure of the STS project is large and complex. A mature data and decision management framework is necessary for the efficient and successful management and analysis of this large volume of data in support of project planning and decision making. Data flows into the data management framework from March through September and the subsequent analysis and planning occurs in October and November of the project year.

Field data are collected using either the STS Trapper Gadget or the commercial Garmin V mapping GPS unit. The STS project deploys approximately 35 STS Trapper Gadgets and over 300 Garmin V mapping GPS units. Field data are downloaded from the Trapper Gadget using the Trapper Gadget desktop utilities and from the standard GPS units using GPSi. Trap data can then be visualized using the TrapView software or directly uploaded to the STS database using the GPS File UpLoader software. Data submitted to the STS database are loaded by an automated service which runs on a 10 minute cycle - 24x7. Data are loaded into temporary tables within the Oracle database where over 50 validations are used to QA/QC the trapping data. Data that passes the validations are inserted into the permanent structure of the database, while failed data records remain in the temporary structure awaiting error correction by project cooperators.

Cooperators and project support personnel can access trapping data errors, as well as validated data through the real-time reporting system served from the project's operations web portal. Information delivery via the IT infrastructure of Slow the Spread is an important integrative component of the operational project and the integrative functions served by the IT infrastructure have been integral to the project's success. Real-time or near real-time delivery of data and derived products allow cooperators to maintain a high degree of data ownership and connectivity to other cooperators. The main information delivery web servers operated by the STS Information Systems Group in support of the STS project are the *Gypsy Moth Slow the Spread Foundation* (www.gmsts.org), *Operations Portal* (operations.gmsts.org), *Decision Support System* (da.gmsts.org), and *ArcIMS Map Server* (mapserver.gmsts.org) web sites. These web servers are the primary vehicle for distributing project documentation, data, software, and products.

Decision Support System Framework

The framework of the STS decision support system (DSS) is responsible for the standardization and optimization of recommended intervention actions. The DSS takes the trap catch data managed under the data life-cycle framework discussed above and models the catch data in order to recommend Potential Problem Areas (PPAs). The PPAs are then evaluated to recommend action, which can include treatment, delimitation, or no action. The evaluation process is guide by the calculation of a Delimiting Index and a Priority Index. The Delimiting Index is used to indicate the need for more intensive trapping in order to delineate the extent of the infestation prior to treatment. Treatments are not recommended without a minimum threshold of traps within the PPA boundary. The Priority Index ranks the PPAs so that the more serious areas under management are addressed first.

The treatment techniques used to manage gypsy moth in the STS action area are evaluated in order to measure the overall effectiveness of the project and to identify opportunities for improving management techniques. This is done with the aid of indices of Treatment Success and Colony Presence. The index of Treatment Success measures the change in the density of the treated area before and after treatment, while adjusting for changes in nearby traps. A treatment may not be considered a success if population levels in traps go down equally inside and outside of the treatment block. This issue is more specifically targeted in the calculation of the index of Colony Presence. This index measures the ratio of abundance in the treated population relative to the surrounding background population. Combined they are used to measure the overall effectiveness of individual treatment blocks.

If the management strategies employed by the STS project are effective than this effectiveness should be detectable through calculations of gypsy moth spread rates. The calculation of spread rates by the DSS is the second evaluation technique used by the STS project. The rate of spread of a population is calculated by measuring the distance between population boundaries in consecutive years for each of the derived population boundaries (1, 3, 10, 30, 100, and 300 isolines). The overall rate of spread of a given year is an average of the individual population boundaries.

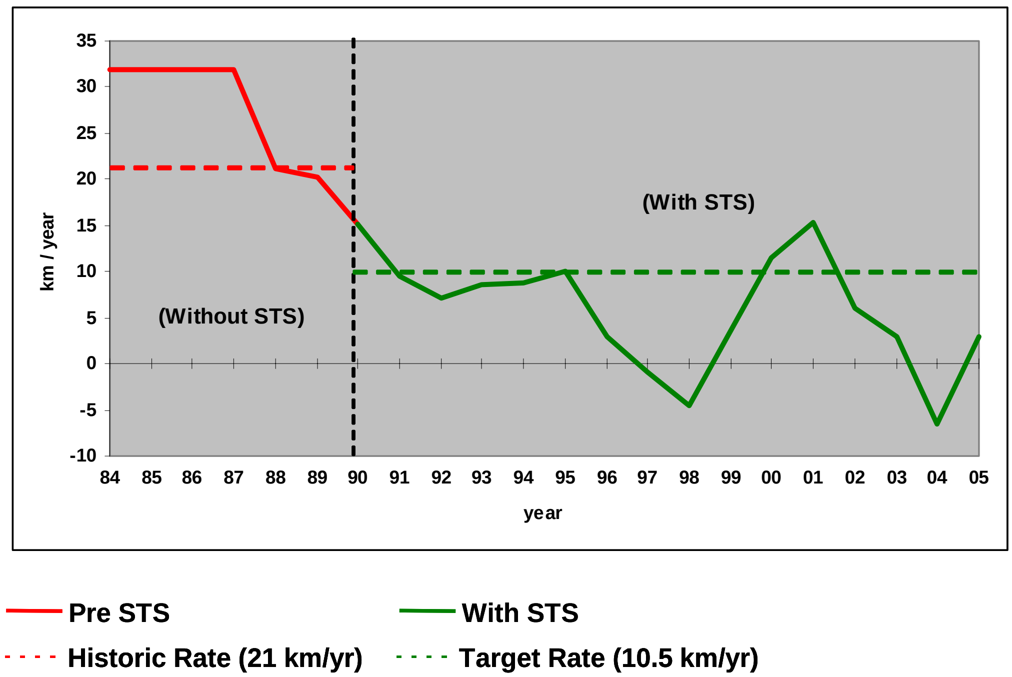

Figure 1 Annual gypsy moth, *Lymantria dispar* (L.), spread rates calculated using a three year moving average.

Summary

The data management, information delivery, and decision support frameworks that have been discussed here represent the evolution of a process that was started over 15 years ago for managing an ever larger gypsy moth program. The mature data life-cycle and decision support framework currently utilized by the STS project represents a model that could be applied to current and future invasive species threats inside and outside of the United States.

BIODIVERSITY AND NATURAL HERITAGE

Ecosystem Complexity in Altered Forests: Influences on Biodiversity, Trophic Interactions and Pest Damage

Moderator: Michael R. Wagner, Regents' Professor, School of Forestry, Northern Arizona University

Overview

Forests around the globe are modified by human activities and natural disturbances. Their alterations usually result in reduced complexity and biodiversity of the forest matrix. Such ecosystem changes can profoundly alter the biodiversity of other species in the forest and change the interactions between trees and insect pests. In this workshop, the participants examined forest alterations including conversion of natural forest to plantation, selective harvesting, stand density modification and experimental variation in overstory biodiversity. How these forest alterations then change the community structure and richness of key insect species such as carabids and ants, trophic interactions and status of insects as pests was presented.

Overstory Diversity and Land Use Practices: Impacts on Biodiversity

Sky S. Stephens and Michael R. Wagner

Humans have undeniable impacts on forest conditions. Natural forest area has been in decline while planted forest area has increased globally. Our understanding of the impacts of land use practices and overstory diversity links to biodiversity is poor. The current literature lacks assessment of a broad range of forest types and biodiversity. And the broadly accepted negative view of planted or managed forests is pervasive. We suggest that better comparisons are needed to assess the impact of overstory diversity and land use on biodiversity.

Trophic Interactions in Altered and Frequently Disturbed Ecosystems: Lessons from Thinned Forests and Short Relation Coppice Plantations

Gaetan Moreau, Dan Quiring and Christer Bjorkman

The simplification of stand conditions caused by plantation, short rotation coppice, selection cutting and thinning could affect the relative strength of both bottom-up and top-down forces acting on herbivore populations, potentially increasing the severity of insect outbreaks. To examine these effects, we studied the trophic webs of *Neodiprion abietis* (Harris), a sawfly defoliator of thinned forests of Atlantic Canada and *Phratora vulgatissima* (L.), a beetle defoliator of short rotation coppice plantations of Sweden. Through the use of cloned saplings and non proximate methods, we were able to generate independent estimates of trophic forces. Results indicated that in both systems, treatments that simplify stand conditions altered the balance between bottom-up and top-down forces. Moreover, nonadditive (compensatory and synergistic) mortality between bottom-up and top-down forces was detected in both studies. This exemplifies that treatments that simplify forest conditions can (1) influence ecosystem function, (2) have a substantial impact on the balance between bottom-up and top-down forces acting on populations from this ecosystem, and (3) reduce the capacity of ecosystems to suppress herbivores. It is stressed that in the occurrence of nonadditive mortality, the approach by proximal methods that is used commonly in life table studies may biased our interpretation of the role of some mortality factors acting on a population.

Effectiveness of Variable Retention for Maintaining Arthropod Diversity in Eastern and Western Boreal Forests in Canada.

Timothy T. Work

The concept of variable retention harvesting as a biodiversity management strategy was tested in Alberta, Canada on the Ecosystem Management Emulating Natural Disturbances research program. Harvesting increased and homogenized rare arthropod fauna across all forest cover types. Harvesting was determined to reduce the impact of inter-stand dispersal compared to within stand factors. Clearly, changing the level of retention harvesting impacts the biodiversity of the insect fauna.

Mixed Native Species Plantation Models to Manage Forest Insect Pests

Paul Bosu and Michael R. Wagner

Substantial literature exists to demonstrate that companion planting of selected species in agroecosystems can alter the susceptibility of individual plants to insects. More recently this companion planting effect has been demonstrated in tropical mixed native tree plantations. Using mixed plantations effectively reduces the negative impact of a gall-forming pysllid, *Phytolyma lata* and a well recognized shoot insect – *Hypsipyla robusta* in tropical Africa. Substantial opportunity exists to develop new silvicultural strategies using companion planting to alter the significance of pests in mixed forests.

Critical Issues in Forest Entomology: Biodiversity and Natural Heritage.

Michael R. Wagner

Three major critical issues emerged from the workshop on biodiversity and natural heritage: endangered species, ecosystem complexity and cultural/non-traditional resources. The risk of species extinctions is a long recognized concern of conservation biologists and the general public. More recently, it has been recognized that there are many endangered insects. Currently about 57 species of insects are on the US Fish and Wildlife Service threatened and endangered list. These insects pollinate plants, regulate populations of pest insects and provide essential food for other endangered animals, i.e. Red-Cockaded and Ivory-Billed Woodpeckers. The critical issue is a need for additional basic research on biology and ecology and the development of management recommendations and species recovery plans for these insects.

A second major critical issue is changing forest ecosystem complexity caused by anthropomorphic factors and how it impacts forest function. It is recognized that loss of individual species or changes in forest structure result in modification of the overall insect biodiversity, trophic interactions among insects and their natural enemies and plant susceptibility to herbivores. There is a critical need to evaluate how changes in forest complexity alter how forest insects impact environmental services and traditional resource outputs of forests.

The third critical issue recognized by the series of workshops in the biodiversity and natural heritage track is impact of forest insects on non-traditional resources. Increasingly it is recognized that non-traditional values of forests such as fungi for human consumption, ecotourism opportunities, medicinal plants and cultural use are held in very high value by society. With the advent of new techniques to value these environmental services and non-traditional resources there is a critical need to evaluate the impact forest insects have on these newly recognized values. Both basic and applied research and development of management approaches is needed to respond to changing forest values.

Endangered species

Moderator: Robert A. HaackUSDA Forest Service, North Central Research Station

General Overview:

There are hundreds of threatened and endangered (T&E) plant and animal species recognized by governments worldwide. For example, there are 745 species of plants and 566 species of animals (including 57 insects) that are on the federal list of threatened and endangered species in the US. Forest insects are tightly linked to many of these T&E species, or are themselves listed as T&E species. For example, some protected plants require specific insect pollinators. Similarly, some protected animals rely on insects as food; biological control efforts may negatively impact protected non-target species; and forest management activities can directly or indirectly impact T&E insect species (Haack 1993, Herms et al. 1997, Paine et al. 2004). This workshop addressed several T&E issues related to possible non-target impacts that result from the release of natural enemies, and the role of insects as food for protected bird species.

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Trouvelot's Legacy? The Disappearance Of Giant Silk Moths (Saturniidae) In Northeastern North America.

Dylan Parry

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The decline in abundance of native giant silk moths (Saturniidae) in northeastern North America is a phenomenon that has been recognized for nearly half a century (Schweitzer

1988). Irrespective of lifecycle, degree of polyphagy, geographic range, and habitat specificity, a number of formerly abundant species as well as others that were historically less common, have become rare. Based on light-trapping records from amateur collectors and professional entomologists, the pattern of decline appears to be real and has become a significant concern to agencies mandated to protect biological diversity.

Several hypotheses have been advanced to explain declines in saturniid populations including anthropogenic habitat loss or modification, extensive broad-spectrum insecticide use for forestry applications in the 1950's, and the non-target effects of biological control operations against gypsy moth and other invasive tussock moths (Lymantriidae). Because similar anthropogenic forces (fragmentation, forest loss, light pollution) occur elsewhere in North America without causing significant declines in saturniids, this hypothesis seems inadequate to explain the disappearance of so many species. In contrast, application of DDT and other pesticides to combat gypsy moth coincides with both the area where declines have been most pronounced and the time period (1950's) where the disappearance of silk moths was most dramatic. Similarly, the initial release and establishment of many gypsy moth parasitoids including some generalist species also coincides with the region of greatest silk moth declines.

Of the exotic parasitoids established in North America for tussock moth biological control, it has long been recognized that the extremely polyphagous Eurasian tachinid fly *Compsilura concinnata* (Meigen) is likely to have the greatest impact on non-target species because of its extensive host range (>175 spp in North America) and multivoltine lifecycle (3-4 generations annually). In fact, by the late 1920's, this tachinid had already become the dominant parasitoid of many forest Lepidoptera in New England, even though it was not released until 1906. In a seminal paper, Boettner et al. (2000) provided quantitative estimates of the impact of *C. concinnata* on saturniids. Using experimental populations in western Massachusetts, they showed that 70 and 80% of the cumulative mortality in Promethea (*Callosamia promethea* Drury) and Cercropia (*Hyalophora cecropia* L.), respectively, was attributable to this fly. The authors suggested that *C. concinnata* maybe the underlying cause of silk moth decline in New England. A subsequent study using Polyphemus (*Antheraea polyphemus* Cramer) indicated similar high rates of parasitism, despite using lower densities, larger spatial scales, and two different regions of Massachusetts (G.H. Boettner and D. Parry, unpublished).

In other regions, research paints a more complicated picture. Parasitism of first generation Luna Moth (*Actias luna* L.) was relatively high in Virginia, while Promethea, Cecropia, and second generation Luna suffered only modest levels of parasitism (Kellogg et al. 2003). Furthermore, Kellogg et al. (2003) found significant levels of hyperparasitism of *C. concinnata* by a trigonalid wasp. Hyperparasitism could be a factor limiting the impact of *C. concinnata* in states south of the regions where silk moth declines are prevalent. However, in central New York state, D. Parry (unpublished) also found relatively low levels of *C. concinnata* in Promethea, a species decimated by *Compsilura* in Boettner et al's (2000) study two hundred miles to the east (Fig. 1). Unlike the Virginia study, no hyper-parasitism was evident in New York. Light trap data suggest that populations of attacine saturniids are reasonably healthy in central and upstate New York.

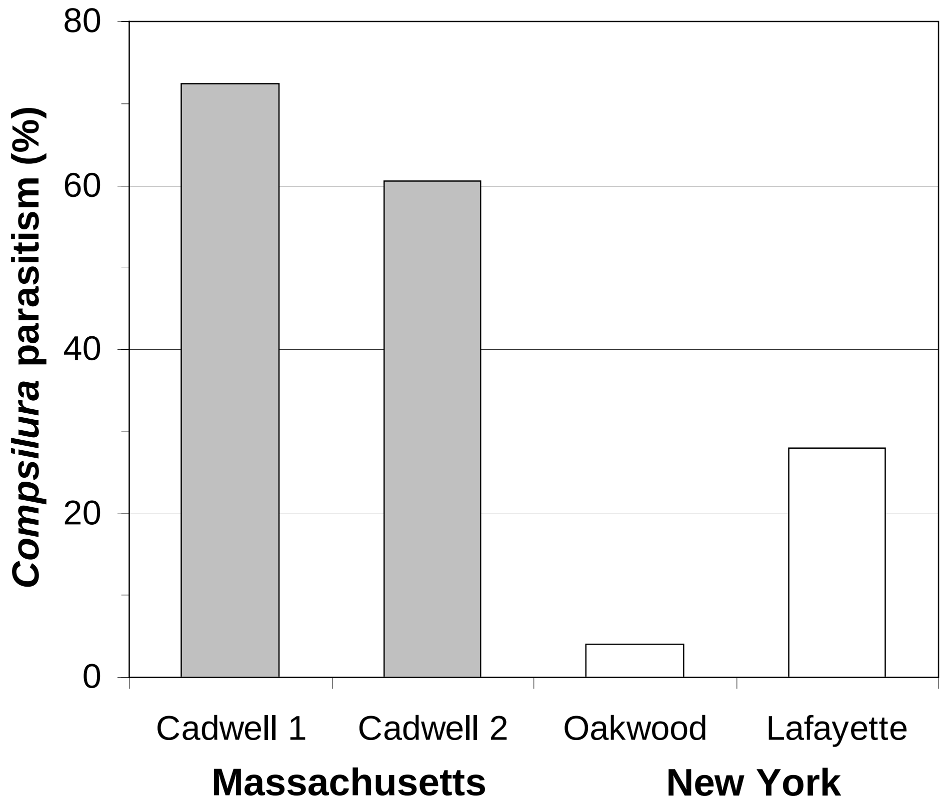

Fig. 1. Parasitism of Promethea moth, *Callosamia promethea* (Saturniidae) by *Compsilura concinnata* in Western Massachusetts (Boettner et al. 2000) and Central New York (Parry, unpublished). Methodology was similar in each study.

Not all silkmoth decline is related to *C. concinnata*. Barrens buck moth (*Hemileuca maia* Drury) is a special concern species in several northeastern states and has disappeared entirely in other states. Studies in both Massachusetts and New York (Parry et al. 2006, D. Parry unpublished) indicate that parasitism by *C. concinnata* is low or absent entirely (Fig. 2), suggesting that loss of critical barrens habitat, especially early successional areas, is a more likely explanation. Loss of habitat may underlie the rarity of Imperial Moth (*Eacles imperialis*, Spiny Oakworm (*Anisota stigma* Fab.), and the extirpation of Pine Devil (*Citheronia sepucralis* Grote and Robinson) from much of New England.

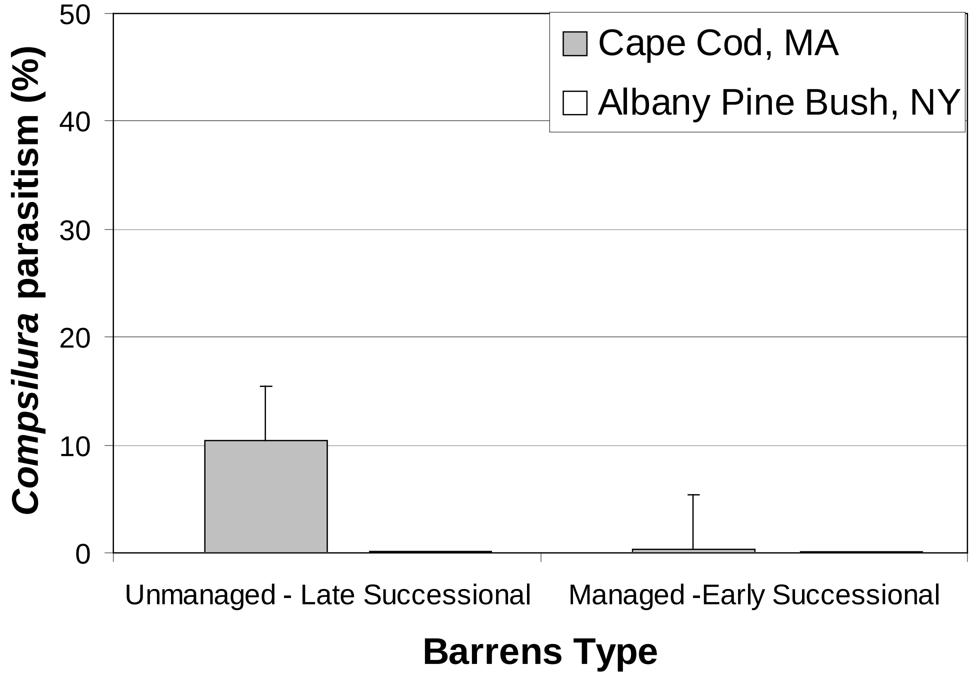

Fig. 2. Parasitism of barrens buck moth, *Hemileuca maia* (Saturniidae) by Compsilura concinnata in managed early successional and late successional unmanaged pine barrens within Cape Cod National Seashore and Albany Pine Bush Preserve. Data from Parry et al. (2006) and Parry (unpublished).

While parasitism by *C. concinnata* provides at least part of the explanation for the rarity of some species in New England, the apparent spatial limits to the area where saturniids are most affected are enigmatic given the distribution of *C. concinnata* through much of the Midwest, Mid-Atlantic, and Northeast as well as parts of the Pacific Northwest. Hyperparasitism may limit the success of *C. concinnata* in some states but this does not appear to be the case in New York. The basic ecology of *C. concinnata* is surprisingly poorly understood. Notably, several critical aspects of its lifecycle including overwintering hosts and overwintering stage (adult, larva, or puparia) remain enigmatic. Potential interactions between *C. concinnata* and pesticide use in the 1950's should not be discounted and may provide an explanation for the geographically limited but regionally significant loss of saturniid diversity.

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Kellogg, S.K.; Fink, L.S.; Brower, L.P. 2003. Parasitism of native luna moths, *Actias luna* (L.) (Lepidoptera: Saturniidae) by the introduced *Compsilura concinnata* (Meigen) (Diptera:

Tachinidae) in central Virginia, and their hyperparasitism by trigonalid wasps (Hymenoptera: Trigonalidae). *Environmental Entomology 32*: 1019-1027.

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The Endangered Red-Cockaded Woodpecker: Diet, Prey Distribution, And Forest Management Impacts On Prey

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Over a 10-year period, we investigated red-cockaded woodpecker (*Picoides borealis*) prey use, sources of prey, prey distribution within trees and stands, and how forest management decisions affect prey abundance in South Carolina, Alabama, Georgia, and Florida. Cameras were operated at 31 nest cavities to record nest visits with prey in four locations that ranged in foraging habitat from pine stands established in old fields to an old-growth stand in south Georgia. Examination of nearly 12,000 photographs recorded over 5 years revealed that, although red-cockaded woodpeckers used over 40 arthropods for food, the majority of the nestling diet is comprised of a relatively small number of common arthropods. Wood cockroaches (Blattaria: Blattellidae) were always the most common prey fed to nestlings, comprising 54.7% of their diet. Other common prey included caterpillars (Lepidoptera larvae), spiders (Araneae), woodborer larvae (Coleoptera: Ceram-bycidae), centipedes (Scolopendro-morpha), and ants (Hymenoptera: Formicidae). Woodpeckers selected prey based on their abundance on tree boles and we saw no evidence that they preferentially selected cockroaches or other types of prey. Analysis of the woodpecker's diet and the community of arthropods on tree boles suggests that the food web supporting red-cockaded woodpeckers is detritus-based. However, the woodpeckers use a variety of arthropods and readily adapt to locally or temporally abundant food sources. Red-cockaded woodpeckers feed primarily on crawling arthropods that move onto the bole from the soil/litter layer. Therefore, most prey are not exclusively bark residents. Prey distri-bution within and between trees was regulated by bark thickness and, more importantly, bark flakiness. More prey were found near the base of the bole and in dead branches in the canopy where thick or loose, flaky bark provided better refuge. Arthropod abundance increased on trees up to 60-70 years of age after which it remained relatively constant on older trees. Prescribed burning had little effect on wood cockroaches but both winter and summer prescribed burns reduced ant and spider biomass. We found no evidence that herbaceous understory cover or diversity increased arthropod abundance on tree boles. Longleaf pine (*Pinus palustris*) trees harbored over twice as much arthropod biomass during the day as similar size loblolly pines (*P. taeda*)

in the same area. The divergence was due to the loose, flaky bark of longleaf pines. Longleaf pines, 25-cm (10 in) diameter at breast height (dbh) or larger, harbored the most arthropod biomass. Our results suggest that management of foraging areas can be fairly flexible without harming the arthropods on which red-cockaded woodpeckers rely.

What Do You Feed An Ivory-Billed Woodpecker?

Nathan M. Schiff and Paul B. Hamel

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If the recent reported sightings of Ivory-Billed Woodpecker (IBWO), *Campephilis principalis*, in sutheastern Arkansas are true (Fitzpatrick et al. 2005), it would be desirable to develop silvicultural practices that enhance conditions for the species. Since, both the literature (Tanner 1942) and the IBWO Recovery Team believe that availability of insect prey is likely the most limiting factor for IBWO, there is interest in increasing the level of wood-boring insects in selected areas.

The most obvious way to increase levels of wood-boring larvae is to wound trees, making them more attractive to ovipositing insects and thus increasing appropriate resources for larval development. A study is proposed that would quantify insect response to a variety of wounding treatments. Combining the results of the study with nutritional values for wood-boring larvae, will allow determination of the woodpecker carrying capacity of an area and hopefully predict its suitability for IBWO.

The study proposes wounding appropriately sized individuals of Sweetgum (*Liquidambar styraciflua*), Nuttall Oak (*Quercus nuttalli*) and Sugarberry (*Celtis laevigata*), the three trees most observed as feeding hosts of IBWO by Tanner (1942), allowing them to be infested for two different time intervals and then harvesting and caging the trees to quantify emergence of insect borers.

The results of the study will enable evaluation of existing forest tracts for IBWO suitability, inform silvicultural decisions to enhance wood-boring larval availability, and contribute to our understanding of the ecology of wood-borers in bottomland hardwoods.

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Cultural/ Non-Traditional Resources

Moderator: Steve Clarke, USDA Forest Service

Forest insect outbreaks and IPM programs have consequences that extend beyond their effects on the target pest. The focus of this session is the impacts of forest insect outbreaks and/or forest health prevention and suppression treatments on cultural traditions and resources or non-traditional forest products. Speakers will address a wide variety of topics illustrating the far-reaching effects of forest pest problems and solutions.

Potential Impacts Of Forest Health On Fungal Diversity In The Smoky Mountains

S. Coleman McCleneghan, SHROOMS, Inc.

The Great Smoky Mountains National Park (GSMNP) located in the southeastern United States is a center of organismal diversity. It is estimated that we know less than ten percent of the species in this 800 square-mile area. Currently an All Taxa Biodiversity Inventory (ATBI) is being conducted. The Agarics ("mushrooms"; Agaricales; Basidiomycota; Kingdom Fungi) portion of this ATBI has collected over 1900 specimens representing 770 species since 1998. Of these 770 species 347 are new species records to the GSMNP and at least 25 are new species to science. Many of the large mycorrhizal fungi previously reported from the GSMNP have not been recollected. Many of these fungi are associated with trees such as beech, hemlock, Frasier fir, and spruce. Many of these trees are threatened by introduced insect and fungal pest/pathogens. Plant stresses may be impacting fruiting of the mycorrhizal fungi previously reported in the GSMNP.

Conservation Of Medicinal Plants: Possible Impact Of Insect Infestations

James Chamberlain, USDA Forest Service

The southern Appalachian hardwood forests of the United States are the source of many medicinal plants, most of which originate from the understory flora. The collection, trade and use of these products have been integral to rural economies since Europeans settled this country. Over the last decade, market demand for medicinal forest products and interest in managing forests for them has increased tremendously. More than 75 species of plants are collected from hardwood forests for their medicinal value. Some of these have been harvested extensively and populations are fragmented, fragile, and endangered. Although, no insect infestations of medicinal plants have been reported, the potential is significant. Interestingly, the ecological distribution for many of these species is similar to the potential distribution for Sudden Oak Death Syndrome. Four potential impacts are identified and discussed. An infestation could directly impact specific species of medicinal plants. An infestation on associated species, either overstory trees or companion herbaceous plants could change habitat dynamics and negatively impact medicinal plants. An infestation could devastate plant pollinators and affect regeneration of medicinal plants. Finally, an infestation could have significant indirect impact on that portion of our society and economy that depend on collection and sale of medicinal plants.

Impact Of Southern Pine Beetle Outbreaks On Wildlife Habitat Suitability

Maria D. Tchakerian, Jaehyung Yu, Robert N. Coulson, Texas A&M University, Forrest L. Oliveria: USDA Forest Service, Forest Health Protection

In this study our goal was to evaluate how changes in forest composition and configuration resulting from Southern Pine Beetle (*Dendroctunus frontalis* Zimmermann) herbivory impact the quality of wildlife habitats in the Bankhead National Forest. We explore the use of a spatially explicit approach (Fig. 1) that integrates forest inventory information (FIADB - Forest Inventory and Analysis Database), growth models (FVS –Forest Vegetation Simulator Southern Variant), SPB infestation data, Geographic Information Systems (GIS), and published wildlife habitat suitability indices (HSI) developed by the U.S. Fish and Wildlife Service. The approach facilitates the description of SPB impacts at the stand level of resolution and at the meso-scale forest landscape. The objectives of the study were as follows: (i) to estimate the changes of forest structure and composition as a result of SPB outbreaks using an adaptation of FIAD, FVS, SPB data, and GIS and (ii) to assess the consequences of these changes for wildlife habitat suitability through accepted habitat models. We used published habitat suitability models for pine warbler (Schroeder 1982a), gray squirrel (Allen 1982), eastern wild turkey (Schroeder 1985b), and northern bobwhite (Schroeder 1985c). These species were selected because models were readily available, and they are considered management indicator species which population changes reflect the effects of management activities. The results from the simulations of SPB scenarios show several differences in terms of general habitat suitability for the wildlife species at the stand and landscape scales. Impact varied in predictable ways by species: pine warbler habitat was destroyed, grey squirrel habitat was not affected, wild turkey habitat was affected both negatively and positively, and northern bobwhite quail habitat was enhanced.

References

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I Got Dem Ol' Beetle Bug Blues Again, Mama, Or How Forest Insects Influence Modern Music

Stephen Clarke, USDA Forest Service, FHP

Insects have played an integral role in modern music, providing names for influential bands and the subject matter for many songs. Forest entomology has not been as well represented overall. The gypsy moth has been a popular title for songs and has been mentioned frequently in lyrics. A large bark beetle outbreak in Norway in 1979 and 1980 provided the inspiration for two songs, while a southern pine beetle outbreak in the mid 80s was the subject of "Louisiana's Got the Beetle Bug Blues". Cicadas, walking sticks, and tent caterpillars have also played a small role in the modern musical landscape. Forest entomology needs a modern anthem to achieve significant musical recognition.

SUMMARY OF CRITICAL ISSUES

North American Forest Insect Work Conference
Critical Issues Formulation

Introduction:

An important part of the '06 NAFIWC was the formulation of **Critical Issues**—priority needs for *research* (acquisition of new knowledge), *development* (integration and interpretation of existing knowledge), *application* (use of knowledge for planning, problem solving, and decision support) and *education* (transfer of knowledge and its implications). In the past, the NAFIWC has served to provide a forum for information exchange for forest entomology. At the '06 NAFIWC we added a formal conclusion to the conference by identifying the critical issues associated with the program agenda. The goal was to conclude the conference with a comprehensive definition of the current and emerging issues facing the forest entomology community. This session provided an opportunity for the ideas generated by each of the individual workshops to be presented and discussed within a broader framework.

Overview:

The program for the '06 NAFIWC was formulated by the constituents of the forest entomology community, so the various workshops and plenary addresses *defacto* provide a coarse overview of the issues of contemporary interest and importance. The program consisted of 28 workshops which were grouped into six tracks: invasive insects (6), management and silviculture (3), scales and interactions (4), change (5), direct tactics in forest insect management (7), and biodiversity and natural heritage (3). Each workshop had a Moderator who was responsible for organization. Typically, several individuals were asked to make a presentation on an important aspect of the subject at hand. We requested each workshop Speaker to identify the critical issues associated with their presentation. The Moderator was responsible for compiling a list of critical issues identified in the workshop. We designated one "Track Coordinator" for each of the six tracks. Their responsibility was to compile, integrate, and synthesize the critical issues identified in the workshops within the track. At the conclusion of the conference, each Track Coordinator presented the results to the meeting at large for discussion and commentary. Ms. Nancy Walters, USDA Forest Service, facilitated this session. The results were presented as the conclusion of the '06 NAFIWC and are published as part of the Proceedings. Following is a brief description of the approach used to identify the critical issues.

<u>Procedure for Identification of the Critical Issues</u>

The flow of information needed to identify and capture the critical issues associated with the '06 NAFIWC Program is illustrated below (Figure 1).

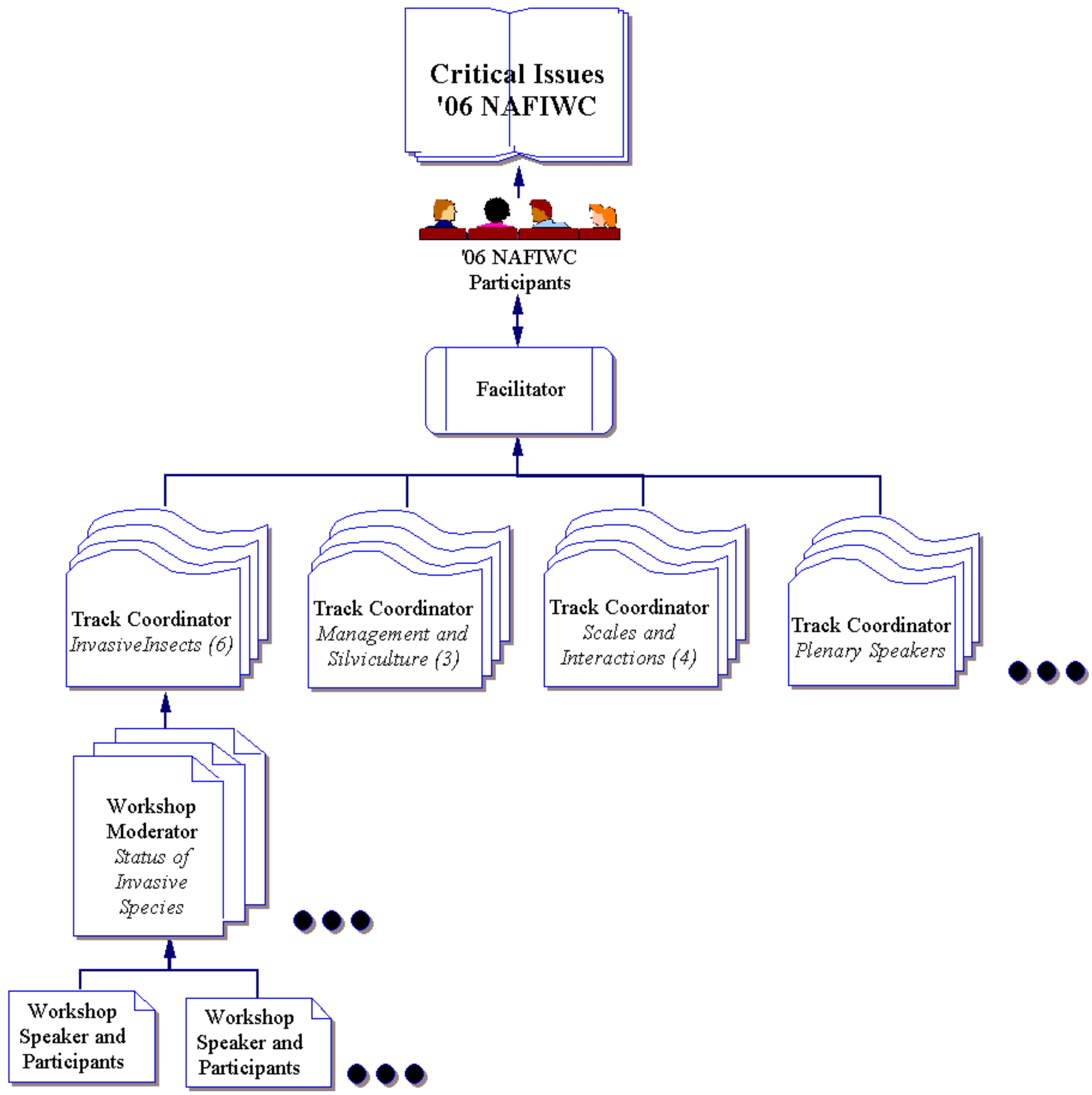

Figure 1: Flow of Information for identification of Critical Issues for the '06 NAFIWC

The procedure for identification of the Critical Issues follows:

<u>Workshops:</u> We asked each speaker in a workshop to prepare a short list of the critical issues associated with their presentation and include this list as a Power Point

slide at the end of their presentation, using the template illustrated in Figure 2. If Power Point was not used, a typed list of the critical issues sufficed. Suggestions from audience participants in the workshop was noted by the Workshop Moderator and added to the list. The Workshop Moderator, with the assistance of the Track Coordinator, compiled the lists of critical issues for the Workshop and developed a summary Power Point Presentation for the overall Workshop.

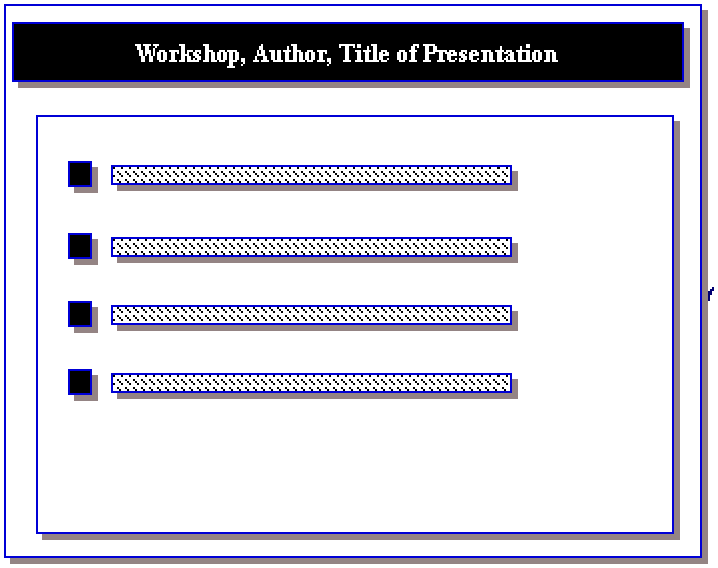

Figure 2: Rendition of the Power Point template for identifying the critical issues associated with individual presentations in a Workshop.

Plenary Addresses: The individuals giving plenary addresses were asked to prepare a list of the critical issues associated with their presentation. They used the same Power Point template. The Plenary Track Coordinator collected, compiled, and summarized the critical issues associated with the addresses.

Workshop Tracks

Each of the six Track Coordinators was responsible for collecting the Summary Power Point Presentations for all workshops in their Track. With the assistance of the Program Staff, a Power Point presentation that summarized the critical issues associated with the Track was prepared.

Critical Issues Discussion

In the Summary Sessions, each Track Coordinator presented an overview of the critical issues associated with their Track. Discussion among the '06 NAFIWC participants regarding the critical issues was facilitated by Ms. Nancy Walters. The discussion led to a prioritization of critical issues for the forest entomology enterprise for the near future. All of the critical issues, as well as any summary statement, are included in the Proceedings for the '06 NAFIWC.

CRITICAL ISSUES

NORTH AMERICAN FOREST INSECT WORKSHOP

A. Invasive Insects (INV) Track Coordinator: Patrick Tobin

Critical Issues: Summarized for each of the Workshops.

1. Invasive insects and forest community structure

Critical Issues:

1. Applying site-specific/local models of changes to broader, more regional/landscape scales.
2. Effects of climate change (temperature, increased CO2 emission) .
3. Incorporate knowledge of forest composition into management objectives.
4. Basic biological knowledge.
5. Improved communication among practitioners in the disciplines involve .
6. Funding for rapid response to teams representing different disciplines, agencies
7. Funding for data (lack of data omnipresent obstacle)
8. Kiss your ash goodbye (the next American chestnut?)

2. *Sirex noctilio* in North America - a new arrival

Critical Issues:

1. Improve survey methods
2. Assess impact / damage in North America
3. Implement quarantine

4. Prepare for long-term management program (monitoring, silviculture & nematode release)

5. Improve interagency / international cooperation – unified program

3. Invasion Pathways

Critical Issues:

1. Solid wood packaging materials.

2. Plants for planting.

3. Increased public awareness of the ecological/economical consequences of international travel, trade, purchasing, etc.

4. Managing exotic Insects

Critical Issues:

1. Bridge the gap between basic research and management so that investments in research pay dividends in the management arena.

2. Foster closely coordinated efforts among forest and agricultural protection agencies and personnel.

3. Use scientific understanding and technology innovation to prioritize protection efforts in an increasingly challenging environment.

4. Support field staff as they gather and store important data; facilitate storage and data access.

5. Identify host resources, early detection of exotics, monitoring of exotics, and targeted management, all from local to landscape scales.

5. International cooperation

Critical Issues:

1. Need for cooperation, collaboration, and information sharing, and to transcend agency and international barriers.

2. Developing the infrastructure to achieve the project goals.

3. Generate a joint, web-based, accessible standardized information system describing biology and ecology of the most potentially invasive forest insect species from one continent to another.

4. Promote development of bar-coding for identification of all life stages, especially larvae, of invasives.

5. Promote studies on the ecological impacts (direct and indirect) of forest insect invaders (and not just from the standpoint of economics).

6. Technology for monitoring and detection

7. Need for taxonomic resources, expertise, and baseline inventories.

6. Quantitative approaches

Critical Issues:

1. Early detection! Generally, there is substantial lag between arrival and detection.

2. Efficient detection method needed (i.e. attractant).

3. Identify characteristics and local conditions that effect establishment and survival.

4. Invasiveness: key to prioritization: some species are poor invaders even though their arrival potential is high.

5. Understanding complexities of forests, from the contiguous to the urban.

6. Behavior of infestations likely to vary greatly depending on details of the life history and behavior of the pest and features of the landscape it interacts with.

B. Management and Silviculture (MGT) Track Coordinator: James Guldin

Critical Issues Summary:

1. Silviculture is more than timber management. It is an art and science used to meet the objectives of ownership whatever they might be (CI#1).
2. In the context of NAFIWC, silviculture has potential to be useful in reducing stand hazard and risk of damage to forest insects (CI#2).
3. Active local markets for timber are critical to broaden the application of silviculture, especially re/ forest health (CI#3).
4. More research is needed to understand the interactions of insects and diseases in relation to forest site, stand and climatic conditions (CI#4).
5. A broader understanding of, and approach to, silviculture is needed in the forest entomology community (CI#5).
6. A better understanding is needed to clarify what silviculture can and cannot deliver in the context of control of forest insects (CI #6).
7. Broader use of demonstration areas and technology transfer would help public acceptance of using silviculture to improve forest health (CI #7).
8. Re/ Applied Silvicultural Assessments under the Healthy Forest Restoration Act of 2003: Need better funding for HFRA (CI #8).

9. Intended advantages of CE provisions under NEPA codified in HFRA have not worked as planned, for reasons related to timeliness, workload, and cost (CI #9).

10. Need more risk-takers in research community and in NFS to take advantage of HFRA (CI #10).

11. ASAs would be improved with better linkage of expertise and resources within different parts of USFS (R&D, S&PF, NFS) as well as between public and private sectors (CI #11).

12. HFRA applies better for insect pests that advance predictably along a wide front (gypsy moth, HWA) than for those that arise in an unpredictable episodic manner (SPB, red oak borer) (CI#12).

13. We need better tools to relate silviculture within stands to forest insects at each of these three scales—stand-level (silviculture) ownership (forest management), and landscape (across ownerships) (CI#13).

14. Opportunities exist to develop and integrate stand-level models with spatially-explicit GIS platforms that can reflect landscape scales. (CI#14).

15. But we are still limited by inabilities to judge among outcomes through common currencies (eg productivity vs biodiversity) (CI#15).

16. Need advancement in ways to integrate science findings from silvicultural studies and adaptive management efforts to better inform policy decisions (CI #16).

7. Different perspectives on silviculture

Critical Issues:

1. Insect infestations are intimately related to forest health.
2. Silviculture can be used to increase the health of our forests.

3. More research is needed to understand the interactions of insects and diseases in relation to forest site, stand and climatic conditions.

4. Need to find NFS personnel who are risk takers.

5. Need to find funding for large scale silvicultural assessments, especially on the NFS side.

6. Need more large scale silvicultural assessments in wider variety of forest types and insect and disease conditions.

7. Applied research and technology transfer regarding forest-damaging insects and diseases is critical for healthy forests.

8. Need better ways to link expertise and resources of both public and private sectors in forest health.

9. Applied silvicultural studies can be useful to broaden our knowledge about forest pests.

10. New research studies will benefit from streamlined approaches to NEPA such as those in HFRA.

11. Clarify the role of CEs under HFRA and broaden the support for agency use of them.

12. Need better funding for HFRA; currently is largely funded from existing programs in FS R&D to fulfill USDA commitment to conduct them.

13. Need to reduce the time lag for implementation of operational practices on NF lands.

14. Address concern by resource managers on NFs about being a “test case” for new NEPA provisions in HFRA.

15. A broader understanding of and approach to silviculture is needed in the forest entomology community.

16. A better understanding is needed to clarify what silviculture can and cannot deliver in the context of control of forest insects.

8. Silviculture and Pest Management

Critical Issues:

1. A need for research on the impact of silvicultural treatments on:

    a. Eruptive populations of herbivores that may be indirectly affected by the treatment; such proactive research may help to reduce potential negative effects of silvicultural treatments.

    b. A longer time scale.

    c. A larger physical scale.

    d. Various ecological conditions

2. The need to use silvicultural innovations

3. Are small scale and short term assessments of silvicultural practices invalid?

4. Different strategies for native vs. non-native pests

5. Thinking ahead. Contemporary "healthy forests" AND future healthy forests.

6. Different guilds require differing approaches

7. Managing declines vs. managing specific insects

8. Need demonstration areas for public acceptance of using silviculture to increase forest health

9. Need more experiments of silviculture and insects, diseases, and plants interactions to determine appropriate treatments, stand density levels, and structures

9. Trade-offs in managing forests

Critical Issues:

1. Common currencies (productivity vs biodiversity).

3. Alternative scenarios needed.

4. Forest management as a part of integrated landscape management.

5. Adaptive management and concept of policy (in what sense can policy be science-based?).

C. Scale and Interactions (SCA) Track Coordinator: Kenneth Raffa

Critical Issues:

1. What information, and what levels of detail, are crucial to a meaningful understanding of the system? .vs. What information can be ignored (and when) in order to make stronger connections across scales, systems, and management strategies?

2. How do these various interactions (insect-microbial, insect-insect, insect-plant) vary with population phase? How do these changes exert feedback in the system's behavior? Do these relationships with population density provide signals that can be exploited for management, such as prediction and mitigation?

3. How do these relationships vary between natural systems, and systems that have been altered by anthropogenic activities: Human transport, global warming, atmospheric change, forest management decisions?

4. How do variation in space and time, management regimes, habitat structure, weather, and genetic variation affect ecological relationships?

5. How can we integrate robust theories of plant-insect and plant-pathogen interactions into dynamic models of tree defense, and implement these for forest protection?

10. Symbiosis

Critical Issues:

1. New knowledge:
    a. Mesonotal mycangium of *X. mutilatus* is a complex structure.
    b. Numerous tracheae and tracheoles
2. Past research:
    a. Adopt a two-tier classification system for mycangia which was proposed by Six (2003)
    b. Glandular or nonglandular mycangia
3. Future research:
    a. Chemical composition of the products and how this relates to fungal growth
    b. Research is underway to identify the fungal species.
4. Education and Public outreach:
    a. Give forest insects approved ESA common names.
5. Mechanisms of colonization by, and maintenance of, fungal symbionts.

6. Molecular basis of adaptation of fungal symbionts to life within mycangium.

7. Benefits of fungal symbionts to beetles.

8. Implications of symbiotic dependencies to beetle control.

9. How do multiple interactions among microbial associates affect their net impacts on beetle fitness?

10. How are these multiple interactions and net impacts influenced by the changing template of host tree condition and chemistry across colonization sequence?

11. How are these multiple interactions influenced by, and how do they influence, the changing template of beetle population density at various levels of scale?

12. Various factors influence the different interactions within the *Sirex-Amylostereum-Deladenus* symbiosis, and thus influence *Sirex* populations and biological control success.

13. These factors may be biological, environmental or management related.

14. A better understanding of these factors is needed to ensure sustainable control of *Sirex* in South Africa …. and elsewhere.

11. The role of habitat mosaics and physical variables in movement of forests-dwelling organisms

Critical Issues:

1. Does mass dispersal of adult male gypsy moth occur?

2. Are dispersal episodes the cause of faster spread rates in the lake states?

3. Why does mass dispersal happen in only certain areas in certain years?

4. Process: pheromones, microclimate, clutter, species composition?

5. Prediction.

6. Tests: natural and manipulated landscapes.

7. Quantify edge behavior by releasing marked beetles bracketing the boundary between habitat and matrix.

8. Look for genetic differences (microsatellite markers) between beetle populations in continuous pine habitat vs. populations separated by various matrix types.

12. Connecting the scales: From molecular through landscape

Critical Issues:

1. Quantification of climate-change effects on forest insect dynamics.

2. Tools/techniques that function across scales to predict impending outbreaks (i.e. more than risk/susceptibility rating systems).

3. Detection and monitoring systems capable of measuring impending outbreaks.

4. Inconsistent commitment to proactive efforts capable of mitigating impacts.

5. Variability:

    a. Some critical to keep (Temperatures, Phenology).

    b. Some can be averaged over at proper scale (Dispersal, host variability).

6. Data:

    a. Landscape scale data problematic (Cover Maps, ADS, satellite).

    b. Reasonable variability can be accommodated.

c. Unreasonable variability can't.

d. Ambient temperatures easy to get.

e. South Side Phloem temps hard to get.

7. Models:

a. Some scaled-up effects easy to include (flight thresholds, winter mortality, succession)

b. Some more problematic (mixed hosts, community)

8. Questions:

a. Some can be answered with confidence (can a population experience outbreak in an area? how rapidly will impacted areas grow?).

b. Some can not (why this tree and not that one? when will MPB reach certain areas?).

13. Insect-plant interactions

Critical Issues:

1. Studies on the direct and indirect roles of microbes in insect-plant interactions must continue.

2. We need to push the boundaries of our understanding of the interrelationships between temporal and spatial scales in insect-plant [-pathogen] interactions.

3. Perhaps plant pathological approaches can be used to address some insect-plant interaction questions.

4. Theory of plant defense should be expanded to more explicitly include microbes interfering with host responses to insects.

5. To understand insect - tree interactions, intra-plant heterogeneity needs to be accounted for.

6. Such knowledge is also important for constructing management plans (i.e., sampling procedures and density-damage relationships).

7. Impacts of induced tree defenses on the population dynamics of bark beetles should be investigated.

8. Characterization of chemical pathways operating in diverse species (and their regulation) will help determine the importance of various compounds alone and in combinations.

9. Identifying the signaling mechanisms involved in establishing patterns of constitutive defenses and in each phase of the induced defense response are critical in improving our knowledge of the mechanisms of tree-insect interactions.

D. Change (CHA) Track Coordinator: Allan Carroll

Critical Issues Track Summary:

1. Major themes: Change

   a. Global warming: largest source of change and uncertainty

   b. Forest management: coping with legacies from the past and uncertainties of the future

   c. Communicating our science: the right message for the right audience

2. Global warming: largest source of change and uncertainty.

a. Climate change is a given, but impacts to forest ecosystems are still largely unpredictable.

b. Despite maturity of our science, more information on the role of climate in insect population processes is required.

c. Effective mitigation of impacts will require proactive management informed by research into impacts of different climate change scenarios on biological pathways – scientists need to get "in front" of the issue.

d. Mitigation efforts must include conservation of genetic resources.

3. Forest management: coping with legacies from the past and uncertainties of the future.

a. Forested lands in western North America are in highly susceptible condition to bark beetles.

b. Risk models need to include the interaction of stand conditions and climate change.

c. Effects of fragmentation on pest management are important, but difficult to sort out correlation and causation.

d. What are the legal requirements for managing "pests" in different land ownerships ?

1. Public vs Private; "Natural" vs WUI settings

e. Regional & international cooperation is required:

1. Research, technology, training, assistance, publications

4. Communicating our science: the right message for the right audience.

a. Exponential increase in information availability

1. Online resources can facilitate information transfer, but how do we deal with the flood?

b. Challenge to the scientist: communicate to decision makers

2. Speak up – inform politicians

3. Avoid the charge of bias by building and communicating consensus

c. Challenge to the teacher: communicate to the student

1. Apply new tools to recruit new entomologists

14. Challenges of using on-line resources to aid in forest entomology education

Critical Issues:

1. Finding Information:

a. Printed or Electronic?

b. If electronic, is it searchable and findable via search engines?

c. Is there a citation?

d. Is it creditable?

e. Is it limited by the hosting agency or organization?

f. What is the geographic scope of information?

2. Finding images:

a. Is it available for educational use?

b. Is it available in high resolution?

c. Is it credited to the photographer and source?

d. Is it properly identified?

3. Increase use of Bugwood and other digital sites

4. Increase use of powerpoints for both presentation and assignments

5. Increase use of GPS and GIS

6. Add material on invasive forest insects

7. Make sure Forest Entomology stays in the core curriculum !!

8. Guiding students to the best information

9. Maintaining a biological background to their studies

10. Providing hands-on experiences

11. A dynamic on-line course requires diverse delivery techniques

12. Asynchronous course delivery offers students great flexibility and greater opportunity to review

13. Emulating some aspects of lecture course are problematic- in particular, hands-on activities

14. On-line delivery restricts the ability of the instructor to learn about students

15. Asynchronous delivery is not for every student… but-Based on our limited experience, student performance in distance delivered courses is comparable to live lecture.

15. Global change and bark beetle outbreaks

Critical Issues:

1. Large changes in climate are likely, but the consequences with regards to the forest are uncertain.

2. Planning for forest resiliency and risk spreading are needed.

3. There will be shifts in insect and host geographic ranges that may be catastrophic.

4. Better science communication with the public is a critical need.

5. Programs to explore potential biological pathways under differing forest management scenarios associated with climate change.

6. Efforts to mitigate climate change should include conservation of genetic resources. Interactions of climate change and biotic agents may cause transitions to be abrupt and precipitous.

16. Effects of temperature and global warming on population ecology of forest insects

Critical Issues:

1. Determine the relative roles of the various climate factors

    a. How important is drought? Winter temperatures?

    b. Are these relative roles the same everywhere?

2. MPB within historical range

    a. Role of anomalously high temperatures in for past large outbreaks

    b. Does a warming climate imply more widespread outbreaks?

3. Further understanding of climate effects

    a. Variability among populations? Response of other bark beetles?

    b. Advance/verify the modeling efforts

4. Develop management strategies for at-risk ecosystems

    a. Prepare for the very likely.

5. Quantify the role of climate warming in spruce beetle outbreaks

6. Application of silvicultural treatments to at-risk areas to maintain spruce types

7. Evidence of climate change impacts on bark beetles should be compiled in a peer-reviewed document and made available to public and government.

8. Insects use a variety of mechanisms to survive overwintering temperatures; the exact mechanism of the adelgid is currently unknown.

9. What aspects of cold temperature are the adelgid most susceptible to?

    a. Variation, no. times below freeze point, timing of molt?

10. Lifetable and climate studies can be used to predict the future range of adelgid, but to date do not include the insect's potential ability to adapt to colder temperatures.

11. Is biocontrol using INA bacteria worth pursuing in this system?

12. Will global warming alter the current distribution of browntail moth?

13. Is there variation in attack rates by *Compsilura concinnata* from one region to another?

14. Is browntail moth a threat to other regions of the country?

17. Status of North American bark beetles

Critical Issues:

1. Setting a Forest Health Protection Program

    a. Pest monitoring and management

    b. Wildfire monitoring and management

    c. Risk mapping

    d. Early warning system

    e. Restoration

2. Regional and international cooperation and funding: research, technology, training, assistance, publications.

3. Impact of environmental and climatic factors

4. Large portions of forested lands in western North America are in a condition susceptible to bark beetles.

5. Bark beetle activity is the result of the interaction of stand conditions and weather events.

6. At least in the short term, managers have the ability to affect and change stand conditions.

7. To what degree will the future repeat the past?

8. Can we define statistical hazard rates of bark beetle outbreaks and beetle / fire interactions for forest planning purposes?

9. Need to incorporate climate change in risk models.

10. How will current outbreaks affect future outbreak potential ? Susceptible age cohorts significantly depleted.

11. Is spatial contiguity of susceptible stands important for bark beetle population growth?

12. Critical issues of outbreak epidemiology in British Columbia

    a. What level(s) of disturbance(s) are tolerable for "natural" areas?

    b. Are there situations where a government can be liable for allowing an outbreak to continue?

    c. Critical knowledge gap: long-distance dispersal

18. Challenging ownerships and fragmentation

Critical Issues:

1. Edge effects are important - Risk factors are nearly everywhere, because of the demonstrated exposure to forest edge nearly everywhere.

2. Connectedness is important –There is a risk factor nearly everywhere, because of the demonstrated connectedness of forest over large regions.

3. Fragmentation can either increase or decrease population stability.

4. Response depends upon many factors related to the specific population system (e.g., behavior of natural enemies, etc)

5. Difficult to sort out correlation and causation

6. Creative strategies for educating the small-tract NIPF landowner about forest health

7. Whenever possible, present forest health issues in contexts with broad appeal.

8. Find ways of making forest management practices on small or WUI tracts more practical and economical.

9. Provide forums that encourage interaction and communication between adjacent landowners and other parties involved.

10. Incentives for keeping land in contiguous forest cover

11. Potential forest resource concerns (e.g., water quality) associated with protection or management of forests considering neighboring land uses, (e.g., poultry operations).

12. Possible, reasonable and legal means of preventing/mitigating future forest protection.

13. Fragmentation is an ongoing concern.

14. Geographic distribution of fragmentation and how it affects pest management, i.e. differences between East and West

15. Investigate and learn how to manage in these landscapes and how to educate landowners regarding these concerns.

E. Direct Tactics in Forest Insect Management (TAC) Track Coordinator: Scott Salom

Critical Issues: Summarized for each of the Workshops.

19. Hurdling over obstacles toward implementation of semiochemical-based forest pest mgt. tools

Critical Issues:

1. Inhibitor Tactic as a successful operational tool requires:

   a. Strong research base

   b. Coordinated and focused effort

   c. Treatments developed that meet research and management needs

   d. Consistent results

2. Marketing issues:

   a. Pursue significant opportunities

   b. Product may be > than it appears

   c Do not depend on others to provide extras

   d. Customers, researchers, and suppliers need to work together

3. Regulatory Issue

   a. Continue to reduce the regulatory burden for arthropod pheromones

20. Tree protection

Critical Issues:

1. Protecting high-value trees in the West
    a. Prevention is always less costly.
    b. Preventive treatments with carbaryl are effective, economical, and longer lasting than other conventional spray options.
    c. New AIs need to be identified to make up for product registrations that are pulled.
    d. MCH works for DFB, yet verbenone remains inconsistent against MPB.
2. Systemic insecticide injections goals
    a. Achieve 3+ years protection of high-value trees in residential, recreational, or administrative sites. Minimize impact on safety and environment.
3. Methods for managing exotic woodborers
    a. ALB:
        1. More cost-effective methods for survey and control are needed.
    b.EAB:
        1. Improved methods for all aspects of management.
        2. Stop long-range movement.
        3. Find EAB-resistant ash.

4. Infestation is beyond the point where eradication is a reasonable goal.

5. N.A. ash species heavily attacked in Asia (biocontrol may have limited potential).

21. Stand level tactics to address forest pest problems

Critical Issues:

1. Modeling Ash borer/ Management Implications

   a. Information on EAB biology lacking

   b. Determine where EAB is in relation to its host.

   c. Review online model for refine and monitor stands where model is used.

2. Mechanical Fuel Reduction impacts on bark beetle activity

   a. Chipping increases beetle activity

3. Bark beetle Protection Projects in Idaho and southern US

   a. Education to landowners and contractors is critical for implementing programs.

   b. Inter-agency collaboration/team work needed.

   c. More effective if focus could be on landscape level forests

22. Perspectives on treatment tactic development and application

Critical Issues:

1. Discovery, development, and registration of pesticides

   a. Driven by markets of major Ag pests

   b. Labeling can then be expanded for forest pests

c. Criteria for acceptable pesticides will continue to become more stringent.

2. Ecological modeling for risk assessment

a. Decision-support tools will be used to predict outcomes, not necessarily insight.

b. Models are able to show effects clearly.

3. Termiticides in urban environment

a. New generation of non-repellents are providing more robust control than their current counterparts.

b. Borates and physical barriers are defining additional paradigms for termite prevention.

4. An alternative to use of transgenics for genetic improvement of pines

a. Biocontainment/gene leakage is a big concern for transgenics.

b. Better opportunities by committing to breeding and silviculture

23. Shaping future forest: Using classical biological control to reduce harm from invasive forest insects

Critical Issues:

1. Winter moth

a. A serious problem in MA

b. Issues related to almost identical Bruce spanworm, where both moth's distribution overlap - ID, hybridization, efficacy of BC

c. Much BC work needed *Cyzenis* parasitoid that was successful in Nova Scotia and British Columbia

2. Eucalyptus Borer

    a. Maintaining adequate moisture to trees reduces susceptibility to borers and red gum lerp psyllid

    b. Systemic insecticides can reduce susceptibility to borers, yet when concentrating in extra floral nectaries can negatively impact BC agents.

3. HWA

    a. Document in detail all aspects of biological control efforts

    b. Shipping of BC agents is far too complicated

        1. Agencies don't talk with each other

        2. Rules constantly change

        3. Countries we ship from all have different rules

4. EAB and ALB

    a. Limited track record for BC of woodborers

    b. Same issues as above regarding permits for and shipping BC agents

5. *Sirex* wood wasp

    a. Develop ID methods for wasps, nematodes, and fungi

    b. Improve trapping methods and trap tree tactic for IPM

24. Challenges to biological control

Critical Issues:

1. Knowledge of systems is critical.
2. Prioritize between "need to know" and "nice to know" studies.
3. Critically analyze and document every step of the biological control process.

4. Create and support an interagency task force to help coordinate and expedite the shipment of biological control agents from their points of origin.

25. Decision support tools

Critical Issues:

1. Remote sensing to survey pests in Mexico
   a. Provides important information on pest presence and background for later use
   b. Less effective on smaller target areas/yet economic limitations at larger scale
   c. More prospective applications are required to refine spectral signatures by causal agents in different conditions.
2. Ortho-rectified imagery for rapid assessment for forest damage
   a. Continue development of automated image analysis to reduce labor intensive activities
   b. Refine sampling strategies to optimize mortality and damage assessment surveys
   c. Improve timeliness for rapid assessments
3. Statistical Tools - Landscapes and insects
   a. Detection of ecologically-relevant spatial scales for studies is critical for interpreting data correctly. ….Do it if you can.
   b. Statistical non-independence of overlapping buffers or landscapes needs to be and can be addressed.
4. Decision support for large-scale IPM - Gypsy moth slow the spread

a. Standardizing procedures for decision-support as early as possible is important for invasive species.

b. Data life-cycle management should support the daily needs of a program.

F. Biodiversity and Natural Heritage (BIO) Track Coordinator: Mike Wagner

Critical Issues:

1. Need for additional basic research, development of management recommendations, and recovery plans for insect species at risk of extinction and insects that are a critical food source for other at risk plants and animals.

2. Need to evaluate how changes in forest complexity alter how forest insects impact environmental services and traditional forest resource outputs.

3. Need for basic and applied research on impacts of forest insects on non-traditional forest products such as edible plants, ecotourism, medicinal plants etc.

26. Natural forests/indigenous trees

Critical Issues:

1. Biodiversity:

a. Endangered species.

b. Ecosystem complexity in altered forest.

c. Cultural / non-traditional resources.

d. Biodiversity and forest type interactions are poorly understood

e. Forestry management and manipulation effects on biodiversity

f. Determining the effect of overstory species diversity on ecosystem function

2. US Fish and Wildlife Service Division of Endangered Species.

a. Endangered Insects - 38 species total

1. Lepidoptera, 23

2. Beetles, 12

3. Dragonfly, 1

4. Grasshopper, 1

3. Ecosystem complexity in altered ecosystems: influence on biodiversity, trophic interactions and pest damage.

a. How much can ecosystems be altered and still fulfill ecosystem functions?

b. Overstory diversity/understory diversity

c. Trophic interactions

d. Pest management effects of native/exotic trees.

e. Structuring overstory biodiversity for pest management

4. Cultural / Non-traditional Resources:

a. Forest pests impacts on fleshy fungi

b. Ecotourism and forest effects

c. Medicinal plants and insects

27. Endangered species

Critical Issues:

1. Endangered insects

2. Insects pollinate endangered plants

3. Non-target effects of biological control

4. Disappearance of giant silk moths

5. Red-cockaded / Ivory-billed Woodpeckers

28. Cultural/non-traditional resources

Critical Issues:

1. Direct impact could affect specific species.

2. Indirect impact by changing habitat dynamics.

3. Possible loss of pollinators.

4. Social and economic impact on already marginal rural economies.

5. NEEDED --> Infrastructure to allow for rapid response to possible infestations to mitigate possible impacts.

6. Loss of plant diversity means loss of and/or changes in fungal diversity.

7. Mycorrhizal fungal diversity reduced as specific plant species are stressed or eliminated.

8. Detailed pre and post spb outbreaks forest inventory data

9. Validation of results of habitat models vs. current data on wildlife species

10. Development of alternative methods to evaluate positive and negative impact of insect outbreaks on forests.

11. Forest entomology, particularly in North America, lacks a true modern anthem.

Western Forest Insect Work Conference Founders Award

Table of Contents

Forest Health Protection Under a Wandering Star

William M. Ciesla[1] Forest Health Management International

Introduction

First, I want to take this opportunity to thank everyone who was involved in my selection for the Western Forest Insect Work Conference 2005 Founders Award. I know Carroll Williams is the one that nominated me for this recognition. I also know that a number of other people were involved but, unfortunately, I don't know who they are. As I said last year in Victoria, BC, this award, along with the Southern Forest Insect Work Conference's A.D. Hopkins award, are the Oscars of Forest Entomology. For me, this is truly one of the high points of my life.

I call this presentation, "Forest Health Protection Under a Wandering Star." For someone who has moved around as much as I have during my Forest Service carrier: Asheville, NC, Pineville, LA, Missoula, MT, Davis, CA, Fort Collins, CO and Portland, OR, plus a few years with FAO in Rome, Italy, it's an appropriate title. In addition, as most of you know, my work wasn't limited to forest entomology. It also involved some forest pathology, a lot of remote sensing and many years of program management.

I also want to say that having the opportunity to give this address in Asheville, NC is special for me. This is where I began my work: first as a seasonal with the Division of Forest Insect Research of the Southeastern Forest Experiment during the summer of 1959 and later as one of the first members of the Asheville FPM Field Office of Region 8.

Special People

Before highlighting some of my own career, I want to take this opportunity to recognize some people that had a significant influence on how my professional life developed. Without their influence and guidance, it may have taken a very different direction.

Aubrey H. MacAndrews

A. H. MacAndrews was the chairman of the Department of Forest Entomology during my undergraduate years at the State University of New York at Syracuse University. Prof. Mac, as he was known around the college, was undoubtedly the best teacher I have encountered. For me, he was a bright star in a faculty filled with gifted teachers. Prof. Mac did two things for me. First, he made it clear in his required Entomology 2 class that there was a great deal about the insects that are damaging our forests that we do not know. He also brought the real

[1] Recipient of the 2005 Founders Award, Western Forest Insect Work Conference

world into the classroom. He often spent entire lectures describing consultations he had done for the City of Syracuse, the activities of unscrupulous tree surgeons or crazy things that happened on spruce budworm spray projects while he was working in Canada.

Prof. Mac's class tweaked my interest to the point that during the summer between my junior and senior years, I sought and found a summer job with the Southeastern Forest Experiment Station's Division of Forest Insect Research here in Asheville. I got involved in aerial surveys, development of methods to predict defoliator outbreaks and had the opportunity to work with a young entomologist by the name of Gene Amman, who is also a recipient of this coveted award. I spent a lot of that summer helping Gene rear and release predators of the balsam woolly adelgid on Mt. Mitchell.

By the end of that summer, I was hooked. I knew what I wanted to do for the rest of my working life. When I went back to Syracuse that Fall, I had some real direction. I loaded up on elective courses in entomology and, despite the heavy course load, my grades improved significantly.

Russ Smith

After receiving my undergraduate degree, I returned to Asheville and the Southeastern Station. A few months later, the applied functions of the Divisions of Forest Insect and Disease Research: surveys, evaluations and technical assistance to suppression projects were transferred to the Regions. In response, R-8 chartered a series of zone or field offices staffed with specialists to do this work. I made the switch and became one of the charter members of the Asheville "zone" office.

At the time, the director of Forest Pest Control in R-8 was Russell K. Smith. Russ was one of the most unforgettable individuals I ever met. He grew up on a homestead in eastern Colorado and would tell fascinating stories about life on the prairie. During WW II he joined the OSS and was a spy. One of the few things Russ told me about his OSS experience was that as part of his training, he had to be able to drink a bottle of whiskey within a certain period and still carry on a coherent conversation. For some unknown reason, Russ felt it necessary to maintain this level of training long after he left the OSS.

When I joined the R-8 Forest Pest Control team in September 1960, Russ took a liking to me. He liked the way I wrote technical reports and two years into this assignment, he made it possible for me to go to graduate school under the Government Employees Training Act. Several years later, at the age of 26, Russ saw fit to select me to be the "Zone Leader" of the Asheville Zone Office. Admittedly, I was a too young for the job but with Russ's support and guidance, it worked and I had my first practical experience as a program manager.

Bob Heller

I first met Bob Heller during the summer of 1959. Bob worked with the Forest Service out of Beltsville, MD and headed up an "Aerial Survey Research Project." Bob and his team would fly to Asheville in their Cessna 190 to take color aerial photos of the balsam woolly adelgid mortality on Mt. Mitchell. Bob's work tweaked my interest and caused me to take an elective course in aerial photogrammetry during my senior year. It was Bob's influence that years later led me to explore aerial photos and other remote sensing approaches on my own for assessment of forest damage and Bob was always a great supporter of the work I did.

Phil Weber

Phil is a contemporary. I first met Phil when he was on Bob Heller's project in Beltsville, MD. Later, when I was Director of the Forest Pest Management Methods Application Group, Phil directed a parallel nationwide remote sensing project. During those years, we had a great deal of contact with one another and took on a number of cooperative efforts. Whenever we worked together, a wonderful synergy developed and together we accomplished some good things.

Patrick Tesha

Patrick is a native of the East African country of Tanzania. I met Patrick when I worked with FAO in Rome and he was in charge of the Africa Desk of the FAO Forestry Field Programme. I had a lot of occasion to work with Patrick and it was under his guidance that I learned the basics of the FAO Field Programme, which was critical to my work in FAO between 1990-1995 when I served as the Organization's Forest Protection Officer.

Sadly, all but the last two of these outstanding people, are gone. They were gone before I fully understood the positive impact they had on my life. I mention this because every one of you in this room can assemble a list of people that had a similar influence on your lives. And, very likely, by the time you get around to doing this, some of them too will be gone. The only way you can really thank them is to have a similar effect on the life and career of a friend or colleague. From that point of view, the one thing that would mean more to me even than receiving this award, would be for one or two of you to see fit to include my name on your own list of special people.

Carrier Recollections

Asheville, NC – 1959-67

I spent a significant amount of my early years in Asheville working with the elm spanworm, *Ennomos subsignarius*, a hardwood defoliator that had reached epidemic levels over portions of north Georgia, southeastern Tennessee and western North Carolina. During the early to mid 1960s, the outbreak encompassed in excess of 1 million acres of mixed broadleaf forests. In 1961, I recovered an egg parasitoid, subsequently identified as *Telenomus alsophilae*, from the egg masses of this defoliator. Two years later, the eggs didn't hatch according to schedule and immediately after returning to Asheville from graduate school, I detected high levels of egg parasitism. A subsequent evaluation indicated that nearly 60% of the eggs had been parasitized. The high level of parasitism was accompanied by a significant decline in outbreak area (Ciesla 1964). A year later, I was able to determine that parasitization occurred about three weeks prior to egg hatch (Ciesla 1965).

During the mid 1960s, I was involved in assessments of seed losses caused by seed and cone insects in southern yellow pine seed production areas and successfully tested a hydraulic lift vehicle to reach into the crowns of tall pines. Several years later R-8 purchased several of these units for tree improvement work.

Another major insect pest with which I continued to be involved was the balsam woolly adelgid, *Adelges piceae*. Through a combination of aerial and ground surveys, we detected localized infestations in each of the areas of spruce-fir forest in the high elevations of the Southern Appalachian Mountains. For several years, we made annual treks into the more remote areas of the Great Smoky Mountain National Parks on horseback to ground check areas of fir mortality. These were real wilderness adventures that involved incidents with half tame black bears coming into our campsites to steal horse feed, horses returning to their stables at night, leaving us stranded, and finding caches of white lightning hidden along the Appalachian Trail.

Of course the major insect pest I dealt with, both in Asheville and later in Pineville, was the southern pine beetle, *Dendroctonus frontalis*. In 1965, I had the opportunity to explore the use of both color and color-IR aerial photos as a tool for assessment and inventory of beetle caused mortality using a multi-stage sampling technique (Ciesla et al. 1967). When I presented the results of this work to Russ Smith, R-8 Director of Forest Pest Control, he was enthusiastic about making the technique operational and we developed project air photo capabilities in both the Asheville and Pineville Field Offices.

Pineville, LA – 1967-70

I transferred to Pineville, LA to manage the Pineville FPC Field Office in 1967. Two years into my Pineville assignment, in August 1969, two things happened simultaneously. My second daughter, Cathy was born and Hurricane Camille struck the coast of Mississippi. Hurricane Camille was a Category 5 storm that caused major damage to property and infrastructure on the Mississippi coast and caused blowdown over a large area of the State. The Mississippi Forestry Commission requested a survey to map blowdown and identify priority areas for salvage. For several days I commuted between the hospital and the office, attempting to coordinate the survey. The survey was successfully completed and the Forest Service aerial survey team mapped over 1.8 million acres of blowdown (Terry et al. 1969). The Mississippi Forestry Commission was so anxious to receive the survey maps that I had to charter a small airplane to deliver the maps from Alexandria/Pineville to the Commission's Headquarters in Jackson.

The forest tent caterpillar, *Malacosoma disstria*, is a recurring defoliator of low-lying water tupelo forests of Alabama's Mobile River Basin and the Achafalaya River Basin of southern Louisiana. In 1969, scientists at the Southern Forest Experiment Station conducted field tests of several chemical and biological insecticides for control of this defoliator in the Mobile

River Basin. Since the areas were inundated with 6-10 feet of spring runoff at the time of spraying, classic pre and post spray larval sampling to determine efficacy of the various materials was virtually impossible. The Pineville F.O. flew aerial photos over the spray plots and successfully evaluated the degree of foliage protection achieved by the various treatments (Ciesla et al. 1971a).

Missoula, MT – 1970-75

During the latter part of 1970, I was selected to fill a vacancy for an entomologist in R-1, Missoula, MT. The move to Missoula fulfilled a childhood dream, the opportunity to live and work in the West. I served as Entomology Section Head for the R-1 Forest Insect and Disease Branch from 1970-72 and as the Region's Director of Forest Insect and Disease Management from 1972-1975.

In the summer of 1971, I was involved in what was to become the last of a series of pilot control projects of the insecticide Zectran for control of western spruce budworm, *Choristoneura occidentalis* (Dewey et al. 1972). We established the test on the Nezperce National Forest, set up a field laboratory in Grangeville, ID, and hired a number of local residents to work both in the field and laboratory. Of the 30 locals we hired for the field crews, 26 were female. In 1971, forestry and forest entomology were still very male dominated professions and I had some concerns about whether or not female field crews could do the job that was needed. I soon learned that they were quite capable of handling the job and moreover, that these ladies enjoyed being out in the hills as much as I did. The only real problem we had was that since they were clipping branches out of trees with pole pruners, I insisted they wear hardhats. At the time, heavily teased hairstyles, such as the beehive, were in fashion, something not conducive to the wearing of hard hats. There were many times during that project when I saw ladies from the field crews running back to their pickups for their hard hats as I turned a corner on a back road.

Later that summer, a major outbreak of Douglas-fir beetle, *Dendroctonus pseudotsugae*, erupted in the North Fork Clearwater river basin in northern ID. In order to assess the magnitude of the outbreak, I designed and conducted a multistage inventory using aerial photos and ground surveys, based on the work I had done with southern pine beetle in R-8 (Ciesla et al. 1971b). The resultant survey produced the needed data and was repeated for several years (McGregor et al. 1972, 1974). In addition, since the outbreak involved largely state and private lands, I used it as an example of why the Idaho Department of Lands should become involved in the Cooperative Forest Pest Action Program and add a forest pest management specialist to their staff. As a result, the Idaho Department of Lands joined the program and hired Ladd Livingston. Ladd did an outstanding job of providing leadership to Idaho's forest health program for many years and just recently retired.

The years 1973 and 74 were the years of the Douglas-fir tussock moth, *Orgyia pseudotsugata*, both in R-1 and R-6. In 1973, work in R-6 established that the insecticide Zectran was ineffective against this insect. This caused the Forest Service to petition EPA for the use of DDT, which was banned in 1972, against this outbreak. Having to use DDT against this massive outbreak was not my proudest moment as a forest entomologist. However, we applied the material with as much precision as possible and conducted a parallel effort of testing other chemical and biological insecticides that met with some success (Ciesla 1975, Ciesla et al. 1976).

MAG (Davis CA – 1975-81, Fort Collins, CO 1981-88)

In 1975, Russ Smith, who had now become Director of Forest Pest Management with USDA Forest Service in Washington DC, chartered the Forest Pest Management/ Methods Application Group (MAG) and selected me to direct this new initiative[2]. This group, whose function was to evaluate and implement new technologies, especially for assessment of pest impacts was originally established in Davis, CA and later relocated to Fort Collins, CO.
During the first years of MAG's existence, we also had a role in aerial application of pesticides and Jack Barry, formerly of the U.S. Army Dugway Proving Grounds, joined the staff. One of the first projects we took on was to characterize a DC-7 spray aircraft based in Burbank, CA for possible use on a spruce budworm project in Maine. We established a characterization grid in a large salt flat in southern CA. While en route to the grid, loaded with a tank mix dyed with a vivid red dye, the engineer running the spray system decided to test it over the community of Valencia, CA. The system worked well. Several local residents witnessed a large aircraft releasing a deep red spay cloud over a rather upscale residential area. Within minutes, the homes turned pink, as did a number of swimming pools, cats and white poodles. One of the witnesses managed to get the tail number of the aircraft and called the FAA. Later that evening, the owners of this aircraft had to do quite a bit of explaining to the authorities while Jack and I maintained a very low profile.

One of the technologies we began to evaluate early on at MAG was geographic information systems (GIS). The ability to integrate spatial information on insect and disease damage with land ownership, vegetation types and other thematic map layers and generate data tables using a computer was, to us in MAG, a fascinating concept. Soon terms such as "polygons, arcs, points, digitizing" and "overlay processing" became an integral part of our vocabulary. Unfortunately, there were people in the Forest Service that didn't share our enthusiasm and had some real concerns about committing to this technology. For a time, a moratorium was placed on GIS development and implementation in the Forest Service until some basic issues could be addressed. However, after we moved to Fort Collins, we developed a partnership with the Western Energy Land Use Team (WELUT) of the U.S. Fish and Wildlife Service, which had an office in the same complex we were housed. This group had developed one of the first working and user friendly GIS, a system known as the Map Overlay Statistical System (MOSS). Together we conducted a number of tests and demonstrations with this system (Pence et al. 1983), organized GIS training sessions and eventually made a copy of the MOSS software available to R-6.

Another of the activities we took on at MAG was the production of traps for the Douglas-fir tussock moth Early Warning System. This system was based on use of pheromone-baited traps developed by Gary Daterman, the 2004 recipient of the WFIWC Founders Award. Through the efforts of Eleanor Franz, MAG Administrative Technician, we established

[2] Known today as the Forest Health Technology Enterprise Team (FHTET)

partnerships with facilities that provided work opportunities for the mentally and physically challenged both in Davis and Fort Collins to coat the milk carton traps with Tanglefoot and package traps and pheromone baits for delivery to the field.

Perhaps the most exciting technology we worked with during my years at MAG was the use of high altitude panoramic aerial photography for mapping and assessment of forest damage. This technology was made available by NASA during the mid 1970s and was introduced to the Forest Service by Phil Weber, who had just taken on the leadership of the Nationwide Forestry Applications Program (known today as the Remote Sensing Applications Center). The ER-2 aircraft, a civilian version of the U-2, and the large area covered by a single frame of photography, allowed us to cover large areas in a short time and acquire complete air photo coverage of outbreak areas (Ciesla et al. 1982).

Our first work with this technology was to evaluate its use for inventory of tree mortality caused by mountain pine beetle, *Dendroctonus ponderosae*. In order to determine if we could resolve mountain pine beetle faders on the 1:30,000 scale aerial photos, Phil Weber ordered a test flight over a portion of the Ochoco National Forest in Oregon during October 1976 using color-IR film. When Phil received the photos, he was ecstatic. “You can hold the photos at arms length and see the faders,” he told me excitedly over the phone. A week later, I had a chance to view the photos and sure enough, you could hold the photos out at arm’s length and see discolored tree crowns.

“Phil, how much larch is on the Ochoco National Forest?” I asked. For a moment there was silence in the room. The photo mission had captured the larch at its peak of fall coloring. For several years, this photo mission was known among the forestry remote sensing community as “Weber’s folly.” However, subsequent tests established that we could resolve mountain pine beetle faders and we successfully used the ER-2/panoramic photo system as part of a multistage sampling system to inventory mountain pine beetle losses in portions of Colorado, Idaho and Montana (Dillman and White 1982, Klein 1982, Klein et al. 1980). Moreover, several years later, we received a request from the Maine Forest Service to help them map the location of larch forests on the coast of Maine to reassess the distribution of larch canker disease. Based on the Ochoco experience, we flew aerial photography at the peak period of fall coloring of larch and obtained a virtually perfect distribution map of larch along portions of the Maine coast.

The big payoff with the ER2/panoramic aerial camera system was with the gypsy moth, *Lymantria dispar*, in the eastern U.S. During the early to mid 1980s, massive defoliation by this introduced defoliator of broadleaf forests was occurring over portions of the Mid-Atlantic States. In 1981, Phil Weber and I requested a flight over a test site in Mifflin CO, PA. The site was photographed with color-IR film and the resulting product was of outstanding quality. I developed a photo interpretation technique, known as “office sketchmapping” that involved monoscopic examination of each photo and transfer of polygons of defoliation onto 1:24,000 scale USGS topographic maps (Ciesla and Acciavatti 1982). In 1983, in cooperation with the Morgantown, WV Field Office of NA, we organized a pilot test of this technique and acquired photo coverage of portions of the eastern 2/3 of PA, all of NJ, DE and MD, portions of southern NY, eastern WV and northern VA. Denny Ward (R-8) trained teams of photo interpreters in each of the states. When the photography was acquired and processed, Denny and I annotated and divided the film among the participating states for interpretation and map transfer (Ciesla 1984, Ciesla et al. 1984). The project was a great success and was continued for several years under the overall leadership of Bob Acciavatti, entomologist with the Morgantown FO (Acciavatti 1990). During one of those years, I was in Harrisburg, PA working with the photo interpretation team from the PA Division of Forestry. I happened to notice that one of the photo interpreters was examining portions of a large lake with a hand lens. When I looked a little closer, I noticed that the lake was filled with boats and water skiers. When I asked him what was so interesting about the lake, he replied, "I'm trying to determine the sex of the water skiers." The resolution of the photos was so clear that it could easily be done.

Chile – FAO Consultation, 1987

During October-November 1987, I had my first opportunity to do a project for the Food and Agriculture Organization of the United Nations (FAO). During the previous year, three species of bark beetles, *Hylastes ater, Hylurgus ligniperda* and *Orthotomicus erosus*, all native to Europe, had appeared in Chile's extensive plantations of Monterrey pine, *Pinus radiata*. Two of these beetles, *H. ater* and *H. ligniperda* were killing young pine seedlings during maturation feeding. By the time the insects were detected, they had spread throughout the country's area of *P. radiata* plantations. However, I was able to recommend silvicultural techniques, such as proper treatment of insect breeding sites and avoiding the "J" rooting of seedlings during planting, to mitigate the damage (Ciesla 1988 a, b).

The opportunity to work in Chile was a life changing experience for both Pat and I. We loved the country and the people. And, despite the fact that we spent long hours in the field each day and had to communicate almost exclusively in Spanish, we both had a great time and agreed that we wanted to become more involved in international forest health protection.

Portland, OR – 1988-90

Within days after our return from Chile, I learned that I had been selected to fill the vacancy of Director of Pest Management in R-6, a position that had been vacant for nearly two years.
A major outbreak of western spruce budworm was underway in the Region, with several million acres of forests suffering defoliation. Plans were already underway for a large suppression project and I arrived just in time for Regional Forester Jim Torrence to announce that, based on the Environmental Analysis that had been completed, he would authorize treatment of up to 1 million areas providing they met the pre-spray insect population densities that had been established.

That project took up virtually all of my time for my first six months in R-6. We successfully treated 600,000 acres, all with undiluted formulations of *Bacillus thuringiensis*. For the first time, we adapted the Incident Command System (ICS), an organizational structure for managing large wildfire suppression projects, to insect suppression. We established five Incident Command units and an Area Command in Portland. The project involved deployment of over 70 helicopters, a fleet of turbine powered fixed-wing aircraft and over 700 people. I believe it still stands as the largest single western spruce budworm suppression project that involved exclusive use of a biological insecticide. The project was a great success and all of the units treated met the post treatment criteria of < 1 budworm larva/15 inch branch. We conducted smaller western spruce budworm suppression projects in 1989 and 1990.

Another initiative in which I was involved was the decentralization of the Forest Pest Management function. Up to that time, all of the Forest Pest Management specialists had been located in the Regional Office in Portland. We established a zone office attached to the Wallowa-Whitman NF in LaGrande, OR and another attached to the Deschutes NF in Bend OR. Several years later, we chartered a third zone office on the Wenatchee NF in Wenatchee, WA to serve all of Washington east of the Cascades. This initiative was a success because it put specialists closer to the field and reduced the number of days they had to spend away from home. Today, five Forest Health Service Centers or Zone Offices are operating in the Region.

By the time I arrived in R-6, some the FPM staff was already involved in the use of the MOSS GIS, which my former unit, MAG, had made available several years earlier. With a little encouragement, in 1989, Tommy Gregg, Cathy Sheehan, Tim McConnell and several others on the FPM staff produced the first R-6 regional insect conditions map generated by a GIS. One of my proudest moments was to display this map at a meeting of the R-6 Leadership Team.

Rome, Italy – 1990-95

During the early part of 1990, I saw a vacancy announcement for the post of Forest Protection Officer in the FAO Forestry Department in Rome, Italy. The job description included work in forest insect and disease management, forest fire management, air pollution effects on forests and climate change. Recalling the fascinating experience Pat and I had in Chile, I applied for the post and six months later received word that I had been selected. In June 1990, Pat and I packed our belongings and headed for the Eternal City. The initial contract was for two years. We ended up staying for five. The job turned out to be perfect for a person born with an incurable case of wanderlust. During those five years I made 45 official trips to 29 different countries. Pat was able to accompany me on many of these trips.

One of the projects in which I was involved was management of the cypress aphid, initially identified as *Cinara cupressi*, in eastern and southern Africa. This insect appeared in Malawi in 1986 and quickly spread across the region, causing severe damage to plantations and natural forests of trees of the family Cupressaceae. The insect appeared in Kenya in 1990 and caused severe damage to the country's extensive plantations of *Cupressus lusitanica* (Ciesla 1991). I was able to obtain funding from FAO for an emergency Technical Cooperation Project (TCP) to conduct surveys, initiate emergency control operations in high value areas in Kenya and begin a search for natural enemies for a classic biological control program. Additional funds were later made available from UNDP, the World Bank and the Canadian International Development Agency. The project funded by UNDP was executed by FAO and Denny Ward from R-8 was selected to be the Project's Chief Technical Advisor. This Project resulted in the establishment of the Kenya Forest Health Centre of the Kenya Forest

Department, the first of its kind in Africa (Ciesla et al. 1995). Attempts at classic biological control, under the leadership of the CABI International Institute of Biological Control met with somewhat mixed results. In 1995, it was determined that the aphid involved was a species new to science and was subsequently described as *Cinara cupressivora*, native to the eastern Mediterranean Region (Watson et al. 1998).

My new job with FAO caused me to end 30+ years as an employee of USDA Forest Service. Fortunately, thanks to the support of people like Jim Space, who was then Director of FPM in Washington DC and Sam Kunkel in International Forestry, my close ties with the Forest Service continued and a partnership on forest health concerns developed between FAO and the Forest Service. On several occasions, I was able to obtain grants from the Forest Service to conduct regional workshops on specific pest issues. In 1991, I organized a workshop on conifer aphids in Kenya and representatives from about 10 eastern and southern African countries participated. It was the first time ever that forest entomologists from the region were able to meet. I called it the "First African Forest Insect Work Conference." A year later, again with a Forest Service grant, I organized a workshop on the European wood wasp, *Sirex noctilio*, in Brazil. Representatives from eight South American countries participated and it too was the first opportunity for forest entomologists from the region to meet (First South American Forest Insect Work Conference). In 1994, thanks to another Forest Service grant, I organized a regional workshop on leucaena psyllid, *Heteropsylla cubana*, in Dar-es Salaam, Tanzania (Second African Forest Insect Work Conference). In each case, a delegation of Forest Service representatives participated in the workshop and proceedings were published that provided a record of the information presented (Ciesla et al. 1991, Iede and Ciesla 1993, Ciesla and Nshubemuki 1995). The FAO/Forest Service partnership also provided opportunities for a number of Forest Service personnel to participate in international assignments on projects in China, India, Kenya and Tanzania.

Another project in which I became involved was a UNDP forestry development project in the People's Republic of China. I formulated and later provided technical backstopping to a project component that involved implementation of improved detection and monitoring of forests pests in Anhui Province. The project introduced to the Chinese technologies such as stand hazard rating, population monitoring with semiochemicals, aerial surveys, airborne video and GIS. One of the things Pat and I immediately learned about the Chinese is that they are among the World's most gracious hosts. During a numerous visits to China we attended many "informal" banquets, which always included copious quantities of beer and a type of clear, white liquor made from rice. The second Chinese work we learned was "*gambay*!" the toast said before hurling down a shot of the strong white liquor or a tall glass of beer.

Fort Collins, CO – 1995-present

In June 1995, Pat and I returned to Fort Collins. After more than 35 years, I decided that I no longer wanted to work full time. Even though I was looking forward to returning to the Rocky Mountains, leaving Rome and FAO was difficult for both of us. During those five years, we had made friends with people from all over the World. And, we had developed good relations with our neighbors and the merchants with who we did business in Acilia, the community we called home for five years.

When we returned to Fort Collins, I chartered Forest Health Management International, a one-person forest health consulting company. This enterprise has been reasonably successful and consulting projects have taken me, and in some cases Pat, to places like to Brazil, Chile, China, Cyprus, Kyrgyzstan, Nicaragua, Pakistan, Trinidad and Tobago and Saudi Arabia. In addition, I have taken on a number of domestic consultancies.

In 1998, in collaboration with Attilio Disperati, a professor of remote sensing at the Universidade Federal de Parana in Curitiba, Brazil, and two foresters from Cellucat S.A., a large pulp and paper company, I conducted a demonstration of aerial sketchmapping to classify tree mortality caused by the European wood wasp in Santa Catarina State. The only available aircraft for the survey was an Aero Boerro, a high wing, two place aircraft designed for flight training. After we completed the survey, my pilot pointed to the starboard fuel gauge and yelled "*combustible, combustible*!" One of the fuel tanks apparently was blocked and the other was nearly empty. The pilot managed to get a message off to the control tower in Lages, the community from which we had taken off and requested fuel and a mechanic. We made an emergency landing at an abandoned airstrip near the community of Curitibanos. Even with our dangerously low fuel supply, the pilot insisted on buzzing the runway to make sure it was free of horses and cows. Several hours later, Attilio and Pat arrived with fuel, and a mechanic. They failed, however, to bring along the most critical of survival rations - several bottles of cold *cerveja*. Despite this mishap, the demonstration was a success. There was good agreement between the aerial classification and existing ground data and we published a paper on the results, which was the basis for further investigations (Ciesla et al. 1999).

Several years later, the Forest Service, in collaboration with the EMBRAPA forest research laboratory in Colombo, Brazil, conducted a study to determine the feasibility of introducing aerial sketchmapping to Brazil. The Forest Service invited me to join with Erik Johnson (R-2) to participate in the study. We looked at aircraft availability and cost, who might provide leadership to an aerial survey program and overall interest. The study established that an aerial sketchmap program was indeed feasible for Brazil and the following year, Erik and I trained a team of aerial observers and conducted a series of operational flights. As part of the operational flights, we defined the aerial signatures of several damaging agents in pine and *Araucaria angustifolia* plantations (Ciesla et al. 2002).

In 2000, I was part of a team to conduct an environmental assessment of a proposed technical assistance project under consideration by the United Nations Office of Project Services (UNOPS) for management of the pine processionary caterpillar, *Thaumetopoea pityocampa* in Turkish Cyprus. This insect is a major defoliator of pine forests throughout the Mediterranean Basin. Two years later, when the project was finally approved, I was recruited by UNOPS as its technical specialist. Cyprus has been a divided country since the Turkish invasion of 1974 and attempts by the UN to resolve the conflict have been unsuccessful. While working in Cyprus, Pat and I lived in the Greek side of the divided city of Nicosia and each day walked across a 500 meter neutral zone lined with razor wire to the Turkish side of the city.

My work involved establishing criteria under which plantations would be treated. This involved the development of a defoliation prediction system based on egg-mass counts. I also conducted an analysis of opportunities for long-term preventative tactics to reduce damage caused by this insect, provided training in forest pest management and evaluated bark beetle damage in pine and cypress forests (Ciesla 2004). A planned pilot project of the biological insecticide *Bacillus thuringiensis* was aborted because funding for the project was terminated after one year.

This project was one of several UN/USAID funded activities designed to increase communication and collaboration between the Turkish and Greek Cypriot Communities. Therefore, an integral part of the project was to organize a work conference on the pine processionary caterpillar that involved the Forest Departments and other stakeholders from both sides of the island (First Cypriot Forest Insect Work Conference). The conference was held in April 2003 in the Ledra Palace Hotel in Nicosia's neutral zone. This old hotel now serves as headquarters for the United Nations Peace Keeping Force in Cyprus and still contains bullet scars from the 1974 invasion. The conference consisted of two days of presentations and workshops followed by one-day field trips on both the Turkish and Greek sides of the island. The conference was a great success and, again, a proceedings was published (Ciesla and Gulensoy 2003). It was the first time professional foresters from Greek and Turkish Cyprus had been able to get together since the events of 1974. Colleagues, who had not had any contact in nearly 30 years, exchanged e-mail addresses and are now communicating on a regular basis. Having had the opportunity to organize this workshop and witness the animated communication between people who had been separated for so many years was one of the most satisfying things I have ever done.

Some Final Thoughts

This presentation has summarized a long journey: sometimes smooth, sometimes rocky, always interesting. There were always opportunities to take on a new challenge, discover something new or travel to a place I had never been before. Confusus said " find a job that you like and you'll never have to work a day in your life." That certainly applies to me. As I look back, I can honestly say that I looked forward to going to work about 80% of the time. This is not to say that I haven't had some tense moments with supervisors, subordinates and a few colleagues. Anyone who knows me knows that. However, I've had the good fortune to be associated with dedicated, motivated people and a good working environment.

Have I reached the end of my carrier? I certainly hope not. As long as my and Pat's health stay reasonably good, I hope to be involved in some capacity in forest health protection. Many thanks for your attention. I hope it's been entertaining and that I've provided you with some food for thought.

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ALLEN-ABRAHAMSON AWARD – STUDENT POSTER COMPETITION

The Allen-Abrahamson Award is offered in recognition of the contributions to forest entomology of Dr. Douglas C. Allen (Distinguished Service Professor) SUNY-ESF and Dr. Lawrence P. Abrahamson (Senior Research Associate) SUNY-ESF and to acknowledge their vision for a NAFIWC. Separate awards are given to PHD students and MS students.

2006 Recipients:

First Place Winners:
Brian Beachy, Michigan Technological University, Houghton, MI
Aerin Land, University of Kentucky, Lexington, KY

Second Place Winners:
Christina Lynch, University of Tennessee, Knoxville, TN
John J. Riggins, University of Arkansas, Fayetteville, AR

POSTERS

AN *OPHIOSTOMA* SPECIES AND *XYLEBORUS GLABRATUS* THREATEN RED BAY AND OTHER MEMBERS OF THE LAURACEAE IN THE SOUTHEASTERN US

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Extensive mortality of red bay (*Persea borbonia* (L.) Spreng) has been observed in maritime forests of the southeastern United States since 2003. Trees exhibit wilt-like symptoms and a black discoloration of the sapwood. A fungus has been consistently isolated from the discolored xylem of symptomatic trees throughout the range of the problem. This fungus has been identified as an *Ophiostoma* sp. based on sequences of the ribosomal DNA and its tolerance of cycloheximide. The anamorph of the fungus is similar to the genus of ambrosia beetle symbionts, *Raffaelea*. Field and growth chamber studies have determined that the fungus is pathogenic to red bay and causes a vascular wilt. A recently-introduced exotic ambrosia beetle, *Xyleborus glabratus* (Eichhoff), also has been consistently found in dead and dying red bay trees, and the *Ophiostoma* species has been isolated from the beetle. The beetle is native to Asia, where it is associated with plant species in the family Lauraceae.

As of February 2006, the disease has been confirmed in ten coastal counties of South Carolina and Georgia. The disease was also discovered near Jacksonville, Florida in the spring of 2005. Most red bay trees are now dead in areas around Hilton Head Island, South Carolina, where the disease has been recognized since 2003. Dead and dying sassafras (*Sassafras albidum* (Nutt.) Nees) with similar wilt symptoms have also been found in some Georgia counties affected by the wilt of red bay. The affected sassafras were infested with *X. glabratus,* and the *Ophiostoma* sp. was isolated from symptomatic sapwood. Pathogenicity tests have confirmed that sassafras and other members of the Lauraceae (swamp red bay, *P. palustris* (Raf.) Sarg., and spicebush, *Lindera benzoin* (L.) Blume) are susceptible to wilt caused by the *Ophiostoma* sp.

Beetle diversity in the mangrove swamps of North-East Langkawi Islands, Malaysia

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A study on beetle assemblage was conducted using Malaise trap at 7 locations in the mangrove swamps of Teluk apau, Tapak Ah Leong, Sungai Belanga Pecah, Sungai Banjar,

Anak Sungai Kilim, Sungai Itau and Pulau Tajuddin Ramli. The samplings were done using light trap at Pulau Tajuddin Ramli and Teluk Apau. During high tide in the day, Malaise trap was fixed in between the mangrove trees by standing on a boat. At night, during high tide at about 22:00 h the light trap was fixed for 1 hour in between the trees. Light trapping was stopped before the water had risen too high to avoid being trapped in the mangrove swamp. A total of 203 specimens from 18 beetle families and 62 species were assembled from the mangrove swamps. Using Malaise trap, 5 species were caught at Teluk Apau, three species from Sg. Pinang Karong and one species each from the other locations. Light trap was more successful in collecting 50 species of beetle from 16 families at Teluk Apau and 11 species from six beetle families from Pulau Tajudddin Ramli. 118 specimens has been identified to generic or species level. Using Simpson index it was found that the diversity of beetles is highest at Teluk Apau followed by Pulau Tajuddin Ramli and Sungai Belanga Pecah. Eight species of mangroves identified from the sampling sites were identified. Beetle assembled using light trap were more diverse and more abundant than those sampled using Malaise trap at Teluk Apau. The beetles identified to species level are all new records for the mangrove swamps.

Beetle Fauna on islands in the Straits of Malacca

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A research expedition aboard the Reef Challenger to the Straits of Malacca was conducted from June 4th to June 11th 2004 on the uninhibited islands of Jarak, Lalang, Rumbia and Perak. From 10:00 h on June 5th to 17:30 the following day, using the steps to the light house as a transect, Malaise traps, pitfall traps and light trap assembled 31 individuals comprising of 20 species from 10 beetle family from Jarak Island. All are new records. Evening arrival on June 6th at Pulau Sembilan (nine islands archipelago) enabled light trapping at Lalang Island from 2000 h to 2400 h yielding 137 individuals comprising of 17 species from 8 beetle family were sampled. Beetle abundance at Lalang Island is higher than Jarak Island whereas there is a higher diversity of beetle at Jarak Island. Big waves on June 7th allows only 5 hours sampling on Rumbia Island using Malaise traps and pitfall traps. Only 6 individuals comprising from 4 species from 4 beetle family were sampled. Due to heavy storm, the ship left the archipelago to the next destination, Perak island. Perak island is a controversial island belonging to Malaysia but Indonesia still put a claim on it. A British voyager wrote in his diary in the 18th century that Perak Island has no vegetation and only birds are sighted there. Thus it was surprise to see Perak Island with vegetation. A helicopter pad and a dangerous hanging jetty provide acess to the island, Since many pirates are known to pass by Perak Island sampling was only done using sweep netting for 4 hours in the morning. Only one beetle was caught. A military boat asked us to leave the dangerous area and thus begins our non-stop return journey back to Port Klang, west coast of peninsular Malaysia with arrival on the June 11th. Beetle abundance using Margalef index was low in the tropical rainforest on all

three islands with the highest value was at Lalang island (2.851) followed by Jarak (1.924) and Rumbia Island (0.693). Beetle diversity was low with Shannon–Weaver index of 2.204 (Jarak), Lalang (1.592) and 0.693 for Rumbia Island. All these index are very low compared to other forests areas in Malaysia.

Efforts Towards Mass Rearing and Release of *Laricobius nigrinus* (Coleoptera: Derodontidae) by Clemson University

C.M. Allard, L.W. Burgess and J.D. Culin

The beetle *Laricobius nigrinus* is a predator of *Adelges tsugae* (HWA) and has a univoltine lifecycle that it is synchronous with that of HWA. During HWA diapause (summer), *L. nigrinus* adults also are in aestival diapause in the soil and emerge in the fall concurrent with the break of HWA diapause. In Fall 2004, Clemson University initiated mass rearing *L. nigrinus* generating 18,000 larvae that entered the soil and aestivated during the summer. In Fall 2005, 3,000 *L. nigrinus* emerged and were released in Georgia and North Carolina. We are currently in our second rearing season and have 15,000 larvae thus far; furthermore, we predict to meet a goal of 20,000 larvae by the end of the rearing season in May. Spring releases of adult *L. nigrinus* have been made in Georgia and beetles have been donated toward the establishment of field insectaries. Improvements in our rearing techniques and facilities will make significant contributions toward the biological control of HWA.

Race differentiation among the European populations of *Pityogenes chalcographus* (Coleoptera, Scolytinae)

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Pityogenes chalcographus is a widely distributed bark beetle in Eurasia, infesting mainly branches and crowns of *Picea abies* stands. In the 1970's E. Führer found evidence for separation of this species into a northern and a southern geographical race by crossing experiments, morphological and biological means. Populations from the autochtonous range of the Norway spruce in Europe were analysed by sequencing the mitochondrial COI gene. A phylogenetic analysis revealed six clades with a maximum sequence divergence of 2.3%. The two major clades represent populations concurring in Central and northern Europe, yet the genetic distance between them suggests that they separated a long time before the last glacial, probably during the early Pleistocene. Moreover crossing experiments between individuals of the two clades revealed reproductive incompatibility in terms of reduced egg niches and larval galleries. Our results thus supported the separation of the European populations of *P. chalcographus* into two geographical races suggested by E. Führer.

Bark and Wood-boring Beetles of Living Trees.

G. K. Douce, D.J. Moorhead, C.T. Bargeron and C.W. Evans, The Bugwood Network, The University of Georgia, Tifton, GA 31793 USA.

The Bark and Wood-boring Beetles of Living Trees website (www.barkbeetles.org) evolved from the Bark Beetles of North America website that focused on content and images contained on a CD-ROM developed and distributed by the Bugwood Network in 2001. Thousands of images and considerable information about bark beetles and other wood-boring beetles of living trees have been added to the Bugwood systems since then through collaborations with many US and non-US agencies, universities and institutes from across the US, Europe and the Pacific that are of concern to North America and other countries. Some information is available in more than one language.

This poster will provide highlights of this website and provide an overview of the information and images that are available.

Kenneth H. Wright, 1921-2002: In Memoriam

Ronald F. Billings, Texas Forest Service

On December 3, 2002, forest entomologist Kenneth H. Wright passed away at age 81, following a long career with the USDA Forest Service. This poster is presented in memory of Ken, who served as a mentor for many younger forest entomologists, including the author. It reviews his long and productive career which began in 1948 with the Bureau of Entomology and Plant Quarantine. He joined the staff of the Pacific Northwest Forest and Range Experiment Station in Portland, Oregon in 1954 when the Bureau was transferred to the USDA Forest Service. He eventually became assistant director of the PNW Station, a position he held until he retired in 1987. He also served as Program Manager of the expanded Douglas-fir Tussock Moth Program from 1974-1978 and was a frequent participant in the Western Forest Insect Work Conference. Ken was a dedicated and hard-working professional even after his retirement. He was my first boss when I joined the USDA Forest Service as a seasonal technician in 1965 and I have fond memories of our time together. Ken is greatly missed by his many friends and colleagues.

Prevention of Southern Pine Beetle (*Dendroctonus frontalis*) Outbreaks in Texas: A State/Federal Partnership Benefits Private Landowners

Ronald Billings, L. Allen Smith, and Michael Murphrey, Texas Forest Service

The southern pine beetle (SPB), *Dendroctonus frontalis*, is the most destructive pest of pines in the southern U.S. and Central America. Overly-dense, unmanaged stands of loblolly pine (*Pinus taeda*) are most prone to SPB attacks and are the target of prevention programs in East Texas. The Texas Forest Service (TFS) has developed a system for hazard rating large areas (18,000 acre grid blocks) for SPB susceptibility, based on the spatial distribution and abundance of dense pine stands on the landscape. Within 25 counties with grid blocks rated as moderate, high, or extreme hazard, TFS is encouraging private forest landowners to take preventive measures by offering federal cost shares for first thinnings of high hazard pine stands. As of May 1, 2006, a total of 29,000 acres of moderate- or high-hazard pine stands in 25 counties have been approved for thinning with use of federal cost shares. Some 380 private landowners have participated in the program. Thinning has been completed on 18,000 acres. The overall goal is to identify beetle-prone areas within East Texas and reduce their susceptibility through public awareness campaigns, forest management, and federal cost-share incentives, prior to the next SPB outbreak. Funding for this project is being provided by USDA Forest Service, Forest Health Protection, Region 8.

California Insect and Disease Database

Michael Bohne, Zhanfeng Liu, Erik Haunreiter, Carlos Ramirez and Lisa Fischer
USDA Forest Service, Pacific Southwest Region
Forest Health Monitoring

A geodatabase has been created for insect and disease detections in California. The database provides spatial and tabular data for pests reported by regional pathologists and entomologists through a simple web portal. The database is currently being populated with historic federal and state detection reports and results from the Cooperative Forest Pest Detection Survey (sponsored by the California Forest Pest Council). The database will help track insect and disease trends, facilitate exploring spatial patterns and assist with aerial survey accuracy assessments

The Role of Gut Bacteria in Gypsy Moth Larval Susceptibility to *Bacillus thuringiensis subsp. kurstaki*

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Many insects rely on microbial communities within their guts for a diverse array of functions. However, the microflora of most insect gut environments, and their functioning, are poorly understood. The gypsy moth is one of the most important invasive species affecting North American deciduous forests. We assessed the role of gut microbiota in susceptibility of gypsy moth larvae to the most widely used microbial pesticide, *Bacillus thuringiensis* subsp. *kurstaki* (Btk). We administered three treatments in the diet, and then measured mortality induced by Btk. These treatments include: the antibiotic zwittermicin A, aspen leaves, and a collection of Alaskan soil bacterial strains. Each of these treatments altered the midgut microflora, and each likewise caused synergism of Btk. Zwittermicin A caused synergism in nanogram quantities. Mortality to Btk was consistently higher on aspen than on other dietary substrates. Two of the Alaskan soil isolates, a *Chryseobacterium sp.* and a *Rhizobium giardinii,* increased the mortality to Btk in a dose-dependent fashion. The manners in which gut bacteria may affect susceptibility to Btk are discussed.

Habitat usage of the forest tent caterpillar (Lepidoptera: Lasiocampidae) in North-Western Quebec

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Central to the study of animal ecology is the usage an animal makes of it's environment: specifically, the kinds of foods it consumes and the varieties of habitats it occupies and yet, very little research has been done to characterise the habitats of forest insects. Based on aerial survey data of north-western Quebec for the 1998-2003 epidemic of forest tent caterpillar and on forest inventory information, the goals of this study are (1) to gain a better understanding of habitat suitability for the forest tent caterpillar, regardless of the phase of the epidemic cycle, and (2) to evaluate the habitat use for each step of the epidemic thereby attempting to establish a progression for habitat preference in relation to the stage of the epidemic. Preliminary results suggest that habitat usage is not random as certain types of habitat were defoliated in a significantly higher or lower proportion than was available within the study area and that habitat use varies from a strong preference for aspen dominated stands early in the epidemic to a more diverse selection of stands in later stages. Though the results conform to our expectations, they also bring to light a new question, whether the progression of habitat usage is the result of spillover from "ideal" habitats as the density of the insect population increases and resources per individual decrease or the result of a spatial dynamic of movement through different habitats at different phases of an epidemic.

The Effects of Jasmonate Dependent Defenses on the Asian Chestnut Gall Wasp, *Dryocosmus kuriphilus*

W. Rodney Cooper and Lynne K. Rieske-Kinney

We investigated the role of jasmonate dependent defenses against the Asian chestnut gall wasp, *Dryocosmus kuriphilus* (Hymenoptera: Cynipidae). *D. kuriphilus* is an exotic invasive insect that forms galls on the stems and leaves of chestnut (*Castanea* spp.), preventing flowering and normal shoot development, and causing tree mortality. The gall wasp threatens chestnut production and efforts to restore American chestnut to Appalachian forests. We artificially activated jasmonate dependent defenses by successively applying a solution of synthetic jasmonic acid (JA) to developing galls and foliage of Chinese chestnut. Activation of JA increased tannin content in leaves and galls and reduced the incidence of pathogen infection. Additionally, JA application resulted in the formation of larger galls with higher moisture content; however, there were no differences in gall dry weights. Analysis of gall contents revealed that JA decreased parasitism and mortality by unknown causes. In addition, the hardened gall tissue surrounding the larval chamber was thicker in galls treated with JA. These results suggest that induction of JA may be beneficial to the gall wasp by enabling it to produce larger galls with higher tannin content, resulting in decreased parasitism and pathogen attack.

Inverse density-dependence in hemlock woolly adelgid (*Adelges tsugae*) dispersal at low population density

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Dispersal of hemlock woolly adelgid (*Adelges tsugae*) in Eastern United States is probably limited to eggs and crawlers; more mature individuals are sessile and have their mouthparts deeply imbedded in the hemlock host. Winged adults that develop with increasing adelgid density and/or reduced host quality do not contribute to range expansion because an obligate alternate host is unavailable in the region. We studied crawler dispersal from hemlock trees in relation to adelgid density and tree health. Initial results indicate that the number of crawlers captured on ground level sticky traps relative to that on branches 1-2 meters above the trap is proportionately higher at very low adelgid densities, which indicates inverse density-dependence in crawler dispersal off hemlock when populations are low. Inverse density-dependence at low population density was also found in the percentage of trees infested in small plots. Crawler capture was significantly ($P \leq 0.05$) correlated with tree health (Pearson's $r = 0.49$), measured as new shoot establishment. Hemlock health quickly deteriorates under adelgid attack. More crawlers leaving when trees are still healthy could be a response to hemlock's defensive chemistry. An understanding of increased adelgid dispersal at lower

population levels could influence strategies for implementation of biological control based on predators and insect-killing fungi.

Effects of season of cut and overstory density on *Ips* spp. utilization of logging slash in ponderosa pine in the Southwest

[1]Chris Hayes, [1]Tom DeGomez, [2]Joel McMillin, [2]John Anhold

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Pine engraver populations are attracted to and generated in slash created during thinning operations (Sartwell, 1970; Livingston, 1979; Parker, 1993). For this reason, slash management has long been recognized as an appropriate tool for reducing attacks by *Ips* spp. on the residual trees after thinning forest stands. Among slash management techniques, scattering logging debris in open areas to promote rapid drying has been recommended to reduce the risk of engraver outbreaks (Livingston, 1979). We tested *Ips* spp. utilization and brood production in slash distributed in lop and scatter treatments. Logging slash was created during four different seasons of the year (October 2004, and January, April, and July 2005 [July exit holes yet to be counted]). Each of these cohorts included slash created in three stand densities, averaging 20 ft^2/ac, 60 ft^2/ac, and 120 ft^2/ac of basal area. Bolt treatments included sixteen sizes, four lengths (6, 12, 18, and 24 in.) of four diameters (4, 6, 8, and 10 in.). Bolts were placed on the ground adjacent to slash piles that served as attractant. Piles were paced on a fifty meter grid. To analyze the effects of season and stand density, our response variable, exit hole density, was averaged across all sixteen treatments per pile. Because our data did not follow a normal distribution and lacked homogeneity of variance, we used Multi-response Permutation Procedure (MRPP) in the analysis. All three cohorts were utilized by *Ips* and had brood production. Season of cut, however, did have a statistically significant effect on exit hole density (Standardized MRPP test statistic = -12.1, P = 5.25E-08, Oct = 2.14, Jan. = 1.49, and April = 0.86 exit holes/69.7 in^2). Stand density had no influence on exit hole density (Standardized MRPP test statistic = -0.94, P = 0.16). Winter conditions included greater than average snowfall. This excess moisture prevented the October and January cut from sustaining sufficient desiccation to preclude brood production. Low exit hole density in the April cut may have been due to *Ips* spp. phenology, with the bolts cut at the tail end of the peak spring flight period. This study is being repeated in 2005-2006 to determine the consistency of results under different weather conditions.

Use of verbenone and non-host volatiles to reduce engraver beetle attack on ponderosa pine in Arizona

[1]Chris Hayes, [1]Tom DeGomez, [2]Joel McMillin, [2]John Anhold, [3]Michael Wagner, and [4]Carl Edminster

[1]Univ. of Arizona, [2]USDA Forest Service, Reg. 3 Forest Health Protection, [3]NAU School of Forestry, [4]Rocky Mtn. Res. Stn.

Pine engraver populations are attracted to and generated in slash created during thinning operations (Sartwell, 1970; Livingston, 1979; Parker, 1993). For this reason, slash management has long been recognized as an appropriate tool for reducing attacks by *Ips* spp. on the residual trees after thinning forest stands. We investigated the use of anti-aggregation pheromones (verbenone) and non-host volatiles to preventing *Ips* attacks of fresh ponderosa pine slash. Verbenone, in the form of Hericon flakes, and non-host volatiles from *Juniperus deppeanna,* and *Abies concolor* needles were tested for their efficacy in repelling attacks by *Ips* spp. and subsequent brood production. A randomized fixed effects block design was used with a conventional slash pile as a sampling unit, with two levels of verbenone treatment, 0 grams and 100 grams, and three levels of non-host volatiles, none, 3.5 kg *J. deppeanna* and 3.5 kg *A. concolor*. Piles were left in the field for 8 weeks, at which time two randomly selected one foot long bolts were removed and dissected. Response variables included density of nuptial chambers, egg galleries, and exit holes. Verbenone caused a significant reduction of nuptial chamber density ($n = 10$, $F = 5.10$, $P = 0.028$) and the square root of egg gallery density ($n = 10$, $F = 5.30$, $P = 0.025$), but not on exit hole density ($n=10$, $F = 3.06$, $P = 0.086$). There were no statistically significant effects on any response variables due to non-host volatiles or the interaction of the two factors. Although we did not find a significant reduction in brood (exit holes serving as a surrogate), disruption of nuptial chamber construction suggests that increased application rates of Hericon flakes could produce the desired results.

Host and mate location in the emerald ash borer, *Agrilus planipennis* Fairmaire – Towards understanding ecology to identify potential field attractants

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The emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) is a new exotic pest of *Fraxinus* spp. in the Midwest and Ontario. Adults oviposit on the bark of mature trees and emerging larvae feed on the phloem and eventually kill the tree. The search is on to identify compounds in ash trees that are attractive to *A. planipennis*. We are comparing volatile profiles of healthy and stressed black, green, Mandchurian, white, blue and European ash seedlings to identify compounds that elicit antennal responses from male and female *A. planipennis*. We are also looking for a possible sex pheromone by aerating males and females at different stages of their adult life in individual vials containing adsorbent Super-Q. Antennally active compounds will be identified by gas chromatography-mass spectrometry and subjected to laboratory bioassays and field tests in the summer of 2006. Results may yield potential attractants for use in traps to control this devastating pest.

SEMIOCHEMICALS PROVIDE A DETERRENT TO THE BLACK TWIG BORER, *XYLOSANDRUS COMPACTUS* (COLEOPTERA: CURCULIONIDAE, SCOLYTINAE)

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The black twig borer (*Xylosandrus compactus*) (BTB) is a serious pest of agriculture, forestry, and native Hawaiian plants. The BTB is a typical ambrosia beetle that bores into the host and inoculates the galleries with an ambrosia fungus (*Fusarium solani*) known to cause cankers, root rot, and wilt. The host list for this beetle is extensive and contains several Hawaiian plant species listed as threatened and endangered. Our approach focused on reforestation of koa plantations, one of the most important of these host species in terms of cultural and economic values, to evaluate attractants and repellants to help monitor, control, or prevent BTB damage.

We had earlier demonstrated that ethanol-baited Japanese beetle traps were an effective means of trapping BTB, so we used that trap/bait combination as the positive control. This system also effectively trapped two nontarget scolytid pest species, the Asian ambrosia beetle (*Xylosandrus crassiusculus*) and the fruit-tree pinhole borer (*Xyleborinus saxeseni*).

We challenged the attraction of the ethanol trapping system using both verbenone and limonene as effective repellents. The study was located in a six year old *Acacia koa* forest restoration stand, in Maunawili Valley on the windward side of the island of Oahu, with high BTB populations and considerable BTB-caused mortality. Treatments, each replicated six times, consisted of ethanol-baited control traps, ethanol and verbenone, and ethanol and limonene. Eighteen traps were placed in a grid at 15 m intervals and were suspended 1.5 m above the ground. Traps were monitored for four weeks, with collections made on a weekly basis. Trap counts were analyzed with generalized linear models for over-dispersed Poisson-distributed responses. Multiple comparisons were based on the maximum likelihood ratio.

Verbenone significantly reduced trap catch of all three beetle species. Limonene significantly reduced trap catch for only the Asian ambrosia beetle. Future work will utilize a higher release system for verbenone. Positive results will be applied to other tree species, with particular emphasis on restoration of endangered species in the state of Hawaii.

Efficacy of Aerial Application of Verbenone Flakes for Tree Protection from Attack by Mountain Pine Beetle

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Verbenone is an effective repellent/inhibitor for many *Dendroctonus* species. We applied verbenone-releasing laminated flakes (4X4 mm^2 and 2 mm in thickness) (Hercon Disrupt Verbenone Micro-Flakes®) using fixed-wing aircraft at 150 g/Active Ingredient/acre, with five 50-acre treated plots and five 50-acre control plots in each of California and Idaho states against mountain pine beetle, *Dendroctonus ponderosae*. Verbenone is stored in the middle of the flakes, protected from UV lights. Five untreated plots served as controls in both states, and all plots were selected from areas of predominantly ponderosa and/or lodgepole pines with significant level of mountain pine beetle activity. Panel traps baited with mountain pine beetle lures were placed near two of the four corners of each plot to monitor beetle flight within the treated and control plots. Beetles were collected from traps at two 14-day intervals following application. At the end of the season, a 100% cruise of treated and control plots was conducted to measure stand characters and pre- and post-treatment beetle infestation levels. Efficacy was determined by determining the number of dead trees in both sprayed and unsprayed sites. Beetle catch between treatments was also compared.

The effects of hazardous fuel reduction treatments in the wildland urban interface on the activity of conifer-infesting bark beetles in ponderosa pine stands.

Fettig, C.J., J.D. McMillin, J.A. Anhold, S. Hamud, R.R. Borys, C.P. Dabney and S.J. Seybold.

Selective logging, fire suppression, forest succession, and climatic changes have resulted in high fire hazards over large areas of the western USA. Federal and state hazardous fuel reduction programs have increased accordingly to reduce the risk, extent and severity of these events, particularly in the wildland urban interface. In this study, we examined the effect of mechanical fuel reduction treatments on the activity of bark beetles in ponderosa pine, *Pinus ponderosa* Dougl ex. Laws., forests located in Arizona and California, USA. Treatments were applied in both late spring (April-May) and late summer (August-September) and included: (1) thinned biomass chipped and randomly dispersed within each 0.4 ha plot; (2) thinned biomass chipped, randomly dispersed within each plot, and raked 2 m from the base of residual trees; (3) thinned biomass lop-and-scattered (thinned trees cut into 1-2 m lengths) within each plot; and (4) an untreated control. The mean percentage of residual trees attacked by bark beetles ranged from 2.0% (untreated control) to 30.2% (plots thinned in spring with all biomass chipped). A three-fold increase in the percentage of trees attacked by bark beetles was observed in chipped versus lop-and-scattered plots. Higher levels of bark beetle colonization were associated with spring treatments, which corresponded with peak adult beetle flight periods as measured by funnel trap captures. Raking chips away from the base of residual trees did not significantly affect attack rates. Several bark beetle species were present including the roundheaded pine beetle, *Dendroctonus adjunctus* Blandford (AZ), western pine beetle, *D. brevicomis* LeConte (AZ and CA), mountain pine beetle, *D. ponderosae* Hopkins (CA), red turpentine beetle, *D. valens* LeConte (AZ and CA), Arizona fivespined ips, *Ips lecontei* Swaine (AZ), California fivespined ips, *I. paraconfusus* Lanier (CA), and pine engraver, *I. pini* (Say) (AZ). *Dendroctonus valens* was the most common bark beetle infesting residual trees. A significant correlation was found between the number of trees chipped per plot and the percentage of residual trees with *D. valens* attacks. A significantly higher percentage of residual trees were attacked by *D. brevicomis* in plots that were chipped in spring. Engraver beetles produced substantial broods in logging debris, but few attacks were observed on standing trees. In a laboratory study, monoterpene elution rates from chip piles declined sharply over time, but were relatively constant in lop-and-piled treatments. The quantities of -pinene, 3-carene, -pinene, and myrcene eluting from chips exceeded those from lop-and-piled slash during each of 15 sample periods. These laboratory results may, in part, explain the bark beetle response observed in chipping treatments.

Nonhost angiosperm volatiles and verbenone for disrupting western pine beetle attraction to pheromone baited traps and trees

Fettig, C.J, S.R. McKelvey, C.P. Dabney, W.P. Shepherd, D.P.W. Huber, D.R. Cluck, and S.L. Smith. .

In 2004, nonhost angiosperm volatiles and verbenone were tested for their ability to disrupt the response of western pine beetle, *Dendroctonus brevicomis* LeConte, to attractant-baited multiple funnel traps. Verbenone significantly reduced attraction, however, no difference was observed between 4 and 50 mg/24 hr release rates. Combinations of six bark volatiles (benzyl alcohol, benzaldehyde, *trans*-conophthorin, guaiacol, nonanal, salicylaldehyde), three green leaf volatiles [(*E*)-2-hexenal, (*E*)-2-hexen-1-ol, and (*Z*)-2-hexen-1-ol], and the nine compounds combined (NAV) did not affect *D. brevicomis* response to attractant-baited traps. However, NAV significantly augmented the effect of both release rates of verbenone, reducing trap catches to levels significantly below that of either release rate of verbenone alone. In 2005, we refined release rates, reduced the number of components in our blend, and demonstrated the successful use of nonhost angiosperm volatiles and verbenone for protecting individual ponderosa pine from western pine beetle attack in two separate studies. Our results suggest that the addition of nonhost angiosperm volatiles to verbenone could be important for developing successful semiochemical-based management techniques for *D. brevicomis.*

Temporal and spatial activity patterns among three exotic predators of hemlock woolly adelgid, *Adelges tsugae* (Hemiptera: Adelgidae)

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Video studies were completed to document temporal and spatial activity patterns among two specialist predators, *Laricobius nigrinus* and *Sasajiscymnus tsugae*, and a generalist predator, *Harmonia axyridis*, of hemlock woolly adelgid, *Adelges tsugae*, and to examine how these patterns are affected by additional conspecific and heterospecific predators. Single- and paired-predator assays were tested in the laboratory under simulated spring and summer conditions. Digital video recordings were captured every 15 min over 24 hr and scored as to the predominant behavior exhibited and relative location of each predator. All species exhibited continuous activity patterns punctuated by longer periods of rest. Predator activity did not appear to be coordinated to any particular time of day or location. In spring conditions, *L. nigrinus* had greater activity and a more even behavior distribution than that of *S. tsugae* or *H. axyridis*, which were skewed towards resting. During the summer, a more even behavioral pattern was seen for these latter two species. Paired-predator assays suggested that conspecifics exert negative influence on one another, leading to increased dispersal movements and decreased resting, feeding and oviposition. In contrast, heterospecific combinations did not significantly affect predator behavior patterns. A high degree of spatial separation, relative to assay size, was maintained in all conspecific and heterospecific combinations, suggesting that avoidance behaviors may occur in these species in response to chemical or tactile cues. Overall, these studies suggest that these species are compatible, as particular temporal and spatial patterns were not highly coordinated, and avoidance behaviors were such that significant interspecific interference may be unlikely to occur under more natural conditions. Management implications include applying low-density releases to avoid the potential negative impacts of intraspecific competition.

Redbay Wilt and Redbay Ambrosia Beetle Discovered in Northeast Florida

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Unusual mortality of redbay, *Persea borbonia*, was discovered on Fort George Island, Jacksonville, Florida in May 2005. Subsequent investigations documented the presence of the redbay wilt pathogen *Ophiostoma* sp. and the redbay ambrosia beetle, *Xyleborus glabratus* here and in several surrounding counties. Initial data from tree mortality plots indicate higher mortality rates in the larger diameter classes. Other ambrosia beetles thus far reared from dead

trees include *Xyleborus affinis, Xyleborus ferrugineus, Xyleborinus saxeseni, Xylosandrus crassiusculus, Monarthrum mali,* and *Euplatypus compositus*.

Male sex pheromone in *Monochamus alternatus* Hope (Coleoptera:Cerambycidae):Behavioral bioassay in wind tunnel

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The behavioral responses of the Japanese pine sawyer beetle, *Monochamus alternatus* Hope (Coleoptera: Cerambycidae) in the field cage showed that female was attracted to a male from a distance. The male attractant phenomena was further studied in a wind tunnel. Upon release from a distance of 1m, a female beetle immediately walked upwards the wall of the wind tunnel, then orientated towards male source by a combination of walking, short jumps and flight which ended in landing on the male source. Whereas a male beetle immediately walked up the wall of the wind tunnel, remained motionless at the downwind end throughout the duration of observation and did not flew upwind towards female beetle. Similar negative response of female was observed in the control experiment whereby an empty container was used as bait. Male whole body surface rinse, male whole body extract and male prothorax extract also elicited positive flight orientation of females upwind towards odor source. Scanning microscopic studies showed the presence of pores on the male prothorax surface. Cross sections of male prothorax showed the presence of sex pheromone gland in the male prothorax of *M. alternatus* whereas similar gland was not observed in female prothorax. Thus this study confirmed that the male sex pheromone which is effective from a distance of 1 m is emitted from the prothorax gland.

Fipronil treatments provide extended protection of pine seedlings from pine tip moth

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Trials were initiated in 2004 to evaluate fipronil as a systemic treatment for protection of pine seedlings from pine tip moth. Pine seedlings were treated at different rates prior to lifting in the nursery bed, after lifting but before planting and/or at planting. Fipronil treatments applied in plant holes or as higher rate root soaks and dips before planting provided good to excellent protection against tip moth through the second growing season (2005). Protection against tip moth frequently resulted in significant improvements in tree height, diameter and volume growth compared to untreated checks. Fipronil treatments applied to nursery beds were ineffective against tip moth.

Emergent Allee effects in multivoltine bark beetles: the interaction of threshold aggregation behavior with stage structure and predation.

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In multivoltine bark beetles, the growth of a local infestation depends upon the continuous maintenance of a pheromone plume over the course of several generations. Offspring that emerge in the absence of pheromone produced by attacking adults are likely to leave the aggregation, promoting both their own failure to reproduce and the dissolution of the infestation. Thus, generations must overlap for plume continuity and local population persistence. Using a diffusion approximation of southern pine beetle growth and reproduction, we show that decreased population growth rate at the scale of a forest can result from the interaction between aggregation behavior, stage structure, and predation at the scale of local infestations. The probability of plume continuity decreases with increasing predation on attacking adults and peaks at intermediate levels of cohort synchrony. In all cases, the probability of plume continuity increases with increasing population size. Thus, our model identifies mechanisms that may mediate the strength of an Allee effect that emerges at the scale of a forest. Evidence for an Allee effect can be seen in the accelerating relationship between adult southern pine beetle abundance in the spring and the number of infestations that are formed in the same year. The Allee effect is also integral to our understanding of the transition between endemic and epidemic states in pest species. We suggest that plume discontinuity is especially likely for southern pine beetle infestations in the spring, when cohort synchrony depends on the stage structure of over-wintering populations, and in mid-summer, when high temperatures may delay the emergence of teneral adults.

Verbenone-Releasing Flakes Protect Whitebark Pine from Attack by Mountain Pine Beetle

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We applied verbenone-releasing laminated flakes (Hercon Disrupt Verbenone Micro-Flakes®) as a simulated aerial application to five replicate 10-acre plots of whitebark pine, *Pinus albicaulis,* located on the Bridger-Teton and Shoshone National Forests, Wyoming. The rate of application was 1 kg of flakes/acre, representing 150 grams/acre of verbenone. Five untreated plots served as controls, and all plots were selected from areas of predominantly whitebark pine with outbreak levels of mountain pine beetle activity (>2 currently infested stems/ha). Panel traps baited with mountain pine beetle (*Dendroctonus ponderosae*) lures were placed near two of the four corners of each plot to monitor beetle flight within the treated and control plots. Beetles were collected from traps at two 14-day

intervals following application. At the end of the season, a 100% cruise of treated and control plots was conducted to measure stand characters and pre- and post-treatment beetle infestation levels. Beetle numbers caught in baited traps was significantly reduced by the treatment. Treated stands showed a 50% reduction in beetle attack rate (10% of trees attacked in control stands vs. ca. 5% attacked in treated stands). Because previous studies have demonstrated a verbenone dosage-response relationship with several *Dendroctonus* spp., we hypothesize that even better protection can be achieved at higher release rates. This study demonstrated significant reduction in mountain pine beetle damage using verbenone-releasing flakes, even at high beetle population levels.

The Gypsy Moth Event Monitor for FVS: A Tool for Forest and Pest Managers

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The Gypsy Moth Event Monitor is a program that simulates the effects of gypsy moth within the confines of the Forest Vegetation Simulator (FVS). Individual stands are evaluated with a susceptibility index system to determine the vulnerability of the stand to the effects of gypsy moth. A gypsy moth outbreak is scheduled in the FVS multi-year cycle if a drawn random number is less than or equal to the estimated probability of outbreak in that multi-year cycle. If an outbreak is scheduled, gypsy moth mortality is leveled against species deemed susceptible and resistant; basal area growth is increasingly reduced in susceptible species during light, medium and heavy outbreaks, whereas during a heavy outbreak, basal area growth is somewhat reduced in resistant species.

This is a strategic model that demonstrates the potential loss of timber and habitat due to gypsy moth. The user can proactively reduce the stand's susceptibility to gypsy moth and the probability of a gypsy moth event by scheduling appropriate management actions within FVS (see Gottschalk 1993). Due to the limitations in FVS's growth and mortality equations, the variability normally seen in response to gypsy moth defoliation cannot be adequately modeled. As such, the user is cautioned that the best use of this Event Monitor is to show relative differences in responses of stands to gypsy moth rather than predicting absolute responses in individual stands. The Gypsy Moth Event Monitor can be used to prioritize stands for treatment or to estimate the overall impacts to a forested landscape.

The Gypsy Moth Event Monitor is intended for use by those familiar with the proper use and execution of the Forest Vegetation Simulator. It is recommended that the user be well versed in interpretation of standard FVS output. Specific Event Monitor variables can be exported to spread sheet programs for further user analysis.

Protection of Lutz spruce in Alaska from attack by *Ips perturbatus* (Coleoptera: Scolytidae) using semiochemicals and methyl jasmonate

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In 2004 and 2005, field bioassays of verbenone and conophthorin, interruptive semiochemicals of the northern spruce engraver, *Ips perturbatus*, and methyl jasmonate, a hormonal stimulant of monoterpene synthesis in conifers, were conducted in south-central Alaska in a stand of Lutz spruce, *Picea* x *lutzii*. The primary objectives of this project were to determine whether a) behavioral chemicals could be used as tools to protect individual standing trees from bark beetle attack and b) the effect of the behavioral chemicals could be enhanced by a plant hormone that induces host tree defenses. During both years behavioral chemicals were placed on study trees in early June and removed in mid-August. Attack density and mortality caused by *I. perturbatus* were recorded. Attacks by *I. perturbatus* were initiated prior to 7 June and increased in number through 15 June. In 2004, attack density was greatest on trees baited with the three-component attractive pheromone (ipsenol, ipsdienol, and *cis*-verbenol). Attack density was significantly reduced by addition of the interruptant (verbenone and conophthorin) to trees baited with the attractant. There was no significant difference in attack density between the attractant + interruptant-baited trees and unbaited trees. Likewise, mortality was highest in the attractant-baited trees, whereas the addition of the interruptant significantly reduced the level of initial (3.5 mos. post treatment) and overall (12.5 mos. post treatment) mortality. In 2005, treatments from 2004 were repeated and supplemented by methyl jasmonate spray or injection with and without the combination of verbenone and conophthorin. As in 2004, the highest attack density was observed on trees baited with the attractant. Again, there was a significant reduction in attack density on trees baited with the attractant and the combination of verbenone and conophthorin. There was no significant reduction in attack density on trees baited with the attractant when methyl jasmonate was sprayed or injected. The highest mortality (3 mos. post treatment) was observed in trees that had been baited with the attractant and injected with methyl jasmonate. Mortality was significantly lower in all other treatments, particularly those that included verbenone and conophthorin. During both years, regardless of treatment, trees treated with verbenone and conophthorin had significantly lower attack densities than any treatment containing the attractant. Treatment with methyl jasmonate did not reduce attack density on trees. However, methyl jasmonate-treated trees (sprayed or injected) exuded copious amounts of resin on the bark surface, and additional trees were treated, cut, and analyzed by light and scanning electron microscopy. Newly formed xylem tissue contained a continuous ring of traumatic resin ducts, indicative of increased monoterpene synthesis and secretion. In summary, treatment with a simple, two-component interruptant system of verbenone and conophthorin significantly reduced *I. perturbatus* attack density and mortality under the severe challenge posed by attractant-baited trees and can provide a full year of protection from bark beetle attack.

A Multi-Criteria Framework for Producing Local, Regional, and National Insect and Disease Risk Maps

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The construction of the 2005 – 06 National Insect and Disease Risk map, complied by the USDA Forest Service, State and Private Forestry Area, Forest Health Protection Unit, resulted in the development of a common GIS-based multi-criteria approach that can account for regional variations in forest health concerns. This framework, utilized by all nine Forest Service regions and 49 states, provides a consistent, repeatable, transparent process through which dynamic spatial and temporal risk assessments can be conducted at various levels to aid in decision making. The national framework consists of a five step process which can be a highly iterative process utilizing input from subject area experts:

1. Identify a list of risk agents and target host species.
2. Identify, rank, and weight criteria that determine the susceptibility (risk of introduction and establishment) and vulnerability (risk of mortality *if* an agent is established) to each risk agent. In some cases susceptibility to a pest approximates vulnerability and therefore represents risk of tree mortality. This is true for pests such as emerald ash borer and oak wilt.
3. Standardize risk agent criteria values and combine the resultant maps using a weighted overlay(s).
4. Convert modeled values for each risk agent to predicted Basal Area (BA) loss over a 15 year period.
5. Identify regions at risk of encountering a 25% or greater loss of total basal area or volume in the next 15 years. This potentially dynamic threshold was set by the National Risk Map Oversight team for the national risk map product.

Following these five steps models are individually run and dynamically assembled into a National Map on a central server located at the Forest Health Technology Enterprise Team (FHTET) in Fort Collins, Colorado. Regional GIS specialists upload and or build individual models on the FHTET server and reference standard data layers also located in the server environment. Separating data layers from the models that are dependant on them forages an environment that; 1) encourages separate critique and understanding of risk models from input data, 2) allows for continuous improvement of the final map by substituting more rigorously vetted data layers and 3) cultures continuous quality improvement of individual models.

This paper will briefly discusses the risk map framework demonstrating how risk maps can be easily constructed at both the local, regional, and national levels using Southern Pine Beetle as an example. Model validation and updating are discussed along with a new ArcGIS toolset that has been developed to allow seamless transfer of GIS technology to resource managers engaged in risk assessments. Lastly, an internet based geospatial portal will be demonstrated which places dynamic risk map products directly in the hands of state, private, and federal resource managers.

Southern Pine Beetle Information System Since the Beginning

Forrest Oliveria, Valli Peacher, James Meeker, James Smith, Judy Adams, Anthony Courter, Robert Coulson, Maria Tchakerian, Saul Petty, Daniel Twardus, Gerry Hertel, Terry Rogers

The Southern Pine Beetle Information System (SPBIS) began as a southern pine infestation monitoring database in 1977 by Terry Rogers, Gerald Hertel and Daniel Twardus at the USDA Forest Service, Forest Health Protection, Alexandria Field Office in Pineville, LA. The original format for the data was the 80 column punch card. Over the past 29 years the database has been expanded and revised several times as the computer and software has changed. The database contains data for more than 100,000 southern pine beetle (SPB) infestations. The amount of data collected for each spot has also increased. SPBIS currently is a relational database in Oracle. It is housed on a server at the Kisatchie National Forest and data is collected and entered from 83 districts in Region 8. Some Districts have the capability to collect SPB infestation data using a Trimble GeoXT personal data recorder and download the data electronically into the oracle tables. Software is currently being developed to move the database to a website that will accommodate both SPBIS and State SPB data.

A Rapid and Cost-effective Method to Assess Spruce/Fir Mortality across Large Areas

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Outbreaks of western balsam bark beetles *(Dryocoetes confuses)* and spruce beetles *(Dendroctonus rufipennis)* have recently caused extensive mortality in subalpine fir *(Abies lasiocarpa)* and Engelmann spruce *(Picea engelmannii)* respectively throughout the Bighorn National Forest (north central Wyoming, USA). Aerial surveys are currently the most common method used to detect insect infestations in the spruce/fir cover type. However, the large extent of this cover type, combined with increasing mortality, has exceeded the ability of aerial survey efforts to cover all areas of interest. In order for management agencies to better respond to the occurrence of this mortality, new tools are needed with which to assess the vast areas that are affected. Several units within the USDA Forest Service collaborated to develop a semi-automated and cost-effective method to assess mortality from strips of high-resolution digital aerial photographs acquired over the Bighorn National Forest. An inertial measurement unit (IMU) onboard the aircraft permitted rapid orthorectification of the imagery while semi-automated image processing techniques allow rapid assessment of mortality within the flight lines. This process will be incorporated into a multistage sample design that will be used to derive a statistical estimate of mortality for large geographic areas.

Ecological impacts of emerald ash borer on forest communities in the Huron River Watershed of Southeast Michigan

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Emerald ash borer (*Agrilus planipennis*) (EAB), a buprestid beetle endemic to Asia, has killed millions of ash trees (*Fraxinus* spp.) over thousands of hectares in southeast Michigan, northwest Ohio and neighboring Ontario. The objectives of this study were to determine (1) if community structure affects forest susceptibility to EAB invasion, and (2) the effects of EAB-induced ash mortality on forest community composition. Transects were established in 31 forested stands in southeast Michigan that varied in ash density, stand structure and community composition. Overstory and understory woody vegetation was quantified in three replicate one-quarter acre plots located along each transect. The impact of EAB was quantified by assessing degree of decline for each ash tree, which was related to density of attacks on the trunk.

There was no relationship between EAB-induced ash dieback or mortality and ash density, ash basal area, or ash importance value. There were also no relationships between EAB impact and total stand basal area, total stand density, and diversity indices. The only variable that was related to ash mortality was distance from the putative epicenter of the invasion ($r = -0.59$, $P = 0.001$). The closer a stand is to the epicenter, the higher the percent mortality, which currently exceeds 80% in some stands. Degree of decline of individual trees was positively correlated with density of EAB attacks ($r = 0.57$, $P = 0.003$), which provides further evidence that EAB is the agent responsible for decline and mortality. Dieback, percent mortality, and percent of infested stems was greater for black ash (*F. nigra*) than for white (*F. americana*) or green ash (*F. pennsylvanica*). As EAB eliminates ash from infested stands, abundance of saplings and seedlings suggests that *Acer* (maple), *Ulmus* (elm) and *Tilia* (basswood) will replace ash in the canopy. Establishment of these monitoring plots will facilitate long term studies of the ecological impact of EAB, which clearly has he potential to functionally eliminate ash from North America.

MONITORING AND FORECASTING MOUNTAIN PINE BEETLE OUTBREAKS IN HIGH-ELEVATION WHITEBARK PINE FORESTS

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Insect outbreaks are significant forest disturbances in the United States. In the western United States, extensive bark beetle outbreaks in recent years have killed thousands of ha of trees. High-elevation whitebark pine forests in the Rocky Mountains have experienced a recent severe infestation of mountain pine beetle. Outbreaks in these ecosystems are associated with unusually high temperatures. Increasing probability of outbreak in these forests may constitute a threat to a keystone species that provides significant services to ecosystems and humans. Here we discuss two studies related to outbreaks in whitebark pine forests. Model results driven by climate change projections suggest that future warming at high elevations will increase the area suitable for mountain pine beetle outbreak across the western United States. We also describe a remote sensing study in central Idaho that quantifies tree mortality using 2.4-m spatial resolution imagery. We will discuss total outbreak area, present landscape patterns, and assess how mortality varies across the landscape with respect to topography.

Regional differences in phoretic mites associated with the bark beetle *Ips pini*

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Ips pini (Say) is one of the most common bark beetle species in North America. *Ips pini* colonizes most species of pine and is often associated with several species of fungi. Mites are commonly associated with *Ips pini* but we know very little about how mites may influence beetle reproduction and beetle-fungal relationships. We present preliminary results of phoretic mite surveys on *Ips pini* in three regions of North America: Arizona, Montana, and Wisconsin. Most *Ips pini* were collected using baited traps with synthetic *Ips pini*-lures (lure varies with region and time of year). Over 200 *Ips pini* were inspected and 20 species of mites from beetle exoskeletons were identified. Mite diversity and richness were greatest in Arizona. Montana and Wisconsin were very similar, with very few numbers of mite species. The degree to which mite species affect *Ips pini* populations is unclear, but their high relative abundances and diversity on suggest that they may influence the dynamics within infested trees and affect beetle fitness.

Can high phenotypic and genotypic diversity of *Pinus ponderosae* regulate bark beetle populations?

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Arizona contains the largest contiguous stand of ponderosa pine in the world. This forest supports 9 *Dendroctonus* and over 10 *Ips* species but extensive tree mortality by bark beetles have only occurred recently. We hypothesize that extreme high inter-tree variability in defenses maintains low survival and adaptability of bark beetles within these forests. More specifically, high variation in resin quality and quantity among trees provides a mechanism to regulate endemic populations of multiple bark beetle species. Analyses of constitutive and induced resin in 40 trees in two large plots revealed the presence of extreme variability in resin composition among neighboring trees. High variability in defenses could negatively affect beetles by influencing beetle host location, pheromone production, egg laying, and growth of associated fungi. For instance, chemical profiles of stressed tree or "susceptible trees" may be difficult for beetles to locate among highly variable host volatiles among forests; Extreme variability in host volatiles may reduce the continuity of pheromone signals released by attacking beetles; Variability in resin compounds may reduce adaptation of fungi to tree hosts and the connection between mutualistic fungi and beetles. Thus, the occurrence of such variability may make it difficult for bark beetle species and their mutualistic fungi to reach outbreak densities. The recent occurrence of bark beetle outbreaks in Arizona may have resulted from landscape level declines in tree defenses due to extreme drought and above average temperatures.

Egg Releases of *Sasajiscymnus tsugae* to Enhance Biological Control Efforts Against the Hemlock Woolly Adelgid: Timing Is Crucial to Survival

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The hemlock woolly adelgid, *Adelges tsugae* Annand, is an invasive insect from Asia that feeds on eastern hemlock, *Tsuga canadensis* Carriere, and Carolina hemlock, *Tsuga caroliniana* Engelmann. This exotic pest has devastated stands of these hemlocks throughout the eastern United States and is considered a severe threat to the survival of these species.

Sasajiscymnus tsugae Sasaji & McClure, a natural enemy of the hemlock woolly adelgid, was imported from Asia for biological control of this pest. *S. tsugae* are currently reared in several facilities in the eastern United States. Releasing *S. tsugae* as eggs, rather than adult beetles, has been suggested as a way to reduce labor and costs associated with rearing and to increase production of the beetles to better meet demand. The germinal idea for the use of egg releases originated at the New Jersey Department of Agriculture.

This paper reports the results of a study designed to investigate the optimum time of year for successful release and survival of eggs of *S. tsugae* under field conditions. Survival of eggs of *S. tsugae* was evaluated for studies conducted from February to July of 2005 and 2006. Our results indicate that April is the optimum time of year to release eggs of *S. tsugae*. Egg releases are a viable alternative method for the establishment of *S. tsugae* and show promise for helping rearing facilities meet the demand for this important biological control organism. A suggested protocol for releases of eggs of *S. tsugae* has been developed and will be refined based upon these studies.

Resistance and resilience of Carabid communities to variable retention harvesting

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Ecological stability measures have become common in disturbance ecology literature. Here we use resistance, the change in the community following disturbance, and resilience, the rate of community recovery, to assess Carabid community stability following 5 levels of variable retention harvesting (75%, 50%, 20%, 10% and 2% residual structure) in 4 canopy cover types (deciduous dominated, deciduous dominated with coniferous understory, mixed wood and coniferous dominated) in the boreal mixed wood forest of Northern Alberta. Overall, higher retention treatments showed a greater resistance to disturbance the resilience was variable. Furthermore, 5 years following disturbance some species showed no signs of recovery and appear to be extirpated in the lower retention treatments.

Ex-situ Gene Conservation of Carolina Hemlock, *Tsuga caroliniana*, in the Southern Appalachian Mountains

Robert M. Jetton, W. Andrew Whittier, Michael E. Tighe, William S. Dvorak, and James "Rusty" Rhea

Carolina hemlock (*Tsuga caroliniana* Engelm.) is a species represented by several small to moderately sized, isolated populations in the Appalachian Mountains and upper Piedmont from northeastern Georgia to southern Virginia. Over the last several years, there has been

great concern about the destruction of Carolina hemlock by the Hemlock Woolly Adelgid (HWA-*Adelges tsugae* Anand.), a pest introduced from Asia into the United States in 1926. Conservation approaches are needed to protect dwindling populations of Carolina hemlock as forest entomologists attempt to find ways to limit the future damage caused by the HWA. In a collaborative effort between Camcore, NCSU and the US Forest Service, seeds of 67 trees from 10 populations of Carolina hemlock in Georgia and North and South Carolina were collected in 2003 and 2005 as part of an *ex situ* conservation attempt to move the species to more protected areas where HWA is not present. Floramap®, a climatic model that predicts where new populations of a species should survive, indicated that central Chile and southern Brazil were potential planting locations. Seed has been shipped to cooperators in these countries and seedlings are currently under cultivation in forest nurseries. Plans to enlarge the existing genetic base for *ex situ* conservation partly failed in 2004 and 2005 because of poor cone crops in natural stands, but a second attempt will be made to sample additional populations in Virginia and Tennessee in 2006. Under this worst-case scenario, genetic material of hemlock from Latin America could someday be returned to the US to repopulate lost Carolina hemlock stands once the technology to control the insect has improved.

Life Cycle of the Hemlock Woolly Adelgid, *Adelges tsugae* Annand, in the Great Smoky Mountains National Park

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The hemlock woolly adelgid, *Adelges tsugae* Annand (Hemiptera: Sternorrhyncha: Adelgidae), is an invasive insect from Asia that feeds on eastern hemlock, *Tsuga canadensis* Carriere, and Carolina hemlock, *Tsuga caroliniana* Engelmann. This exotic pest has caused extensive mortality of eastern hemlock throughout the northeastern United States. It was first found in 2002 in the Great Smoky Mountains National Park, where it is now widely distributed. In the Park, management programs (including applications of insecticides and releases of predatory beetles) have been implemented to reduce the impact of this exotic species on native eastern hemlocks. The biology and seasonality of hemlock woolly adelgid are well understood in the northeastern United States, but specific information is lacking in the southern Appalachian areas. In 2005, a two-year research project was initiated to address the following questions regarding populations of hemlock woolly adelgid in the Great Smoky Mountains National Park: 1) what is the life history of this pest in our region?, 2) what is the relative density of each life stage of this parthenogenetic species?, and 3) how does the life cycle of the hemlock woolly adelgid differ, if any, from those in the northeastern United States?

This paper will present an overview of the life cycle of the hemlock woolly adelgid in the Great Smoky Mountains National Park. Development of hemlock woolly adelgid in our study was about one month earlier than that reported for similar studies in the northeastern United States. The warmer climate in our region may have enhanced development. The early development of the hemlock woolly adelgid in our area may influence applications and timing of control procedures. As more information on life history and seasonality becomes available, management programs can be improved to enhance regional efforts to reduce this pest.

A Comparison of Six Aerial Observers

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During a pre-season aerial survey workshop near Buena Vista Colorado in June 1999, aerial observers flew separately over a comparable area for training purposes. Six of the resultant maps were chosen for spatial and tabular comparisons. Of the six maps, three were produced by state employees and three were produced by Forest Service, Forest Health Protection (FHP) employees; all six employees annually contribute aerial survey data for inclusion in the national aerial survey data base. Minimal ground truthing was carried out following the training and an accuracy assessment was not performed to validate the maps based on ground "truths".

The intent of this poster is to demonstrate the variation among six aerial observers mapping the same area on the same day under similar atmospheric conditions and to facilitate understanding among forest health managers that there is inherent variation in aerial survey data. It is not the intent of this poster to assess the accuracy of the six aerial survey maps. Sketchmapping is highly subjective and is intended to detect forest change events and impart the information to land managers.

Forest health specialists are cautioned to recognize the variation in skill levels of aerial observers whose maps they may be utilizing for reporting purposes, especially when aerial observers are new to the challenge. Some have a natural aptitude for sketchmapping, while others are simply doing the best they can. No matter what the map scale, the intensity of the outbreak, or what the survey methodologies are, sketchmapping is a humbling experience every day.

But the bottom line is this question: Are all six of these aerial survey maps acceptable to you as an entomologist, forest health specialist, land manager or supervisor of an aerial survey program manager? And if the answer is "no", then what can you do to improve the aerial survey product you receive?

The Guts of *Adelges tsugae* and *Adelges piceae*

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Guts of the *Adelges tsugae* and *Adelges piceae* were examined under compound and stereomicroscopes. The alimentary canals look simple and consist of foregut, midgut and hindgut. Foreguts consist of an oesophagous (a thin tube at the anterior end), and a group of spherical salivary glands, connected to the buccal cavity via salivary ducts. The foregut leads to the midgut. The longest section of the canal further leads to the hindgut. The hindgut at the posterior end resembles like a large rectal pad. Contents of the midgut appear to be particulate, which suggest that they feed on cellular debris such as organelles, which are particulate; however, the small size of these insects make it difficult to make definitive conclusions. Further studies of feeding targets of the adelgids will be undertaken using other methods of staining and microscopy.

Low-Pressure Vacuum Treatment as a Potential Alternative to Heat Treatment or Fumigation for Killing *Anoplophora glabripennis* in Solid Wood Packing Material

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The intent of this project was to assess the potential of using vacuum technology to control *Anoplophora glabripennis*, referred to as Asian longhorned beetle, in the solid wood packaging materials (SWPM) and other wood products. Survival of larvae exposed directly to different vacuum pressures (10, 20, and 75 mm Hg) and temperatures (20 and 30 ºC) for different lengths of time was assessed. Some larvae were also placed in wood with different moisture contents and exposed to a pressure of 20 mm Hg at 20 ºC to determine the effects of wood moisture content on vacuum lethal time.

Anoplophora glabripennis larvae can be killed by low-pressure vacuum treatment. Larval mortality under vacuum was the result of evaporative removal of body water. Larvae died after loosing as little as 26% total body weight and all larvae in the trials that lost $\geq$ 40% weight were dead. Larvae were completely desiccated after 60-67% weight loss. The rate of larval weight loss was constant for about the first 30 hours at 20 mm Hg vacuum pressure at 20 °C. Desiccation rate significantly increased if either the temperature was raised or the pressure lowered, for example the larvae lost weight twice as fast at 30 °C (6.17 %/h) compared to 20 °C (3.35 %/h).

Larvae placed in the test wood pieces with 21.6% MC lost weight but at a slower rate than if they had been directly exposed to the same vacuum treatment and the desiccation rate averaged only 1.2 % per hour under 20 mm Hg vacuum pressure at 20 °C. About 50% of the larvae held in wood under these conditions had lost > 40% body moisture after about 20 hours and were dead. Plans are being made to test the vacuum technology on naturally infested wood in China. Further work to determine the exact treatment conditions for wood material in a commercial facility will be necessary to prepare documentation needed to have this method considered for adoption as part of the International Standard for Phytosanitary Measures ISPM 15 which is used by the United States and its trading partners.

Molecular Diagnostics of *Enaphalodes rufulus* (Coleoptera: Cerambycidae)

M. Brent Kelley, Stephen W. Wingard, Allen L. Szalanski, Fred M. Stephen, and Larry D. Galligan

Oak-hickory forests in northwestern Arkansas, eastern Okalahoma and southern Missouri have recently experienced an oak decline event with widespread oak mortality. The oak mortality is associated with an outbreak of a native wood-boring cerambycid, *Enaphalodes rufulus* (Haldeman), the red oak borer. Taxonomic identification of larval Cerambycidae below family level is not usually possible through traditional morphological methods. We employed molecular diagnostics, using polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP), to distinguish *E. rufulus* from other closely related species of cerambycids. A portion of the mitochondrial DNA 16S rRNA gene, isolated from legs or thoraxes of adult museum specimens, was amplified and digested with *Alu* I and *Hind* III restriction enzymes. Both restriction enzymes independently produced fragments for *E. rufulus* that were significantly different from any other cerambycid tested. *Alu* I had one restriction site for *E. rufulus* and two restriction sites for all other cerambycids tested, while *Hind* III did not cut for *E. rufulus* but did cut at one restriction site for all other cerambycids. Eggs, larvae, and pupae of *E. rufulus* along with an unknown cerambycid larva and pupa were successfully amplified and digested using this method to verify validity of this technique for multiple life stages.

Burn severity, salvage logging and boreal post-fire forest diversity

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Forest fires are among the most important natural disturbance events on the boreal forests of Canada and thus have potentially a crucial effect on the abundance and distribution of forest species in this region. Forest industries, however, carry out intensive post-fire salvage logging, which removes vast amounts of potential food, shelter and nesting sites from various forest organisms. We sampled beetles, birds and vegetation at the House River fire (2700 sq-km), Alberta, to study the effects of post-fire logging and fire severity on the focal taxa. The sampling was done during the two first post-fire summers (2003-04) in 24 landscapes (each 2.5 x 2.5 km) that varied in the pre-fire amount of merchantable mixed-wood forests (low, high), the intensity of post-fire logging (control i.e. no logging, and low, moderate and high) and burn severity. We sampled in the forest type subjected to salvage, viz. mixed-wood (trembling aspen and white spruce), and their adjacent coniferous (not salvaged) areas. Ground dwelling forest beetles mostly responded negatively to burn severity and salvage logging, with one fire specialist species as an exception. Also woodpeckers responded mostly negatively to salvage logging (with one exception) but often positively to burn severity. Songbird data showed that although salvage-logged areas still hosted most songbird species, these were several times less abundant there, and an analysis for the songbird community structure indicated a strong homogenizing effect of salvage logging on the bird assemblage.

A Tree-Centered Mechanistic Basis for Drought-Induced Bark Beetle Outbreaks in Arizona

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Bark beetle populations and mortality of ponderosa pine (Pinus ponderosa) increased dramatically in 2002-3 at the end of eight years (1996-2003) of below-average precipitation that included severe droughts in 1996, 2000, and 2002. We present a mechanistic explanation for the role of severe drought in causing bark beetle outbreaks in Arizona which emphases linkages among water availability, tree growth, constitutive resin defenses, and xylem cavitation. A synthesis of current and past studies reveals the following linkages: 1) Large differences in constitutive resin defense are associated with tree radial growth – resin defenses are generally greatest for trees with high growth rates. Tradeoffs between growth and resin defense can occur, but are weak and do not explain large differences in resin defenses. 2) Tree radial growth is positively associated with winter and growing season precipitation and even more strongly associated with a drought index based on water balance (Palmer). The strength of the relationship between growth and water availability is stronger at low- (hot) versus high-elevation (cool) sites. 3) Tree water potentials measured in previous studies and xylem vulnerability curves to water stress suggest that tree root systems lose much hydraulic capacity because of cavitation during severe droughts. Loss of hydraulic capacity because of cavitation likely results in a large decrease in photosynthesis which reduces photosynthate available for all carbon sinks, including growth and resin defense.

The Japanese *Laricobius*: Recently Discovered And Imported To The U.S. As A Potential Biological Control Agent For HWA

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Several predators are currently being investigated for their potential as biological control agents. On-going foreign exploration has revealed several new predators from China, including 2 *Laricobius* spp. and several cocinnellids. Mike Montgomery (USDA FS) recently initiated collaboration with Shigehiko Shiyake, a Japanese scientist at the Osaka Natural History Museum. While sampling *Tsuga seiboldii,* a previously unknown *Laricobius* species was discovered in May 2005. In March 2006, a collection trip was made and over 300 adult beetles were collected and brought back to the U.S. for study. Current investigation is focused on: female oviposition rate, a few host suitability tests, and developmental studies. Next year, we hope to conduct choice and no-choice feeding and oviposition tests, host suitability tests, and developmental studies.

An attractant bait for the invasive Mediterranean pine engraver

Jana C. Lee, Pavel Jiros, Shakeeb Hamud, Mary Louise Flint, Steven J. Seybold

The Mediterranean pine engraver (MPE), *Orthotomicus (Ips) erosus* (Wollaston) (Coleoptera: Scolytidae), was first detected in May 2004 in North America in the Central Valley of California. MPE is a pest of pines in the Mediterranean region, South Africa, and Chile, and they may also vector pathogenic fungi. In California, MPE has been found to colonize and develop in Monterey, aleppo, Scots, Canary Island, and brutia pine. Other frequently planted pines in the United States (Afghan, Coulter, Turkish, eastern white, shortleaf, and slash pine) may potentially be affected as they are recorded hosts in other countries. To optimize early detection of this new invasive throughout the U.S., we began developing an attractive semiochemical bait based on preliminary studies abroad. In a series of six experiments, we tested the attractiveness of various components in various combinations, release rates, and enantiomeric compositions. Twelve-unit funnel traps were baited with each treatment and replicated in four sites in Fresno, Kingsburg, and Visalia.

In study 1, treatments included: 1) unbaited control, 2) 2-methyl-3-buten-2-ol (MB), 3) racemic ipsdienol, 4) α-pinene, 5) MB and racemic ipsdienol, and 6) MB, racemic ipsdienol, and α-pinene. Adult beetles responded synergistically to MB and racemic ipsdienol; α-pinene slightly enhanced the response to the two-component attractant. However, this was only evident in one trap capture, and the role of α-pinene was revisited in study 6. In study 2, various release rates of MB in the presence of a constant racemic ipsdienol (200 μg/day) were tested. A low to moderate release rate of MB (0.5-60 mg/day) elicited the highest response from *O. erosus*. Study 3 tested the optimal release rate of racemic ipsdienol, and captures of MPE were similar whether racemic ipsdienol was released at low to high rates, 0.11-5.55 mg/day. Study 4 tested the enantiomeric specificity to ipsdienol, and compared the artificial baits to the natural pheromone produced by 25 males. MPE was highly attracted to the bait with (–)-ipsdienol, but inhibited by (+)-ipsdienol suggesting the racemic ipsdienol would not be effective. Also, the optimal bait outperformed the natural pheromone produced by 25 males by 3-5-fold, possibly because the release rates from artificial baits were much higher. Study 5 tested the synergism of MB and (–)-ipsdienol, and compared the attractiveness to the natural pheromone. Both MB and (–)-ipsdienol were not attractive alone, but attractive synergistically to MPE. Again, the optimal artificial bait attracted 3-6-fold more beetles than the infested log with pheromone-producing males. Study 6 is currently ongoing, and tests various α-pinene enantiomers. Treatments include an unbaited control, MB and (–)-ipsdienol, and these two components with racemic α-pinene 1X or 2X, with (+)-α-pinene, or with (–)-α-pinene.

Response to an Asian Longhorned Beetle, *Anoplophora glabripennis,* Detection In Sacramento, California

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The Asian longhorned beetle (ALB), a voracious pest of hardwood trees, was discovered on the grounds of a warehouse on McClellan Air Force Base, in Sacramento, CA on June 16, 2005. The beetle is native to China and Korea and has forced the removal of thousands of trees in Illinois, New Jersey, New York and Ontario, Canada.

The California Department of Food and Agriculture (CDFA) and Sacramento County Agricultural Commissioner's Office investigated the site and found a total of three Asian longhorned beetles. A live adult beetle was captured outside on the loading dock and two adults were found in the warehouse. Further investigation of the warehouse turned up wooden pallets with beetle damage. ALB has been found in the California warehouses before, however this is the first time that the beetle has been found outdoors. The new outdoor ALB find prompted officials to respond quickly by fumigating the warehouse and inspecting nearby street trees for the tell-tale signs of beetle activity (include tree symptoms). Smokejumpers from Redding, CA climbed trees in search for beetle activity. A scientific advisory panel was convened to help strategize the State's extended response to the potential threat. The panel provided trapping and survey recommendations for the McClellan site and also storage facilities in San Diego and Los Angeles Counties owned by the same company. Survey, treatment and eradication procedures will continue for the next few years at these locations to verify that the areas are beetle-free.

Distribution and biological control of Ambermarked birch leafminer in Alaska

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Ambermarked birch leafminer (ABLM) an invasive European sawfly was believed to have been introduced to Alaska sometime in the early 1990's. Currently, it infests 140,000 + acres of birch in urban and rural areas of South-Central, Interior and South-east Alaska. ABLM prevalence and abundance in urban and rural areas has been increasing in recent years and damage appears to worsen in hot, dry years. Current management options available to homeowners are limited to systemic soil drench or stem-injected insecticides. Similar outbreaks in western Canada during the 1970's and 80's were controlled by a native Ichneumonid parasitoid *Lathrolestes luteolator*. A classical biological control program was launched in 2003 to import, rear and release *L. luteolator* in Alaska to control ABLM. We adopted an adaptive approach for the introduction of *L. luteolator* to begin releasing parasitoids as early as possible to slow the spread of ABLM. Since 2004 we have reared and released 213 parasitoids (116♀:97♂) in Anchorage. We developed a successful method of field rearing parasitoids and optimized our method to synchronize parasitoid emergence with leafminer development. In 2006 we will evaluate the effectiveness of transporting larvae versus pupae, varying rearing site conditions and begin to monitor for parasitoid establishment.

Dr. John B. Simeone (1919-2005)
Forest entomologist and pioneer in chemical ecology

Albert E. Mayfield III and Douglas C. Allen

Through more than half a century of teaching, writing, research and service, John B. Simeone made many important and lasting contributions in the fields of forest entomology and chemical ecology. John served for 45 years as professor of entomology at the State University of New York in Syracuse, where his lecture series in chemical ecology with Dr. Ernest Sondheimer was published as a seminal text in the field. Along with Dr. Robert Milton Silverstein, John co-founded the International Society of Chemical Ecology and the

Journal of Chemical Ecology, which they co-edited for 20 years. John actively promoted international scientific exchange in forest entomology, including cooperative work in Burma, China, and former USSR republics. He had a special interest in the biology and ecology of wood-destroying insects and contributed to important research on bark beetle pheromones. John and his wife Etta established a graduate fellowship in forest entomology, providing financial opportunities for students to pursue the academic disciplines he loved. John was a warm-hearted, generous man who is dearly missed and remembered by family, friends, and a scientific community that continues to benefit from his foundational work.

The attraction of saprotrophic ambrosia and bark beetles (Coleoptera: Scolytidae) to coast live oaks (Quercus agrifolia) infected by Phytophthora ramorum

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The disease known as sudden oak death, caused by Phytophthora ramorum, has infected and killed large numbers of oaks (Quercus spp.) and tanoaks (Lithocarpus sp.) in California since the mid 1990s. Saprotrophic bark and ambrosia beetles that normally colonize dead or severely weakened trees selectively tunnel into the resulting bleeding bark cankers in coast live oaks, Q. agrifolia. This study was designed to determine the efficacy of permethrin in preventing beetle attacks and to evaluate the role of saprotrophic beetles in disease progression. In Marin County, California, coast live oaks were inoculated in July 2002 with P. ramorum, wounded but not inoculated, or left as controls. Sticky traps were placed on the half of each experimental group that was treated with permethrin. Following inoculation, traps on infected trees attracted 97% of the total beetle catch throughout 2003. Permethrin delayed the initiation of attacks and reduced the mean number of attacks per tree. Through December 2005, insecticide treatment had not affected disease progression or mortality. Prior to the first beetle attacks, larger canker size was the only significant predictor of beetle trap catch. However, once beetles attacked infected trees, those having the greater numbers of entrance tunnels caught significantly more beetles than trees with few or no attacks. Only the trees attacked by beetles developed fruiting bodies of the decay fungus Hypoxylon thouarsianum. In decreasing order of abundance, we trapped the scolytids Monarthrum scutellare, M. dentigerum, Xyleborinus saxeseni, Pseudopityophthorus pubipennis, Xyleborus californicus, Gnathotrichus pilosus, and the bostrichid Scobicia declivis. Trap catch in April 2003, prior to any beetle attacks, was positively correlated with advanced disease stage at the end of 2003. Numbers of beetle attacks in April 2003 were positively correlated with advanced disease stage in December 2003 and through 2005 on untreated trees. Trap catch was significantly

higher on beetle-colonized infected trees. The attraction of these saprotrophic beetles to P. ramorum cankers on coast live oaks may be due to a kairomone-mediated shift in host selection behavior, from weakened or recently dead trees to discreet infection sites on otherwise sound trees.

Attracting and Trapping Native and Non-Native Siricids (Woodwasps) in Louisiana, U.S.A.

James Meeker, William Ross, Brian Strom and Wood Johnson

Due to the potential pest threat posed by the recent introduction of *Sirex noctilio*, the U.S.D.A. Forest Service's Early Detection and Rapid Response (EDRR) program initiated trapping trials in several states in 2005 to develop more effective detection and monitoring methods. Evaluations were based on the catches of native and other established non-native Siricids serving as surrogates for *S. noctilio*. In the Louisiana trial the trap systems that were evaluated included: baited 12-unit Lindgren funnel traps and baited Intercept™ panel traps, baited sticky panels and unbaited traps (funnel trap and sticky panels) on experimentally debilitated trees. Experimental 'trap trees' were created by applying a mixture of Metam-Sodium+DMSO (MS+DMSO) to evenly separated hatchet frills encircling the base of the tree, a technique known to create trees attractive and susceptible to a variety of pine infesting insects. Baited traps contained a Hercules turpentine 170 g UHR sleeve and an ethanol 120 g UHR sleeve (Synergy Semiochemicals Corp.). The study was located in a 22 yr-old loblolly pine plantation in Winn Parish, which had been commercially thinned in April-May, just prior to deployment of traps on June 7. Four replicates of each of the four trap systems were installed with at least 30 m between traps and 0.2 km between replicates. Lures were replaced monthly and unbaited traps moved to a corresponding set of four new chemically-debilitated trees following treatments on May 25, June 29, August 18 and Nov. 17. Traps were serviced and maintained bi-weekly until Nov. 10, when the original site was abandoned for administrative reasons, and the study reinstalled in a similarly treated nearby pine stand on Nov. 17.

A total of 57 Siricidae, all females, was collected between June 15 and Dec.15. Thirteen *Eriotremex formosanus*, a non-native species introduced into the southeastern U.S. in the mid to late 70's, were collected beginning on June 15 and ending on Oct.12, prior to detecting any native species. Peak catch of *E. formosanus* occurred on Sept.14, when six specimens were collected. The natives, *Sirex nigricornis* and *S. edwardsii* were both first collected on Nov.10. Twenty-two specimens of each of the native species were collected, with the last catch of *S. nigricornis* occurring on Dec. 1, and for *S. edwardsii* on Dec. 15. Peak catch of both species occurred on Dec.1, when 18 and 19 specimens of each were collected, respectively. Baited panel traps caught the greatest number of siricids (30) followed by baited funnel traps (15), unbaited traps on MS-DMSO treated trees (10) and lastly baited sticky panels (2). Although baited traps caught the most siricids, we were unable to compare their catch with that at trap trees because our experiment was displaced during the short flight period of the native species. Based on the catch of *E. formosanus* we believe that trap trees may offer an improved means of detecting, investigating and potentially managing siricids. However, more robust evaluations are needed and planned for 2006. A Special Technology Development Project (STDP) has been initiated this year to further explore the creation and attractiveness of 'trap trees'--created with the herbicides dicamba and glyphosate, in addition to MS+DSMO treatments-- and comparing trap catches at these trees against traps baited with the EDRR national trapping protocol and other suspect attractants including ethanol and *Ips* bark beetle pheromones.

Ips pheromones attract southern sawyer beetles and southern pine engravers

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The effects of ipsenol (+50/-50), ipsdienol (+50/-50) and lanierone on catches of bark and wood boring beetles in eight-unit multiple-funnel traps were determined in 2003-2004 in Florida, Georgia, Louisiana and North Carolina. We found that the southern sawyer beetle, *Monochamus titillator* (Cerambycidae) was attracted to traps baited with ipsenol and/or ipsdienol in all four southern states. In North Carolina, the pine engraver, *Ips pini* (Scolytidae) was attracted to traps baited with ipsdienol and lanierone. Ipsenol interrupted attraction of *I. pini* to traps baited with ipsdienol although interruption was nullified by lanierone. In Florida and North Carolina, catches of the small southern pine engraver, *Ips avulsus* were highest in traps baited with all three compounds whereas the highest catches of *I. avulsus* in Georgia and Louisiana were in traps baited with ipsdienol and lanierone with no effect of ipsenol. In Florida, catches of the eastern fivespined ips, *Ips grandicollis* were highest in traps baited with ipsenol and ipsdienol with no effect of lanierone whereas in Georgia, North Carolina and Louisiana catches of *I. grandicollis* were highest in traps baited with ipsenol with no effect of ipsdienol or lanierone. The combination of (±)-ipsenol, (±)-ipsdienol and lanierone seems to be an effective lure combination for detecting the southern pine sawyer and southern species of pine engravers.

Flight responses of root-feeding weevils to baited funnel traps in Florida

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In 2001-2004, the effects of various trapping parameters on the flight response of root-feeding weevils were determined in pine stands of northern Florida. We found that the pales weevil, *Hylobius pales*, and the pitcheating weevil, *Pachylobius picivorus* (Curculionidae) preferred 8-unit traps baited with the combination of ethanol and (–)-α-pinene over control traps or traps baited solely with ethanol or (–)-α-pinene. Attraction of *P. picivorus* was unaffected by enantiomeric composition of α-pinene. In contrast to bark and ambrosia beetles, weevils preferred 8-unit funnel traps baited with ethanol and (–)-α-pinene over 16-unit traps baited with the same lures. In funnel traps baited with ethanol and (–)-α-pinene, we found that cups using propylene glycol as the killing agent contained more weevils than those using Vaportape insecticidal strips suggesting that attraction of weevils may be interrupted by volatiles emitted by Vaportape strips or enhanced by those emitted by propylene glycol. Alternatively, the number of weevils escaping from cups containing Vaportape may simply be higher than those from cups containing glycol. We found no effect of trap design on catches of weevils.

Attraction of ambrosia beetles to ethanol and (-)-α-pinene in the South

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In 2002-2004, the effects of ethanol and (–)-α-pinene (released at high rates) on catches of ambrosia beetles (Scolytidae) in eight-unit multiple-funnel traps were determined in Alabama, Florida, Georgia and South Carolina. We found that some species such as *Xyleborus pubescens* preferred traps baited with the combination of ethanol and (–)-α-pinene. Other species such as *Xyleborus crassiusculus*, *X. affinis* and *Xyleborinus saxesenii* preferred traps baited solely with ethanol with little, if any, effect by (–)-α-pinene. Attraction of some species such as *Monarthrum mali* to ethanol-baited traps was interrupted by (–)-α-pinene. Exotic ambrosia beetles were more common than native species of ambrosia beetles with the percentage of exotic beetles ranging from 53% to 78% of all ambrosia beetles captured in the study.

Optimizing efficacy of experimental design in beetle trapping experiments

Sylvia Mori (USDA FS, PSW Research Station, Berkeley, CA)

Beetle trapping experiments present several challenges to researchers. First, the responses are counts, so the statistical analysis cannot be accommodated with the usual analysis for normally distributed data. Second, there is often a strong “location” effect, so a statistical model should be able to account for this random effect. A Generalized Linear Model (GLM) for over-dispersed Poisson distributed data could serve that need by accommodating both count distribution and random effect. However, when faced with comparing treatments, researchers still need to select a sampling design that minimizes that location effect. Variance of the estimated difference of treatments’ mean effects and their P-values are used as a measure of the sampling design efficacy for four Completely Randomized Designs (CRD), and for three one-replication Randomized Complete Block Designs (1-Rep RCBD). These sampling designs are the most frequently used in forest entomology research. Smaller variances and smaller P-values can be thought to yield more efficient sampling designs. Six of the presented experimental designs involve repeated measures for counts responses. The four designs CRD are: (1) the Completely Randomized Design (CRD), (2) the Completely Randomized Design with repeated measures (CRDRep), (3) the Completely Randomized

Design with re-randomized repeated measures (CRDRan), and (4) the Completely Randomized Design with rotated repeated measures (CRDRot). And the three RCBD are: (1) the 1-Rep Randomized Complete Block Designs with repeated measures (RCBDRep), (3) the 1-Rep Randomized Complete Block Designs with re-randomized repeated measures (RCBDRan), and (4) the 1-Rep Randomized Complete Block Designs with rotated repeated measures (RCBDRot). Three sources of variability are assumed: Location, Location-treatment interaction, and the natural variability in insect abundance. Each sampling design is matched to a statistical model for over-dispersed Poisson counts that includes the three sources of variability. Each the statistical models considered belongs to a GLM family with treatment as a fixed effect, and location and location-treatment interaction as random effects. For some of the models some of the random effects variance components are not estimable. The variance of two estimated treatment effects' difference and their P-values within each sampling type (CRD or RCBD) are compared via simulated data. The estimations are done with the SAS 9.1 Glimmix procedure that relies on Wald-type test statistics. The simulated data shows that the sampling designs that re-randomize or rotate the treatments to other locations at sampling time yield smaller variances and P-values.

PHORETIC MITES THAT DRIVE DUTCH ELM DISEASE

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Ten species of mites are known to be phoretic on *Scolytus* spp. infesting elms in Austria. In addition to the beetles, only females of *Tarsonemus crassus*, and *Proctolaelaps scolyti* carry enough spores to significantly infect trees with DED (*Ophiostoma novo-ulmi*). *Pr. scolyti* is the larger of these two mite species, and possesses opposed edentate chelae for grasping, enabling this mite to ingest large numbers of whole spores from the beetle galleries. The smaller *T. crassus* has fused fixed digits for piercing, permitting only the ingestion of liquids, perhaps from DED hyphae.

Although both mite species carry ascospores and conidia of DED on the surfaces of their bodies, *T. crassus* carries most of its spores in two paired structures under tergite 1 termed sporothecae, which function similar to those of "sportcoat pockets". Both ascospores and conidia of DED may be stuffed into these mite “pockets”.

Larvae of *Scolytus* spp. feeding in galleries cannot develop in presence of DED, whereas this pathogen may be essential to the nutrition of both *T. crassus* and *Proctolaelaps scolyti*. Hence it should not be in the interest of *Scolytus* spp. to transport DED; whereas it should greatly enhance the survival of the spore-feeding mites to do so. It therefore appears that populations of these two mites, and not *Scolytus* spp., may be the most meaningful drivers of DED in Austria, at least.

Host Resistance to Balsam Woolly Adelgid in an IPM Strategy for Christmas Trees

Leslie Newton, Fred Hain, John Frampton
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The balsam woolly adelgid (*Adelges piceae* Ratz.) (BWA), a tiny piercing-sucking insect specific to the genus *Abies*, was introduced into the southern Appalachians in the 1950 and rapidly caused extensive damage to native Fraser fir (*Abies fraseri* [Pursh] Poiret) stands. The BWA is also a major pest in Fraser fir Christmas tree plantations throughout the southern Appalachians. Chemical treatments for BWA cost the industry over $1.5 million annually and minimize the effectiveness of IPM practices. The insect and its effect on fir species have been researched extensively for the past century. Much is known about the biology of the BWA and the reaction of various fir species to infestation, but little is known about host resistance and the mechanisms of resistance. The general consensus at the current time is that host resistance—inherent or bred—is the primary hope for the continuation of native stands of Fraser fir and for lessening the financial burden on Christmas tree producers. This proposed research relates to the development of reliable techniques for artificially infesting and bioassaying fir seedlings for resistance to BWA, and screening for host resistance across multiple fir species and within Fraser fir. Four studies, which will take place during the growing seasons of 2006 and 2007, are outlined. The first will compare different infestation techniques and the other three are resistance screening trials.

Roger Anderson and the Roger F. Anderson Outstanding Graduate Student Award

Fred P. Hain, Department of Entomology, NC State University

Roger F. Anderson was Professor of Forest Entomology at the School of Forestry, Duke University for 30 years; during which time he advised many graduate students who went on to distinguished careers in forest entomology. He was the first recipient of the A. D. Hopkins Award given by the SFIWC for outstanding service to the discipline of forest entomology. He published many scientific articles and was the author of a textbook, which was in print for over 20 years. The SFIWC is honoring the memory of Dr. Anderson by establishing the Roger F. Anderson Outstanding Graduate Student Award. This award will be given annually, starting in 2007, to recognize excellence in research and outstanding contributions to forest entomology by a graduate student.

Invasive Plants Established in the United States that are Found in Asia and Their Natural Enemies

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Invasive Plants of Asian Origin Established in the United States and Their Natural Enemies (Volume 1) and *Invasive Plants Established in the United States that are Found in Asia and Their Associated Natural Enemies (Volume 2)* were published by the USDA Forest Service-Forest Health Technology Enterprise Team (FHTET) in December 2004 and December 2005, respectively. Due to demand, both volumes have been updated and being reprinted.

Invasive species are significant threats to the integrity and health of the nation's forests and grasslands. In order to meet the challenge of dealing effectively with invasive plants, background information is needed to better understand them in their native range. This two-volume set is the first of its kind in that all of the information was obtained by searching and reviewing the Chinese literature, as well as discussions with Chinese scientists. Prior to these publications, this information was scattered, inaccessible or available only in Chinese. These volumes represent a three-year (2001-2004) effort involving the Chinese Academy of Agricultural Sciences-Institute of Environment and Sustainable Development in Agriculture, and the USDA Forest Service-FHTET, and International Programs.

The two volumes, co-authored by Hao Zheng, Yun Wu, Jianqing Ding, Denise Binion, Weidong Fu, and Richard Reardon, summarize existing information on more than 80 species of plants that either are of Asian origin or found in Asia and introduced into and established in the United States.

The two-volume set contains background information on the biology of each plant species, an image of the plant to help with identification, maps of its China and U. S. distributions, a glossary of botanical terms, and a scientific name index. Also, included are tables of fungal and arthropod natural enemies for each plant species and over 200 references for each volume.

Copies of this publication can be ordered from Yun Wu or Richard Reardon, USDA Forest Service, 180 Canfield Street, Morgantown, West Virginia 26505, Phone: (304) 285-1594 or (304) 285-1566, or email: ywu@fs.fed.us or rreardon@fs.fed.us.
Online versions are also available at: http://www.invasive.org/weeds/asian/ for volume 1 and http://www.invasive.org/weeds/asianv2.pdf for volume 2.

RECENT BARK BEETLE RELATED PROBLEMS IN CROATIA WITHIN THE WIDER EUROPEAN SCALE

Milan Pernek, Boris Hrašovec

Bark beetle damages in the forests increased during the last few years in Croatia. On a national level this is considered as a new trend in forest health status. At the same time this has been present in a larger European scale for more than 10 years minimum. Most of the dominant damaging bark beetle species listed in Europe, like *Ips typographus*, *Pityokteines chalcographus*, *Ips acuminatus*, *Tomicus piniperda*, *Ips sexdentatus*, *Tomicus minor*, *Trypodendron lineatum*, *Ips amitinus* and *Pityokteines curvidens* (Gregoire&Evans 2004), cause timber losses also in Croatia. However, some of them, like *Ips duplicatus* or *Dendroctonus micans* so far haven't been recorded in Croatian forests, while others, like *Pityokteines spinidens* or *Tomicus* spp. seem to be much more damaging than in the rest of the Europe.

It is well known and thoroughly documented that *Ips typographus* and *Pityokteines chalcographus* are the most important European bark beetles attacking more than 3 million ha of spruce forests in the last ten years and causing death of trees and timber loss of 40 million m^3. These two bark beetles are present in Croatia but the area of forests with spruce being a dominant species is negligible compared to forest types throughout the rest of Europe. Definitively, this is reflected in the relative insignificance of spruce timber in the gross national timber production. Silver fir, on the other hand, is the most important conifer species in Croatian forests where the increasing fir bark beetle outbreaks in the north caused timber losses from a few thousand m^3 in 2002, 60.000 m^3 both in 2003 and 2004 and up to 170.000 m^3 in 2005.

As another differing example, it can be said that there has been no consistent evidence of bark beetle outbreaks in the genus *Tomicus* in European scale, while these seem to appear in recent years in the central part of Croatia where *T. piniperda* and *T. minor* attacks clearly caused death of pine trees, much in a pattern known for the most dangerous and aggressive spruce bark beetles like *I. typographus*.

All wood is not created equal: Importance of wood quantity and decay stage for carabid beetles (Coleoptera: Carabidae)

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Downed wood (DW) serves as an important habitat component for many organisms. Although the importance of DW to these organisms is assumed most studies do not directly study the relationship between DW and organism use of this resource. We surveyed carabid beetles using pitfall traps and meander surveys in piles of DW that varied by volume of wood and decay stage in the following classes: 1) very low volume (small branches and twigs), 2) one large tree (early decay), 3) one large tree (advanced decay), 4) two large trees (early decay), and 5) two large trees (advanced decay). Pitfall traps were placed adjacent to the wood piles and carabid abundance, species richness, and species-level relationships were compared among the five DW classes. Five replicates of each DW class were chosen within each stand and twelve stands Michigan's Upper Peninsula were used for this study. Four stands were heavily infested with beech bark disease, four stands were selectively thinned ten years prior to this study, and four stands were undisturbed. Carabid abundance and species richness increased as volume and decay of DW increased. Carabid abundance was highest in stands with beech bark disease which may be due to increased DW available from beech tree mortality. Overall advanced-decayed wood had significantly higher carabid abundance and species diversity compared to wood in the early decay stages. Carabid abundance among DW classes varied by species with seven out of nine species highly correlated with specific DW types. Since certain species favored specific DW classes preliminary results suggest that a variety of types of DW is necessary to maintain biological diversity within forest stands.

MODELLING THE PINE PROCESSIONARY MOTH RANGE EXPANSION IN THE PARIS BASIN

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The geographic range of the winter pine processionary moth (PPM), *Thaumetopoea pityocampa* (Den. & Schiff.) (Lep.: Notodontidae) is currently expanding northwards and at higher elevations in South-central Europe. For example, in the Paris Basin the PPM front has shifted northwards by 5.6 km per year during the last 10 years while the minimum winter temperatures increased by about 1°C.

In order to understand this expansion process and the effect of climate warming on PPM dynamics, we coupled several models: a diffusion model to describe the dispersal capacity of the female moths, a delayed Ricker model to describe the population growth and its self-limitation according to pine density, and a mortality function associated with climatic conditions. The mortality function was based on the climatic conditions required by the PPM larvae to feed on needles, i.e; a nest temperature above 9°C during the day and an air temperature above 0°C during the following night. These eco-physiological constraints were determined by lab and field experiments. When we reconstructed PPM feeding ability in the Paris Basin during 1992-1996, we observed that this area was divided into two zones favourable for PPM development, a southern area around Tours (historically colonized) and a northern area near Paris (not colonized), crossed by a stripe where conditions were not favourable. PPM feeding conditions became more favourable in 2000-2004, and the in-between stripe finally turned favourable enough to enable PPM to progress towards Paris. The mean of minimum temperatures from October to March was identified as a simple climatic indicator of the feeding ability. This variable clearly showed a warming trend since the late 1980s. Since PPM would encounter favourable conditions nearly everywhere in the Paris

Basin, the effective shift would mainly depend on its dispersal capacity and the pines distribution.

Our mathematical model supplied a nice simulation of the past dynamics of PPM (especially the retraction of PPM front during cold winters) as well as the expansion since the early 1990s. We also showed that females could disperse at longer distance than previously known *i.e*. within 3-4 km *vs* 2 km. When a GICC climate scenario for next 50 years was included, the model forecasted that PPM could arrive in downtown Paris by 2025 if nothing is done to slow its spread.

The Use of Mobile Mapping Technology to Automate Surveying and Monitoring Southern Pine Beetle Infestations: Development and Implementation

Saul D. Petty, USDA Forest Service, Forest Health Protection

This poster deals with the development and subsequent implementation of a mobile mapping system designed to improve data collection and storage for the Southern Pine Beetle Information System (SPBIS). SPBIS is an ORACLE database which is maintained by the USDA Forest Service, Forest Health Protection. Improvements to SPBIS will aid in management of Southern Pine Beetle (SPB) infestations to reduce losses, and to assist resource managers. The time required to manually enter data into the database is substantial. Due to negligent data entry practices the database is lacking many years of survey and infestation data which limits its usefulness. This system introduces a custom digital data collection form which runs within ArcPad® mobile GIS software. Ultimately, this system eliminates the need for manual entry of field-collected data, while improving field data collection in terms of efficiency and accuracy. The system is currently in the implementation stage. National Forests in Alabama have been trained to use the system operationally and National Forests in Mississippi are scheduled for training in early summer 2006. The system will eventually be distributed throughout the Southern Region (R8). Development of the system will be continuous to keep pace with changing technologies.

Development and Evaluation of an Improved Releaser for Bark Beetle Semiochemicals

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Semiochemicals have been used for decades to affect behavior of bark beetles. Extensive evaluation in the laboratory and field has produced many attractant and antiaggregant compounds; however, results have been inconsistent when semiochemicals have been applied in real-world management situations targeting forest-dwelling scolytids. Semiochemical release devices have remained primarily passive (those with wicks or membranes, etc.) and therefore respond significantly to meteorological conditions. This uncontrolled release can be problematic in that the effective radius from each lure varies with meteorological conditions, and release devices are prone to emptying faster than planned or disposed of prematurely.

This project, funded by the Special Technology Development Program (Forest Health Protection, USDA Forest Service), is beginning its third year. The project brings together USDAFS personnel and Med-e-Cell to develop improved release devices for semiochemicals. Med-e-Cell is a company based in Southern California with expertise in pumping small amounts of fluids at precisely metered rates. The project has two goals: to develop a releaser for the semiochemical antiaggregant verbenone that elutes 300 mg per day, and to develop a releaser for the general attractant ethanol that releases 1 g per day. In each case the releaser is designed to elute the semiochemical at a consistent rate over a range of environmental conditions greater than that likely to be observed during field deployment.
The centerpiece of this project is a semiochemical releaser that is based on a miniature gas generator developed by Med-e-Cell. The gas generator pressurizes the container holding the target fluid, which then moves it to a destination outside the device where it is released. The volume of liquid pumped can be controlled very precisely, and relatively independent of meteorological conditions, by varying certain engineered components of the releaser, especially the electrical current (supplied from a tiny hearing aid battery) that reaches the gas generator. Med-e-Cell's products have been used primarily to deliver pharmaceuticals to patients; however, for the past number of years Med-e-Cell has been working with USDA Forest Service personnel to develop a new generation of releasers that elute semiochemicals consistently over a wide range of environmental conditions.

We have evaluated the fourth generation of the verbenone device engineered by Med-e-Cell under this project and are awaiting the fifth for testing. Data generated so far suggest that Med-e-Cell's verbenone devices nearly meet our project goals, with final improvements being implemented in the fifth version. The ethanol device (1 g / day release rate) has been developed and will be evaluated this field season.

Climatic Variables Can Determine the Ultimate Distribution of Hemlock Woolly Adelgid in Eastern North America

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Since 1951, when the hemlock woolly adelgid, *Adelges tsugae* Annand, was first documented in Richmond, Virginia, populations of this exotic insect pest have spread to 17 states, and infest much of the range of eastern and Carolina hemlock. Pest management tactics under development for control of hemlock woolly adelgid include the use of both chemical and biological controls. To maximize the efficacy and efficiency of these management tools, it is important to understand characteristics of the landscape, such as climate parameters, which act to control the spread of adelgid and limit its potential landscape distribution. Using 70 locations across the eastern U.S., we take advantage of both latitudinal and continental gradients to show that ~60% of the variation in rates of winter adelgid mortality is explained by mean (30 year) minimum January temperatures based on a Krieged temperature estimate for the landscape using data from 2800 weather stations. These results also suggest that the use of contemporary weather data from the weather station nearest to the point where adelgids were collected increases the explanatory power to ~90%. Temperature variation also appears to play a role in the survivorship of hemlock woolly adelgid, such that insect mortality appears positively correlated with the difference in mean temperature extremes during winter months. These data suggest that the ultimate limits of adelgid range expansion can be estimated using landscape climatic analyses in combination with field observations, and that further regional sampling can be used to refine the estimates of the potential maximal range of hemlock woolly adelgid in eastern North America.

Modeling the Eastern Spread of the Mountain Pine Beetle in Canada

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The mountain pine beetle, *Dendroctonus ponderosae* Hopk., has been epidemic in British Columbia for the past 15 years. During this time the area of lodgepole pine, *Pinus contorta latifolia*, tree mortality has expanded to over 8 million hectares (20 million acres). Due in part to changing climate the epidemic has expanded to areas that were previously considered to be climatically unsuitable to the beetle. Currently the mountain pine beetle is killing trees in western Alberta in Banff and Jasper National Parks, and the Willmore Wilderness Area. There is serious concern that if the beetle can continue to move eastwards across Alberta that it will become established in jack pine, *Pinus banksiana,* the range of which extends across Canada.

We have developed a graph-based connectivity model to identify the least cost path of spread of the mountain pine beetle through susceptible host. Based on a stand level mountain pine beetle susceptibility rating system, the most likely routes of epidemic spread are identified. By examining areas of high and low host connectivity recommendations can be made on where to focus management efforts to reduce the risk of spread.

Resurrected from the ashes: A historical reconstruction of emerald ash borer dynamics through dendrochronological analyses

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Presentation Description: Emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), was identified in June 2002 as the cause of widespread ash (*Fraxinus* spp.) mortality in southeastern lower Michigan and Windsor, Ontario. We are using dendrochronological analyses to reconstruct the historical dispersal patterns and rates of spread of emerald ash borer throughout the core infestation in southeastern lower Michigan and several isolated outlier populations. Increment cores or cross-sections from emerald ash borer-killed ash trees were collected on at least a 4.8 × 4.8 kilometer grid over an area greater than 15,000 square kilometers encompassing the core emerald ash borer infestation. Results to-date on the reconstruction of the temporal and spatial dynamics of emerald ash borer using crossdating techniques and other dendrochronological analyses will be presented.

Modeling the spread of isolated emerald ash borer populations

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Emerald ash borer is an exotic, invasive beetle capable of causing widespread ash mortality throughout North America. Since its discovery in 2002 in southeastern lower Michigan and adjacent parts of Ontario, survey efforts have identified localized outlier populations across much of lower Michigan and in areas of Indiana, Ohio and Ontario. The ability to predict the temporal and spatial dynamics of emerald ash borer in outlier populations is needed for continued development and evaluation of effective management strategies. Results to-date on the development of coupled map lattice models to predict the spread and dispersal of emerald ash borer at outlier sites will be presented.

The bark beetle, *Pseudips mexicanus* Hopkins

Greg Smith

The bark beetle, *Pseudips mexicanus* Hopkins is often found cohabitating stressed lodgepole pine trees with endemic mountain pine beetles (*Dendroctonus ponderosae* Hopkins). A native to British Columbia, *P. mexicanus* is not an economic pest; hence little is know about it. A description of the life history of *P. mexicanus* was undertaken, allowing discussion of interactions between the two species. Experiments were conducted to determine the key developmental and behavioural parameters of this beetle using a series of growth chambers maintained at seven different temperatures over the summers of 2004 and 2005. The parameters measured included number of degree days required for development from egg to mature adult (950 DD at 26.5 ^{o}C), mean ovipositional gallery length (5.9 ± 0.28 cm), number of larval instars (4), mean sex ratio of offspring (2 females to 1 male) and mean pronotal width of each sex (Female =1.63 ± 0.006 mm, Male = 1.74 ± 0.008 mm). The effect of interactions between *P. mexicanus* and endemic mountain pine beetles on the latter's resource use and brood characteristics, is currently unknown. A second facet of this study evaluated the effect of *P. mexicanus* on the quantity of resources available to endemic mountain pine beetles and the subsequent effect on brood characteristics. Specific measures of interaction were assessed, such as ovipositional gallery overlap, ovipositional gallery lengths, mountain pine beetle brood size and emerging sex ratio. Preliminary results suggest that endemic mountain pine beetles produce similar sized broods in trees occupied by *P. mexicanus* and in trees colonized by mountain pine beetles alone. Three management applications are discussed.

Estimating Snag Densities Using Aerial Survey Data

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Forest land managers interested in maintaining healthy forest ecosystems must evaluate effects of existing or proposed management activities on organisms that use snags, down wood and other wood decay elements. Recent development of the "DecAID Advisor" has provided an important tool for helping estimate dead wood requirements in analysis areas. DecAID is an internet-based synthesis of published scientific literature, research data, wildlife databases, forest inventory databases and expert judgment and experience. It addresses current vegetative conditions (un-harvested and managed); provides relevant summaries of snags and down wood; and presents information on wildlife use of snags and down wood. It also provides information on insects and pathogens and their role in creating and retaining dead wood.

One important aspect of dead wood analyses is ascertaining the current status of snags and down wood within and in the vicinity of a project area. This project examines how aerial survey data can aid managers in developing a picture of the 'current situation' for the incidence and condition of snags (which are potential down wood) across a landscape.

The study area, located in south-central Oregon, consists of federal lands within the Upper Sycan River Watershed. Two wildlife habitat types (WHT) were sampled, the Ponderosa Pine/Douglas-fir (PPDF) and Eastside Mixed Conifer (EMC_ECB). In order to use aerial survey data to estimate snag densities, we developed aerial survey code conversion factors based on inventory plot (CVS, FIA, and BLM) summaries of snag data from each WHT. Ten years of cumulative mortality data, as recorded by aerial detection surveys from 1995-2004, were then compared to ground data collected from stratified systematic random samples within two wildlife habitat types.

Aerial survey data consistently provided a conservative estimate of snag densities in the study watershed in both the PPDF and EMC_ECB WHT in all diameter breakpoints. Furthermore, aerial survey data predicted that as a percent of forest cover, snag density distribution categories exceeded those of "ideal" unharvested conditions for the $\geq$ 10" diameter category within the PPDF WHT. Our analysis shows that this approach to snag density estimates provides a cost effective method for estimating snag densities at 5th field watershed scales.

CONIFER WOODWASPS OF WEST VIRGINIA: SEASONAL OCCURRENCE AND RESPONSE TO SEMIOCHEMICALS

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Recently the Sirex Woodwasp, *Sirex noctilio* (Hymenoptera: Siricidae), was discovered beyond a port-of-entry, in Fulton County, New York on September 7, 2004. It is a serious pest of many North American pines in several Southern Hemisphere countries and, therefore, considered a high risk pest in North America. Since its introduction, there has been an ongoing effort to develop efficient survey tools to delimit its distribution. This project utilized native *Sirex* species as surrogates for *S. noctilio*. In 2005, we established red spruce (*Picea rubens*) and eastern white pine (*Pinus strobus*) sites in the Allegheny Mountains, to evaluate semiochemicals for more efficient monitoring of native and invasive woodwasps. Species response varied over time and forest stand type. A total of six siricid species responded to the lures (*Sirex cyaneus, S. edwardsii, S. juvencus juvencus, S. nigricornis, Urocerus albicornis,* and *U. cressoni*). Ethanol alone or in combination with α-pinene was a primary attractant for all species. Results indicate that response to trap type (Lindgren funnel *vs*. Intercept panel trap) was the same throughout the season. Frequency and abundance of species occurrence was greatest from July through October. In our study, *S. edwardsii* and *S. nigricornis* were only found in pine stands, *S. juvencus juvencus* and *U. albicornis* in spruce stands, and *S. cyaneus* and *U. cressoni* associated with both pine and spruce stands. Species determinations were verified by Nathan Schiff, USDA Forest Service, Southern Research Station, Stoneville, MS.

Spatial Separation of Release Points Enhances the Synergy of Two Aggregation Pheromone Components of the Southern Pine Beetle, *Dendroctonus frontalis*

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(+)-*endo*-Brevicomin, a pheromone produced by male southern pine beetle, is a potent synergist for the female-produced aggregation pheromone, frontalin. In a trapping experiment conducted >1 mile from the nearest active *D. frontalis* infestation and employing >100 meter trap spacing, we found that attraction to traps baited with (+)-*endo*-brevicomin, frontalin, and turpentine was significantly enhanced when the (+)-*endo*-brevicomin release device was relocated 4-16 meters from the traps. In a second experiment, a trap was baited with all three substances while two additional traps baited with frontalin/turpentine alone were placed on opposite sides and at 1 and 4 meters distance from the middle trap. When the (+)-*endo*-brevicomin dose at the middle trap was either 0.05, 0.5 or 5 mg per day, all three traps of the trio caught significantly more beetles than when no *endo*-brevicomin bait was present, with mean catch at all positions increasing with increasing concentrations of (+)-*endo*-brevicomin. Furthermore, for both the 0.5 and 5.0 mg/day (+)-*endo*-brevicomin doses, beetle catch at the 4-meter trap was significantly greater than at the middle trap, while mean catch at the 1-meter trap was intermediate between the other two traps. When the (+)-*endo*-brevicomin dose was 0.05 mg/day, beetle catch did not differ significantly among the three traps of the trio.

Our results indicate that the attractive effect of relocating (+)-*endo*-brevicomin baits away from frontalin/turpentine-baited traps cannot be explained simply as the result of reduction in concentration of (+)-*endo*-brevicomin at the traps themselves. Rather, the beetles must be detecting the physical separation of the pheromone release points using qualities of the odor plume that are, at least in part, independent of pheromone concentration. The ability to detect spatial separation of frontalin and *endo*-brevicomin sources may aid dispersing beetles in locating ideal sites for reproduction, namely, sites with trees containing established beetle pairs (producing *endo*-brevicomin) as well as trees containing attacks by pioneer females (producing frontalin). Multi-tree infestations containing both fresh and established attacks have a good probability of future growth; hence they may provide dispersing *D. frontalis* with relatively greater opportunities for reproductive success.

Previous to our work, *endo*-brevicomin had been considered to be a potent attractant antagonist for *D. frontalis*. We believe that this conclusion resulted from misinterpretation of trapping experiments that employed inadequate trap/bait separation. Our data show that the addition of *endo*-brevicomin to traps baited with frontalin/host terpenes would be incorrectly interpreted as causing antagonism if the positive control traps (those with frontalin/host terpenes alone) were positioned fewer than ~30 meters away. Our data therefore reveal a major potential pitfall in researchers' use of attractant-challenge tests to identify bark beetle repellants and aggregation inhibitors.

(+)-*endo*-Brevicomin is a Male-Produced Component of the Aggregation Pheromone of the Southern Pine Beetle, *Dendroctonus frontalis*

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Aggregation pheromones are essential to the ability of southern pine beetle, *Dendroctonus frontalis* Zimmermann, to organize lethal mass attacks on healthy, mature pine trees. Studies conducted in the late sixties and early seventies identified frontalin, a bicyclic ketal produced by female beetles, as the major aggregation pheromone for *D. frontalis.* Frontalin in combination with host-produced compounds (turpentine or alpha-pinene) was found to be highly attractive to *D. frontalis*, particularly males, and since the mid 1980's this bait has been used in an annual, south-wide trapping survey for predicting regional population trends for this pest. However, frontalin/host odor combinations alone fail to duplicate the attractiveness of naturally-infested hosts, and the aggregation pheromones for other pine-infesting *Dendroctonus* species in North America have generally been shown to consist of both female and male-produced components. We therefore conducted studies to identify possibly overlooked pheromone components in male *D. frontalis*.

Coupled gas chromatography-electroantennographic detection (GC-EAD) studies revealed that *endo*-brevicomin present in male beetles consistently elicited stronger responses from the antennae of both sexes than frontalin or any other compound isolated from *D. frontalis*. The antennae of both sexes were much more sensitive to the (+) than the (-)-enantiomer of *endo*-brevicomin, and coupled gas chromatography-mass spectrometry (GC-MS) analyses of headspace collections and hindgut extracts revealed that males produced only the (+)-enantiomer. Male production of (+)-*endo*-brevicomin increased approximately ten-fold following pairing with a female, while, in contrast, all other olfactory stimulants in newly-emerged male beetles were found to decrease in concentration following pairing. Addition of baits releasing 200 micrograms per day (+)-*endo*-brevicomin to traps baited with frontalin and turpentine increased catch of female *D. frontalis* 75-fold and males 30-fold. However, (+)-*endo*-brevicomin alone or in combination with host odors failed to attract more *D. frontalis* than unbaited traps. Based on these data, we believe that (+)-*endo*-brevicomin is a potent aggregation synergist for *D. frontalis*, and that it is a male-produced aggregation pheromone component roughly analogous to frontalin in male *D. brevicomis* and *D. ponderosae*, and *exo*-brevicomin in male *D. adjunctus.*

Digital image and regression analysis to quantify viable beech scale

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Beech scale, *Cryptococcus fagisuga*, (Hemiptera: Margarodidae) is a non-native invasive insect associated with beech bark disease. Studies involving quantitative estimates of scale density have relied on subjective classification schemes based on visual inspection of scale wax masses. We developed a method of quantifying viable scale in order to provide more precise determinations of scale density at the levels of the individual tree and more localized bark patches. We removed 10 x 10 cm bark patches with a chainsaw at 0, 1, and 2 meters above the ground and at each of the four cardinal directions. We used a Nikon D100 with a 50 mm macro lens to make digital images of each sample. We randomly selected two 1 x 1 cm subsamples on each bark patch for measuring the area of each wax mass using ImageJ image analysis software. We also counted individual scale insects by carefully dissecting away the wax under a dissecting microscope. Regression analysis revealed a strong positive relationship of wax mass area with the number of underlying scale insects. An advantage of this method is that it does not disrupt the insect or its interactions with the host tree. Limitations are that it can only be used where the bark is smooth, and care must be taken to distinguish between current year and older wax masses.

The role of spatially-explicit Allee effects in invading gypsy moth populations

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The gypsy moth, *Lymantria dispar*, was introduced in North America approximately 135 years ago, and has gradually expanded it range such that it now occupies about half of the eastern United States. The spread of gypsy moth is largely thought to be due to the growth and coalescence of isolated colonies that become established ahead of the generally infested area. One important question is thus the ability of these isolated colonies to persist when subject to Allee effects. We were motivated by our previous studies on the role that Allee effects play in gypsy moth dynamics, and in this study, quantified the Allee effect over geographic regions. We analyzed data collected under the gypsy moth Slow-the-Spread Program from 1996-2005, and observed that the strength of the Allee effect can be subject to spatial and temporal variability. In particular, that this strength appears to be either minimized or enhanced depending on the region of the United States in which gypsy moth is invading.

Persistence of disparlure following the use of mating disruption treatments against gypsy moth

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The gypsy moth, *Lymantria dispar*, has been gradually expanding its range in North America since its accidental release approximately 135 years ago. Under the USDA Cooperative Management Program Slow-the-Spread (STS) Program, colonies ahead of the population front are targeted for eradication to prevent their growth and coalescence, which could accelerate gypsy moth spread. The principle control tactic in STS is mating disruption, in which synthetic sex pheromone is aerially applied to foliage to interfere with the male moth's ability to locate females. We were motivated by preliminary field data that suggested residual flakes from previous treatments may obfuscate our interpretation of the effect of this tactic. We thus explored historical STS treatment data, from 1996-2004, to determine if there was a pattern that would suggest potential biological effects due to environmental persistence of disparlure.

Estimating Host Distributions for Use in Foreign Exploration for Biological Control Agents

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The recent rapid expansion of the Hemlock Woolly Adelgid (*Adelges tsugae* Annand), and the resulting decline in eastern and Carolina hemlock (*Tsuga canadensis* and *T. caroliniana*, respectively) populations in the eastern United States has highlighted the need for effective and efficient control methods. Classical biological control is one of the primary tools under development for controlling the HWA, and, as the native range of *A. tsugae* includes much of China and Japan, these regions are the primary areas being explored for natural enemies. Successful foreign exploration requires knowledge of the distribution of host species, however, available information on the distribution of hemlock in China is limited. To assist in continued foreign exploration for biological controls, new data currently being acquired by Chinese cooperators and USDA FS scientists, in combination with previous data sources are being used to produce distribution models for *Tsuga spp*. in central and southern China. Currently available data shows that the rough distribution of hemlock on the landscape can be estimated using latitude and elevation, and suggest additional variables include slope, aspect, and proximity to southerly monsoon tracks will further refine the distribution estimates.

Current limits in the precision of the maps are the result of a lack of verification data, and complete site descriptions for known hemlock stands. As these become available, they will be integrated into the model using additional analytical tools (eg. CART, Random Forest, Decision Tree analyses, etc.).

Gut Microflora of a Wood-Boring Invasive Insect, the Emerald Ash Borer

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The goal of this research is to identify and characterize gut microbial flora of the emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) in its larval, prepupal and adult stages. This insect consumes a diet comprised largely of wood, but little is known about how cellulose degradation is accomplished. This exotic beetle is native to Asia and has killed several million trees since being introduced into North America. We cultured microorganisms from entire guts of ten fourth instar larvae, ten prepupae and forty newly emerged adult beetles. We characterized bacterial isolates based on colony morphology and 16S ribosomal RNA gene sequence, which indicated that the culturable community from guts of newly emerged adult beetles contained members of the α-, β- and γ-Proteobacteria, Actinobacteria and low G+C Gram-positive bacteria. The dominant species among bacteria isolated from fourth instar larvae and prepupae were members of the Actinobacteria and low G+C Gram positive bacteria. To assess the composition of the entire community, we constructed a library of 16S rRNA genes amplified from DNA that was extracted directly from guts. Sequence analysis indicates that fifty of seventy-five clones derived from fourth instar larvae are closely related to members of the γ-Proteobacteria. Surprisingly, in light of the data on cultured members of the community, only six of the clones affiliate with the Actinobacteria. . In preliminary assays, isolates of *Burkholderia cepacia*, and an *Erwinia* sp. from adult beetles digested carboxymethylcellulose *in vitro*. The potential role of cellulolytic activity of gut microbiota in the life cycle of this insect is discussed.

Daniel M. Benjamin: Forest Entomology Researcher, Teacher and Mentor
1916-2005

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Dan Benjamin taught and researched forest entomology at UW-Madison for 30 years. He had numerous accomplishments in both the basic and applied aspects of his science. He generated many advances on insect life histories and their interactions with host plants at a time when Wisconsin was just beginning reforestation efforts to recover the landscape from decades of clear-cutting and slash-and-burn practices. He extended this knowledge to developing nations in Africa and Asia, and was the first American forest entomologist invited to lecture in Mainland China at a time when that society was largely closed to westerners. Dan was an inspiring teacher to undergraduates, and mentored over 40 graduate students. His students went on to become a Who's Who of forest entomology in academia, government, and industry around the world. His record six students recognized for excellence by the Entomological Society of America is unlikely to be broken.

Host tree-HWA location behavior of a predator, *Laricobius nigrinus* Fender (Coleoptera: Derodontidae)

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The ecological, evolutionary, and behavioral aspects of predation are of interest to the applied field of biological control. For our present purpose, the primary reason for studying predation is to determine the role of *Laricobius nigrinus* in suppressing pest populations of hemlock woolly adelgid, *Adelges tsugae* Annand (Homoptera: Adelgidae) (HWA) in eastern and western United States. Research approaches include laboratory studies comparing monthly differences in host tree-HWA location among field caught *L. nigrinus*. In addition, we compared behavioral responses to host tree-HWA among field caught *L. nigrinus* to those reared in the laboratory on eastern hemlock. Our results indicate significant variation in host tree-HWA location with month, fecundity, and field caught versus laboratory reared *L. nigrinus*. These results, in addition to the life histories of a native predator and introduced prey, suggest *L. nigrinus* may have supplemental or alternate nutritional requirements. To further understand *L. nigrinus* life history and predatory role in controlling HWA, we will continue with experimental laboratory and field experiments, direct observations in the field, and monthly gut analysis of *L. nigrinus*.

Spatial patterns in growth rates of invading gypsy moth populations

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Exotic invasive species pose economic and environmental consequences to native ecosystems. One example is the gypsy moth, *Lymantria dispar* L., which has been expanding its range in N. America since its introduction in 1868 or 1869, during which it has gained a reputation as one of the most destructive exotic species in the United States. Gypsy moth spread is a function of the growth and coalescence of isolated colonies ahead of the generally infested area. We have previously shown that rates of low-density colony persistence from year-to-year differ across the geographic range of the expanding population front. In this study, we

examined growth rates of gypsy moth populations across geographical regions using data collected from pheromone-baited traps deployed under the gypsy moth Slow-the-Spread Program from 1996-2004. Our results indicate that growth rates differ along the population front, with higher growth rates in Wisconsin than in Midwestern or Appalachian states. Growth rates were also spatially autocorrelated but the degree autocorrelation varies annually. Lastly, we explored the spatial relationships between gypsy moth growth rates and a variety of landscape variables to ascertain patterns of spatial cross-correlation.

Volatile profiles of hosts vs. non-hosts of the Asian Longhorn beetle, *Anoplophora glabripennis* (Coleoptera: Cerambycidae)

Jacob D. Wickham and Stephen A. Teale

Asian Longhorn beetles (ALB) host selection is mediated in part by plant volatile olfaction. The olfactory cues emitted from hosts vs. non-hosts, or a stressed vs. healthy host may provide the long-range cues for host location by ALB. The relative concentrations of antennally active compounds may provide the basis for host discrimination. Aerations were performed *in situ* on three host tree species: Sugar Maple (*Acer saccharum*), Striped Maple (*Acer pennsylvanicum)*, and Horsechesnut (*Aesculus hippocastanum*), and two non-hosts tree species, Ailanthus (*Ailanthus ailanthus)*, and Callary Pear (*Pyrus calleryana*). Volatiles were collected on Super-Q adsorbent. In a separate experiment, clones of a poplar hybrid clones (*P. nigra* x *P. maximowizii*) were hydroponically grown in the lab and volatile production were induced by manual damage or methyl jasmonate (MeJA) treatment. Volatiles were collected using solid phase microextraction (SPME). GC-MS analyses revealed that hosts and induced (manually damaged and MeJA treated) *Populus* sp. share green leaf volatiles (GLVs), aldehydes, and mono- and sequiterpenes, including cis-2-hexanal, cis-3-hexen-1-ol, octanal, nonanal, decanal, camphene, delta-3-carene, trans-caryphyllene. GC-EAD analysis confirmed male ALB antennae detected these same compounds. *P. calleryana* shared only hexanal and cis-2-hexanal with *A. ailanthus* and had no detectable terpenes. *A. ailanthus* samples contained octanal, nonanal, decanal, delta-3-carene, and farnesene, which are all host volatiles with the exception of farnesene. Although visual and gustatory cues are also be involved, these findings may uncover the olfactory basis for host discrimination.

Mortality of *Quercus phellos* L. (willow oak) Due to Galling by *Callirhytis cornigera* (Otsen Sacken) (horned oak gall) in the Ouachita River Floodplain (Southeastern Arkansas, Northeastern Louisiana)

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Recurring mortality of *Quercus phellos* L. (willow oak) in the Ouachita River floodplain (southeastern AR, northeastern LA) has been recorded since the 1950s (Morris, 1955). This poster presents preliminary findings from an ongoing evaluation of recent mortality in willow oaks in conjunction with a severe infestation of the gall wasp *Callirhytis cornigera* (Otsen

Sacken) (horned oak gall). The evaluation is being conducted by the USDA Forest Service, Forest Health Protection (Southern Region, Alexandria Field Office), in cooperation with the Arkansas Department of Game and Fish, on the Beryl Anthony-Lower Ouachita Wildlife Management Area (WMA). The WMA is in southeastern Arkansas within the Ouachita River floodplain (Ashley and Union Cos., AR). The gall wasp is one of several factors suspected of contributing to the recent mortality; other factors include alternating instances of drought and flooding. Flooding has become more prolonged in some areas due to lock and dam construction for waterway commerce. Adverse soil characteristics also are believed to play a role. Similar mortality also has been observed on the D'Arbonne National Wildlife Refuge, also within the Ouachita River floodplain, in Ouachita and Union Parishes, LA. Here, declining stands both with and without gall infestations are evident.

PROTEOMICS APPROACH FOR IDENTIFYING MOLECULAR TARGETS IN THE SOUTHERN PINE BARK BEETLE MYCANGIAL GLANDS

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The southern pine bark beetle (SPB), Dendroctonus frontalis Zimmermann (Coleoptera: Curculionidae: Scolytinae), is the most economically and ecologically important insect pest of southern forests. Because it is difficult to control the SPB by conventional methods, we are seeking genomics solutions for the management of the SPB. The female SPB has an obligate mutualism with two species of fungi that are Ceratocystiopsis ranaculosus and Entomocorticium sp. A. The adult female SPB possesses a prothoracic cuticular invagination called the mycangium. Fungi from the surrounding host tissue enter the mycangium under the control of secretions from the mycangial gland cells, and they proliferate. The beetle migrates to a new host where the symbiotic fungi are released from the mycangium and inoculated within the phloem of pine trees during oviposition. Fungi proliferate in the wood and the resulting hyphal mass provides essential nutrients as food for larvae. These indicate that the mycangium serves as a medium to culture the fungi and transport them into new host trees. We have taken a proteomics approach for identifying molecular targets in the mycangial gland cells that are essential to the adaptation of the two specific fungi into the mycangial environment. We will present our approach and findings.

An Efficient Technique for Estimating the Spatial Uncertainty of an Aerial Detection Survey GIS Layer

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Analysis of Aerial Detection Survey (ADS) data has the potential of detecting and quantifying the spatiotemporal ecology of various forest disturbance agents. Antecedent to such efforts, however, is the estimation of spatial accuracy of the data set. Positional and shape inaccuracies of a given GIS polygon data layer can be assessed via a comparison with a second layer in which such errors are known to be comparatively negligible. Hence, by comparing given locations of infestations of Douglas-fir beetle (
Dendroctonus pseudotsugae Hopk.) to locations within a spatial RIS layer where Douglas-fir trees (Pseudotsuga menziesii (Mirbel) Franco) are shown to be the dominant host type, estimations of spatial accuracy are obtained and are expressed as a “standard error distance”. Estimations are given for White River National Forest, Pike / San Isabel National Forests, and for all forests in Wyoming. These estimations averaged from 1994-2005 are, respectively, 1850 meters, 790 meters, and 1230 meters.

STUDENT POSTERS

Changes in insect communities as indirect impacts of beech bark disease in forests of the Upper Peninsula of Michigan

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Indirect impacts of non-native organisms on forest biodiversity are rarely quantified. To gain a better understanding of these indirect impacts, we measured insect communities in relation to beech bark disease (BBD). BBD is an invasive disease complex that can cause high mortality of American beech (*Fagus grandifolia*) in infected stands. From 2003-2005, we have examined indirect impacts of BBD on several insect groups during the summer months: bark and wood-infesting insects (2003-2005), ground-dwelling insects, and moths (2004, 2005). We used flight intercept panel traps baited with ethanol to capture bark and wood-infesting insects, pitfall traps to capture ground-dwelling insects, and blacklight traps to capture moths at sites with and without BBD. Bark beetles were significantly less abundant at sites with BBD than at sites without BBD. Ground beetles were less abundant at diseased sites in 2005. Also, several moth species that utilize beech and/or maple as a larval host plant were significantly less abundant in forests with BBD. These results indicate that BBD is having negative indirect impacts on some forest insect taxa, and this in turn will affect measures of forest biodiversity.

Stand Characteristics and Fuel Loads of Dwarf Mistletoe and Mountain Pine Beetle in Colorado's Northern Front Range Ponderosa Pine

Russell D. Beam, Jennifer G. Klutsch, William R. Jacobi, & José F. Negrón

Dwarf mistletoe and bark beetle infestations are suspected to change fuel complexes and fire hazards. Common assumptions maintain that certain stand characteristics in ponderosa pine (*Pinus ponderosa* var. *scopulorum*) infested with dwarf mistletoe (*Arceuthobium vaginatum* subsp. c*ryptopodum*) or mountain pine beetle (*Dendroctonus ponderosae*) should alter fire behavior, as compared to un-infested stands. Furthermore, stands with both dwarf mistletoe and mountain pine beetle activity should have different fuel levels and stand characteristics than separately infested stands. The stand structure and fuel loads in the ponderosa pine forests of the Front Range of Colorado were surveyed in areas with dwarf mistletoe and mountain pine beetle infestations. Thirty-one transects, each 1500m in length, were established throughout the Canyon Lakes Ranger District, Roosevelt National Forest through the Summer 2005, to determine the extent and intensity of the dwarf mistletoe and mountain pine beetle populations. Within the 91 tree plots (0.04 hectare) where stand characteristics were recorded, fuel levels were measured using modified Brown's transects. The data collected will test whether, and to what degree, these disturbances influence stand characteristics. As well, fire behavior models will help determine the potential surface fire behavior, torching potential and independent crown fire potential in infested stands.

LastCall™ NPTM: A new approach for tip moth control

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The Nantucket pine tip moth (*Rhyacionia frustrana*) is a significant pest of pine plantations in the southeastern United States. Current industry practice for controlling tip moth includes backpack application of permethrin insecticides. However, rising societal concerns demand an increase in the use of environmentally friendly, cost-effective pest control options. *LastCall*™ NPTM is a hydrophobic, UV stable attracticide encapsulating both pheromone and insecticide components. This technology attempts to address the environmental concerns by eliminating pesticide drift and minimizing nontarget effects such as residues in surface, soil and groundwater. Varied rates of *LastCall*™ were tested in loblolly pine plantations in the Georgia Coastal Plain to determine optimal application rates. Applications were made to control the first three tip moth generations. Applications varied in the area treated and the per acre rate of application. Efficacy of treatments was determined by quantifying shoot damage and pre- and post-treatment tree volume measurements. All treated plots had significantly less damage than control plots, exhibiting up to 88% decline in damage in the first generation for the most intensive treatment. Two treatments showed substantial volume differences compared to controls with a 30% gain in volume for the most intensive treatment and a 13% gain in the reduced area treatment.

Transport of Fungal Symbionts by the Mountain Pine Beetle

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Many bark beetles have close associations with fungi. While some bark beetles transport symbionts on their exoskeleton, often in elytral pits, a few species transport their associates in specialized structures called mycangia. We used scanning electron microscopy to examine mycangial openings and bodies of newly emerged mountain pine beetles for the presence of fungal associates to determine if mycangia and elytral pits are redundant in the transport of the two primary filamentous fungal associates. We found yeasts, conidia (asexual spores), and hyphae protruding from mycangial openings. Yeasts and conidia were also found on the exoskeleton, including the head, pronotum, and elytra. While yeasts and conidia were common in elytral pits, most contained relatively few when compared to elytral pits on some non-mycangial bark beetle species. In addition, conidia of one fungal associate appeared relatively infrequently compared to the other on the exoskeleton. Our results suggest the following: (1) mycangia may be critical to fungal dissemination by the mountain pine beetle; and (2) mycangia of mountain pine beetle may support the germination and growth of the fungi. Future work will examine if the main fungal associates of mountain pine beetle are differentially vectored in the mycangia and on the exoskeleton.

Invasion Genetics of Emerald Ash Borer (*Agrilus planipennis* Fairmaire) in North America

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Emerald ash borer (EAB) was detected in Michigan and Canada in 2002. mtDNA gene sequencing and analysis of amplified fragment length polymorphisms (AFLPs) were used to assess the genetic structure of EAB populations and to estimate the geographic origin(s) of North America's EAB populations. These analyses will help understand invasion dynamics of EAB and to identify geographic localities of potential biocontrol agents.
Mitochondrial cytochrome oxidase I (COI) sequences (485 bp) yielded one common haplotype and five unique COI sequences from individuals in two populations in South Korea that differed from the common sequence by 2-4 nucleotides. In addition, a single EAB from Japan differed from the common sequence by 22 nucleotide changes (3.7%). AFLP profiles were obtained from these same EAB individuals. Neighbor-joining analysis of the 139-band AFLP data set showed that EAB individuals from MI cluster more often with individuals from China than with EAB from South Korea. However, South Korea cannot be ruled-out as the origin of North American EAB since the common mtDNA sequence shared by all Chinese and North American EAB, exists in South Korean populations. Increased Asian sampling and additional molecular genetic data will be necessary to elucidate the geographic origin(s) of North American EAB.

Habitat usage of the forest tent caterpillar (Lepidoptera: Lasiocampidae) in North-Western Quebec

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Central to the study of animal ecology is the usage an animal makes of it's environment: specifically, the kinds of foods it consumes and the varieties of habitats it occupies and yet, very little research has been done to characterise the habitats of forest insects. Based on aerial survey data of north-western Quebec for the 1998-2003 epidemic of forest tent caterpillar and on forest inventory information, the goals of this study are (1) to gain a better understanding of habitat suitability for the forest tent caterpillar, regardless of the phase of the epidemic cycle, and (2) to evaluate the habitat use for each step of the epidemic thereby attempting to establish a progression for habitat preference in relation to the stage of the epidemic. Preliminary results suggest that habitat usage is not random as certain types of habitat were defoliated in a significantly higher or lower proportion than was available within the study area and that habitat use varies from a strong preference for aspen dominated stands early in the epidemic to a more diverse selection of stands in later stages. Though the results conform to our expectations, they also bring to light a new question, whether the progression of habitat usage is the result of spillover from "ideal" habitats as the density of the insect population increases and resources per individual decrease or the result of a spatial dynamic of movement through different habitats at different phases of an epidemic.

POST-WILDFIRE SALVAGE LOGGING THREATENS BIODIVERSITY AND ECOSYSTEM FUNCTION IN THE BOREAL

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In North America, rising economic demands for forest resources along with current and predicted increases in wildfire activity have increased pressure to salvage log burned forests. At present, however, the ecological implications of this practice are too poorly understood to develop effective management guidelines or to adequately inform policy. Using field surveys and a series of field and laboratory experiments, we examined the effects of post-fire salvage logging on saproxylic (dead wood-associated) beetles and their ecological function in recycling nutrients from fire-killed trees. Our results suggest that continued economic emphasis on post-fire salvage logging will not only impact biodiversity, but will also alter decomposition processes, nutrient cycling, and successional trajectories in forest ecosystems.

From the ground up: Woody vegetation composition and succession following southern pine beetle disturbance

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During the southern pine beetle (SPB), *Dendroctonus frontalis* Zimmerman, outbreak of 1999-2002 nearly 100% of the pine forest type in Kentucky and the Cumberland Plateau region suffered stand-altering mortality. Because recurrence of SPB in the region is infrequent, and pine mortality so complete, the dynamics of revegetation are unpredictable. We established plots in SPB-impacted forest stands in Kentucky so that natural and managed reforestation processes could be documented. We evaluated shortleaf pine, *P. echinata*, and shortleaf pine/ oak, *Quercus* spp., stands with and without prescribed fire to survey woody plant composition and stand succession. The southern variant of the Forest Vegetation Simulator was used to predict future forest types.

Effected stands showed a significant loss of pine in the mid- and overstory strata, with little regeneration. Revegetation of SPB-impacted stands is dominated by red maple, *Acer rubrum*, and several oak species in the seedling, sapling, and midstory strata, and the overstory strata is dominated by oak. The Forest Vegetation Simulator forecasts shifts from pine-dominated or co-dominated stands to white oak/ red oak/ hickory and mixed upland hardwood forest types. Initial results suggest additional management is needed to maintain the desired shortleaf pine component.

Geographic differences in lodgepole pine-mountain pine beetle interactions in British Columbia during an epidemic

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The current mountain pine beetle outbreak in north-central British Columbia is the largest in recorded history. This outbreak provides a unique opportunity to study populations during an epidemic of this magnitude and at higher latitudes. This study was conducted to investigate how insect-host relationships during an epidemic differ between northern and southern BC.

Ten lodgepole pine stands were sampled in the summer of 2005, five stands in north-central BC and five in southeastern BC. Both regions were experiencing MPB epidemics. A total of 263 trees were felled, 175 in the north, 88 in the south. Each felled tree was sampled for maximum beetle attack height, and attack and productivity densities were measured at 3 equidistant heights on both the north and south aspects along the attacked portion of the bole.

Several important differences between the two geographic regions have emerged from our first summer of field sampling. Attack heights for all tree sizes were significantly greater in northern stands than in southern stands. Attack densities were lower in northern stands than in the south, but brood production (pupal chamber density) was greater. Our preliminary results indicate that northern beetles may utilize their host more efficiently than southern beetles.

Red oak borer semiochemicals: preliminary investigation of cues for mate location and recognition

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Red oak borer, *Enaphalodes rufulus* (Haldeman) (Coleoptera: Cerambycidae), has been identified as a contributing factor in an oak decline event occurring in the Ozark National Forests of Arkansas and Missouri. Investigating semiochemicals associated with mate location and recognition may provide insight into host selection and permit the development of a cost efficient survey method for red oak borer. The objectives of this research were twofold: 1) to determine if mate recognition and mating behaviors are mediated by contact pheromones, and 2) to test a series of lures to confirm attraction to an isolated synthetic red oak borer compound, 2S, 3S-hexanediol and 2S, 3R-hexanediol. A sequence of fixed action patterns in mating behavior was described. Bioassays were performed to confirm the role of cuticular hydrocarbon recognition. Lures charged with 2S, 3S-hexanediol and 2S, 3R-hexanediol in flight intercept traps caught only a few red oak borer adults in the field. Preliminary electroantennographic analyses have been conducted. Results and discussion of these studies are presented.

Guild structure and composition of arthropods associated with eastern hemlock *Tsuga canadensis (L.)* in the southern Appalachians.

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A project was initiated to determine guild structure and composition among 300 insect species associated with eastern hemlock, *Tsuga canadensis* (L.), in the southern Appalachians. Phytophagous, predaceous, scavenger, parasitoid, fungivorous and detrivorous guild assignments were made for species collected using beat sheet, sweepnets, malaise and pitfall traps. These groups comprised 50%, 14%, 25%, 3%, 1%, and 6% respectively, of the species associated with eastern hemlock. Phytophagous insects were subdivided into chewers, sapsuckers, flower feeders, pollen feeders, and seed feeders. The percent exotic and indigenous statuses for species within these guild structures were also determined.

Variation in Lepidopteran Communities Across Landscapes – Implications for Forest-dwelling Bats in eastern North America

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It is not fully understood how the lepidopteran prey base of forest-dwelling bats varies on a landscape scale. We investigated changes in moth availability of an endangered moth specialist, the Ozark big-eared bat (*Corynorhinus townsendii ingens*). Habitats were sampled via light traps during May-August 2005 near roost sites in two landscapes in Arkansas: an agriculturally fragmented landscape and a forested landscape. In the agriculturally fragmented landscape, old fields yielded significantly ($P<0.05$) lower moth abundance, species richness, and family richness than forested and edge habitats. Differences in moth assemblages were not related to roost location. Conversely, moth assemblages in forested landscapes did not vary by stand age (size class of timber), but did vary by roost location. Patterns suggest that diversity of woody plants and landscape position may be more important to entire moth assemblages than density of woody stems, though common ($n>100$) moth families varied in their respective selection of habitat. Future research will investigate potential predator-prey patterns on a broader regional scale in the central Appalachians. In 2006-2008, mist netting, echolocation surveys, fecal analysis, and moth surveys will be conducted, and the response of moths and forest-dwelling bats will be quantified in relation to silvicultural prescriptions.

The Spatial Relationships of Southern Pine Beetle Infestations and Environmental Features

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In order to model Southern Pine Beetle populations, an understanding of the spatial structure and scale of various factors affecting populations is necessary. The time series spatial relationships of infested counties, refuge creating disturbance patterns, and topographic and climatic features form the environment within which populations develop. The scales at which these factors operate, are the scales modeling efforts must incorporate. Some variables operate over regions larger then the southern pine beetles range while others vary below the range of available data.This poster sums up the preliminary analysis of the spatial and temporal processes which are the environmental backbone to a population model.

Living with Emerald Ash Borer: The Relationship between Diameter, Canopy Position, and Light in Modeling Phloem Reduction

Tara L. Eberhart, Andrew J. Storer, and Linda M. Nagel

School of Forest Resources and Environmental Science, Michigan Technological University

The exotic emerald ash borer, *Agrilus planipennis*, (Coleoptera: Buprestidae), is established in Michigan, Indiana and Ohio. At high population densities, all green, black, and white ash trees are apparently susceptible to attack and can be expected to die. Emerald ash borer larvae develop in the phloem of ash trees in stems and branches above approximately 2.5 cm in diameter. Removal of ash from high priority areas such as those stands in close proximity to outlier populations will reduce the population density of this insect. Measurements of ash trees suggest a strong relationship between diameter at breast height and calculated surface area of the tree and the estimated amount of phloem throughout the tree. These relationships, in addition to others involving tree vigor, form, and growing conditions, are being integrated into a model related to the amount of phloem in a forest stand.
Forest resource managers will be able to use this model to determine the size above which all trees should be cut in order to meet prescribed ash phloem reduction targets. This will also enable the genetic diversity of ash to be optimized in light of ash reduction efforts by retaining small trees in the forest.

Lethal and sublethal effects of imidacloprid on *Laricobius nigrinus* and *Sasajiscymnus tsugae*, two predators of hemlock woolly adelgid

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Systemic injections of imidacloprid are the most widely used technique for control of Hemlock Woolly Adelgid (Hemiptera: Adelgidae). Two predators, *Laricobius nigrinus* (Coleoptera:

Derodontidae) and *Sasajiscymnus tsugae* (Col: Coccinellidae), are being mass reared and released as biological control agents of the pest. In laboratory bioassays, predator adults fed on hemlock woolly adelgid populations that were surviving on hemlock branches systemically treated with imidacloprid. Both beetle species exhibited sublethal effects such as twitching, spasms, and paralysis. Both beetle species also exhibited a dose-dependant relationship of concentration and mortality. Temperature was a significant factor, with greater predator mortality at higher temperatures. At 4ºC, *L. nigrinus* mortality ranged from 4-45%, and at 12º it was from 45-76%. *S. tsugae* mortality ranged from 33-48% and 25-100% at 12 and 20º C, respectively. There was no control mortality except *S. tsugae* had 25% mortality at 20ºC. Mortality increased over time at each concentration, with more rapid rates at the warmer temperatures.

Oak Defenses Against Red Oak Borer

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Red oak borer, *Enaphalodes rufulus* (Haldeman), is a native wood-boring beetle indicted as a major contributor to high levels of northern red oak, *Quercus rubra* L., mortality in northwestern Arkansas. Potential defense mechanisms were investigated in northern red oaks grouped into three red oak borer infestation history classes. Class I (low infestation history) trees had significantly higher callous formation than Class III (high infestation) trees. Class II (moderate infestation) trees were intermediate. Phloem (inner bark) moisture, total phenolics (TP) and protein-binding capacity (PBC) were measured in phloem samples removed one day, one week and four weeks post-initiation of three treatments: control, mechanical wounding and larval insertion. Class I trees had lower phloem moisture, TP and PBC. There were no significant differences in measured potential defenses among the three treatments. HPLC yielded phenolic profiles and peak area analysis revealed three compounds in higher concentrations in mechanically wounded and larval insertion samples, but none were present or in higher concentrations in Class I trees compared to Class II and Class III trees. Callous overgrowth, but not phloem moisture, may be a tree defense mechanism against red oak borer. None of the measured chemical defenses were higher in healthy trees vs. declining trees.

How does the red-headed ash borer, *Neoclytus a. acuminatus* (Fabricius), perceive a fragmented landscape?

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The movement of longhorn beetles (Coleoptera: Cerambycidae) between forest habitat patches is poorly understood. In particular, it is not known how adults in this family utilize different parts of the landscape, i.e., are some types of land cover easier to fly through than others due to differential resource availability, probability of mortality, or physical barriers to movement. Understanding relative costs of movement may be particularly important in areas where forest

patches are highly fragmented. We are using the least-cost path tool in a Geographical Information System (ArcGIS 9.1™) to examine the relative costs of moving through different types of land cover for the red-headed ash borer *Neoclytus a. acuminatus* (Fabricius). We present preliminary results from a survey conducted throughout the state of Indiana in the summer of 2005. We also suggest how this method can be adapted to suit other species of longhorns, and outline plans for future work.

Condition of Ash Resources in Recreational Areas in Michigan's Upper Peninsula

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Michigan Technological University School of Forest Resources and Environmental Science

The exotic emerald ash borer (*Agrilus planipennis*) is causing mortality of ash (*Fraxinus* spp.) resources in lower Michigan. In fall of 2005 we confirmed emerald ash borer at Brimley State Park at the eastern end of the Upper Peninsula of Michigan. This was the first record of emerald ash borer infesting standing trees in the Upper Peninsula, and this population was likely established as a result of the movement of infested firewood or nursery stock. Inspection of firewood piles at campgrounds throughout the state has shown that movement of ash firewood is continuing. In summer of 2005 we evaluated the condition of ash resources at recreational sites throughout the Upper Peninsula of Michigan. The results of this survey indicate the prevalence of ash in recreational areas of different types and of differing ownerships. The condition of these resources provides baseline data ahead of the threat of emerald ash borer.

Modeling the influence of beech bark disease on root sprout regeneration in hardwood forests of northeastern North America

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Beech bark disease (BBD), an insect-fungal disease complex comprised of the scale insect *Cryptococcus fagisuga* Lindinger (Homoptera: Eriococcidae) and (primarily) *Neonectria coccinea* var. *fagisuga* (Ascomycota: Nectriaceae), is now endemic throughout most of northeastern North America. Despite sustained elevated adult mortality (Houston et al 1975), reduced annual growth rate (Gavin and Peart 1993), and models and empirical data predicting replacement by competitor species (LeGuerrier 2003, Twery and Patterson 1984), American beech (*Fagus grandifolia* Ehrl.) remains an important forest component 116 years after BBD's introduction. An enduring hypothesis that could resolve the paradox of beech persistence invokes positive feedback between the disease and root sprout regeneration, though this relationship has been historically difficult to test (Houston 1979). We present a probabilistic, spatially explicit model predicting root sprout distribution in closed canopy stands as a function of the size and location of adult beech within 0.27 hectare plots. We modify these functions by

overlaying various indices of BBD infection and severity at the tree and stand level, and compare resulting models using Bayesian Information Criteria values. A significant model containing one or more disease terms will be interpreted as support for a linkage between BBD severity and root sprouting behavior in beech.

Flight temperature thresholds for southwestern ponderosa pine bark beetles

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The bark beetle complex in the ponderosa pine forests of northern Arizona includes, *Dendroctonus brevicomis*, *D. frontalis, D. ponderosae*, *D. adjunctus*, *D. approximatus, D. valens, Ips pini*, *I. latidens*, *I. lecontei*, *I. knausi* and *I. calligraphus*. Studies conducted in other regions indicate that initial bark beetle flight in several species is determined primarily by a minimum temperature requirement. Determining the temperature threshold necessary for bark beetle flight in northern Arizona will aid managers in predicting the onset and cessation of beetle flight and to determine the optimal timing for bark beetle monitoring, pheromone treatments, preventative spraying, and silvicultural treatments. Beetle flight and ambient air temperatures were monitored for three years at multiple elevations in northern Arizona. Our data indicates that the majority of bark beetle flight begins when daytime maximum temperatures are between 15°C and 20°C. Additionally, knowledge about bark beetle predator flight may help managers minimize their impact on predator populations. *Temnochila chlorodia* flight is initiated when temperatures are between 20°C and 25°C. *Enoclerus* sp. and *Elacatis* sp. were captured when maximum daytime temperatures exceeded 15°C. Daytime maximum temperatures in our area did not appear to exceed the upper temperature limits for flight activity for the majority of species.

Development of a submerged culture system for mapping the proteome of *Entomocorticium* sp. *A*, a mutualistic fungal associate of the southern pine beetle

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Entomocorticium sp. *A* is one of two fungi which are obligately mutualistic with the southern pine beetle, *Dendroctonus frontalis*, the major pest of coniferous forests of the southern United States. This fungus, along with *Ophiostoma ranaculosum*, is transported in a yeast-like form, within a mycangium in the exoskeleton of its beetle host. Our long term goal is to identify the molecular basis of adaptation of these fungi to this specialized structure. The lack of a reliable submerged culture system for *Entomocorticium* sp. *A* has been an impediment to reliable production of abundant and high quality proteins. Here we report the development of an *in vitro* system that is effective for culturing this fungus in liquid medium. We found that cornmeal agar is the best culture base for this medium. The addition of specific carbon (starch) and nitrogen (yeast extract) sources, and an increased pH led to the most prolific tissue growth. We suggest a liquid medium (ME^{+}) at pH 9.0 that contains 0.4% cornmeal agar, 1.0% yeast extract, and 1.0% starch for effective liquid culturing of *Entomocorticium* sp *A*. This medium was also found to be suitable for the growth of other fungi (*O. ranaculosum* and *Ophiostoma minus*) associated with this forest-damaging insect.

Red oak borer, *Enaphalodes rufulus* (Haldeman), and *Armillaria* root rot contribute to oak mortality in northern Arkansas forests

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Oak decline is of major concern in the Ozark National Forest of Arkansas. An outbreak of red oak borer is implicated as the major contributing factor to red oak mortality. A model was developed that estimates the number of red oak borer heartwood galleries, and was applied to dead trees. Significant differences were found among three topographic positions; ridges, south-facing and west-facing slopes. *Armillaria*, a root rot fungus, is also known to contribute to oak mortality in other decline events. No documented evidence is available for *Armillaria*'s occurrence in the Arkansas Ozarks. Molecular diagnostic techniques were used to identify species of *Armillaria* present in this area. *Armillaria mellea*, *A. gallica*, and *A. tabescens* were positively identified from three different landforms; ridges, south-facing and west-facing slopes. Measures were taken to show relationships between red oak borer and *Armillaria*. Red oak borer heartwood gallery density is greatest on ridges. *Armillaria* was only identified once from ridges. This suggests more red oak borer in trees when *Armillaria* is not present.

Prescribed Fire and Mechanical Treatments in Red Pine: Impacts on Insect Pests and Fungal Pathogens, Muskrat Lakes, Michigan

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This project is studying the effects of fire and harvesting on insects, pathogens, and understory diversity in naturally regenerated red pine, *Pinus resinosa*. Treatments include fire only, mechanical harvesting only and combination of fire and harvesting to achieve silvicultural goals. In 2004 and 2005, pre-treatment data were collected from twenty 0.04-hectare plots in each of twelve 10-hectare treatment areas. All trees in these plots were measured and tagged. Spore traps measured the presence of shoot blight fungi in the genera *Sirococcus* and *Sphaeropsis*. Pitfall traps were used to assess the diversity of ground-dwelling arthropods. In addition, forest health and understory vegetation data were collected. Mechanical treatment areas were harvested in fall 2005, and prescribed fire treatments will be applied in spring 2006. Post-treatment data will be collected in summer 2006 in the 0.04-hectare plots. Damage by pine engraver (*Ips pini*), red pine cone beetle (*Conophthorus resinosae*) and red turpentine beetle (*Dendroctonus valens*) will be evaluated throughout each treatment area. The treatment

prescriptions are of the type that may be utilized on a large scale in red pine forests with goals of achieving structurally diverse stands containing multi-aged trees and an increased proportion of white pine, *P. strobus*.

Predators associated with hemlock woolly adelgid (Hemiptera: Adelgidae) infested western hemlock in the Pacific Northwest

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The hemlock woolly adelgid (HWA), *Adelges tsugae*, is causing widespread mortality of eastern hemlock, *Tsuga canadensis*, in the eastern U.S. In the West, HWA causes negligible damage to western hemlock, *Tsuga heterophylla*. Host resistance and presence of endemic predators may be contributing to the relative tolerance of western hemlock. Field surveys of the predator community associated with HWA infestations on 116 *T. heterophylla* at 16 locations in Oregon and Washington were conducted monthly from March 2005 through March 2006. A total of 3,365 predators collected from 1,664 beat samples represent 37 species in 12 families including Derodontidae (41.2%), Chamaemyiidae (19.6%), Coccinellidae (8.9%), Reduviidae (7.2%), Hemerobiidae (6.5%), Syrphidae (3.8%), Miridae (3.6%), Cantharidae (3.1%), Chrysopidae (2.6%), Coniopterygidae (2.4%), Staphylinidae (0.9%), and Anthocoridae (0.2%). *Laricobius nigrinus* (Derodontidae) and *Leucopis* spp. (Chamaemyiidae) are the dominant predators. The remaining 40% of predators represent a diverse complex potentially attacking HWA. The phenology of immature and adult predators suggests temporal partitioning of prey across all seasons. *Leucopis* spp. and *Conwentzia californica* (Coniopterygidae) have been successfully reared from larvae to adult on a diet of HWA in the laboratory. Field collected larvae of *Hemerobius pacificus* (Hemerobiidae), *L. nigrinus, Leucopis* spp., syrphids, and adults of *Dichelotarsus* sp. (Cantharidae) have been observed feeding on HWA eggs in the laboratory.

Prescribed fire following southern pine beetle disturbance impacts shortleaf pine seedling performance and herbivore pressure

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Natural and artificially regenerating shortleaf pine seedlings were monitored for survival, growth, and herbivore pressure in forests that suffered extensive overstory mortality during the southern pine beetle outbreak of 1999-2002. Seedling performance was evaluated based on survival and height and diameter growth. Arthropod and mammalian herbivory was manipulated using treatment combinations of fencing and insecticide applications and herbivore pressure was observed. Seedling performance and herbivore pressure were compared between stands treated with prescribed fire and unburned controls. Naturally regenerating seedlings experienced higher survival and absolute growth rates than planted seedlings and grew more vigorously in burned areas. Prescribed fire lowered planted seedling survival, but did not influence growth. Arthropod herbivory was the major component of herbivore pressure and was greater on natural

regeneration, possibly due to superior seedling health and vigor. Herbivore-induced seedling mortality was low and survival correlated positively with pine weevil feeding frequency and negatively with feeding severity. Pine weevil and Nantucket pine tip moth feeding frequency also correlated positively with seedling diameter growth, but did not differ between burned and unburned stands. Pine webworm infestations were more frequent and severe in burned stands and severity increased with diameter growth. Conifer sawfly herbivory was not observed.

Predators of *Fiorinia externa* (Hemiptera: Diaspididae) in the Southern Appalachians

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A project was initiated in September 2004 to determine the indigenous predators of *Fiorinia externa* Ferris, elongate hemlock scale, and their impact on the pest populations. Predators of the exotic elongate hemlock scale were collected in eastern Tennessee and western North Carolina at four sites from beat sheet samples and branch cuttings from September 2004 to April 2006. There were two forest sites and two urban sites selected. Laboratory tests were conducted on the field collected predators to assess food consumption, development, feeding behavior, and to assess intraguild competition among predators of elongate hemlock scale. Seven predator species were documented to feed on elongate hemlock scale. *Scymnillus horni*, *Rhyzobius lophanthae*, and C*hilocorus stigma* were beetle predators with the highest feeding rates. The larvae of *C. stigma* consumed the most elongate hemlock scale. A species of *Coniopterix* collected was also found to occasionally feed on the elongate hemlock scale. Percent beetle damage in elongate hemlock scale populations from field collected branch samples was 6.5 % for Lynnhurst urban site, 9.5 % for Biltmore urban site, 3.6 % for Bay's Mountain forest site, and 7.7 % for Biltmore forest site.

Life history and mortality factors affecting an invasive species: The case of Ambermarked birch leafminer in urban Alaska

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Ambermarked birch leafminer (*Profenusa thomsoni*) is a European native sawfly introduced to North America during the last century. In Europe the species is a rare or occasional minor pest. However, in North America it can cause significant damage, as seen in Alaska where following its introduction sometime in the 1990's, it defoliates 140,000+ acres of birch every year. To understand the species' dynamics in this new ecosystem I studied the effect of crown position on *P. thomsoni* development, survivorship and life history on urban birch. Crown position did not play a role in mortality however leafminers utilize the lower canopy earlier than the upper canopy. Egg mortality appears to play a role in the species' population dynamics as a significant

portion perish before hatching, Furthermore, females appear to make sub-optimal choices in leaf selection as they will over-utilize leaves by depositing more eggs than the leaf can support.
Thus earlier hatching larvae appear to have an advantage, since only 2 – 3 leafminers can successfully develop on most leaves. Furthermore, because larvae are unable to disperse from the natal leaf, mortality of later hatching larvae increases as resources within the leaf are consumed by larger, earlier hatching larvae.

The role of interspecific competition in maintaining endemic populations of southern pine beetle

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Southern pine beetle (SPB) populations routinely switch between being very abundant (epidemic), to virtually non-existent (endemic). Epidemic populations are extremely destructive to pine forests, causing millions of dollars of damage, and exerting dramatic ecological impacts. Alternatively, endemic SPB populations are benign in terms of forest health. It remains unclear how populations switch from endemic to epidemic levels. For the last several decades our understanding of southern pine beetle population fluctuations has been dominated by the paradigm of predator-prey cycles. However, this hypothesis has been weakened by (1) the extended period of endemic conditions in Louisiana and east Texas, (2) the absence of second-order feedback in time series analysis of SPB population dynamics, and (3) a distinct bimodality in the frequency distributions of SPB abundance (from SBPIS database and the regional trapping program). An alternative hypothesis is that endemic populations are regulated around a locally stable equilibrium and tend to remain there until some perturbation permits them to escape that endemic equilibrium point. My research tests a mechanism for maintaining endemic SPB populations through interspecific competition from other bark beetles. I provide evidence for this mechanism through experimental field tests and a mathematical model.

Establishment of *Laricobius nigrinus* (Coleoptera: Derodontidae) for classical biological control of the hemlock woolly adelgid

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A mixed release approach was used to introduce the Pacific Northwest native *Laricobius nigrinus* (Coleoptera: Derodontidae), a predator of the exotic hemlock woolly adelgid, *Adelges tsugae* (Hemiptera: Adelgidae), on eastern hemlock trees. Three manipulated factors included: (1) the number of beetles released; (2) time of release, and; (3). location. There were 10 open releases in 2003-2004 consisting of the replicated treatments: 300 adults in fall 2003, 300 in spring 2004, or 300 in fall 2003 plus spring 2004 (sum = 600). There were 12 releases 2004-2005 including the new release sizes: 75, 150, or 1,200 adults in fall-spring. Beetles were released throughout the HWA distribution from Massachusetts to Georgia. In fall 2004, beatsheet sampling recovered 4 *L. nigrinus* F_1 adults at 2 of 10 sites. In spring 2005, branch clipping recovered 285 F_2 *Laricobius* larvae from 8 of 10 sites. In fall 2005, beatsheet sampling recovered 13 F_2 and 33 F_1 *L. nigrinus* adults at the 2003-2004 and 2004-2005 sites, respectively (4 of 22 sites). In spring 2006 to date, over 500 F_2 and F_3 larvae have been collected from 17 of 22 sites. Recoveries of F_3 *L. nigrinus* indicate that this important predator can establish permanent populations in the eastern U.S.

Comparisons of Trap and Pheromone Catch Efficacies for Woodboring Insects in a Three Year-Old Burn Area

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Exotic species are being discovered in the United States yearly. The Early Detection Rapid Response program is designed to detect, monitor, and limit the potential establishment of new exotic species. With these goals in mind, different trap designs and pheromone lure combinations were tested from June to September 2005 in a burned area of *Pinus ponderosae* to determine the most efficient technique for monitoring woodboring insects. Intercept panel traps, Lindgren funnel traps, and Sante traps were baited with a combination of Synergy ethanol and terpentine lures and monitored weekly.
Significantly more Scolytidae beetles were collected in the Sante trap design. However, consistently higher levels of insects from the Siricidae, Buprestidae, and Cerambycidae families were collected in the funnel trap. Three lure combinations: 1) Synergy ethanol and terpentine, 2) Phero Tech ethanol and Synergy ethanol, and 3) Phero Tech ethanol and alpha-pinene were placed on Intercept panel traps. The collections from the traps baited with the Phero Tech ethanol and alpha-pinene combination contained significantly more woodboring insects than the other lure combinations. From these results, it appears that using a combination of ethanol and alpha-pinene on a funnel trap would be the most effective technique for monitoring forests for exotic species.

Detection Tools for Emerald Ash Borer (*Agrilus planipennis* Fairmaire) (Coleoptera: Buprestidae) in Michigan

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In 2002, exotic wood-boring beetles collected from ash trees in southeastern Michigan were identified as Emerald Ash Borer (EAB). Trapping tools used to detect populations of this insect include girdled trap trees with sticky bands to trap adults, and cutting and peeling of girdled trees to detect larvae. In order to refine these trapping methods and gain insight into landing behaviors of EAB, studies were conducted in southeastern Michigan in 2005. Traps were established prior to beetle emergence and monitored through August. The landing behavior of EAB on all tree species was characterized on 0.2 ha. plots where every tree was used as an ungirdled sticky trap tree. Traps on ash trees accounted for 93% of EAB captured, indicating a preference for landing on ash. In a study comparing attractiveness of ungirdled trees, ash trees girdled in 2004 and ash trees girdled in 2005, trees girdled in 2004 caught significantly more EAB than the other treatments. Additional studies considered the use of colored sticky traps as an alternative to trap trees, but none were as effective as the trap trees. Results of these studies are variable, and most likely reflect differing population densities of EAB at the various field sites.

Ground beetle response to natural disturbance-based management in boreal aspen stands of western Québec

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The use of natural disturbance events in boreal forests as a template for silviculture has been proposed as a way to maintain native species, along with their ecological functions, while at the same time providing a sustainable supply of timber. The SAFE Project (Sylviculture et aménagement forestier écosystémiques) is a fully replicated landscape experiment in the Lac Duparquet region of Québec designed to study the effects of coarse-filter conservation strategies across a range of successional stand types. Experimental treatments include partial cuts, clear cut, prescribed burning following clear cutting, and uncut controls. Here we report on initial surveys of ground beetles collected in 2004 and 2005 using pitfall traps in the experimental aspen stands.
We collected 2595 and 2380 carabids in 2004 and 2005 respectively, with approximately 30,000 other coleoptera, the majority of which were represented by staphylinids. Carabids were identified to species for all analysis. Initial results suggest differences among prescribed burning and other cutting treatments. Examining staphylinid assemblages closely associated with deadwood and other important ecosystem functions should provide a more complete picture of the effects of alternative management methods on native beetle communities. This work will begin summer 2006.

Termites (Rhinotermitidae: *Reticulitermes*) occurring in woodlands of Missouri

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Data regarding subterranean termite distribution in Missouri are mainly based on samples from home infestations. The relative frequency of termite species in wooded areas has not been clearly documented or compared between urban and forested habitats. The main objective of this project was to record species composition and geographic distribution of *Reticulitermes* (Isoptera: Rhinotermitidae) species in Missouri by examining termite species occurring in conservation areas within the state.

Identification of species in the genus *Reticulitermes* is difficult because reliable morphological characters only occur in the adult stage that is seasonal. The soldier caste can also be identified but is less reliable. Data from morphological identification of samples supported by discriminant function analysis of morphometric characters suggest that *Reticulitermes hageni* is the predominant specie in Missouri's woodlands. We are currently working on species identification using 16S mitochondrial DNA. As a result more accurate information regarding species composition and genetic structure of termites in Missouri is expected.

Chemical Ecology of the Invasive, Exotic Ambrosia Beetle, *Xylosandrus crassiusculus* (Coleoptera: Curculionidae)

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Despite typically being weak mortality agents in their native environments, exotic bark and ambrosia beetles may cause significant tree damage upon introduction into the United States. These potentially invasive insects are increasingly being detected attacking and inhabiting trees in the US, and in some cases they are causing significant economic losses. We describe our efforts to develop baits for facilitating the detection of exotic ambrosia beetles and assessing the threat posed by them. Our approach involves three steps: (1) artificially eliciting attractiveness in potential host trees, (2) identifying olfactory stimulants produced by attractive hosts via electrophysiological studies of beetle antennae, and (3) evaluating candidate bait components in field and lab assays.

Fungal Interactions And Forest Stand Correlations of the Exotic Ambrosia Beetle, *Xylosandrus crassiusculus* (Coleoptera: Curculionidae).

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Exotic ambrosia beetles are an escalating problem within the United States, with at least one recently-introduced species (*Xyloborus glabratus*) demonstrating the ability to attack living host trees and vector a devastating *Ophiostoma* sp. pathogen. Multiple other ambrosia beetle species (*Xylosandrus compactus* and *X. crassiusculus*), within the Xyloborini tribe, have been found within the *Ophiostoma* infected host along with *X. glabratus*. We therefore performed laboratory experiments in an artificial media to determine whether long-established ambrosia beetles (*X. compactus* and *X. crassiusculus*) might be capable of vectoring the pathogen. Ambrosia beetles maintain a strict obligate mutualism with mycangial fungi that they cultivate in galleries constructed in the xylem. The interactions of the *Ophiostoma* sp. and mycangial fungi involved may affect vectoring capabilities. Therefore, we conducted fungal differential competition experiments to determine competitive effects between the pathogen and the beetle's symbiotic fungus. We also report the progress of a two-year trapping survey of selected ambrosia beetle populations within a variety of forest stand conditions in Central Louisiana.

PROTEOMICS APPROACH FOR IDENTIFYING MOLECULAR TARGETS IN THE SOUTHERN PINE BARK BEETLE MYCANGIAL GLANDS

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The southern pine bark beetle (SPB), *Dendroctonus frontalis* Zimmermann (Coleoptera: Curculionidae: Scolytinae), is the most economically and ecologically important insect pest of southern forests. Because it is difficult to control the SPB by conventional methods, we are seeking genomics solutions for the management of the SPB. The female SPB has an obligate mutualism with two species of fungi that are *Ceratocystiopsis ranaculosus* and *Entomocorticium* sp. A. The adult female SPB possesses a prothoracic cuticular invagination called the mycangium. Fungi from the surrounding host tissue enter the mycangium under the control of secretions from the mycangial gland cells, and they proliferate. The beetle migrates to a new host where the symbiotic fungi are released from the mycangium and inoculated within the phloem of pine trees during oviposition. Fungi proliferate in the wood and the resulting hyphal mass provides essential nutrients as food for larvae. These indicate that the mycangium serves as a medium to culture the fungi and transport them into new host trees. We have taken a proteomics approach for identifying molecular targets in the mycangial gland cells that are essential to the adaptation of the two specific fungi into the mycangial environment. We will present our approach and findings.

All wood is not created equal: Importance of wood quantity and decay stage for carabid beetles (Coleoptera: Carabidae)

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Downed wood (DW) serves as an important habitat component for many organisms. Although the importance of DW to these organisms is assumed most studies do not directly study the relationship between DW and organism use of this resource. We surveyed carabid beetles using pitfall traps and meander surveys in piles of DW that varied by volume of wood and decay stage in the following classes: 1) very low volume (small branches and twigs), 2) one large tree (early decay), 3) one large tree (advanced decay), 4) two large trees (early decay), and 5) two large trees (advanced decay). Pitfall traps were placed adjacent to the wood piles and carabid abundance, species richness, and species-level relationships were compared among the five DW classes. Five replicates of each DW class were chosen within each stand and twelve stands Michigan's Upper Peninsula were used for this study. Four stands were heavily infested with beech bark disease, four stands were selectively thinned ten years prior to this study, and four stands were undisturbed. Carabid abundance and species richness increased as volume and decay of DW increased. Carabid abundance was highest in stands with beech bark disease which may be due to increased DW available from beech tree mortality. Overall advanced-decayed wood had significantly higher carabid abundance and species diversity compared to wood in the early decay stages. Carabid abundance among DW classes varied by species with seven out of nine species highly correlated with specific DW types. Since certain species favored specific DW classes preliminary results suggest that a variety of types of DW is necessary to maintain biological diversity within forest stands.

Assessing the impacts of imidacloprid applications on non-target soil arthropods in imperiled eastern hemlock forests

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The University of Tennessee Agricultural Experiment Station and the USDA Forest Service are working in conjunction to assess the potential non-target impacts of insecticide applications used in the fight against an invasive insect, the hemlock woolly adelgid (*Adelges tsugae* Annand). The neonicotinoid insecticide, imidacloprid, is widely applied in infested eastern hemlock (*Tsuga canadensis* (L.) Carriere) forests by one of four methods-soil drench, soil injection, trunk injection, and foliar spray (horticultural oil). Soil arthropod community responses to each application method and to each application time (spring and fall) are being recorded. In addition, imidacloprid is being extracted from the soil habitat and quantified with high performance liquid chromatography. Also, standard toxicology studies with cultured Collembola are being conducted to elucidate lethal dose (LD_{50}) concentrations of imidacloprid. Initial data suggest a reduction in some groups of soil arthropods in the soil drench and soil injection treatments. The drench and soil injection sites appear to have the highest concentrations of imidacloprid. By August 2007, the laboratory toxicology tests and the field trials will have been completed, and we will have a clearer understanding of the impacts of chemical management practices commonly used in natural systems such as the Great Smoky Mountains National Park.

Missing in Action: The Abrupt Demise of a Red Oak Borer Outbreak in the Arkansas Ozarks.

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Extensive oak mortality due in part to a native wood-boring beetle, the red oak borer *Enaphalodes rufulus* (Haldeman) (Coleoptera: Cerambycidae) has been occurring in the Arkansas Ozarks. This outbreak has caused economic, ecological, and public safety concerns. Red oak borer has previously been reported at relatively low population density, but estimates in 2001 and 2003 reported remarkably higher populations. During 2005, late instar red oak borer population densities were estimated from ridge tops across the Ozark National Forest. At each of seven sites, nine red oak trees (*Quercus rubra* L.) were categorized into one of three classes using a Rapid Estimation Procedure (REP) designed to indicate tree health and red oak borer infestation history. Trees were felled, cut into 0.5 m logs that were then split, and larval density was recorded. Seven bolts, proportionally selected from each tree based on height of infested bole, were removed and returned to the laboratory for dissection and quantification of current generation galleries. During 2003 an average of 5.30 late-stage larvae/m^2 bark surface area was recorded from ridge trees vs. 0.15 in 2005. Density parameters did not differ between locations or REP classes. Causes and extent of this abrupt decline have not been determined.

Evaluation Semiochemical Trap Out Strategies for the Protection of High Elevatidon Pines against Mountain Pine Beetle Attack

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Whitebark (*Pinus albicaulis*) pine is widely considered to be a keystone species of subalpine habitats due to the critical ecosystem services it provides, such as wildlife habitat. However, recent increases in mountain pine beetle (*Dendroctonus ponderosae* Coleoptera: Curculionidae Scolytinae) activity have threatened the stability and possible future existence of these stands. Typical silvicultural strategies are not an option due to the often isolated and fragile nature of these high elevation stands. Such stands may benefit from repellent-semiochemical intensive holding tactics to provide stand-level protection against mountain pine beetle attack. In addition to repellent-semiochemicals, baited pheromone traps may absorb beetles dispersing from treated areas, creating a population "sink," reducing beetle populations in subsequent years. During 2004 and 2005, combined trap-out/anti-aggregation strategies were tested at three whitebark pine sites within the Greater Yellowstone Ecosystem (GYE). Verbenone (2004) and verbenone + C_6 non-host volatiles (2005) were applied (25 pouches of each per .25 hectare) in combination with single (2004) or clusters (2005) of baited pheromone trap(s), replicated four times at each site. Ongoing analyses indicate that surrounding mountain pine beetle population pressure and overall stand density index (SDI) influenced treatment efficacy.

Competitive interactions between *Pseudips mexicanus* and endemic mountain pine beetles (*Dendroctonus ponderosae*).

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The mountain pine beetle (*Dendroctonus ponderosae*) has no strong competitors when in the epidemic population phase; however, it is possible that competition occurs when beetles in the endemic phase must interact with other bark beetle species while occupying a host. The non-eruptive beetle *Pseudips mexicanus* is often found cohabitating with endemic mountain pine beetles in stressed lodgepole pine trees. *P. mexicanus* emerges early in the spring and attacks such hosts prior to the arrival of endemic mountain pine beetles, which disperse in late July. As the endemic phase of the mountain pine beetle has not been well studied, little is know about subsequent interactions. An experiment was conducted to evaluate the effect of *P. mexicanus* on the quantity of resources available to endemic mountain pine beetles and the subsequent effect on brood characteristics. Specific measures of interaction were assessed, such as ovipositional gallery overlap, ovipositional gallery lengths and mountain pine beetle brood size. Expected results are a decrease in the brood size of mountain pine beetles in relation to broods not interacting with *P. mexicanus*, shorter ovipositional gallery lengths and smaller individual emerging adults. Management applications, such as baiting to increase *P. mexicanus* populations in a stand, are explored.

Interspecific interactions among symbionts associated with two populations of southern pine beetles (*Dendroctonus frontalis*)

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Southern pine beetles (*Dendroctonus frontalis*) are symbiotic with mutualist mycangial fungi, other fungi (*Ophiostoma* spp.) that are antagonistic competitors of the mycangial fungi, and *Tarsonemus* mites that are mutualists of *Ophiostoma* spp. These interactions may influence the population dynamics and the evolutionary ecology of *D. frontalis*. We are examining interspecific interactions between these symbionts from two geographically-distinct *D. frontalis* populations: one in the southeastern United States, and one in Mexico and Arizona. We have three questions: 1) how do the growth rates of different *Ophiostoma* spp. strains vary under different environmental conditions; 2) are there antagonistic interactions between *Ophiostoma* spp. strains from the two regions; and 3) do symbiotic mites from the two regions differ in their ability to grow and reproduce on fungi from these regions? To address these questions, we are growing *Ophiostoma* strains from the two regions with media of low to high quality. We are also conducting bioassay challenges between *Ophiostoma* strains from both regions. Finally, we are conducting growth assays of *Tarsonemus krantzi* collected from both regions on *Ophiostoma* spp. and mycangial fungi from each region. These experiments will contribute to our understanding of the impacts that mutualistic and antagonistic symbionts have on *D. frontalis*.

The Response of Ground Beetles (Coleoptera: Carabidae) to Group Selection Harvesting

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We compared the response of ground beetles (Coleoptera: Carabidae) to the creation of canopy gaps of different size (0.13 ha, 0.26 ha, and 0.50 ha) and age (1 and 7 yrs) in a bottomland hardwood forest (South Carolina, USA). Samples were collected 4 times in 2001 by malaise and pitfall traps placed at the center and edge of each gap, and 50 m into the surrounding forest. Species richness was higher in the centers of young gaps than in the centers of old gaps or in the forest, but there was no statistical difference in species richness between the centers of old gaps and the forests surrounding them. Carabid abundance followed the same trend, but only with the exclusion of *Semiardistomis viridis* (Say), a very abundant species that differed in its response to gap age compared to most other species. Many species exhibited strong habitat preferences and were more abundant in young gaps, old gaps, or in the surrounding forest.

Because group selection harvesting creates a wide range of wildlife habitats and supports diverse assemblages of species, it may be preferable to other more disruptive timber removal practices.

Resin Production in Clonal Loblolly Pines: An Indicator of Southern Pine Beetle Resistance

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Resin production in loblolly pines is considered to be the primary factor contributing to southern pine beetle resistance. Previous studies indicate that trees bred for good growth characteristics are often those with high resin production. Resin samples were taken from clonal loblolly pines in Walterboro, SC in the spring of 2005. The site was composed of nine complete random blocks, each containing a single ramet of each clone as well as control trees from families 7-56 and CC-4. Two samples were taken from each tree, dried to reduce them to resin acid, weighed, and are currently being analyzed. The samples will be compared to determine if within clone variation is less than between clone variation and control family variation. Less variation within clones will suggest that it is possible to utilize cloning technology in plantations to plant trees that are more consistently resistant to southern pine beetle attacks.

Volatile profiles of hosts vs. non-hosts of the Asian Longhorn beetle, *Anoplophora glabripennis* (Coleoptera: Cerambycidae)

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Asian Longhorn beetles (ALB) host selection is mediated in part by plant volatile olfaction. The olfactory cues emitted from hosts vs. non-hosts, or a stressed vs. healthy host may provide the long-range cues for host location by ALB. The relative concentrations of antennally active compounds may provide the basis for host discrimination. Aerations were performed *in situ* on three host tree species: Sugar Maple (*Acer saccharum*), Striped Maple (*Acer pennsylvanicum)*, and Horsechesnut (*Aesculus hippocastanum*), and two non-hosts tree species, Ailanthus (*Ailanthus ailanthus)*, and Callary Pear (*Pyrus calleryana*). Volatiles were collected on Super-Q adsorbent. In a separate experiment, clones of a poplar hybrid clones (*P. nigra* x *P. maximowizii*) were hydroponically grown in the lab and volatile production were induced by manual damage or methyl jasmonate (MeJA) treatment. Volatiles were collected using solid phase microextraction (SPME). GC-MS analyses revealed that hosts and induced (manually damaged and MeJA treated) *Populus* sp. share green leaf volatiles (GLVs), aldehydes, and mono- and sequiterpenes, including cis-2-hexanal, cis-3-hexen-1-ol, octanal, nonanal, decanal, camphene, delta-3-carene, trans-caryphyllene. GC-EAD analysis confirmed male ALB antennae detected these same compounds. *P. calleryana* shared only hexanal and cis-2-hexanal with *A. ailanthus* and had no detectable terpenes. *A. ailanthus* samples contained octanal, nonanal, decanal, delta-3-carene, and farnesene, which are all host volatiles with the exception of farnesene. Although visual and gustatory cues are also be involved, these findings may uncover the olfactory basis for host discrimination.

Identifying ecologically-relevant spatial scales for longhorned beetles

Shulin Yang

Ecologically-relevant spatial scales on two habitat patterns, forest area density and forest connectivity, were determined for longhorned beetles for the Indiana Cerambycidae Survey 2005. The habitat patterns data were generated in ESRI Geographic Information System, ArcGIS, and a standalone C++ program written by me from the forest pattern of National Land Cover Data 1992. The scales were identified by the FOCUS 2 program based on the beetle data from the survey and the habitat pattern data generated.

Volume Gains in Loblolly Pine Produced by a Reduced Spray Regime to Control the Nantucket Pine Tip Moth

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The Nantucket pine tip moth (NPTM) is a pest of economic concern that can damage several species of economically important southern pines. This pest is multivoltine and in the Georgia Coastal Plain there are typically four generations per year. Our goal was to determine if stem volume can be increased using a single annual pesticide application. In January, 2003, 1000 trees entering their second year of growth and 1000 newly planted 1/0 seedlings were randomly assigned one of five treatments. Treatments tested to determine how stem volume is affected by independently controlling the first three generations during the first, second or first and second growing seasons. After three years, one experimental treatment was found to significantly increase average stem volume when compared to an unsprayed check. We found that trees that were protected from the first generation of NPTM during both the first and second years of growth were approximately 740 cm^3 or 25% larger than the unsprayed check.

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