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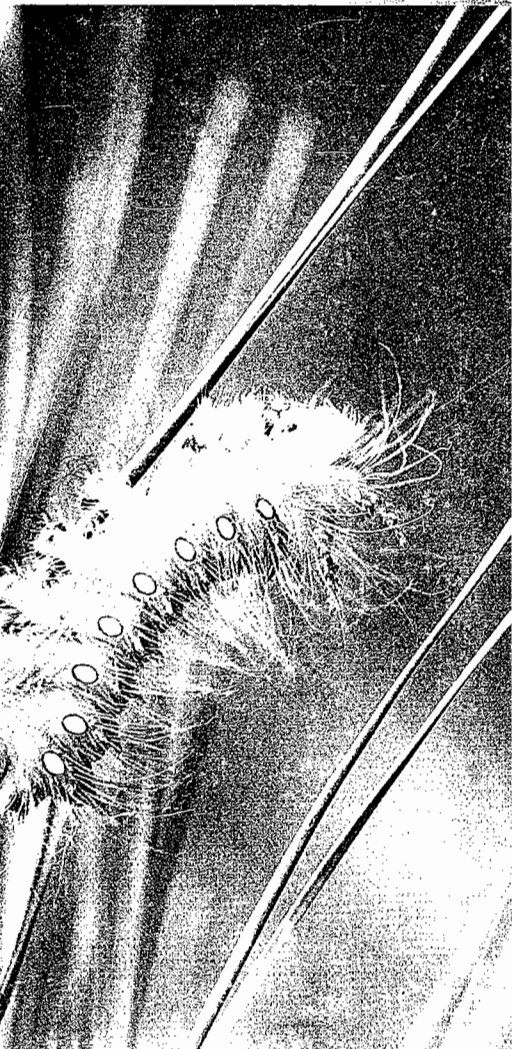
PROCEEDINGS:

NORTH AMERICAN FOREST INSECT WORK CONFERENCE

*Forest Entomology
Vision 20:21*



*• Forest Entomology • Forest Health •
Exotic Forest Pests • International
Protection Issues • Ecosystem
Management • Pests of Intensive Forestry
• Biological Control • Biodiversity •
Semiachemicals • Insect/Host
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Insect Photo Salon and more...*



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Abstract.—Proceedings of an international conference held to stimulate discussion and interaction among research scientists, pest management specialists, and foresters working in forest protection. Issues of national and international concern relative to forest insect and disease management, education, and research were addressed. National issues discussed included the future of forest protection, established and potential exotic forest pests, integrated pest management, biological control, forest health, ecosystem management, pests of intensive forestry, biodiversity, threatened and endangered species.

Keywords: Forest pests, forest insects, forest diseases, entomology, pathology, pest management, forest health, forest insect research

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Cover Photos by Ron Billings: (1) mixed pine/hardwood stand in east Texas; (2) lodgepole pines killed by mountain pine beetle in Oregon; (3) southern pine beetle galleries; and (4) larva of the imperial moth on loblolly pine.

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2ND NORTH AMERICAN FOREST INSECT WORK CONFERENCE

ORGANIZERS

Chairmen:

Ronald Billings, Texas Forest Service, Lufkin, Texas

Evan Nebeker, Mississippi State University, Mississippi State, Mississippi

Steering Committee:

Larry Abrahamson, State University of New York, Syracuse, New York

Douglas Allen, State University of New York, Syracuse, New York

David Appel, Texas A&M University, College Station, Texas

Scott Cameron, Union Camp Corporation, Rincon, Georgia

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Local Arrangements and Field Tours:

Texas Forest Service

PREFACE

The first North American Forest Insect Work Conference (NAFIWC) was held in Denver, Colorado in 1991. This pioneering effort was led by Douglas Allen and Larry Abrahamson, State University of New York, Syracuse. The success of the first NAFIWC, combined with the overwhelming endorsement from participants for a second Conference, were the catalysts that brought us to San Antonio. In April 1992, Doug Allen contacted the chairmen of the four regional forest insect work conferences to encourage the organization of a second NAFIWC. Participants in the East Texas Forest Entomology Seminar decided to accept this great challenge, with support of the Southern Forest Insect Work Conference. Chairmen and steering committee members were identified from the regional work conferences throughout North America to bring about this Conference, which was more than three years in the planning. After much debate, it was decided we needed to have a theme for the Conference. Upon review of suggestions solicited from steering committee members, the theme "Forest Entomology: Vision 20:21," offered by Scott Cameron, was selected. A look back and a look ahead as we approach the 21st century was the intent (although some thought it might refer to our fuzzy vision of the profession).

Clearly, the challenges facing forest entomologists and forest health specialists have changed dramatically since we met in Denver in 1991. Recent shifts in emphasis toward ecosystem management, rare and endangered species, forest sustainability, and biodiversity have changed the management of public and many private lands. These changes, in turn, are affecting forest health in many regions of North America. Exotic pests already present in North America, such as the Asian gypsy moth, European pine shoot beetle, and hemlock woolly adelgid, together with increasing raw log imports, add to existing forest pest problems and forest protection challenges. Forestry school curricula across the continent are being modified to address future needs in forest resource management and forest health protection. Concurrently, severe cutbacks in financial support for forestry research and technology development in both Canada and the United States have forced agencies to reduce their professional staffs and operating budgets. In addition, the last five years have seen an explosion of computer technology, including the Internet and World Wide Web, that affects the way we do business.

Our goal, as with the first conference, was to stimulate scientists and practitioners to work together in addressing forest resource issues of national and international concern in which we all have a vested interest. In formulating the agenda, the steering committee tried to pay particular attention to current issues of mutual concern throughout North America with the intent of broadening our perspective and our base of participation. Approximately 320 forest entomologists, forest pathologists, foresters, and specialists from related fields attended the four-day session. Participants included representatives from research institutes, universities, national and state forestry agencies, and private forest industry from Canada, Mexico, and the United States. The Conference also attracted scientists from New Zealand, Germany, Sweden, Finland, Spain, Russia, and the Czech Republic.

In addition to panel discussions, workshops, and poster presentations, participants were offered a choice of several field trips in the Hill Country of central Texas, hosted by the Texas Forest Service. These included a tour of areas devastated by oak wilt and a discussion of state-federal cooperative suppression efforts, a visit to Enchanted Rock Natural Area, a tour of limestone caverns, an urban forestry/urban forest pest tour, a self-guided tour of San Antonio, and the Frontalis Cup Golf Tournament. Also, participants with photographic skills were given an opportunity to compete in the first NAFIWC insect photo salon.

Following a welcome by the Texas State Forester, the Proceedings are organized into nine sections: I. Plenary Panel Addresses, II. Invited Paper, III. Panel Abstracts, IV. Workshop Abstracts, V. Poster Abstracts, VI. NAFIWC Insect Photo Salon, VII. Conference Evaluation, VIII. Author Index, and IX. Names and Addresses of Participants. Panel and workshop abstracts appear in the order they were presented at the Conference, whereas poster abstracts are organized alphabetically by first author. Manuscripts were edited following submission and each was returned to a moderator for review. Authors are responsible for the contents of their contributions.

These Proceedings reflect the forest entomological concerns of the time, as did the proceedings of the first NAFIWC, and as such should be of historical interest for many years to come. We thank all the speakers, moderators, participants, sponsors, and contributors who together made the second NAFIWC an unquestionable success. We look forward to the third NAFIWC (or perhaps the first global work conference) and the many challenges that await us in the 21st century.

ACKNOWLEDGMENTS

Many people in addition to the steering committee and sponsors contributed to the success of the second North American Forest Insect Work Conference. We thank Douglas Allen and Larry Abrahamson, State University of New York, Syracuse for taking the initiative to organize and serve as chairmen for the first NAFIWC. Their experience, encouragement, and numerous suggestions also greatly facilitated organization and successful conduct of the second NAFIWC. Jane Hayes, USDA Forest Service, Pineville, LA served most ably as chairman of the poster session while Sharon Anderson, USDA Forest Service, Pineville, LA and Herbert "Joe" Pase III, Texas Forest Service, Lufkin assisted her in compiling and editing the poster abstracts. Gerald Lenhard, Louisiana State University, Baton Rouge organized, selected judges, and served as moderator for the first North American forest insect photo salon; and Joe MacGown, Mississippi State University, Mississippi State designed the NAFIWC logo used in the Conference program, proceedings, and souvenirs. We appreciate the valuable contributions provided by each of these volunteers.

The tireless dedication and attention to detail of Martha Johnson, Texas Forest Service, Lufkin was key to successful conference registration, fiscal management, and organizational matters. Special thanks are extended to the many other Texas Forest Service employees and spouses who also voluntarily contributed time and effort to Conference preparation, on-site registration, and the various field tours. These included Cathy Wallace, Herbert "Joe" Pase III, Don Grosman, Gene Gehring, Donna Work, Bill Upton, Jeff Anderson, Susie Shockley, Mark Duff, Mark Peterson, Robert Edmonson, Renee Burks, Amy Bailey, Brian Sichel, Jan Davis, Thomas Johnson, and Carmen Billings. We also thank David Appel, Texas A&M University, College Station for his valuable contributions to the oak wilt field trip and Robert Coulson, Texas A&M University, College Station for organizing the Frontalis Cup Golf Tournament.

For their instrumental roles in securing funding to support the Conference, we extend our appreciation to Ann Bartuska, USDA Forest Service, Forest Health Protection, Washington, DC, Wesley Nettleton, USDA Forest Service, Forest Health Protection, Atlanta, GA, and Robert Bridges, USDA Forest Service, Forest Insect and Disease Research, Washington, DC. The Conference also was funded in part by Grant No. 96-3502-3019 from the USDA National Research Initiative Competitive Grants Program, awarded to the co-chairmen.

Finally, we are indebted to Cathy Wallace, Texas Forest Service, Lufkin for her word processing skills, limitless patience, and hard work which greatly facilitated the preparation and timely publication of the Conference registration flyer, program, and proceedings.

R. F. Billings
T. E. Nebeker

WELCOME TO TEXAS

Bruce R. Miles¹

¹Director, Texas Forest Service, College Station, TX 77843

As the State Forester of Texas, it is my pleasure to welcome the over 300 participants to the North American Forest Insect Work Conference. San Antonio is an ideal conference city.

Dr. Billings, his staff, The Texas A&M University System agencies and departments all worked hard to make this a successful meeting. I am sure the results will bear this out.

Texas is not well known for its forest resources but they support a \$14.6 billion dollar economy with its roots in the 11.7 million acres of commercial forest land of east Texas. Its ownership has become a major factor in recent years as federal lands in the West have essentially been shut down as the nation's woodbasket. With 93% of the east Texas commercial forest land in private ownership (60% by small private landowners), many western wood producers have looked to Texas and the South for timber supplies. This point was brought home to me a few years ago at an Association of Consulting Foresters meeting in Ashland, Oregon. A western timber analyst said, "You people in the South are going to laugh all the way to the bank over the spotted owl issue."

Indeed, that has happened. In the last three years we have seen timber prices escalate to \$300, \$400, \$500, and a few cases over \$600 per thousand board feet before declining and leveling off as mills try to make a living with expensive raw material. This has brought on numerous problems, viz. the resource is being overharvested, timber theft is on the increase, and local tax assessors are asking for increases to reflect the new markets. If that were not enough, foreign buyers have moved into east Texas to the pleasure of the landowner and the bane of the domestic mill owners. Additionally, preservationists have continued efforts to stop harvesting on the four National Forests in Texas.

While the 650,000 acres of national forests comprise only 6% of the total commercial forestland, they are an important segment of the economy for those mill operators without a land base. This timber also

produces a disproportionate amount of the higher quality logs because of the rotation age (70 years for pine; 85 years for hardwood). It also produces a disproportionate number of southern pine beetles, the South's most destructive forest insect.

It has been considered criminal by many that the Wilderness Act has allowed over fifteen thousand acres (nearly 50%) of Texas wilderness pine trees to be destroyed in the name of "letting nature take its course." This has resulted in the loss of millions of dollars of federal assets, the destruction of timber on adjacent private lands, and created a catastrophic wildfire potential as well as a "beetle factory" in future years. As one adjacent affected landowner, who is also a physician, said, "What if we in the medical profession had let nature take its course with polio, smallpox, or the bubonic plague?"

The southern pine beetle is not the only forest pest problem in Texas. Oak wilt, vectored by insects, is a major disease problem in over fifty counties in central Texas in and around the San Antonio area. I hope the oak wilt field trip makes this point. This disease has affected ranchland, wildlife habitat, real estate values, and the scenic beauty of the Texas Hill Country.

So I hope you have a productive visit in Texas, leave with a better understanding of its forest resources, and share your knowledge with the other participants. As Colonel Travis pled for assistance at the Alamo, I too welcome your continued efforts to address the forest pest problems in Texas and the remainder of North America.



Section I

Plenary Panel Addresses

FOREST PROTECTION: A PAPER TIGER OR AN EVOLVING SCIENCE?

Moderator: Douglas C. Allen¹

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When I was asked to organize the Plenary Session for the Second North American Forest Insect Work Conference, the organizers were generous in the latitude allowed for subject matter and format. A variety of titles and potential speakers came to mind as I thought about the Conference and my perception of what it should accomplish. This meeting affords a unique opportunity for convening a critical mass of forest entomologists to review and discuss research, teaching, and extension needs and to reflect on important concerns in these rapidly changing times.

Two social events are having a major impact on our profession: (1) unprecedented budget reductions for all public agencies and reconfigurations in the way these agencies function; and (2) public awareness and perceptions relative to environmental issues. A desire to balance local, state, and national budgets and a steady increase in public awareness about the environment suggest that these trends will continue. Additionally, forestry and other resource management curricula in North American universities are being massaged to accommodate an ever-increasing demand for a diverse array of subject matter, which often dilutes student exposure to forest biology courses.

As a consequence of these events, public agencies have embraced an array of publicly appealing philosophies such as "forest health," "ecosystem management," and "sustainability." Indeed, public scrutiny of forestry has stimulated interest in certification programs aimed at achieving sustainable forest management. These programs will affect forest pest management activities and our ability to employ scientifically and economically sound management strategies. Similarly, educational institutions are struggling with more imaginative ways to adequately prepare resource managers to deal with a range of scientific and social issues.

With this in mind, I asked speakers from a federal agency, a state organization, a forest industry, and an educational institution to speculate on the impact these social mandates and changes in public agency agendas

will have on our profession. Also, they were invited to speculate on how well forest entomology is situated to deal with budgetary constraints and environmental concerns that inevitably will impinge on our research, teaching, and public service activities. Are we willing and able to change with the times (an evolving science) or will we continue business as usual (paper tiger)?

All four speakers touched on major policy and scientific issues that are reshaping the forestry community. As I listened to their messages and absorbed what was said at several sessions during the meeting, an old concern repeatedly came to mind -- all of us must become active in our respective professional forestry organizations; the Society of American Foresters (SAF), the Asociación Profesional de Forestales (APF), and the Canadian Forestry Institute (CFI). It is from these organizations that political entities often seek guidance in the decision-making process that shapes forest policy. And, like it or not, this policy has a major influence on forest entomology. The SAF, for example, accredits forestry curricula in the United States and takes positions on forest policy issues that will shape our future. We must actively participate in these debates if we want to assure that students of resource management have a solid foundation in the basic sciences and that forest policy is based on good science relative to pest management.

These professional organizations often critique proposed budget cuts and are asked to review legislation that will influence the way we do business. They must provide informed responses about issues such as forest health, ecosystem management, log importation, pesticide use, and many other subjects which should have the benefit of input from forest entomologists and pathologists. Forestry is our *raison d'être* and, in my judgement, we fail to invoke our responsibilities as forest entomologists and pest managers if we choose not to influence debates that will determine the future condition of our forests.

FOREST PROTECTION: A PAPER TIGER OR AN
EVOLVING SCIENCE? FEDERAL AGENCY
PERSPECTIVE OR A FOREST HEALTH
PROGRAM FOR THE 21ST CENTURY

Ann M. Bartuska^a

We have been asked to address the issue of forest protection -- are we seeing a true evolution in the science of forest protection? The answer is an unequivocal YES! Part of this evolution is evident in the words used to describe who and what we are. The title "forest health specialist" more aptly conveys the role we play and the work we do. In my presentation, I will explore what changes have and are continuing to occur - and I will more often discuss 'forest health' than 'forest protection.' My remarks reflect not only the position I hold in the USDA Forest Service as Director of the Forest Health Protection staff (previously Forest Pest Management), but also the role I and the staff have played in addressing forest health as a policy for the Forest Service.

Recent events have brought the issue of forest health and forest protection squarely into the public's eye. This visibility was driven initially by the wildfires of 1994, where the loss of life brought renewed attention to the condition of the western forests. More recently, the epidemic-level outbreak of southern pine beetle in 1995 through most of the southern U.S., and an unusually early start to the fire season in the southwestern U.S. in 1996, has kept the issue of forest health in the news. On the political front, forest health and forest protection are getting high-level attention largely due to two key Congressional actions -- the addition of the "salvage rider" to the Recissions Act (P.L. 104-19) and the Forest Health Bill (S.391) proposed by Senator Craig of Idaho. Unfortunately, much of the rhetoric has so closely tied salvage activities with accomplishing forest health objectives that more far-reaching needs for forest protection and restoration are being undermined. The cry from many environmental groups that salvage is just an excuse to cut timber does not acknowledge that vegetation management, especially thinning and species-specific harvesting, is a scientifically valid approach to restore numerous ecosystems. However, this is the subject for a different presentation.

The visibility of forest health issues is enabling the forest health professionals -- entomologists, pathologists, mycologists, ecologists, fire professionals,

and silviculturists -- to interject understanding of insect and disease dynamics and fire cycles into debates on timber harvesting and salvage. The debate provides an opportunity to emphasize the necessary role of vegetation management and the reintroduction of fire in order to accomplish restoration of many of these ecosystems to an ecologically-sustainable condition. It is also an opportunity to clearly show that forest health is not just a western issue nor just a fire issue, but that every region of the country is faced with some stress that affects land management objectives.

Two other issues in the forest health/forest protection lexicon have recently increased in visibility. Air pollution and acid rain, which never really went away as environmental problems, fell off the public's viewscreen with revision of the Clean Air Act at the beginning of this decade. However, scientists and practitioners continued to monitor precipitation and soil chemistry and patterns of ozone symptoms. Recent studies from Hubbard Brook made the front sections of both the *New York Times* and the *Washington Post* with reports that ecosystem recovery from the reduction in sulfur dioxide will occur at a much slower rate than predicted when the revised standards were set.

The second issue is noxious weeds, a short-hand for non-indigenous invading plants. High level of attention at both the State and Federal levels is focusing on control, eradication, and exclusion strategies nationwide. There has been increased recognition that noxious weeds have profound effects ecologically (e.g., reducing native biodiversity) and economically (e.g., poorer quality or unpalatable forage). Thus, the expertise of scientists and field practitioners in forest protection who have long dealt with introduced insects and diseases is increasingly called for to deal with introduced weeds. As society demands that use of chemical pesticides be reduced, the move to biocontrol measures has a direct effect on the role of entomologists and pathologists.

The positive side of this attention is that it is bringing entomologists and pathologists squarely into the policy debate on forest and range health. Our professionals are well on the way to the evolution from pest management specialists to forest health specialists, from solely focusing on insects and diseases to include considerations of fire, vegetation management, and disturbance cycles at the landscape level. One of the more exciting advances in our thinking in addressing forest health issues is the consideration of insects and

diseases as regulatory mechanisms in ecosystem structure and function; for example, in resetting succession. The disciplinary expertise of entomologists and pathologists brings a desirable and necessary understanding of critical ecosystem components. That is why I believe we will see more of our professionals looking at the beneficial role insects and fungi play in the landscape, and not just the “pest” view. Taking a landscape view also is a change in our land management approach, forcing us to look beyond individual tree or stand dynamics. What is the role of a single beetle-infested tree? a beetle spot? a root-rot center? in a watershed or vigorously growing forest. What is the interrelationship of normal insect and disease cycles to long-term forest sustainability? These are the types of questions we will increasingly be asked to answer.

Commensurate with this expanded thinking about the role of insects and diseases is the enhanced use of advanced technologies. For example, remote sensing is being used for change detection in California, a different approach to describing trends in areas of stress and mortality than annual aerial surveys. In other locations, geographical information systems (GIS) are being coupled with pest models. A new “Forest Health Home Page” is providing easy access to forest health information on the Internet. Engineering advances have created timber-harvesting equipment that can selectively thin a stand, leave mulch under the wheels to minimize soil compaction and add organic materials, cut the stems to length, AND treat the stump to reduce *annosus* infection. I bring forward these examples to illustrate that forest health professionals are taking advantage of advanced technologies to better solve complex, natural resource problems. In response to the question posed by the session title, I would like to suggest that the recognition, use, and support for these advances is contributing to the evolution of forest protection science.

A Forest Health Policy

In order to bring some focus to the forest health issue, and to provide a common framework within which to operate, the Forest Service has been developing a policy and definition of forest health. The Forest Service’s *Western Forest Health Initiative*, developed in 1994 in response to concerns raised by the wildfires of that year, identified the need to develop a long-term strategy for addressing forest-health concerns

nationwide. The articulation of a policy for operations was considered key to that strategy, in recognition that forest health as a concept or a land-management goal does not appear in any Forest Service directives or guidelines, except for the Forest Health Protection function within State and Private Forestry.

The key elements of the draft policy are:

- Flows out of the Chief’s “Ethics and Course to the Future”
- Provides for integration of forest health direction across the Agency
- Provides concise direction within the Agency to:
 - Manage to promote healthy conditions;
 - Evaluate at the landscape or larger scale;
 - Use criteria and indicators to assess accomplishments;
 - Use monitoring data to evaluate forest health trends; and
 - Work with other governmental agencies and with the public across the landscape to promote forest health
- Defines forest health as:

A condition wherein a forest has the capacity across the landscape for renewal, for recovery from a wide range of disturbances, and for retention of its ecological resiliency while meeting current and future needs of people for desired levels of values, uses, products, and services.

We recognize that, while the policy and definition bring some clarity to the forest health issue for the Forest Service, uncertainty still exists in implementation. It is our intent to implement this policy in an adaptive manner, providing opportunities to further clarify, test, evaluate, and revise the policy and our approach.

(NOTE: For those readers who are interested, the full policy will be published in the Federal Register later this year as interim direction to the Forest Service, and a public comment period provided.)

What Will a Forest Health Organization Look Like in The 21st Century?

I wish I could say with some certainty what the organization will be like five years from now, but the best I can probably do is to describe the characteristics of the organization I would like to be leading as the new century arrives. This may be my wish list, but I believe it is achievable. What will we look like?

- We will be characterized by a diverse, professional workforce whose high standards and quality ensure credibility in the work we do -- and in the subsequent management decisions. To get there, we must maintain a critical mass of entomologists, pathologists, and other forest health specialists in our ranks. We must work with the professional societies and universities to stop the slow (or in some cases, not so slow) erosion of our scientific capability, and increase the recruitment and development of new professionals.
- We will know where the current and emerging problem areas are located in the United States through the full implementation of a forest health monitoring program. Through the integration of the current aerial pest survey with the Forest Health Monitoring Program, a nationwide, annual assessment of the condition of America's forests can be accomplished. Such a reporting process will provide an important tool to prioritize those parts of the country with critical or emerging problems. Given the desire by the American public to reduce the size of the Federal government, this system is a way to make the most efficient use of scarce resources.
- We will increase our efforts in boundariless behavior in program delivery. Forest health professionals have long recognized that critical insect and disease problems do not respect political boundaries, and our activities on the ground have been characteristically collaborative. This level of collaboration must be maintained and enhanced.
- We will continue to take advantage of new technologies and will maintain support for research and technology development as a priority. During times of budget reductions, this is an effort often difficult to maintain, but it is misguided to support actions on the ground at the expense of developing new knowledge. It can not be an

either/or choice! A balance must be retained between these two classes of activities.

- We will become communications specialists as well as technical specialists. There is a critical need to share the knowledge and trends we are observing with land managers, a larger public and, arguably more necessarily, to elected officials. There is an opportunity to bring our skills to where the people are, especially to the urban environment. Urban forest health (or forest protection) is only marginally recognized, except by urban foresters.

To return to the subject of the panel discussion, I believe we are an evolving science (or sciences) engaged in evolving management. It is too late for those who would take a "wait and see" approach or assume forest health is today's buzzword -- the paper tiger. Forest health as an issue is here to stay. We are only now beginning to grasp the implications of the last century's lessons, and the translation to practice is a slow and arduous one. I believe that forest health specialists will be in the vanguard of this transition.

FOREST PROTECTION: A PAPER TIGER OR AN EVOLVING SCIENCE? STATE PERSPECTIVES

David A. Leatherman^b

First, let me say it is an honor to participate on this panel and I thank Doug Allen for the opportunity to do so. Being a part-time college lecturer and frequent talk giver, my only problem with it is my time allotment - I would be more comfortable with 50 minutes. The students, arborists, and homeowners I talk to are barely in their seats in 15 minutes!

My task is to represent the point of view of the states, and I think what I say could also be interpreted on behalf of local governments (counties, cities, and towns). My approach in preparing was threefold. I first considered the question from a personal, Colorado viewpoint. Then at the urging of my conscience and others, I polled all State Foresters for input. Finally, I struggled for a composite. I heard from 28 states, which I am told was a good response on short notice. I appreciate very much the time and effort of those who answered my request. I also understand why responding may have been too inconvenient for some. I think I know what your "IN" boxes look like. I can

see homeowners, pieces of sick trees in their hands, filling your doorways and wanting immediate, accurate diagnoses. I can envision those memos with "please handle" across the top. And I can hear the phone or see the voice mail light beeping. Then there's the e-mail screen, which you turn on with intrepidation each morning. How many "UNREAD" messages this time? [Who says we are not evolving? They didn't even have e-mail when Le Roy Kline started working in Oregon a few years ago.] Another reason for no response may have been the lack of a body in the chair to respond. Some states have never had forest protection specialists. Even more alarming, recently some of these positions have been vacated and not filled. Rich Dorset, we miss you.

So, given the chance, what did my peers say? As you might expect, the pressing issues are quite varied. The horizon looks cloudy or bright, depending on the particular state highway scenic overlook. It is impossible to capsulize all the various viewpoints but here are some themes. Before I get too far, I commend the program committee for this Work Conference. Many of the panels, field trips, and workshops planned for the next few days directly address state-identified issues and needs.

Depending on the definitions selected for the elements of our question here, the discussion could take many directions. The states have various missions and these help them to individually select program direction. This is particularly true in considering the term "forest protection."

In states with strong markets for forest products, especially those charged with maximizing revenues from state lands, the job of protection is complex but clear. Emphasis is on silvicultural prevention of outbreaks, plus suppression and/or salvage of trees that succumb to pests. In states like Washington, Oregon, and Idaho, stocking reduction and promotion of seral species receive emphasis.

Other states have no or few lands of their own to manage. Rather than no priority, this inevitably means several #1 priorities. On behalf of private forest owners, forest protection specialists may perform primarily in an extension or technical-support role. As such, the particular flavor of forest protection called for is dictated by the goals of various landowners. The forest entomologist may be asked to prescribe and execute a protection strategy that: protects outputs

valuable in a traditional marketplace (i.e., "timber"), protects habitat for a particular wildlife species, protects esthetics and other factors contributing to property value, protects a key watershed, protects total biodiversity, protects a highway from blowing snow or a farm field from erosion and wind, or even protects the vigor of an individual tree. More and more, state participation in protection finds us actively facilitating the local interests who actually own, shape, and finance ultimate solutions. Maine is a model in this regard.

As for what we are protecting the forest from, most of my peers spoke in terms of insects and diseases. Others included fire, exotic plants, and the after-effects of severe weather. Perhaps at times we are protecting the forest from exposure to ignorant human practices, and we do so "simply" by aggressively disseminating the best, most-current information available.

On the question of "paper tiger" or "evolving science," the raw vote was 17 science, 9 tiger and one response I could not categorize as either. Amid yet another response was a very creative and vivid description of a mauling at the jaws and claws of an imaginary tiger. [Karen, if it doesn't work out in Washington, you have a bright future as a writer.] Within the majority view affirming our field as an evolving science, I should note the many large, Hyakutake-sized asterisks.

My personal response upon exposure to our panel's title was this does not have to be a "pick one" question. We are often evolving but sometimes unable, for various reasons, to effect much change in practice or result. I was not alone in this thought.

Everybody probably feels in the middle, but the state position seems particularly so located. Being sandwiched between the forces represented by the rest of this panel is awkward at times but ultimately proper.

Each state's situation is different, but to some extent we all depend on federal funding. Two types of funding are involved: automatic formula types and specific grants. First, there are some problems with the existing bases for formula-funding. An example would be funding based on a rather artificial definition of "commercial" forest acreage. When a major tree pest develops on "non-commercial" forest land, it must still be addressed. Under the current scheme, to do so requires dollars from non-federal sources or federal suppression funds (the latter requiring an annual application and often the uncertain and/or delayed

reception of funds midway or even later within the federal fiscal year). Secondly, any general decrease in federal support for state protection programs, such as access to suppression contingencies, will hurt. Formal declarations of disaster, as the southern pine beetle now necessitates in some southern states, depend on such funding for partial resolution. New programs, like Forest Health Monitoring, are both a source of hope and concern to many states. While we certainly support long-term, statistically-sound monitoring of environmental change, such regional or national programs should not be done at the expense of programs of more immediate or local benefit. We need both, not one or the other. Related to this, where programs with national benefits like FHM solicit state participation, funding should be realistic enough to cover the new workload. We are wary (weary?) of having to divert resources from state-mandated duties.

On the question of research, a similar situation exists. Again, the states are largely dependent on university, federal, and industry-sponsored research. We appreciate it. Decreasing support for research will certainly be felt by those of us with one or both feet in the field.

In response to the declining research capabilities of our suppliers, there are various tacks we could take. One, which is obvious but overlooked, should be to make certain we are familiar with, and incorporate, existent research results. I know much good work, performed by those in this room and those who formerly made up this body, still awaits application. Just because something was done without the aid of modern computers or GIS does not mean it's invalid. Another approach is to do what we can to increase awareness of our needs and then to support people who are in positions to help. At the risk of raising some blood pressure, I would be remiss if I did not mention the following viewpoint: At times it feels like the needs of forestry practitioners are somewhat forgotten during research planning, but our support is eagerly solicited in times of attack by the RIF monster. Lastly, we could undertake research efforts ourselves to fill in gaps. On a limited scale this has and is being done. Florida and Texas are examples.

As for types of research, some of my colleagues feel we have most of what we need to address traditional forest protection questions. Others would disagree. This seems to indicate an uneven treatment of research questions historically between regions, and/or that

better local dialogue between researchers and users is needed. In areas with unanswered questions, research should not totally abandon familiar territory, such as improved risk-rating schemes, development of new pesticides, and associated application technologies. The inevitable emergence of exotic plants and exotic pests will likely require novel detection, evaluation, suppression, and prevention tactics.

But a major challenge, and in some cases "the rub" with research, comes from the "newer" questions -- those dealing with landscapes or vast temporal scales, of biodiversity and disturbance interactions in ecosystems, and questions not yet asked. Such areas obviously need rigorous, sustained investigation. As a recipient and benefactor of research findings, I believe that current funding deficiencies create an undesirable situation -- effort is put into new fields of study, crippling or eliminating efforts in many of the old ones, including established veins of research which continue to be productive. Why is it that, if we explore the impacts of habitat fragmentation on forest-interior birds, we have to abandon traditional insect life-history studies? If we allocate effort to ground-breaking, interdisciplinary, basic research, must we drop single-issue, applied problem-solving? The choices are tough, but as states we argue strongly that any research pallet be balanced but at least include an ample assortment of applied colors.

For states a major barrier to practicing protection is excessive regulation. Most, if not all, regulations and laws were created for good reasons. My personal opinion is we need leaders who will help us cleanse the bath water, not politicians whose only "vision" is pitching the baby.

The gamut of sticking points with regulation ranges from threatened and endangered species protections to trade agreements, from data requirements to archeological site safeguards. I do not intend to wade too far into this tar, but one example I will bring up falls both within the research and regulatory arenas. Why in 1996 is MCH still not (or just being) registered, when the first discoveries of its utility for managing Douglas-fir beetle came over 20 years ago? Requiring the same testing protocols for it (and other naturally-produced semiochemicals) as for synthetic chemical pesticides seems to eliminate viable markets and is distinctly anti-evolutionary. Similar molasses affects utilization of verbenone and other promising materials. [I hope you have better luck with 4-aa, Jane. I have

forested subdivisions where people know all about it and wait with check books in hand. We need the rapid development of these tools and others for protection to progress.

In reading the various state communiques, I sensed an underlying frustration with fire issues. Wildfire generates unbounded public demand for protection services, yet organisms cause greater losses. One state entomologist only half-jokingly suggested in order to garner appropriate support we need an insect with fire characteristics. If you ever see a promo for an upcoming "Nightline" about the East Texas Smoke Beetle (*Dendroctonus billingsii*), you'll know of whom I speak. No doubt this indicates a need for more, innovative outreach about entomological issues. Smokey has been a headliner for decades, but is not so fat that stage-sharing is impossible.

Our other major fire concerns -- (1) fire suppression tactics leading to insect-prone conditions, and (2) extensive pest-caused mortality creating fuel loads of catastrophic potential -- are almost cliches to most of us, but the public and legislators still need to hear it and hear it again. I have never understood the chasm that exists in our hallways between various forest protection factions. I suspect fire is unique because of safety and legal considerations. There are signs we are coming together and the states should encourage continued evolution of cooperation between these natural, at least on paper, protection partners.

We need to get definitions straight or adopt new concepts for which we can come to mutual understandings, if not agreement. Many business cards of my peers now say "Forest Health Specialist" right under their names. Others argue strongly that "forest health" is such a nebulous term it creates false expectations in our customers and should be abandoned.

Other issues, in no particular order, inherent in the paper tiger versus evolving science answers I received include:

- The need for further resolution of value system clashes. The goals for public and private lands differ about as often as their boundaries abutt.
- Many states still feel we are far too reactionary in our approach to "pests." We know much more about prevention than we practice.

- Exotics, including plants, are an increasing problem and receive far too little attention. This is particularly true of Florida where they are considered the number one issue.
- The increasing numbers of people living in, using, and dependent on the forest dictate an increasing need for protection, however defined.
- Our forest landowner clientele is changing. Besides being more of them, they come from more urban backgrounds. They individually own smaller fractions of ecosystems but think of their land as self-contained planets. While familiar with environmental issues unimportant or unknown to their predecessors, much education is needed to move their ecological understanding beyond the superficial. A word of caution, this will require as much listening on our part as preaching.

In summary, the states are in the middle. We depend on universities, the federal government, and industry for sustenance, tools, assistance, and inspiration. When appropriate we lead, support, and follow the other factions. Among others, we have concerns about funding, the future of research, fire issues, and regulation. The health of our relationship with these issues largely determines how our profession evolves. Are we part of a crisis? Perhaps, but the crisis is one we can and will survive. The states welcome our role in the challenge to do so.

FOREST PROTECTION: A PAPER TIGER OR AN EVOLVING SCIENCE? A UNIVERSITY PERSPECTIVE

John A. McLean^c

The March 1996 issue of the Journal of Forestry is devoted to the topic of "Educating Tomorrow's Foresters." This is the *raison d'etre* for those of us who teach in the Universities. We have all seen the red suspender-snapping logger (Egan 1996) who was single-minded in his wish to extract the most commercially-valuable logs from the forest. As pointed out by Fisher (1996), there have been some dramatic changes in the forestry curriculum. Basic surveying courses are replaced by advanced courses in geographic information systems. Silviculture not only includes the basic activities of planting and growing the forest to

maturity but also now includes high-powered decision support systems that invariably include complex growth and yield models.

In the same issue of the Journal of Forestry, two lady foresters, Deborah Gaddis and Heidi Rieckerman, make a call for multidimensional learning. They rate the hands-on summer camp program as an absolute necessity. How can anyone manage a system he/she does not know first hand and understand well? they ask. I will come back to some of these points. Suffice it to say that you know today's reading assignment!

Along with the development of a more complex, multidisciplinary curriculum, there is also an increasing globalization that is affecting forestry just as much as any other commodity area. We were blessed with a high grade of product in our virgin forests. Now that much of the virgin forest has been liquidated or declared a protected area, we are coming face to face with second-growth stands that we harvest at much younger ages. These trees do not produce lumber of the same quality as that from the outer regions of old-growth trees. This in turn has led to some innovative product development -- particle boards and flake boards replace the old plywood, parallam® replaces glulam and long-reach large timbers. Just as our fisheries are taking smaller and smaller sizes in their catches so we are now looking to harvest the second-growth stands as soon as possible.

It is interesting to reflect on the utilization of wood world wide. While we consider it to be mainly a building material, there are many areas of the world where wood is used more as fuel than as a structural material (Table 1).

Table 1. World production of roundwood in 1993 (millions of m³).

Region	Soft-wood	Hard-wood	Fuelwood/Charcoal	Total
North and Central America	458.7	128.0	156.7	743.5
South America	55.9	64.0	247.9	367.8
Africa	10.2	49.4	493.6	553.1
Europe	191.3	61.9	50.9	304.1
USSR/ Russia	95.5	36.8	51.6	183.9
Asia	94.1	175.5	866.4	1,136.0
Oceania	23.6	13.3	8.8	45.7
Totals	929.3	528.9	1,875.9	3,334.0

Source: FAO 1995

You will note that the world uses more than 3.3 billion m³ of roundwood each year. More than half of this is used for fuelwood and charcoal. North and Central America produce almost half of the world's coniferous roundwood. Will we maintain this position? I think not. Canada and the United States have only 26% of the world's softwood growing stock (Fig. 1). Markets that we have worked hard to establish will see increasing competition from the southern hemisphere with its ever-increasing exotic pine resources. What will happen to our high-value markets in Japan, Korea, and China should the Russians ever develop an infrastructure that allows them to market their immense softwood resources? In the short haul though, we must ensure that we maintain our rich sustainable forest resources as well as we can, and indeed should even be able to increase them by practicing good silviculture and keeping insect and disease impacts to a minimum.

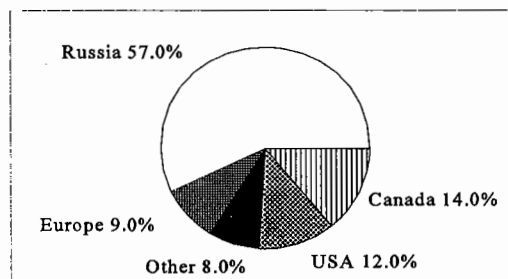


Figure 1. Distribution of the world's softwood resources (FAO 1995)

Are we still needed? as entomologists? as teachers of forest entomology topics in the lecture halls of our Universities? I plan to consider questions in three areas: (1) Do insects still damage our forests? (2) What does the 21st century forester need from us?, and (3) How do we provide information in a timely manner?

Question 1: Do insects damage our forests and forest products?

Advanced remote sensing capabilities, conventional aerial sketch mapping, and ground sampling all serve to show us that insects destroy a significant proportion of our forests every year. In eastern Canada, most of this volume loss is caused by defoliators such as spruce budworm, forest tent caterpillar, and gypsy moth to name but three. In the West, western spruce budworm, Douglas-fir tussock moth, and western hemlock looper

also have been depletion agents, but the major impact comes from mountain pine beetle and spruce beetle (Fig. 2).

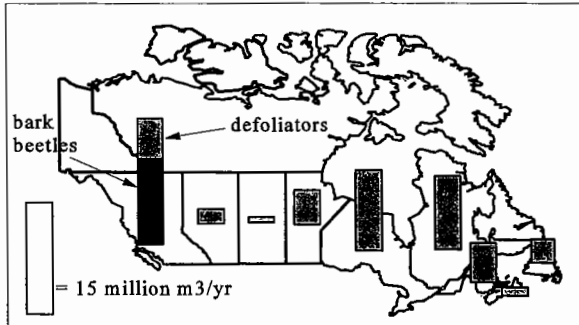


Figure 2. Forest depletions caused by forest insects 1982/87 in Canada, by province (Compendium of Canadian Forestry Statistics 1994).

In British Columbia, approximately 100 million m³ are removed from the forests annually: 71 million m³ are harvested, 2.6 million m³ are killed by fire and 26.8 million m³ are lost to pests (Fig. 3). Analysis of the pest losses indicates that 71.4% is destroyed by rots, 6.7% by dwarf mistletoes, 10.4% by defoliators, and 11.5% by bark beetles (Fig. 4). At least half of the defoliator impact is growth loss while all of the bark beetle impact is mortality. In the 1980s a large proportion of the forest harvesting in interior British Columbia was directed salvage or sanitation logging. In addition to losses to the forest itself, ambrosia beetles attack logs and their degrade of lumber values is more than \$100 million each year. My answer to this first question is yes, there are damage and volume losses in our forests. Let's be very sure that when we seek to intercede that there is real benefit. It has taken a while to accept that defoliators may have a role as a super silviculturalist (Baskerville 1975). Certainly, well structured studies by Alfaro et al. (1982) and Wickman (1978) have shown that insects in unsprayed stands act as thinning agents and their activities can result in higher merchantable volumes.

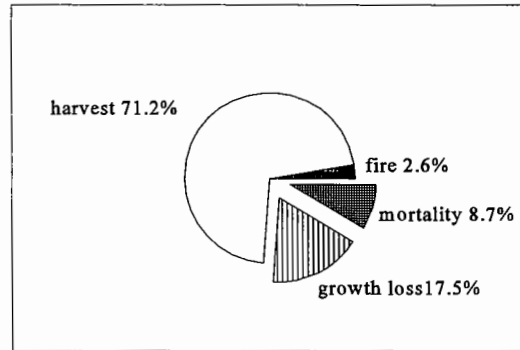


Figure 3. Annual depletions in British Columbia forests. Total depletions = 102 million m³ (Wood and Van Sickle 1994).

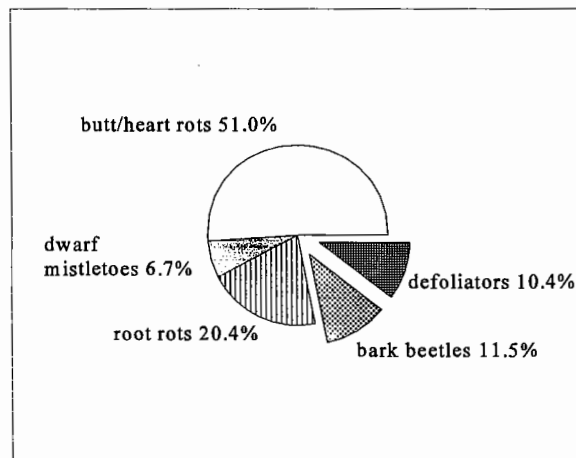


Figure 4. Proportions of the 28.8 million m³ of forest lost to insects and diseases in the forests of British Columbia (Wood and Van Sickle 1994).

Our chances of doing something about these pest deletions are improved by targeted research and adequate funding. The "big bug" programs were successful in focusing attention on target insects such as the western bark beetles, gypsy moth, Douglas-fir tussock moth, southern pine beetle, and the spruce budworms. Unfortunately federal and provincial governments are using a greater proportion of your tax dollar and mine just to pay the interest on mounting public debt. This severely limits options as to what is supported. Do we rate forest entomology research above health, higher education, or welfare? The politician and the public needs to see that the dollars

that we do get are well utilized. Our share of the pie will diminish in the near future until these public debts are brought under control.

Question 2: What does the 21st century forester need from us?

You will be pleased to know that “the ability to recognize fauna and flora and to make consequential distinctions in the natural world, and to use this ability productively ... is exercising an important intelligence” (Gardner 1995). You might like to check out the original seven multiple intelligences defined by Gardner in 1983 - linguistic, logical-mathematical, spatial, musical, bodily-kinesthetic, interpersonal, and intrapersonal. Our 21st century forester still needs the best possible information from us in order to succeed at the multidisciplinary tasks ahead. Your research is vitally important to someone out there and the challenge is for you to present it in a lucid manner that explains the impact of insects on forests. Many important concepts have developed from entomological studies. Our foci, the insects, have relatively short life cycles and have been modeled with some success. The greater challenge has been to connect them to the trees. This has been done by detailed growth and yield research along with appropriate linking functions that brought the trees and insects together. The “big bug” programs of the eighties played a role here. We are now working hard in British Columbia to provide our foresters with stand hazard rating systems that will help them assess the risk of bark beetle infestation. Biogeoclimatic zonation systems have helped greatly in rating the risk of insect damage. In addition, heat sum models are under development to improve the predictability of pest population success.

Question 3: How do we provide this information in a timely manner?

We are relatively faithful about publishing our research findings and producing conference proceedings. The use of CD-ROM-based technology speeds the searching of Forestry Abstracts, CAB Abstracts, etc. This greatly helps to identify individual scientific articles, often with abstracts. Unfortunately, libraries are cutting back on their journals and interloans are being used more frequently to recover the complete article. Electronic journal publishing is with us now. The Florida Entomologist was first published electronically in June 1994.

One disturbing trend that I have noticed with USDA Forest Service publications is their reduced availability. In particular, classics such as *Western Forest Insects* by Furniss and Carolin (1977) are no longer available. Yes, the book may need revision, but in the meantime it is the most comprehensive reference available. I must add that Solomon's (1995) volume on *Insect Borers in North America* is written in a similar manner to Furniss and Carolin and is most useful.

We have several forest entomology textbooks to choose from in North America, but how do we develop a good information base on the insects in specific areas? In B.C., the Canadian Forest Service has published all their forest pest leaflets on a CD-ROM called HFOREST. Photographs of individual insects, life stages, and damage are linked by hypertext to a narrative. There is a separate nursery pest product called HYPERNUR. In addition, recently we have been presented with a series of Forest Practices Code Guidebooks. While these might sound like prescriptive documents, they are in fact the best considered opinion of the forest health professionals in British Columbia. Not only are the guidebooks on bark beetles, defoliators, and forest health surveys available in conventional written form, but they also are available over the World Wide Web. This means that any student with web access can not only check for current information on the insect of concern but also can check out the legal requirement of the Forestry Act, as all these documents also are accessed through the B.C. Ministry of Forests' home page.

This raises the question of how to search quickly for this latest information? In thinking about this **Forest Entomology Textbook CHallenge for the 21st century (FETCH21)**, in line with the theme of this conference, I thought it would be most useful to create a listing of all the forest insect web pages that could be relevant to my forest entomology courses. I have initiated such a page on the web and would be happy to list your page. The URL is <http://www.forestry.ubc.ca/fetch21/fetch21/FETCH21.html>. At the moment it is indexed by feeding guild. It can be located directly or by a search for FETCH21 in the search engines Infoseek, Yahoo, or WebCrawler.

Anyone searching the web for forest entomology is quickly pointed toward the informative pages set up by NAPIS - the National Agricultural Pest Information System. The Virginia Tech pages on the gypsy moth are a very good example of effective web page

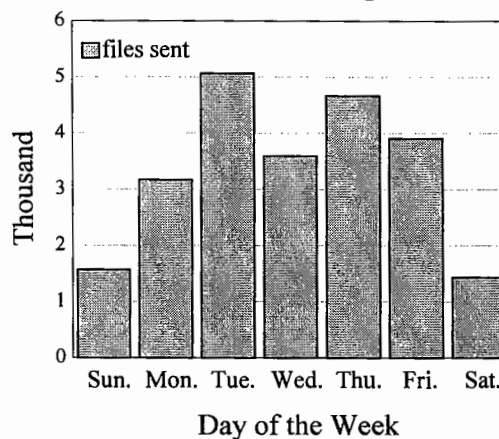
construction. The Virginia Tech Pesticides Program pages, managed by Mike Weaver, have published some use statistics that I thought you might be interested to see. I compared the use statistics of the Virginia Tech pesticide pages with those of the Clayoquot Sound/Long Beach Model Forest web site that is maintained on our forestry server. My thanks to the two site maintainers for explanations of the data.

The use of these web sites gradually increased in the latter part of 1995 and has been sustained at steady levels in the first three months of this year. People are accessing these pages seven days a week. The moderate level of Sunday hits (Fig. 5) might be a surprise, but remember that Sunday in North America is already Monday in Australia and New Zealand. Australia had the third highest number of hits from offshore countries (Table 2). Similarly, off peak hours in North America are normal working day access hours for our colleagues in Europe. Note that the Clayoquot Sound access is mainly in the evening (Fig. 6). One might rate this as a recreational page. In searching for material on the web, I, too, considered doing it on my own time in the evenings, but the access was so slow that I stole a few hours of fast access during the day in order to progress.

Table 2: Summary of user groups who used the Virginia Tech Pesticides Program web site during the period September 1995 - January 1996. Total of 23,338 files in analysis.

<u>User Group</u>	<u>Percentage of Total</u>
U.S. educational	48.3%
Total U.S. users	68.7%
Unresolved and network users	23.4%
Countries with more than 100 files copied	
	<u>Number of files</u>
Canada	716
United Kingdom	154
Australia	139
Denmark	115
Italy	115

Virginia Tech Pesticides Program



Clayoquot Sound

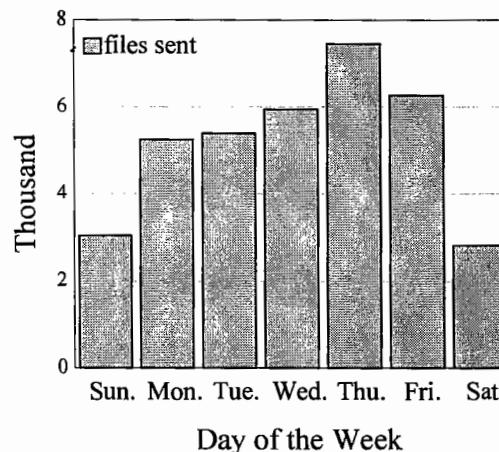
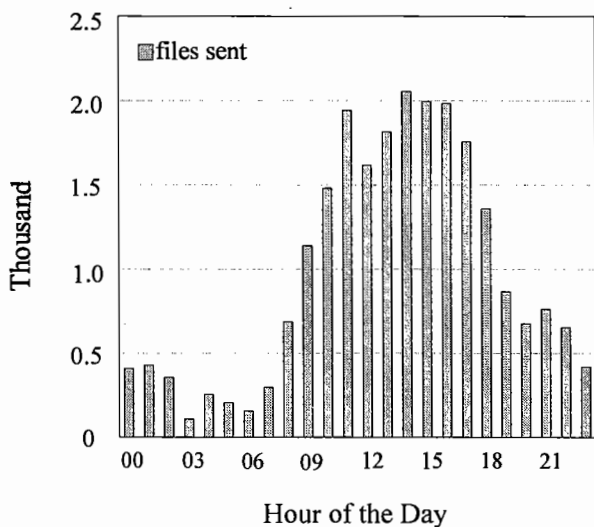


Figure 5. Use statistics by day of week for two web sites. Virginia Tech Pesticides Program for the period September 1995 - January 1996, Clayoquot Sound for the period June 1995 - February 1996.

VT Pesticides Program



Clayoquot Sound

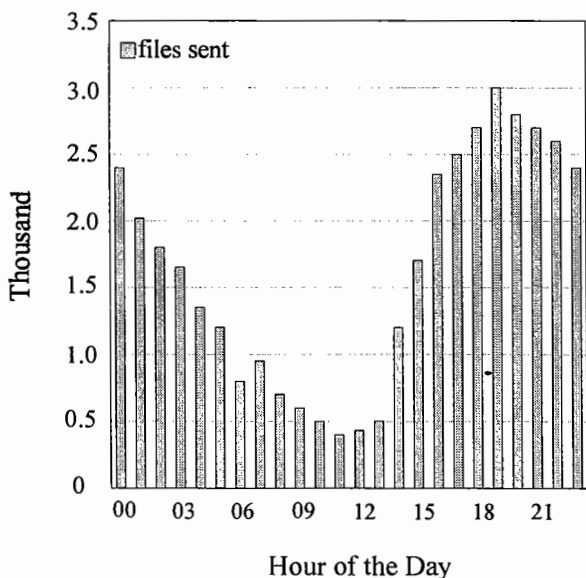


Figure 6. Use statistics by hour of day, local time, for the Virginia Tech Pesticides Program and the Clayoquot Sound web sites.

What does the web offer? I suggest that each of us has a specialty, a favorite system that we think we know better than most. Here is your opportunity to author a web site that will make the very best information available to current undergraduate students, to foresters on the job wherever they may be, and of course to our colleagues in forest entomology world-wide. Once you have your site up and running, I would be happy to list your site address so my students and any other person who elects to make FETCH21 a bookmark will be able to find you relatively easily.

You can also use a web site to give access to people who would like to download a program. SBexpert Version 2.0, a knowledge-based decision support system for spruce beetle management in south central Alaska, is distributed this way by Keith Reynolds at Oregon State University. You might ask why bother with FETCH21? Surely search engines will be able to find your web site. Try searching for "bark beetles" and see what turns up. While some web search engines will find FETCH21, others produce a long list of Macintosh software sites concerned with the program "fetch." I also suggest that our forest insect work conferences are ideal places to discuss the merits of various web page styles.

I leave you with a challenge -- complete that research you have been involved with, write up the papers, and, while all the figures and photos are close by, create a web site. Our next quinquennial meeting will be in 2001. I hope we see your contributions on the World Wide Web a lot sooner than that.

FOREST PROTECTION: A PAPER TIGER OR AN EVOLVING SCIENCE? AN INDUSTRY PERSPECTIVE

R. Scott Cameron^d

I appreciate having the opportunity to participate on this panel and to share with you my ideas on the status of forest protection from an industry perspective. However, this assignment was accepted with considerable reluctance, because I have been with Union Camp Corporation for less than two years and have had more experience with state, federal, and university organizations than with private industry. Thus, in preparation for this presentation, I consulted

with several forest industry representatives including Bud Broerman and John Godbee (Union Camp), and Steve Cade (Weyerhaeuser), among others. Some of my comments undoubtedly will be controversial, but hopefully they will stimulate meaningful discussion that leads to effective and reasonable solutions.

In answer to the question -- "Is Forest Protection a Paper Tiger or an Evolving Science?" -- I believe it is both. Changes in the world population, markets, public policy, and new technology are rapidly altering the way we do business. At the same time, we are becoming progressively more vulnerable to potential catastrophic pest problems and less prepared to deal with them.

I will begin with a brief review of the status of world forest resources, how forest industry is responding to these trends, and forest industry's approach to forest pest management. I will then review how recent changes within the USDA Forest Service have affected various pest management programs and our preparedness for dealing with serious forest pests. This is followed by a discussion of potential pest management opportunities and conclusions.

World Fiber Supply

Fiber and other forest resources have become global commodities. Forest industry has experienced local and regional wood shortages in the past, but for the first time in history, world-wide fiber shortages are being predicted for the future. The overriding factor driving demand for forest resources is increased consumption associated with a rapidly expanding world population which is expected to double from 5.7 to 11 billion in about 40 years. On a global scale, far more wood is expended for fuel than any other use, including industrial consumption. Increases in living standards also are expected to increase the demand for paper, panels, and solid wood products, especially in countries with large populations, such as China.

Wood fiber supply shortages could be ameliorated somewhat in the future through the use of alternative fuel sources, increased use of electronic media for communication, increased recycling, higher yields from forest plantations, and the use of alternative fiber sources, such as agricultural residues. However, wood shortages are already being experienced in many areas in North America and the preponderance of evidence indicates that world-wide shortages are imminent.

Increased public demand for less intensive management and non-timber commodities from forest land, harvest restrictions, and a reduced land base for productive forestry have significantly reduced the availability of timber, especially in the West, and increased the cost of doing business for forest industry.

Constraints on fiber availability, increased costs, and impending shortages have forced industry to look for new ways to secure supplies of raw materials. Many companies are looking at off-shore opportunities, ways to increase yields on less land, developing new technologies, product substitution, and new product development. Increased competition among forest industries also has resulted in a restricted flow of information and more complicated arrangements for cooperative research and development projects.

Short-Rotation Intensive Culture Plantations

Fast-growing, high-yield forest plantations (short-rotation, intensive culture plantations) are becoming key components in the strategic positioning of many leading companies in the international pulp and paper business. These plantations reach harvestable maturity in the range of six to 13 years for pulpwood and 12-25 years for sawtimber. Species used include pines (Caribbean, loblolly, Monterey, and slash) and hardwoods (eucalyptus, gmelina, pawlonia, poplars, and willows). Intensively-managed industrial plantations have average growth rates ranging from 10 to 70 m³/ha/yr, compared to 2-5 for naturally-grown conifers in North America. At the low end, intensively-managed pine plantations in the U. S. South are in their infancy and may attain growth rates up to 10 m³/ha/yr. Eucalyptus plantations in Brazil are the most advanced with some plantations attaining over 70 m³/ha/yr.

Short-rotation, intensive culture usually starts with a strong genetic foundation (sometimes with clonal plantations), and cultural practices include cultivation, irrigation (occasionally), weed control, fertilization, and pest management.

By virtue of the small land base required to generate high wood volumes in a short time, these intensively-managed plantations reduce the demand for natural forests that would otherwise be needed for pulp, solid wood products, or fuel supplies.

Forest Industry Support of Pest Management

Pest management specialists, especially those working in the West, are perceived by some forest industry representatives as ineffective. They have long worked on intrinsic pests (dwarf mistletoe, root rots, and bark beetles); defining, studying, and surveying damage, but rarely finding acceptable solutions to significant problems. This is not to say that surveys are unimportant. Survey data provide the basis for evaluating economic damage and for directing resources toward the most important pests.

Forest industry in the South has been blessed with productive native species and a lack of serious introduced pests. Effective methods for dealing with the most important pests have been developed and incorporated into management systems. Severe impact from the southern pine beetle, for example, can be avoided through sound management practices and losses can be minimized through timely cut-and-leave or salvage operations. Fusiform rust impact has been dramatically reduced by planting rust-resistant families developed through tree-improvement programs and by not planting slash pine in high incidence areas.

Forest industries generally do not have large pest management programs, primarily because there is no sense of urgency in the absence of persistent, major pests in commercial forests. Also, it is difficult to justify pest management expenditures in forestry because of the long period of time between investment and the realization of returns at harvest. Marginal increases in productivity cannot offset expensive early management costs. However, the economic impact of pest damage in intensively-managed, short-rotation systems increases significantly.

Few companies have internal forest pest management programs. Instead, they traditionally have relied on universities and government agencies to provide fundamental forest pest management research, and they have provided funding and "in-kind" support for research projects of special interest. Examples include the University of Florida (UFL), Integrated Forest Pest Management (IFPM) Cooperative, and a variety of seed orchard insect control studies.

Very significant growth and form losses caused by the Nantucket pine tip moth have been demonstrated in experimental plots in the South. Yet, it took two years to initiate the University of Georgia Tip Moth Research

Consortium and there are only four forest industry companies signed up as full members with two more pending. The Texas Forest Service has encountered similar difficulties with the initiation of the Western Gulf Forest Pest Management Cooperative. Also, after about fifteen years in existence, the UFL IFPM Coop will be dissolved in 1996. The UFL Forest Biology Cooperative that is emerging in place of the IFPM Coop has a limited pest management component.

Status of the USDA Forest Service

Through most of the 20th century, the USDA Forest Service has been the preeminent forest research and land management organization, respected and emulated throughout the world. However, the Forest Service recently has undergone dramatic policy and personnel changes which have led to reduced support from forest industry and other important support groups.

In its zeal to provide for public input into the decision-making process, the Forest Service has effectively transferred management responsibility from trained professionals to extremist groups that are not technically competent to make management prescriptions. Public input is needed and can be very beneficial, but it also can be biased and misguided, and should not be relied upon exclusively for making decisions.

The Forest Service has invested heavily in "ecosystem management," "biodiversity," and "sustainability;" concepts which do not have well-established scientific foundations and lack accepted measures for application and criteria for success. Forest Service policy has shifted away from multiple-use management towards a preservation-based approach. Large areas of federally-owned forest lands have been withdrawn from timber production. Clear-cut harvesting and planting are being replaced by "selective harvesting," and "natural regeneration" which effectively eliminate the need for improved seed, seed orchards, and nurseries.

In many cases, pest management policy has reverted to "no control," or "let nature take its course." This has resulted in many injustices to private timberland owners when pest populations build to high levels on federal lands and then move onto private lands.

By embracing preservation management without continued support of commercial forestry, the Forest Service in effect is neglecting its legislative mandate to

provide the leadership needed to keep public and private forest lands fully productive.

The Forest Service has undergone major reorganization and downsizing that has led to low morale, loss of many outstanding employees, and reduced productivity. Forest Insect and Disease Research (FIDR) programs have been cut drastically and may have fallen below the "critical mass" in numbers of scientists to be able to carry out meaningful programs in some areas.

USDA Forest Service funding for research has declined 29% in terms of numbers of scientist years (SYs) from 950 to 675 in the past two decades (Table 1). Forest Insect and Disease Research declined by 50% during the same time period with a particularly severe cutback (13%) in FY96. The forest entomology program in the Southeastern Forest Experiment Station has been especially hard hit, going from a high of seven Research Work Units (RWU's) and 29 RSYs in the early 1980s, to one joint entomology/pathology RWU and two RSYs in 1996.

Table 1. USDA Forest Service Research Staff

Year	USFS	Research Scientist Years ¹	
		FIDR	SE Exp Sta
1970	950	197	24
1975	932	167	-
1980	964	165	-
1985	799	145	29
1990	716	142	-
1995	675	103	-
1996	-	89	2

¹ R. Bridges and G. DeBarr - personal communication

Loss of Advocacy Groups

Through this process of change, the USDA Forest Service has lost some of its most important advocates which are all important in the congressional funding process, especially in times of budget reductions. By overemphasizing public concerns and largely ignoring commercial forestry, the agency has inadvertently compromised its political support system. Industry has little confidence that the U.S. Forest Service will deliver on key resource issues and considers fighting

for Forest Service budgets a poor investment for its limited political capital.

Forestry industry is directing most of its political support toward essential, comprehensive issues, such as environmental regulations and investment climate improvement. Key regulatory issues include the Clean Water Act, Clean Air Act, Endangered Species Act, and solid waste management. Taxation issues include unfavorable capital gains treatment of forestry investments and investment tax credits eligibility, disallowing forest land owners to expense instead of capitalize annual expenditures.

Universities and private research organizations have little to gain by lobbying for the Forest Service because they are sometimes in direct competition for limited governmental research funds. The primary responsibility of many state forestry agencies is to assist small private landowners which occasionally puts them in direct conflict with Forest Service policies. Ironically, environmental groups which have fostered many of the recent Forest Service policy changes have nothing to gain by lobbying for the Forest Service. In fact, some environmental groups continue to fight every move made by the Forest Service in a battle to achieve a "no management" policy, and it doesn't take many people to "close the gates and turn out the lights."

Impending Pest Management Crisis?

A careful evaluation of the current status of forest protection in North America might lead one to conclude that the stage is set for forest pest outbreaks of unprecedented magnitude, and we are unprepared to deal with them. Some of the pertinent elements to consider are listed below.

1. Previously-managed forests (plantations with prescribed burns, wildfire control, etc.) suddenly set aside to "let nature take its course," are likely to suffer from severe insect or disease outbreaks (i.e., southern pine beetle in new wilderness areas in Texas).
2. Increased pest activity also can be expected as we push tree growth to the limit in intensively-managed plantations.

3. Relatively little is known about the effects of intensive cultural treatments (clonal plantings, fertilization, irrigation, herbicides, and insecticides) on tree health and pest populations.
4. Intensively-managed hardwood plantations are being established at increasing rates and knowledge is sparse on which pests to expect and how to control them.
5. With steadily increasing movement of wood and other products around the world, exotic pest introductions are more likely than ever.
6. Insect and disease research positions and funding are at critically low levels and further reductions are likely.
7. Forest industry support of pest management programs is limited.
8. Many pest management professionals in government and university positions are nearing retirement age and may not be replaced upon retirement.
9. Foresters receive little training in forest protection, and many forest pest management specialists lack sound forestry backgrounds.
10. Direct control has become unfashionable and pesticide applications experts are fading from view.
11. Stringent environmental protection standards have decreased the availability of effective control measures, and more environmentally-friendly pest management tools often are less effective, more expensive, and difficult to use.

Forest Protection Opportunities

The points outlined in the preceding section paint a rather bleak picture for the future of forest pest management in North America. The “negative side” has been emphasized to focus attention on areas needing improvement. Actually, the current situation offers many unique and promising opportunities. Also, some of the undesirable trends listed above probably have reached their limits and the pendulum may swing back to more reasonable middle ground.

Future forest protection priorities will vary widely depending on the type of management involved. In intensively-managed plantations attention may be focused on:

1. Interactions between intensive cultural treatments, pests, and host physiology,
2. Effects of insects and pathogens on sustainable productivity,
3. Screening for pest-resistant genotypes, and, eventually,
4. Development of genetically-engineered pest-resistant planting stock.

Protection forest management probably will continue to emphasize:

- Intrinsic diseases (root rots and dwarf mistletoe),
- Bark beetles,
- Native and introduced defoliators, and
- Interactions between pests and endangered species.

Exotic pests have the potential to cause catastrophic damage to forests under both management systems. Introduction of a serious exotic pest might reverse current forest research funding trends, both in the public and private sectors, and unite pest management specialists with those from other disciplines to work for a common cause. But hopefully, it will not take a disaster to bring about needed changes.

Private industry and government agencies are jointly responsible for protecting the environment and increasing forest productivity. Companies have voluntarily embraced the “best management practices” and “sustainable forestry” initiatives in an effort to promote good environmental stewardship, to improve their images, and to maintain a political and biological climate in which they can continue to operate profitably.

We should look for opportunities for government agencies, universities, and companies to jointly support integrated research and development projects that advance common goals. The new “Agenda 2020,” a joint initiative between the U. S. Department of Energy (DOE) and forest industry, serves as an example of a non-traditional partnership with the objective of

promoting basic productivity research. Whenever possible, concerted efforts should be made to integrate forest health and pest management components into these types of cooperative projects.

Two years ago in the *Journal of Forestry*, George Staebler (Weyerhaeuser - retired) proposed “dominant-use” forests. Under this concept, the most suitable, productive sites would be designated as “commodity-production forests” on which successive crops of timber would be grown using the most advanced silviculture methods available. This system could produce wood in sufficient quantities to greatly reduce pressures to import logs from other countries and to produce wood in forests set aside for other dominant uses.

The movement to reduce the use of traditional pesticides is directing attention toward other more “environmentally-friendly,” longer-term solutions, such as genetic resistance, cultural control, and biological control. However, as in agriculture, intensive forest management has increased the need to use pesticides to maintain high levels of productivity.

Forest industry is especially interested in fundamental process research which will provide the foundations for increasing forest productivity without stressing trees and increasing pest problems. This type of research might be an excellent fit for USDA Forest Service, FIDR, especially in the areas of tree nutrition, physiology, pests, and cultural treatment interactions.

Surviving in a Changing Forest Pest Management Discipline

Change has a destabilizing effect and is often ardently resisted. However, as outlined in this presentation, change is a part of doing business in forest pest management today. Listed below are a few suggestions on how to deal with the rapidly changing field of forest protection, especially as it relates to forest industry:

1. Stop complaining, accept changes, and adjust.
2. Be willing to work in supportive roles on cross-functional teams.
3. Prepare for change by obtaining more generalized education and experience.
4. Be knowledgeable in forestry and forest management.
5. Be flexible in technical disciplines and in work location.
6. Be willing and able to solve problems, not just identify, survey, and study.
7. Look for opportunities to develop and transfer new technology.
8. Hang in there, new pest problems may expand pest management opportunities.

Conclusions

In summary, wood resources are becoming scarce in a global economy. Population growth is the primary factor driving increased demand for forest resources. We are facing an uncertain future with many changes. To secure future fiber sources, forest industry is focusing much attention on highly-productive, intensively-managed plantations, both domestically and off-shore. Funding of forest protection research has declined dramatically, especially within the USDA Forest Service. Forest managers and the forest protection discipline in the United States are ill-prepared for new, severe, and more complex forest pest problems. Yet, such problems are likely to occur in the future, especially with increased intensity of forest management and the heightened probability of exotic pest introductions. However, this situation offers many new and exciting opportunities in forest pest management research and development. New management options will be developed with advanced technology. Whenever possible, forest health and pest management components should be integrated into interdisciplinary cooperative research and applications programs.

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Section II

Invited Paper

FOREST HEALTH MANAGEMENT BEYOND THE BORDERS

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During the period 1990-95, I served as Forest Protection Officer in the Forestry Department of the Food and Agriculture Organization of the United Nations (FAO) in Rome, Italy with responsibilities for forest fire management, forest insect and disease management and matters relating to climate change and forests. I had occasion to work with a number of situations which affected the health of both natural and planted forests in Africa, Asia, Eastern Europe, the Near East, and South America. The following paragraphs give brief summaries of projects I was involved with in Brazil, Kenya, the Sudan, Poland, Lithuania, Pakistan, and China.

Brazil

Brazil has approximately two million hectares of fast growing pine plantations. In the southern-most states of Paraná, Santa Catarina, and Rio Grande do Sul, some one million ha of *Pinus elliotii* and *P. taeda* plantations have been established, mostly by industrial private landholders. In 1988, infestations of the European wood wasp, *Sirex noctilio* (Hymenoptera: Siricidae) were discovered in the state of Rio Grande do Sul. These infestations are believed to have spread from neighboring portions of Uruguay where the insect has been known since 1980. Initial introduction into South America is believed to have been either Argentina or Uruguay via infested wooden containers or pallets.

Pinus taeda is sensitive to the fungus, *Amylostereum areolatum*, which this insect introduces into woody tissue. Trees growing on poor sites or in plantations in need of thinning are especially susceptible to attack. Since its initial introduction in Brazil in 1988, infestations have spread rapidly and are now present in all of the country's three southernmost states. In addition to countries already infested, the insect poses an immediate threat to Chile's 1.1 million ha of *Pinus radiata* plantations, a species highly sensitive to infestation.

Shortly after the discovery of this insect in Brazil, scientists at Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) in Curitiba arranged for introduction of the parasitic nematode *Deladenus siricidicola* from CSIRO, Australia. This nematode renders the female wood wasps sterile. Unfortunately, the initial culture received from CSIRO lost its capacity to function as a parasite and a second, more virulent culture had to be introduced.

Kenya

In 1986, a conifer aphid, initially identified as the cypress aphid, *Cinara cupressi* (Homoptera: Lachnidae), was discovered in Malawi. This insect attacks all members of the family Cupressaceae and is especially damaging to the Mexican cypress, *Cupressus lusitanica*, which has been widely planted in the region. Damage consists of a desiccation of the foliage of infested trees during the dry season. While some recovery occurs during the rainy season, successive desiccations can result in tree mortality. The insect spread rapidly within the region with infestations and damage appearing in Tanzania, Burundi, Rwanda, and Uganda in subsequent years. In 1990, the insect was discovered throughout Kenya.

Since most of Kenya's indigenous forests are closed to commercial timber harvesting, the country relies almost entirely on forest plantings for wood and wood products. Approximately 46% of the country's industrial forest plantings are *C. lusitanica*. As a result of the discovery of this insect, the government of Kenya appealed to the world community for assistance in combating this insect. FAO responded with assistance in the development of a master plan of emergency response, research and development, and technology transfer leading to an IPM program for this insect. In addition financial assistance was provided through its Technical Cooperation Programme (TCP) to initiate aerial and ground surveys, conduct limited chemical control operations in high value areas, and to begin a search for natural enemies in collaboration with

the CABI International Institute of Biological Control (IIBC). FAO also assisted in the formulation of projects funded by the United Nations Development Programme (UNDP) and The World Bank. As a result of funding provided by USDA Forest Service, the government of Kenya, in collaboration with FAO and IIBC, organized a regional workshop on African conifer aphids which was held in June 1991. This was the first ever forest insect work conference held in Africa.

IIBC has undertaken a regional biological control program on three species of introduced conifer aphids in eastern and southern Africa including cypress aphid. This program was funded by the British Overseas Development Administration (ODA) for Malawi and by the Canadian International Development Agency (CIDA) for other countries in the region. IIBC has thus far found a single parasitoid, *Pauesia juniperorum* (Hymenoptera: Aphididae), which shows promise as a biocontrol agent. This insect has been established in release sites in Malawi but thus far attempts to mass rear and establish this insect in Kenya and Uganda have failed. Recently, an exhaustive taxonomic study of the *Cinara* present in Africa suggests that this insect is an undescribed species which may originate in the eastern Mediterranean region.

One of the outputs of the UNDP funded project on cypress aphid was the establishment of the Kenya Forest Health Management Centre, a unit of the Kenya Forest Department. This Centre is the first of its kind on the African continent. No sooner had the ink dried on the document chartering this Centre when another major insect problem appeared. The leucaena psyllid, *Heteropsylla cubana* (Homoptera: Psyllidae), appeared in Kenya and Tanzania in late 1992. Leucaena psyllid is native to Mexico and Central America and is a pest of leucaena, a fast-growing, nitrogen-fixing tree which has been widely used in agroforestry programs throughout the tropics. Since 1984, this insect has spread rapidly across the Pacific Islands, Australia, southeast Asia, and the Indian Subcontinent causing severe damage. Following the discovery of this insect in eastern Africa, FAO responded with TCP assistance to Kenya and Tanzania for surveys, awareness training, and release of two species of parasitoids. Through additional funding provided by USDA Forest Service, a regional workshop on this insect was organized. Recent assessment of parasitoid releases in Tanzania indicate that one species has been recovered up to 10 km from original release sites.

The establishment of a Forest Health Management Centre in Kenya resulted in increased awareness of forest insect and disease damage throughout the country. Additional forest health problems detected include a dieback of indigenous *Juniperus procera* forests in the Kenya highlands, dieback caused by a lepidopterous borer in *Sonneratia alba*, a mangrove species, and mortality of groups of *Causuarina equisetifolia*, the result of infestation by a root infesting mealybug, *Dysmicoccus brevipes* (Homoptera: Pseudococcidae). The latter insect is a known pest of pineapple and other agricultural crops.

Sudan

The Sudan is an arid country where trees, woodlands, and forests are a scarce resource. One of this country's most valuable trees is *Acacia nilotica* which occurs naturally in pure stands in oxbow lake beds along the banks of the Blue Nile and other major drainages. This tree has a hard, decay-resistant wood which is used for railroad ties, structural lumber, and fuel wood. Plantations are established via direct seeding and managed on a 35-year rotation.

Reports of a decline of *A. nilotica* have been reported since the 1930s and attributed to attack by a cambium- and wood-boring-beetle, *Sphenoptera chalcicroa arenosa* (Coleoptera: Buprestidae). During the late 1980s, an increased incidence of this condition was detected in high-value plantations along the Blue Nile.

An assessment of the decline was made by the author in 1993 in conjunction with an FAO executed forest sector development project. This assessment indicated that the decline is due to a complex of factors. Predisposing factors are believed to be senescence of even-aged stands and silt deposition from annual floods. Siltation gradually alters the volume and duration of annual flooding that trees require in order to survive the long dry season. Periodic droughts and a catastrophic flood in 1988 which deposited up to two meters of silt in the stands and insect defoliation were identified as inciting factors and infestation by wood borers was identified as a contributing factor.

Poland/Lithuania

Poland's forests have a history of devastating outbreaks of nun moth, *Lymantria monacha* (Lepidoptera:

Lymantriidae). Extensive plantations of *Pinus sylvestris*, which are established at high stocking levels (8,000-12,000 seedlings/ha) on low nutrient, sandy soils, are particularly susceptible to damage. Nun moth and other pine defoliators again reached epidemic proportions in 1993 and the government of Poland considered direct treatment of 600,000 ha of pine plantings with aerial applications of chemical insecticides and the bacterium *Bacillus thuringiensis*. A request was made to FAO for an independent analysis of the proposed project in order to support a request for financial assistance from The World Bank and the European Union. This analysis supported the need for an emergency spray operation but also attempted to provide insights into the underlying reasons for defoliator outbreaks in Poland and suggested preventative measures which might reduce their impacts.

Pine defoliators reached epidemic levels in portions of Belarus, Latvia, and Lithuania in 1994. In 1995, FAO provided TCP assistance to the government of Lithuania for purchase of Micronair atomizers to equip three aircraft for an aerial spray operation directed against *L. monacha* and *Dendrolimus pini* (Lepidoptera: Lasiocampidae). Assistance also was provided from the European Union who contributed the bacterial insecticide, *Bacillus thuringiensis*, for the project.

Pakistan

The Province of Balochistan, in southern Pakistan, is said to contain the world's most extensive juniper forest (approximately 141,000 ha). *Juniperus excelsa* forms pure, open, multi-storied forests between elevations of 1,980 and 3,350 meters (6,500 - 11,000 feet). These forests are an important source of fuel wood for local residents. They also afford protection to watersheds which provide irrigation to apples and other fruit crops grown in the high mountain valleys. The scenic beauty of these forests attracts many visitors and the age of some trees and stands (>2,000 years) makes them of potential scientific interest.

A dwarf mistletoe, *Arceuthobium oxycedri*, was first identified from this area in 1973. The infection is believed to be much older, however. Presently a single area of about 4,000 ha in two mountain valleys is infected. This represents less than 5% of the total area of juniper forests in two forest districts. As a result of

an assessment made by the author in conjunction with an FAO executed forest and range development project in southern Pakistan, recommendations were made to reduce the intensification and spread of infections, tree damage, and mortality while retaining as much juniper on the infected sites as possible.

One of the major concerns about the health and sustainability of these forests is the lack of natural regeneration. During the assessment of dwarf mistletoe, damage by three species of insects was detected in the fruits and seeds of *Juniperus excelsa*. These have a potential negative impact on seed production and viability.

Management of dwarf mistletoe will be an integral part of a Balochistan forest sector development project to be financed by The World Bank.

China

In 1992, as part of a UNDP funded forest sector development program, the government of the People's Republic of China requested a component on improved monitoring, assessment, and prediction of forest insect and disease outbreaks. This project was headquartered at the Anhui Province Forest Biological Control Center in the city of Hefei, in south central China. This project is focusing on the introduction and testing of tools such as expert systems, pheromone-based early warning systems, stand risk rating, aerial sketch mapping, airborne video, and GIS. Key pest species which are being addressed are the pine caterpillar, *Dendrolimus punctatus* (Lepidoptera: Lasiocampidae), a multivoltine forest defoliator, and the pine wood nematode, *Bursaphelenchus xylophilus*, which has been recently introduced into China and is causing extensive damage to *Pinus massoniana*, an indigenous pine widely used in planting programs.

While participating in the UNDP forest sector project formulation mission, the author detected active infestations of Douglas-fir beetle, *Dendroctonus pseudotsugae* (Coleoptera: Scolytidae) and the flatheaded fir borer, *Melanophila drummondi* (Coleoptera: Buprestidae) in Douglas-fir and western hemlock logs brought into the highlands of Anhui Province for construction of a new Buddhist temple. Recommendations were made on how to dispose of the infested material and FAO TCP assistance was provided to the government of China to train foresters

and plant quarantine officials in the recognition and treatment of bark beetles, wood borers, and decay fungi in imports of unprocessed logs coming into the country.

The loblolly pine mealybug, *Oracella acuta* (Homoptera: Pseudococcidae), was accidentally introduced into Guangdong Province in southern China in 1988 on pine scion material collected in Georgia, USA for tree improvement. The insect has spread rapidly throughout the province and as of 1993, some 136,000 ha of *Pinus elliotii* plantations were infested. The level of tree damage is not yet alarming but the insect could become more damaging when it spreads further north where extensive plantings of *P. taeda*, this insect's favorite host, have been established. China and the USA are cooperating on a program to introduce parasitoids of *O. acuta* into the infested areas.

Discussion

The examples of forest health problems described briefly in this paper point out that insects and diseases are major pests of forests worldwide, especially in cases where extensive areas of single-species plantations are established. Therefore, it is essential that forest sector development programs consider the risks of pest damage during the planning and program formulation process and include components which provide for monitoring, prevention and, if needed, suppression of pest outbreaks. Much of the technology developed for the protection of forests from destructive pests in North America, using principles of IPM, can be applied globally.



Section III

Panel Abstracts

EXOTIC PESTS: IMPACT AND MANAGEMENT

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More than 4,500 exotic (non-indigenous) plants, animals, and microbes are now established in the United States (OTA 1993). These alien organisms range from being considered mostly beneficial (e.g., wheat, soybeans, and cattle) to mostly harmful (e.g., zebra mussel, gypsy moth, chestnut blight, and kudzu). In the forestry sector, nearly 400 exotic insects and disease organisms attack woody plants in North America (Bridges 1995, Haack and Byler 1993, Mattson et al. 1994). Many of these exotics have greatly altered North American forest ecosystem diversity, function, and productivity (Bridges 1995, Liebhold et al. 1995). Some of the North American woody plant genera that support the most exotic insect species are, in decreasing order, *Prunus*, *Pinus*, *Salix*, *Malus*, *Populus*, *Quercus*, *Betula*, *Acer*, *Picea*, *Alnus*, *Ulmus*, *Crataegus*, and *Abies* (Mattson et al. 1994).

The list of established exotic pests keeps growing each year. Three exotic pine-feeding scolytids -- *Hylastes opacus*, *Pityogenes bidentates*, and *Tomicus piniperda* -- have recently become established in the Great Lakes region (Bridges 1995). Also in the past few years, the spruce-feeding scolytid *Ips typographus* has been intercepted at various points in the Great Lakes region, but apparently it has not become established. Because of these recent introductions, USDA Animal and Plant Health Inspection Service (APHIS) initiated annual surveys in 1994 for exotic scolytids in many U.S. port cities, using pheromone-baited traps (Cavey and Passoa 1994).

With the signing of major treaties such as GATT and NAFTA, levels of world trade will certainly increase in future years. Many countries and continents have or are developing lists of quarantine pests (CABI and EPPO 1992). The North American Forestry Commission, Forest Insect & Disease Working Group is supporting the development of a list of exotic pests that are of quarantine significance to North American forests.

Recent efforts to import logs into the U.S. from foreign countries such as Chile, New Zealand, and Russia have

resulted in large, formal "pest risk assessments" or PRAs to be conducted by the USDA Forest Service (Bridges 1995). Currently, in 1996, a PRA is being conducted on the movement of unprocessed pine and fir logs from Mexico to the U.S.

Trade is not the only mode of entry for exotic pests. For example, the Asian form of the gypsy moth was apparently introduced into North Carolina in 1993 on a U.S. ship returning with cargo from a U.S. military base in Germany (Hofacker et al. 1993).

The goal of this panel session was to view exotic forest pests at various scales; first, to look broadly at possible reasons as to why so many exotic organisms have become established in North America and what life-history traits are commonly associated with successful exotic forest insects; second, to review the current status of exotic forest insects in Mexico; and, third, to look in detail at the impact and management strategies of one recently-introduced scolytid, *Tomicus piniperda* (Haack et al. 1993).

INVASION OF NORTH AMERICAN FORESTS BY ALIEN PHYTOPHAGOUS INSECTS: HOW TO EXPLAIN THEIR SUCCESS

William J. Mattson^a and Pekka Niemelä^b

Nearly 400 species of phytophagous insects from distant biogeographical realms have become naturalized in North American forests, woodlands, parks, orchards, and urban tree-scapes. Most of these exotics are derived from either Europe (271 species) or Asia (70). The four biggest invasive groups in descending order are Homoptera (115 species), Coleoptera (103), Lepidoptera (84), and Hymenoptera (39) (Mattson et al. 1994, Niemelä and Mattson 1996).

Although heightened international trade and travel in the past 150 years largely explain the ever escalating transport and introduction of exotic organisms

everywhere, the exchanges have not been equal in all directions. For example, approximately 10-fold more insects from Europe have colonized North American woody plants than vice versa (271 vs. 29). To explain this substantial trade imbalance, and to shed some general light on the highly receptive nature of some environments, and the reasons for the incredible invasive success of some groups, we offer several hypotheses (Nimelä and Mattson 1996).

First, North America (north of Mexico) offers substantially greater floral richness, about two-fold more species (ca. 600) and genera of trees than does Europe. Moreover, North America has a much higher percentage of forest and woodland (especially mixed species) cover, particularly in coastal areas where entry is more likely to occur.

Second, we propose that European insects (and other organisms) may be uniquely superior in their colonizing abilities because they, more than other biota around the world, have been exposed to cyclical, severe selection pressure (owing to the very fractured and limited area for refugia in southern Europe) during the repeated Pleistocene cooling episodes. The resulting to and fro migrations increased the commingling of species, encouraged hybridization and speciation, and encouraged the evolution of suites of ruderal traits. For example, one such trait, uniparental reproduction (e.g., parthenogenesis), is unusually common among many groups of European insects and plants, thereby allowing such organisms to reproduce even at very low populations when mating is unlikely. It also allows for more rapid population growth when suitable, but ephemeral, conditions arise. About half of the immigrant phytophages are parthenogenetic. In addition, polyploidy is also unusually common among these parthenogenetic groups, conferring perhaps much broader life tolerances than for ordinary diploid organisms.

Finally, we propose that it may be much easier for organisms adapted to high latitude, long-day, summer environments to transfer to lower latitudes, shorter summer-day environments than vice versa. This advantage may reflect the greater relative ease for European insects to get into proper synchrony (entering and terminating diapause or dormancy) in new environments, and thereby ensure greater survival. Furthermore, insects that overwinter as immatures inside living plant tissues may more easily get into proper synchrony because the plant itself could provide

important phenological signals (instead of relying just on day-length and/or temperature cues).

STATUS AND MANAGEMENT OF EXOTIC FOREST PESTS IN MEXICO

David Cibrián Tovar^c and José Cibrián Tovar^d

Mexico, as does almost any country in the world, maintains a high level of trade with many nations worldwide. Under NAFTA, trade will increase dramatically to levels never before recorded. The forest products sector is no exception. For example, the number of permits processed for imports of forest products into Mexico increased from 289 in 1988 to 6,800 in 1995. Forest products are imported to Mexico from all parts of the world, with North America ranking first. The probability of introducing new exotic forest insects into Mexico is high and in fact at least seven noteworthy pest species have been introduced into Mexico in the last few years (Cibrián et al. 1995). Briefly, these seven species are:

Coptotermes formosanus Shiraki (Isoptera: Rhinotermitidae). The Formosan subterranean termite may have entered on products from China, Formosa, or Japan. Apparently it is not yet established in Mexico, but it has been found in customs inspection yards in Acapulco, State of Guerrero; Manzanillo, State of Colima; and Coatzacoalcos, State of Veracruz, in 1994. These localized infestations were destroyed.

Scolytus multistriatus (Marsham) (Coleoptera: Scolytidae). The smaller European elm bark beetle was apparently introduced to Mexico from the United States. This bark beetle was first found in Ciudad Juarez, State of Chihuahua in 1987, where it is established. A new infestation has been recently reported 1380 km further south in the city of Aguascalientes.

Paranthrene dollii (Neumoegen) (Lepidoptera: Sesiidae). The cottonwood clearwing moth is now established in nine states in northern and central Mexico. It was likely introduced from either Canada or the United States. The first established populations were found in Tijuana, State of Baja California, during 1980-1983.

Xylosandrus morigerus (Blandford) (Coleoptera: Scolytidae). This ambrosia beetle was first detected in

Mexico in 1980 and is now established in at least four states of southeastern Mexico. This pest of commercial mahogany plantations may have entered Mexico from Asia, Micronesia, or Central America.

Calophya rubra (Tuthill) (Homoptera: Psyllidae). The pepper tree psyllid may have been introduced into Mexico sometime between 1988 and 1990, possibly from Peru. The actual point of entry is unknown. This psyllid is now established in much of northern and central Mexico.

Ctenaritayna eucalypti (Mask) (Homoptera: Psyllidae). The eucalyptus psyllid is established in much of central Mexico. It was first detected in Mexico in 1994.

Gynaikothrips ficorum (Marchal) (Thysanoptera: Phlaeothripidae). The Cuban laurel thrips is established throughout Mexico. The original place and date of introduction are unknown.

The management of introduced forest insects considers regulations at national and international levels. For *Scolytus multistriatus* and *Paranthrene dollii*, domestic quarantines have been employed and control campaigns have been applied where outbreaks have occurred. The importation of the host plants of these two pests is now regulated by international quarantine. The regulations developed for *Coptotermes formosanus* include placing additional requirements on exporting countries where infestations occur. For example, in the case of South Korea, exporters are requested to use only new wood for crating cargo shipped to Mexico. This regulation was initiated because this termite was regularly intercepted in old crating material from South Korea. The species *Xylosandrus morigerus*, *Calophya rubra*, *Ctenaritayna eucalypti*, and *Gynaikothrips ficorum* are under general regulation, with some controls being applied in nurseries, plantations, or on urban trees. Inspectors at the Mexican ports of entry are provided training on detection of these and other pests.

MANAGING AN EXOTIC SCOLYTID IN NORTH AMERICA: *TOMICUS PINIPERDA*

Robert A. Haack¹

The pine shoot beetle, *Tomicus piniperda* (Coleoptera: Scolytidae), was discovered in six states in the Great Lakes region of the U.S. during 1992 (Haack et al. 1993). By the end of 1995, it was found in eight U.S.

states (IL, IN, MI, OH, NY, PA, MD, and WV) and one Canadian province (Ontario). Because of this exotic beetle's potential damage, a federal quarantine was imposed in 1992 to prevent movement of infested pine material to areas outside the infested region. The quarantine includes pine logs with bark, Christmas trees, and large nursery stock (Haack and Lawrence 1995a). The quarantine requires that regulated pine material be treated or pass inspection before being moved to areas outside the infested zone.

Although this beetle has caused severe shoot feeding and mortality of pines in China and Europe, no similar large-scale losses have yet been observed in North America. Nevertheless, it is probably too early to determine what the full impact of *T. piniperda* will be in North America. This beetle's current distribution in the Great Lakes area overlaps primarily with agricultural lands and scattered Christmas tree farms. Over the next few years, however, *T. piniperda* will spread into many major pine growing areas, and then a more accurate assessment of its true impact can be made.

Over the past three years, several state, federal, and university investigators have studied various aspects of *T. piniperda* biology, behavior, and control. Much of this new knowledge is now being put to use by USDA APHIS in developing a "compliance management program" for Christmas tree and nursery managers in the regulated (i.e., quarantined) counties. The aim of this program is to ease the burden on the regulated industries, but still minimize the risk of accidental movement of *T. piniperda* to uninfested counties and states. Exact details of the program are still being worked out, but will likely require managers to adopt a set of practices that include monitoring, cultural and chemical controls, and record keeping. Similarly, using current research findings, new guidelines are being formulated for movement of pine logs with bark from regulated to unregulated counties.

On another front, a biological control option is being considered as part of the overall management strategy for *T. piniperda*. During spring in the Great Lakes area, *T. piniperda* often becomes active 4-8 weeks before any of the native pine bark beetles and their associated natural enemies (Haack and Lawrence 1995b). Therefore, *T. piniperda* encounters little to no competition in North America. As a consequence, the European clerid *Thanasimus formicarius* is now being evaluated for possible release into the U.S. This clerid

is phenologically matched with *T. piniperda* in that they both become active in very early spring. Three USDA agencies are involved in this effort: the Agricultural Research Service (ARS) is making collections of *T. formicarius* in France and shipping the beetles to the U.S.; APHIS is developing rearing techniques, and the USFS is evaluating non-target impacts of this European clerid, primarily on the native clerid *Thanasimus dubius*.

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INTEGRATED PEST MANAGEMENT IN FOREST PROTECTION

Moderator: Michael R. Wagner¹

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The concept of integrated pest management (IPM) has been well established as the preferred management strategy of forest and agricultural pests for more than two decades. The driving force behind the evolution of IPM was the relative failure of single control strategies such as chemical control. The more comprehensive view offered by IPM incorporated the notions of economic injury levels, use of a cadre of approaches such as regulatory and preventative measures, and the integration of pest management into forest management decision making.

The development of IPM systems in agriculture has evolved to very sophisticated local sampling systems connected to centralized computer-based decision support systems. Individual crop growers input local temperature and phenological data and receive nearly daily recommendations of control options. In forestry these systems are not nearly as well developed except in the higher economic value crops such as Christmas trees or seed orchards. Even though the implementation of IPM in forestry is behind agriculture, there remains strong conceptual understanding and support for this concept among forest entomologists.

The goal of this panel was to solicit the views about the efficacy of IPM from forest entomologists representing the geographical range of Canada to Mexico and across the continental U.S. While the panel invitee from Canada, Rich Fleming, could not attend, some of his ideas are incorporated in this panel summary.

The panel in various ways emphasized the distinctions between IPM in agriculture and in forestry. Many of the available control products were developed in agriculture and foresters are often left with the option of "making do" with agricultural products. In general, the long management horizons in forestry, with the exception of Christmas tree production, necessitate the use of low cost natural or cultural control approaches. The public perception of forests as an undisturbed plant ecosystem leads to the expectation that pest problems in these systems be dealt with using "natural" strategies. Also, the large landscape scale upon which

forest related pests operate creates many more complex problems than are found in agricultural IPM. Finally, there are regional differences between the small private woodland owner in the eastern U.S. and the government agencies in Canada and Mexico in terms of their willingness to invest in various management activities. In general, private owners are willing to spend more and apply more cultural treatments than is feasible in larger government-managed forests.

The future direction of IPM in forestry will be defined by the increasing environmental orientation of the general public. Large-scale aerial applications of chemicals are a thing of the past. Management of ecosystems to preserve biological diversity, ecological functioning, and protection of non-timber resources will increase. Forest entomologists will be increasingly seen as insect ecologists focusing on the role of insects in ecosystem processes. Political considerations have in the past and will continue in the future to influence the direction of IPM in forestry. Compromise decisions, such as the pine shoot beetle compliance program described by Dr. McCullough, will become increasingly common. Likewise, consideration of endangered plants like Chihuahua spruce as discussed by G. Sanchez-Martinez will continue to impact how IPM is achieved. Consequently, IPM of forest pests will become increasingly ecological with an emphasis on cultural and biological control strategies in the context of an expanded understanding of the role of insects in forest ecosystem functioning.

The panel was well attended and active discussion followed each speaker. The broad range of representation was appreciated. The presentation by our Mexican colleague and the good attendance by other Mexican forest entomologists are especially noteworthy. With the signing of the North American Free Trade Agreement, perhaps we can continue to increase the emphasis on "North America" in the North American Forest Insect Work Conference. How about a NAFIWC in Mexico?

INTEGRATED MANAGEMENT OF *TOMICUS PINIPERDA*, THE PINE SHOOT BEETLE, IN MICHIGAN

Deborah G. McCullough^a

Tomicus piniperda, the pine shoot beetle (PSB), is an exotic bark beetle that was first discovered in the U.S. in 1992. As of March 1996, it had been found in 150 counties in 8 states in the U.S. and in 13 provinces in Ontario, Canada. The infestation is centered in the North Central region of the U.S.

This secondary bark beetle colonizes fresh pine slash, logs, and stumps early in spring. Maturation feeding by new adults occurs in shoots of live pine trees during the summer. Federal and state quarantines currently regulate movement of pine logs, Christmas trees, and nursery stock out of the infested counties.

To date, PSB has caused little observable damage in pine forests in Michigan. Damage can likely be prevented by avoiding slash-generating silvicultural activities such as partial harvests or thinning that would provide brood material in consecutive years. Studies are in progress to determine whether native clerid predatory beetles or other natural enemies will prey on PSB and whether an exotic clerid, currently in quarantine, should be considered for release.

The PSB regulations have had major impacts on the Christmas tree industry in Michigan and other North Central states. An IPM program for pine Christmas tree production has been developed and successfully implemented in selected fields in Michigan and Indiana. Cultural practices, including destroying potential brood material, managing fresh stumps, and using trap logs, are the main components of the IPM program. Cover sprays also can be used at the start of maturation feeding to protect live trees.

A PSB Compliance Program is being evaluated in Christmas tree fields in Michigan and Indiana to determine the feasibility and effectiveness of the IPM practices. Under a Compliance Program scenario, participating growers who agreed to implement the IPM protocol would be able to harvest and ship trees without subsequent inspection and certification. The Compliance Program was initiated in 1995 and will continue through 1997. The National Plant Board and several state and federal agencies are cooperating in the project. Preliminary data from 11 Michigan fields in

1995 indicate that the IPM practices effectively reduced PSB populations to very low or undetectable levels. Adoption of the PSB Compliance Program strategy could reduce risks of PSB introduction to other states. A Compliance Program also could provide regulatory agencies with a new management alternative for future exotic pest introductions.

FOREST PEST MANAGEMENT IN PINE AND SPRUCE FORESTS OF CHIHUAHUA, MEXICO

Guillermo Sánchez-Martínez^b

Chihuahua is the largest state of Mexico and has the most extensive temperate forests of this nation (7.1 million ha); however, in contrast to what might be expected, these forests have the lowest pest incidence in comparison with central and southern Mexico, and perhaps western United States of America. Chihuahua montane woodland is endowed with irregular physiography, 15 pine species, 33 oaks, two spruces, two firs, and several madroño species. These natural barriers plus the silvicultural treatments seem to be enough to keep common pest insects in balance with nature.

Bark beetles, such as *Dendroctonus frontalis*, *D. adjunctus*, and *D. mexicanus*, represent serious problems in central and southern Mexico, because of heavy infestation on mature stands. However, in Chihuahua, bark beetles infest pine regeneration instead of adult trees, which is an uncommon situation according to the general knowledge on conifer-bark beetle interactions. *Dendroctonus rhizophagus*, the major forest pest in Chihuahua, kills only pine regeneration (3-10 yr-old trees). With single attacks, this species kills hundreds of thousands of trees every year. Nevertheless, because of site resilience and host size, economic losses are minimum, and damage needs to be assessed in a different way than the traditional utilitarian view.

Ips integer, *I. pini*, *I. lecontei*, and *I. bonanseai* also concentrate mostly on young saplings and rarely on adult trees, but infested areas are insignificant in comparison with those infested by *D. rhizophagus*. Consequently, most forest pest management activities in Chihuahua seem quite simple, consisting of terrestrial surveys and sanitation cuts. Pest management crews extract the whole infested trees, and leave them exposed to the direct sun rays during winter, to kill

larvae of *D. rhizophagus* while in the roots. *Ips* outbreaks are controlled by cutting, piling, and burning the infested trees.

Chihuahua spruce (*Picea chihuahuana*) is the only conifer that is strongly affected by seed insects in the adult stage. Actually, Chihuahua spruce is in danger of extinction and receives special protection. Chihuahuan spruce seed borer (*Cydia phyllisi*) is managed by burning infested cones. Other insects exist at endemic population levels. Forest pest management is under the responsibility of landowners and land users. Private and government agencies provide technical assistance and supervision for pest identification, assessment, and control. Research institutions and other nonprofit organizations also are involved in operational and research projects regarding pest management.

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BIOLOGICAL CONTROL OF FOREST PESTS

Moderator: Michael L. McManus¹

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As we move towards the 21st century, forest managers and pest control specialists are becoming knowledgeable about new terms, such as ecosystem management, forest sustainability, forest health, and biodiversity, to mention only a few. Therefore, the topic of this panel, "biological control of forest pests," is especially appropriate because biological control is an old technology that fits nicely within the ecologically-based concepts that are implicit in these terms. Simply stated, biological control is the use of living organisms -- predators, parasites, pathogens, antagonists, and competitors -- to suppress pest populations.

Most scientists are familiar with successes that have been realized in agriculture where biological control and other biologically-based technologies have been utilized within a framework of integrated pest management. However, successes in forest pest management have been fewer and not very well publicized. Many of our major forest insect pests are not necessarily good candidates for biological control; defoliators such as the gypsy moth and spruce budworms undergo eruptive outbreaks in nature, and bark beetle species pose an additional challenge for natural enemies because of their endophagous behavior.

Recent studies by the U.S. Congress Office of Technology Assessment (OTA) address current issues that are both relevant to this discussion and challenging to the biological control community. In "Harmful and Non-Indigenous Species in the United States," the OTA concluded that: (1) the total number of harmful non-indigenous species (NIS) and their impacts are creating a growing economic and environmental burden for the country; and (2) continued unintentional introductions are inevitable, as are those that are illegal and those that produce unexpected effects. The OTA also noted that increasing international trade such as that fostered by the North American

Free Trade Agreement, including commerce in biological commodities, will open new pathways for NIS. The introductions of the Asian strain of the gypsy moth into the Pacific Northwest on Russian grain ships in 1991, and into Sunny Point, NC, on a vessel transporting containers of armaments in 1993, demonstrate the diversity of these pathways. Shipments of timber, wood chips, crates, pallets, and packing material from unprocessed wood could provide an entryway for new pests into North American forests.

The assessment also addressed the sale and release of biological control organisms and provided options for Congress to either create new legislation, amend existing law, or increase the environmental review required for importation of biological control agents. It is the consensus of biological control specialists that the development of better informal guidelines for pre- and post-release evaluations is preferred over stricter legislation.

The second OTA study, "Biological Based Technologies for Pest Control," discussed the changes that have been occurring in pest management in the United States, and the importance of biological control and other biologically-based technologies in reducing the reliance on conventional pesticides. The OTA suggests that, although biological control can provide selective and effective pest control, biological control agents also pose risks to non-target organisms. This critical issue of host specificity is addressed at length in a series of articles in a recent special issue section of *BioScience* (1996). The assessment also concluded that past regulatory review of biological control releases has been inconsistent, and suggested that USDA research agencies need to better focus biological control research onto nationally

identified needs, and to reduce the "gap" between the development of these technologies and their implementation.

In organizing this panel, I recognized the need to identify a speaker who could provide a historical perspective on the biological control of forest pests and a realistic assessment of future opportunities. With this background, additional speakers were selected to present examples of: (1) a recent success in classical biological control; and (2) a novel approach to augment the survival and impact of a native biological control agent.

During the discussion that followed the formal presentations, there were several comments from the audience suggesting that management activities or lack of management has disrupted levels of natural control in the nation's forests. The new emphasis on ecosystem management is welcome if, indeed, this accelerates a return to a common-sense approach to managing natural forest systems.

After the presentation on the biological control program directed against the ash whitefly, there was a spirited discussion about how extremely successful programs such as this receive too little recognition. Too much emphasis is placed on the failed biological control attempts; conversely, the ash whitefly program is an excellent example whereby careful attention to detail, i.e., matching the source of parasite strains to climate at the release sites, resulted in a high level of success.

Several questions were directed at the research of Fred Stephen, whereby supplemental feeding is being evaluated as a means to increase the longevity and effectiveness of southern pine beetle parasites. There was general concurrence that this was a novel approach to augment the effectiveness of native parasite species against this serious pest of southern pine forests.

Although the formal presentations were limited to the use of parasites in biological control, the potential for using pathogens for classical biological control of forest pests also was briefly discussed. Of special significance is the dramatic impact that is being exerted by the introduced fungus, *Entomophaga maimaiga*, on populations of the gypsy moth in the eastern United States. Despite the downsizing of forest entomology over

the past decade, there is reason for optimism and hopefully a recognition that biological control should be an integral component of an ecological approach to manage our nation's forests.

THE FUTURE OF BIOLOGICAL CONTROL IN AMERICAN FORESTS: WHERE ARE THE OPPORTUNITIES?

Joseph Elkinton,^a Roy Van Driesche,^a and
Richard Reardon^b

Literature on biological control and population dynamics of 300 forest pests in North America has been reviewed to identify existing knowledge and potential relevance of biological control to prevention of damage by these species. Species were selected based on pest outbreak reports, advice from forest entomologists, and a classic text on forest insects (USDA 1985). One hundred species were considered from within each of three regions: Northeast, Southeast, and West. Knowledge about the natural enemies of each species was summarized, especially to assess if biological control factors are causally related to the occurrence of damaging numbers of the pest. The report identified species against which any method of biological control may be usefully employed, including importations of new natural enemies, conservation to enhance existing agents, or augmentative applications. We considered the feasibility of directing biological control activities against both new target and old target species. Species whose outbreaks or damage are fundamentally not related to the actions of enemies were identified where possible; such species present little opportunity for biological control. Examples of species in these different categories were provided and discussed.

BIOLOGICAL CONTROL OF THE ASH WHITEFLY

Juli R. Gould^c

The ash whitefly, *Siphoninus phillyreae*, was first detected in southern California in August of 1988. Without effective natural enemies, populations quickly reached high densities and spread rapidly throughout much of California. This pest has

since been found in Nevada, Arizona, New Mexico, Texas, South Carolina, and North Carolina, probably having spread on infested nursery stock. The ash whitefly feeds primarily on trees and woody shrubs and causes economic as well as aesthetic damage. Insecticides did not provide a solution to this pest problem. The coccinellid beetle, *Clitostethus arcuatus*, and the aphelinid parasitoid, *Encarsia inaron*, were imported, mass reared, and released against the ash whitefly. The beetle established only in parts of California where summer temperatures are not exceedingly hot. *E. inaron* was first released in Riverside, CA, in 1989-1990. Levels of parasitism were high, and densities of ash whitefly remained low at the release sites, while the pest increased in density at the beginning of the summer at the control sites. By mid-summer, however, *E. inaron* had appeared at all control sites and densities of the ash whitefly declined to levels similar to those at release sites.

E. inaron was subsequently released in 43 of the 46 California counties affected by ash whitefly. Within two years, densities of whiteflies fell from an average of 8-21 individuals/cm² to an average of 0.32-2.18 individuals/cm². Six years after the biocontrol program in California began, populations of the ash whitefly continue to be maintained at extremely low density by the action of *E. inaron*. Based on the economic value of preserving healthy trees, the biocontrol effort provided \$219,822,823 and \$298,803,970 in aesthetic benefit to California in wholesale and retail replacement values, respectively. For every dollar spent on biological control in California, it was estimated that \$181 in wholesale and \$245 in retail aesthetic value were preserved.

In November of 1993, the ash whitefly was found in downtown Raleigh, North Carolina. The North Carolina Department of Agriculture initiated a proactive biological control program to import *E. inaron* from California. Parasites were released in the spring of 1995. As in California, rates of parasitism were high and densities of whiteflies were low at release sites. Densities of the ash whitefly continued to increase until leaf drop at the control site. Field surveys indicated that *E. inaron* moved up to two miles from release sites in less than a year after its release in North Carolina.

BIOLOGICAL CONTROL OF SOUTHERN PINE BEETLE THROUGH ENHANCED NUTRITION OF ITS ADULT PARASITOIDS

F. M. Stephen,^d M. P. Lih,^d and L. E. Browne^e

Southern pine beetle (SPB), *Dendroctonus frontalis*, is native to southeastern pine forests and has a rich complex of insect parasitoids. When large, rapidly-growing beetle infestations occur, the abundance of continuously available suitable bark beetle hosts, coupled with extremely fast parasitoid development, should result in high probability of parasite populations exhibiting functional and/or numerical responses. We believe forest stand structure, coupled with current forest management strategies, are the primary reasons why natural enemies, and especially parasitoids, are not effective in regulating SPB populations. We monitored SPB and parasitoid populations over an 18-month period in a large infestation in east Texas and noted that although parasitoid numbers track SPB population growth and decline, percent parasitism never exceeded 10% and averaged 5 to 6%.

The question must be raised as to why these parasitoids are not able to better respond to increasing SPB host populations. Our data suggest that parasitoid adults are limited in the length of time that they live and constrained in production of additional eggs because food for adults is not available. Pure, even-aged pine plantations provide extensive and readily available host material for SPB, and indirectly favor bark beetle epidemics by creating conditions unfavorable to survival and reproduction of bark beetle parasitoid populations. The closed canopy and heavy shade found in densely-stocked pure pine stands reduce understory diversity and prevent establishment and growth of flowering plants that would normally provide the nectar and pollen used as food by adult parasitoids. Historically, southern pine forests were diverse, open forests with an understory approaching 200-300 plant species per 100 hectares before wide-scale harvesting, fire control, and single-species, even-aged regeneration became standard forest management practices. These more open forests, with an abundance of flowering annuals and perennials, would have favored survival, longevity, and greater fecundity of bark beetle parasitoids.

We have been conducting research with a synthetic food, Eliminate™, developed by Entopath, Inc., that substantiates our hypothesis that longevity and egg production of adult SPB parasitoids can be increased by feeding on nutrient-rich diet. We believe an applied biological control tactic for southern pine beetle can be effective, safe, economical, and of extreme value to private landowners, forest industry, and federal land managers.

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ECOSYSTEM MANAGEMENT:
IMPACT ON FOREST HEALTH AND LONG-RANGE MANAGEMENT PLANNING

Moderator: Robert N. Coulson¹

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A change in societal values and priorities, stemming from a concern for the environment (UNCED 1992), has provided the stimulus to examine alternative ways and means of land-use management. Many of the contemporary issues associated with land-use management are considered under the umbrella of ecosystem management. In this panel four perspectives on the subject of ecosystem management are considered.

ECOSYSTEM MANAGEMENT: DESPERATELY
SEEKING A PARADIGM

Robert T. Lackey^a

Ecosystem management is widely proposed as the modern and preferred way of managing natural resources and ecosystems. Advocates describe ecosystem management as an approach that will protect the environment, maintain healthy ecosystems, preserve biological diversity, and ensure sustainable development. Critics challenge the concept as a new label for old ideas. The definitions of ecosystem management are vague and clarify little. As with all management paradigms, there is no "right" decision, but rather those decisions that appear to best respond to society's current and potential future needs as expressed through a decision making process. Ecosystem management could be enhanced by developing: (1) credible procedures to determine ecosystem health, which is within the domain of social and biological science; (2) scientifically sound options upon which to base policy decisions about biological diversity and endangered species; and (3) a clear understanding of the relationships between ecosystem stability and biological diversity, and how each responds to external stress, such as altering habitat and harvesting biotic resources.

FOREST HEALTH FOR A HEALTHY NATION: A
FOREST SERVICE PERSPECTIVE ON
ECOSYSTEM MANAGEMENT

Ann M. Bartuska^b

Ecosystem management has acquired a bad rap over the last few years, but to me it is fairly simple -- it is an ecological approach to management, utilizing the principles of ecology in the development of management strategies to meet the needs of society. Forest health is an objective to be accomplished through ecosystem management. Clearly, the interconnections between the two concepts must be closely made.

Why are we concerned about forest health? In the summer of 1994, the United States spent nearly \$1 billion to fight wildfires. Even so, 4.8 million acres burned and 34 lives were lost. Society has recognized that the cost in human and natural resources is too high. Decades of fire suppression have altered the landscape; forest structure and composition have dramatically changed. The western landscape is characterized by older and more dense stands, sites increasingly susceptible to insect and disease attack leading to mortality. The commensurate fuel loadings increase the opportunities for intense crown fires in areas where ground fires of lower intensity were relatively common.

Added to the mix is the invasion of non-indigenous species which has already altered forested ecosystems (e.g., gypsy moth, leafy spurge, kudzu). There are also social changes as residential homes increasingly are placed in these highly-stressed forested environments. The Forest Service has developed a policy to provide direction on forest health within the agency. We are defining forest health as -- *a condition wherein a forest has the capacity across the landscape to be renewed, to recover from a wide range of disturbances, and to retain its ecological resiliency while meeting current and future needs of people for desired levels of values,*

uses, products, and services. The policy recognizes both the underlying ecological context of forest health and the values society places on forests. A critical aspect of the policy is that it puts forest health as an objective at the landscape scale. The management tools (e.g., prescribed fire or commercial thinning) exist to accomplish forest health objectives; however, it is a societal decision whether those tools will be used.

A KNOWLEDGE ENGINEERING APPROACH TO ECOSYSTEM MANAGEMENT

Michael C. Saunders and Bruce J. Miller^c

Ecosystem management is a collective term used to embrace a suite of approaches for land-use management. These approaches are centered about the notions of biodiversity, sustainability of ecological systems, maintenance of ecosystem health, and preservation of ecosystem integrity. Problems in ecosystem management have a substantial knowledge base associated with them. The knowledge base consists of different types of information including spatially-referenced data, tabular databases, simulation model outputs, and the heuristics of human experts. These diverse types of information are continuously evolving as new research is completed, and as a consequence of expanded human experience.

The fundamental problem in ecosystem management centers on how to use existing knowledge for land-use planning, problem solving, and decision making. In effect, ecosystem management is information management, and the enabling technology for ecosystem management is an integrative computer-based system. In the last decade, major advances have been made in the area of computer-aided decision support, most notably in the adoption of qualitative modeling approaches borrowed from the parent discipline of artificial intelligence. These applications enable a knowledge engineer to capture the heuristics of acknowledged experts in a form that is useful for decision support by managers. The processes of knowledge elicitation, knowledge representation, and knowledge verification are iterative and comprise the most important steps in knowledge-based system development.

Unfortunately, no commercially available software development shell provides the knowledge engineer with assistance in this critical aspect of knowledge-

based system development. In the absence of formalized representations of knowledge, data requirements for assessing the health of ecosystems and for monitoring the long-term effects of restoration projects are difficult to identify. Consequently, many ecosystem management efforts begin with a flurry of data acquisition followed by the realization that, given the problem at hand, the wrong data were collected and/or the best data were not collected.

A rapid application development (RAD) tool for knowledge base development would greatly assist in the ecosystem management process. NetWeaver^(®) is one example of this type of RAD tool and examples of its utility to ecosystem management were discussed. NetWeaver assists the knowledge engineer in the creation of graphical logic diagrams that can be executed and debugged during the knowledge elicitation phase of software development. This permits very rapid creation of executable code that represents the heuristics of an expert(s). These logic diagrams can be nested within other logic diagrams resulting in an extensive knowledge-based ecosystem model. Instantiation of all or part of the logic diagrams network results in the identification of those data that are needed in order to perform an assessment.

NetWeaver is based on fuzzy set theory, and as a consequence, it permits uncertainty to be robustly represented in a decision model. Adoption of this knowledge engineering approach to ecosystem management will: (1) greatly reduce the time required to develop an ecosystem management decision support system; (2) permit extensive creation of site specific knowledge bases for use in decision making; (3) facilitate data needs assessment for decision making; and (4) result in standardization and widespread use of those knowledge-based modules that may be common to multiple ecosystems.

DEPLOYMENT AND IMPLEMENTATION OF ECOSYSTEM MANAGEMENT PRACTICES

Robert N. Coulson^f

Although scientists prefer to deal with quantities, managers rely also on qualitative judgments based on their experience (or the experiences of others), i.e., they use heuristic knowledge as well as quantitative data and information to solve problems, make decisions, and develop plans. Furthermore, scientific understanding of a specific ecosystem management problem will

rarely be so complete as to eliminate the need for qualitative assessment and human judgment. Integrative computer-based systems are the enabling technology for ecosystem management.

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What has been demonstrated to date is that it is possible to develop and deliver complex computer-based systems suitable for addressing ecosystem management problems. If the systems are to be used in an operational setting, three additional issues must be addressed: (1) efficacy; (2) deployment; and (3) implementation. *Efficacy* (i.e., do the computer-based systems actually provide correct and useful ecosystem management plans and enhanced decision-support capability) is a subject that has not been addressed in a critical way. This circumstance may simply be a reflection of the fact that few systems are actually in use at the present time. *Deployment* refers to the operational use of the computer-based system by an agency or organization. Activities associated with system input and output are critical to deployment. *Implementation*, which deals with establishment of the computer-based technology into the infrastructure of an agency or organization, includes: (1) enterprise integration; (2) maintenance and evolution; and (3) systems documentation. Although most government agencies have rigorous procedures for selecting commercial software products, in general there is no mechanism for integrating custom software products developed through contract research.

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PESTS IN INTENSIVE FORESTRY

Moderator: C. Wayne Berisford¹

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During the past 20 years, there has been an accelerating trend toward more intensive forest management mostly due to a decrease in land available for commercial forestry. There are several reasons for this, including reduced allowable cuts on public land as higher values are placed on recreation and other uses, protection of old growth, or conversion of forest land into agricultural production or incorporation into urban areas.

Since demands for forest products have remained high, foresters are faced with the obvious problem of producing more fiber on less land. The response to these demands to produce more with less has been to improve planting stock through genetic selection, reduce the time between harvest and stand establishment, or use intensive mechanical and herbicidal site preparation and fertilization. Additionally, mid-rotation cultural practices such as thinning, competition control, and fertilizer applications have been employed.

Although these practices have produced some impressive gains, in some cases the potential gains have not, or will not, be entirely realized due to unanticipated damage by forest insects. Some insect problems associated with intensive management are new while others are manifested as increased damage by formerly minor pests. Four forest entomologists have provided here some examples from different regions in North America in different tree host types.

INSECT PESTS ASSOCIATED WITH INTENSIVE MANAGEMENT OF HARDWOODS AND CONIFERS IN THE NORTHEASTERN UNITED STATES

Lawrence P. Abrahamson^a

Insect pests associated with intensive management of conifers were covered under the major headings of Forest Plantations, Christmas Tree Plantations, Seed Orchards, and Forest Tree Nurseries. Intensive

management of hardwoods was covered under the major headings of Short Rotation Intensive Cultivation (SRIC) Plantings, Forest Tree Nurseries, and Future Hardwood Plantings.

Under conifer forest plantations the following insects and their impacts on conifers were discussed: white pine weevil (*Pissodes strobi*) on white pine and Norway spruce; European pine shoot moth (*Rhyacionia buoliana*) on red pine; (Scotch pine - Christmas trees); pine engraver (*Ips pini*) on pines; European pine sawfly (*Neodiprion sertifer*) on red pine (Scotch pine - Christmas trees); redheaded pine sawfly (*N. lecontei*) on red pine; pine false webworm (*Acantholyda erythrocephala*) on red and white pines; yellowheaded spruce sawfly (*Pikonema alaskensis*) on white spruce; larch sawfly (*Pristophora erichsonii*) and larch casebearer (*Coleophora laricella*) on larch; pine needle scale (*Phenacaspis pinifoliae*) on pines; pine tortoise scale (*Toumeyella parvicornis*) on red pine (Scotch pine - Christmas trees); red pine scale (*Matsucoccus resinosa*) on red pine, Saratoga spittlebug (*Aphrophora saratogensis*) on red pine; the pine spittlebug (*A. (Parallela) cribrata*) on Scotch pine (Christmas trees); eastern spruce budworm (*Choristoneura fumiferana*) on balsam fir and white spruce; pales weevil (*Hylobius pales*) and northern pine weevil (*Pissodes approximatus*) on conifers and Christmas trees.

Other insect pests and their impacts covered under Christmas Tree Plantations were: pine shoot beetle (*Tomicus piniperda*) on Scotch pine; spruce bud moths (*Zeiraphera* spp.) on white spruce; twig aphids (*Mindaras* spp.) on balsam fir and white spruce; spruce spider mite (*Oigonychus ununguis*) on spruce; eastern spruce gall adelgid (*Adelges abietis*) on Norway and white spruce, Cooley spruce gall adelgid (*A. cooleyi*) on Colorado blue spruce, white spruce, and Douglas-fir.

The following insects and their impact on conifer seed orchards also were discussed: cone beetles (*Conophthorus* spp.) on white and red pines;

coneworms (*Dioryctria* spp.) on all conifers; spruce seed moth (*Laspeyresia youngana*) on white spruce; chalcids (*Megastigmus* spp.) on balsam and Fraser firs and Douglas-fir; seedbugs (*Leptoglossus corculus* and *Tetyra bipunctata*) on all conifers.

The following forest tree conifer and hardwood nursery insect pests and their impacts were discussed: pine tip moths (*Rhyacionia buoliana* and *R. frustrana*) on red and Scotch pines; root weevils (*Otiorhynchus ovatus* and *O. sulcatus*) and white grubs on both conifers and hardwood seedbeds.

SRIC hardwood crops/plantations in the northeast have the following insect pests: cottonwood leaf beetle (*Chrysomela scripta*) on cottonwood and hybrid poplars; imported willow leaf beetle (*Plagioderda versicolora*) on willow; Japanese beetle (adults) (*Popillia japonica*) on willow; gypsy moth (*Lymantria dispar*) on willow and hybrid poplar; forest tent caterpillar (*Malacosoma disstria*) on hybrid poplar and cottonwood; mourning cloak butterfly (*Nymphalis antiopa*) on hybrid poplar and willow; various leafrollers, -tiers, and -miners on hybrid poplar; leaf feeding sawflies and aphids on hybrid poplar and willow; potato leafhopper (*Empoasca fabae*) on willow; willow shoot sawfly (*Janus abbreviatus*) on willow and hybrid poplar; cottonwood twig borer (*Gypsonoma haimbachiana*) on cottonwood and hybrid poplar; poplar and willow borer (*Cryptorhynchus lapathi*) on hybrid poplar, cottonwood, and willow.

Other common hardwood insect defoliators and borers may become important on future high value hardwood plantations such as selected sugar maple (sweet trees) plantations for maple syrup production and "Super" black cherry trees selected and bred for black cherry veneer log production.

INSECT PESTS ASSOCIATED WITH INTENSIVELY-MANAGED SOUTHERN PINES

R. Scott Cameron^b

Traditional insect pests associated with commercial southern pine plantations can be conveniently grouped by the distinct stages of plantation management, from seed orchard to plantation harvest. Primary pests by management stage are as follows; 1) seed orchards -- coneworms, seed bugs, and pitch canker, 2) nurseries -- damping off, fusiform rust, plant bugs, and white

grubs, 3) plantation establishment -- pales weevil, tip moth, and fusiform rust, 4) saplings -- sawflies, fusiform rust, and pitch canker, and 5) poles to saw timber -- southern pine beetle and pitch canker. The amount of direct pest control activity generally is correlated with intensity of management, ranging from nurseries and seed orchards receiving frequent pesticide applications to control persistent pests, to mature pine plantations which occasionally require interventions to stop the growth of scattered SPB infestations.

Current regional wood fiber shortages and worldwide shortages looming on the horizon have stimulated forest industry to intensify management to grow more, in less time, on less land. The most-intensively managed pine plantations are expected to reach harvest age in 15 to 25 years for pulpwood and saw-timber, respectively, through genetic improvement and cultural treatments including site preparation, weed control, fertilization, and pest management. Greatly increased levels of management in pine plantations may create an environment more conducive to pest outbreaks, similar to agricultural situations. An extreme case of a "management-induced" pest problem was observed in an irrigated, intensively-managed loblolly pine plantation in Georgia. A survey revealed faster growth, as well as much higher levels of shoot die back (unknown causes), reproduction weevil feeding, *Dioryctria* stem attacks, and *Toumeyella* scale populations in the irrigated portion of the plantation compared to growth and pests in the unirrigated portion of the plantation. This demonstrates the potential for increased pest problems in intensively-managed pine plantations.

The Nantucket pine tip moth is another case in point. Tip moth populations often reach high levels and cause heavy growth losses in plantations that receive fertilization and weed control. Results from tip moth impact studies in North Carolina and Georgia have shown that tip moth control nearly doubled wood volumes through ten years compared to untreated check blocks. These data and other similar observations have rallied forest industry to support a Tip Moth Research Consortium at the University of Georgia under the direction of Dr. Wayne Berisford. Current research topics include: impact, improved direct control measures, natural enemies, effects of vegetation management, biology and life cycle, host physiology, and resistance/tolerance mechanisms.

The European pine shoot moth (EPSM) is another example of a pest problem associated with intensively-managed "southern pines." The EPSM was recently introduced into Chile and is causing serious growth and form losses in Monterey pine (*Pinus radiata*) plantations. In contrast to a generally passive approach in dealing with forest pests in North America, forest industry and government organizations perceive the EPSM as a serious threat to commercial forestry in Chile and have joined forces to implement an impressive control program. Millions of dollars and experts from around the world have been focused primarily on a biological control program involving rearing and releasing a larval parasitoid introduced from Europe. Forestry companies also are using other control tactics including mechanical removal of infested shoots, silvicultural treatments, and chemical control. This serves as a good example of how a significant forest pest management program can be mobilized in the face of a serious pest problem.

SHORT ROTATION FORESTRY: PEST MANAGEMENT PRIORITIES IN AN EMERGING SYSTEM

Elwood R. Hart,^c R. B. Hall,^d and H. S. McNabb, Jr.^e

Short-rotation woody crops usually are distinguished by the following characteristics: carefully controlled spacing; rotation in 1 to 20 (usually 3 to 12) years; use of genetically-improved stock; fertilization, pesticides, and irrigation as allowed by local conditions; intensive weed control during establishment; whole-tree harvesting. The objectives of such plantings are: pulp; biofuels; engineered wood products; agroforestry; wind and water amelioration; reduction of water, air, and soil pollution; waste disposal; wildlife habitat, and sawtimber. The major reasons that such systems are being developed are because of the decreasing ability of traditional forest resources to meet fiber needs, the need to have resources closer to the point of utilization, and environmental concerns.

There has been increasing research and development involvement by universities, federal, state, and provincial agencies, and industry in this area. Research in North America began in earnest about 30 years ago, with the major thrusts being in silviculture and in selection and breeding for growth and form. About 20 years ago, because pathogens emerged as limiting factors in the development of the systems, selection and

breeding for disease resistance began to receive increasing emphasis. During the past 15 years, insect pests also began to be evident as economically important, and selection and breeding programs for insect resistance became necessary. Today, in North America, in recognition of the need for holistic approaches to the commercial development of short-rotation woody crops, multidisciplinary teams, involving geneticists, pathologists, entomologists, economists, biochemists, and other specialists, have formed to work cooperatively in developing short-rotation woody crops. At present, nearly all focus in North America is on selections of *Populus* and *Salix*.

Because this approach to meeting timber needs is still in the early stages, we have not yet identified all major pest problems. Some, such as Septoria canker, Marssonina leaf spot, cottonwood leaf beetle, forest tent caterpillar, and gypsy moth, are known to be potentially of great economic importance. Others, such as tile shoot, stem, and root borers, are beginning to show increasing evidence of developing into commercial problems.

As multidisciplinary teams, we are involved in the following research activities: breeding, selecting, and genetically engineering resistant clones; evaluating natural enemies complexes for potential use; and selecting effective, environmentally-safe pesticides for commercial use; determining economic injury levels and economic thresholds.

PESTS OF INTENSIVELY-MANAGED FORESTS OF THE PACIFIC NORTHWEST

Darrell W. Ross^f

Intensive forest management for the production of wood fiber in the Pacific Northwest involves primarily conifers, although interest in hardwoods has increased in recent years with the establishment of red alder and hybrid poplar plantations. Some important insect pests of these hardwoods have been identified and others will undoubtedly be discovered.

Intensive forestry often results in simplifying the structure and composition of natural forests. Some insects are favored by the newly-created conditions and may threaten the productivity of the managed stands. In parts of eastern Oregon where uneven-aged ponderosa pine forests have been replaced by extensive even-aged

plantations, the western pine shoot borer has become abundant. Shoot borer larvae feed in the pith of expanding shoots, stunting their growth. Repeated attacks can significantly reduce tree growth and may result in poor stem form. The shoot borer preferentially infests the fastest growing trees in a given stand and seems to be favored by silvicultural treatments that promote rapid tree growth. Without management, the shoot borer will partly negate the expected growth increases from intensive forest practices.

Many pine plantations that were established in the interior region of the Pacific Northwest over the last several decades are now in need of thinning. These conditions are ideal for bark beetles in the genus *Ips*. Current efforts to minimize *Ips* problems focus on timing and location of thinning operations to limit population buildups. Managing stand density to minimize susceptibility to bark beetles will continue to be a priority in these young plantations in the near future.

Not all intensively-managed eastside forests have been converted to even-aged stands. Selective harvesting and fire control on some private lands and most public lands also have resulted in dramatic changes to the landscape. Douglas-fir and true firs are more abundant than they were historically and are growing in dense stands. These conditions have contributed to recent outbreaks of defoliators and bark beetles including the western spruce budworm, Douglas-fir tussock moth, fir engraver, and Douglas-fir beetle. Silvicultural treatments are being implemented to improve the health and sustainability of these forests on private and public lands.

The primary pests in forests west of the Cascade Range are vertebrates, pathogens, and weeds, although several insects can occasionally cause problems. The Douglas-fir beetle may become an increasing problem with recent changes in management practices on federal lands designed to increase the abundance of down woody debris. The thinning that is needed in many westside forests may increase the abundance of root weevils and bark beetles that are known to vector the pathogen causing black stain root disease. The spruce weevil is the major factor precluding active management of Sitka spruce on private lands in coastal areas. With increasing international trade and the proximity of westside forests to port cities, there will continue to be threats of exotic pest insect introductions.

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KEEPING EXOTIC FOREST PESTS OUT OF NORTH AMERICA: VIEWS FROM THE QUARANTINE AGENCIES

Moderator: Nancy Lorimer¹

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Exotic forest insects and diseases are arguably the greatest threat to forest health. Exotic pest exclusion is one of the most effective efforts for protecting forest health. We have clear lessons from the past that prevention of exotic pest introductions is cheaper than the consequences of pest introductions, cheaper both in monetary costs and in ecological costs.

Those of us in entomology research and in pest management may be less familiar with regulatory policies and practices. The federal organizations represented on this panel have the legal mandate in their respective countries for pest exclusion and quarantine. They are Agriculture and Agri-Food Canada, Sanidad Forestal of Mexico, and the Animal and Plant Health Inspection Service of the United States. The fourth organization, the North American Plant Protection Organization, plays a continental role.

CANADIAN QUARANTINE POLICIES AND PROGRAMS

Robert Favrin^a

The Canadian government plans to create a single inspection agency by 1997 that will report to the Minister of Agriculture and Agri-Food Canada (AAFC), and will deliver all of the operational aspects of Canada's food quality and safety programs, and quarantine programs relative to animal and plant health.

The Canadian government as a signatory member of the International Plant Protection Convention (IPPC) of the United Nation's Food and Agriculture Organization (FAO), is obligated to develop and implement plant quarantine legislation and programs consistent with the Plant Protection Principles adopted in the IPPC. The Plant Protection Division (PPD) of AAFC develops policies and programs, under the Plant Protection Act and Regulations, to administer all aspects of this legislation to: (1) prevent the introduction of quarantine pests into Canada; (2) prevent the spread of

quarantine pests within Canada; and (3) ensure that Canadian plants and plant products meet the plant quarantine import requirements of foreign countries for export purposes.

The Plant Protection Act gives AAFC the authority to impose movement restrictions on commodities. The vehicle for doing this is the policy directive. Risk analysis, the process by which import requirements are determined, is made up of three components: *risk assessment*, *risk management*, and *risk communication*.

Pest risk assessments evaluate biological and technical information in response to a request to import (new commodity/country), a pest interception, or a pest outbreak (in Canada or abroad) which has domestic implications. Historically, risk of pest introduction via forestry products was low because the imported material was generally high value, often tropical, shipped in low volumes, and used for manufacturing purposes. Canadian importers now look abroad for sources of wood products traditionally supplied domestically, such as logs, railway ties, and wood chips. Potential risks are higher because the products would be shipped in large quantities, are often comprised of genera related to our own, come from temperate areas, and are intended for non-manufacturing purposes. Difficulty in assessing risk may be due to a lack of scientific and economic information on the pests in question.

Asian Gypsy Moth - Plant Protection Policy for Ships (D-95-03). This policy applies to any ships which have visited Russian Far East ports during lymantriid egg-laying periods. High-risk ships are inspected by AAFC inspectors at designated off-shore anchorages before being allowed entry into Canadian waters.

Import Requirements - Logs, Lumber, Unmanufactured Forest Products (D-95-14). This Directive applies to the importation of all non-propagative unmanufactured forest products from everywhere except the continental United States. All

unmanufactured wood products, except for tropical species, will have to be heat treated to 52°C for a minimum of 30 minutes at the core of the wood or kiln-dried to attain a moisture content of less than 20 percent.

Import Requirements for Loose Wood Dunnage (D-95-10). This is policy regarding wood dunnage at Canadian ports of entry. Port authorities are obligated to designate dunnage storage areas and all wood dunnage not bark free and pest free must be disposed of or treated in a manner approved by AAFC.

Import Requirements for Plant Propagative Material from Off-continent. A comprehensive policy review is underway to consolidate several regulations related to propagative material, including several forest species.

U.S. QUARANTINE POLICIES AND PROGRAMS

Jane E. Levy^b

The Animal and Plant Health Inspection Service (APHIS) mission is to protect American agriculture by providing leadership in ensuring the health and care of animals and plants. Plant Protection and Quarantine (PPQ) is one part of APHIS, with a mission to protect the health of U.S. plant and animal resources and facilitate their movement in the global marketplace. PPQ must find a balance between these two concepts, which can be conflicting. By assessing the pest risk of imported articles, PPQ decides if it is possible to allow importation of the article, and whether mitigation measures are required.

The first aspect of exclusion is the permit process. PPQ assesses the pest risk associated with the import of a product based on the origin and degree of processing. If the article can be imported, a permit is issued which explains the conditions required to import.

The second aspect of exclusion is inspection at ports of entry. PPQ provides officers at most ports of entry, both airport and maritime, to inspect cargo entering the U.S. They verify that mitigation measures have been met, if required, and inspect for live pests. The officers supervise treatments, destruction, or reexport if pests are found.

Survey programs are conducted to determine if exotic pests are present, such as Asian gypsy moth, and to determine the spread of introduced pests, such as pine shoot beetle and North American gypsy moth. The survey results impact exports from the U.S. because other countries require mitigation measures based on the presence or absence of pests. Eradication or control programs are initiated based on the results of the surveys.

The exclusion activities for Asian gypsy moth (AGM) include ship inspections before arrival at U.S. ports. Ships which are in Russian Far East ports during the flight period are considered high risk since female gypsy moths are attracted to the lights on the ship. Cargo and containers that are stored outside from Russia and Germany are inspected for AGM. U.S. military cargo and containers from Europe are inspected and precleared before being shipped to the U.S. Finally, surveys are conducted at U.S. ports to determine if introductions have occurred.

The USDA Forest Service and APHIS have a cooperative survey program with the Russian Forest Service and the State Plant Quarantine Inspection Service of Russia. Ports and forested areas surrounding ports are surveyed to determine which ships are high risk, which were in port during the flight period. The survey results also are used to predict the next outbreak, so APHIS can be prepared with mitigation measures such as increased inspection levels.

Changes in types and quantity of imported wood created a new pathway for pests. APHIS published a new regulation: Importation of Logs, Lumber, and Other Unmanufactured Wood Articles. The regulation provides a process for risk assessments. The USDA Forest Service conducts these assessments through a special team. The regulation provides universal import options which allow any wood product to be imported if it meets one of the universal options prior to arrival. These options are heat treatment of 71.1°C for 75 minutes, kiln dried, or pressure treated with approved preservatives.

NORTH AMERICAN QUARANTINE POLICIES AND PROGRAMS

Bruce E. Hopper^c

Guided by the International Plant Protection Convention (IPPC), the North American Plant Protection Organization's (NAPPO) primary role in keeping exotic forest pests out of North America is the provision of the science-based phytosanitary standards called for under the North American Free Trade Agreement (NAFTA). The Sanitary and Phytosanitary Agreement section of NAFTA specifically requires that trade-restricting phytosanitary measures shall be based on biological and economic evidence that the pests under consideration have the characteristics of quarantine pests.

To this end, NAPPO has already established standards on: (1) the plant quarantine principles which are to be used when drafting new regulations; (2) a pest risk analysis process which is used by the three member countries to determine which pests are quarantine pests, the likelihood of their entry and establishment, and the measures to be taken to reduce the likelihood of such introduction to an acceptable level; (3) the use of pest-free areas as a phytosanitary certification procedure; and (4) the use of preclearance as a measure to better ensure that pests are not introduced by performing importation inspections on products while the products, and their pests, are still in the originating country. Currently, NAPPO has standards under development which relate to: (1) the regional trading of Christmas trees; (2) nursery stock certification; (3) the use of the systems approach to phytosanitary certification; and (4) the use of irradiation technology as a quarantine treatment.

NAPPO cooperates with the other four regional plant protection organizations in the western hemisphere in activities to develop pest exclusion programs that offer a common defense of the hemisphere. And via FAO, NAPPO contributes to the development of harmonized phytosanitary standards at the global level.

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BIODIVERSITY: THREATENED AND ENDANGERED SPECIES

Moderators: John R. Spence¹ and David W. Langor²

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Adoption of the Biodiversity Convention by more than 150 nations at the 1992 UNCED Earth Summit in Rio de Janeiro has fueled increased attention to the loss of species that is associated with economic development. Forestry and deforestation have been identified as among the most important threats to biodiversity worldwide. As a result, market pressures inspired by environmental concerns are propelling forestry into a new mode of operation. In this "new forestry," issues related to species conservation, ecosystem integrity, and sustainability of the resource will share center stage with the more traditional approach of giving highest priority to productivity goals. We are presently in the midst of a social process to sort out the balance desired among these goals.

With the shift in public attitudes, foresters suddenly must explain how their management practices affect the fauna and flora of forested lands. Insects and other arthropods play an important role in the developing debate because they represent an overwhelming majority of species on earth, fulfill many important functions in forest ecosystems, and because data about their communities can be used to assess the extent to which a managed forest resembles its pristine precursor.

Though particular arthropod species are less fretted over than those of the charismatic, furred, or feathered megafauna, some conspicuous but uncommon taxa such as the Karner blue butterfly have attracted widespread attention. Public concern flows from worry that forestry will affect populations of such species negatively and thus increase the probability of their extinction. Study of the biota of forested lands of northern Europe, which have been subjected to several harvest rotations, suggest that such worries are justified, and it has dawned on us that our actions could contribute to the demise of forest species. From a broader viewpoint, we have come to realize how little is actually understood about the biota of North American forests. The realization that we are woefully ignorant of forest biodiversity and its relation to forest function has sent forest entomologists scurrying in new research

directions, often in the company of biologists of other taxonomic persuasions.

As in any area that has suddenly sprung to the forefront of public attention, the general literature about insect "biodiversity" in forests is awash with motherhood statements. There is little agreement about the best approaches to helpful research. Rather than simply reiterate the importance of biodiversity and bemoan the inadequate state of knowledge, we asked the panelists to focus their comments on the following matters and to be prepared to discuss them:

1. How should we build concerns about threatened species and biodiversity into our thinking about forestry?
2. What sorts of general policy would be constructive?
3. What sorts or challenges are presently most important for researchers? Under this topic, we indicated that it would be most appropriate to illustrate remarks with a précis of any special work in which panelists were participating.

Abstracts of the presentations by the five panelists are provided below. The presentations ranged from practical examples, through emerging general principles, to more philosophical discussion about why we should be concerned at all.

Two philosophical issues raised from the floor were dealt with during a short general discussion. W. J. Mattson (Michigan State University) suggested that we need to address the value of biodiversity in relation to its causal relationship to our quality of life, whether this be physical or spiritual. As flows from E. O. Wilson's "biophilia" hypothesis, a primary reason for being concerned about endangered species might be simply that we like them, i.e., that we feel more comfortable being connected to a world that includes particular wild creatures. If humans depend psychologically on

components of “natural” ecosystems, loss of a species amounts to much more than simply rearranging atoms in the universe, even if particular species cannot be directly connected to ecosystem integrity or tangible economic return. Some may experience discomfort as our biological surroundings shift in response to perturbations associated with human-centered development. In essence, this seems to come down to the contrast between an eco-centric viewpoint, which holds humans responsible for their collective effects on other species, and a homo-centric viewpoint, which sees human action as a part of the natural course of events on earth, and thus a legitimate factor in the extinction of other forms of life. C. B. Williams (University of California, Berkeley) pointed out that western culture represents only one of a number of viewpoints about the value of particular species, and cautioned against generalizing our culture-based values. As an example he stated that the aboriginal people of North America may have had a much different view of the reduction of wild species like the bison than did our western European ancestors. Overall, the general opinion seemed to be that forest arthropod communities should be sustained and that our efforts might better focus on habitat management than efforts to ensure the survival of particular species.

A NORTH EUROPEAN PERSPECTIVE

Jari Niemelä^a

I discussed the issue of boreal insects and forestry in Fennoscandia in the framework of the three topics that were provided by the panel moderators.

1. Concerns about threatened species and biodiversity. Concern about threatened species on the one hand and about biodiversity on the other hand form two ends of a continuum of approaches to nature conservation. Protection of threatened species or environments focuses on species/environment specific protection measures, whereas the maintenance of biodiversity involves a holistic approach to conservation. As diversity is a fundamental property of natural systems, this approach emphasizes the overall structure and functioning of the entire ecosystem, e.g., boreal forest. Thus, in addition to understanding of the biology of the forest, a wide variety of human activities related to forest use need to be considered. In this context, insects can be the

targets for conservation measures or they can function as surrogates (indicators) of biodiversity (or ecosystem function).

2. General policy. Use of three complementary approaches to the maintenance of forest biodiversity seems fruitful: (1) protected areas need to be established for sensitive species and environments; (2) by using biodiversity-friendly logging methods, it may be possible to maintain populations of the less sensitive species in the managed forest; and (3) restoration of habitats that have already been altered by forestry.
3. Challenges for researchers. In Fennoscandia, the most urgent question in this field is: Is it possible to maintain biodiversity in the managed forest while logging in an economically viable way? I am involved in an experimental study examining the ecological effects and technical-economical possibilities of alternative harvesting methods. The ecological emphasis is on invertebrates and plants. The team includes researchers from several universities, government research institutes, and forest industry's research unit.

A UNIVERSITY PERSPECTIVE

John D. Lattin^b

In my opinion, there is no special “university perspective” on the biological diversity of insects and other arthropods found in forests but rather a common concern for the many species these ecosystems contain. Insects make ideal biological probes of many different environmental phenomena because they are abundant in numbers and species, they are often habitat specific and host specific, and usually they are quite sensitive to environmental perturbations. In order to maximize the utility of such organisms, we need adequate knowledge about their habits and relative abundance under different circumstances. The sheer numbers of different species make this a daunting task but it is still an essential activity if we are to understand and maintain maximum diversity of the most speciose group of organisms on earth.

In spite of our great need for more detailed information, we are asked daily to extrapolate our present information to address such questions as the impact of management plans for forest landscapes; to protect the

Northern Spotted Owl and associated species; the biological impact of raw log importations; the impact of different forest harvesting practices on the forest biota; a review of the entire fauna of a state for sensitive species; to characterize the riparian zone in forests using insect assemblages; and to compare elements of the insect fauna found in boreal forests at large spatial scales.

If we are to make contributions to such programs and activities we must continue to add to our general and specific information on the forest biota in order to use that knowledge to make the very best decisions on land use possible and develop sound management practices across the landscape. Our forests contain the greatest native arthropod diversity in many parts of the world. We all have a special responsibility to help maintain that rich biological heritage.

SPACE, TIME, AND THE HUMAN DIMENSIONS OF BIODIVERSITY

M.W. McFadden^c and J. Kathy Parker^d

In an earlier paper we examined biodiversity from the viewpoint of the evolutionary processes of extinction and speciation and discussed human values in light of some controversial biodiversity issues. In this presentation, we revisited the biodiversity issue and examined the human values associated with it in terms of time (geological) and space (biogeography). We also pondered questions of human feelings of loss and arrogance. The issue of arrogance is not directed at attempts to validate human values associated with the conservation of biodiversity but rather to examine the arrogance of *Homo sapiens* in light of this species' attempt to control natural selection and the course of evolution.

AN INDUSTRY PERSPECTIVE

William R. Gilbert^c

An interesting dilemma is presented when trying to address issues related to incorporating listed species conservation, and biodiversity into commercial forestry. On one hand, industry has the responsibility to cooperate in the proactive conservation of listed species, and on the other hand it is imperative that conservation planning not over-ride the legitimate

economic goals that are critical to the viability of the business itself.

Congress clearly intended that the burden of conserving listed species would be borne by the federal government and therefore the argument that management of federal lands may have to be integrated into conservation measures for listed species has substance. However, there is no wording in the Endangered Species Act (ESA) that suggests that Congress intended for listed species conservation to dramatically and adversely affect normal, legal use of non-federal lands, particularly private lands.

It is likely that an increasingly large number of listed species will occur primarily on non-federal lands, and many species will not occur on any public lands at all. If conservation of threatened species is to progress on a meaningful scale, it must involve the non-federal lands, including the working landscape, most of which is privately owned. If private lands, including both industrial and non-industrial private lands, are to be involved in this level of conservation, both economic realism and private property rights must be respected. The conservation front may then be advanced.

So the concept can be fairly straightforward. If larger, non-federal landowners can adjust their management practices in an economically-viable manner to accommodate conservation programs, habitat availability is unlikely to jeopardize the existence of endangered species. Thus, little of the potential burden would need to be passed on to small private landowners, who own the majority of our landscape.

As an example, the Karner blue butterfly habitat conservation planning effort is a unique attempt at "grassroots" state-wide conservation of an endangered species. Government agencies and private entities that have land or financial assets committed to the plan jointly work as partners in the planning process. This process is coordinated by a government agency, in this case the Wisconsin Department of Natural Resources. The DNR will be the applicant for the state-wide incidental take permit on behalf of all partners.

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Section IV

Workshop Abstracts

NEW CONSIDERATIONS IN DEVELOPMENT OF SEMIOCHEMICAL-BASED PEST MANAGEMENT FOR BARK BEETLES

Moderators: Patrick J. Shea¹ and Scott M. Salom²

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Twelve papers were presented that gave us the latest information on pheromone studies for bark beetle species from different regions, for pest management tactic development, and for preparing tactics for operational use. The pheromone research included presentations on the Jeffrey pine beetle, *Dendroctonus* beetles of Mexico, *Ips pini* research in Idaho, inhibitor pheromones of spruce beetle in Alaska, new analytical techniques for identifying bark beetle semiochemicals, and the importance of enantiomeric ratio of southern pine beetle pheromones.

Hanlon and others have demonstrated that currently a combination of 1-heptanol in heptane in a 1:4 ratio is a very effective attractant for Jeffrey pine beetle. However, this combination has a strong male bias indicating that additional compounds are needed. Livingston and Gibson tested an array of potential antiaggregation compounds for inhibiting attraction of *Ips pini* to its aggregation pheromone. Ipsenol plus verbenone and ipsenol plus *cis*-verbenol were the most effective inhibitors, although 4-allylanisol alone also significantly reduced the trap catch of beetles compared to baited traps.

Bioassays of the deterrent effects of host volatiles to spruce beetle aggregation in Alaska were reported by Werner. His data indicates that the degree of deterrence can be greatly affected by the size of the spruce beetle population. Ross reported that under some circumstances pheromone baited traps may be a useful management tool. Baited traps can be used to influence the location and possibly the amount of Douglas-fir beetle-caused tree mortality during outbreaks. There are still today a number of important bark beetles whose pheromone(s) are still unknown. Teal describes a new approach that utilizes GC-EAD, GS-MS, and multivariate analysis to ascertain the identities of chemical odor components.

Development of semiochemical-based pest management tactics are the next step in taking behaviorally

active compounds and using them to either sample for bark beetle populations or suppress their impact on forest stands. Grosman highlighted the potential importance of geographic variation in the response of a bark beetle species to semiochemical enantiomers. Strom and Hayes described the potential of using a naturally-occurring host compound and visual deterrents for suppressing southern pine beetle attacks on trees. Semiochemical-baited traps play an important role in sampling and research of bark beetles. McCravey et al. compared trap catches between standard Lindgren funnel traps and German-made Theysohn slot traps. Miller discussed the numerous considerations that need to be accounted for in developing semiochemical elution devices. Burke discussed regulatory issues associated with semiochemicals in North America. Once you have a tactic ready for operational use, what is the best way to transfer the technology to users? Salom et al. presented results of a southwide survey that will serve as a basis for a technology-transfer program for the southern pine beetle verbenone suppression tactic.

ATTRACTANTS FOR THE JEFFREY PINE BEETLE

C. C. Hanlon, T. D. Paine, J. G. Millar,
and S. Hwang^a

The Jeffrey pine beetle, *Dendroctonus jeffreyi*, is the key pest of *Pinus jeffreyi* in California, southern Oregon, and Baja California, Mexico. However, lack of an effective attractant has limited the ability of forest managers to monitor flights and population trends. The object of the research project is to identify all pheromone constituents from males and females and develop an effective trap lure.

1. Gas Chromatographic Analysis of Frass Extracts and Beetle Aerations: Frass was obtained by introducing newly emerged beetles into fresh Jeffrey

pine logs through holes drilled through the outer bark. Frass was collected daily and stored at low temperatures until it could be extracted. Beetle aerations were obtained by placing newly-emerged beetles fed on fresh *P. jeffreyi* phloem into glass tubes, passing filtered air through the tubes, and collecting volatiles by the beetles on activated charcoal. The charcoal was extracted with solvent. The extracts were analyzed using a gas chromatograph. The chromatographic analyses suggested that 1-heptanol is produced by both female and male beetles. 2-Heptanol was also found in both sexes. Frontalin [32.5%(+)/67.5%(-)] and *exo*-brevicomin [99%(+)] were found in males but are not present in extracts from females.

2. Electroantennagram (EAG) Analyses: Both males and females respond strongly to 1-heptanol and heptane. The response of females was examined with the electroantennograph coupled with the gas chromatography and indicated that this sex responded to frontalin, *exo*-brevicomin, and 1-heptanol in male aeration extracts. The results were confirmed using chemical standards. Additional EAG analyses with selected bark beetle pheromones suggested that both sexes respond not only to frontalin and *exo*-brevicomin, for also to a variety of stimuli. However, the response was greatest to 1-heptanol and all responses to other compounds are presented as a percentage of the response to 1-heptanol.

3. Laboratory and Field Bioassays: Extensive laboratory bioassays have been conducted but the data are not completely analyzed. However, it is clear from walking and arena bioassays that male and female frass are attractive. Males are most attracted by female frass and mildly attracted by male frass. Females are mildly attracted by male and by female frass. Phloem and frass collected from entrance holes to galleries containing both males and females did not attract either sex. Studies are continuing to determine the response of beetles to the mixture of 1-heptanol/heptane plus different concentrations of frontalin and *exo*-brevicomin.

Beetle catches in Lindgren funnel traps baited with 1-heptanol or heptane alone were not different from unbaited traps, but treatments containing the combination of both compounds caught significantly greater numbers of beetles. Addition of 2-heptanol did not change the response of beetles to 1-heptanol plus heptane. Similarly, addition of *exo*-brevicomin,

verbenone, *trans*-verbenol, or verbenone did not change the beetle response when compared with 1-heptanol plus heptane.

The combination of 1-heptanol plus heptane appeared to be the most potent attractant. However, it was important to determine the most effective ratio of the mix of the two compounds. A mixture of 5% 1-heptanol mixed directly in heptane was most attractive in the first test. A subsequent test with higher ratios indicated that the 10% and 25% 1-heptanol in heptane were most effective in traps. A release rate of 250-300 mg/24 hr of the 25% mixture was the most effective rate in a dosage study.

The 1-heptanol/heptane lure was very attractive in the field studies, but twice as many male beetles as females were caught in the traps. The unbalanced sex ratio and production of frontalin and *exo*-brevicomin by males suggests that the lure can be improved. It is probable that the release rates of *exo*-brevicomin and frontalin tested in combination with 1-heptanol plus heptane in earlier tests may have been too high and deterred arrival at the traps. Also, we have examined the response of beetles to racemic *exo*-brevicomin in laboratory and field studies, but males produce only the (+) enantiomer.

PHEROMONE RESEARCH WITH *DENDROCTONUS* SPECIES IN MEXICO

J. Flores L.^b and P. J. Shea^l

A series of tests was conducted to evaluate the response of several species of *Dendroctonus* to aggregation and antiaggregation pheromones. The species tested represent the three most economically important bark beetles in Mexico.

The objective was to contribute to the development of control strategies under low to medium population densities. Field studies with *D. frontalis* were conducted in southern Mexico in the municipality of Tlaxiaco, Oaxaca, while studies with *D. mexicanus* were conducted in Sierra Fria, Aquascalientes, Central Mexico. The tests involving *D. adjunctus* were carried out at the national park "Nevado de Colima" in Jalisco and in San Miguel del Valle, Oaxaca.

Ten traps/site were located in each of the respective study areas. Traps baited with aggregants and

antiaggregants were alternated throughout the study areas. The traps were collected periodically on an interval of 5 days during a 20-day period. In all locations Lindgren funnel traps were used as individual experimental units.

In 1994 and 1995, in the tests with *D. frontalis*, the addition of verbenone to the frontalin aggregation compound resulted in a 34 and 65% reduction in trap catch, respectively. The overall average sex ratio in 1994 in the trap catches was 1:1.8 (F:M) in the frontalin-baited Lindgren funnel traps. The experiments with *D. adjunctus* indicate that verbenone can reduce trap catches by approximately 78%. For this reason further work is being planned in an attempt to develop a semiochemical-based pest management system for this bark beetle. Finally, verbenone was also effective in reducing trap catches of *D. mexicanus* (reductions averaging 88%) but these data must be cautiously interpreted because of the low populations in which the tests were conducted.

INHIBITION OF PINE ENGRAVER ATTRACTION BY SEVERAL SEMIOCHEMICALS

R. L. Livingston^c and K. E. Gibson^d

Ipsenol, and a combination of ipsenol and verbenone, functioning as synomones, have effectively suppressed attacks of the pine engraver, *Ips pini* (Say), in ponderosa pine, *Pinus ponderosa* Laws, and Jeffrey pine, *P. jeffreyi* Grev. & Balf., slash in California and lodgepole pine, *P. contorta* Dougl., slash in British Columbia, Canada. Various attempts to duplicate this work in north Idaho and western Montana have not proven as successful.

Ipsenol is but one component of the attraction pheromone of both *I. paraconfusus* Lanier and *I. latidens* LeConte, competitors with *I. pini* for attack sites. (+)Ipsdienol and *cis*-verbenol also function in the attraction of *I. paraconfusus*. Verbenone is a component of the antiaggregation pheromone of both the western pine beetle and the mountain pine beetle. These compounds and 4-allylanisol were tested in various combinations to determine their ability to suppress the attraction of the pine engraver to ipsdienol- and lanierone-baited Lindgren funnel traps. Eight treatments including an unchallenged check were replicated five times in both Idaho and Montana. The

treatments were installed prior to beetle flight and evaluated by the end of June after the spring flight was completed and prior to flight of the next generation. Combinations containing ipsenol and verbenone or ipsenol and *cis*-verbenol were most effective in reducing the number of beetles caught. In the most effective treatment (ipsenol and verbenone alone), the catch was reduced to a total of 20 beetles caught compared to 565 for the check. The host volatile 4-allylanisol by itself reduced the catch significantly compared to the check (123 total beetles : 565), but did not add to the inhibition of ipsenol and verbenone.

DETERRENT EFFECTS OF HOST VOLATILES ON SPRUCE BEETLE AGGREGATION

Richard A. Werner^e

The spruce beetle, *Dendroctonus rufipennis* (Kirby), is one of the most damaging insects affecting North American forests. It is currently exhibiting outbreak behavior across spruce ecosystems of Alaska with over 900,000 acres infested in 1995. Silvicultural and chemical strategies have been developed for preventing or reducing populations but additional environmentally-safe methods are needed for high-value stands and areas inhabited by people.

The use of semiochemicals to manipulate spruce beetle populations has been studied in Alaska for the past 15 years. This includes aggregation and antiaggregation pheromones, host volatiles or combinations to prevent attack or reduce the attack density of bark beetles to a level below the threshold density required for the development of brood trees. The use of antiaggregation pheromones or deterrent host-produced volatiles have the largest potential "payoff" of all operational use strategies in Alaska because they are more cost-effective than other methods.

An aggressive RD&A effort is underway in the boreal spruce forests of Alaska to develop technology needed to manipulate populations of spruce beetles using behavior-modifying semiochemicals. The most promising practice for reducing losses to natural resource productivity from bark beetles in Alaska is the use of host- and insect-produced volatiles. The most recent operational use strategy involves the use of a spruce beetle-produced antiaggregation pheromone, 3-methyl-2-cyclohexen-1-one (MCH), and host-produced volatiles 4-allylanisol (methyl chavicol) and (L)-(-)-limonene, to deter beetle attacks.

Laboratory and field tests showed that host-produced volatiles myrcene, beta phellandrene, (L)-(-)-limonene, 4-allylanisole at 20 ppm caused beetle mortality at 24 hrs after topical application. Of these, (L)-(-)-limonene and 4-allylanisole were the most toxic. These semiochemicals were formulated in slow-release polyethylene bubble caps and vials for field tests. MCH at 50 bubble caps per acre has thus far provided the best protection from beetle attacks at the stand level for one growing season. The host compound 4-allylanisole deterred beetle attraction to funnel traps when compared to other host compounds in areas with high populations; whereas, its effectiveness in low populations was similar to (R)-(+)- and (L)-(-)-limonene when tested alone in funnel traps. When compared to MCH dispersed from funnel traps, its deterrent qualities were the same as MCH in low populations, but MCH was more effective in high populations.

PHEROMONE-BAITED TRAPS FOR AREA-WIDE MANAGEMENT OF BARK BEETLE POPULATIONS

Darrell W. Ross^f

Pheromone-baited traps have been used in past research and operational projects designed to reduce damage caused by several bark beetle species. The results of these projects suggest that trapping may be a useful management technique for some beetles under certain conditions. The efficacy of a trapping program will depend on a number of variables including available technology, the size of the area and beetle population being treated, duration of trapping, management objectives, and integration with other management activities. Traps offer several potential advantages over trap trees such as a greater capacity to remove beetles from the flying population, no possibility of reemerging parent adults, no need to sacrifice trees *a priori*, greater flexibility in trap location, and more possibilities to minimize impacts on natural enemies. Potential disadvantages are higher cost and the need for regular maintenance.

A study conducted in northeastern Oregon during 1992 and 1993 demonstrated the feasibility of using pheromone-baited traps to reduce losses caused by the Douglas-fir beetle. Subsequent studies have provided further information to improve the efficacy of trapping. Lures containing frontalin combined with seudenol and

ethanol attracted more Douglas-fir beetles to traps than did any other lures tested. Although seudenol significantly increased the number of Douglas-fir beetles collected in traps, it also significantly increased catches of *Thanasimus undatulus*, a clerid predator. Increasing the release rates of frontalin and seudenol above 20 and 10 mg/day (at 24° C), respectively, at a constant ethanol release rate did not increase the number of Douglas-fir beetles trapped, but did significantly increase the number of *T. undatulus* trapped. The ratio of bark beetles to predators did not differ between slotted-panel traps and multiple-funnel traps that were baited identically. Placing a metal screen with 6- or 12-mm openings in the base of the funnel trap above the collection cup significantly reduced the percentage of clerids caught without affecting the total number of Douglas-fir beetles caught. Providing an escape route with a 30-mm-wide strip of window screen extending from the bottom of the collection cup to the top of the lowermost funnel had a similar effect on trap catches. Further studies are needed to fully develop trapping technology for the Douglas-fir beetle.

Baited traps can be used to influence the location and possibly the amount of Douglas-fir beetle-caused tree mortality during outbreaks. Trapping should be considered as one component of integrated programs for preventing resource losses from the Douglas-fir beetle.

USING GC-MS, GC-EAD, AND MULTIVARIATE METHODS TO DECIPHER COMPLEX BARK BEETLE/HOST ODOR BOUQUETS

Stephen A. Teale^g

The primary challenge in identifying bark beetle pheromones arises from the complexity of the mixture of volatiles emanating from the insect and its host tree. The number of chemical components that are detectable by GC-MS can easily exceed one hundred. The single most effective and widely employed method for determining which components are responsible for mediating aggregation is the bioassay-fractionation procedure espoused by Silverstein et al. in the 1960s. However, in some insects the behavior that is suspected to be mediated by semiochemicals may itself be poorly understood, leaving us without a bioassay. Yet, intricacies of the insect's biology may give us reasonable cause to suppose that there may in fact be

some type of pheromone. Two insects that fall into this category are the white pine weevil (*Pissodes strobi*) and the pine shoot beetle (*Tomicus piniperda*). In both, strong primary attraction has been demonstrated, but the investigation of secondary attraction has been problematic.

We are using a combination of GC-EAD, GC-MS, and multivariate analysis to ascertain the identities of chemical odor components in these two insects in a manner akin to general image analysis as opposed to the deterministic, bioassay-driven approach. Volatiles are sampled by aeration at frequent and regular intervals throughout the host colonization process to ensure that brief periods of signal emission, if any, are sampled. Volatiles are screened for detectability by GC-EAD. By excluding compounds that cannot be detected by the insect, the number of compounds is greatly reduced. A factor analysis is then conducted and the outlier samples are identified. Chemical compounds (variables) with high loadings on the appropriate factors are then considered good candidates for behavioral experiments. In *T. piniperda*, these compounds also gave EAD responses comparable to *alpha*-pinene at concentrations several orders of magnitude less. We are currently conducting field and laboratory experiments with the newly-identified compounds in *T. piniperda*.

VARIATION IN SEMIOCHEMICAL MESSAGES WITHIN A SPECIES' GEOGRAPHIC RANGE: DOES IT MATTER?

Donald M. Grosman^h

The southern pine beetle (SPB), *Dendroctonus frontalis* Zimm., utilizes several semiochemicals as part of its communication system. Among these are two chiral pheromones, frontalin (F), in operational use for predicting regional population trends, and verbenone (V), currently being evaluated as a means to suppress the growth of infestations. Experiments were conducted to determine if production of and response to these pheromones vary across the SPB's geographic range.

One experiment involved collection and quantification of chiral semiochemicals released from SPB-infested logs from eight infestations in Texas (TX), South Carolina (SC), and Virginia (VA). Significant geographic differences were found in the quantities and chiralities of F and V released from infested host

material within and among these geographic areas. The enantiomeric ratios of F ranged from 12.4%(+):87.6%(-) in SC to 39.3%(+):60.7%(-) in TX, whereas V ranged from 62.3%(+):37.7%(-) in SC to 76.7%(+):23.3%(-) in VA.

The response of SPB from two or three geographic areas to different enantiomeric ratios of F and V (released at rates comparable to those used in surveys and infestation suppression) was evaluated via walking and trapping (V only) bioassays. In both experiments, male SPB response to both F and V was significantly greater than that of females. Males showed little or no geographic differences in response to V and responded similarly to each ratio. Female SPB response to V differed considerably among geographic areas and enantiomeric ratios.

The studies indicate that the chiralities of F and V released from SPB-infested logs can vary considerably among geographic areas; however, with regard to V, different enantiomeric ratios of the compound are equally effective at inhibiting SPB response. This suggests that a single enantiomeric ratio (preferably the cheapest) can be used effectively to suppress the growth of infestations throughout the beetle's contiguous range. Additional field trials are needed to determine if similar conclusions can be made with regard to SPB response to F.

THE PROSPECTS OF EMPLOYING SEMIOCHEMICAL AND VISUAL DETERRENTS IN PROTECTING TREES FROM BARK BEETLES

B. L. Strom,ⁱ L. M. Roton,ⁱ J. L. Hayes,ⁱ and R. A. Goyer^j

Tree protection tactics based on semiochemicals are being investigated by many forest scientists but their consistent effectiveness remains a concern. One approach toward increasing the efficacy of such treatments is to combine semiochemically-based tactics with deterrents that disrupt other cues necessary for host finding and colonization. In this study we attempted to deter colonization of southern pine beetle (SPB), *Dendroctonus frontalis*, through disruption of the visual stimulus created by a dark, vertical silhouette. White paint was chosen as one easily evaluated deterrent since it is visually dissimilar to loblolly pine bark and readily available.

Studies were conducted at eight sites in Florida and Louisiana during the summer and fall of 1995. With funnel traps, three semiochemical (frontalure only; frontalure and verbenone; frontalure and 4-allylanisole) and two visual (black paint; white paint) treatments were evaluated. Additional experiments in Louisiana included beetle arrivals at Plexiglass sticky panels (black, clear, white) baited with frontalure (two replications), and beetle attacks of trees painted (white or black, to 4m height) in front of active infestations.

We found that 4-allylanisole in funnel traps reduced trap catch of SPB significantly (~50% reduction) when compared to frontalure alone. Verbenone had no effect on trap catch; not unexpected since elution rates were ~1/4 that recommended for disruption. The visual deterrent, white paint, reduced trap catch of SPB more than any semiochemical (~70% on average). The combination of 4-allylanisole and white paint reduced trap catch by ~90% (as compared to frontalure), which was significantly lower than any other treatment. Plexiglas sticky panels gave similar results, with white panels catching the fewest beetles, followed by clear and then black (each significantly different from each other). Trees painted white to 4m also altered normal SPB colonization and were attacked primarily above the paint. Trees painted black were colonized in a pattern not discernibly different from unpainted trees.

These results show that visual disruption of SPB is possible, and when combined with semiochemicals, may improve efficacy of tree protection programs where insecticidal control tactics are not desired or feasible.

COMPARISON OF LINDGREN AND THEYSOHN TRAP EFFICACY FOR SOUTHERN PINE BEETLE AND *IPS* SPECIES

K. W. McCravy,^k J. Nowak,^k C. W. Berisford,^k
and G. K. Douce^l

The Lindgren multiple-funnel trap is widely used throughout North America in bark beetle detection and survey programs, while the German-made Theysohn slot trap is commonly used in Europe, especially for trapping of *Ips* engraver beetles. In this study, we compared the effectiveness of Lindgren and Theysohn traps in collection of southern pine beetles (SPB), *Ips* spp., and two bark beetle predators, *Thanasimus dubius*

(Cleridae) and *Temnochila virescens* (Trogossitidae), using paired comparison tests.

Six pairs of frontalure-baited traps were placed in an active SPB infestation in Oconee National Forest, Greene Co., GA, in September and October, 1994. Lindgren traps collected 1556 SPBs and 334 clerids compared to 1149 and 88 collected in Theysohn traps. Differences for both insects were significant (SPBs: $P=0.03$; clerids: $P=0.0001$).

Trapping for *Ips* spp. was done in September through October, 1995 in three sites that had received cut-and-leave treatments for SPB control. At each site, four pairs of traps were set up. At two of the sites, traps were baited with ipsdienol for collection of *I. avulsus* and *I. calligraphus*; at the third site, ipsenol was used for collection of *I. grandicollis*. Theysohn traps captured greater numbers of all three species than did Lindgren traps: 754 versus 470 *I. avulsus* ($P=0.008$), 23 versus 17 *I. calligraphus* (NS), 114 versus 72 *I. grandicollis* ($P=0.055$). Lindgren traps again caught more clerids (46 versus 11, $P=0.02$), and also more trogossitids (41 versus 10, $P=0.01$).

Results indicate that Lindgren traps capture greater numbers of SPB and predators, while Theysohn traps show greater efficiency in collection of southeastern *Ips* spp. The greater efficiency of Lindgren traps in capturing bark beetle predators could be an advantage in bark beetle prediction systems that rely on estimates of natural enemy populations. However, if one is more interested in conservation of these natural enemies, Theysohn traps would be preferable.

ELUTION DEVICES: CONSIDERATIONS FOR ENTOMOLOGISTS

Dan Miller^m

Semiochemicals are critical for the reproductive success enjoyed by forest insects, especially bark beetles. Forest entomologists desire elution devices that release these semiochemicals in order to better understand the behavioral ecology of insects, and hopefully mitigate their impacts. Using live insects is expensive, and problematic at best. Luckily, elution devices are commercially available. They generally consist of a plastic container filled with semiochemical. Semiochemicals pass through the plastic membrane into the atmosphere. The technology is not very

complicated. However, the behavior of these devices in field situations is quite complicated. Entomologists should be familiar with the vagaries of elution devices to ensure appropriate interpretations of data as well as the use of appropriate technology.

There are three categories of effects that influence the "successful" use of elution devices: (1) contaminants; (2) release rate characteristics; and (3) field scenarios. "Success" is a relative term, varying among entomologists. Contaminants can be any potentially-active compound whose presence is not desired. The following factors should be considered when purchasing devices: (1) chemical purity; (2) enantiomeric composition; (3) presence of solvent(s) and additive(s); and (4) storage factors. Release rate characteristics describe the probable response of semiochemicals passing through the plastic membrane under controlled environmental conditions. The following factors can affect release rates: (1) temperature; (2) wind and humidity; (3) stability of semiochemical(s); and (4) inherent properties of the device. And lastly, the response of bark beetles is governed by a variety of conditions depending on the application scenario. Some of these considerations include, but are not limited to, the following: (1) trapping device; (2) placement relative to vegetation; (3) proximity to nonhost trees; (4) proximity to host trees; (6) proximity to attacked trees; (7) stand density and structure; (8) area of coverage; (9) immigration/emigration; and (10) proximity and density of competing species. The use of appropriate replication can obviously minimize some of the error in terms of experimental analysis. It won't do much for interpretation of results for operational uses.

One simple task, rarely done by entomologists, is to measure devices before and after use in the field. Another task is to verify the composition within devices. Please note that devices should be kept separate, in appropriate storage containers, in order to minimize cross-contamination. Inferences and conclusions based on the use of elution devices should always be tempered by consideration of these factors. Erroneous interpretations and frustrations can be minimized with proper planning and due diligence.

BIOCHEMICAL INSECTICIDE REGULATORY ISSUES

Stephen Burke"

The regulatory climate and process with respect to biochemical pesticides is imprecise and often not well understood. This presentation attempted to bring understanding and clarity to this arena. Comments focused on a number of areas key to forest pest management.

Pest management objectives have become confused with an objective determination of human and environmental risks. Mass trapping is often assumed to be subject to regulation because the objective is to mitigate the pest population even if the toxicological risk is low or lower than products used to monitor populations. The U. S. Environmental Protection Agency (EPA) recognizes this in print and has established three criteria to be met in order to have products exempt from regulations. A case in point is mass trapping of *Ips pini*.

Upon examination it is evident that tree baiting is more akin to mass trapping than mating disruption with respect to toxicological concerns. Canada quickly acknowledged this but the U. S. took three years to deliberate before exempting tree baits from registration. A convincing argument was a comparison of estimated natural versus introduced semiochemical concentrations. In some forestry mating disruption situations, natural:introduced ratios were as high as 1:4000. With tree baits the ratio was estimated at 1:3.

Naturally-occurring semiochemical repellants such as anti-aggregation pheromones and nonhost volatiles are similar to mating disruptants if one compares dosages (e.g., grams/acre) and density of point source releases, yet dosages are not excessively above natural levels. Typically, mammalian toxicity is very low. How should they be regulated?

In 1994 EPA changed its upper limit for experimental use permit exemption from 10 to 250 acres for products used in non-food situations at dosages not exceeding 150 g/ac. Unfortunately, most States have retained the 10-ac. limit, making meaningful research in forest situations very difficult. Canada is proposing a 1 - 5 ha (2.2 - 14 ac.) nationwide limit prior to notification and up to 50 ha prior to an EUP. Why? Possibly because its regulators have only agricultural crops in mind.

In the U. S., similar toxicity data is required for EUP's and full registration. The difference lies in the flexibility of EPA to entertain waiver requests for more involved tests such as Immune Response. Further, it is unlikely that EPA would request testing beyond Teir 1 for an EUP.

Although somewhat fractured, there is some level of harmony between the U. S., Canada, and Mexico. The U. S. has taken the lead; Canada and Mexico appear to be following this lead. Canada is further ahead and has recently invited comments on the proposal to regulate semiochemicals. Both will likely fine tune their requirements by using earliest registration packages as guinea pigs.

BASIS FOR TECHNOLOGY TRANSFER OF THE INHIBITOR-BASED SUPPRESSION TACTIC FOR THE SOUTHERN PINE BEETLE

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A new inhibitor-based suppression tactic for the southern pine beetle (SPB), *Dendroctonus frontalis* Zimm., is nearly ready for operational use. A critical component for its acceptance and successful use by foresters is a carefully constructed technology transfer program. To achieve this goal, we developed a questionnaire and sent it to as many foresters practicing in southern pine ecosystems as we could. The questionnaire was designed to provide a profile of foresters based on their experience with SPB, their goals for managing the pest, their knowledge of the insect's biology and control options, their interest in learning this new tactic, and the methods by which they prefer to be educated.

3426 questionnaires were sent out to foresters in ten states and 1028 (30%) were returned of which 995 were used. Experience with SPB did differ among states and seemed to follow along the lines of frequency of outbreaks in those respective states. However, this did not affect the level of knowledge foresters had with SPB biology and control. 73% of the foresters did an excellent job of relating crown color to brood development in trees, 91% knew that SPB uses semiochemicals as cues for aggregating on hosts, 97% and 79% knew that stands with high basal areas and older trees, respectively, are more susceptible

to SPB than stands with lower basal areas and younger trees. 90% picked a buffer strip width that could be considered correct for use in direct suppression tactics. Less success was reported for differentiating between *Ips* and SPB infestations.

Methods used for evaluating infestations favored revisiting sites and counting the number of green infested trees. Few foresters picked examination of brood galleries, a method we believe is best. Although foresters would prefer 100% suppression after one suppression treatment, they were willing to accept suppression at a level of 75-95%. Most respondents (92%) said they would like to learn about the inhibitor-based suppression tactic and the same number said that if the tactic was shown to work and be cost effective, they would recommend its use. The preferred choice for learning the new tactic would be to combine an in-class workshop with field activities. Use of videos as a teaching and review tool also was preferred.

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SURVEY/MONITORING/PREDICTION OF FOREST PESTS

Moderators: W. Jan A. Volney¹ and James D. (Denny) Ward²

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New technologies offer forest pest managers an array of opportunities to monitor and forecast pest populations. These technologies include many of the remote sensing modalities that may be used to acquire and process information related to forest health conditions. As importantly, precise and accurate methods of determining position are crucial to the display, analysis, and reporting of geographically-referenced data. As Dull suggested in the first paper of the workshop, we face challenges to assimilate and process remotely-sensed information that might be useful in monitoring and predicting pest populations.

Despite the availability of new technologies, Dix emphasized that a challenge remains in developing and applying cost-effective techniques at scales that are appropriate in agroforestry. As importantly, there is a tremendous need to integrate approaches at the international, national, and local levels.

Some tried and true technologies remain useful as suggested by Sapio and Lusch. Sketch mapping, despite its inherent lack of precision, still provides useful information and may be the most cost-effective way of acquiring defoliation data.

Several technologies were integrated by Pendrel to monitor and display endemic population densities of several defoliators simultaneously. This approach offers an opportunity to exploit geographical information systems (GIS) and detailed forest inventories, combined with pheromones, to explore ideas over landscapes that would have been technologically impractical 20 years ago.

Finally, the information on single species pest systems described in the three papers by Alfaro, Billings, and Volney point to the opportunities to tailor monitoring and detection schemes to the various intensities of forest management contemplated. The individual tree approach still finds value in the intensely-managed plantation, the stand approach is useful in describing the regional picture, and the landscape level approach

is useful in extensively-managed forests. Despite the different scales of concern, all approaches rely on a sound understanding of the pests' biologies to be effective.

REMOTE SENSING AND ADVANCED TECHNOLOGIES TO SUPPORT FOREST HEALTH PROTECTION

Charles W. Dull^a

Forest health protection specialists and resource managers have every right to be optimistic about recent advances in remote sensing and associated technologies. Imagery will help "view" natural resources from landscape to eco-regional levels. The USDA Forest Service is using remotely-sensed data, working in partnership with other land management agencies on broad-area assessments to identify current conditions, trends, and future planning considerations. A broad framework exists to support the various levels of planing: from the RAP Program, Forest Plans, and project level plans. Just as we have established a hierarchy of ecological units, there is a corresponding information hierarchy. All of it is interconnected and dependent on each other, and available to help integrate forest health protection issues in the planning process.

A multi-resolution imagery data base is now available to support forest health protection activities and broad-area assessments. Working with a federal consortium of imagery users, the Forest Service and affiliates have access to full CONUS coverage of multi-date imagery from AVHRR and Landsat MSS. Leveraging of our dollars with this federal consortium consisting of the GAP Program, EPA/EMAP, NOAA/C-CAP, USGS Water Resources, and EROS Data Center, we now have domestic coverage with Landsat TM data, with the prospect of multi-date coverage within the next two years. With the availability of imagery to support forest health monitoring, broad-area assessments, and the National Forest planning process, with new sources

of data emerging soon, the institutional capability for managing remote sensing data in the Forest Service is materializing.

There are 50 current, planned, or proposed earth-observing satellites scheduled by the year 2010. Costs for satellite data and the hardware and software to process it are falling. However, decisions on how to gather, process, store, and access data collected by these new satellites won't be easy. Already, governments, research institutions, and private industry are struggling with how to make the expected influx of satellite data more accessible and usable to more users and establish imagery acquisition and distribution policies. Land management agencies have been asked about their information requirements to support systems designs for several of the proposed systems to be launched by the United States. However, we have much work to do to match forest health protection and land management information requirements with system capabilities. These systems will offer much finer spatial and spectral resolutions with more frequent coverage. We also can expect more timely data delivery through the use of the information super highway, and new image browse and ordering capabilities.

Although there is a wealth of proposed new and existing satellite data available, aerial photography is still relied upon for most mapping and resource management operations. New airborne sensors, such as the CIR digital camera, are increasing the opportunities to rapidly respond to forest health issues.

Navigation and positioning technologies are moving rapidly. The Forest Service now has approximately 1500 GPS receivers in use and available to all Ranger Districts and Stations. We continue to support a base station network for differential correction and have a variety of GPS training opportunities for our employees. Receivers capable of using the Precise Positioning Service are now available to support forest health monitoring, allowing for real time positioning and navigation to inventory plots.

With all the advances in remote sensing and related technologies, be they currently planned or proposed, we have good reason to be optimistic about the direction of these technologies to support forest health protection.

DETECTING AND MONITORING PESTS IN AGROFORESTRY SYSTEMS

Mary Ellen Dix^b

The USDA Forest Service International Forestry and the National Agroforestry Center recently conducted a world-wide survey of pest management specialists to identify research, technology transfer, and implementation challenges in agroforestry. We found that techniques for detection and monitoring pests in agroforestry systems were available for a few pests and usually were adaptations of those available for selected major forest pests. However, information and techniques for most pests in agroforestry systems were not readily available, poorly understood, or inappropriate. In addition, available technology often did not reach practitioners or farmers because the infrastructure to communicate the message was unavailable or ineffective.

Pest management strategies varied with the farming style and availability of funds. Thus, research needs to develop detection and monitoring techniques appropriate for large mechanized farms as well as for small traditional farms. Successful development and implementation of these technologies also require a two-way exchange of information among pest management partners in industrial and non-industrial countries and between farmers and professionals.

International government organizations must play a major role in development of IPM programs at international, national, and local levels. These organisations must fill the gaps in IPM infrastructure and coordinate detection, monitoring, and control activities among countries, government organizations, and non-government organizations. This requires an intensive cooperative effort among foresters, agronomists, farmers, and other partners in industrial and non-industrial countries.

GYPSY MOTH DEFOLIATION SURVEYS IN MICHIGAN: A TEN-YEAR HISTORY OF TECHNOLOGY

Frank J. Sapio^c and David P. Lusch^d

Gypsy moth populations first reached major outbreak levels in Michigan in 1985. Aerial sketch mapping was then the only locally controllable method that would

allow survey completion during the relatively short biological window between peak defoliation and tree reflush. Several technologies existed at that time that could be employed although there was no guarantee that imagery could be acquired during the relatively short defoliation window. Aerially-acquired color infra red (CIR) video imagery was thought to be a possible method to map defoliation. This method, under local control of state pest managers, could respond to local weather conditions much like aerial sketch mapping.

To investigate the potential of this method, a pilot test was developed. The video camera (Biovision, E. Coyote Enterprises, Mineral Wells, TX) was leased for a two-week period to investigate its potential as a defoliation mapping tool. This bench-modified color camera is sensitive to near infra red radiation given off by green plants. The video picture provided by this camera emulates a typical false color infra red image. It is also inherently insensitive to blue light scattering, therefore making it an excellent tool for acquisition on hazy days. It was therefore felt that this would make it an appropriate tool for use in the Lake States.

In 1986 we pilot tested this technology. The mission area encompassed almost 1/4 million acres. Flight lines were predetermined and logged onto maps at 1-mile intervals. Waypoints were taken from the maps and programmed into the Loran-C navigation system of the Cessna 180. The entire mission was captured on several video tapes. Tapes were later viewed on a monitor and deck with freeze-frame capability. Defoliation polygons were then sketched onto maps with flight lines. The test proved quite favorable. Maps produced through videography showed more detail and precision than did conventional sketch mapping.

In 1987 we purchased a Biovision camera. We paired the camera with a new recording technology called SVHS. This format increases screen resolution of the viewed image over 60 % compared to standard VHS. Over the next four years an additional camera system was purchased to accommodate the ever-growing mission area. By 1992, the mission area grew to approximately 12 million acres. Sketch mapping was used in areas of highly broken defoliation to more efficiently utilize airplane time while video was used on large block defoliation. It became obvious that video was no longer an appropriate tool to map the entire mission area. We therefore set up a permanent video block of approximately five million acres. We

estimated a 2.5 million acre limit per camera system during the biowindow.

In 1992 we investigated NOAA COASTWATCH data (AVHRR 1.1 KM resolution) for defoliation mapping. This high temporal resolution (daily images) imagery can be used to produce a map of the Normalized Difference Vegetation Index (NDVI). This ratio of two AVHRR bands is highly correlated with the volume of healthy green foliage in an image pixel. By using NDVI image differencing, principal components analysis, and other image analysis techniques, we attempted to model defoliation during two seasons with little success. AVHRR is an uncalibrated sensor, yielding a very low signal to noise ratio for defoliation information.

After ten years of monitoring defoliation using sketch mapping, CIR videography, and satellite remote sensing, aerial sketch mapping is still the method used most often. CIR videography remains an alternative over a limited area producing high quality maps. It is possible to use digital frame grabbing technology to automate capture of defoliated polygons. However, sketch mapping off of the monitor onto maps and subsequent digitizing is much more efficient. This is primarily a function of the large number of video frames and the number of ground control points necessary to georectify those frames. Areas of highly fragmented defoliation remain very difficult to capture, requiring a lot of time and effort through sketch mapping. Sketch mapping is still the status quo for damage mapping in most areas of the country. It is still the most cost efficient method. Sketch mapping, however, produces maps that are inherently imprecise. After many years of technology development, the forest pest management community still needs a "snapshot" type of acquisition method to capture forest damage over broad geographic areas.

UNDERSTANDING ENDEMIC PEST POPULATIONS IN A CANADIAN MODEL FOREST

Bruce Pendrel^e

An approach was described for monitoring forest pests in a "model" situation over a 410,000 hectare tract of eastern Canadian forest. The site is one of Canada's ten Model Forests.

Our objective was to put in place an operational system for the pheromone monitoring of forest pests. Our purposes are to demonstrate the use of pheromones in monitoring of forest pests in an endemic situation, to interpolate among point source pheromone data in order to better display information about population distribution, and to create surfaces which can be used in a GIS for further analysis. A sensitive survey describing population differences across a landscape during a period of endemic population might: (1) reveal where populations are and how they are utilizing their habitat; (2) indicate where incipient outbreaks might first occur, and; (3) give an early warning of an impending outbreak.

Concentrating on the Fundy Model Forest, we planned a data collection scheme where a single pheromone trap for each pest species was to be placed every 5 km on a grid pattern, to optimize the use of the pheromone traps while at the same time maximizing the efficiency of the interpolation procedures.

Results were obtained in 1994 and 1995 for the spruce budworm, hemlock looper, forest tent caterpillar, and the gypsy moth. The interpolation procedure used was kriging. The numbers of moths in a trap are relatively low and the system gives a rarely seen view of endemic populations. There was no defoliation from any of these pests in either year and larvae were extremely difficult to find. Comparing the population surfaces for the four pests shows interlocking patterns and mutually exclusive areas which are presumed to be a reflection of habitat preference and niche. A comparison of results from the two study years demonstrated a method of estimating population changes quantitatively.

These images, in themselves, are of use to the managers of the model forest, but we also see them as a research tool. We examined the detailed forest inventory for the model forest, some 93,000 polygons each with several attributes in an attempt to relate inventory to endemic pest distributions. Provincial and regional levels of spatial interpolation of pheromone data were described and the use of this information in a management decision support system was noted.

SURVEY AND PREDICTION OF WHITE PINE WEEVIL IMPACTS IN BRITISH COLUMBIA

René I. Alfaro^f

The white pine weevil (=spruce weevil), *Pissodes strobi* Peck (Coleoptera: Cuculionidae), is the most serious pest of spruce regeneration in British Columbia. This insect attacks primarily Sitka (*Picea sitchensis* (Bong.) Carr), white (*P. glauca* (Moench) Voss), and Engelmann (*P. engelmanni* Parry) spruces. The larvae burrow downward in the tree's leader, feeding on the phloem, eventually causing its destruction. Repeated attacks cause stem deformities, general bushiness, and loss of height.

The recommended management approach is to apply an integrated pest management (IPM) system, in which several control methods are combined. Although individually each of these methods brings only partial control, the system results in satisfactory control. The system includes silvicultural control, genetic resistance, hazard rating, and direct control. Silvicultural control options include variation of plantation density, sanitation thinning, and overstory shade conservation. These management options can be evaluated using the SWAT (Spruce Weevil Attack) Decision Support System. SWAT is a single tree model working in combination with the Tree and Stand Simulator (TASS) program developed by the Province of British Columbia, and is capable of modelling weevil impacts on crown development and defect formation. As with other IPM systems, the system for white pine weevil requires frequent monitoring of insect populations or damage. A sequential sampling system has been developed which is fast and inexpensive.

A SOUTHWIDE SYSTEM FOR PREDICTING SOUTHERN PINE BEETLE INFESTATION TRENDS

Ronald F. Billings^g

A practical system for forecasting infestation trends of the southern pine beetle (SPB), *Dendroctonus frontalis* Zimm., has been in operational use in the southern United States since 1986. In 1995, the forecast system was deployed in 110 different locations (counties or National Forest Ranger Districts) within twelve southern states (TX, AR, LA, MS, AL, GA, TN, VA, FL, SC, NC, and MD). The system correctly predicted

the outbreak levels of SPB activity that occurred in AL, MS, SC, NC, and FL as well as the declining or low SPB levels experienced in TX, TN, VA, and MD.

Developed by the Texas Forest Service and implemented in cooperation with numerous state, federal, and University entomologists across the South, the system utilizes Lindren multiple-funnel traps baited with the SPB aggregation pheromone frontalin and steam-distilled loblolly pine turpentine. From 1-3 traps per county or Ranger District are placed in pine forests in March and/or April when dogwoods bloom (and long-range SPB dispersal occurs) and monitored weekly for a 4-week interval. Parameters used for prediction are: (1) mean numbers of SPB/trap/day; and (2) proportion of SPB in relation to the major predator *Thanasimus dubius* (expressed as % SPB). Changes in these key parameters from one year to the next for a given locality provide additional insight into SPB population shifts (increasing or declining) and infestation levels to expect in the current year.

SPB predictions based on these pheromone trap surveys have been 70% - 90% accurate in most years. In general SPB outbreaks can be expected when trap catches average more than 30 SPB/trap/day and contain more than 30% SPB. Conversely, SPB infestation levels are likely to decline or remain low when few SPB and large numbers of predators are captured in early-season pheromone traps.

Results from the southwide SPB survey are published each June in the USDA Forest Service newsletter *SPB Update*, providing foresters and pest managers with an early warning of SPB outbreaks or population collapses. This information, in turn, facilitates the scheduling of aerial detection flights and the planning of suppression projects on federal, state, and private lands.

INCORPORATING PEST MONITORING INFORMATION IN DECISION SUPPORT SYSTEMS

W. Jan A. Volney¹

The need to forecast pest populations and the damage they cause in decision support systems (DSS) has long been recognized. In the case of defoliators, large-scale outbreaks that occur periodically in west-central Canada are characterised by mapping the extent and

severity of defoliation. This information is used as a proxy for pest populations where only a small number of population monitoring sites can be visited on the ground. Thus, there is a problem to convert defoliation survey information to forecast damage over various time spans in a geographical area that spans several million hectares.

This problem is made more tractable by attempting to understand the factors that govern the extent, severity, and frequency of outbreaks. Recent work has suggested that jack pine (*Pinus banksiana* Lamb.) defoliated by the jack pine budworm (*Choristoneura pinus* Freeman) may sustain various levels of damage depending on the degree to which trees are infected with armillaria root disease. Furthermore, the frequency and severity of outbreaks may be governed by local site conditions. This pattern also may be controlled to some extent by climatic events. Thus the prevailing site, stand, and weather conditions over the forecast period can dramatically alter the behaviour of the pest population and hence its potential for damage.

It is also necessary to associate the extent of defoliation with tree mortality observed in stands. Traditional approaches to this problem have not been effective in indicating the factors which determine the risk of tree mortality. More recently, work with survival analysis techniques, developed for use in human populations, has suggested that they may be appropriate in developing hazard models to forecast tree mortality in defoliated stands.

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APPLICATION OF SPATIAL ANALYSIS TO FOREST MANAGEMENT

Moderators: Andrew M. Liebhold¹ and D. Barry Lyons²

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The adage “space is the final frontier” is applicable to forest entomology in the same way we hear it so often from science fiction dramas. Historically, forest pest management programs have averaged samples within a stand and concentrated on changes through time; relationships and patterns across spatial dimensions remained largely unexplored. The complexity and difficulty of handling multi-dimensional data have perennially hindered researchers in their quest to understand spatial phenomena. The major impediments to understanding spatial processes in insect ecology have thus been the lack of adequate analytical and data management tools. Recent development of technologies such as geographical information systems (GIS) and spatial statistics have suddenly provided a means for addressing these problems.

In this program we attempted to touch on the many ways in which spatial analysis is being applied in forest entomology. As such, participants discussed applications of spatial analysis to both basic problems in forest insect ecology and very applied problems in forest insect management. Throughout the program, we attempted to focus on the principles of spatial analysis and their application rather than dwell upon the technicalities of GIS. We feel that GIS is just a tool and the real needs for research and development are in development of new concepts and approaches to problems that use spatial information.

Many participants turned to the field of landscape ecology as a foundation for concepts that can be applied to solve old problems in forest entomology. This discipline emphasizes large-area phenomena and the effects of spatial patterning in the analysis of ecological phenomena. As such it is highly appropriate to forest insect problems since both the dominant biological processes and pest management occur over very large spatial scales. Participants touched on some important concepts in landscape ecology (e.g., scaling, fragmentation) that are fertile

areas for further application to basic and applied forest ecology problems.

As the session developed, one problem that became evident from several of the presentations was that we need to apply new statistical techniques when working with large spatial data. When data are compiled in a raster GIS and each raster cell is used as an independent sample in statistical analyses of association, we generate very large sample sizes but we are typically violating the assumptions of independence among samples that are basic in traditional statistical techniques.

During the closing discussion of the session, one idea that arose was the need to convene a meeting where the sole topic is the application of spatial analysis to forest pest management. A session of this nature was held in 1992 in Mountain Lake, VA but participants agreed that considerable progress has been achieved since then and interest in this area has intensified. Thus, the group agreed to work toward reconvening a similar meeting in the future.

LANDSCAPE ECOLOGY: A NEW APPROACH TO UNDERSTANDING FOREST INSECT ECOLOGY

Robert N. Coulson^a

Recent advances in computer-based tools have provided us with new ways and means for investigating insect/forest interactions. Accompanying the technological advances has been a solidification of basic principles of landscape ecology. This combination of events has provided a new focus for interpretation of forest insect impacts at broad spatial and temporal scales. Accordingly, the objectives of the paper were: (1) to examine the scope of landscape ecology; (2) to consider the issue of spatial and temporal scaling; and (3) to explore the knowledge

engineering approach to analysis and synthesis of ecological information.

Landscape ecology is the academic discipline that provides a scientific base for planning, problem-solving, and decision making in land-use management. The science deals with the study of landscape structure (components of the landscapes and their linkages and configurations), function (quantities of flows of energy, materials, and species within and among landscape elements), and change (alteration of the ecological mosaic over time).

The issue of spatial and temporal scaling is being addressed as part of the landscape ecological research agenda. Ecology is a science where the objects of interest or study (plants, animals, the elements of the environment) can be described by units and dimensions, e.g., biomass in g/m². Interpretation of results from ecological research usually involves the analysis or synthesis of data and information represented as scaled quantities, i.e., objects defined by units and dimensions. However, at present there is little consensus as to the resolution (grain size) and range (extent) needed to properly characterize and describe activities of insects in forest landscapes.

Knowledge engineering is an activity that embraces a set of concepts and methodologies dealing with: (1) acquisition of knowledge; (2) analysis and synthesis of data and information [quantities]; (3) integration and interpretation of knowledge [quantities and qualities]; and (4) application of knowledge. The goal of this activity is to facilitate use of the full extent of knowledge available for a specific problem of interest. Historically, scientists have used personal flavors of this basic approach to conduct, summarize, and report their research discoveries.

SPATIAL ANALYSIS OF SPRUCE BUDWORM PHEROMONE TRAP DATA

D. B. Lyons,² C. J. Sanders,² A. M. Liebhold,¹
B. G. Pierce,² and P. S. Robertson²

Each year pheromone-baited traps are distributed throughout the range of the spruce budworm, *Choristoneura fumiferana* (Clemens), in North America by cooperating agencies and the number of male moths captured is determined. However, these point data cannot be used to analyze spatial patterns

in a geographic information system (GIS). A series of software tools, that convert the point data into contour maps for GIS use, has been developed and incorporated into a user-friendly graphic user interface (GUI). Opening the database module from the GUI allows the user to add, edit, or delete trap catch and related data. In the geostatistical module, for a subset of the data (i.e., by year and region), the spatial relationship between point data is described using a variogram model and data between points is interpolated using a technique known as kriging. IDRISI[®], an inexpensive, fully-functional, raster-based GIS, is used to display, manipulate, and analyze the kriged output data. The resulting maps have contour intervals showing estimated areas of equal moth densities or 'isomoths.' CoreDRAW![®], the vector-based structured drawing program, is used to prepare high quality maps for reporting trap-catch results.

As the first step in developing a logistic regression model for predicting spruce budworm defoliation, individual annual defoliation maps (1941-1994) provided by the Forest Insect and Disease Survey Unit were summed in the GIS to produce a frequency map showing proportion of years defoliated. This frequency of defoliation map was combined with individual defoliation maps and interpolated pheromone maps (1986-1994) to create a logistic regression model. To predict defoliation for 1995, the logistic regression model was solved using the previous year's defoliation map (1994) and the previous year's pheromone catch (1994) as input variables. The resulting map depicts the probability of defoliation for Ontario in 1995. This probability map was compared with the observed defoliation map for 1995. For areas where estimated probabilities were available, there was good correlation between observed defoliation and probability values greater than 0.20.

LANDSCAPE LEVEL RELATIONSHIPS BETWEEN FOREST DEFOLIATOR DISTRIBUTIONS AND CLIMATE

David W. Williams^b and Andrew M. Liebhold¹

The geographical ranges and the spatial extent of outbreaks of forest defoliator species are likely to shift under climate changes resulting from the greenhouse effect. We investigated potential changes in geographical distribution of outbreaks of the western spruce budworm, *Choristoneura occidentalis* Freeman,

in Idaho and Montana and the eastern spruce budworm, *Choristoneura fumiferana* (Clemens), in the northeastern and north central United States. To do so, we employed maps of historical defoliation, climate, and forest composition in a geographic information system. Maps of defoliation frequency were assembled from historical aerial reconnaissance data. Maps of monthly means of daily temperature averaged over 40 years were developed using an interpolation technique. Maps of the distribution of forest types susceptible to each defoliator species were developed from maps provided by USDA Forest Service Forest Inventory and Analysis, which were derived from AVHRR satellite imagery. Relationships between defoliation status and the environmental variables were modeled using a linear discriminant function. The functions estimated for both data sets were highly significant. However, the function estimated for the eastern spruce budworm provided a better fit to the data than did that for the western spruce budworm, as reflected by squared canonical correlations (0.67 versus 0.28, respectively) and total misclassification counts (9.6% versus 19.8%, respectively).

By extrapolating from current climatic conditions using the discriminant function, potential effects on the geographical distribution of defoliation were investigated for five climate change scenarios: an increase of 2x °C, an increase of 4x °C, and equilibrium projections of temperature by three general circulation models (GCMs) at doubled CO₂. With incremental increases in temperature, the projected defoliated area decreased successively relative to ambient conditions for both budworm species. Under the GCM scenarios, projected defoliation was low or nonexistent, in inverse relationship with the generally high temperatures predicted by these models. Under the Geophysical Fluids Dynamics Laboratory scenario, defoliation by eastern spruce budworm decreased to less than one fourth that projected under ambient conditions, while defoliation by western spruce budworm decreased to less than 4% of that projected under ambient conditions. Under the Goddard Institute for Space Studies and United Kingdom Meteorological Office scenarios, defoliation disappeared completely for both species. In general, these results appear to reflect long-term range changes of susceptible forest types (i.e., to higher latitudes and elevations), as well as defoliator populations, in response to increasing temperature.

FOREST STRUCTURE AND SPATIAL PATTERNS OF FOREST TENT CATERPILLAR MORTALITY

Jens Roland^c

The effect of forest structure on rates of parasitism and predation of forest tent caterpillar was estimated over a 400 km² area of aspen-dominated boreal forest in Alberta, Canada. Spatial patterns of parasitism are estimated for the tachinid flies *Carcelia malacosomae*, *Patelloa pachypyga*, and *Leschenaultia exul*, and for the sarcophagid fly *Arachnidomyia aldrichi*. Predation by birds on cocoons also was estimated. Forest fragmentation is associated with increased parasitism by *C. malacosomae*, but reduced parasitism by *P. pachypyga*, *L. exul*, and *A. aldrichi*; predation by birds also was reduced in fragmented forests. The spatial scale at which fragmentation alters parasitism and predation differed among the mortality agents. The smallest parasitoid (*C. malacosomae*) was affected by the structure of the forest within 53 m of each sample site; larger parasitoids were affected by forest structure within 200 to 400 m of each sample site. Bird predation was affected by forest structure estimated at the scale of 800 to 1700 m. The impact of forest structure on population processes may account for variation in dynamics seen among populations of forest insects.

GIS AS A TOOL FOR ANALYZING THE EFFECTS OF GYPSY MOTH SUPPRESSION AND ERADICATION ACTIVITIES

Andrew M. Liebhold^d

The effectiveness of aerial applications of *Bacillus thuringiensis* (Bt) and diflubenzuron (Dimilin) in a gypsy moth, *Lymantria dispar* (L.), management program was evaluated using a geographic information system. System data included counts of overwintering egg mass densities, defoliation maps, and treatment block boundaries collected by the Appalachian Integrated Pest Management Program in Virginia and West Virginia from 1989 to 1992. Diflubenzuron treatments resulted in greater foliage protection and population reduction than did applications of Bt except when egg mass densities before treatment were < 1,000 per hectare. Generally, neither treatment provided foliage protection in the year following treatment, especially when treatment blocks were small or near to defoliating populations, or both.

HOW CAN WE USE SPATIAL DATA AND ANALYSIS IN GYPSY MOTH MANAGEMENT PROGRAMS?

Frank J. Sapio^d

Desktop geographic information system (GIS) capabilities have improved dramatically over the last few years. Useful analytical capabilities once required fully functional GIS shops. This "high end" functionality, typified by multiple workstations networked together, can now be achieved autonomously on the desktop. PC-based GIS programs are now quite powerful providing complex analytical capability only found before in the UNIX or mainframe environment. Access to this type of capability is now within the reach of most gypsy moth managers.

Detection, monitoring, evaluation, and management is a realistic functional model for most gypsy moth management programs. Analysis of spatial data should play a strong role in any or all of these categories. In gypsy moth trapping programs, spatial representations of moth populations are quite useful.

Mathematical techniques now exist to interpolate data among gypsy moth trap locations. These maps can show surfaces of varying moth density. Many of these procedures are available on desktop GIS. Gypsy moth traps can be viewed as point samples of a continuous surface, making this an appropriate approach to visualize data. As gypsy moth- and natural resource managers, we manage the entire surface, not just the trap locations. It is therefore appropriate that we use representations of these surfaces in decision making. Desktop GIS now offers the ability to develop these data layers or maps. These maps are also useful to communicate with other resource managers and the public. High quality color output is also useful for leveraging future funding.

Spatial data analysis may lead to different conclusions than would otherwise be reached through conventional analysis. In Michigan, spatial/temporal analysis of detection data has documented an interesting phenomenon. Moth blow or long distance male moth migration is a reoccurring phenomenon in Michigan. Male migration was well documented with the Slow the Spread Project in Michigan's Upper Peninsula. This analysis may call into question the validity of male moth capture alone in making

management decisions. In the monitoring arena, spatial data also is very important. Accurate well-constructed defoliation maps based on sound survey techniques could be used to predict tree mortality. Those same maps could be used to build risk assessment maps used for organizing gypsy moth egg mass surveys. Analysis of egg mass data can yield suppression maps. Often spatial analysis may yield an insight that would be missed if maps were not part of the analysis. I cited a defoliation/tree mortality analysis in Roscommon County, Michigan where spatial analysis of the data showed negative correlation between four years of high quality defoliation data and subsequent tree mortality. This analysis helps to demonstrate that forest decline after a gypsy moth outbreak is not always what it seems.

In control programs the benefits of spatial data are obvious. Spray blocks may be downloaded into a GPS format for subsequent navigation of spray aircraft. Analysis of flight log data also will yield gained efficiencies in evaluating spray contractors. Defoliation data gathered by photographic methods can be readily used to evaluate spray programs.

Spatial data are becoming increasingly available. Many of these data commonly reside in the file cabinets of pest- and resource managers. Data can now be purchased, developed by contract, acquired off the internet, or shared by other resource management agencies. How we collect these data is becoming increasingly important. The collection of spatial data by our own organizations may even have organizational implications as we begin to reorganize, think, and manage our resources spatially.

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PESTS IN AGROFORESTRY/SHELTERBELTS/SHORT-ROTATION FORESTRY

Moderators: Elwood R. Hart¹ and Marc Linit²

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In the past few decades, research involvement has expanded in three specialized forestry areas: agroforestry, shelterbelt, and short-rotation forestry. Increasing concern about resource conservation and efficient crop production has driven increasing shelterbelt research; increasing concern about alternative crop production, biological control, and soil and nutrient conservation has driven increasing agroforestry research; increasing concern about escalating demands and reliable sources for pulp and biomass fuel production have driven short-rotation forestry.

As trees are grown intensively in such systems, however, many insect pest problems increase significantly. The major reasons for this most probably are: concentration of food source material (which occurs naturally as rather patchy, widely-distributed growth) into concentrated plantings; ecosystem simplification, which would tend to reduce the impact of natural enemies on the insect pests; an increased percentage of plantation foliage and stem material in a succulent, insect-preferred state typical of immature trees.

If these systems are to be developed as economically- and ecologically-viable alternative resources, more traditional pest management practices, such as pesticide use, must be minimized and alternative methods defined that will protect such plantings.

DEFINING THE SYSTEMS

Elwood R. Hart,¹ Marc Linit,² and Mary Ellen Dix^a

These specialty areas of forestry share many aspects. Among the major shared characteristics are a dependency upon many of the same fast-growing tree selections and similar planting and spacing techniques and patterns. It is not surprising, therefore, to discover that many of the same pest insect and pathogen problems also are shared. Although there are many

similar characteristics, there are some functional aspects that differentiate among them.

Shelterbelt forestry is, in great part, defined by the role that the trees, as perimeter plantings, play in ameliorating wind conditions in agricultural areas. Not only soil movement, but light conditions, evapotranspiration, and water and snow patterns may be regulated through planting designs. With these physical modifications, there are also modifications in insect and other arthropod distribution and density.

Agroforestry involves the interplanting of herbaceous and woody crops in agricultural holdings. Both physical and biological factors are modified in ways that lead to increased production. Through selection of the types of planting material, both the herbaceous and woody crops can show profitable increases with better conservation of the available resources. One of the major benefits of such selection promises to be more effective and efficient insect management in these areas.

In two areas, fiber sources for paper production and biomass for fuels, there is increasing evidence that traditional forestry may not be capable of meeting present and projected needs. For these two markets, short-rotation woody crops have been proposed as a means of satisfying demands.

LAND APPLICATION OF WASTEWATER: IMPACT ON INSECT RESISTANCE IN SHORT- ROTATION STANDS

Michael R. Wagner^b

Two major trends are changing waste-disposal strategies in the pulp and paper industry. The first trend is an increase in the total residue produced because of the use of recycled paper instead of raw wood. The second trend is toward finding new waste disposal methods to reduce cost and increase competitiveness

with worldwide producers who may not have the high disposal costs. These two trends have led Stone Container Corporation to initiate an experimental land application wastewater treatment system. Part of this land application system is the establishment of short-rotation biomass plantations of fast growing trees such as *Populus*.

Experiments were established to determine whether irrigation of *Populus* spp. would change their susceptibility to damage by the cottonwood leaf beetle, *Chrysomela scripta* F., significantly. Five *Populus* clones were tested: Fremont (*P. fremontii* var. *wislizensii*), Walker (*P. deltoides* x *P. deltoides* 14392), Robusta (*P. deltoides* var. *angulata* x *P. nigra* var. *plantierensis*, Imperial (*P. deltoides* x *P. nigra*), Northwest (*P. deltoides* x *P. balsamifera* [*P. jackii*]). *Populus* clones were grown in the greenhouse under irrigation with pulp and papermill wastewater and a fresh water control. *Chrysomela scripta* larvae were caged on branches and reared to the adult stage. Insect survival, development time, and pupal weight were measured as indicators of population performance. Numerous plant traits were measured, including: growth, foliage toughness, mineral content (N, P, K, Mn, Mg, Na), and eight phenolic glycosides. Results indicate that the beetle performed better on control trees than on wastewater irrigated trees. It does not seem that land application technology will increase the susceptibility of *Populus* to the cottonwood leaf beetle. While numerous plant characteristics changed when trees were irrigated with wastewater, none of these changes consistently correlate with changes in insect performance.

MODIFICATION OF PLANT DIVERSITY THROUGH AGROFORESTRY: THE ARTHROPOD PERSPECTIVE

Marc Linit²

Agroforestry systems, such as alleycropping, have greater plant diversity than high intensity monocultural crop systems or tree plantations. This is of interest to pest managers because of the widely held belief that diverse plant communities are less prone to insect outbreaks than are communities with less diversity. Should this be true, agricultural, horticultural, and tree crops grown in an alleycropping system should be subject to less feeding pressure from phytophagous insects than when grown in monoculture.

Crop diversity in agroecosystems has been examined in numerous studies, with the aim of reducing pest populations by increasing diversity among insect populations over those found in traditional monoculture. The benefit of associational resistance, reduced herbivore attack experienced by a plant grown in association with genetically or taxonomically-diverse plants, might be explained by the resource concentration hypothesis, the enemies hypothesis, or both. Experimental results have been mixed, but insect diversity tends to be greater in polycultures than in monocultures. Increased arthropod diversity with increased tree diversity also has been observed; however, fewer studies have been conducted in forest systems than in agricultural systems. Agroforestry systems may increase insect diversity and reduce pest problems compared to either traditional agricultural or forest plantation systems because the combination of trees and crops provides greater niche diversity and complexity in both time and space.

Currently, there is little information on the impact of plant species and plant structural diversity on arthropod communities in agroforestry systems. As part of the University of Missouri Center for Agroforestry, we are in the process of establishing annual perennial vegetative research plots in a black walnut alleycropping system to assess the impact of tree-plant associations on ground-level and tree-level arthropod communities.

ASSESSING THE ROLE OF DIVERSITY ON NATURAL ENEMIES IN SHELTERBELT AND RIPARIAN SYSTEMS

M. E. Dix,^a M. O. Harrell,^c L. Hodges,^c J. R. Brandle,^c R. J. Wright,^d J. Irwin,^a R. J. Johnson,^c R. M. Case,^c K. G. Hubbard,^c R. L. Fitzmaurice,^c N. J. Sunderman,^c and M. M. Schoenberger^a

Research in Nebraska demonstrated that trees in shelterbelts and riparian edges increased crop yields, reduced adverse climatic conditions by modifying wind profiles, increased available moisture, and influenced temperature and other microclimate factors. These woody edges provide beneficial and pest arthropods and vertebrate species with food, shelter, ovipositional, and overwintering sites. Information on the use of shelterbelts by arthropods and birds and the impact of woody edges on their distribution and abundance is limited.

In 1991, a three-year study was initiated by a multi-agency and multi-disciplinary research team to evaluate the role of tree edges in agroforestry ecosystems on the population dynamics of natural enemies of crop pests, and to develop practical approaches for manipulating shelterbelts to increase predator abundance. Pitfall traps, sweep samples, and branch shakes were used to monitor arthropod abundance in the crops and nearby shelterbelts and riparian edges.

In 1991, 1992, 1993, and 1994, spiders, ants, aphids, flea beetles, and grasshoppers were the most abundant predators or pests (prey) caught in the pitfall traps and sweep samples in most crops. Spiders and aphids were the predominant arthropods caught on the trees. Abundance of these arthropods varied with site, vegetation type, and year. Predator to prey ratios were high in litter pitfalls and low in alfalfa pitfalls, grass sweeps, and alfalfa sweeps. Ratios in grass pitfalls did not vary within a year, whereas ratios for muskmelon were highly variable. The large number of predators to potential prey in the litter samples and on the trees indicates that the shelterbelts could serve as a reservoir of predators that migrate out into the surrounding crops. Results of this study will be used in future studies to enhance predator abundance in and near tree shelterbelts and riparian edges.

DEPLOYMENT OF PEST RESISTANCE CHARACTERISTICS IN SHORT-ROTATION SYSTEMS

Daniel J. Robison^c

Intensive plantation forestry offers expanded opportunities to manage insect (and other) pests by coupling host plant resistance with clonal (varietal / provenance) deployment strategies. Substantial insect pest resistance can be found and used in trees through selection, screening, breeding, and improvement (including the potential of genetic engineering). To secure the long-term stability of pest resistant plantations and to manage multiple-pest complexes, a diversity of host plant resistance mechanisms should be deployed among the trees. This requires more than one clone to be planted. The arrangement and number of clones to maximize pest resistance and stability is an important research area. Experiments in willow and poplar plantations are underway to determine the growth compatibility of adjacent clones, the importance

of clonal juxtaposition in limiting pest success, and eventually the appropriate size and number of clonal blocks for widespread planting.

DEVELOPMENT OF ECONOMIC THRESHOLDS IN BIOMASS PLANTATIONS

Elwood R. Hart^f

The major purpose proposed for short-rotation woody crop systems in Iowa and surrounding states is the production of biofuels. Such use has the potential benefits of: reducing fuel transportation costs by placing fuel sources nearer the points of utilization; reducing the dependence on imported fuel sources; providing a fuel source that is renewable and provides a viable source of income for growers; increasing the rate of carbon cycling; and providing a relatively low potential for pollution.

Because these systems are under relatively recent development in North America, there is an uncertainty as to the dynamics of the systems, including which insects eventually will present the greatest pest problems. The perceived priorities for insect management in these plantings is to: integrate pest management research with the entire development program; identify the most immediate pest problems; establish monitoring programs to identify new pest problems; determine damage and loss relationships; determine pest population and damage relationships; and determine economically-, ecologically-, and environmentally-sound management practices.

In Iowa, the cottonwood leaf beetle has been identified as being of economic concern. The beetle threatens, as it does in other regions, to be a limiting factor in some plantings. Research at Iowa State University has concentrated on understanding the beetle biology sufficiently to predict insect activity and determine the relationships among population levels, damage, and loss. To this point, we have determined that the insect prefers leaves of LPI 0 through 8, that defoliation over 50% on these leaves causes significant biomass loss in the first two years of growth, and from preliminary data, that egg mass density of > 0.50/terminal will cause > 50% defoliation on that terminal.

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IMPACT OF INSECTS AND DISEASES ON NON-TIMBER RESOURCES

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Historically, bugs have liked the same trees that people do!

This workshop comprised informal discussion on impacts of insects and diseases to non-timber resources. In lieu of speakers, delegates were asked to address their subject area, not with prepared talks, but by raising key questions, issues, comments, or information for discussion by the group. By definition, "non-timber resources" is a hodgepodge - a collection of topics related by what they don't have in common. Workshop discussions covered impacts to wilderness, biodiversity, wildlife, aesthetics, recreation, and property values by discussing a variety of cases, as summarized below.

SOUTHERN PINE BEETLE IN AN ANTHROPOGENIC WILDERNESS

Steve Clarke described a "wilderness" in east Texas legislatively formed from existing pine plantations. Pre-settlement conditions of fire-subclimax longleaf pine savannas, with loblolly pine and hardwoods in the bottoms, were replaced with loblolly plantations with a minimal hardwood component. A deficit of roadless and wilderness areas in Texas, rather than recognition of a relatively undisturbed ecosystem, drove the politics behind the wilderness designation. Southern pine beetle control is prohibited in the 37,000 ac area, which is currently developing increasingly severe fuel and southern pine beetle conditions. The situation is complicated by the presence of a red-cockaded woodpecker population, further restricting management options. The problem raised dealt with imminent beetle activity and high fire hazard. If there was group consensus, it was that the wilderness is an unsustainable ecosystem unlikely to reach the desired future condition of hardwood forest without management intervention, and probably not with it. There was agreement that fire inclusion was inevitable, and that education was the key to social acceptance if prescribed fire was to prevail over wildfire. Much

discussion followed on different policies of fire and smoke management, public education efforts and strategies, and the idiocy of some political mandates for ecosystems. Dave Leatherman^h summarized it well "The problem is preserving an unnatural wilderness."

GYPSY MOTH, BLACK BEARS, AND BIODIVERSITY ON THE SHENANDOAH N.P.

In the mid-1980s, gypsy moth was moving down the mountains of Virginia and West Virginia. Alan Bullard reflected upon the question of the time: What would the black bears do in the defoliated areas? The hypothesis then was that bears would move into nearby urban areas in search of food to replace diminished hard mast resources. What actually happened was that the bears stayed in the forest, with no apparent change in reproductive success, utilizing soft mast produced in abundance when spring defoliation episodes opened up the stands. However, studies were initiated before this came about, to determine if gypsy moth could be sufficiently controlled to prevent bear migration, using *Bt* treatments. Although the original study objectives were moot by the time studies were completed, much interesting information was obtained. Both gypsy moth defoliation and *Bt* treatment drastically altered biodiversity, especially non-target canopy arthropods and neotropical migrants, and particularly late-season nesting neotropical birds. Virus treatments are now being evaluated. Discussion indicated that this impact is reduced in subsequent years.

OAK DECLINE IN THE SOUTH

Dale Starkey gave a brief overview of oak decline and the implications of reduced acorn production on wilderness and scenic areas management. Agents

implicated in oak decline include biotic (gypsy moth and linden looper defoliation, root disease, canker fungi, two-lined chestnut borers and red oak borers), abiotic (drought, frost, long-term climate trends, past climate events), and stand/site history (anthropogenic disturbances). Factors associated with oak decline are categorized as predisposing, inciting, or contributing. Black oak, scarlet oak, and northern red oak are most rapidly and severely affected, with white oaks, chestnut oak, and hickories less so. Overstory trees are particularly affected, but populations affected by oak decline are inherently different than populations NOT affected. It was suggested that oak decline might embody a normal pathological rotation for red oaks on these sites, about 70-80 years, since dominant and co-dominant trees are affected most severely before they reach maturity, and the effect increases with time. Acorn production is greatly reduced in the presence of decline. This presents management problems in wilderness and scenic areas, as the "best" management strategy of enhancing regeneration and then clearcutting the overstory is not compatible with the objectives. Discussion indicated that progression to other tree species was inevitable.

OAK WILT AND PROPERTY VALUES IN THE TEXAS LIVE OAK URBAN FOREST

Discussion naturally moved from oak decline to oak wilt, which Gene Gehring emphasized are not the same. The two are often confused, as oak wilt was originally called "oak decline" and "oak wilt decline" (indeed, our own group used the terms decline and wilt interchangeably when discussing oak wilt). Other conference sessions cover the central Texas oak wilt situation in detail. Briefly, fire exclusion and selective cutting since the turn of the century have favored live oaks over other native tree species. Invasion by live oak was followed by houses and increased human population. The live oak forest is now the preferred residential setting, greatly affecting real estate values. Oak wilt, spread through root grafts and by (inefficient) nitidulid beetles, threatens property values, with losses in the millions of dollars. Additionally, removal of each diseased tree costs \$500, on average. Juniper replaces oak on affected sites, and is much less preferred as a residential property tree. Extended discussion followed regarding the valuation of residential trees and the economics of managing such a pathogen in an extensive urban environment, leading into discussing the political ramifications of no-action management.

Again, it was indicated that the problem constitutes attempting to manage an unnatural and unstable ecological type. It was felt that pest management activities should emphasize detection and public education.

PEST MANAGEMENT UNDER NEW DIRECTIONS

In situations where resource management objectives have recently changed, there are challenges for pest managers, as illustrated by Bruce Hostetler and Brian Geils. With new management directions, we are doing things not done before, the biotic agents are unpredictable, and old pest problems are sometimes seen in a new light. Bruce illustrated the potential for Douglas-fir beetle problems in areas designated as spotted owl reserves. Accelerating progression to a late successional stage is being attempted by thinning from below, with the dropped trees serving as coarse woody debris. Even though Douglas-fir beetle has historically not been a problem on the west side, caution is advised because these conditions mimic wind throw situations known to promote beetle activity. The situation is unprecedented, and the beetle's response is not predictable. There is a real need to monitor insects and diseases under such circumstances, and insect and disease experts need to be involved in the planning processes. A potential benefit of beetle activity might be the creation of desirable snags - an old pest seen in a new light.

Darrell Ross' indicated that a similar situation exists with the abundance of Douglas-fir established in the wrong climate zones, referring to the narrow seed source zones associated with elevation. We should anticipate that insect and disease activity in these forests will be different from that in the original type.

Brian Geils illustrated the situation in the Sacramento Mts. of southern New Mexico, a desert island forest with a high density of nesting Mexican spotted owls, a listed species. The southern owl species is different from the northern spotted owl in that it nests in treeless canyons and caves. Also, the forest is quite different from those in the Northwest, in that they are almost entirely second- or third growth, with an extreme deficit of old growth, and an unnaturally high abundance of shade-tolerant species. There is a wealth of disturbance agents: western spruce budworm, dwarf mistletoe (on pine and Douglas-fir), roundheaded pine

beetle, white pine blister rust (an exotic), needle rusts, and root diseases. The problem was described as trying to maintain owl habitat in the face of these agents. Harvest is seen as contrary to owl use, but the forest may not be in a stable condition. Dense mixed-conifer stands are far outside their historic range of variability, may be unsustainable, are subject to unpredictable pest activity, and contain extreme fuel conditions. It was suggested that owl-oriented management actually threatens the owl habitat - that continued fire and logging exclusion will inevitably result in catastrophic wildfires that destroy the existing habitat. A similar conclusion was made at the 1995 Silviculture Workshop held in the Sacramentos.

This situation was contrasted with that on a nearby Native American reservation where timber harvest is one of many management objectives. Here, there is lots of tree cutting, and lots of owls. Discussion illustrated the drawbacks of single-species management. It was mentioned that our job, as pest experts, is to present different scenarios and let the managers or public choose. Dave Leatherman cautioned against the danger of oversimplifying things in education efforts, that the public needs to be fully informed in order to make choices. Brief discussion followed by John Anhold and Ann Lynch on the benefits and opportunities of using data visualization in the education arena, especially for communicating the temporal aspects of our issues.

In summary, we were struck by the commonalities amongst the discussion topics: management problems instigated by management of unnaturally occurring and unsustainable ecosystems, and by new problems posed by contemporary management objectives.

Many thanks to Bill Schaupp for his extensive notes!

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INSECT DISPERSAL

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The workshop was opened by the moderators giving a brief introduction to the ecological/operational significance of insect movement. For the purposes of the discussion, dispersal was defined as the movement of individuals from one place to another. A population undergoing dispersal normally shows a time-ordered tendency to spread out spatially. Migration is a special case of dispersal where populations move from one locality to another more or less as a group. Thus, migration results from directed movements of individuals coordinated in time.

The nature and effects of insect movement are not well understood mainly because of technical and conceptual difficulties involved studying it. Our current knowledge of forest insect dispersal are mostly derived from observations of infestation/damage spread, mark-recapture studies, trapping insects in unbaited and baited traps, laboratory studies of flight capacity and reactions to environmental stimuli, and collections of insects outside their host ranges such as on snowfields. This information is usually specific to time and place and, at best, permits only limited generalization as to the underlying mechanisms involved in dispersal. Recent modeling work based on key elements of population dynamics and behavior appears to offer a profitable approach to assessing the mechanisms and role of dispersal in insect reproduction and survival, and the development and spread of infestations.

The ecological views of dispersal changed through time. Formerly, dispersal was thought of as a steady leakage of individuals from an area, forcing out of surplus stock from overcrowded habitats, or accidental transport of individuals. Current views hold that dispersal is an adaptive response to habitat, often involving a period of obligatory travel independent of previous or current densities.

The main purpose of this workshop was to provide an overview of some of the current/recent work and

ideas for future research relating to insect dispersal. Dispersal is a key aspect of population dynamics as it affects the distribution and abundance of insects in space and time. From a basic biological point of view, the main interests are the understanding and description of the processes and factors involved in insect movement and their significance concerning reproductive success and survival. In this context the basic questions are: why do insects disperse, what mechanisms are involved in the dispersal process, and what are the consequences to reproductive success? In pest management, we are interested in utilizing the knowledge of dispersal characteristics of insect pests and associated organisms in order to reduce damage and infestation spread.

The eight presentations given at the workshop covered a wide range of topics such as the physiological basis of insect migration, measurement and analysis of insect movement, and management implications of dispersal.

Jeremy McNeil showed that insect migration is not a random act but a physiologically-coordinated sequence of behaviors that are determined both by genetic and environmental factors. An interdisciplinary approach is indicated in future work to understand the diversity of life history strategies at various times and places in order to gain better understanding of the physiological integration of migration. (Abstract not provided).

A common theme of the balance of the presentations was that by combining a modeling approach with detailed knowledge of insect biology in field experiments, statistical or mathematical analysis can provide valuable insights regarding host-pest interactions and the nature and effects of insect dispersal.

Mike McManus reviewed windblown dispersal of forest Lepidoptera. Many of the passively-dispersing species exhibit intricate behaviors prior to or during the dispersal event in order to enhance their chances of being carried by wind. Weather and settling velocities

are key factors determining the onset and extent of dispersal. An atmospheric dispersal model was developed for predicting the dispersal pattern of first instar gypsy moth larvae. The analysis showed that, contrary to popular belief, most larvae are deposited relatively short distances (1-2 km) from the points of their origin.

Alexei Sharov and Andrew Liebhold examined the spatial spread of gypsy moth populations by an analysis of spatio-temporal changes in the progress of the population front and effects of landscape variables in moth abundance. On average, the boundaries of one moth/trap and visible defoliation were separated by 110 km and 11 years. Landscape characteristics, especially elevation, affected moth abundance depending on the dominant ecological processes affecting moth populations in an area.

Haiganoush Preisler presented a novel statistical method for assessing the simultaneous effects of unmeasured spatial variables and observed covariates on response variables of interest. This is a very useful method for the analysis of spatially-correlated data and estimation of spatial trends. This method was used to analyze mountain pine beetle infestation pattern in lodgepole pine and the spatial patterns of a twig beetle infestation in a Douglas-fir seed orchard.

John Reeve and co-investigators described a mark-recapture experiment for assessing the movement of the clerid predator *Thanasimus dubius* within and between southern pine beetle infestations. Analysis based on a simple diffusion model indicated that this predator tends to disperse more widely than the southern pine beetle and hence may have an important effect on the dynamics of southern pine beetle infestation spread.

The main objective of mark-recapture studies with the southern pine beetle by Jane Hayes and co-investigators was to assess effects of the cut-and-leave suppression tactic on beetle movement compared to that from untreated infestations. The results suggest that, although locally effective in suppressing infestations, the cut-and-leave suppression tactic does not appear to significantly reduce southern pine beetle dispersal.

Les Safranyik described the dispersal behavior of the mountain pine beetle and the characteristics of the beetles, the host tree, and the host environment that

have important effects on beetle survival as well as the dispersal behavior and capacity of individual beetles.

Barbara Bentz and Jim Powell described a new mathematical approach to investigating the basic question in mountain pine beetle biology: What factors cause changes from endemic to epidemic populations? The approach is based on the concept of self-generated spatial patterns as a consequence of feedback between the beetle and its biotic environment. The main thesis in the analysis was that the dynamics of outbreaks are inherently linked to dispersal behavior and local population dynamics. This approach appears to be well suited for testing key questions about outbreak dynamics that would be very difficult or logically impossible through experiment.

WIND BLOWN DISPERSAL OF FOREST INSECTS: PERCEPTIONS AND REALITY

Michael L. McManus^a

Much is known and has been published about the long-distance dispersal of aphids, leafhoppers, migratory locusts, noctuid moths, mites, and spiders. Many of the species in these groups are either serious pests in agroecosystems or are vectors of pathogens that cause plant disease. Conversely, little is known about the dispersal of forest insect pests, especially those species that are passively dispersed by wind, meaning that they have no control over the direction or duration of their flight. However, most species that are dispersed passively exhibit intricate behaviors, many of which are obligatory, prior to or during their dispersal episodes which enhance the probability that they will be carried aloft.

Individuals may orient to specific physical stimuli, posture their bodies or extremities to improve their buoyancy, or extrude silk to reduce their settling velocities. This latter behavior, referred to as "ballooning," is characteristic of the aeronaut spiders and larvae of some forest Lepidoptera. The extent of dispersal of forest insect larvae such as the gypsy moth, Douglas-fir tussock moth, and eastern and western spruce budworms, is determined by their settling velocities and the synchrony of their behavior to specific weather events. The settling velocities of first instars of these four species vary from 20-125 cm/s, depending on the length of silk that is attached to their bodies while they are airborne. And contrary to popular

belief, maximum dispersal activity of passive forms occurs when the wind velocity is less than 3 cm/s, whereas high-velocity winds actually inhibit the dispersal behavior of many insects and arachnids.

Windblown dispersal of wingless species can be a very high-risk event that results in substantial mortality when individuals are deposited in unsuitable habitats or on unacceptable hosts. For example, the average mortality of eastern spruce budworm larvae that disperse in the fall prior to seeking hibernacula, ranged from 44-88% depending on the age, structure, and composition of the forest in which they were deposited.

We developed an atmospheric dispersion model which integrated biological and physical processes to predict the extent of dispersal and pattern of deposition of newly-emerged gypsy moth larvae. The model, based on an advecting Gaussian puff model, predicted that most windblown gypsy moth larvae would be deposited within 1-2 km of their point of emergence. This prediction did not support the public perception that gypsy moth larval populations could be displaced from 25-40 km by wind, resulting in the establishment of new infestations far removed from their source. Field evaluations of the model's predictions and subsequent modeling exercises support the conclusion that gypsy moth larval dispersal is not extensive. Field studies conducted by other scientists on the dispersal of the Douglas-fir tussock moth and spruce budworm also concluded that most larvae of these species are deposited within a few kilometers of their origin.

There is a need to continue investigations into the dispersal of insects and other biota in order to improve our understanding of aerobiology and to improve our capability to predict the atmospheric movement of biological organisms. To this end, I support the activities of the "Alliance for Aerobiology Research" (AFAR), an interdisciplinary group of scientists that is coordinated through the Department of Entomology at the University of Illinois, and the Illinois Natural History Survey. This group is focusing on aerially-transported organisms and the meteorological processes that directly govern their movement.

SPATIO-TEMPORAL PATTERNS OF GYPSY MOTH SPREAD IN NORTH AMERICA

Alexei A. Sharov^b and Andrew M. Liebhold^c

Gypsy moth, *Lymantria dispar*, was introduced into North America near Boston in 1869 and since that time has been spreading mainly to the west and south. The patterns of population spread were studied at two spatial scales: (1) large scale, which is the progression of the population front; and (2) small scale, which is the effect of landscape characteristics on population numbers that distort the shape of the moving population front.

The rate of spread through the central Appalachian Mountains was measured as a distance between population boundaries in two consecutive years. Boundaries are lines that separate areas with population densities generally above and below a specific threshold. They were estimated using the best cell classification method (Sharov et al. 1995). The boundary of one moth per trap was on average 110 km from the boundary of defoliation, and the male moth capture rate increased 10 times per 29 km perpendicular to the population front. Approximately 11 yrs separated the time when traps caught one moth per trap until defoliation first occurred in the same area. Gypsy moth spread rate declined from 1984 to 1995 from 15-20 km/yr to 5-10 km/yr. Reduction in gypsy moth spread rate may have been due to intensive population management in the area.

Effect of landscape characteristics (elevation, slope, aspect, and vegetation) on population numbers depends on dominant ecological processes in the area. We define K-, r-, and c-effects as differences in carrying capacity, population growth rate, and colonization rate, respectively, that are associated with variation in landscape characteristics. To differentiate among these effects, we analyzed three zones individually: infested (K-effects), transition (r-effects), and uninfested (c-effects). Among landscape characteristics, elevation was most highly correlated with moth counts. Moth counts increased with increasing elevation in the infested and transition zones (K- and r-effects) which may be associated with good habitats at high elevation. However, in the uninfested zone, the highest moth counts were found at low elevation. Possibly this was the c-effect which resulted from a greater colonization rate in the low-elevation areas where human population densities are greater and the probability of inadvertent

transfer of egg masses on human vehicles is increased. The effect of vegetation on moth counts was much less pronounced than the effect of elevation. In the transition zone, landscape characteristics were more strongly correlated with moth capture than in other zones.

PREDATOR MOVEMENT BETWEEN AND WITHIN SOUTHERN PINE BEETLE INFESTATIONS

John D. Reeve,¹ James T. Cronin,⁴ and Peter Turchin⁶

We presented a summary of research on the clerid beetle *Thanasimus dubius*, a predator of the southern pine beetle (SPB), *Dendroctonus frontalis* with emphasis on dispersal studies. Previous work suggests that *T. dubius* is an important SPB predator, especially on adult SPB, and we hypothesize that this predator could influence the spatial pattern of infestation growth. We first quantified the long-range dispersal of *T. dubius* using mark-recapture methodology. We collected several hundred adult predators, using multiple-funnel traps baited with frontalin and turpentine, and marked each individual with a paint dot. The marked predators were then released at the center of a trapping grid with a radius of two km. We analyzed the data using a simple diffusion model that allows for mortality during dispersal, and then calculated the median dispersal distance. The median dispersal distance for *T. dubius* (0.9 km) was greater than that for SPB (0.7 km), which suggests *T. dubius* is a highly mobile predator, readily able to find SPB infestations.

We also described an experiment to quantify predator movements within and near SPB infestations, and to determine the effect of this predator on the spatial pattern of infestation growth. Flux traps and tree traps will be used to determine the direction of predator and prey movement, and their densities, at different locations within the infestation. One type of information gained from this experiment will be the spatial distribution of predator and prey about the infestation. If predators are under-aggregated with respect to the prey, for example, the ratio of predator to prey will be higher in the periphery of the spot than in the center. In this case, predation would contribute to the formation of a sharply defined head

to the infestation, because SPB wandering too far from the head would experience more intense predation.

THE EFFECT OF SUPPRESSION TACTICS ON THE REGIONAL DYNAMICS OF THE SOUTHERN PINE BEETLE

James T. Cronin,⁴ Peter Turchin,⁶ Jane L. Hayes,¹ and Chris Steiner¹

A major emphasis of the ongoing research of the Southern Research Station's Forest Insect and Disease Research Unit in Pineville, LA is development and improvement of technology to predict changes in insect populations in space and time, and to use this technology to evaluate the effects of pest control tactics in relation to resource management practices. A focal component of this effort has been dispersal capabilities, patterns, and impacts on the population dynamics of southern pine beetle (SPB), *Dendroctonus frontalis*. Both laboratory and field studies have been conducted to determine flight capacity or potential and the pattern of dispersal. Subsequently, using this information and the field techniques developed, dispersal of beetles from infestations (with and without control efforts) was examined in order to assess the effects of suppression tactics on the mobility and regional dynamics of this destructive pest of southern forests. We describe the results of this work here.

Small natural SPB infestations (spots) were assigned to one of two treatments: cut-and-leave or no suppression. Over a three-year period, a total of six spots were used for the former and four for the latter treatment. In each spot, beetles were indirectly marked by coating felled (cut-and-leave) or standing (no suppression) trees with fluorescent powder. Beetles were self marked upon emergence from the trees. Dispersal of marked beetles was then assessed with a standard array of "trap trees" centered on the infestation and extending in four cardinal directions to a distance of 1000 m. These trap trees were baited with SPB aggregation pheromone (frontalin plus turpentine) to induce attack, and so represent small incipient infestations.

Our experiments indicate that proportion of marked beetles landing at all trap trees was higher, but not significantly different, in the cut-and-leave versus the no suppression treatment (36% versus 19%). For both treatments, the proportion landing decreased with distance from the source infestation, indicating that trap

trees closer to the source had a much higher chance of being discovered by dispersing beetle than trees farther away. Also, the median dispersal distance for each treatment was similar and averaged 155 m. This range of movement among incipient spots was ca. 4.5 times less than the distance estimated from earlier dispersal studies that used Lindgren funnel traps to recapture beetles, and almost 20 times less than the maximum potential flight distance determined from tethered flight studies. Finally, there was no difference between treatments in the proportion of trap trees successfully attacked and killed by beetles (mean = 53%). From a management standpoint, these data suggest that although the cut-and-leave method is effective at suppressing spot growth locally, it has little effect in reducing the regional impact of SPB relative to untreated infestations.

A REGRESSION METHOD FOR ANALYSIS OF SPATIAL DISTRIBUTION OF BEETLE ATTACKS IN FOREST STANDS

Haiganoush K. Preisler and Nancy G. Rappaport^f

We presented a statistical procedure for studying the simultaneous effects of observed covariates and unmeasured spatial variables on responses of interest. The procedure uses regression-type analysis that can be used with existing statistical software. Specifically, by using nonparametric local regression routine, loess (Cleveland and Devlin 1988), within a generalized additive model (Hastie 1992), we were able to analyze spatially correlated data, test the significance of covariates, and estimate spatial trends. We used the method to analyze two data sets. The first data set was collected in a lodgepole pine stand to study the effects of tree size, vigor, and age on the pattern of trees attacked by mountain pine beetles in a given year. The second data set was collected in a Douglas-fir seed orchard to study the effects of tree vigor, clone variety, and number of cones per tree on the number of twig beetle attacks per tree. Results of the analysis of the seed orchard data indicated a significant spatial trend in beetle attacks that was not accounted for by the observed covariates. We also were able to identify at least one clone that appeared to be resistant to beetle attacks (Preisler et al. 1996).

DISPERSAL OF THE MOUNTAIN PINE BEETLE: SOME PROBLEMS AND APPROACHES TO MODELING INFESTATION SPREAD

Les Safranyik, Terry Shore, and Bill Riel²

Although there is extensive published information on the biology and habits of the mountain pine beetle, the processes and function of dispersal are poorly understood. The following is a summary of our interpretation of information relating to dispersal and the establishment, growth, and proliferation of infestations.

Emerged beetles are strongly photopositive and orient toward the brightest point source of light. They take off into the wind, soar towards the tree crowns, then turn and drift downwind in the absence of attractive semiochemicals. This initial flight tends to displace the beetles relative to their brood trees roughly in proportion to their flight potential.

Locally, most beetles disperse in the clear bole zone, between the lower crown and the canopy of the understory vegetation. The frequency of dispersing beetles declines in the overstory crown zone. It has been estimated that 3-5% of the beetles moved above the canopy of the overstory trees. Catches of dispersing beetles under the canopy of their host trees is inversely related to distance from the release point or points of emergence. The bulk of the beetles are captured within 30-40 m of their origin.

Pioneer beetles locate suitable hosts through random landings on trees and, presumably, through gustatory or olfactory stimuli. As beetles appear to locate host trees by sight from close range, landing incidence on trees is roughly proportional to tree diameter. Following mass attack, final attack density is a complex function of beetle population size, attack rate, and host condition. Consequently, at endemic levels, beetles tend to colonize low vigour trees, often of small diameter and/or infested by other scolytid species. These trees tend to produce small beetles of low vigour which are less able to disperse and to locate new host trees.

As infestations age they spread out in space due to a combination of increased beetle numbers and cumulative mortality of the most productive (of beetles) trees. The abundance of natural enemies and competitors is also expected to increase with the age of infestation. As a consequence of breeding in

progressively less productive trees and under generally more crowded conditions with a higher incidence of natural enemies, the size and hence the flight propensity of the adults will decline. Owing to the increasing size of the “dead ground” in the interior regions of older and larger infestations, the adults of decreased vitality produced in brood trees located in these regions will face a progressively more difficult task of locating brood trees. Under these conditions, dispersal to and beyond the edges of the infestation or to new host stands is a must for survival and may not be possible through active flight, depending on beetle vigour. However, wind-aided dispersal above the stand canopy may still be quite feasible.

Some of the major problems associated with modeling infestation spread and proliferation of new infestations:

1. Determination of the number of trees to be attacked during the attack period.
2. Average attack density and its distribution among the infested trees.
3. Spatial distribution of attacked trees.
4. Movement of beetles out of infested spots.
5. Decline of infestations.

Regardless of the purpose of modeling, development of rules is required to capture the essential features of these processes in order to derive reasonable inferences/conclusions concerning the nature and effects of beetle-host interaction. Consequently, better quality information is needed through research to address these problems.

SPATIAL SELF-FOCUSING AND SELF-DISSIPATION: STRATEGIES FOR MOUNTAIN PINE BEETLE SURVIVAL

Barbara Bentz,^g Jim Powell,^h Jesse Logan,^g and Peter White^h

Spatial dynamics play an important role in ecological systems and can result from both underlying patterns of the physical environment and complex biotic interactions. In fact, the complex spatial patterns of a particular system are often self-generated as a result of feedback between organisms and their abiotic and biotic environment. In particular, spatial complexity can arise from nonlinear self-focusing and self-

dissipating. This occurs when a dispersing population is itself responsible for chemical, audible, or other types of cues that lead to aggregation. Self-dissipating forces are also an important ecological adaptation that helps populations avoid dangerous habitats or over-exploitation of a resource. The interplay between self-focusing and self-dissipating forces leads to a complex variety of patterns and spatial dynamics that are important in ecological systems such as *Dendroctonus ponderosae* Hopkins (mountain pine beetle) and pine trees.

Because the mountain pine beetle has both economic and ecological significance, a great deal of monetary and intellectual resources have been invested in understanding outbreak events. Nonetheless, some of the most basic questions regarding mountain pine beetle outbreaks remain unanswered. One important question is ‘What are the factor(s) which cause a population to make the transition from an endemic phase to an epidemic phase?’ Many hypotheses have been put forth, most of them contradictory, or at least inconsistent. In our opinion, one important reason for the lack of synthesis in outbreak theories is the inadequate treatment of spatial dynamics and population phase dynamics. Our basic thesis is that mountain pine beetle outbreak dynamics are inherently dependant on dispersal behaviour, as well as the local population dynamics, and that dispersal behaviour is inherently dependant on the chemical ecology of the species (e.g., the self-focusing and self-dissipating forces).

In an effort to answer questions that may be physically and logistically impossible to test on the ground, we are developing a mathematical model of mountain pine beetle dispersal, including the chemical ecology and spatial interaction between beetles and host forests. The model is based on a system of spatially explicit nonlinear partial differential equations. We use model simulations to investigate three important ecological issues in mountain pine beetle ecology: (1) the loss of environmental determinism that accompanies successful attacks; (2) the effect of synchrony in adult emergence on the likelihood of successful attack and outbreak potential; and (3) the impact of the spatial proximity of weakened trees to act as foci for an outbreak.

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SILVICULTURE/PREVENTION/TREE RESISTANCE/HOST STRESS

Moderators: Kurt W. Gottschalk¹ and Kenneth E. Gibson²

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This workshop was set up with the objective of showing the linkages between the basic processes of host stress as it relates to insect success and tree resistance to insect attack and the more practical techniques of using silvicultural treatments and other preventative measures to manipulate these basic processes to prevent successful attack by insects.

The workshop started off with a discussion on the resistance mechanisms of conifers with Douglas-fir and the spruce budworm as the example. It was pointed out that there are so many factors involved in resistance that it takes a long-term approach of designed studies to systematically account for the factors either through elimination or by showing how they are important. We then moved to a similar discussion in broad-leafed trees. A major point made here is the wide genetic variation that exists in most broad-leafed trees and how wide variation in the insects helps to maintain their success when confronted with wide variation in their hosts. Oak-gypsy moth, aspen-gypsy moth, and aspen- tent caterpillar were the examples used. The final presentation capped this genetic interaction theme by showing that the mechanism of resistance to white pine weevil is related to the density of resin canals which is under strong genetic control; the same spruce families were consistently susceptible or resistant to the weevils based on their density of resin canals. It also was shown that induced defenses play a role via the formation of traumatic resin canals.

The third presentation bridged the gap between host/insect resistance and silvicultural treatments. Using ponderosa pine long-term thinning plots, it was shown that many measures of resistance to insects were enhanced by thinning to prevent overcrowded, high density stands. There was no effect of crown position in these measures but residual basal area was highly correlated with the resistance responses.

The fourth presentation discussed the interactions between silvicultural treatments and defoliators. The primary example was spruce budworm-spruce fir

stands with similar responses in gypsy moth-oak stands. Silvicultural treatments for defoliators are used to manage the damage that occurs, not the outbreaks. A decision support system for spruce budworm has been developed to make it easier to manage this damage. It was brought out that large-scale trials of these types of silvicultural treatments need to be implemented to test them. One such study has been started for gypsy moth-oak, but more are needed.

The fifth presentation dealt with silvicultural treatments and bark beetles. In similar results to the ponderosa pine study, thinning studies put into ponderosa pine stands for mountain pine beetle control showed fewer beetles and less mortality in the heavier thinnings compared to the light thinnings and the controls. There was some discussion about the validity of the numbers, given that mountain pine beetle was heavy in the area. Discussion also centered around what the correct level of thinning needed to be to provide prevention against mountain pine beetle.

The workshop adequately portrayed that we know a fair amount about plant resistance, host stress, and susceptibility to insects--and we know how to use this information to some degree in designing silvicultural treatments. However, there is still much we do not know and the need for continuing studies, research, and demonstrations, especially large-scale silvicultural demonstrations, exists.

INSECT RESISTANCE IN CONIFEROUS TREES

Karen M. Clancy^a

Not all conifers are equally susceptible to damage from insect herbivores. Variation in resistance is known (or hypothesized) to be related to many factors that affect interactions between insects and their conifer host trees, as well as interactions between insect herbivores and their natural enemies. Several factors that affect insect resistance in conifers were discussed, including: host

tree genotype (interspecific variation and intraspecific variation associated with different varieties, populations, and individual trees); tree age (ontogenetic variation affiliated with seedling, sapling, mature, and senescent stages); stand age (young/juvenile, mature, or overmature); stand density (number and size of trees per unit area); stand structure (even-aged versus uneven-aged, and diversity of host and non-host trees); and environmental stress (water stress, nutrient stress, air pollution).

A number of specific mechanisms of conifer resistance to insect herbivores are associated with variation in these factors. Examples cited were: nutritional quality of plant tissues (nitrogen, water, sugars, minerals, defensive compounds or allelochemicals [primarily terpenes in conifers], fiber); foliar toughness (important for folivores); host plant vigor (tree growth rate); tolerance to damage (compensation); vegetative phenology; induced defenses; microbial associations (mycorrhizae, fungal endophytes); and three-trophic-level interactions among conifer trees, insect herbivores, and natural enemies of the herbivores (predators, parasites, pathogens).

Finally, various hypothesized physiological mechanisms of Douglas-fir resistance to western spruce budworm damage were evaluated. I focused on the role of vegetative phenology, needle anatomy, and tolerance to defoliation (i.e., compensation). The potential mechanisms of Douglas-fir resistance to western spruce budworm damage include nutritional quality of the foliage, vegetative phenology, and perhaps tolerance to defoliation. Needle anatomy does not appear to be important. Other mechanisms that have not been tested to date are induced defenses, induced susceptibility, and characteristics of the root systems and rhizosphere environment (e.g., mycorrhizae). Future research will examine how tree genetics and the environment (e.g., water and nutrient stress) affect these mechanisms. In collaboration with Tom Kolb and Kim Dodds, I also am currently exploring the role of the budworm in regulating tree growth and in recycling nutrients to host trees.

INSECT RESISTANCE IN BROAD-LEAFED TREES

Michael E. Montgomery^b and Kurt W. Gottschalk^c

Variation in the resistance of broad-leaved trees to insect attack has focused more on factors such as air pollution, soil fertility, drought, and prior herbivory than on the role of genotype. Many studies of insect herbivory sample foliage from only a few trees on a single site, ignoring variability in foliage quality among individual trees. Genetic variation in oak and aspen was examined since these species represent different types of variation and considerable information is available for them.

Northern red oak is almost completely outcrossing, with 99 percent of the variation at allozyme loci occurring within local populations (Schwarzmann and Gerhold 1991). A study that examined the suitability of three oak species from various locations as food for gypsy moth larvae found the largest sources of variation were differences among larvae on the same tree and differences among trees of the same species (Gross et al. 1990). Within a 4-ha stand, the amount of insect herbivory of red oak seedlings from acorns transplanted from microsites was greater than seedlings from acorns native to the microsite (Sork et al. 1993). Because it produces a heterozygous population of offspring, red oak can occur on a variety of microsites. The gypsy moth is polyphagous and maintains genetic variability in diet breadth; thus, it is well suited to feed on tree species with polymorphic phenotypes.

Poplar and aspen can occur as clones of genetically similar individuals covering several hectares. Variation in weight of gypsy moth pupae on trembling aspen was about three-fold greater among clones than among trees within a clone (Chilcote et al. 1992). Differences in budbreak phenology among clones was associated with differences in gypsy moth survival among clones, but not pupal weights. Hwang and Lindroth (1996) found a negative correlation between gypsy moth growth and concentration of phenolic glycosides of aspen clones. Robison and Raffa (1994) observed considerable differences in the preference and growth of the forest tent caterpillar on 15 hybrid *Populus* spp. clones. Larval development was positively correlated with the tolerance of the clones to defoliation. This implies that the planting of the fastest growing clones may result in more problems from insect herbivores.

SILVICULTURAL MANAGEMENT OF INSECT RESISTANCE IN PONDEROSA PINE

Thomas E. Kolb and Michael R. Wagner^c

Dense pine stands are often very prone to insect outbreaks. The tree resistance hypothesis explains this phenomenon by reduced tree resistance mechanisms against insects in dense stands because of intense resource competition that limits resource acquisition. The objectives of this study were: (1) to test the tree resistance hypothesis as an explanation for the high susceptibility of dense ponderosa pine stands to insect outbreaks; and (2) to compare resource acquisition (water, nitrogen, carbon) among four stand basal areas of ponderosa pine in a long-term thinning experiment in northern Arizona.

Resistance against foliage-feeding insects was measured by foliar toughness and resistance against bark beetles was measured by resin flow in response to phloem wounding. Pre-dawn water potential was consistently more negative (more water stress) in high-versus low basal area plots, with no effect of basal area on mid-day water potential. Net photosynthetic rate, foliar toughness, and resin flow were lower in high-versus low basal area plots. Foliar nitrogen concentration was greatest at an intermediate basal area. The results indicate regulation of resource acquisition, canopy physiology, and insect resistance mechanisms by stand basal area in Arizona ponderosa pine forests, and strongly support the tree resistance hypothesis.

SILVICULTURE AND DEFOLIATORS

David A. MacLean^d

This paper presented a brief introduction to the role of silviculture as a component of integrated forest pest management, and describes the Silvicultural Insect Management Network, a group of Canadian silviculturists, entomologists, and ecologists that since 1991 have been conducting research on the role of silviculture in pest management. I also reviewed the status of knowledge of vulnerability of spruce-fir to spruce budworm (*Choristoneura fumiferana*), the role of silviculture and forest management in spruce budworm management, and the role of silviculture in gypsy moth management. Spruce budworm outbreaks cannot be prevented, but the amount of damage that

occurs can be managed. Tree species, stand age, hardwood content, and drainage class, as well as the outbreak severity and length, determine the amount of tree mortality during budworm outbreaks.

Recent results (Su, MacLean, and Needham 1996) demonstrated that defoliation of balsam fir caused by budworm is strongly negatively related to stand hardwood content, with 58-71% defoliation, on average, in stands with <40% hardwoods versus 12-15% defoliation in stands with >80% hardwoods. Silviculture and forest management can be used to reduce the incidence of the most damaged stand types across the landscape. The Spruce Budworm Decision Support System (DSS) links models of stand and forest response to budworm outbreaks and inventory interpretation to a GIS, and can be used to evaluate effects of outbreaks and management on forest structure and timber supply. An example using the Spruce Budworm DSS for a portion of the Fundy Model Forest indicated that losses from a future budworm outbreak could be reduced 34% by directing harvesting and silviculture towards conversion of one-half of the most vulnerable stand types into low susceptibility or non-susceptible species.

A comparison with published data for gypsy moth indicated that silvicultural recommendations are similar for both species, including maintaining high vigor, eliminating the most vulnerable species, and promoting between-stand diversity. However, actual effects of forest structure changes on insect dynamics and impact are not known, and large-scale trials are needed.

BARK BEETLES AND SILVICULTURE

John M. Schmid^e

The status of tested silvicultural prescriptions for *Dendroctonus* beetles (Coleoptera: Scolytidae) was reviewed. Although tested silvicultural prescriptions exist for some *Dendroctonus* beetles, they are generally lacking for most *Dendroctonus* species. Specific prescriptions for the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, were reviewed in more detail. In addition to providing information on the relationship between specific prescriptions and beetle-caused mortality, silvicultural studies also provide information useful for developing hazard ratings and for estimating the length of time specific prescriptions will minimize beetle-caused mortality. If forest

managers want to minimize mortality from beetle infestations, then silvicultural studies rank as the highest priority for research.

RESISTANCE OF SPRUCE TO THE WHITE PINE WEEVIL

René I. Alfaro^f

Interior spruce family trials in British Columbia, located at Clearwater, Little Bensen, and Quesnel, were surveyed for weevil resistance using an index which measured intensity of attack (number of attacks per tree), severity of each attack (how many internodes were destroyed), and tree tolerance to attack (i.e., if tree develops good form after an attack). The study demonstrated significant family variation in attack index. Variation in resistance was related to ecoclimatic conditions of place of origin of parent trees. Analysis showed parents from locations with high weevil hazard or high weevil populations yielded a higher proportion of resistant trees. These sites are primarily low elevation, low latitude sites, especially on warm-moist habitats of the Sub-Boreal-Spruce (SBS) biogeoclimatic zone. Results indicate an important role of tree phenology in expression of resistance.

A study of resin canal distribution on resistant and susceptible families at the Clearwater trial showed significantly denser resin canal system in the bark of resistant families when compared to susceptible ones. This study demonstrated significant family variation and potential for selection.

Another resistance mechanism was found. Dissection of leaders on interior and Sitka spruce, in which weevil attack failed (eggs laid but no adults emerged), demonstrated existence of an induced defense reaction. Response was initiated shortly after the shoot was attacked and consisted of the cambium switching from producing normal tracheids and parenchyma ray cells to production of epithelium which differentiated into traumatic resin canals, arranged in ring fashion in the developing xylem. Traumatic resin canals emptied contents into feeding and oviposition cavities, which killed eggs and larvae. When the leader survived attack, the cambium reverted to producing normal xylem tissue. Additional studies are attempting to quantify the prevalence of this response.

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SEMIOCHEMICALS OF INSECTS OTHER THAN BARK BEETLES

Moderator: Gary E. Daterman¹

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Five speakers presented a range of topics that included: (1) a status report on the use, effectiveness, and potential for continued application of Douglas-fir tussock moth pheromone; (2) discussion of new pheromone compounds that could be useful in detecting exotic lymantriid moth species which are potential pests of North American forests, including the nun moth, several species of browntail moths, and the rosy Russian gypsy moth; (3) the economic gains from ponderosa pine plantations that are hypothetically obtainable by treating western pine shoot borers with pheromone mating disruption applications. (Pheromone treatments were the preferred alternative at two rotation ages and at all discount rates evaluated); (4) forest entomology in the Czech Republic, with specific discussion on differences in the pheromone chemistry between the spruce and larch forms of the larch bud moth; and (5) the closing topic featured discussion of the needs and opportunities for semiochemical technology and commercial development. This discussion revealed good cause for optimism with reports of improved trapping systems, more successful applications of mass trapping in agricultural applications, use of pheromone and pesticide combinations, and improved dispensers for application of mating disruption.

All speakers did an excellent job in highlighting key issues, advances, and problems associated with their topics. More specific information is provided in their respective abstracts.

STATUS OF PHEROMONE TECHNOLOGY AND APPLICATIONS FOR DOUGLAS-FIR TUSSOCK MOTH, *ORGYIA PSEUDOTSUGATA*, IN WESTERN NORTH AMERICA

John Wenz^a

The Douglas-fir tussock moth (DFTM) pheromone (Z-6-heneicosen-11-one) has two current applications throughout the West: (1) in an early warning detection

monitoring system; and (2) for mating disruption. The early warning system, utilizing a five-trap basic plot design, is intended to predict, based on the number and trend of adult males caught in traps, when and where populations are likely to increase to damaging levels. This "early warning" helps to focus more intensive population sampling and provide for more timely decision making. Monitoring has been conducted throughout the west since late 1970s and, during that time, nine "outbreaks" have occurred.

Analysis of how well the early warning system worked relative to these outbreaks can be summarized as follows: (1) The system predicted the outbreak in at least three areas: British Columbia, northern Idaho, and northeastern Oregon; (2) the system predicted a population increase but not in the locations where the outbreak occurred due to traps not being placed in the outbreak area; (3) the system predicted an increase that did not reach damaging levels -- the early warning system picked up low level population oscillations not detected before; and (4) in one case, central Idaho, the system did not predict the outbreak even though traps were located in the outbreak area. The reasons why the system did not predict this outbreak are unclear. The consensus is to continue to use the early warning system but evaluate its use in light of declining budgets and a potential reduced need for direct suppression of DFTM outbreaks due to a changing recognition of the role of native defoliators in western forest ecosystems. Cooperators will continue to look at alternative trap deployment strategies and, in some situations, focus monitoring in high-use, high-value areas.

The DFTM pheromone has been shown to be effective in reducing mating in several areas in the western United States and British Columbia. The basic question is whether to pursue registration given declining budgets and a perceived reduced need for direct control. The general consensus is that registration is a low to moderate priority at this time.

RECENT ADVANCES IN PHEROMONE STRUCTURE IDENTIFICATIONS FOR KEY SPECIES OF LYMANTRIIDAE

Joseph C. Dickens^b

Recent investigations into pheromonal communication in lymantriid moths have revealed not only diversity in chemicals emitted by different species, but also complexity in interspecific interactions. For example, monoepoxides, e.g., (+)-disparlure, [(7R,8S)-*cis*-7,8-epoxy-2-methyloctadecane], emitted by *Lymantria dispar* (gypsy moth) and *L. monacha* (nun moth) females attract conspecific males. While a single isobutyrate [(Z,Z,Z,Z)-7,13,16,19-docosate-tetraen-1-ol isobutyrate] released by female browntail moths, *Euproctis chrysorrhoea*, attracts males of the same species, the closely-related browntail moth, *E. similis*, utilizes a blend of four monounsaturated 18-carbon esters [(Z)-7-octadecenyl 2-methylbutyrate = Z-7-18 2-mebut; Z-7-18 isovalerate; Z-7-18 isobut; Z-7-18 but]. Males of tea-tussock moth, *E. pseudoconspersa*, are attracted by a blend of three 15-carbon saturated butyrates (10, 14-dimethyl-15 isobut; 14-methyl-15 isobut; 10, 14-dimethyl-15 but) emitted by calling females.

Increased complexities in the nature of chemical signals released by calling females, and received by conspecific males and sympatric species, also have been discerned. (-)-Disparlure released by *L. monacha* females was shown previously to inhibit response of *L. dispar* males to (+)-disparlure, thus facilitating reproductive isolation. However, Gries and his colleagues in Canada recently showed chemical interactions between these two species to be more complex. For example, both enantiomers of an isomer of disparlure [(7R,8S)-*cis*-7,8-epoxy-octadecane] along with (-)-disparlure emitted by *L. monacha* females prevent cross-attraction with *L. dispar*, while enhancing responses of *L. monacha* males to (+)-disparlure.

Recently, we initiated collaborative investigations with USDA, APHIS, Otis Methods Development Center, to identify the sex attractant pheromone of the rosy Russian gypsy moth, *L. mathura*. Using coupled gas chromatography / electroantennogram (GC/EAD) recordings, at least two areas of EAD activity were noted in extracts of female ovipositors. While it was possible to identify a candidate compound with a retention time corresponding to one of the areas of

EAD activity, a compound with retention time corresponding to the second area of EAD activity could not be confirmed. Thus, several analogs of the identified compound were made which might correspond to this second area of EAD activity. Dose-response curves constructed from EAGs revealed one class of analogs to be most active. Single sensillum recordings from sexually-dimorphic trichoid sensilla of male moths showed that, while both the identified compound and its analog may activate associated neurons, the neurons are more sensitive to the analog of the identified compound. While this analog has been active in our flight tunnel bioassays, we have been unable to positively identify it in female extracts.

PROPOSED PHEROMONE TREATMENT SCENARIOS FOR THE WESTERN PINE SHOOT BORER, *EUCOSMA SONOMANA*, AND THE PROBABLE ECONOMIC BENEFITS

Darrell W. Ross,^c James F. Wiegand,^f Gary E. Daterman,^f and Susan A. Willits^f

The western pine shoot borer can reduce the growth of ponderosa pine throughout its range in western North America. Larvae feed in the pith of expanding shoots stunting their growth. Leaders are preferred over lateral shoots and the fastest growing trees in a stand have a higher probability of being infested than slower growing trees. Previous studies have found that a single infestation can result in a 20-25% loss in potential height growth. Infestation rates of 50% or more are common in pine plantations throughout central Oregon. A treatment that disrupts the normal mating behavior using artificial pheromone releasers was developed by USDA Forest Service and Weyerhaeuser scientists in the late 1970s and early 1980s. Despite the demonstrated efficacy of this treatment, it has been used only in a few high-valued stands due to inadequate impact data to justify expenditures on control efforts in other situations.

The purpose of this analysis was to model the benefits of a hypothetical pheromone treatment scenario using the best available information. Ponderosa pine stand growth and yield were modeled with SYSTM1 (\leq 20-years-old) and ORGANON, ver. 4.2 for southwest Oregon ($>$ 20-years-old) with 50-yr site index set at 80. Infestation data were obtained from an unpublished report for a stand on the Rogue River National Forest in southern Oregon. Since shoot borer impact is most

likely built into existing growth and yield models developed from natural stands, model output was increased for lower infestation rates resulting from pheromone treatments. In the baseline scenario, ponderosa pines were planted at a density of 400 per acre, cattle grazing presumably minimized competing vegetation, the stand was commercially thinned at 25 years to 120 trees per acre, and the stand was harvested at either 60 or 70 years. The second scenario was the same as the first, but the stand also was thinned at 40 years to 55 trees per acre to minimize bark beetle susceptibility. The third scenario was the same as the second with the addition of pheromone mating disruption treatments at 3-5 year intervals from age nine to 40 for a total of nine treatments. All assumptions used in modeling were conservative to minimize the potential benefits.

Results of modeling indicated a 12% volume gain (1,000 ft³/acre) with mating disruption for a 70-year rotation. Volume gain was 19% with a 60-year rotation. Total yield at 60 years with pheromone treatments was roughly equal to yield at 70 years without pheromone treatments. Soil expectation values indicated that pheromone treatments were the preferred alternative for both rotation lengths and all discount rates (0.1, 4.0, and 10.0 %).

MAJOR FOREST INSECTS OF THE CZECH REPUBLIC, WITH SPECIAL REFERENCE TO PHEROMONE VARIATIONS OF THE LARCH BUD MOTH, *ZEIRAPHERA DINIANA*

Jan Vrkoc^d

Forests in the Czech Republic cover about 30% of the land, and the proportion of conifers varies from 60 to 90%. Over the last century mixed species forests were changed to mostly monoculture spruce forests, *Picea abies*, with only a small area covered by several species of *Pinus*. The main pests of spruce are the nun moth, *Lymantria monacha*, the spruce bark beetle, *Ips typographus*, and the spruce form of the larch bud moth, *Zeiraphera diniana*. Less abundant are the web-spinning spruce sawfly, *Cephalcoia abietis*, the spruce sawfly, *Pristiphora abietina*, the rusty tussock moth, *Orgyia antiqua*, and the sawfly, *Pachynematus montanus*. Main pests of pine are the nun moth, the large brown pine weevil, *Hylobius abietis*, the pine sawfly, *Diprion pini*, and the fox-colored sawfly, *Diprion sertifer*. Less abundant are the European pine

shoot moth, *Rhyacionia buoliana*, the pine moth, *Dendrolimus pini*, and the pine looper moth, *Bupalus piniarius*.

According to its economic importance the spruce form of the larch bud moth (LBM) is the third most important pest of spruce in the Czech Republic, following the spruce beetle and the nun moth. In contrast to regular outbreaks of the larch form of LBM in the Alps region, the spruce form occurred in irregular outbreaks in central Europe. The last outbreaks (1924-1929, 1956-1960, 1966-1969, and 1979-1983) started in regions where air pollution caused weakened tree resistance, and probably destroyed a balance between LBM and its *Trichogramma* sp. parasites.

The differences in development and life cycles of the spruce form and the larch form of LBM were discussed. It was found that the main pheromone component of the spruce form of LBM is E9-12:Ac, which differs from the main component of the larch form of LBM (E11-14:Ac). The screening of different mixtures of the main component of the spruce form of LBM (E9-12:Ac) with E11-14:Ac and Z9-12:Ac revealed no inhibition and/or synergism. The last outbreak of LBM in 1979-1983 in mountain ranges of the north part of the Czech Republic started soon after the electric power stations were built in former East Germany and Poland. The outbreak of LBM was slowed by large numbers of parasites, but the complete damage of the weakened spruce forest in the area was finished by an outbreak of the spruce bark beetle, *Ips typographus*.

AN INDUSTRY PERSPECTIVE ON SEMIOCHEMICAL TECHNOLOGY AND COMMERCIAL OPPORTUNITIES IN FORESTRY

Philipp Kirsch^e

Although mating disruption as a method of insect population regulation has been demonstrated with a high degree of efficacy, and with many different species of Lepidoptera that also include forest pests, it has not been consistent, and commercialization has proved difficult. Considerable advances have been made in the past few years, with new products and approaches from several sources. New trapping systems are taking market share in monitoring, mass trapping is proving quite versatile in crop production

applications, and pheromone plus insecticide combinations are showing considerable utility in conventional pest management. In the specific area of mating disruption, breakthroughs have resulted from the development of radically new dispensers, and by the implementation of blends that manipulate a broader range of target pest behavior.

While discussing such advances, this paper presented an analysis of the current global semiochemical industry, and discussed the different factors that are affecting implementation and establishment of semiochemical products. The analysis considered applications in monitoring, mass trapping, mating disruption, and attract and kill techniques; and reviewed use of pheromones and other semiochemicals in agriculture, government-sponsored detection and area-wide eradication projects on introduced insects (such as gypsy moth in North America), and commercial pest management and forestry. We can then ponder, "what does it take to be successful in the commercial pheromone world?"

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NOVEL INSECTICIDES

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Different types of new insecticides with novel modes of action have been developed in recent years for controlling various types of pests. Each type has both attractive and questionable features but in general each one has a role to play in controlling specific types of pests. We examined five different representative classes leading from a broad spectrum control agent to pest-specific control. These are by no means all inclusive but are examples of groups with diverse modes of action. The five groups are: (1) spinosads; (2) diflubenzuron; (3) juvenile hormone analogues; (4) ecdysone analogues; and (5) transgenic baculoviruses.

SPINOSAD, THE FIRST MEMBER OF A NEW CLASS OF INSECT CONTROL PRODUCTS, THE NATURALYTES

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Spinosad, the first product in the naturalyte class of pest management tools, is a mixture of two fermentation-derived products produced by *Saccharopolyspora spinosa*, a new species of Actinomycete discovered from a soil sample in 1982. This material exhibits such a favorable environmental and mammalian toxicity profile that it has been designated as a reduced risk pesticide by the EPA. Spinosad is rapidly degraded in sunlight, but is stabilized on leaf surfaces. Its rainfastness as a suspension concentrate is comparable to commercial standards, and its activity is unaffected over a wide range of pHs. Spinosad is selectively active on insects in the orders: Lepidoptera, Diptera, Thysanoptera, and some Coleoptera and Hymenoptera. Targeted crops are cotton, vegetables, tree fruits, and nuts at use rates from 50-180 g AI/ha. In the laboratory, on important forestry pests, spinosad is effective on spruce budworm and the gypsy moth. Spinosad, with its unique characteristics, does indeed fit a product class of its own, and will offer an exciting pest management alternative for the future. No other naturally-sourced material has such a combination of excellent contact and residual efficacy

on target pests and safety to beneficial, aquatic organisms, and mammals. It will fit very well into an integrated pest management system.

FOREST USE OF DIFLUBENZURON AND ITS IMPACT ON NONTARGET ARTHROPODS

Linda Butler^c

Diflubenzuron or Dimilin is a broad spectrum insect growth regulator that interferes with chitin synthesis at the time of molting. It therefore has its major effect against immature insects. Diflubenzuron was first approved in the United States in 1976 for use against cotton boll weevil, mosquitoes, mushroom flies, and various herbivores of fruit, vegetables, and woody ornamentals. It has a registration for forest Lepidoptera and, in addition to gypsy moth, it is used against Douglas-fir tussock moth, tent caterpillars, cankerworms, fall webworm, elm spanworm, browntail moth, hemlock looper, tip moths, European pine sawfly, and terminal weevils. Worldwide forestry uses include pine looper, pine caterpillar, nun moth, winter moth, pine beauty moth, processionary caterpillar, green oak tortrix, and cone borer. Because it is broad spectrum, diflubenzuron affects arthropods in aquatic and terrestrial environments that are considered nontargets.

In a six-year study in West Virginia, we evaluated the impact of diflubenzuron on richness and abundance of arthropods in deciduous forests. Foliage samples were taken with pole pruners from the forest canopy of four small deciduous watersheds; burlap bands were employed on tree trunks. Pretreatment sampling was conducted May into August 1989 through 1991. Diflubenzuron as Dimilin 4L was applied by helicopter to two watersheds at a rate of 35.1 g AI/ha on 16 May 1992. Analysis of variance (ANOVA) was used to compare treatment means. Significant reduction on treated plots was seen for arthropod family richness and macrolepidoptera abundance remained reduced at the end of the study, 27 months post-treatment. Non-significant declines were seen on treated watersheds for

Carabidae, Gryllacrididae, some sapfeeders, Psocoptera, and Phlaeothripidae.

APPLICATION OF JUVENILE HORMONE ANALOGUES AND RELATED COMPOUNDS FOR CONTROL

Karl H. Dahm^d

Growth, reproduction, and metamorphosis in insects is under endocrine control and two hormones, ecdysone (Ec) or moulting hormone and juvenile hormone (JH) are the principal players. Ec controls the moulting process whereas JH is responsible for programming the outcome of the moult. A high titer of JH is responsible for larval-larval moult, a low level for larval-pupal moult and absence for pupal-adult moult. JH is a terpenoid compound and JH-1, 2, 3, and 0 are some of the more common forms. JH-3 is the general hormone for most orders of insects but JH-1 and 2 are found in Lepidoptera. Several JH analogues (JHA) have been synthesized and some of them are Methoprene, Hydroprene, Kinoprene, Fenoxycarb, and Pyriproxifen. JHA acts on the last larval instar and adversely affects the larval-pupal moult. Control of the adult is achieved. Therefore, when the adults are the damaging stage, they are useful but if the larval stage is the damaging stage, they are not very effective. Fogging with hydroprene has been successfully used for controlling the cockroach, *Blattella orientalis*, in hospitals in the UK. Also, Methoprene has been used to increase silk production by 30% by treating the last instar larva. Last instar larvae of gypsy moth were treated with Methoprene to increase virus production by 20%. Compounds that show anti-JH activity have been developed such as precocenes, disubstituted imidazoles, and KK-42. They interfere at various stages of JH biosynthesis. In general, the control potential of JH analogues has been disappointing.

ECDYSONE ANALOGUES FOR PEST CONTROL

Arthur Retnákaran^f

During the early part of 1980, chemists at Rohm and Haas Company (Spring House, PA 19447) discovered that 1,2-diacyl-1-substituted hydrazines possessed an unusual type of insecticidal activity, inducing precocious, lethal moults. RH-5489 (1,2-dibenzoyl-1-tertiary butyl hydrazine) was the first such compound that was extensively tested for biological activity and

was shown to imitate the action of the moulting hormone, 20-hydroxyecdysone (20E). Even though this compound does not resemble the steroid moulting hormone, it acts through the ecdysone receptor (EcR) at the molecular level, initiating the moulting process by gene regulation primarily in Diptera but also in other insects. RH-5992 (tebufenozide) is an analogue of RH-5489 that appears to be lepidopteran specific and has the potential to be developed as an environmentally-friendly insecticide. We found that RH-5992 is active on the eastern spruce budworm, *Choristoneura fumiferana* (Clem.). Upon ingestion, the larvae stop feeding and go into a precocious, lethal moult. There is very little defoliation and the control is close to 100%. It is environmentally attractive because RH-5992 is lepidopteran specific and does not have any effects on Hymenoptera such as bees, parasitic ichneumonids, as well as on crustaceans.

TRANSGENIC BACULOVIRUSES CARRYING INSECT TOXIN GENES AS CONTROL AGENTS

James M. Slavicek^e

Nucleopolyhedroviruses (NPVs), members of the *Baculoviridae*, are double-stranded DNA viruses that replicate in the nucleus of the host cell. Approximately 450 different species of NPVs have been identified to date that infect primarily insects in the orders Lepidoptera, Hymenoptera, Diptera, Coleoptera, Neuroptera, and also spiders and crustaceans (prawns and shrimp). Most baculoviruses are very host specific, infecting only a single or a few insect species. When NPVs are used as biological insect control agents, this trait provides an advantage over chemical insecticides that negatively impact on nontarget insect pests.

NPVs produce two morphological forms, a budded virus form and a form that is occluded into a paracrystalline matrix, termed a polyhedron. During the early stages of infection, budded virus is produced that infects a variety of cell types and is thought to cause a systemic infection in the larval host. During the later stages of the infection process, the occluded form of virus is produced and is released upon death of the host. The occluded form of the virus is used for biocontrol purposes.

In comparison to chemical insecticides, NPVs are slow acting, requiring approximately four to 14 days to kill the host. Enhancement of virus-killing speed has been

the thrust of research and development efforts on NPVs that infect insect pests of agricultural crops. Genes from the scorpion, *Androctonus australis*, and the predatory mite, *Pyemotes tritici*, that code for insect-specific toxins have been added to the genome of the *Autographa californica* NPV (AcMNPV) through genetic engineering. *Heliothis virescens* and *Trichoplusia ni* infected with AcMNPV expressing the scorpion toxin gene and the mite toxin gene, respectively, exhibit a 36% and 41% decrease in survival time (ST50), and consume approximately 65% less foliage compared to insects infected with wild type virus.

Research on NPVs that infect forest insect pests has focused on virus characterization, application technology, and reduction of production costs. High *in vivo* production cost is the primary factor that has prevented commercial scale production of NPVs. As an alternative to *in vivo* production, generating NPVs in cell culture has the advantages of lower cost, a readily controlled production process which can be scaled-up to generate large quantities of virus, and that generates a product free of bacterial, fungal, and viral contaminants. A factor complicating production of NPVs *in vitro* is the formation of few polyhedra (FP) mutants. FP mutants arise at a high frequency and produce very few polyhedra that are essentially devoid of viral nucleocapsids. Consequently, polyhedra produced by FP mutants are not infectious. In addition, FP mutants produce approximately five to ten fold more budded virus compared to wild type virus. This latter trait enables FP mutants to become the predominant virus type during production in cell culture systems. Commercial production of NPVs *in vitro* may now become feasible since strains of NPVs that are less prone to FP mutant formation have been developed.

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FOREST HEALTH MONITORING

Moderator: Gerard D. Hertel¹

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The workshop was introduced with a brief history of the Forest Health Monitoring (FHM) Program. The Program was conceived during the mid-1980s when so many were concerned about acid rain effects. By 1990 it was implemented in the New England States. For the first time (except for the North American Maple Project that started in 1988), we began to collect quality-assured data across space and time that would allow us to provide forest health trend data with known confidence. These same quality standards were extended to the types of information being collected by the USDA Forest Service's Federal and Cooperative Forest Health Management programs. Support from the National Association of State Foresters enabled the Forest Service and EPA to move the program forward. Unfortunately, the EPA support all but disappeared in 1996 and the Forest Service struggles with how to continue the effort. There are, however, many dedicated people still involved in the effort. Some of them are presenters in this workshop and their reports follow:

FOREST HEALTH MONITORING IN THE WESTERN UNITED STATES

Dwane D. Van Hooser^a

A national program implemented regionally began in 1991 in the western United States with pilot efforts in Colorado and California. In 1992, FHM began in earnest in both States as field locations were established using the interpenetrating or rotating panel sample design where one-fourth of the total locations are established each year. Thus, by the end of 1995 the complete panel was in place in both States. Analysis of indicators measured (i.e., crown density and dieback, and foliage transparency) indicated that the vast majority of trees measured were considered normal and healthy.

Issues perceived as emerging in each State also were investigated. In Colorado, aspen decline was an issue,

and FHM found fewer acres of the type than recent Statewide inventories. On those locations dominated by aspen, the overstory and understory composition on 30 to 50 percent of the locations was considered vulnerable to takeover by fir and other species. In California, mortality along the Sierra Nevadas was an issue. FHM found mortality in every county along the Sierras, but overall mortality rates were only slightly higher than those found throughout the rest of the State. Both States considered urban buildup/interface an issue. And in both, the "problem" was encountered with about one-fourth of the locations exhibiting forest/urban condition mixes. In 1996, FHM will expand to include Idaho.

FOREST HEALTH CONDITIONS IN THE SOUTH

William G. Burkman^b

There are a total of 211,838,000 acres of forest land out of a total 534,523,000 acres of total land area in the 13 southern States, which converts to 39.6 percent of the total area in forests. This value is virtually unchanged since the 1950s. The distribution by forest type group shows that two forest type groups have decreased in the area occupied since 1963 as a percent of all forest land; longleaf-slash pine, down 4.9 percent, and oak-gum-cypress, down 2.7 percent. Increases are noted for oak-hickory and oak-pine forest type groups. Changes in growing stock volume per acre showed the first negative trend for softwoods since 1952--516 cubic ft. per acre in 1992 compared to 535 cubic ft. per acre in 1987. Hardwood growing stock volume is still increasing but at a decreasing rate. The volume of mortality as a percent of previous inventory volume has been increasing slightly since the 1950s with the rate of 1.01 percent and 0.82 percent in 1991 for softwoods and hardwoods, respectively. This is up from 0.83 percent for softwoods and 0.68 percent for hardwoods in 1986.

There are six insects and diseases that are of regional concern across the entire South--southern pine beetle, dogwood anthracnose, butternut canker, oak decline, annosum root disease, and fusiform rust disease. There are an additional five situations which currently are of local concern but which could expand under the right conditions--European gypsy moth, Asian gypsy moth, littleleaf disease, pitch canker, and pine engraver beetles. Localized issues in the South are as follows: hemlock woolly adelgid throughout the range of eastern and Carolina hemlock; balsam woolly adelgid in high-elevation spruce-fir forests of North Carolina, Tennessee, and Virginia; oak wilt in Texas; coastal tree mortality in Florida; and beech bark disease across the limited range of American beech. Limited results from the FHM Program in Alabama, Georgia, and Virginia show that tree crowns are in relatively good condition.

On a regional scale, southern forests are generally in good shape, but local areas and specific tree species, insects, and diseases continue to impact forest health. There is a need to continue the inventory, monitoring, and evaluation of southern forests including the expansion of FHM Program into additional southern States.

FOREST HEALTH MONITORING IN THE NORTH

Gerard D. Hertel¹

FHM began in New England in 1990 and, as of December 1995, 14 States participated in all or a portion of northern FHM detection monitoring. There are a total of 713 forested plots in these 14 States. Only partial implementation occurred in Pennsylvania due to limited funds. Indiana is being added in 1996.

Every year since 1990, an annual report summarizing the results from both the plot and off-plot surveys has been published. In 1993 for the first time, the report "*Forest Health Assessment for the Northeastern Area, 1993*," covered both plot network and off-plot surveys in an integrated manner.

Following is a list of FHM reports as of January 1996:

1. "*Forest Health Highlights for the Northeastern States, 1995*." 1996. (In press).
2. "*Forest Health Assessment for the Northeastern Area, 1993*." 1995. NA-TP-01-95.
3. "*Northeastern Area Forest Health Report, 1992*." 1994. NA-TP-01-94.
4. "*Summary Report - Forest Health Monitoring, New England/Mid-Atlantic, 1992*." 1994. NE/NA-INF-115-R93.
5. "*Northeastern Area Forest Health Report*." 1993. NA-TP-03-93.
6. "*Summary Report - Forest Health Monitoring, New England/Mid-Atlantic, 1991*." 1992. NE/NA-INF-115-92.
7. "*Forest Health Monitoring in New England: 1990 Annual Report*." 1992. Resource Bulletin NE-125.
8. "*The New England Forest: Baseline for New England Forest Health Monitoring*." 1992. Resource Bulletin NE-124.

The results from the plot network have identified that over 95 percent of the trees are in good condition. The plot network was sufficiently powerful to detect the regional eastern hemlock/spruce defoliation in 1992 associated with the hemlock looper outbreak in Maine, as well as expected damage associated with beech bark disease.

The major forest health issues identified by the off-plot surveys (and in some cases corroborated by the plot network) are associated with exotic insects and diseases. The species with forest health concerns are: American beech (beech bark disease), white and green ash (ash yellows), butternut (butternut canker), eastern hemlock (hemlock looper, hemlock scale, and hemlock woolly adelgid), oaks (gypsy moth), and various species of pine (southern pine beetle, jack pine budworm, and larger pine shoot beetle). The species with forest health concerns without causal agent identified are brown ash, hickory, and various hardwoods, especially sugar maple on the Allegheny Plateau in northern Pennsylvania and across northern Pennsylvania and southwest New York.

Other forest health concerns include the impacts of white-tailed deer on regeneration, continued high levels of acidic deposition and ozone, high grading of harvest operations, and the Chesapeake Bay's water quality.

Recommendations from workshop discussion:

1. System should be implemented as soon as possible in all States.
2. The Chief of the Forest Service should annually speak on the health of the nation's forests.
3. A communications plan should be developed to reach Congress, the media, and conservation and environmental groups.

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TEACHING APPROACHES AND PRIORITIES IN FOREST HEALTH

Moderator: B. Staffan Lindgren¹

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Traditionally, forest entomology curricula have emphasized the organism, its damage, and control. The objective has been to provide the technical tools that the forestry professional was deemed to require. Changes in professional requirements have perhaps made this model inadequate, and this session aimed at sampling some of the approaches used at institutions in meeting the new demands placed on the forestry professional.

Ursula Franklin, Professor Emeritus in Physical Engineering at the University of Toronto, defined a professional as “a citizen with a toolbox” (Kessler 1995). Our tendency has been to add tools to that toolbox, while more or less ignoring the development of citizenship skills. In the changing profession of forestry, citizenship skills have become every bit as important as technical skills. Thus, we should see an increased emphasis on problem-solving skills and big-picture thinking, e.g., integrating forest entomology in natural resource management. This session showed that all institutions, whether forest entomology is taught as a separate course or under a broader forest health heading, are cognisant of these changes, and that forest entomology education is responding to society’s needs.

The audience, which eventually grew to 37, listened to a series of five presentations representing different models of teaching forest health at institutions in the United States and Canada. The intent of the workshop was to present different approaches to forest health teaching, ranging from the more traditional, disciplinary entomology course to the integrated, problem-based learning model.

In spite of the superficially very different approaches, the presentations had a common theme. This was a theme of change, and the need to adjust our curriculum to meet the changing demands of the forestry profession, while at the same time accommodating a more broadly based job-market requirement for professionals with some level of expertise in tree-forest health agent interactions, whether at the individual

tree, stand, or landscape level. The trend toward integration of entomology with other forest health-related topics was evident, although the selection of speakers may have biased the sample somewhat.

Several comments from the audience emphasized the utility of “hands-on” experience as the best approach for effective teaching. The session ended appropriately with a comment by S. L. VanLaerhoven, a graduate student at Simon Fraser University, relating the positive experience she had taking a Forest Pest Management field course in the Master of Pest Management program. Her comments served to remind us that we need to listen to the recipients of our teaching, rather than assuming that we always know what is best for them.

FOREST HEALTH ENTOMOLOGY: THE CHALLENGES OF TEACHING A COMPULSORY COURSE

John A. McLean²

The best method for generating interest in our forest entomology course is to ensure that it is relevant to other parts of the curriculum. At all times, I find that it is very important to ensure the entomological topics I endeavor to explain to my students are of interest and also clearly linked to their future role as professional foresters.

Forest Entomology at UBC is taught as a two-credit course in third year. First and second year courses in Dendrology, Forest Ecology, Soils, and Silvics prepare the student for their field school that immediately precedes third year. Here the students spend a day in each of four major ecosystems in British Columbia’s interior regions. A large number of the Forest Sciences professors participate in the field school. For the students it means that they see the work of second year applied in different ecosystems. In addition, new professors, including myself for entomology as well as

professors for pathology, wildlife management, and silviculture, all add interesting sections that contribute to the students' improved knowledge of the total forest ecosystem they are observing. We firmly believe that this joint field school activity, a real team teaching endeavor, has greatly strengthened the interest of both the students and the professors in the forest biology areas.

A recent mail-out questionnaire showed that insects/diseases ranked fourth after forest soils, dendrology, and terrestrial ecosystem processes in importance in a list of ten forest biology subject areas rated by the 480 respondents. A gap analysis of current faculty and students assessments of the importance of the forest biology areas and the need for additional emphasis in areas showed that the professors thought the amount of entomology/pathology in the curriculum was sufficient. The students, however, rated insects/diseases as very important, and that more time should be allowed for this subject area. We are reviewing the syllabus and wrestling with an obvious demand for extra content. In particular, we are considering reinstating a five-year program in order to provide the time required for full professional development of tomorrow's professional foresters.

CHALLENGES OF TEACHING FOREST PROTECTION WITHIN A CHANGING CURRICULUM

Scott M. Salom^b

In the past 20 years, there has been a strong trend to combine entomology and pathology courses into one forest pest management course. While this can be viewed as a step forward, as integration of these subjects is suitable and realistic, it has often come at the expense of reducing the overall level of exposure to the students from two courses to one. In addition, increased urbanization has strongly influenced the job market for forestry students, creating a need for teaching shade tree pest management courses that focus on the urban landscape. I am currently team teaching two such courses and will present a brief overview of each.

"Forest Protection" is a three-section, one-semester required course taught to senior Resource Management and Industrial Operation forestry students. Each section, entomology, pathology, and fire, is taught by a different instructor. Interaction among instructors is

limited to course scheduling, and an occasional field trip. Topics in entomology cover introduction to insects, importance of insects in forest ecosystems, insect ecology, study of different forest pest groups, IPM, and chemical control. Some students have a strong background in biology and are interested in the material, while others have little interest in biology and are generally skeptical about the course material. Little attention is given to forest pest problems in earlier course work, which likely plays a role in the general level of skepticism that must be overcome.

The other course, "Pest and Stress Management of Trees", is one of several courses that horticulture and forestry students can take in place of more traditional required courses. The course is team taught with a shade tree pathologist. The introductory sections of the course are taught separately for two weeks at a time. Afterwards, lectures covering different pest groups are alternated between pathology and entomology (e.g., foliar pathogens are followed by defoliators, etc.). This course focuses more on individual trees, yet much overlap exists with the traditional course. Students have a strong biology background and are eager to learn the material. Students have a greater appreciation for the need to study this material than traditional forestry students.

I believe the key to reducing skepticism among traditional forestry students lies in strengthening the curriculum with more biology and increasing student exposure to forest pests in courses taken earlier. While this contrasts with the direction of many forestry curricula, we should stand strong and push for biology or else forest protection may soon be considered non-essential.

TEAM TEACHING FOREST HEALTH: THE NAU EXPERIENCE

Michael R. Wagner and Thomas E. Kolb^c

Faculty at Northern Arizona University (NAU) have been actively involved in the national debate over the emerging concept of forest health. The NAU concept of forest health recognizes the dichotomy between a utilitarian and an ecosystem-centered view of forest health, and is fully consistent with emerging views on ecosystem management. This view of forest health is taught to undergraduate and graduate students through a series of integrated and team taught courses. NAU

developed an integrated forestry curriculum in 1971 for the professional portion of the undergraduate degree in forestry. While the curriculum has undergone numerous changes, the current curriculum is still largely integrated and team taught. A recent addition to the NAU curriculum is the team taught, graduate level forest health course. This course discusses the biology, epidemiology, and management of biotic and abiotic agents that affect tree health. There is a strong emphasis on abiotic agents such as air pollution, global climate change, and environmental stresses. The course also examines the broader ecosystem level issues, including concept, indicators, and monitoring of forest health. Team teaching offers the opportunity for faculty to integrate diverse professional experiences, and creates a very rich learning environment for students. The cost of team teaching includes the greater time commitment and increased complexity of evaluation. The team taught forest health course was discussed within the context of the forest pest management training offered by the School of Forestry at NAU.

AN INTEGRATED APPROACH TO TEACHING FOREST ENTOMOLOGY AND PATHOLOGY

B. Staffan Lindgren and Kathy J. Lewis¹

Traditionally, forest entomology and forest pathology have been taught as two separate courses in the forestry curriculum. However, Mother Nature does not support this separation. Ecologically, diseases and insect pests often affect trees and forests in very similar ways. Thus, we feel that it only makes sense to integrate the two subjects into one for the purpose of forestry education.

In order to be able to communicate a subject, you have to have some basic understanding of the processes at work. Nowhere is this more true than in forest health. Therefore, we focus on the processes and principles, rather than the causal agent in the UNBC Forest Health course. The assumption is that if you understand the processes, you can determine appropriate action. We place a lot of emphasis on the ecological roles of insects, fungi, and other forest health agents, i.e., we try to train the students to view these organisms in an ecological context, rather than as “pests.” In other words, we want to dispense with the knee-jerk mentality of the past (Action: see spruce beetle; Reaction: clear-cut), and replace it with a thought process that includes a balanced interpretation of the

ecological processes at work, and how these are affected by forest management practices, followed by an informed and innovative decision-making procedure, including the consequences of a no-action decision.

In terms of their physiological effects on the hosts, insects and fungi can generally be categorized in similar ways. We have chosen to present them concurrently, grouped by the part of a tree that they affect. Thus we divide the course up into organisms that affect foliage, trunk, roots, etc. For each category, we attempt to provide the student with a basic understanding of the anatomy and physiology specific to that region of the tree. We then introduce the important organisms, discussing how these organisms disrupt the functions of the tree, the life cycles of the organism, including weaknesses in the life cycle and the resistance responses of the host which may be used for management purposes. The intent is to give the student basic knowledge about both groups of forest health organisms, as well as a good understanding of the processes resulting from their activity. We also make sure that students understand the connectivity between disturbance processes, e.g., fire, blow down, logging, etc., and the health of the forest landscape as affected by biotic agents. In fact, we spend several lectures at the beginning of the course discussing general forest health concepts and definitions, as well as disturbance ecology.

The lectures are complemented by weekly labs, in which there is more emphasis on recognition of the signs and symptoms of major forest health agents. Students learn to recognize disease groups and important insect orders, using keys or reference literature. Field labs and trips allow the students to place the forest health problems in their proper perspective.

We have chosen to team teach the course, because we wish to emphasize common concepts as much as possible. This means that the course will be evolving gradually as we learn each other's material, and develop the best sequence of delivery. Thus, both of us attend all lectures and labs. It would certainly be much easier to divide the course in two halves, leaving each instructor complete freedom to do what he or she sees fit. The strength of the team teaching approach is that we can make both lectures and labs more interesting through the interaction between the instructors. The weakness is that the course rests on the ability and

willingness of the instructors to collaborate, i.e., if one of us were to leave, the course itself may be in jeopardy.

A TEAM- AND PROBLEM-BASED APPROACH TO TEACHING ENTOMOLOGY, PATHOLOGY, AND FIRE

Daniel R. Quiring^d

Until two years ago, all forestry students at the University of New Brunswick took at least one course in entomology, pathology, and fire management. We redesigned our entire five-year undergraduate curriculum with the goals to graduate students who: (1) had a "broader" base of knowledge; and who would be better (2) communicators; (3) ecologists and (4) problem-solvers. In response we: (1) increased the required content in social sciences; (2) increased both the oral and written requirements of many courses; (3) greatly increased the ecology portion of the curriculum; and (4) integrated most courses so that students were forced to think in an interdisciplinary fashion. This led to a team-teaching and problem-based learning approach in most courses. In particular, it led to the creation of a new course on management of insects, fungi, and fire.

We integrated the three courses because we felt that the basic concepts (e.g., pro- versus reactive management, the estimation and use of knowledge on hazard and risk, and the three hierarchical levels (i.e., operational, tactical, and strategic) of management) were similar for each. Similarly, most aspects of the biology of fungi and insects are now covered in physiology and ecology courses that emphasize a comparative approach. Team teaching the course forced professors to interact during the preparation of classes as well as during classes.

This fourth-year course emphasizes field work and a problem-solving approach but includes lectures as well as laboratory sessions on taxonomy and fire simulations, monitoring, utilization of population dynamics, and insect/fungi/fire - plant interactions to predict hazard and risk. Students learn the different strategies and tactics available to influence the distribution and abundance of pests but we emphasize general approaches to different guilds of organisms on different types of plants. Our objective is to graduate students able to design pest management programs for novel situations at both the stand and landscape levels.

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PESTS OF URBAN FORESTS

Moderator: David N. Appel¹

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During the past few decades, urban forestry has become a well-defined, focused discipline with distinct objectives, methods, and needs. This maturation process has been hindered by a reluctance on the part of the traditional forestry profession to accept a new discipline in tree management that involves more than merely extending the principles of production forestry into our towns and cities. The urban forest grows in a unique ecosystem, imposing unfamiliar conditions on tree growth and survival but affording new opportunities for significantly improving our standards of living. In order to meet the challenges of growing trees under severely stressful and rapidly changing conditions, our knowledge base for such areas as tree genetics, stress physiology, and pest control must be expanded.

The speakers in this discussion session were selected to provide a variety of perspectives on problems and solutions designed specifically for urban tree health. The backgrounds of the speakers comprise a variety of professionals connected to urban forestry management, care, and research. Hopefully, this workshop will contribute to our knowledge base, as well as stimulate much needed research into some critical issues for an improved urban tree management.

THE AUSTIN, TEXAS OAK WILT SUPPRESSION PROJECT

John Giedraitis^a

The City of Austin Oak Wilt Suppression Project is a branch of the Parks and Recreation Department's Urban Forestry Program. The staff works in direct cooperation with the latest research and most recent techniques to identify, prevent, or suppress the spread of this deadly tree disease.

Since the start of the Oak Wilt Suppression Project in 1988, staff foresters have assisted Austin property owners with the installation of nearly 10 miles of suppression trenches and nearly 500 diseased-tree

removals. Public awareness campaigns and individual site inspections have helped educate thousands of Austinites, and citizens in surrounding areas, about oak wilt prevention and control on their property.

PEST MANAGEMENT IN THE URBAN FOREST: A PRACTITIONER'S VIEW

Jerry Pulley^b

With the incidence of pest outbreaks in the urban forest, like that of natural forests, there appears to be a positive correlation between host distress and vulnerability and pest attraction. A primary difference, however, is that urban forests commonly exist in some greater or lesser degree of distress. Consequently, pest pressure is a normal condition occasionally exacerbated by pest population explosions, often seasonal in nature.

A natural forest becomes an urban forest simply by the introduction of houses and their support utilities. Stress on incipient urban forest trees is initiated at the engineering survey stage, followed by site clearing for roads or other utilities. Root injuries occur to all trees adjacent to construction corridors. Soil structure is altered by a variety of events from compaction to contamination. Existing water sheds are altered and trees suddenly receive either more or less moisture than they had previously.

As development further progresses, exotic plant species are transplanted into the landscape, bringing their own peculiar pests and diseases from the nursery or original area. Trees with girdling roots (rarely found in a natural forest), are often brought from the nursery. Transplants often develop girdling roots once they are installed in a soil incompatible with the nursery growing medium.

Upon completion of the construction phase, the remaining native trees, and the installed ones, encounter *People Pressure*. Turf grass installation, excessive irrigation, fertilizers, salts, herbicides,

additional compaction, all are contrary to the natural environment of trees.

Urban forest pest management is most successful when approached as an integrated program. An effort expended to improve tree health is often a singular step in reducing vulnerability to insect pests. Pest prevention (to the extent possible) is generally easier than pest control. Pest outbreaks are particularly difficult to manage in an urban environment. In many areas it is virtually impossible to apply cover sprays to trees due to large volumes of liquids required. Rigorous local environmental regulations and public hysteria often preclude spray applications of even the most nontoxic materials.

Compounds and techniques for urban pest management must be selected with considerable forethought. Biological insecticides are used whenever possible. Systemic insecticides applied via soil application or direct vascular injection are generally effective and rarely initiate public hysteria. When cover sprays are the only option, pyrethroids, particularly the recent ones -- cyfluthrin, bifenthrin, fluvalinate, and lambda-cyhalothrin -- are relied on by many urban pest managers. They have longer residual activity and fewer adverse side effects than the earlier generation compounds. They are applied at tenths or hundredths of pounds per acre. Those minuscule units are important in terms of environmental load and also the transporting of toxic compounds on public roads.

OVERLAND SPREAD OF *CERATOCYSTIS FAGACEARUM* BY NITIDULIDS: A DIFFERENT PERSPECTIVE

Jennifer Juzwik, Thomas C. Skalbeck, and Kory R. Cease^c

Oak wilt is a major disease of oaks in eastern USA and is of particular concern in certain northern states and in Texas, especially in urban and urban-rural interfaces. The current federal oak wilt cost-share suppression program in Minnesota is resulting in impressive reductions in the number of actively expanding oak wilt centers in the Metropolitan Region of Minneapolis-St. Paul, largely through disruption of common root systems. Current measures used in control programs for preventing overland spread of the causal organism (*Ceratocystis fagacearum* (Bretz.) Hunt) by the primary vectors (F: Nitidulidae) in

Minnesota include: (1) preventing wounding of healthy trees during May and June; (2) removal of potential spore-producing trees before mid-April; and (3) girdling of the lower trunk of potential spore-producing trees soon after wilting. Overall, effectiveness of these measures has ranged from efficient to haphazard, and improved methods are needed.

We believe improved or new methods could be developed if more information on the predominant nitidulid vectors was available. In the past, a "broad brush" approach generally has been taken to explain nitidulid involvement in oak wilt spread. Based on the literature and our observations, however, it appears that there are perhaps as few as two to six species of nitidulids that are predominant vectors of the pathogen in a region. We speculate that these may vary by region and by season (e.g., spring versus fall). *Colopterus truncatus* Rand, two *Epuraea* spp., *Glischrochilus sanguinolentus* Oliv., and *Carpophilus sayi* Say. are likely predominant vectors during spring in Minnesota.

A second common view has been that the relationship between nitidulids and the oak wilt fungus is a casual one. Evidence in the literature, however, suggests ecological specialization of particular nitidulid species for the oak wilt disease cycle, but not for others. Finally, little is known about the life history, odor preferences, differential responses to attractants, and phenology of individual species of nitidulids associated with *C. fagacearum* spread. Novel oak wilt management tools could arise from increased knowledge in these areas. For example, phenologically-based models for the predominant nitidulid species could be developed. The models could be used to predict when the species are active, seeking oak wilt spore mats, and moving to fresh wounds on healthy trees. Similarly, if aggregation pheromones are associated with one or more of the predominant species, monitoring with pheromone traps also might help to annually pinpoint critical weeks during the spring.

SOUTHERN PINE BEETLE AS AN URBAN FOREST PEST: THE GAINESVILLE EXPERIENCE

James R. Meeker^d

An unprecedented outbreak of southern pine beetle, *Dendroctonus frontalis*, developed in urban forests of

Gainesville, FL during the spring of 1994, posing a serious threat to high-value pines, surrounding forests, and the economic well-being of numerous landowners. To minimize the adverse economical, ecological, and sociological impacts of an epidemic, a concerted, cooperative, community-wide suppression program was rapidly developed and implemented, with financial assistance from the USDA Forest Service.

The program evolved from discussions involving a variety of state and federal entomologists and forestry personnel, concerned citizens, and commissioners and staff of the City of Gainesville and Alachua County Governments. Municipal governments quickly passed resolutions, declaring tree emergencies and adopting a subsidized suppression program (whereby infested trees could be treated for \$75 each by city utility crews). A Technical Advisory Committee of natural resource/science professionals was created to oversee the program and recommend modifications.

The objective of the suppression program was to rapidly detect and treat all actively-infested trees. The Commissioner of Agriculture's statutory authority to suppress pests on private lands prompted voluntary compliance. Designated phone lines were established to assist landowners, and an aggressive education/information campaign was conducted utilizing mass media. The Department of Florida performed weekly aerial detection flights and on-site landowner assistance for every infestation and request.

Direct suppression/protection services were primarily performed by private tree service businesses, loggers, and pest control operators, and were facilitated by forest industries' willingness to process material. Problems occurred with reluctant/absentee landowners, unscrupulous/undependable contractors, illegal dumping of infested material, and most notably, public lands. During the outbreak (1994-95), a total of 648 infestations killed 42,239 trees, yet on public lands fewer spots (12% of infestations) accounted for the vast majority of tree losses (66%).

The SPB outbreak in Gainesville was likely due in part to the unnatural abundance of loblolly pine and widespread occurrence of over-stocked, mature, monoculture-like stands resulting from dramatic changes in land use (e.g., urbanization). Area forests were also affected by drought and damaging storms preceding the outbreak.

The suppression program was successful based on control of enlarging spots and the occurrence of fewer and smaller infestations over time. Although 76% of the infestations occurred on homesites, the effectiveness of the program limited residential tree losses to only 19% of the total. Future efforts will focus on alleviating susceptible conditions throughout the urban forest.

INTEGRATED PEST MANAGEMENT AND URBAN FORESTRY: A CASE STUDY

David N. Appel¹

Integrated pest management is a relatively new concept for urban tree managers and arborists. Although some of the principles of IPM have been applied for many years, shade tree professionals have not adopted a unified concept of IPM for the urban forest. Although there may be a reluctance to accept IPM principles that are standard for production forestry, it is useful to analyze the development of those principles as a model for similar progress in shade tree management.

When arborists do advocate an IPM philosophy, it often encompasses more than controlling insects and diseases of trees. Manipulation of fertilization regimes and pruning practices is usually considered to be an important part of a shade tree IPM program. Most tree care firms have reduced cover sprays and incorporated strategic, target spraying under the auspices of IPM. However, there has been little movement by those in the arboricultural profession toward a widespread acceptance of novel approaches for shade tree care. There are several reasons for the lack of progress. Foremost among these reasons is the paucity of research specifically designed to address urban forestry problems.

The success of IPM in production forestry can be attributed to the systematic application of well-defined major research and development components. These components may not be thoroughly understood for all model systems, but are nonetheless useful for decision-making in most pest management problems. They include an understanding of: pest population dynamics and epidemiology; forest stand dynamics; available treatment tactics; the impact of the pest on the resource value, and; integration of benefit-cost values. These same components would be useful for pest

management in urban tree problems, as is illustrated by their application to the oak wilt problem in Texas.

Ceratocystis fagacearum, the oak wilt pathogen, is the major tree pathogen in central Texas towns and cities. Oak wilt is responsible for enormous losses of native and planted live oaks (*Quercus fusiformis*), and to a lesser degree red oaks (*Q. buckleyii*, *Q. marilandica*). These oaks are the best adapted and most valuable shade tree species in central Texas, contributing as much as 13 - 19% to the property values in some locations. The disease cycle for *C. fagacearum* is fairly well understood. The pathogen is known to be transmitted by two means; through root connections among adjacent trees and via an insect vector. Vegetative propagation by root sprouting and root grafting in the typically thin soils exacerbate the spread among live oaks. Due to selective inoculum formation on the red oaks, stand composition has a strong influence on the rates of pathogen transmission and subsequent losses. A great deal has been learned about these processes, so that an integrated approach to disease management is available for most conditions where the disease is found.

A decision to control oak wilt in central Texas is based on comparing the tree values to the cost of the appropriate management plan. The management plan may consist of a variety of techniques, including scouting for potential inoculum sources and incipient symptoms, tree removals, wound painting, trenching to break root connections, and/or intravascular injection with fungicides. The values of oaks vary considerably, so that management plans will also vary from simple, single-step measures to large-scale, complex, and expensive projects.

An urban tree disease must have a significant impact on property values in order to justify the research needed to develop and regularly apply an IPM program. Most disease problems for shade trees do not meet these requirements. However, with a greater understanding of the causes of how stress-related pathogens operate, the options for disease management could increase in both quality and variety.

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MORTALITY FACTORS IN GROWTH AND YIELD MODELS

Moderator: David A. MacLean¹

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Quantifying and modelling effects of insects on forest stands is a lynch-pin of pest management. For many insects, increases in natural tree mortality rates caused by feeding is the key effect. Methods of incorporating mortality factors into growth and yield models was the theme of this workshop, along with the sub-theme of the role of permanent sample plots in defining mortality factors for growth and yield models. Speakers also discussed the current status of calibration of mortality factors for several important North American insect pests.

We had a good geographic and international distribution of speakers in the session, with two Canadian and two U.S. speakers, as well as two eastern and two western speakers.

ACCOUNTING FOR PEST LOSSES IN BRITISH COLUMBIA: CASE OF DEFOLIATORS AND WEEVILS

René I. Alfaro^a

Accounting for insect losses requires forecasting of stand development under various scenarios of epidemiology and forest management practices. A crucial need is to gain a clear understanding of the reciprocal interaction between insects and forest management, i.e., how modification of forest practices influences insect epidemiology and how insects change the forest.

A number of research projects have been completed in British Columbia which are providing relationships or equations to determine the expected change in particular stand parameters, from various levels of pest infestation. Insects under study include the Douglas-fir tussock moth, black-headed budworm, spruce and western budworm and the white pine weevil. Changes measured include mortality, growth rates, top-kill, deformities, impacts on diameter classes, and age distributions. With different degrees of success, these relationships have been incorporated into stand models

capable of projecting stand development (volume-age curves) under various scenarios of pest infestation. One example is the Spruce Weevil Attack Model (SWAT) which is capable of projecting stand development under various population levels and stand management alternatives. Management options include sanitation thinning, varying plantation density, utilization of resistant stock, and direct control by stem injections.

Individual projects also have been completed to study pest losses in the context of multiple-use forestry. It is very important to determine how the various products expected from a unit of land (timber, wildlife, recreation, grazing, etc.) are affected by insect infestations. In some cases some of these uses are antagonistic, i.e., higher production of one product (e.g., timber) reduces the output of another product (e.g., forage). Hence, calculation of the losses at the forest or landscape level requires the balancing of positive and negative impacts of insects on each resource.

GYPSY MOTH MORTALITY: INDIVIDUAL TREE AND STAND APPROACHES

Kurt W. Gottschalk^b

Different approaches to modeling mortality of trees and forests following defoliation by gypsy moth (*Lymantria dispar* L.) were presented. The first approach involved the use of a stand-level growth simulator. A simulation of the effects of three gypsy moth outbreak scenarios on forest vegetation changes over 20 years was done for all ecoregions in the coterminous United States. Simulations were done using the Forest Vegetation Simulator of the USDA Forest Service and SE-TWIGS. Outbreak scenarios included no outbreak (baseline), moderate, and heavy. Mortality and growth modifiers (multipliers) were developed for trees grouped by gypsy moth feeding preference based on the literature on mortality and growth loss. National Forest inventory data from the western U.S. and Forest Inventory and Analysis (FIA) data for state and private lands and

eastern U.S. national forests were used as simulation inputs.

Under baseline, no outbreak conditions, susceptible trees increased slightly, decreased slightly, or maintained their relative position depending upon the ecoregion and successional status. Under moderate outbreak conditions, susceptible species decreased somewhat while resistant and immune species increased slightly. When subjected to a heavy outbreak, susceptible species decreased significantly and resistant and immune species increased significantly. These results suggest that in the long term, U.S. forests will gradually become more resistant to gypsy moth as the proportion of susceptible species is reduced.

The second approach is to develop probabilistic models of an individual tree dying based on its characteristics. Work by Herrick and Gansner (1987) provided individual tree mortality risks for a gypsy moth invasion of central Pennsylvania mixed oak forest stands. The mortality risks are valuable for use in predicting potential mortality from gypsy moths and for selecting high-risk trees to remove in silvicultural treatments. However, they did not use defoliation as part of their analysis. A new analysis was done to develop mortality risks using defoliation intensity classes as a variable. Classification and regression tree (CART) analysis was used to develop significant combinations of variables to predict risk of mortality. It produces binomial decision trees that can be used by forest managers for predicting mortality risk. Different decision trees were developed for undefoliated, moderately defoliated, and heavily defoliated trees. Selection of high-risk trees to remove in silvicultural treatments can be based on projected defoliation levels for the stand and the appropriate model of risk. The probabilities of mortality can be incorporated into growth models or used with stand tables in a spreadsheet or inventory program to estimate losses and to compare predicted mortality to undefoliated levels.

INCORPORATING SPRUCE BUDWORM- AND HEMLOCK LOOPER-CAUSED MORTALITY IN STAND DYNAMICS MODELS

David A. MacLean¹

There are two general approaches to including insect impacts in growth and yield models: (1) estimating

combined natural and impacted growth and survival rates; and (2) estimating base growth and survival without insects and then estimating incremental defoliation effects. The first approach is more common but the second is more flexible. In either case, defoliation-based functions are needed to reduce growth and increase mortality rates. In this paper, I described the process of calibrating a defoliation-based stand dynamics model for spruce budworm (*Choristoneura fumiferana*) mortality, and emphasized the role of permanent sample plots (PSPs) in calibrating mortality factors.

The STAMAN model (Vanguard Forest Management Services Ltd. 1993, Contract report to Can. For. Serv.) is a simulation-based stand table projection model, in which tree classes (cohorts) are defined by species, dbh, and age. Base survival (%) in the absence of budworm is calculated as a function of tree species, age, and stand basal area; then incremental defoliation effects are determined as a function of tree species, age, and defoliation. STAMAN mortality calibration used three-year data from 314 PSPs, or 22,300 host trees. These were stratified based on species, stand basal area, dbh, percentile in the basal area distribution and age class, and five-year survival rates in each of six cumulative defoliation classes per stratum were calculated.

There were no significant differences in survival between defoliation levels <41%; these were assumed to represent survival independent of budworm. Survival rates for trees in each stratum were then divided by base survival rate for that stratum (i.e., rate with defoliation <41%) to determine incremental survival rates attributable to budworm. Incremental survival at a given defoliation level decreased with stand age and increased with competitive status (dominance), but was not affected by stand basal area or dbh. Therefore, data of similar dbh class, basal area, and competitive status were pooled to calculate incremental survival rates. STAMAN is used in the Spruce Budworm DSS for prediction of stand development under different defoliation/ protection scenarios and for calculation of a stand impact matrix look-up tables for different stand types.

In addition, hemlock looper (*Lambdina fiscellaria fiscellaria*)-caused mortality observed in ten PSPs in northern NB, Canada was described. Mortality was significantly related to cumulative defoliation and to dbh class.

I concluded that: (1) modeling mortality caused by natural stand development and disturbance by insects is a key component of growth and yield models, and (2) PSPs provide the best data source for calibrating and validating mortality factors.

SIMULATING MORTALITY IN U.S. CONIFERS: THE FOREST SERVICE APPROACH

Eric L. Smith^c

The USDA Forest Service has developed the Forest Vegetation Simulator (FVS) system to predict the effects of growth, management, insects, and diseases on forest stands. The Forest Health Technology Enterprise Team (FHTET) coordinates new insect and disease model development, and maintains existing models. Insect impact models exist for Douglas-fir tussock moth (DFTM), western spruce budworm (WSBW), Douglas-fir beetle (DFB), and mountain pine beetle (MPB).

FVS is a distance-independent, individual tree model. Mortality in the base FVS system, without use of the insect or disease models, is done in a variety of ways in the 15 western geographic variants. Two basic approaches are used. An empirically-based logistic model is used in older variants, fit to field data with nonlinear regression. A limit is put on how large the basal area can be. Newer variants use the principle of maximum stand density index (SDI). Mortality rates are set to achieve an SDI of 85% of the maximum. Mortality is applied as a continuous variable to individual trees, where each tree represents a number of trees per acre. The mortality thus reduces the number of trees per acre.

The insect models linked to FVS have been developed over many years. The DFTM model uses a simple "look-up" table, which relates percent mortality by tree species to percent defoliation. The WSBW model uses a similar approach, using more variables. It includes the five-year cumulative defoliation, tree diameter, and the stand basal area of trees larger than the subject tree, as a proportion of the estimated maximum basal area of the stand. The west-wide pine beetle model, now under development, estimates "beetle killing pressure" (BKP) present in the stand, a surrogate for numbers of beetles, to establish the amount of basal area to be killed. A

scoring system of factors related to tree size and condition order the tree list; mortality is distributed down the list until the BKP is used up.

In all of the insect models, the mortality is applied against the tree list multiplier. The base FVS mortality is calculated and compared against the insect mortality level. The greater of the two is applied to each tree in the list. The current system does not allow for multiple insect models to be applied at the same time. The differences in the methods used in the variants will create difficulties in implementing multiple pest capabilities.

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MICROBIAL AND ARTHROPOD SYMBIONTS OF BARK BEETLES

Moderators: Kier D. Klepzig¹ and John C. Moser¹

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In considering microbial and arthropod symbionts of bark beetles, we limited ourselves here to the fungi and mites closely associated with bark beetles attacking conifers. In recent years we have seen a resurgence of interest in the study of bark beetle/fungus/mite complexes. The investigators whose work follows are among those who are beginning to challenge long-held assumptions and expand our knowledge about bark beetle-associated fungi. In particular, the work represented here is providing new insights into the taxonomy and evolution of bark beetle-associated fungi and revealing the highly complex nature of the interactions between these fungi and their vectors.

THE TAXONOMY AND EVOLUTION OF FUNGI ASSOCIATED WITH BARK BEETLES

Thomas C. Harrington and Portia T. W. Hsiau^a

Fresh phloem surrounding beetle galleries is rich in nutrients, and many fungal groups have adapted dispersal mechanisms and competitive strategies to take advantage of this resource. Three major groups have been of primary interest as bark beetle symbionts. Among the ascomycetes, species of *Ophiostoma* are perhaps most common and have received the most attention. They are generally saprophytic (Dutch elm disease and black stain root disease are exceptional) and many produce perithecia and asexual fruiting bodies (e.g., *Leptographium*) with sticky spores in galleries of conifer bark beetles. *Ceratocystiopsis* species are closely related to *Ophiostoma* and have a similar biology. Although *Ophiostoma* species are widely believed to be essential partners with tree-killing bark beetles in overwhelming tree defenses, the evidence is inconclusive. Lesion development in phloem of inoculated trees may reflect a strategy to compete with other fungi rather than a strategy to aid bark beetles.

In contrast to *Ophiostoma*, species in the morphologically similar but unrelated genus *Ceratocystis* are primarily plant pathogens, produce

volatiles that attract insects, and are disseminated by a wide range of insects, primarily flies and Nitidulidae. Only three species (*C. polonica* from *Ips typographus*, *C. laricicola* from *Ips cembrae*, and a species from *Dendroctonus rufipennis*) are known associates of bark beetles. These *Ceratocystis* species rapidly colonize phloem and sapwood of beetle-attacked trees and may hasten tree death.

Basidiomycetes comprise a third group of fungal associates, but lack of fruiting structures for many has hampered a clear understanding of their systematics and biology. DNA sequence analysis has shown that mycangial associates of *D. brevicomis*, *D. frontalis* (southern pine beetle, SPB), and *Pityoborus comatus*, as well as basidiomycetes with *D. ponderosae* and *D. jeffreyi*, belong in the genus *Entomocorticium*, which apparently evolved from *Peniophora*, a genus of wind-disseminated wood decay fungi. *Entomocorticium dendroctoni* produces basidiospores in beetle galleries and likely provides nutrition to *D. ponderosae*. Similarly, *Entomocorticium* sp. A from mycangia of SPB is nutritionally beneficial, while another mycangial fungus, *Ceratocystiopsis ranaculosus*, confers little benefit. The blue stain fungus *Ophiostoma minus* is only weakly pathogenic to trees and appears to be antagonistic to SPB. The fourth common associate, *O. nigrocarpum*, may have little effect on SPB biology. It is likely that most bark beetles have a similarly complex and varied array of fungal associates.

COMPETITIVE INTERACTIONS AMONG BARK BEETLE-ASSOCIATED FUNGI

Kier D. Klepzig and Richard T. Wilkens¹

Two fungi, *Ceratocystis ranaculosus* and SJB122, are transported within specialized structures (mycangia) in the beetle exoskeleton and are mutualists of the southern pine beetle (SPB), *Dendroctonus frontalis*. A third fungus, *Ophiostoma minus*, is transported phoretically and may act as a mutualist or an antagonist of the SPB. In contrast, SPB are presumed to feed on

and gain substantial nutritive benefits from the mycangial fungi.

To investigate the degree to which competitive interactions occur among these fungi, we varied the number of disks of inoculum placed on media and after two weeks, we measured the total area occupied by each fungal species. *O. minus* quickly colonized the available substrate and outcompeted SJB122. However, the SJB122 disks remained uncolonized by *O. minus*. *O. minus* also overgrew and colonized the *C. ranaculosus* inoculum disks. The two mycangial fungi competed more or less equally.

To quantify the primary resource capture capabilities of these fungi, we pitted the species against one another. In all cases, *O. minus* rapidly outcompeted these fungi and colonized all available substrate. It was not able to colonize the SJB122 inoculum disks and colonies but was able to colonize the *C. ranaculosus* inoculum disks and colonies. Growth by both of the mycangial fungi was inhibited by the presence of competing fungi.

To quantify the ability of these fungi to capture substrate which was already colonized by a competing fungus, we inoculated a competing fungus at the edge and near the center of an established colony of another fungus. The areas of the colonies were measured and compared to diameters of the same fungi grown alone. *O. minus* dominated in these competitive interactions and SJB122 and *C. ranaculosus* were approximately equal competitors - with one another. *O. minus* was only able to capture a small amount of territory from SJB122 but captured large amounts of territory already occupied by *C. ranaculosus*. Neither SJB122 nor *C. ranaculosus* were able to capture any territory already occupied by *O. minus*.

O. minus was most able to capture both uncolonized and colonized resources, and SJB 122 was able to maintain space free of *O. minus* to a much greater degree than was *C. ranaculosus*. It is hypothesized that these interactions may be affected by external factors such as temperature, host allelochemicals, and nutrient levels, and that the outcome of these interactions may have significant impacts on the biology of the SPB.

EFFECTS OF SYMBIOTIC FUNGI ON BARK BEETLE FITNESS

Diana L. Six and T. D. Paine^b

Several species of bark beetles in the genus *Dendroctonus* possess structures in their integument termed mycangia that are specialized for the transport of fungi. Usually only one or two fungi are carried in the mycangia to the exclusion of many other species present both on the exterior of the beetles and in the wood of the host tree.

Despite considerable research, the role of mycangial fungi in these associations remains unclear. It is generally assumed that these associations are mutualistic due to the presence of highly specialized structures (mycangia) and because they have been maintained through evolutionary time. The fungi clearly benefit by being consistently transported to the host trees upon which they are dependent for growth and reproduction. Benefits gained by the beetles are not so apparent. One hypothesis suggests that the fungi provide a source of nutrients which have a positive effect on beetle development and reproduction.

We are currently exploring the possibility that ascomycete mycangial fungi (*Ophiostoma* and *Leptographium*) affect the reproduction, development, and host range of the sibling species, *D. ponderosae* and *D. jeffreyi*.

We have developed a technique for production of adult *D. jeffreyi* and *D. ponderosae* in the laboratory that are fungus-free or carrying one of the following fungi: *Ophiostoma clavigerum*, *O. montium* (mycangial associates of *D. ponderosae*) or an undescribed fungus similar to *O. clavigerum* (the mycangial associate of *D. jeffreyi*). Preliminary results with *D. ponderosae* found that fungus-free pairs re-emerged without producing egg galleries. Brood produced by beetles associated with fungi successfully re-acquired the fungi and emergence rates and numbers of brood produced were affected by fungus species and host tree species.

Future research critical in aiding our understanding of these associations should include assessments of the specificity of the mycangia, populational differences in mycangial fungi, and the differential effects of various fungi on a single beetle host. We must also address particular questions focusing on the exact roles these fungi play in beetle nutrition including: do the fungi

concentrate nutrients (e.g., carbohydrates and nitrogen) thus allowing the beetles to develop more quickly, or do they provide critical nutrients (e.g., sterols or vitamins) required by the beetle for development and/or reproduction?

DISPERSAL OF BARK BEETLE-ASSOCIATED FUNGI BY *TARSONEMUS* MITES

John C. Moser¹

Ascospores of the heterothallic fungus *Ceratocystiopsis ranaculosus* were found in sporothecae of three mite species of the genus *Tarsonemus*. These mites were phoretic on the coniferous bark beetles *Dendroctonus frontalis*, *D. brevicornis*, and *Ips acuminatus*. The females of these species possess a mycangium in which conidia are protected, nourished, and transmitted into host trees. *C. ranaculosus* inhabits the mycangium of both *Dendroctonus* species as conidia in a budding yeast-like form. Ascospores are not known to occur in mycangia of bark beetles, and the means of ascospore dispersal has not previously been reported. It is postulated that ascospores transported by phoretic mites may be responsible for establishing sexually compatible colonies of the fungus in beetle galleries.

CLOSING REMARKS AND DISCUSSION

We have made a good deal of progress towards understanding bark beetle-fungal-mite interactions. In particular, the group recognized the important early contributions of Stan Barras and Thelma Perry. However, many of the central questions which arose out of their work have yet to be even addressed. In light of the findings presented here, it becomes even more critical to address these basic aspects of bark beetle biology. Some of the questions and areas for future inquiry which were raised are presented in the list below:

- What role do the various fungi play in the nutritional ecology of bark beetles?
- What stages of bark beetles actually feed on mycangial fungi? What specific benefits (provision of sterols? improvement of nitrogen content?) do the fungi confer to their vectors?

- What role(s) do bacteria and yeasts play in the bark beetle life cycle? What species of bacteria and yeasts are associated with the various bark beetles?
- What proportion of mites carry the various fungi?
- What role do the various fungi play in the nutritional ecology of mites?
- To what degree are phoretic mites a driving force in transmission of blue stain fungi? Is the mite a key factor in bark beetle population dynamics?
- To what extent do mites function as vectors of phytopathogenic fungi in other systems (for example, oak wilt)?

Future studies aimed at increasing our understanding of the taxonomy and basic biology of these organisms will necessitate collaboration among entomologists, acarologists, and mycologists, and continued interactions such as the opportunity afforded by this workshop.

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DECISION SUPPORT SYSTEMS FOR FOREST PESTS

Moderator: Michael C. Saunders¹

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Virtually all management problems, including forest pest management, are concerned with the management of information. Computer-based decision support systems offer the most powerful and effective means of manipulating information and data to deal with the complexity and uncertainty associated with natural resource management.

There is a definite agreement that decision support systems for forest pests must be widely accessible for practitioner use. In addition, these decision support tools must be easy to use, maintain, and update. Although there appears to be strong consensus that adoption of these technologies for the purpose of forest pest management and other forms of forest management is likely and needed, there are strong institutional and behavioral hurdles that must be crossed before their implementation as part of the management *status quo*.

At the present time, the tools and the technology are evolving faster than software developers and forest management organizations can implement them. There are many excellent applications that have been developed, including those discussed in this workshop. We were all excited by what was presented, and eager to participate in what the future will bring.

WHERE DO ALL THE KNOWLEDGE-BASED SYSTEMS GO?

Robert N. Coulson^a

In the early and mid-1980s, computer-based decision support systems were projected for use across a spectrum of applications ranging from business to natural resource management. There was particular interest in expert systems, as this artificial intelligence technology was expected to have a significant impact in the commercial marketplace. The impact was not as great as anticipated and this fact led to an investigation of the fate of the first wave of commercial expert systems (Gill 1995, Yoon et al. 1995). In an

examination of ca. 100 such expert systems built before 1987, Gill (1995) found that, during the five-year period between 1987 and 1992, ca. two thirds of the applications fell into disuse or were abandoned. Furthermore, the brief longevity of the systems was not attributable to failure to meet technical performance or economic objectives. Prominent factors associated with the demise of the systems included lack of acceptance by users, inability to retain developers, problems in transitioning from development to maintenance, and shifts in organizational priorities (Gill 1995).

At present, there are not sufficient examples of the integrative systems to permit an evaluation of their fate. What has been demonstrated to date is that it is possible to develop and deliver complex computer-based systems suitable for addressing ecosystem management problems (Coulson et al. 1995). What has not been demonstrated is that these systems can be used in an operational setting to assist managers in planning, problem-solving, and decision-making activities. If the systems are to be used in an operational setting, three additional issues must be addressed: (1) efficacy; (2) deployment; and (3) implementation.

GYPSES: A DECISION SUPPORT SYSTEM FOR GYPSY MOTH (*LYMANTRIA DISPAR* L.) MANAGEMENT

Kurt W. Gottschalk, Susan J. Thomas, Daniel B. Twardus, John H. Ghent, James Colbert, and Milton E. Teske^b

GypsES is a decision support system for gypsy moth management, being jointly developed by the USDA Forest Service, Northeastern Forest Experiment Station, and State & Private Forestry represented by the Northeastern Area, Region 8, and Washington Office Forest Health Technology Enterprise Team. GypsES provides decision support to gypsy moth managers by: (1) identifying areas of concern; (2) recommending areas to monitor; (3) recommending areas to treat using silvicultural alternatives, direct suppression for

established populations, or eradication of localized spot infestations; (4) providing treatment support options for modeling losses with and without treatment; (5) uploading and downloading of spray block and spray line information through global positioning system files; and (6) spray deposition modeling. The system is based on GRASS, a public domain set of geographic information system routines. It has been extended to handle all geographic data, a spatially-referenced database, and a full featured map creation and edit facility using topographic backgrounds. The system was designed and created with a user-friendly interface programmed in C under Unix, X windows/Motif w.

Also, rule-based logic and independent models are integrated to support users' management decisions. The system can produce reports, create maps, and export graphics files for use in other programs. The basic objectives of GypsES are to model the sequence of evaluations necessary for gypsy moth management decisions and to provide those managers having a gypsy moth problem with useful tools to make their work more efficient and to enable better decisions.

A DECISION SUPPORT SYSTEM FOR SPRUCE BUDWORM AND FOREST MANAGEMENT

David A. MacLean^c

Composition and age structure of much of the spruce-fir forest in eastern Canada is related more to past spruce budworm (*Choristoneura fumiferana*) outbreaks than to harvesting or wildfires. These outbreaks are a natural component of forest succession, but must be taken into account in forest management planning, if plans are to be accurate. Managers need tools to predict outbreak occurrence and effects on forest development, to ensure that expected timber supply/stand types will be present at the expected time of harvest/other usage, and to utilize silviculture and management planning to reduce the severity of future outbreaks.

The Canadian Forest Service has developed a budworm and forest management decision-support system under a five year multi-agency project supported by Canada's Green Plan. Our DSS design philosophy is to build individual tools targeted at specific forest management problems and to integrate these tools under an interactive graphical user interface and a GIS (currently implemented using Arc/Info). I described and

demonstrated use of three components of this DSS, the STAMAN defoliation-based stand growth model, a Protection Planning System, and a dynamic Inventory Projection System.

The Protection Planning System provides a systematic methodology for designing forest protection (insecticide use) under the threat of spruce budworm. It is based on quantifying the marginal timber supply benefits of protecting stands. The methodology comprises three steps: measure the impacts of defoliation, calculate the protection priority for each stand, and evaluate protection strategies. A defoliation-based stand growth model (STAMAN) and a timber supply model (FORMAN+1) are used to forecast forest development with and without defoliation. Protection priority (m³/ha) is then calculated for each stand based on both direct (stand-level) and indirect (harvest queue disruption) marginal timber supply impacts associated with applying protection. This priority value is used as a mapping attribute to generate protection planning maps, and the user can digitize protection blocks into the DSS and quantify m³/ha benefits.

The Inventory Projection System allows evaluation of effects of budworm outbreak and insecticide use scenarios on the forest inventory at user-specified times in the future. Stand dynamics are governed by volume yield curves and a set of rules which determine effects of two severities of budworm outbreak, protection, and successional changes. Display of current and projected stand attributes, attribute changes, different scenario results, and generation of thematic maps is under the user's control within a graphical user-interface. Common queries and map composites are prepackaged and selectable from a menu, and several forest performance indicators in the areas of landscape biodiversity, insecticide use, and timber supply perturbation are being developed. The idea here is to provide an efficient and effective way to visualize alternative future scenarios.

A KNOWLEDGE-BASED REASONING TOOLKIT FOR FOREST RESOURCE MANAGEMENT

Stephen B. Williams and David R. Holtfrerich^d

Forest Resource managers on two United States Forest Service (USFS) National Forests are using a prototype decision support system known as INFORMS R8

(Integrated Forest Resource Management System Region 8) to support common district planning activities. The more broadly applicable and more robust operational version known simply as INFORMS is now in development. Both INFORMS R8 and INFORMS provide access to data management functions, spatial data manipulation functions, and various resource models through a user-friendly graphical user interface. Of particular interest to many users, however, is the knowledge base component. The knowledge base component is a versatile tool that is being applied to a broad range of issues ranging from selection of public firewood sites to assessment of pest issues and wildlife habitat.

In all, more than 30 issue specific rulebases have been defined and used via the INFORMS knowledge base component. Until recently, the expert-defined rulebases were converted into C Language Integration Production System (CLIPS) code by highly skilled programmers. The CLIPS encoded rulebases were then integrated into INFORMS R8 for use. In order to enable distribution of this technology for use by many USFS staff, a knowledge-based reasoning toolkit, or "rulebase toolkit", is being built to promote self sufficiency by USFS staff in building and maintaining CLIPS encoded rulebases. The history of rulebase use on this project and preliminary feedback from users of the early toolkit version highlights the value of rulebase technology in natural resource management and the need for this knowledge base reasoning toolkit.

KNOWLEDGE ACQUISITION, REPRESENTATION, AND REASONING MADE EASY: NETWEAVER

Michael C. Saunders and Bruce J. Miller¹

NetWeaver™ is a rapid application development tool for knowledge base construction, maintenance, documentation, and debugging written at Penn State University to provide an efficient knowledge engineering environment for cross platform knowledge-based systems development. NetWeaver™ is written in C++ and reads and writes platform-independent ASCII scripts that can be read by an embedded inference engine in stand-alone applications.

NetWeaver™ renders knowledge dependency (AND/OR) networks with a fully editable graphic

representation so that the networks appear just like they would on the white board. All the typical editing functions are available (i.e., Cut , Copy & Paste) and can be used on single nodes or whole sections of a network. Because the inference engine is built in, networks can be evaluated in real-time with nodes changing color to indicate their changing trueness levels. This ability to peer into the logical workings of a knowledge network greatly optimizes the knowledging engineering process. On some projects, NetWeaver™ alone is a suitable substitute for stand-alone knowledge-based systems.

NetWeaver's inference engine is completely object oriented and not just in the typical programming sense. Each logical operator (node: ANDs, ORs, NOTs, etc.) is handled as an object in memory which knows its connections, holds its own data, performs its own calculations, and communicates via messages to other, connected nodes. As an embedded tool, versions of the inference engine are available to run under the Macintosh OS, HyperCard, MSDOS, MSWindows, UNIX, and XWindows. NetWeaver evolved to handle not only standard Boolean connections but also mathematical calculation connections and fuzzy logic. Fuzzy logic is used to handle missing data, to evaluate between competing goals, and for the classical use of determining a variable's membership in a given class.

The inference engine reads NetWeaver-generated knowledge bases stored in LISP-like ASCII scripts that describe the construction of the knowledge networks. These scripts are editable in a normal text processing environment or, preferably, with NetWeaver. As the scripts are read, the inference engine constructs and links the objects in memory to represent the knowledge base. Knowledge base functions are extremely efficient as all objects are in memory, their routines are all compiled, and no on-the-fly interpretation is required. Efficiency is further enhanced by firing only nodes when they have changed. When data changes, the associated variable passes a "dirty" message up through the network. When a dirty message reaches the top of a network, an "evaluate" message is propagated back down through the network. As each node receives the message, it checks itself to see if it is "dirty." If it is "dirty," it fires its evaluation routine and returns its new value to the requesting node once the evaluation routine is done. If the node is not dirty, the message stops propagating and the node returns its current value without performing its evaluation routine. Once the

dirty nodes have been resolved adequately (as indicated by the receipt of evaluation results), results can be obtained.

NetWeaver was developed under cooperative agreements with the USDA Forest Service, Soil Conservation Service, and the USDI National Park Service. NetWeaver is currently available on Macintosh OS™ and MSWindows™.

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INSECT/HOST/TRI-TROPHIC INTERACTIONS

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Challenges posed by insects to forest productivity and natural resource management are ultimately questions of population dynamics. Most populations of most insect herbivores usually occur at densities that do not seriously impact stand dynamics. Yet a few species periodically erupt, exhibiting order of magnitude increases in relatively brief periods of time, and consequently impact stand economics, structure, susceptibility to other stress agents, and landscape level disturbances. Understanding how best to predict, manage, and control such outbreaks, forecast responses to long-term environmental change, and incorporate insect management programs into overall ecosystem management requires a fundamental understanding of the major forces affecting population change, and likewise the major forces constraining population growth.

Prevailing views on how population processes interact with environmental constraints have been the subject of much debate, but most workers agree that a combination of bottom - up (e.g., plant defenses, phenological synchrony), lateral (e.g., competition for limited resources), and top - down (e.g., predators, parasitoids, and pathogens) forces is critical (Barbosa and Schultz 1987, Berryman 1988, Cappuccino and Price 1995). However, the relative importance of these factors is difficult to estimate. Moreover, their relative importance is likely to vary from system to system, which makes any robust interpretation very difficult. The goal of this workshop was to provide an update on our current state of knowledge, and try to establish a balance between specific information and robust theoretical interpretation.

One approach to finding general patterns in integrating forces across multiple trophic levels is to evaluate plant - herbivore - predator systems on the basis of different feeding guilds (e.g., Baranchikov et al. 1989). Herbivores tend to show some general patterns depending on whether they are free feeding or endoparasitic, and on the type of tissue which they consume (Larsson 1989). Interestingly, there appears

to be some convergence between the “basic” and “applied” literature on this point. We followed this construct in addressing this workshop. Speakers were invited to describe aspects of plant suitability, competitive relationships, and natural enemy interactions for members of six feeding guilds. Each speaker was provided three questions in advance: (1) What is the relative importance of top down, bottom up, versus lateral forces? (2) What features of the environment affect the relative importance of the above? (3) What opportunities exist for integrated manipulation of top down, bottom up, and lateral forces?

Individuals were selected to provide a range of experiences across different feeding guilds, insect taxa, geographic regions, ecosystem types, and institutional affiliations. The overall consensus from this workshop is that bottom up (i.e., host related) forces appear to be more important than the other factors affecting five of these feeding guilds: bud, shoot, seed, and cone; gall forming; leaf mining; sucking; and subcortical insects. This is especially true when the role of plants in structuring same - trophic level competitions and mutualisms, and natural enemy performance, are incorporated, as opposed to viewing these as strictly lateral or top - down effects. The types of key bottom - up forces vary extensively, however, from system to system. These mechanisms include host availability, substrate quality, phenological synchrony, and plant resistance. In the leaf-feeding guild, the available evidence appears to support equivalent roles of bottom - up, lateral, and top - down forces.

FOLIVORES

Mark D. Hunter^a

Folivore populations, like those of all herbivores, are influenced by both bottom-up and top-down forces. A simple graphical model demonstrates that population equilibria are always determined by a dynamic balance

of resource quality/quantity and depredation. The relative impact of these forces, however, can vary among species. Analyses of sampling data for the winter moth (*Operophtera brumata*) and the green oak leaf roller moth (*Tortrix viridana*) demonstrate that the relative importance of top-down and bottom-up forces can be inferred from data collected at the appropriate spatial scale. Temporal variation in *O. brumata* densities are driven by a t-2 lagged density-dependent process, consistent with pupal predation. Top down forces account for about twice the variation in winter moth density as bottom-up forces, the latter of which determine spatial rather than temporal variation. Analyses of *T. viridana* sampling data suggest that both spatial and temporal variation in numbers are determined primarily by bottom-up forces. Plant quality influences the spatial distributions of *T. viridana*, while the quantity of plant resources, acting through competition, influences temporal variation.

THE IMPORTANCE OF TOP-DOWN, BOTTOM-UP, AND LATERAL EFFECTS IN THE BUD, SHOOT, CONE, AND SEED INSECT-FEEDING GUILDS

Steven Katovich^b

Cone and seed insect populations are regulated primarily by annual fluctuations in cone abundance. For most conifers, the annual production of cone crops is erratic, varying from years when cones are almost nonexistent to years of tremendous abundance. Cone crops tend to be initiated by climatic or weather events that affect crop abundance or lack of abundance over large areas. Further, several tree species may be affected in a similar manner, i.e. Douglas-fir and grand fir tend to have large cone crops in the same year and vice versa. The general theory is that the erratic production of cone crops has evolved to thwart animals that feed on cones and seeds. In other words, periodic bursts of cone production overwhelms the few herbivores that have survived the intervening years of low cone production.

Competition for cones and seeds, both inter- and intra-specific, is rare during years of cone abundance, but intense during years of small crops. However, cone and seed insects have evolved several adaptations that allow them to survive periods of smaller cone crops. The two most prevalent adaptations are prolonged diapause and the ability to feed and reproduce on other

plant structures such as buds and shoots. Further, many of the species that utilize prolonged diapause are capable of timing their peak emergence to coincide with large cone crop years.

The role that natural enemies have in the population dynamics of cone and seed insects is generally considered to be minimal. Current management practices for seed production in seed orchards such as using wide spacing, plant hormone treatments, and fertilization have removed much of the annual variability associated with cone crops. By doing this we have removed the most important regulator of cone and seed insect populations. Manipulating occasional cone crop failures in seed orchards could act as an insect-regulating mechanism.

The resources utilized by the bud and shoot insect guild are annually much more consistent than are cones and seeds. Natural enemies appear to play an important role in the population dynamics of this guild. Also, the quality of the resource becomes important, i.e. shoot size, terpene content and resin flow. In many cases, poor site quality has increased bud and shoot insect populations most likely through effects on the host trees.

TRI-TROPHIC INTERACTIONS IN BARK BEETLE ECOLOGY

Kenneth F. Raffa²

Interactions between bark beetles and other species within or between trophic levels largely arise from their relationships with host plants. Scolytid - host relations are characterized by: (1) a requirement to kill trees in order to reproduce; (2) integrated constitutive and rapidly-induced defenses, that are largely carbon-based and quantitative; (3) pheromonal systems that can facilitate cooperative depletion of host defenses, and are linked to tree allelochemistry; (4) association with moderately phytopathogenic fungi; and (5) stress mediation of defense physiology, which includes both translocation and *de novo* synthesis. There is high variation among trees in resistance to scolytids, and beetles often face trade-offs in terms of host suitability versus susceptibility, interspecific competition versus host defense, and exposure to predators versus intraspecific communication. Features of the host plant community can largely structure optimal beetle

colonization strategies, and to some extent contribute to landscape disturbances such as fire.

Interactions with conspecifics include elements of both cooperation and competition. Each beetle contributes to the likelihood of successful host utilization, but likewise depletes the available substrate. The net contribution among members of a cohort is largely determined by host condition. Likewise, beetle interactions with Ophiostomatales fungi include elements of both mutualism and cooperation. Fungi can reduce some of the host parameters that negatively affect beetles, but also function as competitors during brood development. Again, their net effects are largely determined by host condition. Other interspecific interactions include both positive and deleterious effects on beetle reproduction. Some organisms, such as root insects, root fungi, and folivores, can predispose trees to subsequent bark beetle development. Conversely, competitors such as related species wood borers can greatly diminish scolytid reproduction. Subcortical feeding guilds show substantial niche partitioning, including elements of host tissue, host condition, chemical ecology, and microbial relationships, that partly alleviate interspecific competition for a common resource. Such niche partitioning occurs within both the above- and below-ground subcortical feeding guilds.

Recent research suggests that natural enemies play a more important role in scolytid population dynamics than previously supposed. A combination of life table analyses, exclusion experiments, and population modeling documents their role. A critical feature of bark beetle predators is their exploitation of prey pheromones as kairomones, which provides a direct chemical link across three trophic levels. Recent evidence suggests that the pheromone systems of some bark beetles may evolve partially in response to predatory pressures. In particular, minor alterations in stereochemistry, secondary components, and behavior may confer some escape from predators while maintaining intraspecific functionality. An understanding of the chemical interactions among bark beetles and predators offers some specific approaches to conserving, augmenting, and evaluating the introduction of natural enemies.

The important role of host tree stress in bark beetle population dynamics suggests that control tactics should be directed at inciting agents, such as root insects, root pathogens, or folivores, where possible. It

also suggests that silvicultural or genetic manipulations can help constrain populations, but that a reservoir of stressed trees is probably desirable in keeping bark beetles in a nonaggressive state. This has implications to proposed genetic engineering for resistance against scolytids, for example. The association of bark beetle behavior and development with tree stress also suggests that some of the less aggressive species might be useful indicators of forest health.

GALL FORMERS IN INSECT/HOST/TRI-TROPHIC INTERACTIONS

Peter W. Price^e

Trophic webs involving gall-forming insects provide excellent opportunities to evaluate the relative forces of bottom-up and top-down influences on the population dynamics of herbivores. Females and/or larval preference for galling sites may be compared readily to larval performance at that site. Natality and mortality factors can be evaluated in relation to plant module quality and quantity and death from plant and carnivore effects.

Many studies have indicated a strong bottom-up influence on gall-forming insect population size and dynamics, from the plant resource to the herbivore. Studies on top-down effects from carnivores to the herbivore generally indicate relatively weaker influences to virtually none, and no trophic cascades from top carnivores have been discovered. Rather, there is good evidence of trophic influences up the food web from plant variation affecting communities of insects on the plant. Plant variation relevant to gall-forming insects involves geographic patterns in vegetation, plant phenotype, genotype, and architecture. Examples used involve sawfly, aphid, and cecidomyiid gall-formers on trees and shrubs.

INSECT/HOST/TRI-TROPHIC INTERACTIONS: LEAFMINERS

Stanley H. Faeth^d

Leafminers, insects that feed internally in foliage for at least some of their larval stages, provide excellent models to test the relative effects of top-down (natural enemies), horizontal (direct and indirect effects of competitors) and bottom-up (plant resource quality and

quantity) forces on population dynamics because mines are semi-permanent records of feeding, survival, and mortality events. In terms of top-down interactions, although leafminers support greater species richness of parasitoids than any other insect guild, recent reviews indicate that parasitoids, as well as predators and disease, have little effect on controlling population densities of most leafminers. Similarly, although direct (exploitative and interference competition) and indirect (induced responses affecting resource quality or attack by natural enemies) interactions with heterospecific herbivores have been well examined for some leafminers, such as *Cameraria* sp. nov. on Emory oak, these interactions apparently play little role in driving population dynamics. Furthermore, survival of the leafminer *Cameraria* is little affected by the presence of endophytic fungi herbivores, despite their high diversity and abundances and proximity to leafminers in oak foliage. Intraspecific interactions in the form of cannibalism, exploitative competition, and increasing leaf abscission, however, can alter population dynamics, particularly at high population sizes. Four long-term studies of leafminers suggest that plant resources, especially plant phenology such as bud break and abscission, have the strongest role in leafminer population dynamics. In terms of forest health, most forests are already "healthy" if health is equivalent to endemic densities of leafmining species. Forests typically become "unhealthy," or attacked by epidemic levels of leafminers, when some aspect of tree phenology is altered, such as creation of even-aged stands so that budbreak phenology is synchronized.

RELATIVE IMPACTS OF BOTTOM-UP, LATERAL, AND TOP-DOWN FORCES ON SAP-FEEDING HERBIVOROUS INSECTS

Robert F. Denno^a

The relative importance of "bottom-up" (host plant) and "top-down" forces (natural enemies) in the population dynamics and community ecology of phytophagous insects has been disputed for decades. Moreover, lateral forces (intraspecific- and interspecific competition) are often ignored altogether. What is badly needed is a synthetic, unbiased approach whereby bottom-up, lateral, and top-down forces are experimentally examined in the same system. To date, however, most multi-factor assessments are non-experimental and have relied on life table-like approaches.

Consequently, for my assessment of the relative impact of bottom-up, lateral, and top-down forces on sap-feeder populations, I had to rely largely on non-experimental, published studies. For my survey, I included only those studies in which at least two factors such as plant quality and natural enemies were considered. In all, 61 species of sap-feeders were available for assessment. The field of players was diverse and was dominated by planthoppers, leafhoppers, true bugs, aphids, adelgids, and scale insects. For each species I simply scored whether bottom-up, lateral, or top-down forces exerted a strong influence on fitness, performance, or population size. Factor strength was assessed either directly from the conclusions of the investigator or indirectly from mortality or performance data.

Major results of the assessment were as follows: Bottom-up effects outnumbered top-down effects more than 2 to 1 in the sap-feeder guild. Bottom-up effects and lateral effects were tightly linked in many species whereby sap-feeder density fed back to influence plant quality and subsequent sap-feeder performance. Lateral effects (competition) were five times more likely to be mediated by bottom-up forces than top-down forces. The relative impact of bottom-up, lateral, and top-down forces on sap-feeders was not influenced by habitat (natural versus agricultural), growth form of the host plant (tree versus grass/forb), or the origin of the herbivore (native versus introduced). Strong top-down forces were relatively more evident in species which rarely erupted than in species which commonly did so, suggesting that natural enemies did deter outbreaks. Last, mobile sap-feeders (aphids and planthoppers) were more likely to be resource regulated than were sedentary species (scale insects) for which top-down forces were more evident. Because of the primacy of bottom-up forces in sap-feeder population dynamics, the answer to their suppression lies in the manipulation of the host plant in ways that simultaneously diminish sap-feeder performance and enhance enemy impact.

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BIORATIONALITY IN PEST MANAGEMENT WITH MICROBIAL AND BIOTECHNOLOGICAL CONTROLS

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IS ENHANCEMENT OF BIOLOGICAL AND BIORATIONAL INSECT CONTROL AGENTS THROUGH BIOTECHNOLOGY USEFUL, PRACTICAL, OR NECESSARY?

James M. Slavicek^a

The ability to clone DNA into bacterial plasmids led to the development of the field of biotechnology. This field has progressed rapidly and has had a major impact on medicine, agriculture, and more recently on forestry. In the area of human health, biotechnology has provided treatments for diseases (human insulin for diabetes and human growth hormone for dwarfism), tests for mutated genes that lead to diseases such as cystic fibrosis, and new antibiotics. In agriculture, biotechnology has led to development of transgenic strains of insect resistant corn and cotton, herbicide tolerant strains of cotton, virus resistant squash strains, the Flavr SavrTM tomato, and other modified crop plants. The aforementioned genetically-engineered crop plants are no longer regulated by APHIS and are being commercially produced.

The application of biotechnology to forestry has been used primarily for research purposes. Within the last few years, however, biotechnology has been used to develop insect resistant and herbicide tolerant strains of poplar trees, engineered strains of *Bacillus thuringiensis* (*Bt*), and improved strains of the *Lymantria dispar* nucleopolyhedrovirus (LdMNPV). The technology to create transgenic plants and microbes is well developed, and recent efforts have focused on the alteration of trees and microbes to achieve a specific goal. For example, genetic engineering can potentially be used to expand or narrow the host range of a nucleopolyhedrovirus (NPV) and *Bt*, increase the potency of NPVs and *Bt*, enhance NPV efficacy, alter fungal growth requirements, and impart desirable commercial production attributes to NPVs.

Several factors, including the cost of the engineering, degree of value enhancement, alternative embodiments, regulatory issues, and public acceptance need to be considered in determining whether the genetic engineering of insect biological control agents can be justified. In the case of biological controls for forest insect pests that affect large areas (e.g., the gypsy moth), the final product should have a clear advantage compared to chemical insecticides (e.g., specificity for the target insect), have the same approximate cost as chemical insecticides, and be able to be applied using conventional methods.

Genetic engineering has the potential to improve *Bt* and the LdMNPV for use as gypsy moth control agents. Possible improvements for *Bt* include potency and efficacy enhancement and development of a toxin specific for the gypsy moth. While these improvements may be desirable, they are not necessary for the continued use of *Bt* since *Bt* is competitive with chemical insecticides in terms of cost and is more specific than chemical controls. In contrast, improvement of *in vivo* production methods and/or development of *in vitro* production systems for LdMNPV is necessary in order to make the virus competitive in terms of cost with chemical insecticides.

BIOTECHNOLOGY: A MODERN TECHNOLOGY IN AN ANTIQUATED PHILOSOPHY?, OR A USEFUL TOOL FOR ADDRESSING GAPS IN TREE PROTECTION AND NATURAL RESOURCE MANAGEMENT?

Kenneth F. Raffa^b

Recent advances in molecular biology enable researchers to transfer novel genes into plants, and thereby express traits conferring resistance against insects and pathogens. This approach has already achieved commercial development in agriculture. The applicability of this approach to tree protection remains unclear and controversial, however. Trees possess some

important differences from agronomic crops, in that they are long lived, they are components of both commercial growing systems and native terrestrial ecosystems, and forest stands are often self regenerating.

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Genetic engineering offers some important opportunities for tree protection, especially considering the logistical difficulties in breeding such large long-lived plants, the economic constraints in tree production and protection, the need for alternative control methods, and the enormous and conflicting demands placed on forest resources. However, there are likewise some serious hazards that have not yet been adequately addressed. These include the risks of gene escape, biotype evolution, and alteration of normal ecosystem processes. The risk of each of these can be considered by understanding the underlying biological mechanisms, and by considering lessons from precedents such as pesticides, resistant cultivars, and naturally-coevolved systems.

In some cases, specific measures such as physiological sterility, biotype delaying tactics, and innocuous gene products can greatly reduce risk. Examples of biotype delaying tactics include providing heterogeneous mosaics at multiple levels of scale, integrating natural and novel forms of resistances, wound-inducible and spatially-limited expression, and compatibility with biological controls. However, components of the growing system are also crucial. For example, genetically engineering urban landscape trees, that are part of an overall diverse landscape, or very short rotation trees such as Christmas trees or biofuel plants, are less likely to impose uniform selective pressures on insect herbivores, than is transforming large forested stands. The latter approach seems almost certain to invite environmental harm, and regardless of the molecular advances involved, remains an antiquated approach to pest management.

A approach to evaluating the risks and benefits of tree genetic engineering, and some approaches to the problem, were discussed.

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ROLE AND IMPACTS OF EXOTICS ON ECOSYSTEM PROCESSES

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Exotic pests are an expense to our economy, disruptive to our ecosystems, and impossible to eliminate once widely established. While not all introduced organisms are pests, it is impossible to predict their impact. The four presentations in this symposium provide insights into the complexity of interactions of pests within forest ecosystems at various trophic levels. These presentations raised a number of questions in respect to accidental or purposeful introductions. For example, should eradication be the first and only consideration? Since most forest ecosystems already have been influenced by exotic pests, should we modify our concepts of ecosystem attributes? Who should make value judgments in respect to action to be taken or acceptable damage to various threatened ecosystems? Should exotic biological control agents be imported for the control of native pests? As resources become limiting, who will decide what exotic pest receives priority attention? Can we manage, let alone restore, forest ecosystems altered by invasive plants, animals, or microbes?

The complexity of exotic pest impacts on ecosystem processes can be expected to be variable. Some, such as the beech bark disease, impose pervasive effects on forest management, ecology, wildlife, wood utilization, and recreation -- effects that occur over a protracted period of time. We need to develop the technology for more rapid impact assessment in different ecosystems for characterizing exotics. Long term, intensive multidisciplinary studies will be required to address these impending challenges in implementing ecosystem management or habitat restoration. Given the likelihood that additional exotics such as hemlock woolly adelgid, balsam woolly adelgid, and yet unknown Eucalyptus pests to be introduced into our forest and urban forest ecosystems is reason for serious concern. Strengthening international linkages between scientists, regulators, and industry is requisite in attempting to find suitable solutions in view of declining research support.

ECOLOGICAL ROLES OF INTRODUCED ORGANISMS AND THEIR EFFECTS ON ECOSYSTEM PROCESSES

Rose-Marie Muzika^a

The number of introduced organisms in North America has increased markedly in the past several decades. The effects of introduced organisms on ecosystem properties appear to be at least as great as the effects of climate change and air pollution. Introduced organisms are found in virtually every taxonomic group. The ecological niches exploited by introduced species are varied, and therefore the functional impacts are widespread. The most disruptive invaders to date have been plants, insects, and fungi. Among these, exotic plants have been given the most attention, but insects and diseases have had known detrimental effects and generally appear more dramatic in agricultural or intensively managed areas than forested lands.

The effects of introduced insects and diseases are complex and likely as severe as the effects of plants, but they may be more subtle, and hence more insidious. The extent to which introduced organisms influence functional relationships and ecosystem - wide processes is poorly understood. The nature of ecological impacts of an introduced organism depends upon its ecological role and can range from species replacement to influencing food web dynamics to altering the physical environment. Furthermore, problems associated with introduced pests are not simply remedied, and can create biological and management dilemmas. Among the examples to illustrate the potential and actual effects of introduced insects and diseases are: gypsy moth (*Lymantria dispar*), balsam woolly adelgid (*Adelges piceae*), pitch canker (*Fusarium moniliforme*), and white pine blister rust (*Cronartium ribicola*).

A FRAMEWORK TO DOCUMENT ECOSYSTEM EFFECTS: EXPERIENCE WITH HEMLOCK AND THE HEMLOCK WOOLLY ADELGID

Richard Evans^b

Dense canopies of eastern hemlock (*Tsuga canadensis*) strongly influence fundamental ecosystem characteristics such as plant/animal species composition, succession, primary productivity, decomposition, and nutrient cycling. Therefore, severe defoliation and mortality of eastern hemlock caused by an exotic insect, the hemlock woolly adelgid (*Adelges tsugae*), are expected to impact these ecosystem characteristics significantly. The National Park Service has sponsored studies to document ecosystem characteristics of two hemlock ravines at Delaware Water Gap National Recreation Area prior to hemlock woolly adelgid infestation. We established 60 permanent plots (stratified by elevation and distance to stream) to describe the ecological conditions in the ravines. We found 318 plant, 12 small mammal, 15 amphibian and 22 breeding song bird species in the ravines.

Several song bird species strongly favor eastern hemlock for breeding habitat. Temperature study demonstrated that the cooling effect of a hemlock ravine can be critical to maintaining summer stream temperatures tolerable to brook trout (*Salvelinus fontinalis*). The impacts of hemlock woolly adelgid on hemlock-dominated ecosystems probably depend on other stressors like other forest insects and diseases, air pollution, drought, deer browse, and invasive exotic plants. However, we expect some of the following changes: (1) reduced abundance of bird species strongly associated with hemlock; (2) increased understory and stream light levels and temperature; (3) reduced abundance of native brook trout; (4) reduced biomass and species diversity of bryophytes; (5) increased soil nitrate-nitrogen availability; (6) increased primary productivity; (7) increased biomass of understory plants (ferns) and stream algae; and (8) increased occurrences of invasive exotic plants like Japanese stilt-grass (*Microstegium vimineum*).

BEECH BARK DISEASE: EFFECTS OF AN EXOTIC CAUSAL COMPLEX ON SOME ECOSYSTEM COMPONENTS AND PROCESSES

David R. Houston^l

Beech bark disease (BBD) occurs when bark of American beech (*Fagus grandifolia*), infested and altered by the introduced beech scale (*Cryptococcus fagisuga*), is invaded and killed by fungi of the genus *Nectria*. *N. galligena*, a native pathogen, incites perennial target cankers on many hardwoods; *N. coccinea* var. *faginata*, probably introduced, is known only from scale-infested beech; *N. ochroleuca*, a native fungus, has an uncertain role in the disease. The introduced members of the causal complex, and the ensuing disease, are spreading west and south from their point of introduction in Nova Scotia and are now present in North Carolina and Tennessee.

American beech is extremely shade tolerant, produces abundant seed that can be distributed widely by blue jays and reproduces vegetatively by root sprouts on injured roots. These features enable beech to colonize gaps created by harvest or death of canopy trees and allow established genotypes to persist.

BBD affects forest structure initially by rapidly killing large numbers of big, old trees (fast gaps). In long-affected forests, trees become highly defective, slow in growth, and eventually die (slow gaps). Forest composition is altered initially as shade intolerant species increase and some tolerant species decrease. Beech persists and increases in abundance.

In the short run, massive mortality of large, rapidly decaying trees probably results in large, transient nutrient pulses. Nutrients presumably are rapidly sequestered by advance regeneration and beech sprouts. In the long run, nutrient cycles are probably "stable."

Energy flows are altered initially as early seral stage species increase and as food webs change in numbers and kind. Reduced mast production affects mast-dependent species including bear, birds, and small mammals and their predators. In the long run, original food webs are restored and new ones persist; beech tree growth is reduced.

Long-affected forests are structurally unstable. Diseased trees are more susceptible to effects of

stresses including defoliation, oystershell scale, drought, and frost. Low diversity beech-dominated stands are perpetuated.

Factors that affect the causal complex occur at the ecosystem level (climate, possibly air pollution); forest level (beech age, distribution, and abundance); stand level (lichen protection); tree level (genetic resistance) and causal organism level (predation, parasitism).

BIOLOGICAL CONTROL PROGRAMS FOR FOREST INSECTS: BENEFITS AND RISKS TO ECOSYSTEMS

Donald L. Dahlsten^c

For many years, concern about exotic species has focused on unintentionally-introduced organisms. Recently, intentional introductions of organisms have been questioned, particularly organisms introduced for biological control. In the United States, intentionally- and unintentionally-introduced organisms (other than plants) have been evaluated as to their harmful effects. Almost half of unintentionally-introduced terrestrial vertebrates, insects, fish, mollusks, and plant pathogens had harmful effects. Of the intentionally-introduced organisms, there have been harmful effects from only three of 210 insect species and none from four plant pathogens. However, there have been harmful effects from about half of the intentionally-introduced terrestrial vertebrates, fishes, and mollusks. Since our concern is primarily with insects used in biological control of forest pests, this is encouraging, but risk exists with every organism introduced.

Biological control in forests differs from that in agriculture. Forests have greater diversity and a multistoried structure, are vast and relatively undisturbed. Their diversity results in a large complex of natural enemies with many complexes exhibiting minor regional differences. Some of their disadvantages are: colonization can be hampered by competition with native natural enemies; vastness and diversity complicate sampling and evaluation; and accessibility is a problem.

Direct inoculative releases of natural enemies have been more successful in biological control programs than mass breeding and release programs. Exceptions are the gypsy moth in the United States, the European spruce sawfly in Canada, and the European wood wasp

in Australia. Conservation of natural enemies from insecticides or silvicultural manipulations may be the best strategy for biological control.

Although biological control has considerable benefits, there are concerns about impacts on biodiversity, ecosystem stability, and endangered species-- particularly in Hawaii. Although vertebrates and mollusks have caused harmful effects, adverse effects from beneficial insect introductions on native nontarget insects have not been well documented.

Every introduction should be analyzed carefully, but generalists are more risky than specialists. An example of a low risk biological control program is the introduced blue gum psyllid in California (a pest on an introduced eucalyptus species) that was controlled with an introduced host specific parasitoid. An example of high risk is to undertake control of native species with exotic natural enemies.

Some scientists support introducing exotics in the Pacific Islands where intense human activity has greatly modified the environment and exotics are a source of biotic replenishment and genetic diversity. Some rare and endangered species may even find refuge in a more favorable exotic location.

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PESTS IN INTENSIVE FORESTRY

Moderators: René I. Alfaro¹ and David L. Overhulser²

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The economic incentives to practice intensive cultivation of conifers are increasing with the worldwide demand for wood and fiber. A common approach to intensive forestry involves the growing of improved conifer stock in monocultures on highly productive sites. These artificial forests can create favorable habitat for pest populations which cause significant damage to tree growth and form. Reducing pest damage in intensively managed conifer regeneration requires a clear understanding of the economic thresholds justifying control efforts and development of the basic components of an integrated pest management (IPM) program. Fortunately, the high value and large acreage typical of intensively managed stands often supports the research needed to develop effective pest management programs.

This workshop reviewed some of the current innovative research on reducing pest damage in intensively managed conifer regeneration. Presentations covered studies on the Nantucket pine tip moth, white pine weevil, Christmas tree pests, and the status of three introduced bark beetle pests associated with radiata pine in Chile. In addition, there was an update on the use of semiochemicals to protect high value conifer stands in Europe.

THE BALSAM TWIG APHID AND BALSAM GALL MIDGE IN WISCONSIN CHRISTMAS TREE PLANTATIONS: POTENTIAL CANDIDATES FOR IPM?

Paula Kleintjes^a

The state of Wisconsin produces over three million Christmas trees each year with balsam fir comprising the majority of sales. For growers, the balsam twig aphid (*Mindarus abietinus*) Koch and balsam gall midge (*Dasineura balsamicola*) (Lint.) are major pests of concern for they cause needle distortion and/or loss which prevents the sale of trees for up to three years after attack. Currently, there are no consistent methods

used by growers to monitor or control either pest. Growers typically use conventional pesticide applications at times too late to control pest damage, but on time to pose risk to beneficial insects and nesting birds. This presentation discussed a project attempting to develop monitoring systems for both aphids and midges to be used by growers to develop predictive surveys of spring population levels. Monitoring data, damage assessment, and the public perception of damage will then be used to determine economic threshold levels for both insects. The project also will investigate the potential of biological and silvicultural controls for the prevention of pest damage and for the conservation of natural enemies.

EFFECTS OF VEGETATION CONTROL ON NATURAL ENEMIES OF THE NANTUCKET PINE TIP MOTH

Kenneth W. McCravy and C. Wayne Berisford^b

The Nantucket pine tip moth (NPTM), *Rhyacionia frustrana*, is a serious pest of loblolly, shortleaf, and Virginia pines in the southeastern U.S. This is particularly true in plantations subjected to intensive site preparation and vegetation control. One possible reason for this is a decrease in parasitoid populations caused by loss of food resources and habitat associated with herbaceous vegetation. Studies of the NPTM and its parasitoids in sites receiving broadcast (total coverage) herbicidal treatment versus banded treatment or no treatment were done in the southeastern coastal plan. As expected, vegetation was significantly lower in the broadcasted plots, although grass was the most dominant plant group in all treatments. In sites with substantial tip moth pressure, infestation rates were higher and tree growth lower in the broadcast plots. Measures of total parasitoid abundance, as estimated using malaise traps, indicated that parasitoids were more numerous in the plots with greater abundance of vegetation. However, rearing studies showed no significant difference in tip moth parasitism rates

between plots. The study will be repeated using wildflower augmentation to create a greater flowering vegetational gradient between plots.

MANAGEMENT OF THE WHITE PINE WEEVIL IN BRITISH COLUMBIA

René I. Alfaro^f

The white pine weevil, *Pissodes strobi* Peck, is an indigenous insect of North America, and can be found in most regions of Canada and the United States. In British Columbia this insect has become a serious pest of reforestation, causing severe damage to young stands of Sitka spruce, Engelmann spruce, white spruce, and their hybrids.

An Integrated Pest Management System has been proposed for *P. strobi*. This system relies on restoring ecosystem balance by reducing the conditions that lead to outbreak development. The system recommends tactics that diminish heat accumulation in the stand by encouraging growth of suitable non-host conifers as well as deciduous species such as aspen or alder. These trees render the stand cooler and shadier, reduce food supply, and probably create conditions which enhance natural enemy populations. Reduction of damage by increasing plantation density also is recommended. Central to IPM is the continuous monitoring of weevil populations and forecasting of weevil impacts on forest productivity. This can be accomplished through a computerized decision support system, which helps to evaluate the need for, and the possible benefits of, a given tactic.

A salient feature of the IPM system for *P. strobi* is the combination of tactics involving silviculture and host genetic resistance. Host genetic resistance could be utilized to allow increased reforestation with spruce species in ecosystems prone to infestation. In low hazard areas, silviculture-driven tactics such as mixed-species planting and increased planting density may be sufficient to produce a successful spruce crop. In high hazard areas, the silvicultural prescription should include the use of resistant stock. However, the deployment of resistant genotypes should take into consideration the need for avoiding the risk of insect selection leading to biotypes capable of overcoming the resistance mechanisms. For this, a component of susceptible stock should be planted along with the resistant material. Judicious use of genetic resistance, together with shade conservation, mixed-species

planting, maintenance of biodiversity, and other measures for restoring ecosystem balance will secure continued production of spruce timber in British Columbia.

USE OF SEMIOCHEMICALS IN INTENSIVE FORESTRY: THE EUROPEAN PERSPECTIVE

Jean Pierre Vité^c

Dr. Vité provided an overview on the use of semiochemicals to manage bark beetle problems in European forests. The talk focused on commercially available trap designs and attractant formulations for suppressing beetle populations. Several innovative trap designs were discussed that are not used in North America. European foresters show a growing acceptance of semiochemical technology combined with traditional forest management strategies to control bark beetle problems.

CURRENT STATUS OF INTRODUCED PINE BARK BEETLES IN CHILE

Ronald F. Billings^d

In November 1995, I was invited to Chile to evaluate the current status and impact of three recently-introduced species of European pine bark beetles on plantations of Monterey pine, *Pinus radiata*. The European scolyid species, introduced into Chile in the 1980s, are *Orthotomicus erosus*, *Hylastes ater*, and *Hylurgus ligniperda*. These same species are of particular interest in the United States as potential pests on untreated log imports from Chile (USDA Forest Service 1993). Following is a summary of findings from this evaluation:

Orthotomicus erosus - This scolytid continues to be the least common and least economically important of the three introduced pine bark beetles in Chile. No evidence of *O. erosus* was found in field observations of logging slash or log decks. Occasional adults were collected in barrier traps baited with *alpha*-pinene and ethyl alcohol in 1994 and 1995. This species restricts its attacks to logging slash and does not infest young pine seedlings. Due to its scarcity in Chile and its secondary attack preferences, it poses little threat for potential introduction into the U.S. on Chilean log imports.

Hylastes ater - This scolytid is less common in Chile than *Hylurgus ligniperda*, but was observed infesting stumps and young pine seedlings in several locations. Adults have been captured in barrier traps in Chile in every month of the year. This species is known as a vector of black stain root disease (*Leptographium* spp.) in New Zealand but whether this insect vectors recently-identified species of *Verticicladiella* (= *Leptographium*) in Chile has yet to be confirmed. This bark beetle species should be considered of moderate concern as a quarantine pest associated with Chilean log imports.

Hylurgus ligniperda - Without doubt, this is the most common and widely-distributed scolytid associated with *Pinus radiata* in Chile. Adults were commonly found in pine stumps and logging debris throughout the pine zone from Valdivia to Osorno. Of 483 scolytids caught in 12 survey traps in the Maule Region in 1994, 84% were *Hylurgus*, 16% were *Hylastes* and < 1% was *Orthotomicus*. In several cases, I observed adult *H. ligniperda* infesting 1-2 year-old *P. radiata* seedlings near Concepción, Chile. *Hylurgus ligniperda* is capable of causing economic losses in recently-established pine plantations when adults emerge in large numbers from pine stumps. This behavior, coupled with its wide distribution and abundance in Chile, render this species of particular concern for possible introduction into the U.S. on untreated log imports. Whether this bark beetle is capable of vectoring black stain root disease fungi remains to be determined.

LOBLOLLY PINE AND NANTUCKET PINE TIP MOTH IN FLORIDA

John L. Foltz^e

Loblolly pine, *Pinus taeda*, has been the predominant commercial species across the South for many decades, but only in recent decades has it been planted and managed in northern and central Florida. This increasing acreage has led to increasing problems with tip moths and bark beetles. Recent research on tip moth biology and an experimental insecticide is summarized here.

The Nantucket pine tip moth, *Rhyacionia frustrana*, is the most serious of the *Rhyacionia* species in Florida. Pheromone trap catches in Alachua County (latitude 29.5N) show that pupal diapause begins in September with almost no moths being trapped during October and

November. A few moths are collected regularly during December and January, then numbers explode in late February. A second peak occurs in April followed by irregular ups and downs until flights ceases in late September. Collections and dissections of pine shoots show corresponding patterns in the development and abundance of larvae and pupae.

A 1991 experiment with imidacloprid at 0, 1, 2, 3, and 4 grams active ingredient per seedling demonstrated the impact of tip moth on loblolly growth and form. Four years after application of this slowly-released systemic insecticide, the untreated seedlings averaged 2.64 m tall and 3.2 cm in diameter at breast height. The 4-gai-treated seedlings were straighter and much larger, averaging 3.82 m tall and 5.4 cm dbh.

SITE AND STAND RELATIONSHIPS AFFECTING NANTUCKET PINE TIP MOTH INFESTATION RATES

David L. Kulhavy^f

Infestations of the Nantucket pine tip moth (NPTM), *Rhyacionia frustrana*, were examined on loblolly pine plantations in eastern Texas. Prediction models were developed including foliage nutrients, tree water potential, and tree height that play an important part in NPTM infestations. Overall, these factors predict whole tree infestations better than infestations of the top two whorls. Earlier investigations examined the role of phosphorus in relation to infestations of the NPTM. Evidence suggested that increased phosphorus levels in the soil and foliage were correlated with lower infestations of the NPTM across sites. Soil amendments of phosphorus tended to decrease infestations of NPTM although this was not consistent over sites and seasons. Additional research is needed on the role of phosphorus and infestation rates of the NPTM. We recommend long-term site examinations and replicated studies of infestations of the NPTM across sites and seasons, especially as cooperative pest management programs develop.

REFERENCE

USDA Forest Service. 1993. Pest risk assessment of the importation of *Pinus radiata*, *Nothofagus dombeyi*, and *Laurelia philippiana* logs from Chile. Misc. Publ. No. 1517.

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ARTHROPOD AND BIODIVERSITY CONSIDERATIONS IN FOREST MANAGEMENT AND PLANNING

Moderators: Roger Sandquist¹ and Christine Niwa²

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With the exception of work associated with the Long-Term Ecological Research site at the H. J. Andrews Forest and a few isolated research projects conducted by academic institutions, there has been little effort towards the study of forest arthropod communities in the western United States. Even basic descriptive information on arthropod community composition is currently unavailable. Ongoing efforts at the H. J. Andrews Forest in Oregon have revealed that arthropod communities are extremely diverse; over 3,500 species of arthropods are known to occur there (Parsons et al. 1991). Olson (1992) estimated that about 7,000 species of arthropods inhabit late-successional forests in the Pacific Northwest and assume numerous ecological roles that are important to ecosystem function.

Arthropods and other invertebrates make up the major portion of the world's organismal biodiversity. They comprise approximately 70% of the 1,400,000 described species on earth (Wilson 1988). Arthropods are known to play essential roles in the flow of energy and cycling of nutrients in all ecosystems. They play primary roles as pollinators, decomposers, and are a primary food source for many other organisms. The objective of this workshop was to highlight examples of studies relating to arthropod surveys. The discussions focused on using survey information to facilitate wildland planning and management.

IMPORTANT ECOSYSTEM FUNCTIONS OF ARTHROPODS

T. D. Schowalter^a

Arthropods influence a variety of ecosystem processes that affect forest structure and forest health. Major ecosystem functions of arthropods include a) pollination, b) seed dispersal and predation, c) effects on primary productivity, d) effects on nutrient cycling processes, and e) effects on vegetation diversity, structure, and succession. Pollination is an essential function for many plants. Although dominant trees in

temperate forests are largely wind-pollinated, insects are important to pollination of many plants in temperate forests and are major pollinators in tropical forests. Seed predators can destroy entire seed crops, but species that cache seeds may be important in dispersing seeds to new locations.

Herbivores are known to affect primary productivity through growth suppression and mortality to hosts, but both herbivores and detritivores also can affect primary productivity through effects on nutrient cycling processes and altered vegetation composition. Herbivores and detritivores affect nutrient cycling processes in a variety of ways, including increased nutrient transport from living tissues to litter, fragmentation of litter and infusion with decay organisms, altered nutrient uptake, and altered composition of plants with differing nutrient usage. Herbivory typically is focused on stressed and/or abundant plant species.

Suppression or mortality to dominant plant species increases resource availability to non-host plants, resulting in increased vegetation diversity and transition to earlier or later successional stages. Fuel accumulation as a result of plant mortality can increase the likelihood of fire and initiation of secondary succession. Canopy opening and increased penetration of the vegetation by light, precipitation, and wind alters forest climate and hydrology, potentially affecting regional conditions.

Although most studies have implied redundancy of arthropod species' roles within functional groups, different species affect ecosystem processes in different ways, at different rates, at different times, under different environmental conditions. Few studies have evaluated these ecosystem functions experimentally for any species, but experimental measurement of arthropod effects on integrated ecosystem processes is necessary for balanced assessment of arthropod contributions or of the need for suppression.

TOTAL ARTHROPOD INVENTORY IN EASTERN DECIDUOUS FORESTS

John E. Rawlins^b

The potential of arthropod inventories for biotic assessment of forest communities was reviewed based on experience with ongoing inventories in Pennsylvania (PA) and West Virginia (WV) by specialists at Carnegie Museum of Natural History, collaborating with Allegheny National Forest, Monongahela NF, Western PA Conservancy, and WV Division of Natural Resources.

Historically, goals for arthropod inventory have differed among collaborators. USDA Forest Service and conservancy participants have emphasized gathering of information fostering effective management of particular species, primarily pest taxa for Forest Service management (e.g., gypsy moth, forest tent caterpillar, elm spanworm), and on species of special concern for Conservancy stewardship. Inventories expedite such species-specific goals by providing: (1) data on the occurrence and status of target species; and (2) current information on distribution and phenology of non-target species potentially influenced by management practices, especially pesticide applications. In contrast, Museum goals augmented by arthropod inventories have stressed basic systematic research, with inventory specimens explaining variation within both populations and species.

Recent management and conservation concerns have clarified new goals involved with forest arthropod inventories, particular those related to conservation of habitats and species of special concern. Forest managers using system-based approaches require inventory data that is ecologically and taxonomically more inclusive in order to determine the biotic status of numerous taxa and potentially for quantified assessment of "forest health." Museum-based collaborators have also shifted their attention to biodiversity issues. This new emphasis has increased their demand for specimen-based information, not just for research on phylogenetic relationships and distribution for numerous taxa, but to clarify and predict ecological associations between those species and other organisms, especially plants.

Experience has revealed four major issues that complicate biotic assessment using arthropods: (1)

limited expertise (lack of knowledgeable systematists for authoritative identifications); (2) appropriate sampling designs (need for multiple trophic levels, context with vegetation, and cost effectiveness); (3) necessity for specimen-based documentation (problems with sorting, preparation, curation, storage, and databasing); and (4) meaningful analysis of association.

Management application based on arthropod inventories should provide more than just predictions of spatial temporal occurrences for species. They should include selection of an indicator cohort of practical size to predict biotic condition of systems, and potentially, to diagnose "system health."

FORAGING HABITAT OF THE RED-COCKADED WOODPECKER: MANAGING TREES OR ARTHROPODS?

James L. Hanula,^c Kathleen E. Franzreb,^d and Kirsten C. P. New^e

Management and recovery efforts for the red-cockaded woodpecker (RCW), *Picoides borealis*, will involve nearly two million acres of southern National Forests, a large portion which will be managed to provide foraging habitat for this endangered species. Foraging habitat guidelines (U.S. Fish and Wildlife Service) specify foraging stand conditions in terms of tree densities and ages. More information is needed on RCW prey and how it is affected by forest management practices to effectively manage foraging habitat.

The RCW forages almost exclusively on the bark of live pine trees, so studies were initiated in 1992 to determine what arthropods were available in that habitat, where they come from, and which were selected as prey. Flight-intercept traps and crawl traps were arranged along the boles of mature (40-60 year-old) longleaf pines, *Pinus palustris*; pitfall traps captured arthropods associated with the soil/litter layer. Arthropod numbers and biomass were similar along the boles except in the canopy where both flight and crawl traps captured fewer specimens. A barrier placed at the base of some trees to prevent arthropods from crawling up the bole reduced the biomass of arthropods captured in crawl traps by 40-80% showing that a significant portion of the arthropod community on the bole is crawling up from the forest floor.

Automatic cameras were used to record the diet of nestling RCWs over three years and at three different locations. Wood roaches, *Parcoblatta* sp., comprised 25-81% of the diet of nestlings and were the most common prey selected regardless of year of observation or location. Other common prey included spiders, ants, centipedes, and wood borer larvae.

Studies of the effects of forest management practices on RCW prey are ongoing. A recently completed study of prescribed burning in RCW foraging stands showed that winter burning had little effect on common prey. Summer burning reduced both ant and spider biomass captured on the tree bole.

Although we are unable to recommend management strategies for the arthropod prey of RCW at this time, these results combined with ongoing studies will provide insight into how arthropod abundance and biomass vary with stand conditions, and how stands might be manipulated to increase prey abundance.

A FRAMEWORK FOR MANAGING FORESTED LANDS ON THE OCHOCO NATIONAL FOREST

Andris Eglitis^e

The Ochoco National Forest developed guidelines for managing forest vegetation in a manner consistent with ecosystem management principles. Vegetation was classified by aggregating similar plant association groups (PAGs). Each of these groupings of plant associations has unique disturbance regimes, distinct productivity, and hence distinct vegetative potential. The framework for management utilizes these PAGs as the basic units for analysis of plant succession, disturbance history (fire, insects, and disease), and wildlife habitat.

A seral/structural matrix was developed for characterizing forest vegetation within each of the plant association groups. This matrix is a departure from the classical plant succession model which describes five successional stages (very early, early, mid, late, very late). In the Ochoco seral/structural matrix, there are only three seral stages based on species composition (early, mid, and late), but each of these stages is subdivided into five size/structure categories (grass/forb/shrub, seedling/sapling, pole, small trees, large trees) based on the predominant size within the stand. This combination of size, structure, and species

composition was considered more suitable than the traditional linear plant succession model for describing the complex array of conditions that can exist on the landscape. The size/structure/species composition matrix is applied to each PAG for consideration of historic condition, existing condition, and desired condition.

Guidelines were developed to be applied at the subwatershed level for maintaining a balance of vegetative conditions. These guidelines include a "Desired Condition" which designates a target percentage and a range of percentages for each successional condition and structural class for each PAG. The percentages in the Desired Condition are generally within the range of variation which characterized the Historic Condition. Collectively, they provide for all of the possible combinations of size, structure, and species composition that are possible within the PAG, in such proportions that all of these conditions will be represented on the landscape at any point in time.

Existing conditions were derived from an analysis of satellite imagery provided by Pacific Meridian Resources. The pertinent satellite data were coded according to the matrix groupings of size/structure/species composition and were summarized through the Ochoco NF Geographic Information System. The consolidated GIS information was combined with plant association group maps to display the current vegetation patterns on the landscape.

It may require several decades to arrive at the Desired Condition, especially where watersheds are significantly out of balance. Watersheds will need to be re-evaluated at periodic intervals to determine the changes that have occurred and to re-assess the Existing Condition which is expected to be very dynamic over time. The Desired Condition may ultimately be a "moving target" that is sought but never achieved, serving mainly as a means of focusing management activities.

BIODIVERSITY AND ABUNDANCE OF GROUND-DWELLING ARTHROPODS IN THINNED AND DEFOLIATED HARDWOOD FORESTS

Rose-Marie Muzika^f

From 1989 to 1992 pitfall traps were used to monitor populations of terricolous arthropod fauna in 16 mixed hardwood / oak stands in north-central West Virginia. Specifically, spiders, ants, carabids, and phalangids (opiliones) were counted and identified to species throughout an 11-week period each of the four years. Eight of the stands were silviculturally thinned in late 1989, and six stands were defoliated by gypsy moth (*Lymantria dispar* L.) in 1990 and 1991. Defoliation and thinning appeared to create a similar response. The canopy-opening disturbances caused an increase in species diversity (species richness and evenness) in ants and carabids. At the same time, however, the abundance of ants and carabids was lower in thinned and defoliated stands, but 'recovery' of carabid abundance seemed to be enhanced by thinning.

Individual species responded to disturbance, e.g., *Camponotus pennsylvanicus* was predictably more common in thinned and defoliated stands, but only immediately following the disturbance. In general, natural variation in abundance of spiders and phalangids appeared to dampen any effect of defoliation or thinning. Species diversity of phalangids was significantly higher in defoliated stands than in thinned, defoliated + thinned, or control stands, but only in 1991. Species richness of spiders was far greater in defoliated stands relative to control stands, but diversity was relatively uniform, irrespective of stand type. Most significant effects of thinning or defoliation on arthropods endured only one or two years. Species-level analysis will provide more information about the distinct effects of thinning and defoliation and the natural variation in populations.

IMPLEMENTING THE PRESIDENT'S FOREST PLAN: VERTEBRATES, PLANTS AND THEIR ALLIES, AND ARTHROPODS

Roger Sandquist^l

President Clinton announced his "Forest Plan for a Sustainable Economy and a Sustainable Environment" in July, 1993. The forest management and

implementation portion of the strategy was analyzed through an EIS. The USDA Forest Service and USDI Bureau of Land Management jointly amended planning documents of 19 National Forests and 7 BLM Districts. The general impetus for these actions was the listing of the Northern Spotted Owl as an endangered species and controversies over managing old-growth forests.

Various standards and guidelines comprise an ecosystem management strategy. In addition to routine methods to mitigate effects, measures called "survey and manage" are implemented to provide benefits to rare species of plants and animals including certain amphibians, mammals, bryophytes, mollusks, vascular plants, fungi, lichens, and arthropods.

The species covered by the survey and manage provision include 234 fungi (boletes, truffles, chanterelles, coral fungi, and various saprobes), 81 lichens, 23 bryophytes, 5 amphibians, 2 mammals, 43 mollusks, 17 vascular plants, and 4 guilds of arthropods (canopy herbivores south range, coarse wood chewers south range, litter and soil dwelling species south range, and understory and forest gap herbivores).

General regional surveys are required for the four guilds of arthropods. The objective is to survey for poorly known taxa to acquire additional information and to determine necessary levels of protection. These surveys are expected to be both extensive and expensive, but the information is critical to successfully implementing ecosystem management. They will be initiated in 1996 and completed within ten years. Currently the general framework for the surveys is being discussed among the cooperating agencies.

THE INFLUENCE OF INSECTS AND DISEASES ON FOREST SUCCESSION: A NORTHERN IDAHO EXAMPLE

Jim Byler, Sandy Kegley, Sue Hagle, John Schwandt, Carol Randall, and Mike Marsden^g

Forest dynamics is sometimes viewed as an interaction between "succession" (trees) and "disturbance" caused by fire, insects, pathogens, management, and other influences. Results of an analysis in progress suggest a major influence of insects and pathogens on succession. Among other things, our analysis quantifies forty years of change in cover types and structural stages for a sample of stands across the

region, and we attribute most of that change to insects and pathogens. Using the Clearwater National Forest in northern Idaho as an example, we found that major insect- and disease-caused changes occurred during the period of our analysis, the mid 1930s to mid 1970s. There was a loss of stands classified as long-lived seral cover types (western white pine, ponderosa pine, and western larch) due to harvesting, bark beetles, and white pine blister rust.

There were also major changes in what might be considered short-lived seral species on these sites -- lodgepole pine due largely to mountain pine beetle, and Douglas-fir due to root diseases and Douglas-fir beetle. The native insects and pathogens apparently acted in historic ways, but the magnitude of their effects likely increased with increased lodgepole pine and Douglas-fir. Given the effects of the introduced white pine blister rust, effects of past management, and altered fire regimes, successional pathways and outcomes were quite different from those of the past. The net result was an unprecedented increase in climax cover types -- grand fir, subalpine fir, and western red cedar. It appears that these trends will continue, given current conditions of forest susceptibility to insects and pathogens and successional processes in progress.

The implications of these changes are very significant for planning, management, and biodiversity. Key forest planning questions are: are these changes caused by insects and diseases desirable? If not, what needs to be done to alter current trends? Management questions include: what actions are needed to maintain desired types and structures? or to restore those that have been lost and may be desirable? With regard to biodiversity, our assessment provides information on what tree cover types and structural stages have been or may be lost and why. Thus, we may want to restore white pine forests, and to at least maintain current amounts of mature ponderosa pine and western larch types, in part because they are likely to be key habitat for plant and animal species.

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FIRE/FOREST/INSECT INTERACTIONS

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The forest ecosystems of North America are a mosaic of vegetation types that have resulted from wildfires and other abiotic or biotic disturbances and the characteristics of slope, aspect, climate, and soil. The diversity and distribution of plants and animals within the forest depend on a combination of the above characteristics as well as those of each other. The distribution of terrestrial species of vertebrates and invertebrates depends in part on plant assemblages and their age and spatial distribution within the forest. Forest ecosystems are constantly undergoing change, and for long-term sustainability, utilization, and biodiversity, these forests must be managed. Changes in the health of forest ecosystems and the effects of forest management can be monitored by or reflected in changes in the density, species composition, range, and behavior of forest insect populations.

Disturbances of forest ecosystems have a direct and indirect impact on the diversity and abundance of species of insects. Fire and timber harvest have been the two major disturbances that alter forests in North America. Both types of disturbance provide habitats that attract bark beetles and wood borers the first year after the disturbance; however, these insect populations tend to decline after the first year unless further disturbance occurs. Recent outbreaks of defoliating insects such as the spruce budworm, *Choristoneura fumiferana*, have caused a decline in tree vigor, and a subsequent increase in infestation by bark beetles.

A classic fire/insect relationship begins with widespread tree mortality caused by defoliating insects or bark beetles. Here, a substantial buildup of dead, standing, and wind-thrown fuels can provide the basis for a fast-spreading, high-intensity fire. In addition, sites once occupied by green trees are then invaded with competing vegetation, which itself creates flash fuels when dry. The reverse also can occur, where fire damage precedes or predisposes trees to bark beetle outbreaks.

Fire regulates the regeneration of forests which serve as habitat for bark beetles and other forest insects. Bark beetles, in turn, regulate the age and composition of the forest and interrupt successional patterns. This interaction often leads to high forest diversity and productivity of hardwood species. Fires are beneficial for the reduction of destructive forest insects that inhabit the forest floor for part of their life cycle. By consuming the loose materials of the forest floor where many insects overwinter, fire provides an important mechanism for controlling them. In parts of Canada, prescribed fire is used to eliminate the favorable winter habitat of insects such as budworms, cone insects, and pine weevils.

The opportunity exists in most forest ecosystems of North America to use prescribed fire to manipulate forest insect pests and associated organisms, including bark beetles. Fire control interferes with the natural means of interrupting succession of forest stands, and results in dense, decadent forests which are highly susceptible to bark beetle infestation. The interactions among fire, forests, and insects are many, complex, and currently poorly understood. Given our current understanding and the renewed emphasis on the role of fire in forests throughout North America, forest entomologists should be poised to contribute to and learn from future uses of fire and conduct appropriate research.

EFFECTS OF FIRE ON FOREST INSECTS IN WESTERN FOREST ECOSYSTEMS

Terry J. Rogers^a

Forest insects are frequently overlooked when viewing forest ecosystems, especially when they are at low endemic levels. This appears to be an example of out of sight, out of mind. It is only when forest insects increase to outbreak levels and cause conspicuous damage to watersheds and landscapes that they become a concern to forest managers and the public. Insects

have coevolved with the successional process of trees and ground vegetation, with the growth and structure of trees and associated ground vegetation, and with the intensity and frequency of fires that occur in forest ecosystems.

Wildfire is a very complex process. It is affected or altered by many interrelated factors such as weather, geographical area, forest type, and site. Its occurrence can be one of the principal natural factors controlling populations of insects and diseases in forest ecosystems. Prior to European settlement in the West, wildfires often occurred over thousands of acres and were either suppressed by natural events or lack of fuel. These large, intense fires had a sanitizing effect on the ecosystem, often eliminating both pest and beneficial insects as well as their hosts for extended periods of time.

As indicated above, the interrelationships among fire and insects are complex. There are four principal effects of fire on insect populations:

Beneficial: those that benefit or favor insect populations.

Adverse: those that are harmful or detrimental to insect populations.

Direct: most visible immediate effects with consumptive and direct damage by flames; cause minor to severe mortality with effects on the host that are manifested in some degree of crown scorch; consume foliage or cause stem damage; cause insect mortality; and mortality to host plants.

Indirect: not readily evident, subtle, and include both beneficial and adverse impacts of heat and smoke; affect both plants and pest organisms.

Exposure of forest insects to temperatures greater than 60° C will usually result in mortality. The effects of exposure to lower temperatures for various periods of time are not well documented. Effects of smoke on insects is also not well understood although some insects such as buprestids and cerambycids are attracted to smoke.

PRESCRIBED FIRE IN FLORIDA'S PINE FORESTS: PROBLEMS AND POTENTIAL

James R. Meeker²

Recent population growth and associated development of undeveloped land has caused Florida's state government to conduct an aggressive land acquisition program for conservation/preservation purposes. Recent purchases have increased public ownership to over 19 percent of remaining forest lands, and currently exceeds 2.8 million acres. Management of these lands now emphasizes complimenting natural systems rather than single purpose management. This ecosystem management approach, in conjunction with recent recognition of the timing, frequency, and benefits of "natural fire cycles" and relaxation of strict fire prevention/control policies, has created a boom in prescribed burning. Agencies are reintroducing fire into numerous, long-established, fire-free stands because fire has been a dominant selective force that historically shaped and maintained pine ecosystems in Florida. This effort will hopefully restore public lands into healthy, native/natural, and/or presettlement condition ecosystems.

Prolonged absence of recurring fires, however, has created stands more susceptible to damage by fire, because of a higher density of trees, increased mid- and understory vegetation, and an accumulation of dead fuels. A "catch-22" situation has developed. The conditions of systems dependent upon fire have changed such that they are no longer as tolerant or resilient to fire's return. Fires are often intended to cause considerable pine mortality as part of rectifying these ecosystems. Many fire (re)introductions have caused extensive fire damage, fostering an increase in pest populations (e.g., *Dendroctonus* spp., *Ips* spp., *Hylastes* spp., *Hylobius* sp., *Leptographium* sp., and *Pachylobius* sp.) which have, in turn, lead to undesirable levels of post-fire tree mortality. Prescribed therapeutic fires can become triggering events for stand-destroying pest activities, with the potential to proliferate beyond burned areas.

With the recent, widespread acceptance and implementation of "growing season" burns, many unrestored systems are being burned at a time when pest insects are seasonally active. Given the expectancy of heightened insect activity, further understanding of the effects of "growing season" burns on tree susceptibility to insects is needed. Better

communication among disciplines facilitating wiser applications of fire, and consideration of alternative treatments, must occur to avoid undesirable insect and disease ramifications of fire, especially during restoration.

Using fire to manage pests of commercial pine forests warrants investigation based on advances in fire science. The safe use and beneficial effects of prescribed fire during the growing season, and in increasingly younger stands, may be tools applicable to pest management. For example, developing outbreaks of sawflies may be checked by prescribed fire given the susceptible location and low mobility of the insect's eggs, larvae, and pupae.

THE EFFECTS OF PRESCRIBED BURNING ON POTENTIAL PREY OF THE RED-COCKADED WOODPECKER IN LONGLEAF PINE

Kirsten New and Jim Hanula^b

The effects of dormant and growing season prescribed burns on the potential arthropod prey of the red-cockaded woodpecker, *Picoides borealis*, in longleaf pine, *Pinus palustris*, stands were studied in the upper coastal plain of South Carolina. Study plots were established in stands burned in the winter of 1991, 1992, 1993, and 1994, and in the summer of 1992. Four types of traps were used to sample arthropods in the litter layer, herbaceous understory, and on the bole of pine trees. Study plots were sampled for arthropod diversity in June, October, January, and April. The same plots also were sampled for numbers and biomass of potential arthropod prey weekly, from June 30, 1993 to June 30, 1994.

The different trap types had similar diversity and evenness, but most had low faunal overlap showing that they effectively sampled different parts of the arthropod community. When captures from all trap types were combined for each plot, arthropod diversity, evenness, abundance, biomass, and faunal overlap were similar among winter-burned plots, and when winter and summer 1992 burned plots were compared. However, when trap types were examined separately, differences were found among burn treatments. Spider (Araneae) diversity and evenness were similar among winter burns but diversity was higher in summer 1992 pitfall trap captures.

Among winter burns, spider numbers and biomass were highest in winter 1991 pitfall trap samples where spider populations had the longest time to recover. Winter and summer 1992 comparisons showed that the winter burn had higher spider biomass on the tree boles, and ant (Hymenoptera: Formicidae) abundance and biomass were higher in samples from both the tree bole and pitfall traps. Spiders appeared to be the only group affected by winter burning while spiders and ants were affected by summer burning. However, in general, burning had little effect on arthropods commonly used as prey by the red-cockaded woodpecker.

IMPACT OF ECOSYSTEM RESTORATION ON OLD-GROWTH PONDEROSA PINE RESISTANCE TO PHLOEM-FEEDING AND FOLIVOROUS INSECTS

M. R. Wagner, T. E. Kolb, S. R. Feeney, and J. E. Stone^c

Experimental restoration treatments were created to reconstruct the pre-European settlement forest structure and function in ponderosa pine, *Pinus ponderosa*, forests in northern Arizona. Partial restoration treatments consisted of recreating pre-settlement structure through thinning. Full restoration consisted of recreating pre-settlement structure through thinning and restoring the natural disturbance regime by the re-introduction of low-intensity fire. Five replicated experimental plots of the above two restoration treatments and an untreated control were used to examine the influence of treatments on resin flow, phloem thickness, and foliage toughness, characteristics presumed to be of importance to phloem feeding and folivorous insects.

Resin flow increased as a result of both the partial and full restoration treatments. Phloem thickness increased in one year but was unaffected in the second year by the experimental treatments. In the second year of the study, foliage toughness increased in five out of six sample dates with restoration treatments. Restoration treatments designed to recreate pre-European structure and function in ponderosa pine forests increased tree resistance mechanisms and would likely result in lower herbivory.

FIRE AND INSECTS IN JACK PINE ECOSYSTEMS

Deborah G. McCullough^d

Jack pine, *Pinus banksiana* Lamb., is an economically important boreal forest species in Canada and the Lake States region of the United States. It is a fire-adapted species with thin bark, volatile foliage, and serotinous cones. Jack pine is shade-tolerant and regeneration most commonly occurs only after fire or clearcut harvesting.

Outbreaks of jack pine budworm, *Choristoneura pinus pinus*, (JPBW) occur at six- to ten-year intervals and persist for two to four years. Larvae feed on pollen cones in spring, then move to current-year foliage once new shoots begin to expand. Severe defoliation can result in growth loss, top kill, and tree mortality. Accumulation of dead tops and trees increases the fuel load and risk of wildfire.

Recent studies in 104 jack pine stands in northern Michigan indicated that a 1991-1993 JPBW outbreak resulted in an average of 17% top kill and 8% tree mortality. Amount of top kill and mortality were related to tree age, indicating that both vulnerability to damage and accumulation of fuels increase as stands age. Spatial analyses indicated that stands with abrupt edges, typically adjacent to openings or recent clearcuts, sustained more defoliation than would be expected. Jack pine management in some areas of the Lake States has created a patchwork of small (<40 acre) stands, perhaps increasing vulnerability to JPBW and altering fire dynamics on a landscape scale.

Other research conducted in Wisconsin addressed ecological differences between seven- and ten-year-old trees on two sites that had regenerated after wildfire and similarly-aged trees on two sites that regenerated after clear cutting. Regeneration was dense on both burn areas; trees were taller but had smaller canopies than trees on the clearcut sites. Nitrogen concentration in jack pine foliage, understory vegetation, and litter was lower on the burned sites, probably due to nitrogen volatilization and loss during the fires. Survival of JPBW larvae caged on 20 trees on each of the sites was associated with foliar nitrogen concentration and was highest on seven-year-old trees in clearcut areas, where nitrogen levels were highest.

Abundance of other insects on the burned and clearcut sites also was examined. Insects were collected using pitfall traps and a sweep net along transects through each stand at two-week intervals during two summers. Predatory, sap-feeding, and foliage-feeding insects were more abundant on clearcut sites, while ants were more abundant on the burned sites.

Results indicated that fire and clearcut harvesting, the two disturbances which most often precede jack pine regeneration, may have different ecological effects. These effects could alter long-term vulnerability to JPBW and native insect communities in jack pine forest ecosystems.

EFFECTS OF A SPRUCE BEETLE OUTBREAK AND FIRE ON LUTZ SPRUCE STANDS IN ALASKA

Edward H. Holsten^e

The spruce beetle, *Dendroctonus rufipennis* (Kirby), has had a major effect on the spruce forests of south-central Alaska. In one area of the Chugach National Forest, 51 percent of Lutz spruce, *Picea lutzii* Little, or more than 90 percent of the commercial stand volume, was killed during the first ten years of an outbreak. Tree species composition remained essentially the same after the outbreak. Forest structure changed with decreased tree density, and species richness declined significantly on the spruce beetle-affected plots. This reduction in plant diversity was probably a result of the significant increase, and competitive advantage of, blue-joint grass and fireweed. Although species richness did not change seven years after a prescribed fire, species composition did change. Specifically, the occurrence and percentage of bluejoint and fireweed cover significantly increased.

The effects of bark beetle outbreaks and fire on wildlife habitat and forage species depend on the density of forage species before the beetle infestation and the wildlife species in question. For example, in the Rocky Mountains, heavily infested spruce stands had an increased density of grasses and forbs but forage plants showed a steady decline following infestation. This is similar to plant succession following beetle infestation on the Kenai Peninsula in Alaska. It was originally thought that increased light brought about by opening

of the stand through beetle-caused tree mortality would stimulate growth of intolerant shrub species such as willow.

Spruce beetle outbreaks produce a large source of fuels that in turn can increase the possibility of fire and increase fire intensity. The invasion of blue-joint grass following disturbance by spruce beetles creates a fire hazard when the grass is in the dry stage in early spring and late fall.

The accumulation of dried grass and fallen beetle-killed trees creates high-risk fuel conditions. As agents of disturbance, spruce beetles are one of the most important mortality agents of mature spruce stands. Various effects are associated with large-scale bark beetle outbreaks. Effects can be viewed positively or negatively, depending on the resource or resource use in question.

RELATIONSHIPS BETWEEN INSECTS AND FIRE IN NORTHERN FORESTS OF ONTARIO

Douglas J. McRae^a

A classic fire/insect relationship begins with the widespread defoliation of balsam fir, *Abies balsamea* (L.) Mill., by the spruce budworm, *Choristoneura fumiferana* (Clem.). Here, a substantial buildup of dead standing fuels can provide the basis for a fast-spreading, high-intensity fire. However, when wildfires occur first, they control budworm infestations since fires eliminate the balsam fir from the forest landscape. Balsam fir, a late successional species, is the primary food species for the budworm. Historically, wildfires covering large areas destroyed the balsam fir, thereby providing a formidable barrier against the spread of any spruce budworm outbreak. The lack of large wildfires to provide these barriers today allows the budworm to spread unhindered. In addition, fire exclusion favors the regeneration of balsam fir, which significantly improves the chances of a budworm infestation. The traditional 40-year budworm cycle has collapsed because wildfires, once a key component of the boreal forest, are not present anymore.

The jack pine budworm, *C. pinus pinus* Freeman, on the other hand, has had a minor influence on wildfire behavior, as this budworm usually only top-kills jack pine, *Pinus banksiana* Lamb. Even when infestations

are severe, areas of complete kill are small. Wildfire behavior is not significantly affected by the jack pine budworm, as the dead fuels remain attached to the tree for a considerable time and this does not increase the amount of woody fuels on the ground.

Wildfires are beneficial for the reduction of insects that inhabit the forest floor for part of their life cycle. By consuming the loose materials of the forest floor that these insects would seek, fire provides an important mechanism for controlling them. Prescribed fire is used to eliminate the favorable winter habitat of insects such as red pine cone beetle, *Conophthorus resinosae* Hopk., white pine cone beetle, *C. coniperda* (Shw.), and white pine weevil, *Pissodes strobi* Peck. The opportunity for further insect control through site modifications by fire needs to be explored for other insects, especially in hardwood forests.

Fire-killed trees attract insects, e.g., wood borers, that many insectivorous birds depend upon for their existence. Because of fire exclusion, some birds are becoming rare because of the elimination of this important food source. In Ontario, some silvicultural prescribed fires are being conducted to kill standing trees adjacent to the traditional slash burn areas. The objective of these fires is to attract the rare three-toed woodpecker by providing the necessary dead trees required to attract adequate wood borer populations for the bird's survival.

The boreal forests of northern Ontario were an example of a fire-adapted ecosystem. While the historical role of fire and its influence on the vegetation mosaic are well documented, the complex relationship between fire and vegetation has not been well investigated. Further studies need to be implemented to understand the consequences of eliminating fire as an important natural agency in insect population dynamics and control.

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NON-TARGET EFFECTS OF SUPPRESSION PROJECTS

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The impact of suppression projects on non-target species is frequently unpredictable, and often the subject of considerable controversy. Public concern about pesticides and their effects on a wide variety of organisms may strongly influence forest pest management practices.

The goal of this workshop was to bring together individuals from across North America who have experience with a wide variety of insect suppression efforts, and who have studied the effects of these efforts on diverse organisms.

It is likely that the large-scale aerial spray projects against highly visible forest defoliators have been most intensively studied. Indeed, a majority of our discussants addressed some aspect of this type of project. They did, however, present information on widely different control strategies, including chemical insecticides, growth regulators, *Bt*, and *Trichogramma* releases on different non-target groups. The results of studies on both arthropods and vertebrates were considered. In addition, the effects of forest management for southern pine beetle and its potential impact on an endangered vertebrate, the Red-cockaded Woodpecker, were discussed.

THE EFFECTS OF ONE OR TWO APPLICATIONS OF *BACILLUS THURINGIENSIS* ON NON-TARGET LEPIDOPTERA

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The impacts of one or two applications of *Bacillus thuringiensis* (*Bt*) on native, non-target Lepidoptera were studied in Virginia and West Virginia. From 1992-1994 in Virginia, larvae were collected from oak and blueberry foliage and from beneath burlap bands on oak trees from five paired plots. Light traps were used to examine the impact on adult Lepidoptera. One application of *Bt* was applied in 1992. After treatment, nearly four times as many macrolepidopteran larvae were collected from under burlap bands in control plots

than in treated plots and overall larval abundance was significantly different. Foliage collections (macro- and microlepidopteran larvae) and light trap samples showed minor, but nonsignificant, differences in abundance between control and treatment plots. Larval numbers under burlap rebounded in 1993 except for two species that were still significantly less common on treatment plots. There was a treatment effect on the adult noctuids (larvae in summer of treatment) collected in light traps from March - April, 1993. By 1994, the larval and adult populations appeared to have completely recovered.

In West Virginia during 1995, 15 plots were established: five with low gypsy moth (GM) densities, five with high GM densities (and possible defoliation), and five that were treated twice with *Bt*. A second objective of this study was to examine the effects of defoliation on native Lepidoptera. Burlap bands were placed on oak and maple trees and only macrolepidopteran larvae were collected twice a week. The high GM-density plots were beginning to show signs of defoliation until an outbreak of the fungus *Entomophaga maimaiga* suppressed GM populations, therefore no defoliation occurred in any plot. The total number of macrolepidopteran larvae collected from the low and high GM-density plots did not differ significantly, however, they were significantly different from treated plots. When larval totals were examined by family, the results were mixed. Both the noctuids and geometrids differed significantly between treatments. Lymantriids were not significantly different between low and high GM-density plots, but they differed from the treated plots.

After one application of *Bt*, macrolepidopterans collected from under burlap bands on treatment plots were reduced by 78%. Two applications of *Bt* resulted in an 87% reduction of larvae collected from treated plots compared to low GM-density plots. In conclusion, non-target Lepidoptera were significantly affected by one and two applications of *Bt*. Two applications of *Bt* appear to have a greater impact on macrolepidopteran populations.

THE USE OF DIMILIN TO SUPPRESS GYPSY MOTH POPULATIONS AND EFFECTS ON FOREST FLOOR ARTHROPODS

Rose-Marie Muzika^b

Despite the known environmental consequences of the use of the insect growth regulator diflubenzuron on aquatic invertebrates, few studies have examined the non-target effects on forest-floor dwelling arthropods. The impact on these organisms may be substantial, because previous research has suggested an increased flush of diflubenzuron to the forest floor with leaf senescence and leaf fall. We used data from pitfall traps for four years to examine how abundance and diversity of spiders, phalangids, ants, and carabids may be influenced by Dimilin (diflubenzuron) when applied for gypsy moth suppression in a mixed oak-hardwood forest in West Virginia. Within the forest were a variety of treatments: stands were sprayed with Dimilin, others were thinned, while others were defoliated by gypsy moth. There were control stands that had none of the aforementioned influences. Ant and phalangid abundance appeared to be unaffected by Dimilin, but there was a notable decrease in carabid abundance. More significantly, single species effects were obvious. *Platynus angustatus*, a carabid that may overwinter as an immature, declined significantly in stands that were sprayed, for two years following spraying. Dimilin had no effect on spider diversity and abundance. Juvenile spiders, a potentially vulnerable group, demonstrated no response to spraying.

IMPACT OF *Bt* ON CANOPY LEPIDOPTERA AND THEIR NEOTROPICAL MIGRANT BIRD PREDATORS

Marita Lih,¹ Kimberly Smith,^c and Fred Stephen¹

In 1994 and 1995, 10,150 and 7,150 hectares, respectively, were aerially sprayed with *Bacillus thuringiensis* var. *kurstaki* (*Bt*) in an attempt to eradicate gypsy moth, *Lymantria dispar* (L.), from the Arkansas Ozarks. Areas sprayed in 1995 were adjacent to but distinct from the area sprayed in 1994. Spraying in the Ozarks occurred in late April and early May, i.e. during the early breeding season of Neotropical migratory warblers. Most warblers feed their nestlings caterpillars gleaned from the forest canopy. This research examines effects of *Bt* spraying on abundance of forest canopy Lepidoptera and structure of the

breeding bird community. In 1994, four study plots were selected prior to spraying: two in the 1994 *Bt* treatment area and two control plots. In 1995, two additional plots were selected in the 1995 *Bt* treatment area. Canopy arthropod sampling and bird population censusing were conducted over several weeks in all study plots.

In both years mean numbers of immature Lepidoptera per kg dry foliage present in the current year's *Bt* treatment area and control area were similar prior to spraying. Abundance of caterpillars in sprayed plots dropped precipitously following *Bt* application, and remained lower for several weeks. By mid-July, mean numbers of caterpillars in sprayed plots were similar to numbers in control plots. Resurgence in Lepidoptera numbers in sprayed plots probably represents different species than were present at time of spraying. There was also relatively low abundance of caterpillars throughout May and into June 1995 on plots that had been sprayed in May 1994, indicating that recovery of early season Lepidoptera did not occur within the first year following spraying.

Forty species of birds were observed on control plots in 1994, and 35 species on sprayed plots. In 1995, 26 species occurred on control plots, 25 species on plots sprayed in 1994, and 31 species on plots sprayed in 1995.

In 1994, yellow-billed cuckoos (*Coccyzus americanus*) were absent from sprayed plots. Ovenbirds (*Seiurus aurocapillus*) were less common on the sprayed plots. In 1995, yellow-billed cuckoos were rare on plots sprayed in 1995, still missing from plots sprayed in 1994, and relatively common on control plots. Red-eyed vireos (*Vireo olivaceus*), scarlet tanagers (*Piranga olivacea*), black-and-white warblers (*Mniotilta varia*), and ovenbirds were more common on control plots than on plots sprayed in either year. These species are known to eat caterpillars during the breeding season.

Cerulean warblers (*Dendroica cerulea*), hooded warblers (*Wilsonia citrina*), and Acadian flycatchers (*Empidonax vireescens*) were found mainly on 1994 sprayed plots in both years. Data will be analyzed to evaluate whether vegetation characteristics explain the abundance of various bird species.

EVALUATION OF NON-TARGET EFFECTS OF *TRICHOGRAMMA* RELEASES

R. S. Bouchier^d

Trichogramma minutum is a polyphagous egg parasitoid currently being studied as a pest-management tool for use against forest insects in Canada. Recent experimental trials using *T. minutum* involved the aerial release of 480 million female parasitoids on 30 ha of boreal forest for suppression of the spruce budworm. The potential effects on non-targets by *T. minutum* are the dominant environmental concern associated with the use of this parasitoid for pest management.

Risk assessment is the scientific portion of the process known as risk management: a framework that integrates both science and policy to assist in decision making about activities such as pest management. The three stages of risk assessment ask: Who is going to be affected, how is the effect going to occur, and what will the effect be? These questions are followed by a decision that is based on an exposure ratio or, more recently, the comparison of experimental probabilities. The use of probabilities to make decisions is useful because it is quantitative; however, it requires the development of specific ranking methods to enable comparisons. Risk assessment methods can be applied to biological control programs if the appropriate methods of ranking effects are developed. It is critical to first define the organisms that are of concern and require ranking because it is impossible to assess all potential receptors (non-targets) in the system.

Field efficacy data and quality control data that are collected for most *Trichogramma* releases can be used to develop vulnerability rankings for non-target Lepidoptera. These rankings are based on the comparison of the functional response of the released parasitoid to the non-target of concern, and the parasitoid's response to an optimal host. Two indices that may be of use in developing vulnerability rankings are: (1) functional response-50: the number of female wasps at the maximum-host density of the optimal host that are required to kill 50% of the host eggs; and (2) host density-50: the host density that results in 50% parasitism of the host eggs. Our focus for the development of ranking methods for non-target vulnerability has been on assays associated with host acceptance and host suitability because of the relative ease of measurement. Consideration of host location

and host finding will provide additional ranking methods that link parasitoid ecology to risk assessment requirements.

IMPACTS OF SEED AND CONE INSECT SUPPRESSION ON NON-TARGET SPECIES AND THE CREATION OF SECONDARY PEST OUTBREAKS

Stephen R. Clarke^e and Gary L. DeBarr^f

Suppression projects against seed and cone insects in southern pine seed orchards have resulted in outbreaks of secondary pests such as scale insects and mealybugs. Research has shown this occurs in part because the scale insects are less susceptible to the insecticides used than are their natural enemies. Knockdown studies on individual trees have shown other effects of treatments. Spider numbers appear reduced by all insecticides, while lacewings are occasionally more prevalent in certain spray blocks. An increase in dolichopodid flies was observed in fenvalerate spray areas in one study. The impacts of such shifts in species diversity are unclear. Secondary pest outbreaks may become more commonplace as intensive forest management increases on industrial lands.

ASSESSING EFFECTS OF *BACILLUS THURINGIENSIS KURSTAKI* ON NONTARGET LEPIDOPTERA IN WESTERN OREGON

Jeffrey C. Miller^g

Studies assessing the effects of *Bacillus thuringiensis kurstaki* (*BTK*) on field populations of nontarget organisms should have a strong focus on species of Lepidoptera because of the mode of action of *BTK* and food web relationships. Coincident with nontarget Lepidoptera, studies on other species of arthropods, rodents, and birds are needed for a more complete assessment of impacts. The objective of this report was to present the results of nontarget assessment studies on Lepidoptera conducted in western Oregon associated with the use of *BTK* for control of the spruce budworm and the gypsy moth.

The decision on how to assess nontarget impacts following *BTK* treatment is dependent upon which life stage is to be sampled. Samples based upon adults (moths and butterflies) or larvae (caterpillars) require

different considerations regarding sampling techniques, advantages, and limitations in the acquisition of appropriate data. For instance, data regarding the larval stage of nontarget species must first consider potential indicator plants as the resource to be sampled. Field assessment on nontarget effects was performed by sampling certain plants for caterpillars in treated and untreated areas. The sampling technique involved standardized timed efforts with a beating sheet. Four such studies have been conducted in the forests of western Oregon from 1986-1995. One of the studies involved an assessment of adult insects using blacklight traps placed in treated and untreated areas. Overall, the field conditions involved: (1) eight plant species and their associated Lepidoptera; (2) rates of application ranging from 18-24 BIU per acre one to three times during May or June; (3) 540-240,000 treated acres; and (4) four project locations separated by a minimum of 250 miles.

In general, the results from the beating sheet samples indicated a 60% reduction in species richness, 85% reduction of individuals, and a 91% reduction in live mass during the first two months following treatment. The treated sites gradually approached pretreatment condition over the next two years. The results from the blacklight samples were not as resolute. Differences in moths only occurred during the fall months in the year of treatment. Perhaps the moth data are less sensitive to detecting impacts because of: (1) mortality factors other than *BTK* during development from larval to adult stages; (2) the time delay between the treatment and the life stage being sampled; and (3) detection of moths in the treated area that did not reproduce in the treated area.

THE IMPACT OF SOUTHERN PINE BEETLE SUPPRESSION ON RED-COCKADED WOODPECKERS

D. Craig Rudolph and Richard N. Conner^b

The red-cockaded woodpecker (RCW) (*Picoides borealis*) is an endangered species adapted to fire climax pine forests in the southeastern United States. The species requires pine and pine-hardwood stands with minimal midstory vegetation for foraging, and living pines of advanced age for construction of nest and roost cavities. Red-cockaded woodpeckers interact with the southern pine beetle (SPB) *Dendroctonus frontalis*, in complex ways. Pines dying of SPB

infestation are very rich sources of potential prey for the RCW. The birds feed extensively on SPB during the later stages of their development, and on the numerous other species of arthropods that occur on trees infested by SPB.

Both foraging and cavity trees are susceptible to mortality from SPB infestation. Thus, the potential exists for negative impacts on RCW populations. Recent data from eastern Texas indicates that SPB infestation is the largest single cause of cavity tree mortality. During epidemics, in excess of 25% of active cavity trees may be lost per year. Nearly all of this mortality occurs following infestation in the fall. Usually only single trees are involved. At the present time effective prevention of infestation is not possible. The use of inhibitory pheromones to deter infestation is actively being investigated, and an effective method of preventing infestation of cavity trees would be of tremendous value in RCW management.

Actively-growing SPB infestations (spots) have the potential to eliminate both cavity tree clusters and needed foraging habitat with negative consequences for red-cockaded woodpeckers. Current control measures involving tree removal are beneficial to woodpeckers to the extent that they limit tree mortality. Experience in Texas (wilderness areas vs general forest) clearly demonstrates that this benefit is substantial.

In summary, measures used to limit pine mortality due to southern pine beetles are of substantial benefit to red-cockaded woodpeckers, both in reducing loss of cavity trees and foraging habitat. Control measures that rely primarily on removal of pines do not pose an additional impact on RCW beyond the loss of pines. This loss is generally less than would be experienced without control efforts.

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USE OF MODELS IN THE STUDY OF INSECT POPULATION DYNAMICS

Moderators: J. Régnière¹ and J. A. Logan²

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Population ecology and, more specifically, population dynamics deal with problems that are characterized by high degrees of complexity and uncertainty. The complexity results from the fact that population behavior is the outcome of processes occurring at two different levels of organization: individual organisms and communities. Uncertainty stems from two sources: (1) a wide knowledge gap concerning the exact nature of many of the key processes involved in population regulation; and (2) the overwhelming number of factors that can have direct or indirect influences on population processes, which confer to populations an often erratic ("noisy") pattern of change. This stochasticity is believed to result from the combined influence of a large number of extrinsic factors that are either too poorly understood or too complex to take into specific account and are lumped together into the category of so-called "random perturbations" acting on the population system.

Complexity and uncertainty have made the use of models a very important tool in the conduct of population studies. The objective of population ecology is to discern and understand the causes of patterns of population change (Royama 1996). Such understanding can then be applied to predict future changes or modify them by management.

In selecting the topics for this workshop, we wanted to contrast two different types of models used in the study of population ecology: deductive and descriptive models. Deductive models are developed as a formal series of mathematical arguments derived from a few, clearly stated, premises and assumptions. Such models are true mathematical models in the sense that the procedure used to derive them (and often to study them) is essentially mathematical. They are often extremely powerful at clearly defining basic concepts such as persistence, stability, regulation, or density dependence itself (see Royama 1992). Two presentations in this workshop focused on the application of such models (time-lagged, autoregressive

stochastic processes) in the analysis and interpretation of observed population patterns (population time series).

Descriptive models are built from more or less detailed knowledge of selected ("key") processes in the ecology of a particular species. Here, mathematics are used more for their descriptive convenience than as a tool for logical deduction or induction. In fact, most such descriptive models use mathematics as an intermediate step towards computer programming. The primary use of descriptive models is as a communication tool to summarize the modeller's understanding of a population system and to generate or test hypotheses about emerging model behavior. Two presentations were devoted to this type of model: mountain pine beetle and spruce budworm population dynamics.

The first point of discussion, which became rather heated at some point, was the relative usefulness of the two types of modeling approaches. The main issue was the lack of a simple line of mathematical logic in the structure of descriptive models. The relative complexity of such models makes it difficult to quickly grasp the implications of model premises, assumptions, and equations. By contrast, deductive models are developed along a single, formal sequence of mathematical logic, so that the implications of all steps in their development are more immediately obvious to the mathematically inclined (which is not the norm among ecologists). In the case of a complex descriptive model, the audience has to trust the modeller's ability and art, and his/her ability to discover the main implications of the formulation used. However, judging from the amount of discussion that took place around each individual presentation, descriptive models (particularly the mountain pine beetle model) stimulated by far the most interest. This may have been partly due to the fact that their formulations and implications had to be explained in more detail after the presentation. However, it also may have been the result of the greater amount of biological detail involved in their description which ecologists could discuss.

A second point of discussion focused on the use of the term “noise” when referring to the influence of external factors lumped into the “random variable” category. It was suggested that “noise” should be restricted to the idea of “error” around population estimates (a strictly additive term), and that “perturbations” should be used when referring to factors that have an impact on the TRAJECTORIES adopted by the population processes rather than just adding fuzziness to that trajectory. In most population processes where density dependence must exist, the influence of external factors is filtered through the population system and becomes an intrinsic part of the population trajectory.

In summary, this was a very interesting workshop, at the end of which peace was made between proponents of diverging modelling approaches to population studies. Luckily, nobody suggested that models were not useful. Also, the issue of “simple” vs “big ugly” models (Logan 1994) was avoided altogether.

ROLE OF MODELS IN POPULATION STUDIES

T. Royama^a

Population studies depend heavily on the use of models. There are different types of models: descriptive, explanatory, deterministic, stochastic, linear, nonlinear, etc. These serve different purposes at different levels or stages of progress in research. A model is, by definition, not a real thing; it is a paradigm or idealization of essential features that we wish to abstract from observations. It is important to use a model within the scope it is designed for. An uncritical application and over-interpretation of a model results in distorted perceptions of population processes. [This presentation discussed the bases and caveats of time series analysis applied to population census data, by describing and applying increasingly “complex” linear stochastic processes to mimic observed time series with a view of inferring the underlying regulation structure.] []Added by J. Régnière.

DETECTION OF DELAYED DENSITY DEPENDENCE IN ECOLOGICAL TIME SERIES: EFFECTS OF AUTOCORRELATION IN EXOGENOUS FACTORS

A. M. Liebhold^b and D. W. Williams^c

Delayed density-dependence is important in regulating animal populations, and recent work has suggested analytical methods for its detection in population censuses. However, theory suggests that autocorrelation in an exogenous factor, such as weather, which acts in density-independent fashion, may give the appearance of delayed density dependence. We examined this question through stochastic simulations of a linear difference equation model and a discrete version of the logistic model, neither of which contained lags. The random term for the simulations was modeled as a first order autoregressive process. We varied the parameters that determine direct density dependence in the population models and autocorrelation and random variation in the exogenous factor, and subjected the resulting series to time series analysis and regression analysis. Using these methods, many simulated series were diagnosed with significant delayed density dependence, and the frequencies of significant cases also increased as the parameter for direct density dependence increased in the linear model, and decreased as r increased in the logistic model. We concluded by discussing generalist predators and weather as possible autocorrelated exogenous factors and urged caution in the use of single-species models and analyses in predicting populations and diagnosing their regulation.

TEMPORAL EVOLUTION OF SPATIAL PATTERNS IN MOUNTAIN PINE BEETLE OUTBREAKS

James Powell^d

We discussed how aggregative population movement can generate spatial heterogeneity, using a model for the chemotactic movement of the mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins) and its ‘predator-prey’ interaction with host species, in particular lodgepole pine (*Pinus contorta* Douglas). Since the prey species is immobile, the predator disperses only once a year, and the details of the

interaction are well-understood qualitatively, we have a singular opportunity to examine deterministic creation of spatial-complexity in an important ecological system.

We have examined the ecological impact of the model's spatial pattern formation. Preliminary indications are that endemic MPB dispersal is dominated by environmental considerations. In epidemic infestations, dispersal is initially seeded by environmental factors, but correlation is rapidly lost. The influence of detailed ecological circumstances on model output, including distribution of sources, timing and density of emergence, indicates that population models without spatially-extended dynamics will never be descriptive.

A SIMPLE MODEL OF INTERACTIONS BETWEEN VARIOUS GROUPS OF NATURAL ENEMIES AND THE SPRUCE BUDWORM

Jacques Régnière¹

A simple descriptive model is being developed to investigate the outcome of the interactions between spruce budworm and its major natural enemies as a function of environmental conditions. In this model, natural enemies have been divided into three groups: generalist predators, the microsporidian *Nosema fumiferanae* (Régnière 1984), and multivoltine parasitoids that require alternative hosts for completion of their life cycle. A logistic function is used as a description of interactions with host plants. Preliminary investigation of the behavior of this model was presented. Interesting parallels can be established between model outputs and actual budworm populations in terms of the changes in relative importance of the three groups of natural enemies over the course of an outbreak. Also, there are striking resemblances between model output and observations in terms of outbreak severity, duration, and frequency, in response to changes in parameter values reflecting changes in environmental conditions (habitat harshness and species diversity).

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INCREASING PUBLIC AWARENESS OF FOREST ENTOMOLOGY

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Increasing public awareness of forest entomology was addressed in this interactive workshop. The workshop was divided into five topics: (1) reaching the individual in a one-on-one situation; (2) reaching a group of interested (or involved) citizens; (3) making an international presentation on an economically important forest insect; (4) discussing with a regional audience the importance of including forest insect and disease impact in a regional assessment program; and (5) emphasizing importance of involving private agencies in presentations and preparing forest entomology for children, varied audiences, and education groups.

Presentation of materials to increase public awareness included one page hand-outs on forest pests or current forest pest problems. The emphasis was on accurate, economical, and easy to disseminate information. Examples included one-page flyers on the southern pine beetle, *Dendroctonus frontalis* Zimm., and posters of current forest insect conditions or availability of information. The latter included a poster of Forest Insects of Mexico (Insectos Forestales de México) that depicted the availability of this reference book. The use of posters is important for a broad audience with material that has a long time span. Posters are fairly expensive to produce and care must be taken in their presentation and distribution. Their use as hand-outs for pest alerts in a small format (8 ½" by 11") was presented as an alternative.

Pest leaflets and booklets on forest insect pests are an excellent presentation but expensive to produce and distribute. Examples include the USDA Combined Forest Pest Research and Development Program, Southern Pine Beetle Handbooks. These handbooks, produced in color, were distributed through the SPB program and used as teaching guides and for forest insect education and awareness.

Video presentations were discussed as a rapid method of reaching a broad audience in a short period of time. An example included the SPB outbreak in Gainesville, Florida. Due to the high value of the pines attacked

and the need for rapid response for detection and control, interviews were conducted for local television. A longer VCR tape was produced on the southern pine beetle in Florida. Other examples include "Living with the Southern Pine Beetle," Forest Pest Management, Southern Region, USDA Forest Service; and the ambrosia beetle in British Columbia. The importance of audience presence and presentation were stressed for successful.

Slide presentations were deemed the mainstay of professional presentations for conveying information to a broad audience in a short period of time. Examples of the Asian gypsy moth were presented as an example of an internationally important forest insect pest. Attributes of survey and detection, direct control, education, biology, regulation entomology, and working in an international arena were presented. The use of slide programs and CD-ROM technology were emphasized for future presentations. Examples discussed included the Forest Insect CD produced for southern forest insects. This format will see increasing emphasis as computer use expands.

Also included in this discussion was the use of the world-wide web for posting of forest entomology information. Interactive web sites are expected to increase rapidly. Interactive classroom sites for education were presented. Forest entomology for children was presented with a display and Insect Expo, both sponsored by the Entomological Society of America. Individual classroom presentation, teacher workshops and conferences, and the importance of educating youth on the fascinating world of forest insects were discussed. A need for increased emphasis on youth education was recommended with emphasis on newspapers, interviews, hands-on field days, and visits.

REACHING THE PUBLIC ONE BY ONE AND RUNNING PEST MANAGEMENT WORKSHOPS

Herbert A. (Joe) Pase III^a

Providing information and education concerning plant health/pest problems is an important part of my job and that of other forest entomologists. I think there are two ways this task can be approached. First is the "mass communication" method where large groups of people are provided information about pest problems. This usually takes the form of a talk or demonstration given at a meeting, seminar, training session, etc. and may be in a classroom or field environment. Second is the one-on-one contact with the person who seeks information about a pest problem, usually on-site. Both methods have advantages and disadvantages, and both methods should be used by entomologists to provide information to the public. From my personal experience, the one-on-one contact seems to leave the customer the most satisfied; however, it may not be the most efficient use of the professional entomologist's time.

The expertise needed to provide the public with pest information and the time and effort expended by entomologists in this area often go unnoticed by administrators. I summarized records of telephone requests for on-site visits related to pest problems for a four-year period and responded to over 60 different problems. Bark beetles and tree problems related to construction damage were the two most common evaluations. Some of the more unusual requests included Africanized honey bees, skunks, squirrels, meloids in alfalfa hay, herbicides, duck weed on ponds, mailing pine seed to Africa, leaf scorch from a portable BBQ pit, ball moss, "squid" beetles, hickory-horned devil, and others. The most frustrating problem for me to diagnose is decline and death of hardwood trees when no insect problem or site disturbance is found.

Organizing and hosting pest management workshops and seminars can be an important part of an entomologist's job. The Texas Forest Service organized the East Texas Forest Entomology Seminar in 1973 and this group has met twice per year for over 20 years. The seminar consists of a series of 30-minute talks by invited participants on forest pest research, applications, current pest problems, among other forest entomology topics. It is now co-hosted by Stephen F. Austin State University, College of Forestry and the Texas Forest Service. Participants include Texas A&M

University, University of Arkansas, Louisiana State University, Mississippi State University, USDA Forest Service, forest industry, and others. The ETFES begins at 1:00 p.m. on Thursday and concludes at noon on Friday, usually in April and October. A meal is served on Thursday evening and is followed by an informal presentation of entomological or biological interest. With an attendance of about 50 people, organizing and hosting the ETFES is not particularly difficult to do. Larger meetings take more time and effort. The Texas Forest Service was heavily involved in hosting the Southern Forest Insect Work Conference in San Antonio in 1987, the National Oak Wilt Symposium in Austin in 1992, and the North American Forest Insect Work Conference in San Antonio in 1996. Each of these meetings required considerable time and effort to organize and host.

REACHING THE PUBLIC: THE SOUTHERN PINE BEETLE EXAMPLE, GAINESVILLE, FLORIDA

James R. Meeker^b and John L. Foltz^c

No record of southern pine beetle (SPB), *Dendroctonus frontalis* (Coleoptera: Scolytidae), occurrence in Gainesville, Florida, existed prior to the detection of an outbreak in April 1994. The presence of this "new" pest in the urban area required educating numerous homeowners about the insect's biology, behavior, dynamics, and control. The overall information and education effort was informally coordinated at regular meetings of the SPB Technical Advisory Committee (TAC). As part of the coordination effort, members identified needs and agreed upon who would develop the appropriate communication. Newspaper, TV, and radio reporters frequently attended committee meetings and greatly assisted in the information effort. Many information sheets and brochures were developed, each created with specific messages for specific audiences. TAC members participated in radio forums and festival displays; members spoke to just about every group wanting SPB information. In summary, the presence of the multiagency, multidisciplinary TAC greatly facilitated the information and education component of the SPB suppression program. Citizens, government agencies, and the news media all had a single source for answers to their questions and concerns. Word processing and desktop publishing provided factual and

timely information in language and formats suitable for audiences ranging from individual homeowners to professional societies.

INCREASING PUBLIC AWARENESS: THE ASIAN GYPSY MOTH STORY

William E. Wallner^d

Accidentally introduced into Vancouver, British Columbia, Seattle, WA, and Portland, OR, in 1981 on Russian grain ships, and then into Wilmington, NC, in 1993 on military equipment and munitions, the Asian gypsy moth, *Lymantria dispar* (AGM), was considered a serious threat to North American forests. This strain, indigenous to the Russian Far East, Siberia, and China, possesses behavioral and physiological traits (female flight, broad host range, premature egg hatch, etc.) lacking in gypsy moth originally introduced from France in 1869. A rapid response was necessary to alert and educate decision makers, policy makers, regulatory officials, and the general public. Following are the procedures and materials used in increasing public awareness to this diverse audience.

It was fortuitous that essential knowledge and experience with AGM was available and clear responsibility was assigned to the USDA Forest Service to support the Animal and Plant Health Inspection Service's regulatory activities. This permitted creation of a video entitled "Dr. Bill Wallner and the Asian Gypsy Moth," which was viewed by the Secretary of Agriculture, among others, for determining the need for releasing emergency funds for agencies and universities to deal with the problem. It proved useful in educating federal, state, and industry personnel and the general public in the U. S., Canada, Germany, Australia, New Zealand, and Russia.

To assess research needs, a panel of international scientists was convened and a five-year program charted that was widely distributed in published proceedings of scientific meetings. The international impact of this pest prompted the newsletter, *Gypsy Moth Exotica*, distributed to more than 200 officials on an irregular basis. It described research accomplishments, program implementations, emerging problem areas, etc. It proved particularly useful as an unbiased briefing document for public officials. In addition to radio, TV, and national newspaper releases, presentations were made at industry trade meetings and

university-sponsored forums. These were accompanied by semi-technical color brochures and other publications. The sheer rapidity of new introductions, scope of action programs, and need to coordinate international trade procedures prompted creation of the AGM bulletin board on the Internet. The overall success of the AGM program has led other countries to adopt this educational approach.

THE SOUTHERN APPALACHIAN MAN AND THE BIOSPHERE PROGRAM

Robert C. Thatcher^e

The Southern Appalachian Man and the Biosphere Program (SAMAB) was initiated in the mountains of Georgia, Alabama, South Carolina, North Carolina, Tennessee, and Virginia in 1988. The area was designated by the United Nations Educational Scientific and Cultural Organization (UNESCO) as a multi-unit biosphere because of its unique geological, biological, and cultural characteristics.

The Program is a public/private partnership that seeks to promote the achievement of a sustainable balance between the conservation of biological diversity, economic development, and maintenance of associated cultural values. The Program accomplishes its objectives by collaborating with stakeholders in information gathering and sharing, integrated assessments, and demonstrative projects directed toward the solution of critical regional natural resource management and economic development issues.

Six management units are currently parts of the Southern Appalachian Biosphere Reserve: (1) the Great Smoky Mountains National Park; (2) the USFS Coweta Hydrologic Laboratory (near Franklin, NC); (3) the Oak Ridge National Environmental Reserve Park; (4) Mount Mitchell State Park Center, Asheville, NC; (5) Grandfather Mountain Center, Boone, NC; and (6) the Tennessee River Gorge Tract Center, Chattanooga, TN. Other areas are being considered for inclusion in the Reserve.

Six working committees, manned by representatives from public and private organizations, take leadership in defining issues, developing plans of work, and implementing a variety of projects. Many projects and programs have or are being addressed during the life of the SAMAB program, as follows:

- I. Environmental Monitoring and Assessment
 - A. Forest health monitoring
 - 1. Three workshops on insects and diseases affecting forests held across region.
 - 2. Grid network of 100 plots established in SAMAB zone of cooperation. Data gathered on agents/events threatening forest health. Summary reports released.
 - B. Landscape ecology and monitoring
 - 1. Two workshops held on integrated ecological assessments.
 - 2. SAMAB collaborating with EPA EMAP Program in landscape scale modeling and analysis
- II. Sustainable Development and Technologies
 - A. Two regional workshops held concerning understanding sustainable development and strategies for implementation.
 - B. Community strategic planning
 - 1. Assistance provided to Pittman Center, TN, in developing a strategic plan for economic development and tourism. Report published.
 - 2. Similar assistance planned for other communities.
 - 3. Geographic Information Systems Regional GIS system being developed.
 - 4. Best management practices. Workshops held on forestry BMPs.
- III. Conservation Biology
 - A. Wetlands. SAMAB sponsored regional conference on upland wetlands
 - B. Use and protection of native plants Regional workshop held to determine needs and opportunities for sustaining, using, and protecting native plants.
 - C. Research on native trout and their habitats Workshop held to determine research needs for maintaining and enhancing trout population and their habitats.
- IV. Ecosystem Management
 - A. Demonstration area White House Interagency Track Force on Ecosystem Management recognized SAMAB program as demonstration area for ecological assessment and ecosystem management.
 - B. Air quality management
 - 1. SAMAB published and distributed a brochure on "Understanding Air Pollution in the Southern Appalachians."
- 2. SAMAB supported planning and implementation of Southern Appalachian Mountain Initiative (SAMI), an 8-state consortium of public and private groups concerned with air quality impacts on Class I airsheds in region.
- C. Program partnered with U.S. Forest Service in Chattooga Ecosystem Demonstration Project.
- D. SAMAB collaborated with U.S. Forest Service, EPA, and other agencies in Southern Appalachian Assessment. More than 150 participants were involved in program.
- V. Environmental Education and Training
 - A. Program sponsored preparation and distribution of Directory of Environmental Education and Training (in member organizations) to all public schools and libraries in SAMAB region.
 - B. Videos, posters, and teacher guides prepared on: (1) introduction of red wolf into Great Smoky Mountains National Park; (2) fate of water from mountains to coast; and (3) dogwood anthracnose copies supplied to all schools and libraries in SAMAB region. Similar materials being prepared on other topics.
- VI. Cultural and Historic Resources
 - A. Workshops held that led to a cooperative program to preserve and promote Southern Appalachian cultural resources.
 - B. Data bases being developed for regional cultural resources.
- VII. Public Information Education
 - A. SAMAB newsletter SAMAB news released several times each year.
 - B. Conferences SAMAB spring planning and fall conferences held each year.
 - C. Program I & E Program color brochure (revised 1996), video, tabletop display (revised 1996), and slide talk prepared and utilized region wide.
 - D. INTERNET SAMAB Home page set up. Describes SAMAB program and summarizes results from Southern Appalachian Assessment.
 - E. Summaries of Southern Appalachian Assessment four technical reports, semi-popular summary report, and five CD-ROM set released in 1996.

- F. Biosphere Reserve visits
SAMAB hosted visitors from Poland, Germany, Czech Republic, Slovak Republic, Indonesia, and China. SAMAB delegations visited Czech and Slovak Republics to share experiences and/or set up international cooperative programs.

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ECONOMIC ANALYSIS OF PEST SUPPRESSION PROJECTS

Moderator: Roy L. Hedden¹

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The papers presented in this workshop are a sample of the type of investigations which involve the economic analysis of forest pest suppression projects. Rigorous economic analyses of pest impact are still lacking for many of the most important forest insects and diseases. There are many reasons for this lack of data. For many pests, there are few long-term studies where both impact and insect population level have been monitored. For some pests, such as the gypsy moth, adequate data on non-timber impacts to homeowners, recreation, and wildlife are lacking due to the difficulty in documenting these impacts. There is also disagreement among forest economists on the appropriate methods to apply to this problem, and to the scale (individual stand, ownership, society, etc.) at which these analyses should be performed. Lastly, social and political considerations drive many pest management decisions resulting in economic criteria being of only a secondary consideration.

The discussion following the presentations raised many interesting questions. They illustrated both the limitations and the strengths of applying economic analyses to pest data. The discussions also stressed the need for more work in this important area of forest pest management.

ECONOMIC IMPACTS OF THE INTRODUCED PINE SHOOT BEETLE

William A. Leuschner and Thomas J. Straka¹

Economic impacts are changes in the production level, production cost, or distribution of production and costs of socially-useful forest products. *Tomicus piniperda* kills new shoots and one-year laterals, may carry blue stain, and may cause growth loss or mortality during severe infestations. Spread throughout the Midwest, and particularly to the southern pinery, it is a major concern. Timber impacts might include changes in the quantity and/or quality harvested and in production costs. Impact is measured by the change in the present value of the attacked timber stand at harvest, without

and with the attack. Urban forest impacts might include the costs of spraying and of replacing damaged or dead trees. Christmas tree plantation and ornamental nursery impacts might include spraying cost and reduced market value of trees attacked with or without spraying. The APHIS quarantine may cause income distribution impacts within the region. Formulas for tentative regional impact models were presented.

ECONOMICS OF THE USE OF SEMIOCHEMICALS

B. Staffan Lindgren^a

The economics of semiochemical use have been affected to a large extent by their inclusion under the umbrella label of "pesticides" by regulatory agencies in the United States and Canada. The literal translation of "pesticide" is "killer of pests." Semiochemicals do not kill pests, thus they do not fit under this category. This may seem like nothing but semantics, but the broader issue is public perception. Semiochemicals are lumped with some pretty nasty materials because of what they are used for, rather than what they are. By lumping semiochemicals under the "pesticide" umbrella, they are perceived as bad by the general public. After all, the public associates pesticides with "Silent Spring." This in turn maintains public pressure on regulatory agencies to treat semiochemicals as they would other pesticides.

Economics of semiochemicals are different from conventional pesticides for a number of reasons. Their mode of action precludes instant gratification on the part of the end user, and the economics of scale make research, production, registration, and application costs relatively expensive. Semiochemicals are rarely used in isolation, but rather as one of many tools in an integrated and sustained pest management system.

ECONOMIC EFFICIENCY OF THE FOREST PEST MANAGEMENT (FPM) PROGRAM

Joe Lewis^b

The objectives of the analysis were to determine if the FPM program (of the USDA Forest Service) is operating efficiently, and to assess and improve our ability to evaluate the program in a systematic fashion. The analysis is part of an on-going effort to use a systematic, analytical approach to program evaluation and management. We have developed an analysis framework, delineated FPM program activities, defined FPM benefit categories, and identified some general assumptions and data common to all Regions.

Program activities were evaluated in a "with and without" framework. We asked what would happen if a program activity is implemented and what would happen if it is not implemented. Scenarios were developed for each situation, and the benefit of the activity was the difference in cash flows with and without the FPM program activity. Results indicated that, overall, the nation-wide FPM program is operating efficiently at a cost of \$9.5 million and benefits exceeding \$56 million. There were indications that efficiency can be improved in some program areas. These areas will be examined in greater detail to determine if program changes are warranted.

In all, 134 production functions were developed. Collectively, they represent the 1989 National FPM program, covering all pests and all forested lands, regardless of ownership. The largest program activity was technical assistance, accounting for 40 percent of the total expenditures. The largest benefit category was "increasing volume at harvest," accounting for 42 percent of total present net value. The activities with the largest expenditures did not have the highest B/C ratios. In fact, some of the highest B/C ratios came from relatively low-cost activities.

In conclusion, this analysis demonstrated that program activities (primarily services) can be analyzed in a systematic fashion. The analysis provides needed information on the effectiveness and efficiency of the FPM program on a national as well as regional basis. We will use this information to improve program efficiency over time.

COSTS ASSOCIATED WITH URBAN GYPSY MOTH CONTROL BY ARBORISTS

Christopher D. Vaughn,^f Thomas J. Straka,^f Roy L. Hedden,^f Donald D. Ham,^f and Kevin W. Thorpe^c

The European gypsy moth, *Lymantria dispar* (L.), is an introduced forest pest that has significantly impacted hardwood forests and urban environments in the northeastern United States. In urban settings, high-density gypsy moth populations generate enormous public concern. This is primarily due to the loss of aesthetic value after defoliation, the nuisance created by the presence of large numbers of insect larvae, and the fear of losing highly-valued shade trees. The objective of this study was to provide a cost analysis of residential gypsy moth management programs. Cost data were obtained from two large commercial tree care companies in the Northeast. On average, pest suppression services in the eastern region cost the residential property owner \$104.70 per hour (does not include materials). This cost per hour was broken down into six major components: (1) labor; (2) administrative overhead; (3) equipment; (4) materials; (5) mobilization; and (6) profit. Labor, equipment, and overhead costs accounted for approximately 48% of the total cost to the customer. Mobilization cost which includes travel and setup time accounted for 14%. Materials costs were highly variable depending on the type of insecticide and the amount applied to each property. A preliminary estimate of 21% of the total cost was assigned to this category.

POTENTIAL ECONOMIC IMPACTS OF GLOBAL CLIMATE CHANGE ON FORESTS OF THE SOUTHEASTERN UNITED STATES

J. E. deSteiguer^d

An integrated assessment modeling framework was used to examine the biological and economic impacts of 60 years of simulated global climate change on pine forests of the southern U.S. Four climate change scenarios were developed from four General Circulation Models (GCM). These GCMs included the Oregon State University model, the Goddard Institute for Space Studies model, the United Kingdom Meteorological Office model, and the General Fluid Dynamics Laboratory model. The climate variables included precipitation and temperature. The integrated assessment framework consisted of a southern pine tree

physiology model (PnET-IIIs), a system for projecting regional forest changes, and a model of southern pine timber markets.

Simulated global climate change-induced impacts on regional pine forests resulted in biological and economic losses. The economic losses varied depending upon the climate scenario. The United Kingdom Meteorological Office model projections of forest losses were so large as to be regarded as catastrophic, thus they were not subjected to further economic analysis. Of the three remaining GCMs, simulations with the General Fluid Dynamics Laboratory GCM yielded the largest economic losses, equal to about 26% of annual market surplus. Simulation from the Oregon State University and the Goddard Institute for Space Studies GCMs yielded economic losses equal to 10% and 12% of annual market surplus, respectively. Future improvements in the integrated assessment framework will include a CO₂ module on the tree physiology model.

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HISTORY OF FOREST INSECTS AND DISEASES

Moderator: Jack E. Coster¹

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Why consider history of our professions? Obviously, we stand to learn something from the past. It has been said that "History balances the frustration of 'how far we have to go' with the satisfaction of 'how far we have come.' It teaches us tolerance for the human shortcomings and imperfections which are not uniquely of our generation, but of all time (Lewis Powell). But Clarence Darrow noted that "history repeats itself. That's one of the things wrong with history."

In spite of the differences in opinion about the value of history, this workshop launched itself on an examination of history in forest entomology and pathology. To prevent us from ranging too widely into antiquity, we decided to focus on events and trends of the recent 25 years.

All of the workshop participants contributed to a brainstorming session. The question to brainstorm was, "If we were developing an outline for a book on the history of forest entomology and pathology over the past 25 years, what issues, trends, or significant events would we include in the book?" Here are the workshop suggestions:

- ◆ The continued introduction of exotic pests into America and the impact of previously introduced pests.
- ◆ Changes in teaching in university and college curricula, especially the reduced emphasis of forest biology in forestry curricula.
- ◆ Rising acceptance of the notion that all problems in forest protection can be solved, i.e. "technology can solve all."
- ◆ Renewed recognition of the high value and usefulness of much "pioneer" research done by the first generations of forest entomologists and pathologists.
- ◆ Integration of "non-wood" considerations into nearly all phases of forestry planning and operations.
- ◆ Increased knowledge and information about the "pre-European settlement" conditions in North American forests.

- ◆ The strong contributions of forest entomology and pathology to understanding forest biodiversity and to improving management risk assessments.
- ◆ The high value of the results of the integrated pest management ("big bug") programs and the lessons learned about the value of interdisciplinary research efforts.
- ◆ The increase in environmental activism and its effects on the practice of forestry.
- ◆ Reduced funding for forest pathology and entomology research and how this is beginning to create a gap between research knowledge and research applications.
- ◆ The continuing apparent lack of adequate basic technical competence of forest practitioners in entomology, pathology, and tree care.

Mary Ellen Dix^a summarized history in forest insect research in the western U.S. Early research was on broader groups of insects (e.g., bark beetles) but current efforts are targeted to key insects and their interactions. Pests in urban environments have received increasing emphasis.

Prior to the 1950s, insect work was of the natural history type. In the 50s-60s there was increased emphasis on life table analyses and silvicultural control. Biocontrol research took hold in federal, state, and university research programs in the 1960s. The 1970s saw the advent of the "big bug" programs and considerable output in the form of models of interactions. And in the 80s, and to the present time, researchers have increased emphasis on IPM, genetic engineering, ecosystem management, and forest health relationships to insects and pathogens. Research on exotic pests has increased.

Research has increasingly found need to be interdisciplinary. The kinds of partnerships forged in research and applications in forest protection have seen change. Researchers and practitioners in forest protection often teamed with state, federal, and industry organizations with direct interest in forest practices during the 1960-1980s period. In the 1990s we see the

entrance of environmental groups into research formulation and planning as well as into the implementation of research and operational plans. This has required new understanding on the part of the forestry research community.

William MacDonald^b reported on the trends in forest pathology research and practice. A major concern of pathologists in the U.S. is the decline in the numbers of professional and scientific practitioners. This is reflected in the downward trends in numbers of pathology professionals in the U.S. Forest Service. Additionally, there is a dilution of forest pathology and entomology in the curricula of many U.S. forestry schools. Pressures on the curricula have resulted in combined courses of entomology-pathology-fire protection. Although there are some pedagogical advantages to such “team-teaching”, there is also a total loss of technical content in each of the disciplines that are combined.

Early forest pathology, like early forest entomology, was characterized by an emphasis on descriptive studies. In pathology, that era gave way to an emphasis in research and practice of implementation of biocontrol measures. In the 1990s, pathology too is attempting to place itself in the context of developing healthy ecosystems.

What’s in the future for entomology and pathology? Will our areas of forest biology be further de-emphasized as forestry (especially public forestry) increases attention to delivery of amenity products of the forest? How closely is the future role of forest entomologists and pathologists in forestry tied to the reputation of foresters themselves as deliverers of sound advice and practice? The amazing advances in semiconductor technology have led to computational capabilities that were unimagined 25 years ago. Have our fields been too taken with our new-found data manipulation and analytic capabilities to the extent that we are running short of “real” data as the basis for new research break-throughs?

Through our perception of the past, most of us make some attempt to estimate what the future may hold. Why should we try to look ahead? “Perhaps the greatest impulse to trying to foresee and plan the future comes from the combination of having new tools with which to do it and the growing realization that every

technological and social innovation has repercussions which spread like a wave through the complex interlocked sections of society.” (Ward Madden).

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BARK BEETLE GENETICS

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This workshop was organized to re-visit and update the discussions of the Bark Beetle Genetics Workshop that was held in Berkeley, CA, in May of 1992 (Hayes and Robertson 1992). At that time, there was a consensus among the organizers and participants that, despite the intensive research efforts aimed at bark beetles, comparatively little attention has been directed toward genetics. Consequently, we know very little about the contribution that genetical research could make to our understanding of scolytid biology and to population management. The situation has changed little in four years. Because bark beetles have such profound impacts on conifer forests, the primary theme of this workshop is the relevance of genetical studies to population dynamics and, ultimately, to management. To this end, each of the participants in this workshop addressed one or more of the following questions:

1. Does genetic variation affect population dynamics? Genotypic variation in either ecologically- or behaviorally-important traits may influence population densities through frequency-dependent selection (Lorimer 1979).
2. Does population structure affect the potential for effective management? Genetically- structured populations can result from several ecological and behavioral mechanisms which can affect the long- and short-term efficacy of management actions either directly or through population structure itself.
3. Does genetic variation of traits affect the potential for effective management? If bark beetle populations are structured according to ecologically- or behaviorally-important traits such as host selection or pheromones, this is likely to have a substantial impact on management activities.
4. Do genetics affect interactions between bark beetles and their natural enemies? Heritable variation in traits subject to selection by natural enemies can lead to fluctuating genotypic and phenotypic frequencies in bark beetle populations.
5. Do genetics affect interactions between bark beetles and their hosts? A genetic component to host selection could profoundly affect aggressive bark beetle/conifer interactions (Raffa and Berryman 1987).
6. What are the relative effects of genetics versus environmental factors on important traits (e.g., semiochemicals)? Generally speaking, individual variation has received little attention in the bark beetle literature. To date, only a handful of studies have looked at the genetic component of that variation. In addition to conventional genetics techniques, we can use biochemistry to give us a mechanistic conception of the relative environmental and genetic influences on biosynthetic pathways.
7. Can genetic studies aid in the understanding of biological invasions? To help us better understand exotic forest pest populations, genetic tools can be used to discern cryptic biotypes and geographic sources of invasions.
8. Genetics provide powerful tools for the resolution of systematic relationships. Does a better understanding of systematics aid in the development of management strategies?

USE OF RAPD-PCR TECHNIQUES TO STUDY BARK BEETLE POPULATION STRUCTURE

Jane L. Hayes^a

Two studies using molecular genetic techniques to assess ecological attributes of scolytids were described. Both studies are indicative of the promise RAPD-PCR offers as a tool for the ecologist. As evidenced in these examples, uses of DNA analysis could include

evaluation of biotypes, dispersal, inter- and intraspecific variation, hybridization/introgression, insect-plant interactions, and fluctuations in population dynamics (Hadrys et al. 1992). One of our long-term goals of this work is to use RAPD-PCR techniques to examine (cause or effect) change in genetic variability of bark beetle populations through outbreaks.

Genetic variability of the exotic bark beetle *Tomicus piniperda* (L.), which was recently introduced into the U.S., was investigated within and among eight populations collected in the Great Lakes region. We used population bulking and DNA fingerprinting by random amplified polymorphic DNA (RAPD) techniques (Williams et al. 1990) to assess genetic relatedness of samples obtained in 1992, the first year of reported introduction (Haack and Lawrence 1994). These methods yielded consensus fingerprints for each primer and eliminated uninformative polymorphisms from the screening process. In addition, variability was assessed by electrophoretic characterization of esterase isozymes. To produce dendrograms showing probable relatedness of the eight populations, data were analyzed by maximum parsimony and by the unweighted pair group method with arithmetic means. We concluded that the *T. piniperda* populations in the U.S. have arisen from two founder events -- one in Illinois near Lake Michigan and one in Ohio near Lake Erie. Insects derived from the two founder groups appear to be interbreeding in a contiguous region in western Indiana. The origin of these founder populations is being investigated through further analyses of specimens from probable sites in Europe, China, and Korea. Additionally, the change in genetic variation over time as these populations continue their ecological and geographical range expansion also is being monitored by further analyses of field collections in subsequent years (from 1993 to present). The initial results of the study are in press in the Journal of Economic Entomology (Carter et al. in press).

Dendroctonus terebrans (Olivier) and *D. valens* (LeConte) are two apparently closely-related species of pine bark beetles (Coleoptera: Scolytidae) which are typically distinguished by body color and geography. These species are very similar in anatomical characters and in habits; *D. terebrans*, black turpentine beetle, is distinguished by its black body color, whereas *D. valens*, red turpentine beetle, is reddish brown in body color (Wood 1982). Both species attack fresh stumps and are typically considered secondary enemies of living pines and, less commonly, other conifers. *D.*

terebrans is one of five species of bark beetles commonly associated with southern pine forests, whereas *D. valens* occurs in western and northern conifer forests. However, it has been previously reported that these two species occur in adjacent areas without apparent hybridization in coastal areas from New Jersey to Massachusetts and into the mountains of North Carolina (Robertson and Whitfield 1968). Unlike other *Dendroctonus* species which utilize pheromone communication to coordinate mass attack of living pines, *D. terebrans* and *D. valens* appear to rely individually on host odor to find suitable reproduction sites. Payne et al. (1987) have speculated that the kairomone-pheromone system in *D. terebrans* may have a significant role in inter- and intraspecific olfactory communications of the species. The differences may provide a classic barrier to interspecific mating where *D. valens* and *D. terebrans* overlap geographically; however, to our knowledge the hybridization and possible introgression of these species have never been determined under laboratory or field conditions.

The polymerase chain reaction (PCR) was used for three techniques to obtain genetic markers for this study. Specimens were obtained of *D. valens* from near Redding, California (CA) and Colfax, Wisconsin (WI) and *D. terebrans* from Olustee, Florida (FL) and Pineville, Louisiana (LA). Total genomic DNA was extracted from single frozen specimens from each location using previously-described methods (Ashburner 1989). We used the technique of RAPD-PCR, and screened 35 randomly-designed 10-base primers. Four primers were subsequently used for diagnostic purposes to assess presence/absence of polymorphisms. For the PCR reaction we followed the methods described by Hidayat et al. (in press) with slight modifications to accommodate the difference in specimen size. Restriction fragment-length polymorphisms (RFLP-PCR) (Simon et al. 1993) were analyzed using genomic DNA from the same individuals used for RAPD-PCR. In RFLP-PCR, a specific sequence is amplified with PCR, digested with a specific reaction endonuclease, then electrophoresed to score fragments and the presence or absence of restriction sites. We amplified a mitochondrial DNA (mtDNA) sequence spanning the cytochrome oxidase subunits I and II (COI, COII) genes, using primers from conserved regions (Liu and Beckenbach 1992). Additionally, we amplified a ribosomal DNA (rDNA) sequence spanning the subunits (ITS1 and ITS2). For the PCR reaction mixture and succeeding steps we followed the methods

outlined by Hidayat et al. (in press) with slight modifications to accommodate differences in specimen size. Although not completed, sequencing also will be performed commercially using genetic material prepared from PCR as described above.

Using RFLP-PCR, DNA analysis revealed diagnostic markers that were consistently associated with specimens from the two *Dendroctonus* species. When subject to RAPD-PCR using selected primers, it was possible to distinguish individuals by location or source population. A sufficient number of scorable bands (or loci) were identified to place individuals within populations of *D. valens* from CA and WI, and *D. terebrans* from FL. Interestingly, *D. terebrans* from LA showed remarkably high individual variation, making this group difficult to characterize. Possible explanations for this phenomenon may include extreme mixing in this area as a result of climatic or geographic conditions. To complete this study we will repeat this work with specimens from these sample localities collected this spring. We will be looking for the ability to distinguish these populations as well as at the degree of genetic variability (change over time). Of particular interest will be LA populations. This work is described in a manuscript in preparation (Hayes, Hidayat, and Raffa, in preparation)

PHEROMONE-BASED POPULATION STRUCTURE IN PINE ENGRAVERS

Alice Shumate^b

There is extensive genetic variation in the pheromone system of the pine engraver beetle, *Ips pini*. Specifically, there is high variation in both the production of, and preference for, particular ratios of the enantiomers of ipsdienol. This is surprising because the pheromone biology is apparently closely linked to fitness and should be under strong selection that would reduce variation. Neither the consequences nor the causes of this genetic variation are fully understood.

Allele frequencies at three allozyme loci differed among beetles caught in the same time and place at traps baited with three different ipsdienol enantiomeric blends; this indicates some sub-structuring of the population based on pheromone preferences. In addition, genotypic frequencies exhibited an extreme deficiency of heterozygotes relative to Hardy-Weinberg expectations; this suggests high levels of inbreeding or

strong positive assortative mating. Genetic sub-structuring could increase the potential rate of evolution within these populations, especially if the selection pressure is linked to pheromone biology (e.g., due to predators that exploit ipsdienol for prey location, or due to pheromone-based mass-trapping programs).

Landscape patterns may further contribute to population substructuring. Suitable habitats for *I. pini* in the Great Lake states tend to be small and relatively isolated, embedded within a mosaic of agricultural fields and deciduous woodlots. This habitat structure could produce metapopulation dynamics. That is, genetic variation within and among plantations could be maintained by low levels of migration between plantations that differ in genotype frequencies. We are presently working to further characterize the genetic structure of *I. pini* populations and testing alternative hypotheses for the maintenance of genetic variation in pheromone systems. Results should contribute to our understanding of evolutionary processes in forest insects and accelerate the development of suitable strategies for managing *Ips* populations.

GENETIC RESPONSE TO PHEROMONE-BASED SELECTION IN PINE ENGRAVERS

Matt P. Ayres^b

Accumulating data indicate that bark beetle pheromone systems tend to have high genetic variation and lead to complex substructuring of populations. Do population structure and genetic variation of bark beetles have implications for: (1) management strategies and (2) interactions between bark beetles and their natural enemies? *Ips pini* makes a good model system because we have some understanding of both the pheromone biology and ecological genetics.

Pheromone-based mass trapping has been suggested as a strategy to control bark beetle outbreaks; some pilot studies and uncontrolled experiments indicate the potential for strong numeric effects on *I. pini*. Allozyme studies indicate limited gene flow among populations inhabiting pine plantations separated by 20 km; this indicates that local control programs could be successful (i.e., need not be swamped by migration from other plantations). High heritability of preferences and production suggests the potential for evolved responses to pheromone-based selection. A quantitative genetics model indicates that the percentage of the *Ips*

population responding to a particular pheromone blend could decrease from 50% to 20-30% in two years, and the average pheromone blend produced could decrease from 60%-(+) to 51-55%-(+) in two years (given selection coefficients of 0.08-0.12).

Genetic studies indicate high levels of inbreeding and/or positive assortative mating, which would accelerate evolutionary responses to pheromone-based selection. This potential for evolved resistance could probably be managed with minimal cost by limiting the duration of mass-trapping or varying the selection pressures exerted by trapping. The capacity for rapid evolutionary responses in bark beetles suggests complex predator-prey dynamics with natural enemies that employ bark beetle pheromones for prey location.

THE GENETICS OF ASSORTATIVE MATING IN PINE ENGRAVERS

Stephen A. Teale¹

Semiochemical communication in bark beetles is of special importance because it mediates reproductive behaviors. The genetics underlying pheromone variation can therefore be expected to have an effect on population genetics by influencing which individuals mate with which. Patterns of nonrandom mating can cause gene frequencies to deviate significantly from Hardy-Weinberg expectations (Jacquard 1974, Hartl 1980). The genetic basis of bark beetle pheromone systems has implications for pest management because the effects of semiochemically-based population suppression on the surviving population can lead to significant alteration of population quality if the mechanisms are not known in advance (Stenseth 1987). In addition, modes of inheritance can influence predator-prey interactions and lead to localized specialization of both predator kairomone perception and prey pheromone production and response. In addition to the genetic control of pheromone production, behavioral mechanisms involved in mate selection, particularly assortative mating, can have profound influences on the genetics and demographics of populations. Assortative mating can increase or decrease fertility, lead to local adaptation of progeny, increase genetic load, and increase male reproductive success (Crespi 1989). Assortative mating based on segregating factors has the effect of increasing the variance of the traits in the population by bringing

together nonhomologous alleles for extreme conditions (Crow 1986).

Assortative mating based on a courtship signal was investigated by examining the relationship between the male-produced pheromone and female preference in the pine engraver, *Ips pini*. Preference in response to the male-produced pheromone was measured in the field using traps baited with a range of 11 synthetic blends of the two pheromone enantiomers, (+)- and (-)-ipsdienol. The production of ipsdienol enantiomers was measured from individual, live-trapped male beetles in the laboratory. There was a significant regression of the blend that male beetles produced and the blend to which they responded, and the sex ratios of responding beetles in the field was not significantly different among the different blends of enantiomers. In a second experiment, male-female pairs were sampled in the field, females were assayed for preference in a laboratory olfactometer, and male enantiomer production was measured in the laboratory. There was a significant correlation between female preference and male blend production (Teale et al. 1994).

Next, the hypothesis that in *Ips pini* independently segregating genetic factors control enantiomeric preference and production was tested. The genetic correlation of production and response was measured under two mating regimes: assortative mating and forced random mating. If enantiomeric production and response is due to pleiotropy or tight linkage then under forced random mating for five generations, the genetic correlation of the traits should be maintained. In contrast, if the traits are slightly linked or unlinked, then five generations is the minimum amount of time necessary to disrupt linkage disequilibrium and the genetic correlation should be reduced to near zero. Both pheromone production by males and the response to it by males and females are highly heritable. Male response is genetically unlinked to pheromone production and therefore it is likely that the traits are not a result of pleiotropy (Hager and Teale, in press).

BIOCHEMICAL GENETICS OF PHEROMONE PRODUCTION IN PINE ENGRAVERS

Steven J. Seybold²

Recent research on *de novo* pheromone biosynthesis in *Ips* spp. (Ivarsson et al. 1993, Seybold et al. 1995) has made it possible to envision a biochemical genetic

analysis of this behaviorally relevant pathway. Prospective biochemical genetic studies were outlined for the *de novo* isoprenoid synthesis of ipsenol, ipsdienol, and related acyclic monoterpene alcohol pheromone components by *Ips paraconfusus* Lanier and *I. pini* (Say) (Byers 1981, Seybold et al. 1995). In theory, there are ~6-8 enzyme catalyzed steps from the common isoprenoid intermediate geranyl-diphosphate to (*S*)-(-)-ipsenol, and these steps are likely to be unique to *Ips* spp. (Seybold et al. 1995). Species of *Ips* which do or do not produce the various enantiomeric combinations of ipsenol and ipsdienol might serve as "wildtypes" or "mutants" in our investigations of this pathway. In a case of intraspecific variation, individuals from California sierran populations of *I. mexicanus* (Hopkins), which produce ipsenol and ipsdienol (Seybold 1992), might be crossed with individuals from California coastal populations that produce only ipsdienol (Seybold 1992). Individuals from the coastal population can be regarded as mutant for the production of ipsenol, and progeny of the sierran-coastal crosses can be followed genetically to clarify the inheritance of the ability to make ipsenol.

In an effort to understand the relative contributions of genetic and environmental effects on pheromone production, data from published studies of *I. duplicatus* Sahlberg (Ivarsson and Birgersson; 1995) and *I. paraconfusus* (Byers 1981) were used to compare the amounts of ipsenol and/or ipsdienol produced via feeding on host phloem to the amounts produced via inhalation of the host monoterpene myrcene (Ivarsson and Birgersson 1995, Ivarsson et al. 1993). Pheromone produced while feeding on the host is hypothesized to be synthesized predominantly from the *de novo* pathway. These comparisons suggest that the genetically-regulated isoprenoid pathway may account for 5-10x more pheromone than that produced from exogenous myrcene. Controlled studies using cellulose-based diets and measured amounts of myrcene will be necessary to establish these relationships more exactly.

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Section V

Poster Abstracts

NAFIWC POSTER ABSTRACTS

SUGAR MAPLE HEALTH: HIGHLIGHTS FROM SEVEN YEARS OF MONITORING BY THE NORTH AMERICAN MAPLE PROJECT (NAMP)

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NAMP was formed in 1987 as a joint effort between Canada and the United States in response to concerns about the health of sugar maple, *Acer saccharum* Marsh. Objectives were: (1) to determine the rate of change in sugar maple condition; (2) to determine if observed changes differed between sugarbushes and stands not managed for syrup production; and (3) to identify causes of maple decline and the geographical relation between cause(s) and extent of damage. Key results from seven years (1988-1995) of monitoring and evaluation are presented.

STRATEGIES FOR RESOURCE SHARING BY THREE SYMPATRIC SPECIES OF *IPS* IN WISCONSIN: COMPETITION AND COOPERATION?

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The bark beetles *Ips pini*, *I. perroti*, and *I. grandicollis* co-exist in red pine monocultures in Wisconsin, often sharing the phloem of the same host plant. We tested the hypotheses that the three species partition this resource in time or space, or that they accrue mutualistic benefits that offset the costs of competition. We employed pheromone traps to test interspecies chemical interactions and to measure seasonal abundance. We peeled trees and logs to determine spatial and seasonal colonization patterns. Finally phloem-plexiglass sandwiches and emergence traps were used to compare development rates. We found

competitive interactions to be asymmetrical and seasonally variable. Phenological differences reduce but do not eliminate resource overlap. Longer development time in *I. perroti* and *I. grandicollis* increase overlap with *I. pini*. Species segregate spatially on co-colonized trees, with a positive correlation between phloem thickness and species size. Interspecies and intraspecies responses to pheromones change seasonally and reduce overlap in some relationships, but appear to promote overlap in others. Although partial resource partitioning occurs in time and space, all three species intimately share a common realized niche, especially in spring and early summer.

HOW TO COMPARE THE SUITABILITY OF HOST PLANTS: ASSESSING THE CONTRIBUTIONS OF TEMPERATURE, PHYTOCHEMISTRY, AND NATURAL ENEMIES

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We propose a general theory of host suitability for polyphagous herbivores that incorporates phytochemistry, climate, and natural enemies. We tested postulates of the theory by estimating reproductive success of hatching caterpillars across multiple host species, under different climates, with and without exposure to natural enemies. We compared our estimates of host quality with oviposition preferences of butterflies. Short summers in Alaska appear to limit larval success on many host species that are otherwise nutritionally suitable, and Alaskan butterflies oviposited preferentially on those few hosts that allowed very rapid larval development. In contrast, Michigan butterflies were variable in their rank preferences of hosts, and average preferences were unrelated to nutritional quality. In the absence of predators, the most preferred host in Michigan afforded lower survival, required longer development times, and produced less fecund pupae than alternative hosts. However, predation rates on the preferred host were lower such that overall host suitability (eggs/per hatching egg in the presence of predators) was higher

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than alternative hosts. The importance of predation in influencing host suitability may be inversely related to phenological constraints imposed by climate. With longer summers, high predation risks on hosts of high nutritional quality may favor oviposition on hosts with low nutritional quality. Understanding patterns of host suitability has utility for understanding population dynamics and distribution limits of forest insects.

PERFORMANCE AND FECUNDITY ON SEVERAL TREE SPECIES OF GYPSY MOTH FROM THREE CONTINENTS

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A comparison of mortality, relative growth rate, pupal weight, and fecundity of gypsy moth, *Lymantria dispar*, from Asia, Europe, and North America has been conducted in laboratory conditions in Krasnoyarsk and Hamden. On all host plants Asian larvae nearly always grew faster, weighed more, and survived better in the first two instars. The differences in growth were less or disappeared in older instars. The fecundity of Asian strain was less on the majority of plants. The feeding aggressiveness of Asian larvae is always realized in younger instars -- the most critical period of their development. The further performance depends on the general suitability (quality) of the food plant. The lower fecundity of Asian females per unit of body weight comparable to European and North American females may be the cost for their ability to fly. The feeding aggressiveness of young Asian larvae is an adaptation for highly unpredictable conditions for the progeny of flying females.

PREDICTING GYPSY MOTH DEFOLIATION: A COMPARISON OF THREE EGG MASS SURVEY METHODS

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Gypsy moth populations in Michigan were estimated using three egg mass survey methods, the five-minute walk, the 0.01-ha fixed-radius plot, and a recently developed method that uses a plot of the nearest 100 trees around a central point. Subsequent defoliation was visually estimated at the same sites. The fixed-radius and 100-tree plot methods were better predictors of defoliation than the timed-walk method, but the walk required much less time. Using the ratio of new to old egg masses in conjunction with egg mass density greatly improved the accuracy in predicting defoliation.

FOREST INSECTS OF MEXICO

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This poster represents a summary of 187 species of forest insects of Mexico that include hosts, distribution, damages, and economic importance, and are ordered according to the part of the tree that they attack. The following groups are included: cone and seed insects, bud and shoot feeding insects, defoliating insects, sap-sucking insects, gall forming insects, and bark and phloem feeding insects.

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SPRUCE BUDWORM (*CHORISTONEURA FUMIFERANA*) PARASITISM IN A PATCHY FOREST

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The most recent outbreak of the spruce budworm in northwestern Quebec caused greater mortality of balsam fir in continuous stands than in isolated stands surrounded by deciduous forest. Higher mortality imposed by enemies may have kept the spruce budworm at low densities in these sites. To test this hypothesis, we placed lab-reared budworm larvae and pupae on the foliage in continuous and isolated stands. Both larval and pupal parasitism were significantly higher in isolated stands. Deciduous trees surrounding the isolated fir stands may provide alternative or alternate hosts for parasitoids, thus explaining the greater parasitism rates in these "habitat islands."

THE EFFECT OF TWO APPLICATIONS OF *BACILLUS THURINGIENSIS* ON NON-TARGET LEPIDOPTERA

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The objectives of our study were to determine both the effects of two applications of *Bacillus thuringiensis* (Bt) and high gypsy moth (GM) density populations on native, non-target Lepidoptera. Fifteen plots were established: five with low GM densities (control), five with high GM densities (and probable defoliation), and five that were treated with Bt. Macrolepidopteran larvae were collected from beneath burlap bands on

oaks and maples. The high GM density plots were beginning to show signs of defoliation when populations were suppressed by an outbreak of the fungus *Entomophaga maimaiga*; no defoliation occurred. A total of 1,476 macrolepidoptera larvae were collected: 895 from low GM density plots, 431 from high GM density plots, and 150 from treated plots. The total number of macrolepidopteran larvae collected from low and high GM density plots did not differ significantly; however, they were significantly different from the treated plots. Forty species representing 31 genera and eight families were collected from all the plots. Rich richness was 28 in each of the low and high GM density plots, but species richness dropped to 16 in the treated plots. In conclusion, non-target Lepidoptera were significantly affected by two applications of Bt. The effects of defoliation are still unknown since high GM populations and subsequent defoliation were reduced by an epizootic of the fungus *Entomophaga maimaiga*.

SUPPRESSING SOUTHERN PINE BEETLE INFESTATIONS WITH VERBENONE: RESULTS OF 1995 FIELD APPLICATIONS

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In recent years, a USDA Forest Service technology development project has been evaluating the efficacy of the beetle-produced inhibitor verbenone for suppressing infestations of the southern pine beetle (SPB), *Dendroctonus frontalis* Zimm. Two different tactics show considerable promise: (1) verbenone only, applied to pines under SPB attack and adjacent uninfested trees and (2) verbenone applied to adjacent buffer trees in conjunction with the felling of all currently-infested trees. Field tests were conducted in TX, MS, GA, and NC in 1995 to reconfirm earlier results. Verbenone (34% (+) 66% (-)) was deployed at 40 ml/ft² of infested basal area from sealed verbenone

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bags (5 ml verbenone/bag) attached at 3- 4 m above ground (1-6 bags/tree). Of 22 SPB infestations (range = 15-88 active trees) treated with verbenone only, 16 were successfully controlled (73%). Nineteen larger infestations (range = 31-351 active trees) were treated with the verbenone + tree felling tactic of which 16 were successfully controlled (84%). In nine of the latter, not a single additional tree was killed following applications of verbenone. Efforts toward the ultimate goal of making verbenone available for operational SPB suppression are continuing.

POTENTIAL COMPETITORS OF THE AMERICAN BURYING BEETLE IN EASTERN OKLAHOMA

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The American burying beetle, *Necrophorus americanus* (COLEOPTERA: Silphidae), is listed as a Category I endangered species. One known population of the insect is located in mixed forest/old field habitat in eastern Oklahoma. In addition to the annual beetle population survey conducted on this site, other arthropods attracted to the carrion-baited traps were collected and identified. Several other beetle species represent potential competitors of American burying beetle at this site. These include several additional species of carrion beetles (Silphidae), dung beetles (Scarabaeidae) and ground beetles (Carabidae), the majority of which varied in abundance based on habitat.

PHEROMONES OF THE WHITE PINE CONE BEETLE, *CONOPHTHORUS CONIPERDA*

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Female white pine cone beetles, *Conophthorus coniperda*, attack the cones of eastern white pine, *Pinus strobus*, and produce a sex-specific pheromone, pityol, that attracts conspecific males. Beetle response is enhanced by host monoterpenes. Males and females produce conophthorin, which is not an attractant for either sex, but repels males. Results are presented from a series of laboratory and field experiments with these two pheromones for distinct and widely-separated populations of *C. coniperda* in the U.S. and Canada.

EFFECTS OF DOUGLAS-FIR FOLIAGE AGE CLASS ON WESTERN SPRUCE BUDWORM OVIPOSITION CHOICE AND LARVAL PERFORMANCE

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The western spruce budworm (*Choristoneura occidentalis* Freeman) prefers to feed on flushing buds and current-year needles of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). We tested the hypothesis that budworm adult oviposition preference is linked to the age of foliage they fed on as larvae. We also compared survivorship between budworm larvae that fed on current year versus older age classes of foliage. We found weak evidence that budworm adults preferred to oviposit on current-year foliage. We also found that budworm larvae had greater survival on current-year compared to older age classes of foliage.

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FOREST INSECTS AND THEIR DAMAGE, PHOTO CDS: VOL. I AND II

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The Southern Forest Insect Work Conference (SFIWC) was organized by federal, state, university, and private sector southern forest entomologists and has met annually since 1956. The SFIWC has maintained a slide series of forest entomology-related images expanded by voluntary member contributions since the early 1970s. "Forest Insects and Their Damage" contains two hundred images in Kodak Photo CD (PCD) format that were selected from the SFIWC slide set. Photographer credits, images identification and descriptions, and a miniaturized representation of each image are given in the reference booklet enclosed in the double jewel-case set. Kodak PCD format provides five resolutions ranging from 128 x 192 up to 2048 x 3072 pixels of each image, thereby providing users with images suited for a wide array of applications ranging from World Wide Web and onscreen multimedia presentations, to Offset Printing for both Windows PC and Macintosh platforms. PC files can be accessed directly by a number of software applications, or may be converted to other graphic formats as needed. For convenience, special arrangements have been made with Kodak to provide the Kodak Access Plus Software on each "Forests Insects and Their Damage" CD. Although the images are copyrighted, they may be copied and used royalty-free, in whole or in part, for any non-profit, educational purpose provided that all reproductions bear appropriate references and credits. Commercial use of images requires the written permission of the SFIWC and the individual photographer or organization. Southern Cooperative Series Bulletin 383, "Forest Insects and Their Damage" is available for \$25.00 per two volume set from The University of Georgia through the senior author.

EVALUATING SCOTS PINE VARIETIES FOR RESISTANCE TO DEFOLIATING, SAP-FEEDING, AND PHLOEM-BORING PESTS IN MICHIGAN

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We evaluated resistance of four varieties of Scots pine Christmas trees in southwest Michigan to three common insect pests in 1994 and 1995. European pine sawfly, *Neodiprion sertifer* (Geoff), pine needle scale, *Chionaspis pinifoliae* (Fitch), and Zimmerman pine moth, *Dioryctria zimmermani* (Grote), were caged on appropriate feeding sites and allowed to complete their natural development. Insect survival and fecundity were measured and related to resin flow, needle characteristics, and other traits. Results from this study will contribute to an on-going tree improvement program.

SUCCESSFUL SUPPRESSION OF A SOUTHERN PINE BEETLE OUTBREAK: HOW IT WAS DONE IN GAINESVILLE, FLORIDA

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The southern pine beetle, *Dendroctonus frontalis* (Coleoptera: Scolytidae), erupted in the Gainesville area in the spring of 1994. The City Commission quickly declared a tree emergency and adopted a program requiring that all infested trees be treated to stop the emergence and dispersal of this tree-killing bark beetle. The Florida Division of Forestry coordinated the detection effort and provided technical assistance (e.g., treatment information) to affected landowners. One treatment option was to pay the city \$75 per tree, about one-half the real cost, for felling and spraying with chlorpyrifos. Analysis of subsequent detection records indicated that the community-wide suppression program substantially reduced outbreak severity and duration. Owners of infested trees benefitted by having a relatively inexpensive method

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for treating small numbers of trees in residential areas. Adjacent owners benefitted because quick detection and control made it unnecessary to apply insecticides to protect yard trees. Forest industries benefitted by having only a small percentage of their incoming material being beetle infested and degraded. The city benefitted because the money spent for cost sharing was less than it would have spent for tree removal in city parks had beetle populations gone unchecked. The Gainesville experience clearly demonstrates how coordinated community action to treat all infested trees can reduce insect numbers and diminish the impact of this tree-killing beetle.

COOPERATIVE OAK WILT SUPPRESSION PROJECT IN CENTRAL TEXAS

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The Texas Oak Wilt Suppression Project was initiated in 1988 to address a severe oak wilt outbreak in central Texas, caused by the insect-vectored fungus *Ceratocystis fagacearum*. The project is administered by the Texas Forest Service, with financial support from the USDA Forest Service, City of Austin, and landowners in central Texas. The overall goal is to limit the spread of oak wilt in key counties of central Texas through public education, technical assistance, and the sharing of control costs with affected landowners. Accomplishments since the project began have been substantial. These include: (a) establishment of a professional staff to provide landowners with technical assistance throughout central Texas; (b) installation of over 1,480,000 feet (280 miles) of trench to halt the spread of ca. 1,000 infection centers throughout central Texas; (c) injection of thousands of high value live oaks with fungicide; (d) detection and removal of infected red oaks to reduce fungal spore production; (e) numerous public education efforts on prevention to reduce the initiation of new oak wilt centers; and (f) post-suppression and economic

analyses to document treatment and project effectiveness.

DWARF MISTLETOES: BIOLOGY, PATHOLOGY, AND SYSTEMATICS: AN OVERVIEW OF HAWKSWORTH & WIENS' REVISION

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The extensively revised dwarf mistletoe monograph will be available this fall as USDA Agriculture Handbook 709 (1995), authored by Hawksworth & Wiens and edited by Geils and Nisley. In addition to systematic and descriptive information for each species, ecological relationships, biotic associates, physiology, anatomy, pathogenic effects, and methods of control are reviewed. Color pictures, distribution maps, and a list of specimens examined are provided. Forty-two species are presented, including eight subspecies and two formae speciales.

PHYSIOLOGICAL AGE AFFECTS DEVELOPMENTAL RESPONSE TO TEMPERATURE IN GYPSY MOTH EGGS: IMPLICATIONS FOR PHENOLOGY MODELS

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There is an underlying assumption in conventional development vs. temperature experiments that there is an identical developmental response to a given temperature over time. We found that this important assumption was badly violated when we examined the developmental response of gypsy moth eggs in the diapause and postdiapause phases of development. Using respiration rate measurements of individual eggs, we measured "instantaneous" developmental

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rates over time and modeled the effect of physiological age on the developmental response to temperature. The implications of the violation of the assumption are presented.

QUANTITY AND CHIRALITY OF SEMIOCHEMICALS PRESENT IN THE HINDGUTS OF SOUTHERN PINE BEETLE, *DENDROCTONUS FRONTALIS* (COLEOPTERA: SCOLYTIDAE)

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Six semiochemicals were isolated from hindguts of male and female southern pine beetles (*Dendroctonus frontalis* Zimm.) from Texas, South Carolina, and North Carolina. Quantities of *cis*-verbenol (cV) and *trans*-verbenol (tV) were greater in females than in males, whereas males contained greater amounts of verbenone (V). Frontalin (F), *endo*-brevicommin (eB), and *a*-pinene (aP) quantities were generally the same in both sexes. Differences were found among states of tV and V in both sexes and in aP and F in males only. Males produced (+)-F and (-)-eB, cV and V. The chirality of tV produced varied among states. In contrast, females produced (+)-cV and V and (-)-F, eB, and V. Both sexes contained (+)-aP; however, the percentage was lower than that determined from host trees from the same state. Differences in chirality of tV and V among states were significant in males as were differences in chirality of eB in females.

NEGATIVE EFFECTS OF ANT FORAGING ON SPIDERS IN DOUGLAS-FIR CANOPIES

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The effect of ant foraging on spider communities was investigated in a five-month ant exclusion experiment in sapling Douglas-fir canopies. The removal of ants resulted in a significant increase in the abundance of hunting spiders, but did not affect the density of web-building spiders. In addition, the exclusion of ants resulted in a significant increase in the abundance of Psocoptera which dominated the complex of potential prey organisms on foliage. We suggest that competition for food between ants and hunting spiders, and antagonistic behavior of foraging and aphid-tending ants may explain the observed changes in this canopy system.

THE ARTHROPOD DIET OF NESTLING RED-COCKADED WOODPECKERS

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Management and recovery efforts targeted at the red-cockaded woodpecker (RCW) (*Picoides borealis*) require that adequate foraging areas be maintained around colony sites. However, very little is known about the prey that are produced in these managed areas. A study was conducted from 1993-1995 in three different physiographic regions (upper and lower coastal plain, and piedmont) to determine how RCW prey selection varies over time and location. Automatic cameras were used to record over 10,000 adult nest visits with prey, made by 14 bird groups during the breeding seasons. Wood roaches (*Parcoblatta* sp.) were the primary prey of all groups, ranging from 25-81% of the nestling diet. Other common arthropod

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prey included wood borer larvae, ants, spiders and centipedes, although none of these comprised more than 15% of the nestling diet of any woodpecker group studied. Our data clearly show that wood roaches consistently make up a large proportion of RCW nestling diet, numerically and in terms of arthropod biomass, regardless of bird group, physiographic region, or year of observation.

NATURAL ENEMIES OF THE GYPSY MOTH AT THE LEADING EDGE OF ITS INVASION INTO THE SOUTHERN U.S.

F.L. Hastings, F.P. Hain, (Dept. of Entomology, North Carolina State University, Raleigh, NC 27695), **H.R. Smith,** and **T.M. Odell** (USDA Forest Service, Northeastern Experiment Station, 51 Mill Pond Rd., Hamden, CT 06514)

During 1991 permanent plots (two each) were established in the coastal plain, piedmont, and mountains to quantify the ecological changes which occur as the gypsy moth moves into the South. These plots were rated for susceptibility with the intent of re-evaluating them after the gypsy moth becomes established. Because small mammals, in particular the white-footed mouse (*Peromyscus leucopus* Rafinesque), are important predators of the gypsy moth, we surveyed their populations and measured predation against freeze dried gypsy moth pupae during 1992-1995. One finding was that invertebrates were often as important as mammals in this predation. F1-sterile egg mass releases allowed the identification of important parasites.

DEVELOPMENT OF NEEM SEED EXTRACT CONTAINING AZADIRACHTIN FOR FOREST INSECT PEST MANAGEMENT

Blair Helson, Barry Lyons, and **Peter deGroot** (Natural Resources Canada, Canadian Forest Service, 1219 Queen St. East, P.O. Box 490, Sault Ste. Marie, Ontario, P6A 5M7)

In laboratory studies, neem was highly active on 12 species of lepidopteran and sawfly larvae. Sawflies

were particularly susceptible (e.g. introduced pine sawfly LC50 - 0.04g azadirachtin/ha). Motorized mistblower applications at 50g azadirachtin/ha against the pine false webworm infesting red pine during egg-hatch provide greater than 85% foliage protection. In similar trials against the late instar introduced pine sawfly infesting white pine, frass output was reduced 89-99% and foliage protection was 65-73%. Neem also provided protection from damage by white pine weevil. Backpack sprayer applications to jack pine or white pine leaders at 50g/ha during egg-hatch provided 70-80% leader protection.

IPS PINI AGGREGATION PHEROMONE: VARIATION AS AN ESCAPE FROM PREDATION

Ken Hobson and **Kenneth F. Raffa** (Dept. of Entomology, University of Wisconsin, Madison, WI 53706)

The principal predators of the bark beetle *Ips pini* in Wisconsin are attracted to its aggregation pheromone, ipsdienol. However, the enantiomeric blend of ipsdienol that these predators prefer is offset from the blend produced by the local *I. pini* population. A third pheromone component, lanierone, is present in small quantities and acts as a powerful synergist. The clerid *Thanasimus dubius* and two species of the histerid genus *Platysoma* are the most abundant insect predators. The response of *T. dubius* but not the *Platysoma* spp. is augmented by lanierone. *I. pini* may be escaping predation by shifting the blend of ipsdienol enantiomers it produces.

DOES PHEROMONE PRODUCTION IN BARK BEETLES (COLEOPTERA: SCOLYTIDAE) REALLY DEPEND ENTIRELY ON HOST CONIFER BIOCHEMISTRY?

Per Ivarsson and **Steven J. Seybold** (Dept. of Biochemistry, University of Nevada, Reno, NV 89557)

Bark beetles are serious pests of conifers throughout the northern hemisphere. In this region, scolytids in the genera *Ips*, *Dendroctonus*, and *Scolytus* can quickly

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kill drought-stressed or otherwise weakened standing timber valued at hundreds of millions to billions of US dollars. Most bark beetles use aggregation pheromones to attack conifers *en masse*. The pheromones, mixtures of volatile compounds, are olfactory signals to conspecific males and females. This poster summarizes our knowledge of the biosynthesis of pheromone components by engraver beetles in the genus *Ips*, including two Eurasian (*I. duplicatus* and *I. typographus*) and two North American (*I. paraconfusus* and *I. pini*) species. The content of the poster represents a synthesis of research conducted at the University of Nevada, Reno and at Göteborg University, Sweden. The biosynthesis has long been thought to be a simple oxidation of monoterpenes from the host tree resin. Thus the tree supplies the building blocks for the pheromone of the beetle. Our research has demonstrated that 2-methyl-3-buten-2-ol in *I. typographus*, ipsdienol in *I. duplicatus*, *I. pini*, and *I. paraconfusus*; *E*-myrcenol in *I. duplicatus* and *I. pini*; amitinol in *I. pini* and *I. paraconfusus*; and ipsenol in *I. paraconfusus* are all produced *de novo*, independent of exogenous precursors. The implications for the forest industry are that pheromone production will be as high in a tree containing low amounts of monoterpenes as in a tree containing copious amounts of monoterpenes. The method of radiolabeling *de novo* produced pheromone components using [1-¹⁴C]acetate offers a valuable tool in identifying new pheromone components that are likely to have biological activity. Our goal with the research program is to study the monoterpene and monoterpene alcohol biosynthetic pathway in detail in bark beetles and address the points of regulation. The *de novo* production of pheromones is induced by juvenile hormone, which is itself probably triggered by environmental cues. This regulatory site can give us an opportunity to control the bark beetles more directly by biochemically blocking pheromone production. Further studies of the hormonal induction system may reveal other regulatory sites that could have implications for practical control methods. Characterization and isolation of the pheromone biosynthetic enzyme systems may also lead to biotechnological production of pure pheromone components for mass trapping and monitoring programs.

INSECTS AFFECTING THE REPRODUCTION OF WHITEBARK PINE IN THE WESTERN UNITED STATES

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In 1995, we began to study the insect complex affecting the reproduction of whitebark pine (*Pinus albicaulis*). Seven sites in the western United States were chosen with three in Idaho, and one each in Montana, California, Oregon, and Washington. Fourteen treatments, which consisted of excluding insects with mesh bags at different times during the two-year cone development cycle, were replicated on each of 15 trees at each site. Mature cones will be collected at the end of 1996 to identify the insect complex and damage they cause. A preliminary study in 1994 showed that between 50-100% of cones collected were infested with a coneworm. To date, we have found six different insects feeding in or on the reproductive structures.

EVALUATION OF A COLOR INFRARED DIGITAL CAMERA FOR FOREST HEALTH MANAGEMENT APPLICATIONS

K. Andrew Knapp (USDA Forest Service, Forest Health Management, Boise Field Office, 1750 Front St., Boise, ID 83702) and **Mike Hoppus** (USDA Forest Service, Remote Sensing Applications Center, 222 West 2300 South, Salt Lake City, UT 83702)

In the Intermountain West fire exclusion, grazing, and past forest management activities have created extensive areas of overly dense stands of trees which are highly susceptible to attack by forest insects and infection by forest pathogens. A major component of forest health management is the detection, monitoring, and quantification of forest insect and disease activity.

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Color infrared digital camera systems are a new remote sensing tool that have the potential to improve temporal, spatial, and quantification limitations of existing remote sensing technologies used for forest pest detection, monitoring, and quantification. A color infrared digital camera system was evaluated in Idaho and Utah during 1995. Digital images were collected over areas affected by various forest insects and diseases and over areas of recent wildfire activity. Images were compared to visual observations and small and medium format photography. Results indicated that the camera system can be successfully used to supplement existing operational remote sensing techniques currently employed for monitoring and quantifying forest insect and disease activity.

THE PINE SHOOT BEETLE IN NORTH AMERICA: LIVING WITH A NEW EXOTIC PEST

Robert K. Lawrence and **Robert A. Haack** (USDA Forest Service, North Central Forest Experiment Station, 1407 S. Harrison Road, Room 220, East Lansing, MI 48823)

The pine shoot beetle, *Tomicus piniperda* (Coleoptera: Scolytidae), was first reported in the United States in 1992. Federal quarantines have been implemented on pine material (Christmas trees, nursery stock, logs with bark) in eight states and one Canadian province where this Eurasian scolytid has been found. We determined the life history of *T. piniperda* in North America, examined interactions with native bark beetles, assessed host suitability of several North American conifers, evaluated trapping techniques for survey and control programs, and determined appropriate timing for pest management activities and transport of pine materials. *T. piniperda* in north America emerges a few to several weeks earlier in the spring than native bark beetles and natural enemies, and can completely colonize available brood sites. All North American pine species tested can be used by *T. piniperda* for reproduction and shoot feeding. The most effective management tactics are sanitation (destroying slash and stumps) and trapping (using trap logs which are then destroyed prior to brood emergence). *Thanasimus formicarius*, a bark beetle predator in Europe whose spring emergence is closely synchronized with that of

T. piniperda, is being considered for release in the Great Lakes area by USDA-APHIS. We are initiating a laboratory study of interactions between *Tomicus piniperda*, *Thanasimus formicarius* (the exotic predator), *Ips pini* (a native bark beetle), and *Thanasimus dubius* (a native predator).

FUTURE SPREAD OF THE GYPSY MOTH AND FOREST SUSCEPTIBILITY ACROSS THE CONTERMINOUS U.S.

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Since the gypsy moth was introduced near Boston in 1869, it has been slowly expanding its range through much of North America. In this study we used forest inventory data collected through the conterminous U.S. to predict forest susceptibility to gypsy moth outbreaks in areas that are currently uninfested. We also used historical information on gypsy moth spread to predict its future range expansion under various management scenarios. Results indicated that while nearly every forested area in the U.S. will eventually be infested by the gypsy moth, only about ½ are likely to ever be subjected to defoliating populations. The three areas most highly susceptible to the gypsy moth are the central Appalachian Mountains, northwestern Lake States, and the Ozark Mountains area. Simulations indicate that if the USDA were to terminate all eradication programs, the gypsy moth would become established over a wide area within 25 years. Simulations also indicated that a program designed to slow the spread of the gypsy moth would substantially reduce the extent of defoliated forests over the next 25 years.

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EFFECTS OF SILVICULTURAL MANIPULATIONS ON GYPSY MOTH POPULATION DYNAMICS

A.M. Liebhold, R.M. Muzika, and K.W. Gottschalk (USDA Forest Service, Northeastern Forest Experiment Station, 180 Canfield Street, Morgantown, WV 26505)

Considerable interest exists in the use of silvicultural methods for management of gypsy moth populations either by reducing forest susceptibility to outbreaks or by reducing the vulnerability of trees to mortality caused by defoliation. The purpose of this study was to determine what effect these silvicultural manipulations have on various population processes that contribute to gypsy moth dynamics. Eight stands were thinned to either reduce total stand basal area or reduce the proportion of basal area in tree species preferred by gypsy moth; another eight stands were not thinned and served as controls. In each stand, we measured gypsy moth egg mass density, fecundity, and larval densities, as well as parasitism rates, disease rates, and rates of predation on gypsy moth larvae and pupae. Results indicated slight, if any, effects of the silvicultural manipulation on most population processes. These results indicated that these thinnings may reduce mortality due to defoliation but probably have little effect on the onset of outbreaks.

RESPONSE OF JUVENILE LOBLOLLY PINES TO FERTILIZATION, THINNING, AND PRUNING

Peter L. Lorio, Jr., Richard T. Wilkens (Forest Insect Research, USDA Forest Service, Pineville, LA 71360), and **Matthew P. Ayres** (Dartmouth College, Hanover, NH 03755)

Treatments were assigned at random to individual trees within a 14-year-old plantation in early 1994 to modify partitioning of carbon to competing sinks; e.g., diameter growth and resin synthesis. Fertilization (746 kg/ha of diammonium phosphate, i.e., 150 kg of P and 130 kg of N per ha) provided two fertility levels. Thinning increased sunlight to crowns, and pruning potentially reduced carbon budgets by removal of about 50% of the photosynthetic leaf area. The

experiment included 12 pruned, 12 pruned and fertilized, 15 controls, 15 fertilized only, 12 thinned, and 12 thinned and fertilized trees (a total of 78 trees). In 1994 pruning greatly reduced bole diameter growth and thinning plus fertilization increased growth. In 1995 fertilization increased diameter growth and reduced resin yields from bark wounds made to the xylem-phloem interface, site of attack by *Dendroctonus frontalis* Zimm. These results indicate a possibly negative effect of fertilization on resistance of juvenile loblolly pines to attacks by *D. frontalis*.

DOUGLAS-FIR TUSSOCK MOTH NEAR THE SOUTH PLATTE RIVER, COLORADO

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The Douglas-fir tussock moth (DFTM, *Orgyia pseudotsugata* (McDunnough), Lepidoptera: Lymantriidae) has primarily been an urban pest in the Colorado Front Range and Wyoming. Historically, the tussock moth has not achieved outbreak status in wildland forests, with previously recorded episodes not exceeding 200 ac. However, activity on ornamental and city park trees has generally increased over the last 30 years. In 1993 Ken Lister discovered an outbreak in the South Platte River drainage southwest of Denver that has subsequently increased to about 20,000 ac. Significant levels of Douglas-fir mortality are expected in 30% to 40% of the outbreak area. Little or no new defoliation is expected in 1996, although Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins, Coleoptera: Scolytidae) activity is increasing. With assistance from Dave Leatherman, we searched historic documents to compile records of DFTM activity in Colorado and Wyoming. Records back to 1913 were examined. Time lines compiled from these records indicate that (1) DFTM has a long history of activity in the Colorado Front Range, (2) wildland DFTM outbreaks have occurred in the past, (3) DFTM and western spruce budworm dynamics appear to be independent, (4) urban pest activity of DFTM has increased greatly in recent decades, (5) population

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increases appear to occur with regularity every 10 to 13 years; there may also be cyclic patterns within individual urban populations (D. Leatherman, pers. comm), and (6) the current forest outbreak is much greater in size than previous episodes, at least in the last 65 years. We speculate that the recent outbreak is unusually large due to one or both of the following factors. The host species, Douglas-fir and white fir, have become much more abundant in the area, occurring in multi-storied stands, due to fire exclusion and logging history, resulting in a more severe outbreak, much the same as western spruce budworm dynamics have been affected in the same general area (Swetnam and Lynch, 1993, Ecol. Monogr. 63(4):399-424). Second, endemic population reserves may have been quite few and isolated in earlier times. Ornamental blue spruce has become quite numerous in the mountain communities, and may support a relatively higher chronic population of DFTM. More numerous and larger reserves over a contiguous area may have resulted in a larger outbreak when the population cycle began its naturally scheduled cycle. A less likely cause might be altered environmental biochemistry caused by air pollution from the Front Range communities, with favorable changes for DFTM and negative changes for tree defensive chemistry or natural enemies.

EFFECTS OF AZADIRACHTIN-BASED INSECTICIDES ON THE EGG PARASITOID, *TRICHOGRAMMA MINUTUM* RILEY (HYMENOPTERA: TRICHOGRAMMATIDAE)

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The effects of azadirachtin formulations on the reproduction and survival of *Trichogramma minutum* were examined in the laboratory. Treated eggs of the Mediterranean flour moth were presented to females as hosts. Eggs were reared until parasitoids completed development. Azatin®EC (3% azadirachtin), 'Neem EC' (4.6% azadirachtin) and a 100% azadirachtin standard were tested. At 50 g AI/ha, no significant effects were observed. At ten times the recommended

dose or 500 g AI/ha, female survival, eggs parasitized, and parasitoid development success were significantly reduced by Azatin® EC and Neem EC. Development success was also reduced by the azadirachtin standard. Sex ratios were not affected.

SAWFLY RESPONSE TO OZONE IN AN OPEN- FIELD EXPOSURE SYSTEM

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Pine sawflies are economically important defoliators on Scots pine (*Pinus sylvestris* L.). Environmental stresses may reduce the capacity of host trees to produce defensive substances leading to greater susceptibility of needles to sawfly damage. The effect of tropospheric ozone on needle quality of Scots pine was tested by rearing two species of diprionid sawflies (*Neodiprion sertifer* Geoffr. and *Gilpinia pallida* Klug) on seedlings with elevated ozone concentration. The experiments were conducted in an open-field fumigation system at the University of Kuopio in summers 1992 and 1994. In 1994 with the experiments of *G. pallida*, part of the seedlings were treated with the fungicide propiconazole to control ectomycorrhizal infection. Current needles were sampled for monoterpene and resin acid analysis. The treatments had no significant effect on sawfly larval weights, relative growth rates, needle consumption, or survival. Fungicide treatment to control ectomycorrhizal infection did not affect sawfly success. There were no differences in resin acid or terpene concentrations between the treatments. The current results from field experiments suggest that elevated ozone concentrations in the future will not strongly affect the needle quality of young Scots pine

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and the performance of these two diprionid sawfly species as forest pests.

SPATIAL DISTRIBUTION PATTERNS OF PINE SAWFLIES IN THE WESTERN U.S. AND SICHUAN, CHINA

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Distribution patterns of pine sawflies were investigated in relation to forest stand characteristics. Infestations of *Neodiprion autumnalis* in ponderosa pine stands of the western US and *N. xiangyunicus* in yunnan pine stands of Sichuan, China were restricted by elevation and physiographic location. Infestations by both species were most common in pure, pole-sized stands and stands of open-grown trees for *N. autumnalis*.

EFFECTS OF GYPSY MOTH AND FOREST THINNING ON GROUND DWELLING ARTHROPODS

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From 1989 to 1992 pitfall traps were used to monitor populations of terricolous arthropod fauna: spiders, carabids, ants, and phalangids (opiliones). During that time, gypsy moth (*Lymantria dispar* L.) populations increased, causing severe defoliation and considerable mortality. Also, several areas were silviculturally thinned in an attempt to reduce stand level susceptibility and vulnerability to the gypsy moth, allowing for contrast of two disturbance types. In most cases, both defoliation and thinning appeared to evoke a similar response. The effect of canopy-opening disturbance was noticeable for ants and carabids -- total abundance decreased but diversity increased. For

spiders and phalangids, the effect of either defoliation or thinning was dampened by natural variation in the populations. Thinning, however, increased the abundance of phalangids, but the effect was evident for only one year.

DYNAMICS OF TWO-LINED CHESTNUT BORER IN FORESTS DEFOLIATED BY GYPSY MOTH

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Abundance data for *Agrilus bilineatus* (two-lined chestnut borer -- TLCB) were collected in 1989, 1991, 1992, 1993, and 1994. This period of time covers an outbreak of gypsy moth in West Virginia. Also, several stands were thinned prior to the defoliation. Populations of two-lined chestnut borer escalated in 1991, following defoliation in 1990. The following year defoliation continued although at a reduced level, but TLCB increased substantially from the previous year. TLCB abundance related significantly with percent defoliation of oaks and this relationship improved with the second year of defoliation. Considerable within-stand variation exists in this relationship, however; on a plot level basis there is no direct correlation between defoliation and TLCB. Thinning did not appear to have a consistent affect on TLCB, and defoliation represented the controlling factor in determining TLCB density.

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ESTIMATING THE PROBABILITY OF INFESTATION BY THE ROUNDHEADED PINE BEETLE, *DENDROCTONUS ADJUNCTUS* BLANDFORD, IN THE SACRAMENTO MOUNTAINS OF NEW MEXICO

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The roundheaded pine beetle (RPB), *Dendroctonus adjunctus* Blandford, is one of the most damaging bark beetles associated with ponderosa pine, *Pinus ponderosa* Lawson, in the Sacramento Mountains of New Mexico. A RPB outbreak started in 1988 and is still causing widespread tree mortality. No attempt has previously been made to quantify and model site and stand conditions conducive to infestations. The objective of this study was to model probability of infestation occurrence during the early stages of an outbreak based on site, tree, or stand conditions. During 1994 and 1995, intensive surveys were conducted in various stands representing different habitat types in the mixed conifer and ponderosa pine zones of the Sacramento mountains. Models to predict the likelihood of infestation have been built using Classification and Regression Trees (CART). These models may be of assistance to land managers in the implementation of silvicultural practices to reduce the likelihood of future catastrophic outbreaks of RPB. It appears that the RPB is selecting forest conditions of high basal area, conditions of slow growth, or tree characteristics associated with high tree density conditions. It has been suggested that fire suppression in the Southwest has resulted in an overabundance of overstocked stands. Since that is the condition that the RPB appears to be preferring, fire suppression may have played an important role on the catastrophic nature of the current outbreak.

MULTIAGENCY BIOLOGICAL CONTROL EFFORT FOR PINE SHOOT BEETLE

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The USDA Animal & Plant Health Inspection Service and cooperators initiated a classical biological control project against the pine shoot beetle (PSB) *Tomicus piniperda* in 1995 by: (1) conducting a pre-release survey of native natural enemies in Indiana, Michigan, and Ohio; (2) importing natural enemies; (3) establishing a culture of the exotic bark beetle predator *Thanasimus formicarius* (Cleridae); and (4) participating in an interagency integrated pest management program for the PSB. Although the pre-release survey produced over 47,000 bark beetles from 210 trap logs, it detected few native natural enemies during the PSB flight and developmental periods. For example, only 20 native clerid specimens were collected.

IMPACT OF SOUTHERN PINE BEETLE OUTBREAK ON THINNED STANDS

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Between 1988-1993, the USDA Forest Service established a Southern Pine Beetle (SPB) Demonstration Area Project on the 109,000 acre Oconee Ranger District in Georgia and the 97,000 acre Homochitto Ranger District in Mississippi. The goal was to demonstrate how forest management practices can minimize SPB and other pest-caused damage while still achieving overall management objectives. All pines stands were hazard rated to evaluate the risk of SPB attack. Most high hazard stands received silvicultural treatments to minimize the risk of significant loss. In 1995, the Homochitto Ranger District experienced one of the worst SPB outbreaks on record. This poster displays some of the impacts of

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that outbreak on the district and focuses in particular on the stands that received silvicultural treatment.

COMPARISON OF INSECT COLONIZATION ON EXOTIC VS. NATIVE TREE PLANTATIONS

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Forest entomologists often anticipate serious pest problems in plantations of fast-growing exotic tree species. This implies that plantations of native trees will have fewer insect problems than exotic tree species. A review of the literature revealed that, in fact, many exotics, at least initially, have a much lower incidence of colonization by indigenous insects in both tropical and temperate zones. Some examples of exotic species which have not experienced serious colonization from indigenous insects include: *Robinia pseudoacacia*, *Eucalyptus* spp., *Pinus radiata*, and *Populus* spp.

DEVELOPMENT AND DISTRIBUTION OF THE OAK ERIOCOCCIN, *ACANTHOCOCCUS QUERCUS*, ON NORTHERN RED OAK, *QUERCUS RUBRA*

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An outbreak of the oak eriococcin (*Acanthococcus quercus* (Comstock)), was observed on northern red oak (*Quercus rubra*) within a U.S. Forest Service seed orchard in 1995. Twenty trees representing ten tree families were selected for study. The life history and seasonality of *A. quercus* were assessed from specimens obtained weekly from each tree. This species overwinters as fertilized adult females. *Acanthococcus quercus* has two overlapping generations with females undergoing three

developmental stages, while males have additional prepupal and pupal stages. Females have a relatively high fecundity rate [avg.=119 (0-300) eggs/female]. Higher numbers of eggs were observed on the felt-like test of females on tree families 701 and 6662, while lower numbers of eggs were recorded for females on tree families 323 and 896. The eriococcin settles and feeds on the underside of branches of northern red oak, especially around forks, wounds, and leaf buds. Newly-emerged first instars often settle on new tree growth. The eriococcin population was dispersed throughout the tree. In July 1995, ca. 49% of the 787 northern red oak trees in the seed orchard were infested with the eriococcin. In 1995, densities of the overwintering generation declined from 6.56 individuals/cm² in July to 0.14 individual/cm² in November. No parasitoids were discovered in 1995; however, one lady beetle (*Scymus* sp.) was observed to feed on gravid eriococcins. Research will be continued in 1996 to assess population density and seasonality of this pest, and to monitor for potential parasites and predators within the northern red oak seed orchard.

RELATIONSHIP BETWEEN BLUE-STAIN FUNGI IN ROOTS OF LOBLOLLY PINE AND SOUTHERN PINE BEETLE ATTACK

William J. Otrrosina (USDA Forest Service, Institute for Tree Root Biology, 320 Green Street, Athens, GA 30602), **Nolan J. Hess** (USDA Forest Service, 2500 Shreveport Hwy., Pineville, LA 71360), **John P. Jones** (Louisiana State University, Baton Rouge, LA 70803), **Stanley J. Zarnoch**, and **Thelma J. Perry** (USDA Forest Service, 2500 Shreveport Hwy., Pineville, LA 71360)

Forty paired plots comprised of southern pine beetle (SPB)-infested (less than 1 month since attack onset) and adjacent non-infested control plots were established in natural stands and plantations of loblolly pine. No statistical differences were found in stand parameters such as age, basal area, DBH, radial growth rate, and height between control and SPB-infested plots. Blue-stain fungi were isolated with a frequency of 0.875 from SPB infested-plots versus 0.45 of the control plots (P<0.001). Three species of blue-stain fungi identified during this study were *Ophiostoma ips*,

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Leptographium terebrantis, and *L. procerum*. Of these species, *L. terebrantis* was isolated most frequently from SPB inoculation studies. *L. terebrantis* was most pathogenic to loblolly pine seedlings.

CHARACTERIZATION OF BLACK OAK DECLINE ON LONG ISLAND

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Dieback on black oaks (*Quercus velutina* Lamarck) has occurred on Long Island, New York since the mid 1980s. Damage from a cynipid gall wasp, *Bassettia ceropteroides* and a fungal canker, *Botryosphaeria* spp., are associated with symptoms of decline. A survey was conducted to assess the geographic extent and severity of the decline in street, park, and natural areas. Park trees exhibited significantly higher percentages of galling, cankering, and crown dieback while street tree symptoms were intermediate to park and natural trees. Tree age did not correlate with dieback severity nor was there a clear relationship between soils and dieback. Ongoing research will investigate the influence of weather, prior defoliation, and other factors on black oak susceptibility.

SLOW-RELEASE PHEROMONE FORMULATIONS FOR MATING DISRUPTION OF PONDEROSA PINE TIP MOTH, WESTERN PINE SHOOT BORER, WEBBING CONEWORM, GYPSY MOTH, AND OTHER FOREST INSECT PESTS

Alberto R. Quisumbing (Hercon Environmental Corporation, Aberdeen Road, P.O. Box 467, Emigsville, PA 17318)

Environmentally-friendly pheromone formulations are now used to control pests by mating disruption for several reasons including: (1) insecticide resistance in target pests; (2) secondary pests outbreaks due to constant application of insecticides and their harmful effects on beneficial parasites and predators; (3)

inability of toxicants to control larvae that may have bored inside plant parts; and (4) shortage or cancellation of EPA-registered products. Mating disruption is now used commercially to control pests in cotton, tomatoes, apples, peaches, and pears. For forest insects, an EPA-registered slow-release formulation of racemic disparlure is now applied for control of gypsy moth, *Lymantria dispar*. In addition, several multilayered ribbon or strip dispensers of pheromones have been evaluated for control of western pine shoot borer, *Eucosma sonomana*, webbing coneworm, *Diorytria disclusa*; and ponderosa pine tip moth, *Rhyacionia zozana*. The suggested applications and field performance of these various formulations are presented.

INFLUENCE OF ELM VARIETIES AND FOLIAGE TOUGHNESS ON THE ELM LEAF BEETLE, *XANTHOGALERUCA LUTEOLA*

Lizong Ren and Michael R. Wagner (School of Forestry, Northern Arizona University, P.O. Box 15018, Flagstaff, AZ 86011)

Laboratory larval rearing and adult feeding preference experiments of the elm leaf beetle, *Xanthogaleruca luteola* (Muller), were conducted on six elm varieties in the summer of 1995. The results indicate that larval mortality, larval developmental time, pupal weight, and adult feeding preference index were significantly different among elm varieties; and these four examined traits were significantly related to foliage toughness.

PROTECTING HIGH-VALUE STANDS FROM DOUGLAS-FIR BEETLE INFESTATION WITH AN ANTIAGGREGATION PHEROMONE

Darrell W. Ross (Dept. of Forest Science, Oregon State University, 020 Forestry Sciences Lab., Corvallis, OR 97331) and **Gary E. Daterman** (USDA Forest Service, Pacific Northwest Research Station, 3200 Jefferson Way, Corvallis, OR 97331)

Studies over a four-year period demonstrated the efficacy of an antiaggregation pheromone, 3-methylcyclohex-2-en-1-one (MCH), for protecting

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high-value stands of Douglas-fir from infestation by the Douglas-fir beetle. In 1992, a combination of aggregation and antiaggregation pheromones was tested. MCH was applied to the perimeter of 1-ha circular plots at a rate of 60 g/plot. Treated plots also had three to four clusters of four multiple-funnel traps baited with frontalin, seudanol, 1-methylcyclohex-2-en-1-ol, and ethanol located outside of the plot but within 160 m of the boundary. The mean percentage of Douglas-fir host trees (≥ 20 cm DBH) that were mass attacked was reduced by 80% within the treated plots compared with the untreated plots. However, there was a significant increase in the percentage of mass-attacked trees outside of the plots in the vicinity of the funnel traps. Therefore, in 1993, we tested the efficacy of MCH alone. The MCH was applied to plots ranging from 1.6 to 2.6 ha in size at rates of 45-76 g/ha. The percentage of host trees that were mass-attacked was significantly lower on the treated plots (0.2%) compared to the control plots (8.5%). Studies were conducted in 1994 and 1995 to determine the optimal dosage of MCH for operational treatments. In 1994, the MCH was applied to 1-ha circular plots at rates of 0, 20, 40, and 60 g/plot. The percentage of host trees that were mass attacked was significantly lower on all of the treated plots compared to the untreated control. However, there were no significant differences among the three MCH dosages. In 1995, MCH was applied at rates of 0, 6, 12, and 20 g/plot. All three rates significantly reduced catches of Douglas-fir beetles in pheromone-baited traps at plot centers compared with the control, but there was no significant effect on percentage of trees mass-attacked. The combined results of these studies indicate that MCH applied at rates as low as 20 g/ha can reduce the probability that high-risk Douglas-fir will become infested.

INFORMS R-8, THE UTILITY OF RULEBASE TECHNOLOGY IN A DECISION SUPPORT SYSTEM

Douglas N. Rubel (USDA Forest Service, Forest Health Protection, 2500 Shreveport Hwy, Pineville, LA 71360), **Stephen B. Williams** (USDA Forest Service, Forest Health/Methods Applications Group, 3825 E. Mulberry, Fort Collins, CO 80524), and **Forrest L. Oliveria** (USDA Forest Service, Forest Health Protection, 2500 Shreveport Hwy, Pineville, LA 71360)

Integrated Forest Resource Management System in Region 8 (INFORMS R-8) is a decision support system designed to aid in project-level planning and in the development of environmental assessments on U.S. Forest Service managed land. Components integrated in this tool include a geographic information system (GIS), a relational database management system (RDBMS), a user interface system (UIS), various simulation models, and an assortment of rulebases. Rulebases can be developed at any management level for specific project analysis. Rulebase technology can benefit resource managers in optimally evaluating land management issues in a consistent and defensible manner. Sample rulebases developed by subject area experts from the Ouachita National Forest in Arkansas are depicted. This display includes rulebases to optimize prescribed burning on forest lands, to highlight foraging areas for the scarlet tanager, and to determine the probability of locating significant prehistoric resource sites.

SPATIO-TEMPORAL PATTERNS OF GYPSY MOTH SPREAD IN NORTH AMERICA

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Gypsy moth, *Lymantria dispar*, was introduced into North America near Boston in 1869 and since that time it has been spreading mainly to the west and south. The patterns of population spread were studied at two

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spatial scales: (1) large-scale, which is the progression of the population front, and (2) small scale, which is the effect of landscape characteristics on population numbers that distort the shape of the moving population front. The rate of spread through the central Appalachian Mountains was measured as a distance between population boundaries in two consecutive years. Boundaries are lines that separate areas with population densities generally above and below a specific threshold. They were estimated using the best cell classification method. The boundary of one moth per trap was on average 110 km from the boundary of the defoliation, and the male moth capture rate increased 10X per 29 km perpendicular to the population front. Approximately 11 years separated the time when traps caught one moth per trap until defoliation first occurred in the same area. Gypsy moth spread rate declined from 1984 to 1995 from 15-20 km/year to 5-10 km/year. Reduction in gypsy moth spread rate may have been due to intensive population management in the area. Effect of landscape characteristics (elevation, slope, aspect, and vegetation) on population numbers depends on dominant ecological processes in the area. We define k-, r-, and c-effects as differences in carrying capacity, population growth, and colonization rate, respectively, that are associated with variation in landscape characteristics. To differentiate among these effects, we analyzed three zones individually: infested (k-effects), transition (r-effects), and uninfested (c-effects). Among landscape characteristics, elevation was most highly correlated with moth counts. Moth counts increased with increasing elevation in the infested and transition zones (k- and r-effects) which may be associated with good habitats at high elevation. However, in the uninfested zone, the highest moth counts were found at low elevation. Possibly this was the c-effect which resulted from a greater colonization rate in the low elevation areas where human population densities are greater and the probability of inadvertent transfer of egg masses on human vehicles is increased. The effect of vegetation on moth counts was much less pronounced than the effect of elevation. In the transition zone, landscape characteristics were correlated with moth captures stronger than in other zones.

EFFECTS OF INSECTICIDE TREATMENTS ON SUBSEQUENT DEFOLIATION BY WESTERN SPRUCE BUDWORM IN OREGON AND WASHINGTON: 1982-1992

Katharine A. Sheehan (USDA Forest Service, Pacific Northwest Region, Natural Resources, P.O. Box 3623, Portland, OR 97208)

Effects of insecticide treatments conducted in Oregon and Washington (1982-92) on subsequent defoliation by western spruce budworm were evaluated. For each treatment, the extent and severity of defoliation was calculated for the treated area and a set of nested rings surrounding the treated area (0-0.5 mile, 0.5-1 mile, 1-2 miles, and 2-4 miles). Insecticide treatments applied in 1982 and 1983 coincided with reduced defoliation by western spruce budworm during the year following treatment. However, defoliation usually returned to pretreatment levels by the second year, and defoliation severity in treated and adjacent untreated areas was nearly identical following treatment. For the period from 1985 through 1992, defoliation patterns (including both extent and severity) following treatment were generally similar in treated and adjacent untreated areas.

THE FOREST HEALTH TECHNOLOGY ENTERPRISE TEAM (FHTET)

Eric Smith (USDA Forest Service, 3825 E. Mulberry, Ft. Collins, CO 80524) and **Allan Bullard** (USDA Forest Service, 180 Canfield St., Morgantown, WV 26505)

The Forest Health Technology Enterprise Team (FHTET) has been formed under the supervision of the USDA Forest Service's Forest Health Protection Director, Dr. Ann Bartuska. The team combines what were formerly the Methods Application Group, Ft. Collins, CO, the National Center of Forest Health Management, Morgantown, WV, and the Pesticide Application Technology Unit, Davis, CA. The organization emphasizes teamwork, partnerships, and shared funding to develop and deliver technology and services to promote forest health protection. General program work areas are information services, technical

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support, training and education, and technology development. FHTET program areas include biocontrol and biopesticide development, non-target pesticide impacts, pesticide application technologies and disruption models, pest impact models and related analyses, decision support systems, remote sensing and GIS, Data visualization, and values determination.

GYPSY MOTH IN MASSACHUSETTS

Dennis Souto, Thomas Luther, Amy Snyder, Susan Cox (USDA Forest Service, Forest Health Protection, P.O. Box 640, Durham, NH 03824), and **Charlie Burnham** (Massachusetts Department of Environmental Management, P.O. Box 484, Amherst, MA 01004)

In 1869, Professor Leopold Trouvelot, and eminent astronomer and naturalist, accidentally released the first gypsy moth in the United States while trying to breed a new silkworm. Since then, attempts to destroy, eradicate, and suppress the moths have varied. Introduction of parasites and viruses, mechanically destroying egg masses, removing preferred host species from the stand, and spraying many different insecticides only temporarily slowed the gypsy moth. The infestation of gypsy moths now covers many eastern states. Gypsy moths have become naturalized in Massachusetts and throughout New England and management now focuses on maintaining trees through the cyclic outbreaks.

FOREST HEALTH MAPS FOR THE SOUTHERN APPALACHIAN ASSESSMENT

Brian M. Spears (USDA Forest Service, 200 Weaver Blvd., Asheville, NC 28804)

The Southern Appalachian Assessment is a cooperative project of several agencies. The Assessment Area contains 37.4 million acres in parts of seven states including Alabama, Georgia, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. It includes seven National Forests and several National Parks. There are four themes: terrestrial, aquatic, air quality, and

social/cultural/economic. The Forest Health Sub-Team of the Terrestrial Team analyzed data and produced graphics to answer forest health questions about insects, diseases, and fire. The poster depicts several forest health graphics developed for the Southern Appalachian Assessment.

FOREST HEALTH MONITORING PROGRAM

K.W. Stolte (USDA Forest Service, Southern Research Station, 3041 Cornwallis Road, Research Triangle Park, NC 27709) and **E. Eastman** (North Carolina State University at Southern Research Station, 3041 Cornwallis Road, Research Triangle Park, NC 27709)

The Forest Health Monitoring program is a multi-agency, national program designed to monitor the status, changes, trends, and association of indicators of forest condition. The RHM program consists of four related components: detection monitoring, intensive site ecosystem monitoring, evaluation monitoring, and research on monitoring techniques. Detection monitoring is currently active in 18 states in the U.S., and five central European countries. Detection monitoring is conducted annually and uses both plot monitoring and off-plot surveys to determine status and change in forest condition, based FHM indicators. These FHM indicators are developed from research and monitoring of key processes of forest ecosystems at watershed research sites. The FHM program currently assesses forest health and sustainability through indicators related to tree growth, spacing, damage, mortality, regeneration, and crown condition; understory vegetation diversity; leaf area index; ozone bioindicator plants; and lichen community diversity and air pollution sensitivity. Other indicators in development include soil erosion, fertility, and toxicity; wildlife habitat; dendrochronology; and fuel loading. These indicators were selected to address key criteria that relate to forest sustainability: productivity, diversity, vitality, carbon cycles, soil conservation, and water conservation.

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ROLE OF VERTICAL SILHOUETTE IN PINE BARK BEETLE HOST SELECTION

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Tree protection tactics based on semiochemicals are being investigated by many forest scientists but their consistent effectiveness remains a concern. One approach toward increasing the efficacy of such treatments is to combine semiochemically-based tactics with deterrents that disrupt other cues necessary for host finding and colonization. In this study we attempted to deter colonization of southern pine beetle (SPB) through disruption of the visual stimulus created by a dark, vertical silhouette. White paint was chosen as one easily evaluated deterrent since it is visually dissimilar to loblolly pine bark and readily available. Studies were conducted at eight sites in Florida and Louisiana during the summer and fall of 1995. We found that 4-allylanisole in funnel traps reduced trap catch significantly (ca 50% reduction) when compared to frontalure alone. Verbenone had no effect on trap catch; not unexpected since elution rates were ca 1/4 that recommended for disruption. The visual deterrent, white paint, reduced trap catch of SPB more than any semiochemical (ca 70% on average). The combination of 4-allylanisole and white paint reduced trap catch by >90% (as compared to frontalure), which was significantly lower than any other treatment. Plexiglass sticky panels gave similar results, with white panels catching the fewest beetles, followed by clear and then black (each significantly different from each other). Trees painted white to four meters also disrupted normal colonization by SPB and were attacked by SPB primarily above the paint. Trees painted black were colonized in pattern not discernibly different from unpainted trees. These results suggest that visual disruption of SPB is possible, and when included with semiochemicals, may improve efficacy of tree protection programs where standard direct control tactics are not desired or feasible.

FIELD RESPONSE OF SOUTHERN PINE BEETLE PARASITOIDS TO SOME NATURAL ATTRACTANTS

Brian T. Sullivan, C. Wayne Berisford, and Mark J. Dalusky (Dept. of Entomology, University of Georgia, Athens, GA 30602)

Studies were performed to isolate and identify semiochemicals that mediate host-tree location by parasitoids of the southern pine beetle (SPB), *Dendroctonus frontalis* Zimmermann (Coleoptera: Scolytidae). Bark or bolts removed from pines infested with SPB broods attracted significant numbers of the hymenopterous parasitoids *Spathius pallidus* Ashmead and *Roptrocercus xylophagorum* (Ratzeburg) to sticky traps placed in an active SPB infestation. An essential oil extract was obtained from the SPB brood-infested bark using a water distillation procedure, and traps baited with this extract attracted both of the above mentioned species of parasitoids. In contrast, a synthetic bait composed of eighteen compounds identified in the headspace of attractive bark failed to trap parasitoids. Using silica gel liquid chromatography, the oxygenated and hydrocarbon components of the crude bark extract were largely separated from each other, and the resulting two fractions were tested in the field. Parasitoid attraction was greatest when both fractions were released from traps simultaneously. The hydrocarbon fraction, which failed to attract parasitoids, acted as a synergist and enhanced the weak attractiveness of the oxygenated fraction. Hence it appeared that no single compound was responsible for mediating SPB parasitoid host tree location and that both oxygenated and hydrocarbon semiochemicals were involved in this process. In addition, the two species of trapped parasitoids appeared to be responding maximally to attractants that differed in their composition and in the SPB brood stages associated with these odors.

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AN UNWELCOMED GUEST IN CHINA: A PINE-FEEDING MEALYBUG, *ORACELLA ACUTA*, FROM THE SOUTHEASTERN UNITED STATES

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A mealybug, *Oracella acuta*, was introduced into Guangdong Province in the People's Republic of China (PRC) from the United States in 1988. Fifty hectares of infested slash pine forest were detected in 1990, increasing to 22,000 ha in 1995. The rate of spread is approximately 17-22 kilometers/year. Severe infestations are currently in exotic slash and loblolly pine plantations, but native mason pine is also threatened. Pines are not killed, but growth and yield are reduced. Natural enemies normally regulate *Oracella acuta* populations in the U.S. at low levels. Natural enemies of *O. acuta* are being introduced into the PRC in a biological control project between the PRC and U.S. Two parasitoids, *Allotropa* spp. and *Acerophagus coccois*, reared from greenhouse and seed orchard infestations of *O. acuta* in the southeast U.S., have been sent to Guangdong Province. The Chinese have released some parasitoids, and are currently monitoring their establishment.

THE SOUTHERN APPALACHIAN MAN AND THE BIOSPHERE (SAMAB) PROGRAM

Robert C. Thatcher (SAMAB Cooperative, 12 Bevlyn Dr., Asheville, NC 28803)

SAMAB (Southern Appalachian Man and the Biosphere Program) was established in 1988 under the umbrella of the worldwide Man and the Biosphere Program. Its goal is to provide the means for active cooperation among the responsible parties in the Southern Appalachian Region, to promote a fuller understanding of the natural resources of the area, to encourage the inner management of those resources,

and to facilitate, encourage or otherwise foster environmental research, education, training, and environmentally sound economic development. Eleven federal agencies, three states, private corporations, universities, colleges, and communities are presently involved in the program.

FOREST FIRE FOLLOWING A SPRUCE BEETLE OUTBREAK IN CENTRAL IDAHO

R.W. Thier, **L. Spillers**, **P.J. Mocettini**, and **R.L. Halsey** (USDA Forest Service, Forest Health Protection, Boise Field Office, 1750 Front Street, Boise, ID 83702)

Spruce trees in central Idaho forests sustained an unprecedented infestation of spruce beetle (*Dendroctonus rufipennis*) beginning in the early 1980's which still continues today. Over 350,000 trees have died contributing to fuel loads over 100 tons/acre. Coincident with the infestation was a hot, dry weather cycle which began in the mid-1980's. This weather likely caused the beetle infestation to intensify. Beetles accelerated their development; shortening their life cycle from the usual two years to one year. The character of fuels also changed as hot, dry weather prevailed. In August 1994 lightning ignited fires in the spruce-fir type which eventually burned trees over 300,000 acres. Weather conditions, fuel conditions and mortality due to the beetle infestation contributed to the eventual size of the stand replacing fires. Investigators state that widespread fire seems to be a rare event in the spruce-fir type and fire hazard seems exaggerated. Indeed, fire histories indicate that this type stand replacement fire occurs approximately once every 300 years. This stand replacement fire radically changed the spruce-fir successional pathway expected following a spruce beetle infestation without fire.

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IMPACT OF ECOSYSTEM RESTORATION ON OLD-GROWTH PONDEROSA PINE RESISTANCE TO PHLOEM-FEEDING AND FOLIVOROUS INSECTS

Michael R. Wagner, Thomas E. Kolb, Shelly R. Feeney, and Joseph E. Stone (School of Forestry, P.O. Box 15018, Northern Arizona University, Flagstaff, AZ 86011)

Experimental treatments in ponderosa pine were established to recreate pre-European settlement old-growth forest structure and function. The influence of these treatments on tree resistance to phloem-feeding and folivorous insects was measured by resin flow and foliage toughness, respectively. Restoration significantly increased tree resistance to both insect feeding guilds.

BEECH SCALE AND BEECH BARK DISEASE IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Greg J. Wiggins, Jerome F. Grant, Robert A. Vance, Mark T. Windham, Paris L. Lambdin (Dept. of Entomology and Plant Pathology, The University of Tennessee, Knoxville, TN 37901), and **Kristine Johnson** (Great Smoky Mountains National Park, 107 Park Headquarters Road, Gatlinburg, TN 37738)

American beech, *Fagus grandifolia* Ehrlich, in eastern North America is currently threatened by the devastating beech bark disease (the fungal causative agents are *Nectria* spp.). In 1993, this disease was first documented in the Great Smoky Mountains National Park (GSMNP), where it is now well established. A study was conducted to determine infestation levels of beech scale and incidence of *Nectria* spp. in the GSMNP. Research also investigated the life history of beech scale and evaluated the incidence of its natural enemies. Permanent plots have been established to allow long-term monitoring of beech scale, *Nectria* spp., and beech bark disease in the GSMNP. During this two-year study, ca. 19% and 50% of all examined beech trees were infected with *Nectria* spp. and beech scale, respectively. The overall status of beech scale within permanent plots has been static since 1994,

while the inoculum load for *Nectria* spp. has increased. The peak period for dissemination of beech scale was in September, when the greatest numbers of crawlers were observed. As in other studies, no parasitoids of beech scale were documented; and only a few predators, including the mite *Trombidium* sp., were observed to feed on beech scale. These data will provide base-line information to determine the spread, distribution, and impact of beech bark disease in the GSMNP.

CONDITIONS OF HARDWOOD FORESTS IN MICHIGAN: THE MICHIGAN IMPACT MONITORING SYSTEM

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Gypsy moth defoliation, drought, and frost are important stress factors throughout various regions of Michigan's hardwood forest in recent years. Little information is available quantifying conditions of oaks, aspens, and northern hardwoods in the Lake States region. Starting in 1991, we established 566 plots in 283 hardwood forest stands (oaks, aspen, and northern hardwood) throughout the lower peninsula of Michigan and are monitoring these plots on a yearly basis to track changes in forest conditions and associated common stress factors. Overall, hardwood forests in Michigan are in good condition. However, much variation in tree vigor, mortality, and regeneration occurs among individual stands and among ecosystem units in each forest type. For instance, northern pin oak stands are experiencing much higher mortality rates than are other types of oak stands. Results to date also indicate that regeneration is, in general, poor in oak stands and adequate to very good in aspen and northern hardwood stands.

THE CONSEQUENCES OF GYPSY MOTH
DEFOLIATION ON GROUND BEETLES IN TWO
NORTHERN HARDWOOD ECOSYSTEMS

Timothy T. Work and Deborah G. McCullough
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The effects of severe gypsy moth defoliation on ground beetle (Coleoptera: Carabidae) diversity and abundance were measured in red oak and sugar maple/basswood ecosystems in Manistee National Forest in northern Michigan. In 1993, 1994, and 1995 ground beetles were sampled from canopy and ground strata using suspended UV traps and pitfall traps. Fifty-five species were collected. Species richness consistently increased in stands the following year after severe defoliation. The effects of defoliation on microclimatic conditions and the increase in potential prey abundance may explain trends in the capture of certain species.

IMPACT OF *THANASIMUS UNDATULUS* (SAY)
(COLEOPTERA: CLERIDAE) ON BROOD
PRODUCTION OF DOUGLAS-FIR BEETLE,
DENDROCTONUS PSEUDOTSUGAE HOPKINS
(COLEOPTERA: SCOLYTIDAE), IN CAGED
BOLTS

Jianlin Zhou and Darrell W. Ross (Dept. of Forest
Science, Oregon State University, Corvallis, OR
97331)

A factorial experiment was conducted to assess the potential impact of *Thanasimus undatulus*, a clerid predator, on Douglas-fir beetle brood production in individual caged bolts. The nine treatments were combinations of three densities of Douglas-fir beetle (30, 60, and 120 pairs/m²) and three densities of *T. undatulus* (0, 5, and 10 pairs/m²). Total mortality of Douglas-fir beetle broods ranged from 27.2% at low Douglas-fir beetle density without predation to 99.7% at high Douglas-fir beetle density with high predation. The average brood parent ratios were 13.3, 2.2, and 0.8, respectively, with increasing *T. undatulus* densities. The results suggest that *T. undatulus* may be a significant cause of Douglas-fir beetle mortality.



Section VI

NAFIWC Insect Photo Salon

NAFIWC INSECT PHOTO SALON

For the first time, the NAFIWC offered an insect photo salon in San Antonio. All Conference participants having skills with a camera were encouraged to enter color slides for judging. Seven photographers submitted a total of 71 entries. Two nature photographers, Nancy Webb and Kenneth Wilson from Baton Rouge, LA selected winners in each of four categories: (1) forest insect; (2) insect-caused damage;

(3) forest insect and/or damage series; and (4) forest entomology humor. First, second, and third place winners in each category were recognized at the Conference and first place winners received framed certificates. Winners within each category, including honorable mentions (HM), are listed below:

Forest Insect

1st	Jerry Lenhard (Polyphemus caterpillar)
2nd	Ron Billings (Cerambycid takes flight)
3rd	Ron Billings (Imperial moth larva on loblolly pine #2)
HM	Ed Holsten (Female wood wasp ovipositing in white spruce) David Leatherman (Bagworm on redbud) David Leatherman (Dragonfly on yucca)

Forest Insect Damage

1st	Ron Billings (Lodgepole pine killed by mountain pine beetle)
2nd	Ron Billings (Uncontrolled infestation of southern pine beetle)
3rd	William Ciesla (Mortality of Englemann spruce caused by spruce beetle)
HM	Ron Billings (Fall colors in east Texas, caused by southern pine beetle) Jerry Lenhard (Feeding damage by the larger elm leaf beetle)

Series

1st	Ron Billings (Life stages of the blue binder butterfly)
2nd	Ron Billings (Impact on southern pine beetle on Texas wilderness)
3rd	Don Rogers (Fall cankerworm)
HM	Don Rogers (Hemlock woolly adelgid)

Forest Entomology Humor

1st	Ron Billings (Expose yourself to the southern pine beetle)
2nd	Ron Billings (Damage from Texas stem snapper)
3rd	Ron Billings (Predator & prey)
HM	Ron Billings (Bee prepared)



Section VII

Work Conference Evaluation

WORK CONFERENCE EVALUATION

Participants in the 2nd North American Forest Insect Work Conference were asked to fill out and return an evaluation form at the conclusion of the Conference. Twenty aspects were rated on a scale of 1 (poor) to 5 (excellent) (see evaluation form on next page). In the space preceding each question is: (a) the average response given by the 102 (of 320) Conference participants who responded; and (b) the percent of responses with a ranking of 4 or 5 (above average). Finally, comments specifically solicited on which topics to omit or add in the next NAFIWC, as well as additional comments received from respondents, are listed below. Hopefully, these comments and suggestions will contribute to an even more successful third NAFIWC.

A vast majority of the respondents (96%) rated the Conference as effective, well-organized, and held in a convenient location. Both the city (San Antonio) and the hotel (St. Anthony Hotel) received excellent reviews. Most felt the Conference was of suitable length and covered an appropriate array of pertinent subjects. Registration materials and the registration process were rated very high.

A majority of respondents liked the idea of a plenary panel to begin the Conference and 2-3 concurrent panels to discuss major issues. Certain moderators of both panel and workshop sessions received criticism for either scheduling too many speakers or not allowing sufficient time for discussion from the floor. Several respondents emphasized the need for more informal workshops and fewer prepared speeches.

A major complaint among nearly half of the respondents was related to the number of concurrent workshops. Many participants had difficulty making a decision on which of seven concurrent workshops to attend, believing they were forced to miss out on other interesting topics. The same criticism prevailed at the first NAFIWC in Denver, and may be unavoidable in future national conferences if workshop size is to be intentionally limited as a means to facilitate discussion.

The inclusion of a poster session was very well received, despite commonly observed problems with access and poor lighting (Anacacho Balcony). Many participants would like to have had more time allotted for formal poster presentations, including a scheduled time period during mid-day when no other activities were in progress. For the first time, poster abstracts were compiled prior to the Conference and distributed in the registration packet. This effort was appreciated.

The inclusion of various field trip options in San Antonio and the Hill Country was well received. Most participants appreciated having a mid-week field trip and enjoyed the opportunity to view local natural attractions and pest problems. Despite a long day of traveling and rather loud music at the evening barbecue, 90% of respondents ranked the field trip they selected as above average and 85% indicated that field tours should be included in the next NAFIWC.

The Insect Photo Salon was another event held for the first time at this NAFIWC. Not all Conference participants attended the evening showing of slides, but most of those who did concluded that it was a worthwhile event. The most common criticism was that too few photographers submitted entries.

Overall, most felt that the Conference was timely, well organized, and flawlessly conducted. Following two successful Conferences, the recommendation to offer a third NAFIWC was nearly unanimous (99%). Most respondents suggested that the third Conference be held in five years in a location to be determined. Various cities in the United States, Canada, and Mexico were suggested as possible locations. Of 72 respondents who specified a preferred country for the next NAFIWC, 47% recommended the United States (particularly the Pacific Northwest) while 32% suggested Canada (western Canada received the most votes) and 21% suggested Mexico. Thanks to all who participated in the planning and successful conduct of the first two NAFIWCs, it appears that a new tradition has been born. Accordingly, we look forward to the next North American Forest Insect Work Conference.

WORK CONFERENCE EVALUATION

SECOND NORTH AMERICAN FOREST INSECT WORK CONFERENCE

Total Number of Responses = 102

The Steering Committee hopes that you have enjoyed the Second North American Forest Insect Work Conference and leave San Antonio with a feeling of accomplishment and time well spent.

In order to identify ways to improve the next Conference, please take the time to rate the following aspects of this Conference using the scale below:

Excellent (Yes)		Average		Poor (No)
5	4	3	2	1

If you wish to provide written comments, please do so in the space that follows each question or at the bottom of the page. Results will be summarized in the Conference proceedings. Return this form to the designated location at the registration/information desk in the Anacacho Foyer or return by mail. Thank you.

- 1. 4.48 * 96%** How would you rate the Conference overall?
- 2. 4.55 90% Was the Conference advertised adequately prior to the meeting date?
- 3. 4.82 98% Was registration handled efficiently?
- 4. 4.32 85% How would you rate the length of the Conference?
- 5. 3.42 51% Were the number of concurrent panels and/or workshops appropriate?
- 6. 4.23 87% Were session lengths appropriate?
- 7. 4.79 97% Was San Antonio an appropriate site for the Conference?
- 8. 4.44 92% Were the hotel facilities adequate?
- 9. 4.72 96% Were registration materials adequate (e.g., registration brochure, poster abstracts, printed program, field tour descriptions, souvenirs)?
- 10. 4.20 77% Was the keynote address by the Texas State forester of interest?
- 11. 3.95 70% Was the Plenary Panel a good beginning to the Conference?
- 12. 3.73 61% Were the concurrent panels an effective means to discuss major topics?
- 13. 4.01 71% Did the poster sessions contribute to the Conference?
- 14. 3.45 44% Was the time available for the poster sessions adequate?
- 15. 4.56 90% Was the field tour you attended interesting and worthwhile?
- 16. 4.54 85% Should field tours be included in the next NAFIWC?
- 17. 4.29 81% Was the evening at The Farm and Texas BBQ enjoyable?
- 18. 4.92 99% Should a third NAFIWC be offered in the future? .
- 19. 4.00 68% Was the Photo Salon a worthwhile event?
- 20. 4.75 98% Was the Conference reasonably well organized and conducted?

What topics/events would you have omitted? _____

What topics/events would you have added? _____

Additional comments: _____

* Mean of 102 responses
 ** Percent of responses with ranking of 4 or 5 (above average).

WORK CONFERENCE EVALUATION

WHAT TOPICS WOULD YOU HAVE OMITTED?

- None (9 respondents); no comment (58 respondents)
- Those that were poorly attended. (I don't know what those were - all those that I attended were great!)
- Too many concurrent sessions... eliminate half of them. In some cases overlapping sessions were on the same topic.
- Maybe fewer concurrent panels.
- Topics included were all important - I don't think you could have omitted any. I wish I could have attended more.
- Would eliminate the loud music from the evening social event - people want to talk, not dance.
- Omit all panels which consist of prepackaged speeches only. Omit all panels with regional perspectives on one topic. They become a laundry list of pests of each region.
- Omit farewell lunch.
- Field trips should be less time consuming; outside event (i.e. BBQ) could have been left out.
- Too many concurrent workshops. Talks not synchronized in time making it difficult to move from one workshop to another.
- Job board.
- Less topics, more discussions on topics selected.
- Plenary and concurrent panels.
- I might of made the (field) tour and BBQ optional so that an individual could enjoy a tour but have the option of not participating in the BBQ, rather than having to stick it out until 9:30 P.M.
- Too many concurrent workshops. Eliminating the morning panels (which were rarely of interest) would have left more time to spread out workshops.
- Fewer sessions on biologicals and modeling. There was duplication in these areas.
- Eliminate the continental breakfast or make sure there is an adequate amount of food and juice for everyone.
- I liked everything. How much would have been saved if you didn't use color in the conference brochure? or didn't make posters? or had T-shirts printed on one side only?
- Reduce number of concurrent workshops.
- Omit plenary panels, welcome, etc.
- None in particular, but I would like to see fewer concurrent workshops - choosing from seven was somewhat taxing.
- Too much general forest health, exotic pests, etc.
- Omit spatial analyses, forest health monitoring, panels in general (make them concurrent sessions).
- Possibly the field trip. Would give more time for poster exposure and possibly more workshops that would not conflict.

WORK CONFERENCE EVALUATION

- No panel until 9:00 AM on Friday to allow more time for check out, etc.
- You could have omitted mugs, T-shirts, etc. (or had them for sale separately) and lowered the cost.

WHAT TOPICS/EVENTS WOULD YOU HAVE ADDED:

- None (4 respondents); no comment (70 respondents).
- I think it was adequately organized---about right mix of panels, workshops, etc.
- Probably include other international speakers and subjects since exotics are becoming more important.
- Promote more informal sessions organized by attendees; interagency session to conduct reality check on our ability to work together with shrinking resources.
- You covered everything I could think of.
- More discussions - less formal presentations in some of workshops. I recommend that at least 1/3 of the time be set aside for discussion.
- States' role in forest health monitoring; suppression programs; and survey and detection. There is a lot of expertise in the states - let's hear from them.
- It would be good as a participant outside North America to have had a session dealing with interface issues with other countries. It would help to get more participation from those countries.
- Would have lengthened exotic pests with more input from regulatory/port of entry agencies.
- More time devoted to tree/insect interactions as affected by environment. Perhaps could separate into bark beetles/leaf feeders/shoot feeders, etc.
- Graduate student sessions, employment opportunities.
- Challenge NAFIWC members to provide new topics/ideas.
- Informal, unstructured workshops on specific subjects instead of formal workshop presentations.
- Group photos would have been nice. But when? where?
- With a theme of 20:21, I would have taken the opportunity to stress where we're been and where we are going - more futuristic as we head into the next century.
- More participation by state employees who take the knowledge turned out by academia and other research units and use it to practice forest entomology.
- More discussion of future vision and how to make it happen.
- Identifying and prioritizing research in forest entomology: federal, state, university, and industry perspectives.
- Perhaps need participation/interaction with more "outside" views and/or people from other disciplines (wildlife, soil, plant physiology, recreation, industry, etc.).

WORK CONFERENCE EVALUATION

- Insect genetics, insect physiology, biochemistry.
- Web utilization - some basic protocols for pest management-type pages.
- A session on information transfer in the electronic era.
- More on aphids/sap feeders.
- Have a session dedicated exclusively to posters.
- More plant/herbivore interactions, modern insect ecology.

ADDITIONAL COMMENTS

- Outstanding meeting and well worth traveling 8,000 miles for. One small criticism, in some of the sessions I attended, speakers abused their time allocation and severely reduced discussion time. Thanks for a great meeting of very knowledgeable and nice people.
- Thank you so much for having orange juice for us non-coffee drinkers and having sodas in the afternoon.
- I know you were trying to get the most out of the time available, but I had to miss Friday's meeting because of travel requirements. That probably was a problem for others. Overall, tho'.....great conference.
- Excellent meeting overall - San Antonio was outstanding selection.
- Hotel rooms—quality varied, but ours was less than satisfactory; poor A/C, painting and construction in hallways, very late cleaning and refurbishing during the day. Rates should have been adjusted.
- Good conference, excellent location.
- Workshops on the same general topic should not be concurrent.
- Having posters manned from 7-8 AM was a major inconvenience for both presenters and observers. I would recommend devoting a significant area for posters next time and giving a 2-3 hour block of time mid-day, mid-week to poster presenters to man posters and observers can attend without other meeting activities going on concurrently.
- Maybe field trip only after lunch. Rearrange sessions so people interested in bark beetles, for instance, don't have all sessions they are interested in at the same time.
- Panels and plenary should have been truncated. They were the least useful.
- The cowboy band at the FARM was excellent but way too loud. This limited ability of participants to discuss topics of mutual interest.
- Workshop organizers should try and reduce number of speakers to allow for discussion; less concurrent sessions.
- Overall, you folks did an excellent job and should pat yourselves on the back. Try to get the proceedings out ASAP! Sacrifice "looks" for timeliness. The value of the proceedings decreases over time.
- Not enough time or space available for posters. They need to be in areas where people can go to look at them when they don't feel like listening to someone speak.

WORK CONFERENCE EVALUATION

- Encourage session chairs (moderators) to keep speakers in line with time constraints.
- Need to know how posters are attached to board (velcro, pins, tape, etc.).
- Great job! Great city!
- Overall, a well-attended and very well-organized conference; San Antonio was an excellent location but severely limited field tours of (forest) entomological interest; hospitality was first rate.
- In keeping with the general workshop idea, I think having fewer speakers per session or shorter time per speaker would lead to better discussions. Frequently, discussions just got rolling when time ran out. What everyone remembers from these meetings is interactions not formal presentations.
- Well done!
- I would limit the number of presenters in the concurrent panels - 5 or 6 is way too many. I would limit it to 2 and depend on unstructured debate.
- Recommend focusing on not more than 3-4 major issues-reduce conflicting panels. This should increase discussion/participation. Recommend more emphases on the "international" component of the conference.
- The concurrent activities should have exact times for each speaker's talk so you can move between sessions. The conference should be a day longer (use Monday or Friday for talks) to reduce the number of concurrent sessions.
- Great food and hospitality. Overall, great meeting. Thank you for all your hard work.
- Truly outstanding overall. Suggestions for improvements include: 1) last name on i.d. badges should be large so that they can be read from a distance; 2) limit concurrent sessions to 4 or 5; 3) arrange evening BBQ to be closer; 4) designate more appropriate space and time during regular conference to display posters.
- Major problems - too much formality; workshop atmosphere needed. Poster session was poorly organized and facilities for posters could have been much better. Otherwise, a very good show.
- Registration fee seemed excessive. No need for such an extravagant meeting - but it was enjoyable and well done.
- Most workshops were not true workshops, but rather ESA-type presentations. Moderators need to have fewer invited speakers, facilitate more discussion. Your organizers did the best job in 22 years I've been around. You have no control over bad overheads, bad slides, bad communication. What you did have control over was excellent.
- Congratulations to the local arrangements and program committees! They have done an excellent job. All sessions were very informative.
- Coverage of exotics was important and should be continued in future meetings.
- Very well done - congratulations. There was a good variety (of panels, workshops). I often wished I could have been in two places at once.
- I would have preferred not to have (field tours) or have them at the end for those who wish to stay longer.
- Too many concurrent choices. If field tours were offered before or after the conference, more time would be available for concurrent sessions thus reducing the "density" of choices.
- We need to keep a "workshop" atmosphere. Fewer formal presentations and more group discussions.

WORK CONFERENCE EVALUATION

- Congratulations... for a very well organized conference and helpful registration desk team. Very well done. My wife and I greatly enjoyed our first visit to San Antonio.
- I thought this was a well organized and well run meeting. The local arrangements were excellent.
- Congratulations. One of the best meetings I ever attended.
- Poster sessions need more space and should be in same room as breakfast and breaks. Even out the number of concurrent sessions to about 4-5 at any one time instead of 2 panels or 7 workshops at a time. Field trips in middle of week is best - gives a good break from typical meeting format.
- The organizers really did a super job. The conference was outstanding, noticeably better than the first one. Good program, good diversity of topics, moderators and speakers.
- On name tags, make entire name big, not only first name. Encourage people to look at posters and give them more time if possible.
- In retrospect, could registration have been \$150 or \$175? For posters, it would have been best if they were in larger rooms, and near the food. If meeting rooms are larger, you could offer 5 workshops instead of 7. But more is better. I'd offer between 5 and 8.
- Try to pick a hotel where no renovations are scheduled. Seems like 90% of meetings I attend have construction of some kind ongoing. Hotel staff excellent and courteous.
- Posters hard to view. Room tied up in sessions. Poor lighting in ballroom mezzanine.
- Name tags - have first and last names in large bold font.
- This should be a work conference - with discussions. Length of speeches should be cut to half of total speakers time. Presentations should be short, sweet, and provocative. In nearly every session, all of the speakers went over their time, and no time was left for discussion/questions.
- The Mexican contingent should have been more represented in the plenary and concurrent panels. The views and assumptions of many panels was too "U.S." and western (European) based.
- Not enough time to have longer discussions and questions and answers. Need strict control by moderators. Suggest no talk exceed 20 minutes with 15 minutes for presentation and 5 minutes for discussion.
- A lot is going on in forest entomology. However, the benefit of "workshop venue" that has occurred in the past was lost at this meeting because too much was planned. Need to focus on fewer topics of interest at next one.
- Why was cost so high? \$200 vs. \$70 - \$90 for average WFIWC. Talked to some entomologists who stayed away for that reason. Having purely recreational events (golf, cave tour, etc.) on the formal announcement was inappropriate - particularly since so many of us are here at tax-payer expense.
- San Antonio was a great spot for this. I enjoyed the conference tremendously. I liked the placement of the field tour/farm BBQ between the two heavy days of presentations - it broke up the time well.
- I had a poster and only 3-4 people came by. It was given very low priority. The poster locations were poor; balcony was better than the exhibit hall.
- Use large first and last names on badges. Overall, I think the organizers did a great job.
- It was probably impossible to do it better, but I found several simultaneous workshops I would have liked to attend.

WORK CONFERENCE EVALUATION

- Need a better system to select speakers. Several moderators/speakers seemed to reflect the “club” rather than new developments/issues.
- Timing of field day in middle of conference was great idea. This broke up the meeting sedentary sessions and got networking going early on. Well done. Thank you.
- I complained last year, I’ll complain again. There should be no more than 4 concurrent sessions.
- One of the most enjoyable conferences I’ve been to. San Antonio is great. Only other suggestion would be to have both first and last names in bold on name tags.
- Numerous concurrent sessions made it difficult to attend interesting presentations. Rooms were too small in some cases.
- A very worthwhile, relaxed and informative conference.
- Plenary session was a good start but USDA people didn’t say anything. Too many concurrent sessions. This may be unavoidable but should at least be considered. San Antonio is a fantastic place for any meeting. Hotel was great, but posters could have been more “available.” (I understand that this was unavoidable though.) Great conference overall.
- I suggest you consider sponsoring a world forest entomology conference either along with the NAFIWC or separately.
- Cash bars are rips offs - not good for mixers. Let’s try to get industry support for the bar in the future.
- Need to have definite times for some of the papers in some sessions so that a person may change from one session to another to hear presentations of interest.
- Many moderators did not keep talks to the limited times, cutting short question periods and running sessions overtime. On the field trip more time at Guadeloupe Park and a few less stops at oak wilt sites. I enjoyed seeing the control methods in progress at one stop.
- Very good conference. There were so many good sessions that even with several days of concurrent sessions it was hard to catch all of the talks. Good job!!
- Instruct “workshop” moderators to maintain informal workshop atmosphere by scheduling fewer speakers. Workshops should have 0-1 speakers per 90 minutes. Moderators should “moderate” discussion.
- I thought the topics were varied and current. I thought that the first NAFIWC was the best meeting I’ve ever attended, but the 2nd NAFIWC was certainly as good, if not better!
- Too many concurrent workshops. Continental breakfasts were nice but seating was inadequate and stand-up space insufficient.
- This was one of the most enjoyable conferences I have attended. Thanks.



Section VIII

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