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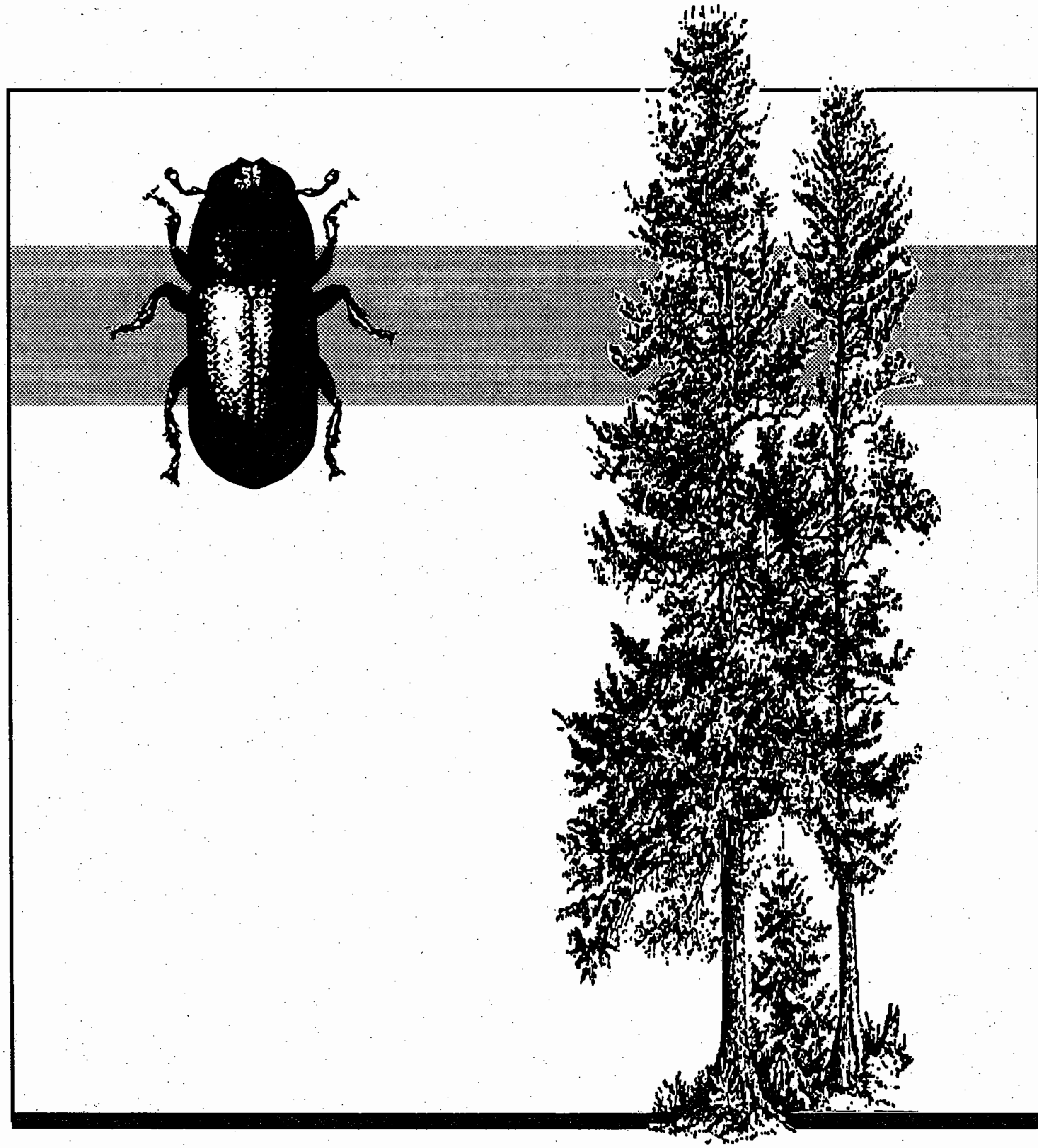

Proceedings: North American Forest Insect Work Conference

Denver, Colorado
March 25-28, 1991

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Abstract

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A proceedings of a conference held to stimulate interaction among people working in areas of forest protection and silviculture and on issues of national and international concern relative to forest insect and disease management, education, and research. National issues addressed were forest productivity, stewardship, biological diversity, and new perspectives and how these issues affect environmentally sound management of forest pests.

Keywords: Forest pests, forest insects, forest diseases, entomology, entomology (research), entomology (education), pathology, pest management.

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NORTH AMERICAN FOREST INSECT WORK CONFERENCE

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PREFACE

We hope that the first North American Forest Insect Work Conference will stimulate organization of future joint meetings for people who work in areas of forest protection and silviculture. Recurrent interaction like this is necessary to address issues of national and international concern relative to forest insect and disease management, education, and research. Historically, the four regional work conferences have been excellent mechanisms for addressing local issues, and they will continue to do so. However, we feel that periodically a more cosmopolitan meeting is essential to address broader concerns. A national meeting allows a wider audience to benefit from the rich array of experience and expertise that characterizes our professions nationally. Certainly, as national concerns about such things as forest productivity, stewardship, biological diversity, and "new perspectives" develop, effective and environmentally sound management of forest pests will require our collective wisdom.

These Proceedings are organized into four sections: I - Keynote Addresses, II - Workshop Summaries, III - Poster Abstracts, and IV - Conference Evaluation. Initially, we thought it might be useful to organize the workshop summaries according to areas of emphasis (i.e., education, research, management), but it became apparent that most summaries touched on all three topics. Therefore, this section is organized alphabetically by Moderator. If an abstract was provided, it appears at the beginning of each workshop summary. Consequently, most parts of section II begin with a review of the major issues that were discussed during the workshop.

To facilitate publication and distribution of the conference proceedings, we chose to take advantage of an offer by the U.S. Forest Service to publish this material as a General Technical Report. Manuscripts were edited following submission, some more so than others. Only heavily edited material was returned to a Moderator for review. Authors are responsible for their own sections, however, and the opinions expressed may not reflect those of the USDA Forest Service.

Acknowledgements: Many people in addition to the Steering Committee and funding agencies contributed to this endeavor, and we wish to thank those who made a special effort to bring the conference to fruition or to publish the proceedings. The patience and dogged perseverance of Cathy Westfall was key to successful completion of this document; Horace Shaw and the SUNY, CESF Office of Continuing Education played an invaluable role in organizational matters; Helmuth Resch, Dean of Research Programs at SUNY, CESF was instrumental in helping to secure funds; the efforts of Richard Werner (USDA Forest Service, Fairbanks, AK), Kenneth Knauer (USDA Forest Service, Washington, DC), and Max McFadden (USDA Forest Service, Radnor, PA) greatly expedited funding and publishing; the unapparent, but important, work accomplished by each Workshop Recorder facilitated the Moderator's task of summarizing workshop material; and finally, we thank Barbara Allen whose voluntary efforts greatly enhanced on-site registration.

D.C. Allen
L.P. Abrahamson

I. KEYNOTE ADDRESSES

THE FUTURE AND FORESTRY EDUCATION

Ross S. Whaley[1]

Forestry education must be evaluated in light of a changing world view. This context includes a world in which:

* population increases are not statistical abstractions but underfed citizens,
* maldistribution of resources is an increasing concern,
* our domestic economy may need fixing, and
* the conflicts between economic growth and environmental quality will become more severe.

My letter of invitation to speak to you today asked me to "speculate about the ways in which changing technologies, environmental issues, international trade, forest management needs and other events could influence . . . forestry education." Later the letter asks, "We would like you to address changes that you anticipate, or would encourage, in forestry education to meet future forestry and pest management needs." For one individual to do this well is impossible. It requires a prophet, futurist, researcher, forester, educator, and the list goes on. The wisdom of the organizers of this conference becomes clear. They invited several keynote speakers instead of one knowing full well that it would take several of us to begin to frame the future and then to draw conclusions from that future as it relates to forests, forest protection, and forestry education.

Burt Nanis and Warren Bemis in their book, *Leaders*, state, "Nothing is more important to modern organizations than their effectiveness in coping with change." I would add that the ability to cope with change depends largely on our anticipating it and having a sense of where and what we want to be at the end of it all; goals, if you need a name for it. If one is more persuaded by fairy tales than by textbooks, then the same idea is captured in a delightful way in Alice in Wonderland.

> Alice confronted a problem when she came to a fork in the road. She didn't know which way to turn. She saw the grinning Cheshire cat in the tree. She asked the cat, 'Which way should I turn?' The cat replied, 'Where are you going?' Alice answered, 'I don't know.' 'Then,' replied the cat, 'it doesn't matter.'

I often think that we in forestry, or parts of it, like forest pest management, or those involved in educating for it, are not quite sure where we are going. So a conference devoted to that is timely, worthwhile, and, let's hope, gives each of us and our firms, agencies, and institutions a better sense of direction and even stronger resolve to not only understand the future, but to influence it in those domains which fall within our responsibility.

I would like to mention five interrelated trends which are having, and increasingly will continue to have, an impact on the way we associated with our forest resources will do business. I mention that these trends are interrelated, because more important for an accurate picture of the future than any individual trend is the congruence of more than one trend. It is the reinforcement of congruent or intersecting trends which causes major social changes, and tests our ability to take advantage of them or to be overwhelmed by them.

I. AN INCREASING TREND TOWARD GLOBAL MALDISTRIBUTION OF RESOURCES.

Some claim that there is abundant evidence that we are running out of adequate resources to feed, house, clothe and nurture our world's populations. Some would even add urgency to this concern by pointing to starvation in the Sahel region of Africa and increasing dessertification

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[1]President, State University College of Environmental Science and Forestry, Syracuse, New York; President, Society of American Foresters.

to claim that the decade of the '90s is a pivotal decade in which severe shortages will doom the poor, the ill-housed, and ill-fed to continue in that condition or, if imaginable, even get worse.

The problem with these forecasts is that for every article or book with these conclusions, I can show you another one which concludes there is no real problem. The counterargument of the optimist is a compelling one. There is no statistical evidence to support the increasing shortage premise. If you look at length of life, caloric intake, education levels, per capita income, or other indices of the quality of life, on the average they have been improving over the past, and there is no evidence of an apparent downturn. So where is the argument for scarcity?

A point on which both optimists and pessimists must agree, however, is the problem of maldistribution. Even accepting the most optimistic scenario of controlled population growth and continuing technological advances increasing the availability of food and fiber resources, one has to conclude that there is a lack of overlap between where the people and resources are located. At best it is a scenario of extreme poverty amongst abundance. So whether you are an entrepreneur looking for business, or an altruist looking for a cause, this will have a major influence on the role of our domestic forest resources.

II. BEWARE OF CREEPING POPULATION GROWTH.

During the environmental era of the late '60s and early '70s, one read much, even in the popular press, about the pressure of population growth. During the last decade much less about population is making its way into *Time*, *Newsweek*, or *USA Today*. Perhaps that is because we saw some reduction in population growth rates from 1.9 percent in the '70s to about 1.7 percent currently. Nonetheless, we must remind ourselves that even with the benefits of declines in population growth rates that:

1) World population doubled in the 36-year period between 1950 and 1986.

2) The 20 fastest growing countries in the world will double again over the next 2-1/2 decades.

3) Over the next couple of decades, 37 percent of the world's population growth will occur in 5 countries: Brazil, China, India, Indonesia, and Mexico. They will add the equivalent of another India.

4) Even in the United States where the population growth rate teeters around 1 percent, we will add the equivalent of another New York, California, and Florida over the next 2-1/2 decades.

More people with greater aspirations for the "good life" have to be significant in the way we view our forest resources.

III. THE DOMESTIC ECONOMY LOOKS BRIGHT, BUT?

We all need be concerned about our domestic economy. I am not speaking about the current recession and its impact on my job, my firm, or agency, but some structural issues facing our economy. Some people look at these issues with fear; others simply point out these as evidence of moving to a global economy, and there is nothing to fear here. You make your own judgment.

1) In 1988 when *Car and Driver* magazine ranked the best automobiles, eight out of the top ten were foreign made.

2) A couple of decades ago, eight out of the top ten banks were U.S. banks. Today only one squeaks into the largest category.

3) The U.S. imports more than it exports. That could mean that it consumes more than it produces.

4) The U.S. government spends more than it collects in tax revenues.

5) The rate of savings in the U.S. is less than in the United Kingdom, Germany, France, or Japan.

IV. AN INCREASING SHARE OF U.S. ECONOMY COULD COME FROM FOOD AND FIBER.

The U.S. has a comparative advantage to grow things. By accident of history, climate, soils, and population density, we are able to grow food, fiber, and forests better than many places in the world. Therefore, I would argue that the forests and fields will be responsible for an increasing share of our economy. So in an odd paradox, the U.S. will not only be moving increasingly into the high tech information society we read about, but will at the same time be promoting economic gains from agriculture and forestry.

V. CONCERNS OVER THE ECONOMY AND THE ENVIRONMENT WILL INCREASINGLY COME INTO CONFLICT.

If you think that the strain between economic growth and a healthy environment is a passing fancy which will come and go like most fads, perhaps coming to revisit every 20 years or so, I think you are wrong. To paraphrase Herman Daly, we have shifted from an essentially empty world to a full world in the sense that the scale of human presence in the ecosystem has moved from negligible to significant in the last century. Consequently, the natural world as measured against the demands on it has moved from super abundant to scarce. And the strain on the weary globe is starting to show. Sure there will be technological breakthroughs, but they will be more costly and have smaller net gains than in the past. Sure there will be times when the environment will receive less press than currently, but look to the second section of the newspaper, it will be there. Sure there will be major shifts toward a social responsibility, but the watchdogs will bark louder as the costs of error become more apparent.

If the previously mentioned trends have a pessimistic tone, I do not mean them to. They are simply facts. There is not equal access to resource by all people, population is growing, the U.S. economy has a less prominent role relative to others than it use to, conflicts between the two goals of economic growth, and an undisturbed "natural' environment are inevitable. One can, in contrast, be quite optimistic after examining the abundance of our natural resources, our ability to rise to a challenge (whether the dust bowl, placing a person on the moon, or international conflicts), and an education system which, though suffering some serious symptoms, has the vigor to rebound.

At the risk of getting into serious trouble with both my faculty and administrative colleagues, let me state that I think there are some fundamental flaws that have crept into our forestry education. Much of this may stem from our need to keep our students abreast of the rapidly advancing developments in tools and techniques. I don't mean to suggest that contemporary tools and techniques are not important, but I think overemphasis on them may have been at a cost which demands scrutiny and possibly course revisions. (Though I am mindful of Chancellor Mitchell's admonition that course revisions require faculty deaths.) Let me give you some examples which I am examining, but am still on less than solid ground myself.

* Have we become so preoccupied with computerized decision making tools that we believe them? That is, we have illusions of precision when the real world is simply not that neat. We expect linear programming models to be able to simulate the real world when the real world does not align itself to inputs, outputs, and constraints.

* Have we become preoccupied with quantitative, statistical measures that our ability to observe, describe, and synthesize information has become dulled? I am always struck by the beauty of the observation and description found in research papers which predate contemporary approaches to sample design, particularly in the fields of wildlife biology and entomology.

* Have we become preoccupied with maximation of net revenue to the point of not adequately considering the long run from a societal point of view in a profession which has historically prided itself in taking the long run view? Learning to discount is not the equivalent of a long run view.

* Have we become preoccupied with a certain scale of viewing the world that we have lost the ability to move between scales? For example, we look at the insect pest without adequate consideration of the overall vigor of the stand? (You can probably tell that I took my entomology under Samuel Graham.) We look at timber without adequate consideration for the larger ecological entity of which it is a part. (I would even venture the temerity to suggest we foresters may not be the ecologists that we claim to be.) We look at the forest without any idea of the fact that it may be an undervalued asset making the firm ripe for corporate raiders. We look at the firm without adequate consideration of what it means to be a multinational conglomerate.

I am not just suggesting curriculum revision. I am suggesting changes in course content. I am not just suggesting changes in programs for matriculated students, but for continuing education. I am not just suggesting advice for educators, but for individual responsibility on the part of all of us.

FIRST AMERICAN BARK BEETLE WORK CONFERENCE

Norman E. Johnson[1]

It has been said that truth is often stranger than fiction. What I am about to do may reverse this adage, but then maybe not. Somewhere, maybe even in this city, there is a conference of bark beetles going on. The beetles may have problems and aspirations of their own that they are grappling with. As hard as it is for us to imagine, they are communicating effectively with a few pheromone words and stridulations; and they are translating among various languages including dendroctonese and ipstalk and English. Let us eavesdrop.

Tessie Terebrans is the conference moderator. The subject is an altruistic one. The beetles in general are pretty happy with what the man creature has done and is doing to promote their welfare. There is general agreement that they would like to erect a monument to the man creature for being good to beetles, but the big debate centers around to whom exactly the statue should be erected. Let us listen.

Scotty Multistriatus is the first to raise his tarsus, and he wants to give the award to whomever made it possible for his ancestors to hitch a ride from Europe to America. He contends that had not the man creature brought those elm logs here in the hold of a ship, his clan would be largely unknown. "Why, my ancestors never had such a feast in their lives as in this country." But Scotty was voted down. "Old news," said one. "We do not really know who should get the credit," said another. Even the western members of the Scolytus tribe wouldn't line up with Scotty.

Alice Frontalis was the next to emit, squeak, or speak and she made a good case. She wanted to make the award in the name of the southern forest products industry. "Neither I nor any of my friends can remember anything like the efficiency of this group to blanket entire counties with pine trees. Talk about quality. Each tree is alike and each equally delicious. Unlike those who accidentally introduced Scotty's ancestors and Dutch elm disease, these guys are going at things with a purpose. They are literally guaranteeing us and some of our 'Ipsity' friends a supply of food for generations to come." Her worry was with her own kind--that they would be too greedy and ruin a good thing. Alice got a few approving nods, but there was no motion to accept her proposal.

Monty Monticolae (he chose to use his old name rather than Pondy Ponderosae) was impressed with Alice's persuasive presentation, but he thought he had a more deserving group to honor. He reasoned that the United States Forest Service and that funny bear with the hat should get the award. Monty said, " We've never had it so good since the Forest Service started controlling wildfire. They have stopped fire and left the tree killing to us--that is the way it should be anyway. Isn't that what 'Dendroctonus' means? Our problem is that we just can't kill those lodgepole fast enough. Look what happened in Yellowstone--even Smokey couldn't keep fire away. It is such a waste to see all those trees being burned."

"Another good cause," chimed in Ipsy. "But for my whole group--and I think Tessie and her western cousin, Valerie Valens, will support me--the award should go to man creatures called developers, the ones who build their shelters. They have no idea how they have made our lives easier. When they cut the tree roots or scar the boles with their large equipment, they set the table for us and many of those low-life scavengers--those longhorns, short horns, roundheads, and flatheads." "Admittedly," said Ipsy, "it is not as showy as what Alice or Monty described; but added up, it is a significant contribution to our well-being. If Monty or Alice would admit it, their tribes have also benefited from the good works of the developers."

It was Brucie Brevicomis' turn to speak up. He was a wise old beetle and one who tended to think to the future. He wanted to make the award to the oil companies. "Something seems to be changing in my neck of the woods," he said. "It seems to get easier and

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easier to kill those old pine trees. In fact, some of them do not need much help at all to die. It appears that all we have to do is keep moving north, and even trees we couldn't touch a few years ago are pushovers." "And," he continued, "it is not just my buddies who are benefiting, but all of 'beetledom'." "From what I hear," Brucie said, "as the air gets filled up with stuff from the burning of oil, the temperature will rise and trees everywhere will be in trouble and we can all have a feast then." It appeared that he would get the votes for the oil companies when a wee squeak from the back of the room begged for attention.

Phloe Sinus was hesitant, but she knew that she had the backing of a large number of not-so-flashy beetles like Harry Hylurgops, Hi Lastes, Polly Graphus and many others. Phloe had thought this thing through pretty carefully, and it was her contention that the environmental groups should be given the award. For her and her many friends, the best thing was to just "lock up" large areas of trees and let them die of natural causes. Though not as spectacular as what others described, it was just as sure. "Trees," Phloe said, "hate each other and have found all kinds of nasty ways to do each other in, thus making it easy for we minority beetles to survive." From her research she learned that one species of tree might deprive another of vital energy from the sun. Others may resort to the use of poisons and in some parts of the world actually strangle one another. "Oh, they look like placid creatures," she said, "but have you ever seen hemlock wipe out Douglas-fir? Insidious, but very effective. And those broad-leaved trees just hate pines. They will kill them all, given time. While it is tough on some of you more powerful tree-killers, my group and I will cast all our votes for the environmentalists. They, more than any other group, are doing the greatest good for the greatest number of beetle tribes over the longest time." And so it was that Phloe won and the award was made.

The Dendroctonus clan in particular didn't like losing; but Phloe's message was beginning to sink in. What they heard here would influence their thinking in the next work session entitled: "Problems facing bark beetles."

Teddy Tsugae, a specialist in population dynamics, had plotted the numbers of man creatures on earth over the past several hundred years. The shape of the curve portended disaster. "Their numbers have trebled in this century," Teddy said. "It has doubled in the last 40 years." When asked where it will end, he said, "there are predictions that the current population of 5.4 billion will increase to 8 or maybe 14 billion in the next half century." Other questions followed: "What factors will bring it back down?" "Will the curve flatten or crash?" "Will the overcrowding lead to irrational behavior on man's part?" "I am convinced," said Teddy, "that for a sustainable world for bark beetles, man's population needs controlling. Oh, as we learned earlier, he's helping us a great deal right now, but it can't go on. If the population goes unabated, forests will disappear and we can't live without trees. My apologies to Katy Chaetophloeus, who does all right in mountain mahogany. If the man population crashes and everything goes back to 'nature,' many of us will disappear. No, we've got to come up with a plan to not only help the man creature survive, but to do so in a way which also guarantees our own well being. "Our challenge," said Alni Phagus, "is to get the man creature to utilize his brain, the thing that really distinguishes it from the rest of us." "I suggest," said Teddy, "that we devote the rest of this conference to beetlebraining this question: What is it going to take to create a sustainable world for man creatures and bark beetles?" And they did just that; and this is a summary of what they came up with after a lot of discussion about whether or not man's population could be controlled by use of predators and parasites, poisons, sex lures and other nasty things that have been used against beetles:

A Strategy for Sustainability: Without a strategy, good decisions will not be made. A good strategy is a visionary one. It must be backed up by a good mission and timely actions.

Good Economies Allow Good Environment: Bill Ruckelshaus said that the single most important finding of the Brundtland Commission study was that only with strong economies can countries afford good environments. A growing number of people like Dixie Lee Ray, former governor and scientist, and Julian Simon, professor and economist, are saying the same thing. Contrast this to what Robert Nelson said in a recent Forbes article: "Religious environmentalism is gaining ground and there is a growing number of people who believe that the human species has become a viral epidemic, the AIDS of the earth." Dr. Ray, in a recent interview, said: "They (the eco-activists) have lost all sense of proportion. They force industry into taking measures that are expensive and do no good." (Big brains do not mean wide agreement.)

Focus on Priority Problems and Opportunities: There just are not enough resources around to take on all problems with the same degree of vigor. Priority setting necessitates gathering the right data to understand "root causes" and life-cycle environmental costs. Trade offs must be made. Man cannot continue to spend money on environmentally frivolous things when there are monstrous problems getting little attention.

Limit to Population Growth: The sustainable carrying capacity of the earth to support people with their current unrestricted behaviors may be less than necessary to support the current population. It stands to reason that there is a limit to the population; and whereas the predictions of Malthus and recently those of Paul Erlich have not come true, the shape of the population curve portends serious problems. The carrying capacity for sustainable development needs to be determined.

Limit to the Use of Fossil Fuels: The man creature must reduce its usage of fossil fuels and shift to less damaging sources of energy including solar, wind, geothermal, hydro, and nuclear power. They must develop a global energy policy.

Reuse and Recycling of Materials: Two-thirds of all aluminum, three-fourths of all steel and paper, and an even greater share of plastic is not now being recycled. Very little of the precious nutrients in sewage is going back to the farm or forest, but rather is being dumped in rivers, lakes, and oceans. More products need to be produced which do not have to be discarded after first use.

Soil Must Be Preserved: Of all the things that could limit both man and beetle populations, poor soil management is one of the most important. Without the thin mantle of topsoil, most terrestrial life would disappear. Yet man continues to let billions of tons erode or blow away each year.

The Man Creature is Part of Nature: Its existence depends on its ability to draw sustenance from a finite natural world (just like every other creature); its continuance depends on its ability to abstain from destroying nature. Man's economic activity must account for the environmental cost of production. Chief Sealth, for whom Seattle was named, said: "This we know: man did not weave the web of life, he is merely a strand in it. Whatever he does to the web he does to himself."

Humans Must Take Care of Humans: With a small percent of humans controlling most of the resources, peace among humans cannot continue. Without peace, man will put too many resources into things that do not lead to sustainability.

Research Must be Directed to Those High Priority Areas where it can make a real difference.

Communicate and Educate: Everybody needs to be fully aware of the priorities and actions and the reasons for them. Whether a person or group is part of the problem or part of the solution depends a great deal on timely communication and education.

Bias Towards Action: The problems are worse than most people are willing to admit. Actions can be taken on some things without a great deal more study. Each person or group doing its best is not enough to achieve excellence. People and groups need to work together rather than against each other.

Plant Lots of Trees. How can we go wrong by making this recommendation? Trees are good for man, beetles, and the environment.

Utilize the Trees we Kill before those nefarious roundheads and flatheads get to them. The trees are perfectly good for the man creature's use if only man would move faster. If man would utilize the trees from which we have only extracted the cambium, he could provide affordable housing for everyone.

In a nutshell, the bark beetles (with some help from the selected bibliography) have told us that civilization as we know it here in America can only survive if the forces of economics, the environment, and the social system or systems are all taken into consideration as we deliberate on how to expend our limited resources in a world which is rapidly being over utilized by man. They quote Mary Good (1990) who reminds us that the future belongs to those countries that have a technological advantage. Good technology can help mankind gain both economic and environmental advantage. As scientists, we have a great responsibility to consider the big picture in all that we do or say. The average citizen is confused by the myriad of positions taken on environmental issues. Scientists are among those speaking out without first trying to understand where their own piece of the puzzle fits in. A growing number of people are losing faith in we scientists. About a year ago I gave a commencement address to the graduating class of foresters at the University of Washington, and I made the plea for a balanced, data-based approach to dealing with environmental issues. A student also spoke on the topic of the environment, but she concluded that we should listen less to the owl and more to Pooh. For those of you who are not students of Winnie the Pooh, what she is saying is that a growing part of the populace is becoming skeptical of what scientists have proposed as solutions to the world's problems. She has reason to have this attitude. Scientists, like any other people subset, have their individual biases. Yet, we are trained to test the null hypothesis in our work. We need to carry this training over into the way we act. The world is too big for any one of us to grasp. An integrated, problem-solving approach is what is going to be needed to create a sustainable world for both beetles and man.

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MEETING FORESTRY RESEARCH CHALLENGES OF THE 21ST CENTURY

Jerry A. Sesco[1]

As we look to the 21st century, there are several major trends that will influence how we protect, manage, and use our natural resources. These trends will profoundly affect the nature of our research programs. First, expanding worldwide populations create tremendously increasing demands on forests for fiber and a variety of other benefits. In addition to people pressures, environmental stresses such as drought and pollution continually threaten the health of our forests. Second, the increasing competition for the many uses of natural resources will complicate management decisions. Increased value is being placed on non-commodity resources such as recreation and wildlife. Third, public interest and awareness of natural resources management issues are increasing. The public is more concerned about environmental issues and are demanding a greater voice in management and policy decisions.

These trends will increase the public's need for up-to-date scientific information. The forestry research community is faced with an enormous challenge to provide scientific information and multi-disciplinary approaches to solve natural resource problems, as the public demands that natural resource management and policy development become even more science-based. I believe we can meet the challenge, but forestry research must change radically if we are to be successful.

Many changes are already occurring, not only in research but in all of forestry. In fact, the forestry profession in this country is undergoing a self examination to better define its role in society. Many people believe we need a new paradigm in forestry. Some argue that the current paradigm of forest management of sustained yield, multiple use forestry will not suffice to address today's (and tomorrow's) problems (Behan 1990, National Research Council 1990). We have been accused of emphasizing timber production at the detriment of other resources. The new paradigm, an environmental paradigm, requires that forests be managed for the simultaneous production of several resources and services. The new paradigm would also broaden the constraints under which management operates from just keeping the harvest of various resources below or equal to the periodic increment. The goal would be the maintenance of the forest system as a forest system (Behan 1990).

Whether or not you agree that a new paradigm is needed, I believe most will agree that natural resource management practices are changing. This is especially true on public lands. These changes will surely affect our future research program and influence how you go about your job of protecting our forests.

The recently-published RPA Program reflects the changing emphases in forestry and provides a description of how Forest Service management will change (USDA Forest Service 1990). This document is the long term strategic plan that will guide Forest Service management decisions as we go into the 21st century. It recommends a long-term plan from 1990 to 2040 for management and administration of our National Forests, for assistance and leadership on State and private land, and for Forest Service research.

The current RPA Strategic Plan is a significant change from previous plans. It has four high-priority themes. First, the plan calls for enhancing outdoor recreation, wildlife, and fisheries resource output on National Forests and State and Private lands through technical and financial assistance for multiple-resource management. Research will focus on how to enhance the compatibility of multiple resource uses on all lands.

Second, the Forest Service will increase the environmental sensitivity with which commodities are produced on National Forest lands. The philosophy is that if commodity production cannot be accomplished in an environmentally acceptable manner, commodity production will be reduced. The research program will develop a better understanding of basic ecology and methods of management that reduce environmental impacts. In this context, your challenge as forest

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entomology professionals will be to develop and use pest management systems that lessen harm to the environment.

A third theme emphasizes the need for the Forest Service to expand its research efforts to enhance the compatibility of competing resource uses. Research will increase the study of ecosystems to expand the array of resource production opportunities and to protect the environmental integrity of the resource base.

And finally, the Forest Service will increase its scientific exchange and technology transfer to other countries to assist in more effective use of forest resources and to reduce adverse impacts on global ecosystems. Research effort will be expanded to better understand global ecological interactions.

The RPA program calls for significant increases in research support. Forest Service research is projected to increase to over $300 million by 2040. Increases are projected in all areas of research including forest protection research. The Forest Service research budget for fiscal year 1991 was a little more than $167,000,000.

If forestry research is to change, and I believe it must, it is imperative that we assess the status of forestry research and aggressively plan the direction of future programs. The recently published report (National Research Council 1990), entitled "Forestry Research: a Mandate for Change" by the National Research Council (NRC) did a good job of describing the status of forestry research in this country. I think it is an excellent report, and I support its findings, conclusions, and recommendations. As pointed out in the report, although good research programs exist, the overall research effort is inadequate to meet the expanding needs of society. We need to improve the quality and scope of forestry research programs, and we need more scientists doing forestry research. The forestry research community must regain the intellectual leadership in conservation. We have a responsibility as forestry professionals to provide information about forest ecosystems so they can be used wisely for this generation and many generations to come. We must work together to see that the recommendations of the report are put into practice.

As you may know, Larry Tombaugh, Dean of Forestry at North Carolina State University and current president of the National Association of Professional Forestry Schools and Colleges, and I co-chair a committee concerned with the implementation of the report recommendations. We will also facilitate the preparation of the assessment report that was mandated in the Forestry Title of the 1990 Farm Bill. Three elements will be addressed in the assessment report. 1) Assessment of the capability of current forestry research programs to address research needs identified in the NRC report, including research on ecosystems function and management; 2) evaluation of alternatives to current organizational frameworks for providing guidance to forestry research programs and establishing research priorities; and 3) recommendations for changes in current forestry research programs, including funding needs. The assessment report will be presented to Congress in May 1991.

We in the Forest Service have already taken steps that will move our research program in the direction recommended by the NRC Report. We have recently prepared a strategic plan for Forest Service research. This plan reflects our thinking about the future and describes how we expect our research programs to change. It is our blueprint for the 1990's and beyond.

Our research will continue to be mission driven. We will continue to need a mix of basic and applied research, as well as both long-term and short-term efforts. Some program areas will be reduced or terminated to provide more support for areas of increased emphasis. Our programs will be more global in scope and more multi-disciplinary in nature. Our success depends heavily on enhancing and strengthening cooperative efforts with our partners.

Our future research direction is divided into 3 major areas. One area is understanding ecosystems. The focus of this area will be to understand the structure and function of forest and rangeland ecosystems. This research will provide the scientific basis for addressing health and productivity issues related to natural resources management and environmental concerns. Forest entomologists and other forest health scientists will play an important role in this area.

The second area of emphasis is understanding people and natural resources relationships. The Forest Service will increase research emphasis on understanding how people perceive and value the protection, management, and use of natural resources. We will emphasize areas such as measuring and assessing the socioeconomic factors associated with wildlands/urban interface, rural development, rural diversification, and international trade.

The third area of emphasis is understanding and expanding resource options. The goal here is to determine which protection and management practices and utilization systems are most suitable for the sustainable production and use of natural resources. All resources will be studied, but increased emphasis will be placed on studying options for the protection and uses of water, fish, wildlife, and recreation resources. Research on extending the use of wood as a raw material, including recycling, will also be increased.

It is important to emphasize that the national program direction allows for region-to-region program variation. Regional differences are necessary and expected. In fact, each of the Experiment Stations and the Forest Products Laboratory have developed strategic plans to guide research programs in each region.

So far I have discussed some issues that will influence forestry research in general. Now I would like to discuss some future issues for forest protection (entomology) research.

First, major pest outbreaks will continue to pose problems for managers. Outbreaks of insects such as gypsy moth and bark beetles still require significant research attention. As you know, the gypsy moth continues to expand its range and severely impact eastern hardwood forests. The Forest Service spent over $15 million on gypsy moth suppression and eradication projects in fiscal year 1990. Another example is the bark beetle epidemic in the West. In many areas where severe drought conditions occur, bark beetle mortality is a major problem. In some areas mortality exceeds the annual harvest. We have no operational suppression tactics for bark beetles in these situations. Because these serious problems exist and will probably worsen, mission-oriented research will be needed to provide answers. Most of our research budget for Forest Insect and Disease Research (FIDR) is currently spent researching major pest problems.

Although the pest outbreaks will continue to demand our attention, we must also broaden the scope of our research. As mentioned above, future programs will increase the emphasis on understanding ecological processes. We will need to increase our study of insects as part of ecosystems--not just to develop control measures, but to understand their function as components of the ecosystem. As you know, there are more species of insects than any other animal or plant group in forest ecosystems. Insects, along with fire, also play major roles in the succession and development of ecosystems. Some insects are classified as threatened and endangered. We will surely need to increase our understanding of these species when they occur in forests and are affected by human activities.

Because the public demands it, we must continually strive to develop pest management strategies that are the least disruptive environmentally. Entomologists will be challenged to provide new integrated pest management systems. Areas like biological control, development of biopesticides and microbial pesticides, and use of behavioral chemicals will require the continuing efforts of our research scientists.

Recently, the Forest Service research program has been described in terms of National Programs areas in addition to our Foundation Program. National Programs include Global Change, New Perspectives, Threatened and Endangered Species, Water Quality, Enhancing Rural America, Recycling, and Forest Health Monitoring. These programs often receive priority during the budget process.

Forest Entomologists can play important roles in some of these National Programs. For example, the Forest Service global change research plan emphasizes that insects play important roles in forest ecosystems. Increases in disturbances from insect outbreaks will undoubtedly be one of the first signs of climate change and may serve as an early warning of changes in ecosystems. We need research to determine how global changes influence the frequency and severity of insect outbreaks. Also important is understanding how outbreaks accelerate ecosystem change from one equilibrium to another.

Another example where forest entomology is needed is in the New Perspectives program. New Perspectives refers to an ecologically-sensitive management philosophy by which forests will be managed as an ecosystem rather than focusing on individual resources. New Perspectives will no doubt result in changes in forest management practices; however, the need for knowledge of the effects of insects on ecosystems is not apt to diminish. Protecting forests managed for wildlife and recreation may be just as challenging and important as protecting timber resources.

The FIDR Staff have prepared a ten-year plan to provide a framework to facilitate needed changes in the FIDR program. The FIDR plan calls for increasing the emphasis on fundamental research to provide a more complete understanding of pest organisms, host trees, the role of natural enemies, and interactions among these organisms as influenced by the environment. There is a need to concentrate critical masses of skills and equipment to address important research questions. The FIDR research program needs to be flexible and responsive to new pest problems. The ten-year plan also highlights the need to increase the overall support of the FIDR program to meet the significant increase in cost of research, the demands for new technology, and the need for viable cooperative and extramural research with Universities and other outside institutions and agencies.

As indicated above, the future requires more from research. Unfortunately, instead of expanding, some of our programs have been shrinking in size. During the 1980's Forest Service research has struggled to maintain adequate budgets as reducing federal spending was a priority of the administration.

Since 1980, total Forest Service funding for research has increased only modestly (Figure 1). In comparison to constant dollars to account for inflation, we were in about the same position in 1990 as we were in 1980. We did receive a considerable increase in 1991, the largest increase, in fact, that we have ever had. We will need to continue to receive increases in our budget in order to build the kind of program we need.

FIDR funding also increased only slightly during the 80's (Figure 2). However, in terms of constant dollars FIDR funding actually declined considerably during this period - in terms of buying power, the FIDR budget decreased by over 20%.

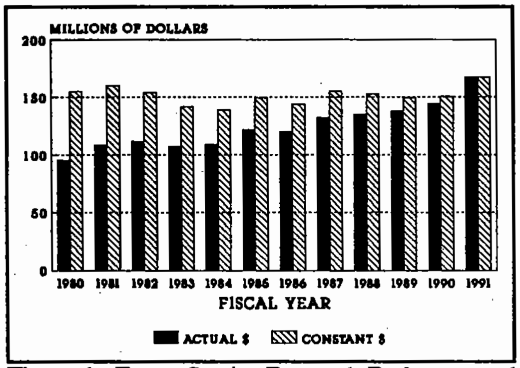

Figure 1. Forest Service Research Budget--actual versus constant 1991 dollars.

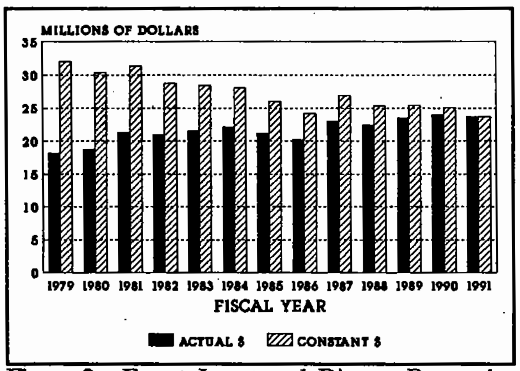

Figure 2. Forest Insect and Disease Research--actual versus constant 1991 dollars.

The FIDR program decreased during the 80's relative to the total Forest Service research budget (Figure 3). FIDR was about 20% of the total Research program in 1980 but is now only about 14%. In the last 10 years while FIDR has decreased relative to the total Research budget, areas such as Forest Management Research (FMR) and Forest Environment Research (FER) have increased (Figure 4).

The number of scientists in the FIDR program has decreased from a high of 185 in the 1970 to less than 130 today (Figure 5). Our inability to hire new scientists means that our workforce is rather old. We estimate that over 50% of our scientists will be eligible for retirement within 10 years. In order to have highly trained scientists to replace our scientists upon retirement, we recognize that more support for research at Universities is needed. Additional support for Universities is needed to help us reach one of our high priority goals, which is to diversify our workforce. I believe a multicultural workforce is a characteristic of a strong organization. We must continue to encourage minorities and women to pursue forest entomology and other natural resource disciplines.

How can we work together to bring about the needed changes in the research programs? One way is to support the recommendations of the NRC Report and work toward seeing complete implementation. I am committed to that end. As the largest forestry research organization in the world, the Forest Service has a responsibility to play a leadership role in shaping the future. We will work hard to do our part. You can participate in the process by learning about our programs and budgets and express your opinions about what you think the priorities should be. As a public agency, we depend on Congress to appropriate funds each year. We prepare the Forest Service part of the President's budget, which is presented to Congress in January or February each year.

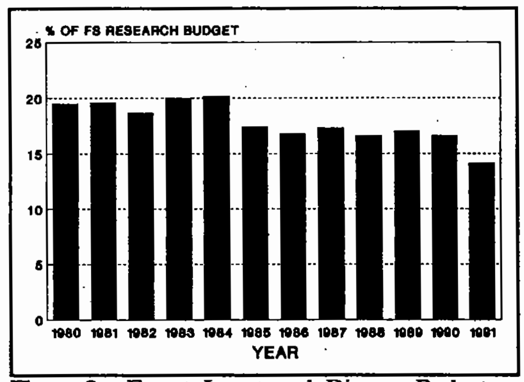

Figure 3. Forest Insect and Disease Budget as Percent of Forest Service Budget.

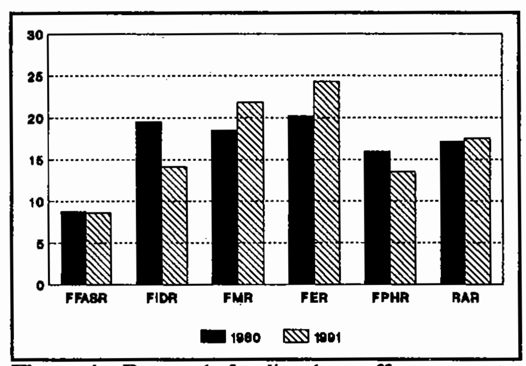

Figure 4. Research funding by staff as percent of Forest Service Research. (FFASR=For. Fire and Atmos. Sci. Res.; FMR=For. Mgt. Res.; FER=For. Environ. Res.; FPHR=For. Prod. & Harvesting Res.; RAR=Resource Analysis Res.)

Once the President's budget becomes public, you can review it and make suggestions to Congress as to your preferences for priorities. If you have questions about the President's budget as related to Forest Service research, we would be happy to provide answers. Congress usually debates budget issues during the spring and early summer, so that is the time when your input into the budget process will be most effective.

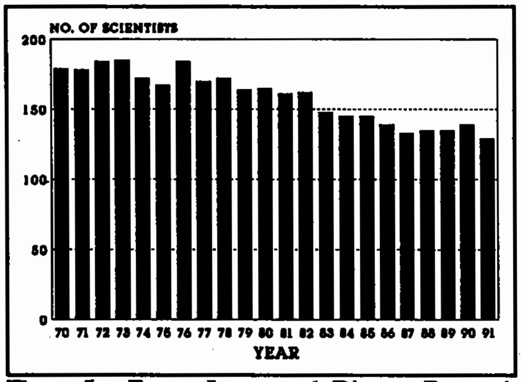

Figure 5. Forest Insect and Disease Research scientific staff: 1970-1991.

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THE FUTURE OF FOREST PEST MANAGEMENT

James C. Space[1]

If we continue to manage our forests as we have in the past, the future of Forest Pest Management is bright, indeed. For example:

* Our highly effective fire control program in western forests over the past 80 years, combined with some past management practices, has led to vast areas of forest types susceptible to insect and disease problems. Thank you, Smokey Bear!

* Management practices such as monoculture and relatively short rotations have caused root disease problems to proliferate.

* We persist in attempts to hold various species (southern pine and lodgepole pine are good examples) beyond their pathological rotations. When combined with off-site planting and lack of stand management, the problems are made even worse.

* Introduced pests, such as the gypsy moth, continue to march through our forests. The eastern forests, which previously experienced the loss of the chestnut and American elm, are now losing much of their oak, an ecological disaster of major proportions.

If these trends continue, they add up to a program of full employment for pest management specialists. In that respect, the future of forest pest management is indeed bright, but I am not sure that is what is intended. Instead, I would rather see our nation's forests be healthy and productive.

I see a parallel between forest health and human health. The modern thinking on human health is to prevent problems before they occur by living a healthy lifestyle, rather than diagnosing and treating problems as they happen. I envision the same approach to forest pest management -- develop and maintain healthy forests by managing them on sound ecological principles, preventing problems before they occur.

LEADERSHIP IN FOREST HEALTH

To facilitate the transition from an orientation toward pests to an orientation focused on forest health, pest management specialists need to take a leadership role. We must take the initiative to make sure that forest health considerations are included in planning and carrying out the management of public lands, and through state and Federal cooperative programs, on state and private lands. In many cases, changes in attitudes and old ways of doing business will be necessary, and we all know that change usually does not come easily. We all have a leadership role to play in improving forest health. I have challenged our FPM field people to take a strong personal leadership role in improving forest health within their area of responsibility.

STRATEGIC PLANNING

In 1988, we assessed the health of our Nation's forests and published a strategic plan, "Forest Health through Silviculture and Integrated Pest Management." This plan was adopted by the Chief of the Forest Service, and we will be working for the foreseeable future to meet its goals and objectives. Most of the actions I will talk about to maintain and enhance forest health were part of this plan.

THE RESOURCES PLANNING ACT

One way for change to begin is at the top, and the Resources Planning Act (RPA) Program issued in 1990 is a major change for the better. For the first time we have a fully integrated forestry program for both Federal and non-Federal lands. For the first time, forest health and protection is an emphasis item.

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FOREST HEALTH MONITORING

To detect changes in forest health over time, and to provide strategic information for the RPA and other national and regional decisionmaking, we have instituted a national forest health monitoring program in cooperation with Forest Service Research and the Environmental Protection Agency. This program is intended to detect changes, to evaluate possible causes of change, and to increase our ability to anticipate and manage change in our forest resources. This year, 12 states in the Northeast, mid-Atlantic, and the South will be participating, and we anticipate adding at least 6 more states in 1992. Reports will be provided annually, with a close tie to the RPA Assessment and Program.

THE FARM BILL

The 1990 Farm Bill rechartered all programs formerly covered by the Cooperative Forestry Assistance Act of 1978. The old "Forest Insect and Disease Control" section is not titled "Forest Health Protection." This section closely follows the objectives of the Forest Health Strategic Plan. While there are no real additions to our authorities, the difference in emphasis between the two acts is striking.

In the new act, the emphasis is on forest health rather than insects and diseases. Provision is made for the forest health monitoring program, and development and application of new pest management technology is encouraged. Prevention and integrated pest management is promoted, including the authorization of increased cost-share rates for cooperative pest management programs that use an integrated pest management approach.

The act authorizes new programs in forest stewardship and urban forestry. States are to develop forest stewardship plans and a Forestry Advisory Council is to develop a "National Urban and Community Forestry Action Plan." The act contains clear language that forest health considerations are to be a part of both the stewardship and urban forestry programs.

We currently have a team, headed by Dave Holland, working to revise pest management policy and direction to comply with the act, with emphasis on prevention programs and the enhancement of forest health. Our discussions with Congress on the intent of the act indicates that they would like to see new approaches less dependent on traditional suppression methods. Dave is also working closely with the Cooperative Forestry Staff to include direction on forest health in the stewardship and urban forestry programs.

MEETING OUR CUSTOMERS' NEEDS

Forest Pest Management is a service organization, and we exist to service the needs of our customers. This means all of our customers, including those who manage the National Forests, other Federal lands, private forest managers and the general public. We simply must spend the time and energy necessary to identify their needs and to work closely with them to implement forest health on the ground. This is probably a more difficult challenge than all of the technical pest management issues that we face.

Our highest priority has been to increase the level of service to our customers. Fortunately, the Chief, the Department, OMB, and Congress have supported increased budgets for us, based on our forest health strategic plan and an economic analysis of our program. This has permitted us to increase FPM staffing nationwide by about 25 positions in the last four years, to expand our technology development and application efforts, and to fully meet all our priority suppression needs.

Another action we have taken as part of our commitment to improve customer service and to integrate pest management into land management decisionmaking has been to encourage the decentralization of regional FPM staffs. Since 1987, the number of field offices and service centers has increased from 8 to 18. As a result of this decentralization, Forest Pest Management is a much more active participant on interdisciplinary teams responsible for preparing both National Forest land management plans and project-specific decision documents. We expect to continue a modest upward trend in both the number of personnel and field offices as funding and personnel ceilings become available. The net effect of this is better service and increased on-the-ground emphasis on forest health.

The original Pest Control Act of 1947 created a single organization, administered by the Forest Service, which would serve all Federal land management agencies. For much of the time since then, though, we have focused on protecting National Forest System lands. In recent years we have re-emphasized our responsibility to other Federal natural resource management agencies. We recently signed a memorandum of agreement with the Department of Defense which puts them on the same basis as the Department of Interior for access to the technical and financial assistance to which they are entitled.

FEDERAL-STATE COOPERATION

Since insects and diseases do not recognize property boundaries, we also need strong partnerships with our state cooperators in order to be able to promote forest health on a nationwide basis and to take coordinated action when problems arise. We are working closely with the states to build forest health into planning and programs, to implement a national forest health monitoring system, and to expand our Cooperative Forest Health Program. Unfortunately, budget problems at the state and local levels threaten this relationship in many states. We must continue to develop opportunities to support our state cooperators' forest health programs for our mutual benefit.

INTERNATIONAL ASSISTANCE

A number of recent initiatives by the Administration and the Forest Service have increased the emphasis on bringing forest pest management technical expertise and experience to the international forestry community. Forest Pest Management intends to move boldly into this arena by using the opportunities provided by the North American Forestry Commission, the USDA Office of International Cooperation and Development, the Agency for International Development, and the Food and Agriculture Organization of the United Nations. We will take an active part in programs at international symposia and conferences. We will make technical assistance site visits to countries requesting help. We recently welcomed the participation by representatives from several foreign countries at our Advanced Pesticide Applicators Training Course in Marana, Arizona. We expect to send teams of administrative and technical specialists to the Soviet Union, the Peoples Republic of China, and Africa in the coming months. We are particularly interested in working with developing countries to establish basic forest pest management programs.

STRENGTHENING RESEARCH

Finally, we need a strong research program to develop new and effective techniques for preventing and managing forest health problems. We have agreed with two Forest Service Research units to jointly staff programs, and are looking at other opportunities. I expect and encourage strong cooperative relationships between pest managers and research scientists.

OPPORTUNITIES FOR THE FUTURE

None of the above are technical forest insect management problems. They all deal with our relationships with people. For the forestry community in general and the forest pest management community in particular, I believe that our relationships with people will dominate our future. They will determine our ability to deliver an effective forest health program that people will support. We still have plenty of technical challenges, and I wish that I had time to talk about some of them with you, but many of them will be covered during the conference.

I do feel that the future of forest pest management is bright, and not because of all the insect and disease problems we are dealing with. I feel it is bright because maintenance and enhancement of the health of our Nation's forests has now been recognized as a major area of concern and importance. The public is increasingly concerned about environmental issues. Support for our job of maintaining healthy forests has increased steadily. We have many opportunities and challenges, but I have every indication that we now have the support and capability to deal with them.

THE 1990s: YEARS OF CHANGE AND CHALLENGE IN FOREST PEST MANAGEMENT

Robert F. DeBoo[1]

"Every Man is like the company he keeps" - Euripides

Abstract: Achieving forest health through pest prevention practices has become a priority in British Columbia during the past decade. The Forest Health Program of the B.C. Forest Service has been linked to planning processes, silvicultural prescriptions, and harvesting techniques. These changes (from isolated pest control operations of the past) require flexibility, commitment, critical placement of staff, experience, and an assured flow of resources. Field operations are fueled by knowledge, teamwork and innovation. The challenge for the 1990s is to build strength, credibility and trust into forest (ecosystem) management practices.

INTRODUCTION

The opportunity to participate in this international work conference is a distinct honor and special privilege. As I close in on the end of an exciting and rewarding career in entomology and applied forest pest management, I would like to recount some of my relevant experiences and current philosophy in keeping with the reasons for these deliberations in Denver. That is, I would like to bridge the past to the present by looking at the tremendous changes that have occurred and the challenges in North American forestry practices we are now facing. This bridge, hopefully, will be useful in finding the road to the year 2000 - the real challenge for everyone attending this conference.

Some of my comments and views might be useful background for the workshop discussions in the days ahead. It would be particularly pleasing if some of what I have to say is incorporated into the proposed recommendations to be included in the published proceedings. If I do not succeed, then you will know why Dutch-Canadians wear wooden shoes - to keep the woodpeckers off their heads! In either case, I look forward to renewing some old friendships and to discussing, in particular, the pioneering work we are doing in British Columbia. I have divided my presentation into three parts: 1) A personal retrospective on educational, operational, and research experiences during the period 1956 - 1980, 2) the challenge I was offered in 1980 to actually implement an operational pest management program, and 3) some of what I feel still has to happen in education, research, and forestry operations. These requirements are needed to secure resources for, and to ensure acceptance of, a comprehensive forest health program during the current critical decade.

A RETROSPECTIVE

A quick review of my career to 1980 probably reads like the path many of you in this room have experienced: My career started during the hiatus of New Brunswick's massive operations against eastern spruce budworm in the 1950s. During that era hundreds of aircraft were mustered from across North America annually to suppress damage to balsam and spruce forests using DDT. My involvement, as a forestry student at UNB was peripheral to these operations - a three year assignment as summer assistant with Dr. Al West's project (Queen's University) on spider predation and, with Frank Cheshire, as a laboratory assistant at the Federal Forest Research Laboratory where I spent dozens of hours picking through the gizzards of small

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forest song birds to record their insectivorous dining habits (Morris 1963).

Later as a graduate student with John Dimond at Maine, I had the good fortune to work on the feeding impacts of a pine adelgid on eastern white pine (DeBoo et al. 1964), using the classic techniques of Mott et al. (1957). At Maine, I had my first exposure to chemical control via some hand-sprayer trials against red pine sawfly, as well as a small role as laboratory instructor in Dr. Dimond's excellent teaching program in forest entomology.

After Maine, I spent the early part of the 1960s at Cornell's No. 1-ranked Department of Entomology. I had the pleasure of working with John Wiedhaas, an extension entomologist specializing on pests of ornamentals and shade trees. I was given the responsibility of research/extension specialist for insect pests of pine Christmas trees. This experience was particularly rewarding 1) for the exposure to the basic principles of economic entomology, 2) for the opportunity to look at a damaging pest complex in depth (DeBoo et al. 1971), and perhaps most important of all, 3) for the first opportunity I had to deal with people outside the classroom and the laboratory.

I spent the next 14 years back in Canada searching for my niche in the protection of forests in every province from Saskatchewan to New Brunswick. All of my efforts as research scientist with the Canadian Forestry Service were typical biology and control investigations of major pests of plantations, shelterbelts, parks, and other high-value stands: budworms, coneworms, midges, mites, weevils,and sawflies. The work furnished growers, farmers, and foresters with basic knowledge about their more important insect pest problems and led to the registration of several dozen insecticidal treatments. I felt satisfied with my work most of the time, and I believe my clients were pleased with these efforts. I guess what I was really trying to do in those days was to deliver effective and uncomplicated direct treatments at the best time possible.

After nearly 24 years of training for, assisting in, and finally assuming a leading role in applied research projects, I became convinced that even though every indication and response suggested progress and contribution, I was still living on the fringe of forest management as aptly described by Ron Stark (1982). About this time I became frustrated with band-aid solutions and quick fixes to forest insect problems. Certainly, the world had changed dramatically during this period. The forestry sector, in particular, was receiving heavy criticism for certain established practices (Young 1986).

Direct control treatments, such as aerial sprays, were now being questioned by both disgruntled citizens and harassed politicians. My traditional, cozy, and self-satisfying world was crumbling. As a matter of fact, during the late 1970s in Canada, two provincial cabinets turned down proposals to treat spruce budworms with chemical insecticides because of gaps in knowledge of the potential side effects. The first of these was in British Columbia.

TEN YEARS IN THE TRENCH

When I came to B.C. in 1980, Hec Richmond, western Canada's pioneering consulting entomologist, accused me of accepting a position which would quickly force me to become a "drop-out" entomologist. He was right. But I was not forced - I chose to drop out. I will tell you why.

British Columbia has about 3 million citizens and 20 million hectares of the best forest land in Canada. Harvest here amounts to approximately 70 million cubic metres of wood annually from public lands alone. Export value of forest products is worth nearly $15 billion every year to the provincial economy. British Columbia takes its harvest mostly from old-growth forests. There is still about a 20 years supply available at the current rate of harvesting. It is the responsibility of the B.C. Forest Service to regulate harvesting, to assure reforestation, and to provide comprehensive protection against fire and pests (British Columbia Forest Service, 1990). These fundamental responsibilities are now compounded by obligations to practice "integrated forest management" and for participation in "green" plans of all sorts. Our spotted-owl equivalent, for example, is called the marbled murelet, an obscure and tough little sea-going bird which nests in old-growth forests. Because accords or treaties were never secured with B.C.'s native people, rights to much of the productive forest land base (called provincial forests) is in serious dispute. Add questions about ownership and land use to those currently being asked about preservation and forestry practices in B.C. and you have perhaps the most confused, but not yet loudest, discussion of natural resource management in all of North America. In any case, I know I am confused and it is not because I have taken off my wooden shoes.

So here is what I was asked to do in 1980: Build, basically from scratch, a program that would enhance the province's capability to deal with pests. Given the economic swings in the 1980s, a devastating outbreak of mountain pine beetle requiring immediate and massive suppression tactics (and resources), and an "inexperienced" Forest Service without formal policy or guidelines for pest management, I am proud of what we have accomplished together in B.C. during this past decade. We are now entrenched in forest management operations across the province. We participate in the planning process, silvicultural prescriptions, and harvesting schedules. And we have maintained our ability to protect forests from some insect attack with improved and safer direct control treatments (British Columbia Forest Service 1982, 1987).

The success we have experienced during the past decade is due in part to:

* Operational level staff - about 20 full-time district forest health technicians, six regional forest entomologists, six pathologists, six pest management foresters, and six specialists at headquarters in Victoria;

  Funding - basic operational funding plus directed pest control dollars (mostly for mountain pine beetle) ranging from $5 - 10 million/year;

* Support - a dynamic and relevant research and development program led by Forestry Canada, a cadre of consulting specialists, and an aggressive hard-core educational system which provides us with technical and professional staff in tune with our program;

* Acceptance - of our ability, now proven; and our local involvement in dealing with a range of pest problems to achieve objectives whether expressed as "maintenance" or "gain" of values attached to forest resources; and

* Regulations, policies, and guidelines - constructive and helpful new references to ensure integration of safe, proven, and practical forest health treatments (British Columbia Forest Service 1982, 1987).

Critical to our accomplishments so far has been a sympathetic and supportive Forest Service. It is worth noting that in B.C., as elsewhere, the British Columbia Forest Service has been struggling with a major transition in forest practices (DeBoo 1987a, 1990, Kimmins pers. comm., Young 1986), because we are changing from an agency of government with a proud tradition as purveyors of quality trees for the lumber industry and aggressive forest fire fighting to a new service promoting the new style of forest management where "all things" are considered (British Columbia Forest Service 1990).

Interestingly, the establishment and growth of the British Columbia Forest Service Forest Health Program happened during economic turmoil in the forest industry and a slump in the provincial economy. For example, our platoon of over 40 Forest Health staff was built during the past recession when the British Columbia Forest Service suffered a 40% "downsizing." We view our survival and growth as an expression of commitment to forest stewardship here as well as to the influence of our supporters (a few wise politicians, some stubborn bureaucrats, and a trio of "mouthy" professors).

What have been the benefits and returns to our "investors" so far? Here are a few examples why we have been successful in vacating the fringes of forest management (Richmond 1986, Stark 1982):

While we lost about a year's harvest to the mountain pine beetle alone during the 1980s, we saved about half as much through our activities. For about a $50 million investment, the British Columbia taxpayer has (or will) recover about 10 times this amount in direct revenues alone. Critical to the success of the beetle management strategy has been good cooperation of all participants, a superior detection program, and deployment of a variety of treatments utilizing fire, semiochemicals, silvicides, and the chainsaw (Begin 1990, Young 1986);

Although *Bacillus thuringiensis* (B.t.) has about the same performance record in British Columbia as in eastern Canada (ca 60% success rate), the economic benefit of treatment for western spruce budworm is now estimated at 3:1 over cost (Stemeroff pers. comm.). Adding in property value, amenity value, and other factors, we may soon be better able to justify use of this insecticide in B.C. forest management;

Several recent analyses of some forest health treatments suggest the possibility of reduced rotation age - perhaps by 30 years (Cozens 1984). Treatments for leader weevils and tomentosus root rot of spruces in northern B.C., for example, suggest equivalent harvest at age ca. 90 if treatments are applied vs ca. 120 years if untreated. Also, similar attention to a pair of root rots and a pair of defoliators (budworm and Douglas-fir tussock moth) in parts of the southern interior suggest a potential productivity gain (wood volume) of up to 50% (DeBoo 1987b).

* Selling a surveillance system to ensure seedling survival has been accepted by silviculturalists in B.C. The problem, snowshoe hare browsing causing patch mortality and a requirement for restocking in lodgepole pine plantations, can be minimized by a delay in planting during years of peak hare occurrence. Surveys, at a cost of about $70,000/year will yield over 40% return on investment via the reduced costs of replanting alone. The key to the solution is synchrony of seedling sewing requests within peaks in hare population outbreaks.

* A novel harvesting technique - "pushover logging" - (Norris pers. comm.) is now in effect on certain sites in the southeastern part of the province. Using an excavator to remove whole lodgepole pines, including roots, and random skidding to the landing, the method has two very desirable features: 1) Chronic infection by armellaria root rot is reduced (or even eliminated), thereby ensuring tree survival and growth and minimal disturbance to the site and 2) increased volume - both during the "treatment" harvest (average so far has been 20% more wood) and for the next harvest because of the sanitation which has occurred.

The purpose in briefly describing some of the forest health treatments in place across British Columbia is simply to confirm the bridge we have built from the age of pest as focus (pest management) to today where "all things" (including people) are considered in forest management practices. Our target has shifted from the pest to the forest. Our objective is the healthy forest and not necessarily pest control. I believe the challenge now is to deal with this change, to influence other programs, and to remain adaptable and competitive for the scarce resources which will flow from concerned taxpayers and frugal shareholders (Norris 1985, Williams pers. comm., Young pers. comm.).

It is also my view that taxpayers and shareholders are fellow stakeholders. People want healthy forests. Our forest health program in B.C. has been developed to do just that.

A PRESCRIPTION FOR THE 1990s

The British Columbia bridge in pest management has been built. We are now on the other side. The bridge is called the "Forest Health Program,"; the other side has a variety of designations - "integrated resource management;" "incremental silviculture," "forest ecosystem management," "sanitation harvesting,"and "integrated forest protection," are a few of these recent appellations. Because of our experience, we have become an integral component of the new "all resource planning" process in British Columbia (Cuthbert in press). As a matter of fact, a lot of our treatments are clearly a "best buy" incorporating a variety of economic, social and environmental considerations. Many silvicultural prescriptions and harvesting regimes depend on forest health and pest occurrence factors.

One of the unique aspects of our critical involvement is that we are cultivating a reputation only acquired by "good guys." That is, our policy to support all programs to prevent pest/forest health problems is our priority. As a result, necessary resources are flowing to us. And our good guys will survive the next economic recession or another bureaucratic shuffle. Best of all, the "public" likes us.

What are some of the keys of our progress to date? I am not sure I can identify them all, but rest assured our high success rate has not been due to luck. Herewith is a short list of attributes which I consider essential for a "healthy" Forest Health Program in British Columbia and perhaps anywhere else. You might wish to put this list into the form of questions (where, when, how, etc.) for your own situation if you too are about to "cross to the other side":

1) Flexibility. I suggest any forest health program must be flexible and adaptable to both technical and social demands. Ciesla (pers. comm.), during a moment of retrospection recently, has clearly identified change as the greatest single influence during his 30 year career with the U.S. Forest Service. The 1990s, in my opinion, will be full of changes too - perhaps equalling those of the past 30 years and then some.

2) Commitment. Another top priority is commitment and conviction that your forest health program must move forward. The forward thrust will be led by assertive individuals; there will be no place for individuals waiting for instructions or for those who "work to live." The commitment will thrive on partnership.

3) Placement. I believe it is wise to be able to contribute in a variety of ways. People must be involved locally and continuously. They must be located in planning, silvicultural, communication, harvesting, protection, and other programs because contemporary forest management on this "other side" demands teamwork. The solitary specialist at headquarters, and entomology as an exotic or fringe discipline, for example, are no longer affordable. This rather harsh statement applies particularly to researchers, academics, and resource managers mired in the traditional isolated or segregated processes of the past.

4) Experience. If you have experience (vs. an idea), it seems to me, people are more willing to listen. The ten or so pushover logging operations to date in southeastern British Columbia is a good example. We are now getting pilgrims from across our borders to view the results, and most importantly, loggers are becoming interested in the superior cash flow. I believe you are worthy of "expert" status when there is a queue at your door. Such is the case now at many of our 49 regional and district offices in British Columbia.

5) Funding. Funds will flow when benefits of treatments are clearly obvious. As you know, this has been a major weakness in explaining our case, especially for aerial application of insecticides, during the past 40 years. Because of increasing values (i.e., stumpage, end products) and the shrinking forestry land base everywhere, we will be doing more with less during the 1990s. Investment in forest health treatments via integrated forest protection, as I am promoting here, is one of the clear pathways to mitigating fall-down in harvesting and forestry sector job loss, and for increasing both quantity (forest products) and quality (healthy, vigorous multi-purpose trees). The scope of your work will reflect the price taxpayers and shareholders will be willing to pay. To acquire funds, I am convinced you must build your business case on the fact that you have a store-full of "best buys." I mean this in the economical, political, social, and environmental senses. The bulk of the basic funding will come through silvicultural and harvesting programs, as well

as from your critical involvement in the planning and forest renewal processes. In my opinion, you can forget about expectations of continuing support (and thereby your survival) for traditional reactive (and isolated) "big bug" control projects of the past (Young 1988).

6) Information. Fundamental to all of the five previous prerequisites is knowledge. That is, to know what is happening in the field (e.g. North America), how the educational processes are serving (or not serving) your interests, and what the research community is likely to provide you within your lifetime. It is my view that you must be aware of social and technical changes especially (just think of the fantastic global accomplishments during the past five years). You must dare to innovate. You must become a proactive liaison/communications specialist via participation in working groups, by keeping up with the literature, and by taking the initiative to ask others when you are uncertain or confused. You must share your success openly. So, in conclusion, this is my recipe for success in the 1990s: JUST DO IT! I wish you success in the years ahead, happiness and satisfaction in all of your accomplishments, and much enjoyment in the company of your colleagues.

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FOREST PEST EDUCATION: FACING THE REALITIES OF THE 1990s

J. Rod Carrow[1]

I understand that an invitation to give a keynote address is a sign of maturity. And an invitation to forecast the future is a sure sign of age. In the past year, I have been asked to give four keynote talks, all addressing the future, so I am forced to conclude that I am finally both mature and aged. All I can say is that age is a very high price to pay for maturity.

Like most things, the future of forest pest management cannot be considered in isolation from larger issues. Concern about the impact of human activity on the integrity of the global environment has grown steadily in the last three decades. With the publication of the Brundtland Commission Report (World Commission on Environment and Development 1987), there is now broad recognition, both in developed and developing countries, that economic development must be biologically sustainable over the long term, if the planet is to retain its integrity. This realization of the importance of biological and economic sustainability has risen to the top of corporate and government agendas across Canada and elsewhere. The use of pesticides, and the broader activity of pest management, especially in the forest environment, will most certainly be on those agendas as Canada attempts to adapt the principles of sustainability to economic development.

Accompanying this is the phenomenon of a shift in human values - an evolution that has seen our historic quest for a high standard of living steadily replaced by a quest for quality of living. More and more, our highly urbanized population is coming to view the forest as one of the very few remaining "natural" environments. Given the increasing stress and artificiality of urban life, it is understandable that many people are opposed to what they perceive to be destruction of the natural environment. Forestry practices such as clearcut logging and pesticide use are clearly opposed by the majority of Canadians (Forestry Canada 1989).

This backdrop of social change is critically important to all of us involved in forest pest management - scientists, managers, and educators. Not one of us can afford to ignore it, because if put to the test, the forces of public opinion and social change will overwhelm the logic of science every time. Education must be particularly sensitive and responsive to this process of change. Forestry education, of course, must always prepare young men and women for the present, because on graduation, they will be expected to move quickly into positions of responsibility and leadership. If they are too far removed from the reality of the day, their education will soon lose relevance. But that same education must also provide a bridge to the future, so that these graduates can contribute significantly to the advancement and future health of the sector and of society.

As with any trend, the future of forest pest education will be determined not only by the present, but also by the past. As I look back on nearly thirty years in forestry, I see tremendous change in the role of pest management in forest management. In the 1960s and 1970s, there were very few, if any "forest pest managers". We were entomologists and pathologists practising our first love - the study of insects and diseases- in the forest environment, with little interest in the health of the forest. Towards the end of the 1970s, Canada's forest sector came to the national realization that, because of historic neglect of forest renewal, Canada was setting the stage for serious regional shortfalls in wood supply in the early part of the 21st century. With that realization, forest managers recognized pest - caused losses as major depletion factors and major threats to the supply. They began saying to scientists "You've told us more than we ever wanted to know about the bug, now tell us what the impact of the bug is on the tree, and especially on the forest". That type of thinking marked the beginning of forest pest management, because for the first time it forced scientists and managers to work together on the common challenge of sustaining a predictable supply of wood over time.

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THE REALITIES AFFECTING FOREST PEST MANAGEMENT IN THE FUTURE

The title of my talk today is "Forest Pest Education: Facing the Realities of the 1990s". Several realities will affect significantly the future of forest pest management in Canada, and therefore, should guide educational programs related to forest pests. Today, I would like to focus on three: timber supply planning; public policy; and pest control technology. As I deal with each of these, you will recognize that they all contribute to the broader endeavour of economic and biological sustainability.

1) Timber Supply Planning. Future timber supplies will be drawn from three sources - the natural unmanaged forest, natural regeneration, and artificial regeneration. Because Canada did not undertake broadscale artificial regeneration and tending until about 1980, our new forests will not become commercially operable for another 30 to 40 years. In the meantime, the natural unmanaged forest will continue to be the sole source of industrial wood for most of Canada. In 1980, Canada's Resource Ministers endorsed a national wood production target of 210 million cu. m. by 2000 - a 35% increase in 20 years. Since then, the pressure to set aside significant forest areas to protect old growth stands, habitat for endangered species, and biodiversity has mounted sharply. Globally, the Brundtland Commission (1987) called for a protected-area network representing 12% of the land and water base. Already this target has become reality in Canada, with the World Wildlife Fund actively promoting completion of our national network by 2000; at present, only 3.4% is protected from industrial activity (World Wildlife Fund 1990), so we can expect continuing pressure in the 1990s. In the past decade we have seen major withdrawals from the forest land base in the South Moresby Islands and Carmanah Valley in British Columbia, and Temagami in Ontario. Added to this is the more significant consideration of aboriginal land claims across Canada, many of which are in the courts. Settlement of these claims has the real potential to affect not only the land base available for timber production, but the manner in which forest management is practised. As an example, aboriginal land claims have the potential to affect 80% of the forest land base in British Columbia. Thus, an increasing industrial demand and exhaustion of surpluses is accompanied by two relatively new factors that will further diminish the industrial supply - protected areas and aboriginal land claims. Clearly, future wood requirements will have to come from a smaller land base. Thus protection of the remaining wood supply from unacceptable losses due to pests will become increasingly necessary if we are to successfully bridge our timber requirements over the next few decades, until the new forests mature.

The new forests that are developing, following harvesting and fires, both through natural and artificial regeneration, presents a different and more complex challenge. They will form a mosaic of smaller stands, with a range of age classes; for example, many provinces have established upper limits on harvest block size, ranging from 32 to 250 ha. These stands will be intermixed with values such as habitation, water supplies, and aquatic habitat that will require protection from pesticides.

From 1980 to 1989, Canada planted about 2.2 million ha. at an average cost of $800 per hectare, and tended another 1.3 million ha. (Carrow 1991). Between 1977 and 1988, silvicultural expenditures in Canada increased 7-fold, from $1 million to $7 million (Smyth 1989). In the next decade, the provinces are forecasting a 30% increase in the area planted, and a 250% increase in tending (Carrow [in press]). Such investment must be protected from pests and fire, not only to ensure a predictable wood supply, but also to justify continuation of major silvicultural investment in the future.

2) Public Policy. For the past year and a half, I had the dubious privilege of representing Canada's forestry sector in a federal review of our pesticide registration system. The process of developing a new system perhaps says more about the future of forest pest management in Canada than any other single factor; it is therefore of real significance to managers, to scientists, and to educators. The reasons for this significance are two-fold; first, 91% of Canada's forest land is publicly owned and is managed by governments in the interests of the citizens. Only 9% is privately owned. And over 70% of the owners disapprove of the use of chemicals in the forest environment (Forestry Canada 1989).

The proposed new system for regulating pesticides (Pesticide Registration Review 1990) is the product of a negotiated consensus, involving 12 people who represented a microcosm of Canadian society - farming, chemical manufacturing, public health, forestry, consumers, the environmental network, biological control, and labour. This negotiation made it clear that even people in responsible positions are painfully ignorant about the forest environment and the forest sector; they lack even an elementary understanding of forest management - harvesting, natural and artificial regeneration, vegetation control, and pest control. Yet, these same people play a role in shaping public policy on forestry and the use of pesticides in forestry. I would like to outline some of the key changes being proposed in the new system:

1) The Pest Control Products Act and Regulations will be completely re-written and re-named the "Pest Management Act and Regulations".

2) The objective of the new system is to protect health, safety, and the environment by minimizing risks associated with pesticides, while enabling access to pest management technology.

3) The new legislation and the regulatory agency will be moved from the Minister of Agriculture to the Minister of Health and Welfare - a risk management agency.

4) The legislation will establish a "Pest Management Promotion Office" with responsibility for promoting safer pest management, establishing sectoral targets for reduction of pesticide use, and funding research on safer technologies.

This represents a radical change in the philosophy and goals of pesticide regulation, and if implemented, it will set the stage for major change in the way pest control technology is developed and regulated in Canada.

Another example of public policy change that will directly affect forest pest management is environmental assessment. The province of Ontario is currently in the midst of the most comprehensive public examination of forestry practices in history, viz., the Class Environmental Assessment of Timber Management on Crown Lands. These hearings which began in 1988 are not expected to conclude before the end of 1992. The result is expected to be a set of "terms and conditions" which will regulate how future forestry operations are planned and carried out in Ontario. At this point, it seems clear that the entire process of timber management will become more restricted, more transparent to the public, and more accountable. Relative to forest pest management, it is interesting to note the terms and conditions being proposed by some of the parties to the hearings. Specifically, the environmental coalition, Forests for Tomorrow, proposes:

- that the provincial Ministry of Natural Resources, which is legislatively responsible for managing nearly all the forest land in Ontario, adopt a specific objective of reducing all pesticide use;

- that the use of all chemical insecticides be prohibited; and that aerial application of herbicides be prohibited.

On the other hand, the aboriginal peoples have proposed that no-spray buffer zones be established around all potable water supplies, fish spawning areas, areas used for fishing, homes, cottages, logging camps, trappers cabins, berry-picking areas, endangered or rare species habitats, and trap lines. If these buffer zones were accepted, one wonders how much of the forest land base would be left.

3) Pest Control Technology. At a number of Canadian forest sector meetings over the past decade - professional, industrial and government - delegates have deplored the lack of knowledge about pesticides by forestry graduates. There is no question that forestry curricula have not adequately addressed this technology in the past, for several reasons:

a) there has been historic disagreement within the profession and the sector about the need and justification for pesticide use in forestry largely because, until recently, there has generally been a surplus of wood supply;

b) many academics have taken the "high road" and distanced themselves from chemical pesticides. I might add, however, that these same people have generally failed to explain how one can adequately manage pest-caused losses during outbreaks, without using pesticides;

c) forest pesticide technology in Canada has been, and still is, very limited. On the latter point, Canada is in a dilemma. Canadian pesticide sales represent about 3% of the world market, and the Canadian forestry sector uses less than 5% of the pesticides sold in Canada, i.e. less than 0.15% of world use. Contributing to this are the policies adopted by provincial government agencies across Canada, either severely restricting, or banning the use of chemical pesticides in the forest environment. In recent years, six provinces (Nova Scotia, Alberta, Quebec, Ontario, Manitoba and British Columbia) have adopted a "no-chemical" policy, using only microbial insecticides in their major insect control programs. In several provinces, the provincial Cabinet, or Executive Council makes the final decision as to what area will be treated and what control products will be used.

The combination of limited demand, a strict federal regulatory environment, and unpredictable provincial policies relating to forestry pesticide use have combined to create a critical gap in forest pest control technology in Canada. At present, there are over 130 active ingredients registered for forestry use in the United States; in Canada there are 27, and only three of these are non-chemicals. The consequence of this limited technology, along with provincial generic bans on the use of chemicals, has put the forest manager in a precarious position . In Ontario, for example, where the use of chemical insecticides is prohibited in forestry, there are 12 major forest pests for which there are no registered non-chemical controls. Thus, no operational control programs can be carried out against these pests, if the need arises.

FUTURE NEEDS

With these realities as background, where should our attention be focused in future forest pest education? Canada's National Forest Sector Strategy (Canadian Council Forest Ministers 1987) contains one section dealing with pesticides and pest management, and even though it is now four years old, it still provides valid direction for the future.

The Strategy establishes the necessity of using pesticides as a component of forest management, but it urges:

- that all pest management operations be ecologically and economically justified;

- that effective alternative methods of pest control, including integrated pest management, be developed and used; and

- that research into the environmental effects of pesticides be accelerated. With this in mind, I see three areas that need particular attention in undergraduate education: justification for pesticide use; protection of mature natural forests; and protection of the new forest.

1) Justification of Pesticide Use. In Canada, where over 90% of the forest land is under public ownership, and where the majority of Canadians disapprove of chemical pesticides in forestry, the forester and the pest manager face a difficult challenge. In the past, some foresters, working in a politically sensitive environment, avoided that challenge by opting not to use pesticides and living with the losses. Nova Scotia adopted that position in the late 1970's. Rather than carry our protection spraying against spruce budworm, the government allowed the budworm to run its course, with the result that it lost 35 million cu. m. of industrial wood supply, an amount equivalent to 10 years of wood supply for the entire province. With the prospect of localized wood shortages in certain parts of Canada, such an option is increasingly unfeasible. Protection is becoming essential.

However, the use of pesticides in protection programs will have to be publicly defensible, or our political masters will simply eliminate their use. To do this, we need to focus on two elements - purpose, and performance standard, both of which are important to public accountability. All pest management operations should have a clearly defined purpose. For example, for forest defoliators, is the program intended to control an outbreak, to contain an outbreak, or to protect a specified forest area? If we haven't defined a purpose, how can one give a public accounting of success or failure?

Having defined a purpose, some standard to be achieved is needed. In most forestry operations - nursery stock production, planting, regeneration, and harvesting - performance standards are used to assess operational success. Yet such standards are uncommon in forest insect control programs. In reviewing published reports, one will see results of control programs characterized as "satisfactory", "unsatisfactory", or more commonly "variable". Bearing in mind the considerable cost and political sensitivity of such operations, this type of assessment is no longer acceptable, and in fact, it will not stand up to public scrutiny. Numerical standards should be established and used for all types of pest management programs, but particularly for those involving the broadscale use of pesticides. One could argue, correctly, that we have little scientific basis for selecting standards at present, but the starting point is to recognize the need for standards of performance, and then get on with the job of defining credible and realistic standards.

Educators then, have a major responsibility to emphasize the importance of purpose, performance standards, and public accountability in their curricula.

2) Protection of Mature Forests. Clearly, for the next few decades, the primary challenge facing forest pest managers is protection of mature natural forests. However protection programs must be carried out selectively and linked more closely with harvesting plans, primarily through the careful scheduling of both operations. This can be achieved through the 5-year, 10-year and 20-year management planning process, particularly using GIS technology. Bearing in mind that the purpose of protecting these forests is to keep them alive, not to preserve annual growth, much more attention is needed to defining the level of protection required to prevent mortality.

We know from experience that 50% foliage protection will keep spruce and fir alive in the face of a spruce budworm outbreak, but perhaps a lower level of protection would achieve the same end. Bearing in mind that these forests are scheduled for harvest, is annual treatment required to prevent mortality, or could spraying be carried out less frequently? Again, the answers to these questions are unknown, but it is time that educators and scientists revisit the traditional approach to protecting mature forests, remembering that the ultimate purpose is to keep the trees in a live state until harvesting, not to kill insects or to preserve a specific amount of foliage.

3) Protection of New Forests. In our new production forests, there is a growing need to protect annual growth, seed and cone crops, and tree form. These pose a difficult challenge, both from the standpoint of developing effective technology, but also in defining realistic standards for protection. New regeneration pests will undoubtedly appear, either because they will move into new stands, or because their damage will assume unacceptable proportions. For the great majority of these potential pests, there are no registered control agents available in Canada. These new stands, of course, represent the future industrial wood supply. Growth and yield models assume that these stands will develop at a certain rate and become commercially operable at some specific time in the future. If pests inhibit this development and growth, then these stands will not be operable when expected, and timber supply planning will be disrupted. Pest management in these new forests represents probably the most difficult challenge, because we have a very poor understanding of what level of protection is required to ensure that a stand will grow and develop to meet a particular growth curve. What I have been alluding to of course, for both the new forests and mature forests, is the concept of "damage threshold" - a concept which is becoming increasingly important, both for the justification of pest management operations, and to undergraduate forestry education.

CONCLUSION

In closing, I would like to summarize by leaving with you four points that I believe have been largely neglected in undergraduate forestry education. All four will be essential for our future graduates to play a significant role in the broader challenge of managing the forest resource to satisfy the complex demands of society.

First, there should be more integration of pest management planning with timber supply planning, through traditional forest management courses, such as regulation. As well, students should be made aware of the importance of linking protection of mature commercial forests to harvesting plans.

Second, students must be prepared for the hard reality that in many situations, despite their personal bias, they will have to use pesticides to protect a valuable resource, simply because there are no alternatives. Their primary responsibility is to manage a resource on a sustainable basis. Whether they approve or disapprove of pesticides is irrelevant. What is relevant is whether the forest needs protection, and if so, what technology is available to provide that protection. They must also realize that they will be publicly accountable for these operations, and will have to stand up to public examination and criticism. Third, as educators, we must establish the importance of the concept of "damage threshold" within the curriculum, recognizing that there is an enormous amount of research needed to define those thresholds. These are vitally important if we are to publicly justify pest management, especially pesticide use.

Lastly, we must ensure that our students and our academics acquire a good understanding of pesticide regulation and the rapidly evolving technology of pesticide use and pest management. A public survey last year showed that 87% of Canadians are unaware that pesticides are regulated by government. We should make sure that our graduating foresters are not among that uninformed group.

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II. WORKSHOP SUMMARIES

BIOLOGICAL CONTROL OF FOREST INSECTS

Moderator: C. W. Berisford[1]

There is increasing concern by the public over many conventional tactics for suppression of forest insect outbreaks such as spraying with pesticides for defoliators or clear cutting large blocks of timber for bark beetle control. Although many of these tactics may be logical and economical approaches to insect control for a forest manager, they may also face public opposition in the future. As concerns about environmental damage increase, there appears also to be new interest in utilizing some form of biological control to prevent outbreaks or at least reduce damage from forest insect epidemics. The idea of using other arthropod parasitoids or predators to control forest pests may have the advantage of causing generally less impact on nontarget organisms, and there may be considerably less physical damage to the system.

Although there have been some demonstrated successes in biological control of forest insects, mostly classical biocontrol of introduced pests, there has not been a long-term effort to fully evaluate natural enemies for control, especially with native forest pests.

This workshop includes presentations on successful classical biocontrol projects, evaluation of some theories regarding introductions of parasitoids and predators into established guilds of natural enemies and new research aimed at evaluating, improving or initiating biological control of specific forest pests.

Since biological control entails dealing with a complex system, successful implementation of control, particularly of native pests, requires an intimate knowledge of the biology of the target organism. It is obvious that in many cases, this information is lacking. For example, the impact of native natural enemies of the southern pine beetle has not been documented over a range of host conditions because adequate and reliable sampling methods have not yet been developed.

It appears that the trend toward ecologically sound management practices for forest insect pests will favor biological control using parasitoids and predators. Likewise, continuing restrictions on the use of pesticides may make biological control a more attractive option. The information presented in this workshop provides a glimpse of the considerable potential for economical and environmentally compatible control if serious efforts are made with adequate funding.

However, new biological control projects will usually require extensive preparation and study plus an in-depth knowledge of the pest and the natural enemies. Therefore, it will not usually provide an immediate "silver bullet" solution to a problem. Control may be manifested several years after new introductions of natural enemies and considerable damage may occur during establishment. This type of management will require patience, understanding of the system and sustained funding as opposed to massive "one shot" funding.

CLASSICAL BIOLOGICAL CONTROL OF NATIVE PESTS: WHAT ARE THE PROSPECTS?

N.J. Mills[a]

Classical biological control has been targeted primarily against accidentally introduced or invading pests. These exotic pests arrive in a new region devoid of any natural enemies and classical biological control is the process of purposeful introduction of natural enemies to restore the natural balance and abundance of the pest. Native pests already support a natural enemy complex and so why introduce other exotic natural enemies? There are now sufficient cases from around the world of the successful use of exotic natural enemies for the control of native pests to make this approach worthy of greater consideration.

Examination of the natural enemy complexes of related hosts from different geographic regions has revealed that both the composition of the complex and the relative importance of the component species are not always equivalent. This provides an opportunity to either fill empty parasitoid niches in a native natural enemy complex or to replace ineffective native species by superior exotic species. The environmental impact of

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exotic natural enemies can be minimized by the selection of sufficiently specialized natural enemies. Preliminary laboratory tests, however, are essential to confirm both the suitability of the target host for oviposition and the physiological compatibility of the natural enemy with the new host during its entire development. This is illustrated with reference to current programs for the classical biological control of the native pests, the eastern spruce budworm in eastern Canada and the spruce (white pine) weevil in western Canada, through importation and release of natural enemies from Europe.

THE ROLE OF PREDATORS AND PARASITOIDS IN GYPSY MOTH POPULATION DYNAMICS

J.S. Elkinton[b]

A prevailing hypothesis about gypsy moth population dynamics has been that low density populations are maintained at an equilibrium by the density dependent predation by small mammals, particularly the white-footed mouse, *Peromyscus leucopus*. Recent studies confirm that *P. leucopus* is the dominant source of mortality in low density populations and that outbreaks may be caused by fluctuations in mouse densities. However, we have not been able to demonstrate that such predation is density dependent. Other studies, however, indicate a strong spatially density dependent parasitism by certain Tachinids. These agents may account for the apparent stability of low density gypsy moth populations.

BIOLOGICAL CONTROL OF THE NANTUCKET PINE TIP MOTH WITH AN ICHNEUMONID PARASITOID

R.F. Luck and G.T. Scriven[c]

In the late 1960's, the Nantucket pine tip moth (NPTM), *Rhyacionia frustrana*, was accidentally introduced into southern California on a shipment of Monterey pine, *Pinus radiata*, seedlings from Tifton, Georgia. It has since spread and now mainly infests Monterey pines in six of the seven southern California counties where the pine is widely planted as an ornamental and a choose-and-cut Christmas tree. In 1974, we introduced and established *Campoplex frustranae*, a parasitoid of the moth, imported from Georgia. It suppressed the moth to levels that were of little concern to ornamentals, and it reduced these trees as a source of moths for the Christmas tree growers. However, the moth remained a pest of young Christmas trees in the more interior coastal areas. A single, carefully-timed insecticide application in June will prevent economic damage to these trees. Prior to *Campoplex*'s introduction, older trees, 9 to 12 meters tall, were severely damaged, especially in the upper crowns. After the parasitoid's introduction, only the younger trees were damaged, similar to that observed for NPTM in the southeastern U.S. where NPTM is endemic. Thus, our results suggest that biological control is important in the suppression of NPTM populations in the southeastern U.S. as well.

NATURAL ENEMIES OF DOUGLAS-FIR TUSSOCK MOTH AND WESTERN SPRUCE BUDWORM: MANAGEMENT IMPLICATIONS

Torolf R. Torgersen[d]

Forest ecosystems support a great variety of folivores and their natural enemies. For example, the Douglas-fir tussock moth and western spruce budworm have many natural enemies. Pathogens include bacteria, fungi, and viruses. Parasitoid complexes are mostly ichneumonids, braconids, chalcidoids, and tachinids, with 50-60 species for each pest. Spiders and insects are the dominant arthropod predators attacking tussock moth and budworm. Spiders outnumber all other arthropods on grand fir. Ants are important predators on foliage and in the litter, particularly for the budworm. About 3 dozen species of birds prey on all life stages of tussock moth and budworm. Over 50 percent of tussock moth eggs may be destroyed by birds.

Research on the quantitative effects of the natural enemies on these pests suggests that these organisms should be protected. What then, are some management strategies that will accomplish this goal? An obvious one is to choose insecticides that will have the least impact on beneficial taxa. Predaceous ants can also be protected by minimizing ground-disturbance when stands are harvested. Providing for standing and down dead wood will benefit both cavity-nesting birds and ants. Providing for some diversity in vegetational strata from the brush layer through several canopy layers also improves stands for birds. Encouragement of flowering plants provides necessary nectar and pollen sources for some parasitoids. Many of these actions will also benefit other organisms such as small mammals that are involved in the mychorrhizal cycle, and provide habitat for other game and non-game birds and mammals.

Natural enemies should be viewed as an important component in the complex of interactions that keep the tussock moth and budworm at innocuous levels. Managers need to select management options to maintain natural enemies and mitigate losses from forest insect pests.

THE ROLE OF INTRODUCED PARASITES IN BIOLOGICAL CONTROL OF THE LARCH CASEBEARER

Roger B. Ryan[e]

The larch casebearer, *Coleophora laricella*, was discovered in western North America in the late 1950's on western larch, *Larix occidentalis*. A parasite introduction program patterned after a successful program in eastern North America was initiated. Two European species, the braconid *Agathis pumila* and the eulophid *Chrysocharis laricinellae* were successfully established in the West.

Long-term research plots were established in Oregon between 1972 and 1976 and were monitored continuously to evaluate the effects of the parasites on casebearer density and dynamics. In the 10 years before, parasitism exceeded 10 percent, casebearer moth density averaged 52.6 per 100 buds, and in a coarse key-factor analysis (three k-values) parasitism was the key factor on only one of 13 plots. Casebearer density generally declined when parasitism exceeded the 10 percent threshold, and now, 10 years later, it is 0.8 per 100 buds. In the 8-year period after parasitism exceeded the threshold, parasitism was the key factor on four plots.

Since 1980, three of the plots have been sampled more frequently than the others. A detailed analysis (10 k-values) for the 8 years following the threshold showed *A. pumila* to be the key factor associated with the changed density on all three plots. The action of *A. pumila* was delayed density-dependent. Moth density now appears to be stabilized at a low level.

EVIDENCE FOR MICROBIAL PRODUCTION OF KAIROMONES FOR BARK BEETLE PARASITOIDS

D.L. Dahlsten[f]

In 1986, we hypothesized that the fungi associated with bark beetles might be used by their parasitoids to locate their prey. Several of us have worked closely on this including C.W. Berisford, T.C. Harrington, D.L. Wood, J.R. Parmeter, T.J. Eager, D.L. Rowney, and W.A. Copper.

Fungi isolated from the beetles have been reinoculated into cut bolts and the bolts were assayed in the field. To date, most of the work has been done with fungi from *Dendroctonus brevicomis* in the western Sierra Nevada from 1987 to 1990. In the *D. brevicomis* studies, the following treatments were used: 1) check, 2) uninoculated bolt, 3) live beetles forced into bolt, 4) crushed beetles inoculated into bolt, 5) bolt with *Ophiostoma minus*, 6) bolt with *O. nigrocarpa*, 7) bolt with *O. ips*, 8) bolt with unidentified basidiomycete, and 9) bolt with combination of 4 fungi. Fungi were isolated and maintained by J.R. Parmeter and T.C. Harrington.

Results have been variable; no doubt some of this is due to trap location, age of the fungal cultures, timing, and improper inoculation techniques. In 1987 a parasitoid (*Cheiropachus quadrum*) was trapped on the crushed beetle and basidiomycete inoculated bolts. In the first generation of 1988, *Coeloides, Roptrocerus, Rhopalicus,* and *Dinotiscus* spp. were trapped on crushed beetle and multiple fungus-inoculated bolts. Also the predators, *Medetera* spp. and *Enoclerus* spp., were trapped in significant numbers at some fungus inoculated logs in 1989 and 1990.

ISOLATION AND IDENTIFICATION OF KAIROMONES UTILIZED BY SOUTHERN PINE BEETLE PARASITOIDS

Göran Birgersson[g], **Mark J. Dalusky**[1], **Karl E. Espelie**[1], **and C. Wayne Berisford**[1]

We are currently studying the volatile compounds that help parasitoids to find their host trees and the larvae and pupae under the bark. Our hypothesis is that general compounds, such as oxygenated monoterpenes, guide the parasitoid females to an attractive bark beetle-infested tree. After the females have landed on the tree, they actively search on the surface for late instar larvae beneath the bark.

Volatiles from bark beetle-infested pines which were attractive or non-attractive to parasitoids were collected on Porapak Q columns. Extracts from the columns were analyzed using combined gas chromatography and mass spectrometry (GC-MS). Chromatograms from different trees (i.e., attractive and non-attractive) were analyzed qualitatively and semi-quantitatively. The amount of each compound was calculated on the basis of arbitrary area units in the chromatograms, aeration time, and extract volumes.

Although hundreds of compounds were identified or described, most were present in all samples. However, there were significant differences in amounts of oxygenated compounds. For example, the releases of oxygenated monoterpenes such as camphor, fenchone, isopinocamphone, pinocamphone, trans-pinocarveol, -terpineol, and trans-verbenol, are much higher from attractive trees than from non-attractive ones. The release of 4-allyl anisole and bornyl acetate from attractive shortleaf pines is much higher than from non-attractive ones, while their release is very low from all Virginia pines.

Several of these oxygenated compounds have been tested in field bioassays (cf. Berisford) and in electroantennogram analyses (E.A.G.; cf. Salom). Preliminary data indicate that some are readily detected by parasitoids and that some attraction occurs.

EAG EVALUATIONS OF POTENTIAL KAIROMONES FOR A SOUTHERN PINE BEETLE PARASITOID

Scott M. Salom[h]

Bark beetle and tree-produced semiochemicals were presented to *Dinotiscus dendroctoni*, a parasitoid of larval state *Dendroctonus frontalis*, in two studies using the electroantennogram. In the first study, twenty compounds were presented individually at one concentration to the parasitoids, and compared to a response to a standard mixture of oxygenated monoterpenes. In the second study, compounds which elicited the greatest EAGs were then tested in serial dilutions, ranging from 0.0001 to 10 ug/uL. The individual compounds did not elicit higher responses than did the standard mixture of oxygenated monoterpenes. Males and females exhibited similar dose responses, although females showed lower thresholds of response to frontalin, terpinen-4-ol, exo-brevicomin, and an unidentified pheromone. In both studies, pino/isopinocamphone elicited the greatest responses at the higher concentrations. Tests of different ratios of the camphone mixture indicated that pinocamphone elicited the greatest response. Overall, similar responses elicited by most of the potential kairomones suggest that the compounds may be used together by *D. dendroctoni* in habitat and/or host community location.

FIELD EVALUATION OF CANDIDATE CHEMICALS AS KAIROMONES FOR BARK BEETLE PARASITOIDS

C.W. Berisford[i], G.O. Birgersson[g], M.J. Dalusky[i] and K.E. Espelie[i]

Bark beetle parasitoids can locate infested trees and can also discriminate among trees with different developmental stages to select those with preferred life stages, i.e., final instar larvae. With the southern pine beetle, *Dendroctonus frontalis*, selection is apparently mediated by olfactory cues produced by microorganisms such as yeasts and fungi which are transmitted from the beetles to tree hosts.

Selected chemicals, primarily oxygenated monoterpenes, which are associated with trees attractive to parasitoids of *D. frontalis* have been tested for attraction to parasitoids in the field. A combination of 12 oxygenated chemicals caught significantly more parasitoids than unbaited traps but less than 50 cm long log bolts infested with yeasts and fungi from beetle adults. Subtractive bioassays did not detect any single chemical in the mix that was critical for attraction.. There appeared to be some differences among different combinations of the compounds, but variability in trap catches prevented determination of an optimum mix. These parasitoid attractants should provide a useful tool for intensive studies on the biologies of SPB parasitoids and perhaps could help to increase their efficacy as control agents.

SOUTHERN PINE BEETLE NATURAL ENEMIES IN RELATION TO INFESTATION DEVELOPMENT

Fred M. Stephen[i]

An international conference on pine bark beetles held in 1989 identified research on natural enemies as an important area for development of future management. In particular, their role in endemic vs epidemic bark beetle populations, sampling methods for realistic impact assessments and possible density-dependent responses by parasitoids and predators were cited as high priority research topics.

The southern pine beetle, *Dendroctonus frontalis*, (SPB) is well suited for studying natural enemies in some ways, because it is multivoltine and produces descrete infestations which often continue to expand for one or more growing seasons. However, the SPB and its natural enemies are highly aggregated spatially. The high variance requires very large samples in order to make accurate population estimates. Collection and evaluation of samples is expensive plus timing of sampling is critical.

Realistic measures of SPB and natural enemies populations are essential if we are to accurately assess the role of natural enemies in regulating SPB populations. It appears that natural enemies may regulate in a density-dependent manner. For example, SPB populations in Arkansas from 1973 to 1978 showed rapid development followed by a population crash. During these same years, natural enemy populations increased five fold, indicating a possible delayed density-dependent response. Further refinement of sampling techniques and evaluations of natural enemy impact through time will be necessary if we are to manage forests in a way to take advantage of these natural control agents.

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WHAT IS COMPLEX DYNAMICS AND CHAOS?

Moderator: Alan A. Berryman[1]

I tried to describe, in a very nontechnical way, what is meant by complex dynamics and chaos. Behavior emerging from population models with non-linear (positive and negative feedback) processes can vary from stable fixed points to cycles of increasing complexity (periodic and quasiperiodic) to irregular (unpredictable) oscillations known as chaos. Chaotic trajectories cause amplification of small errors of estimation and thus long-term predictions are impossible. However, long-term predictions are impossible anyway in ecology, because we cannot predict weather (weather may be chaotic). In fact biological organisms may be considered anti-chaotic in that they have to evolve control mechanisms for living in an unpredictable (chaotic?) world.

We and others have argued that there are good reasons for biological systems not to exhibit chaotic dynamics [e.g., Berryman and Millstein 1990]. This is borne out by analysis of numerous data sets, few of which turn out to be chaotic. However, the interest in chaos is well founded because all ecological systems can be made chaotic by certain human activities; e.g., bioengineering more virulent pathogens, spraying very effective insecticides, making habitats very suitable for pests (monocultures), etc. Our objectives, therefore, should be to maintain forest pest populations in a non-chaotic, predictable state.

Several examples of forest insect population dynamics were displayed and their stability properties analyzed on the POPSYS microcomputer system.

A NEW LIFE-SYSTEM APPROACH TO THE ANALYSIS OF POPULATION DYNAMICS

Alexei A. Sharov[a]

Life-system approach was developed primarily by Clark et al. (1967) for analysis of complex interactions of elements in the system that includes the population and its effective environment - the life-system. They defined life-systems as being composed of two basic kinds of elements: ecological processes and "co-determinants". I will refer to these elements of the second kind as "factors". Factors are characteristics of the life-system state: air temperature, population density at a certain stage of development, density of predators and so on. A process is a flow of similar ecological events; e.g., reproduction, death of larvae due to parasitism, development of eggs etc. Factors are changing in the course of processes, and process rates depend upon factors. So there are no density-dependent factors, but density-dependent processes. A factor will be called an input factor if it is not determined by processes inside the life-system (e.g., temperature, control measures).

I use this terminology for linking theoretical population ecology and simulation modelling. Theoreticians and modelers are usually speaking in different languages. The former talk about different kinds of density-dependant and key mortality factors, while the latter talk about variables and differential or difference equations.

First, there are no mortality factors, because this term assumes that a certain process of death depends only on one certain factor. But in nature each process depends on several interacting factors. Mortality factors do not exist even in simple analytical models, where death due to predators depends not only on predator density but also on prey density, its spatial distribution, etc. Second, variables and equations have no biological sense if they have no certain interpretation in terms of factors and processes.

I define my life-system approach to the analysis of population dynamics as a multi-level description of the life-system with between-level correspondence. At least two levels should be considered: the macro-level of density fluctuations, which can be characterized by the mean value and variance of log-transformed population density, and the micro-level of factors and processes (in

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more complicated systems there are factors and processes on several structural levels).

Resistances of mean value and variance of log-transformed population density to the change of mean value and variance of some input factor are called buffer ability and homeostasis, respectively. They can be considered as two aspects of stochastic population stability. Coefficient of buffer ability is defined as

$$b = (\alpha \bar{x} / \alpha \bar{v})^{-1} \qquad (1)$$

where x - mean log-transformed population density, and v - mean value of input factor. Coefficient of homeostasis is defined as

$$h = (\alpha s_x^2 / \alpha s_v^2)^{-1} \qquad (2)$$

where s_x^2 and s_v^2 - are variances of log-transformed population density and input factor, respectively. In particular case, when there is a stable equilibrium point and v -is a single fluctuating input factor, then

$$h = s_v^2 / s_x^2 \qquad (3)$$

For population models with stable equilibria, coefficients of buffer ability and homeostasis can be estimated using linearization technique.

The contribution of ecological processes and their interactions to these coefficients can be estimated using the mathematical population model and multiple regression:

$$y_i = c_1 z_1 + c_2 z_2 + c_{12} z_1 z_2 + c_3 z_3 + ..., \qquad (4)$$

where y_i is the coefficient of buffer ability or homeostasis, z_j is a dummy variable indicating the dependence of j-th ecological process rate on factors (z_j=1 if the rate of j-th process naturally depends on factors and z_j=0 if this rate is fixed at the mean or equilibrium level), c_j is the contribution of the j-th individual processes; c_{jk} is the contribution of the between the j-th and k-th interaction to the value of y_i.

Using analytical host-parasitoid models it was shown that parasitoids enhance the buffer ability of a host population but reduce homeostasis (Sharov 1989). This means that if parasitoids are present it is more difficult to change host mean density but host density fluctuations are greater than without parasitoids.

Coefficients of buffer ability and homeostasis can be used for planning a pest management strategy. If it is necessary to decrease mean pest density, then the k-value of additional mortality applied to the population must be equal to the integral of the coefficient of buffer ability from initial to terminal mean log-transformed population density. Changes in the coefficient of homeostasis will indicate changes of population fluctuations. If the coefficient of homeostasis is higher than in the previous position at the new mean level of population density, then the variance of log-transformed density will be lower than that before application of additional mortality. The same method can be used to predict consequences of natural enemy introduction.

For populations with highly non-linear dynamics, coefficients of buffer ability and homeostasis can be estimated only by numerical methods. Correlation between variances of the input factor and population density is usually non-linear in this case and, therefore, it cannot be comprehensively described by the coefficient of homeostasis. Then, additional characteristics are necessary such as initial variance of population density in the absence of stochastic noise (the size of attractor).

THE DYNAMICS OF SPRUCE BUDWORM POPULATIONS: STOCHASTIC PROCESSES, MIGRATION AND THE BEHAVIOR OF OUTBREAKS

Jacques Regniere[b]

Outbreaks of the spruce budworm have occurred at irregular intervals for at least the past 3 centuries, probably for thousands of years (Blais 1985). There is some evidence that outbreak frequency and severity have increased in recent years (Blais 1983). While outbreaks seem to occur as monolythic events over vast expanses of territory, there are notable geographical patterns in their behaviour, in terms of timing, duration, and severity (Hardy *et al.* 1983, Royama 1984). In particular, they tend to appear first, to be shorter-lived and less damageable along the St-Lawrence river and Great-Lakes basin. They tend to appear somewhat later, be far more serious, and last longer in the boreal forest, and to be quite erratic even further north or at higher elevations.

The very few instances where spruce budworm densities were measured with any accuracy in one given locality show little evidence to support the commonly heard multiple-equilibrium paradigm of spruce budworm population dynamics (Clark et al. 1979). Particularly, there is little evidence of a so-called endemic period during which the insect would be kept in check by a "saturatable" natural enemy, such as bird predators. Perhaps the most difficult observation to conciliate with the release-collapse concept is that collapse occurs even in the absence of much damage to trees.

Evidence from the life tables compiled by R.F. Morris and his co-workers (Morris 1963), as reanalysed by Royama (op. cit.), suggest that a lagged, density-dependent stochastic process underlies the population fluctuations of the spruce budworm. Cycling would be the result of a slow, gradual change in larval survival rates which, if left undisturbed, would produce regular population oscillations of 30-40 years frequency. Disturbance of this regular pattern would come from two sources: the effect of moth migration on apparent fecundity, and occasional sharp drops in larval survival rates. However, life tables so far available have not provided enough information to identify much further the mortality factors involved in these changes in large larval survival rates. In the early 1980s, Forestry Canada embarked on an ongoing research program involving several colleagues, including Tom Royama, Eldon Eveleigh, Vince Nealis, Tim Lysyk, Chris Lucarotti, and David Perry, as well as members of the Quebec Department of Energy and Resources. The objectives of the project are: 1) to identify the mortality factors involved in the observed patterns of mortality (new life tables), and from this knowledge 2) to devise new or improved approaches to biological control of the budworm and 3) to develop predictive models of population dynamics.

So far we have found that the events recorded in the 50s By Morris's group, as emphasized by Royama, are pretty well universal and recurrent. We have also identified several organisms which are consistently involved in causing high mortality among large budworm larvae during the first stages of outbreak decline: the most important being *Meteorus trachynotus, Nosema fumiferanae, Synetaeris tenuifemur* and bird predators. However, we have now established that the complex of natural enemies changes drastically as budworm populations continue to decrease, and normally rare parasitoids such as *Actia interrupta* and *Enytus montana* become quite important. Many of these natural enemies are not specific to spruce budworm, but rather require other hosts to complete their life cycle (e.g., Maltais et al. 1989). These observations suggest that there is a buildup of natural enemies in outbreak budworm populations which is limited by the availability of these alternate hosts. In none of the several collapses that we have documented did the budworm population cause extensive damage to its resource. We believe that a collapse may be precipitated by any factor that reduces budworm numbers to a sufficient extent for these natural enemies to have a significant impact on mortality rates and exert lasting control.

We have also determined that there is a notorious lack of important parasitoids in budworm populations that have been low for 10-15 years. We suggest that populations of many natural enemies are decimated during the prolonged period when budworm is rare, leading to the development of a new outbreak cycle.

These results are quite consistent with the concept of a stochastic density-dependent stochastic process as a description of the spruce budworm's population dynamics, but show a far more complex dynamic structure than we expected. Simulation studies, using a disease-host model (Regniere 1984), demonstrated the ability of such simplistic stochastic processes to describe the essential aspects of spruce budworm outbreak behaviour, taking various facts of budworm biology into account. First, environmental conditions determine the inherent, local oscillation frequency. In general, milder and more diverse habitats lead to lower-amplitude, higher-frequency cycles. Second, spatially correlated stochastic influences (mostly weather) act as an imperfect synchronizing mechanism. Third, dispersal (moth migration) acts as a very effective synchronizing mechanism, which helps produce the widespread, monolythic outbreaks that are budworm's trademark.

It is increasingly clear that outbreaks of the spruce budworm are the result of particularly pronounced population cycles which occur at a frequency of 30-40 years pretty well throughout the insect's range. The recent apparent increase in outbreak frequency may be the result partly of better monitoring and record-keeping in the last 60-80 years, partly of the stochastic nature of budworm population oscillations. Also, if the findings discussed here are true, outbreak epicenters are more an "optical" illusion than biological reality, and an early-intervention, epicenter-abatement control strategy is bound to fail. Finally, the idea that outbreaks develop and crash more or less deterministically as a result of forest maturation and destruction seems pretty well discredited.

WHY ARE GYPSY MOTH NUMERICAL DYNAMICS SO IRREGULAR IN NORTH AMERICA?

Michael E. Montgomery[c]

Populations of the gypsy moth, *Lymantria dispar*, undergo dramatic changes in density in both North America and Europe. Peaks in population density occur at 8-10 year intervals on both continents, but outbreaks that cause widespread defoliation seem less common in Europe.

An analysis of the numerical dynamics of a population in Yugoslavia, monitored for over 35 years, showed peaks in gypsy moth density occurring regularly at 9 year intervals, although the amplitude of the peaks varied greatly. Variation in the per-capita rate of change in the population, R, was best explained by a model where the density of the population was lagged one year. Mortality by oligophagous parasitoids peaked at 50-60% in the year after the density of a population peaked. Parasitism by a generalist parasitoid, *Compsilura concinnata*, was highest when populations were low, but never exceeded 20% and was independent of the density of the gypsy moth.

The numerical behavior of populations followed for 18 years in New Jersey was more irregular. Variation in the rate of population change was best explained by a model where density was lagged two years. This model accounted for only 38% of the variation whereas the model of the Yugoslavian population explained 64%. In North America, mortality of gypsy moth by oligophagous parasitoids during outbreaks is generally below 20%. Mortality by *C. concinnata* seems to be higher than in Yugoslavian populations of similar density. Predation of pupae by small mammals is a significant source of mortality in sparse populations in North America, but there are no reports of the impact of small mammals in Europe.

During the periods of low density, gypsy moth densities may not fall as low in Europe as in North America. At least some egg masses were always found in the Yugoslavian plots, and the lowest densities reported in a cycle ranged from 6 to 32 egg masses per hectare. Zero egg masses were often reported for the plots in North America during the low density phase. Although the small size of study plots in North America makes it difficult to estimate the true density, it seems that egg mass densities usually drop below 4 per hectare during the latent period.

My interpretation is that density-dependent regulation of North American gypsy moth populations is weak. This may be a consequence of populations being driven to extremely low densities by generalist parasitoids and predators. The density may be so low that oligophagous parasitoids cannot respond adequately to a surge in the population caused by extrinsic factors, such as favorable weather or the demise of generalist predators and parasitoids. This would lead to irregular numerical dynamics.

Gratitude is extended to Pelagija Sisojevic and David Williams for sharing with me data from, respectively, Yugoslavia and New Jersey.

NEW FINDINGS IN GYPSY MOTH POPULATION DYNAMICS

J.S. Elkinton[d]

The tachinid parasitoid *Compsilura concinnata* has been shown to cause strong spatially density dependent parasitism that decimated experimentally created gypsy moth populations in Massachusetts. However, this parasitoid is a multivoltine generalist with obligate alternate hosts which presumably accounts for the failure of subsequent experiments to detect any between-generation numerical response. Thus, the potential of this agent to maintain gypsy moth at a low density equilibrium is tenuous at best and probably depends on the spatial scale at which population densities are synchronized. Further experiments found no evidence that predation by the white-footed mouse, *Peromyscus leucopus* on gypsy moth is positively density dependent, although it clearly is the dominant source of mortality in low density populations and may be responsible for the onset of gypsy moth outbreaks. The gypsy moth life system appears dominated by mortality agents whose abundance is uncoupled to the density of gypsy moths. It would appear more likely that the evident irregular fluctuations in gypsy moth densities are a result of essentially random variation in the abundance of these agents as opposed to deterministic chaos of predator/prey interactions.

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QUALITY CONTROL AND RELIABILITY OF PEST MONITORING INFORMATION

Moderator: William Burkman[1]

The integration of quality assurance (QA)/quality control (QC) procedures into forest monitoring and research programs is relatively new. The first survey projects with required and financially supported QA programs were part of the Forest Response Program. This program included the Sugar Maple Decline Study, conducted in the northeastern United States and Canada. As more integrated environmental monitoring and survey programs are implemented, the number of participants, each with certain data needs, increases. Users of field monitoring data must have confidence that the data are reliable.

This workgroup may be the first of its kind at a Forest Insect Work Conference, and reflects the increased interest in the application of QA/QC principles to the collection of pest monitoring data.

DESCRIPTION OF SESSION

Participants

Participants included US and Canadian foresters and researchers involved in data management, or collecting and using forest and pest monitoring data. Most participants expressed concern over the need for increased data reliability and comparability, and lack of guidance available on how to proceed in developing a program with stated data quality. Several shared professional experiences of their work on programs without QA/QC that resulted in data of limited usefulness.

Robert Mickler defined the following data quality attributes: accuracy, precision, completeness, comparability, and representativeness. He used survey data from southern pine beetle outbreaks in the southern US as a case study to discuss these attributes, and emphasized the need to evaluate data quality before combining data sets from different states or using existing data in predictive models. He encouraged clear statements and early consideration of the intended use of the data.

Questions raised from Mr. Mickler's talk focused on the following issues:

* When data from different states are combined and summarized in regional maps, how do you indicate that data were not consistently collected? Should a disclaimer be added? Can data be back-corrected? How can confidence limits for existing data be established?

* To what extent can existing databases be used? If data quality in a particular dataset is known to be a concern, yet no other dataset exists and the information is needed, how do you proceed?

* What if the intended use of the data is unclear, or changes over time?

Dan Twardus described the evolution of documentation for evaluation of the effectiveness of Gypsy Moth suppression treatments. In the past, success has been defined by the number of acres sprayed, with limited assessment of pre- and post-treatment conditions. Dan discussed QA/QC by drawing the analogy of a suppression treatment with activities on an auto assembly line, stating the following similarities: both processes are operational, both are producing something (in suppression treatments, the product is a successfully treated block), and in both cases, deterioration at any stage results in deterioration of the product. Dan has been working towards more QC by developing a data dictionary, and a methods manual. He emphasized the need for looking at each step in the data collection process, and clearly stating meaningful definitions of success.

Discussion following this talk focused on the following issues. Projects of all kinds need upfront objectives, which focus on the product and clearly define success.

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In insect suppression projects, data collection techniques can be largely administrative. We need to focus on biologically meaningful methods and performance criteria, and consider the possibility of sequential sampling.

Steven D'Eon described the three types of errors that can occur as data are entered into FIDSINFOBASE, a large national pest monitoring database that contains pest information dating back to the 1940's. These are keypunch errors, data collection errors, and survey errors. Keypunch errors are relatively straightforward to find and correct using database management techniques. Collection errors, which occur as data are being collected in the field, are the most common errors, and can be difficult to correct. Survey errors result as changes are made in survey design or field definitions. Mr. D'Eon described the QC methods that he uses to identify, correct, and control these three types of errors.

Questions following this presentation were primarily points of clarification:

* What is the purpose of the database? Ans: FIDSINFOBASE is primarily a service to organize and store the large pest database.

* How are changes in the database documented? Ans: The goal is to store the data as collected, and to minimize conversions or manipulations of the data. Changes in the data collection procedures are documented in a National Survey Manual.

* How are the field crews trained? Ans: Training is a regional responsibility. Efforts are being made to train crews consistently across regions.

* Are the plots permanent or non-permanent? Ans: The database contains information from both permanent and non-permanent plots, depending on the region. The sampling intensity also varies with region.

* Are there insects or diseases for which each region is required to conduct surveys? Ans: Yes; certain regions require surveys for some insects, (e.g., spruce budworm). Sub-sampling is conducted for widespread, common pests across several regions.

Bruce Nash described how QA/QC techniques have been applied to research on pest damage evaluation for hardwoods. He discussed: 1) the effects of leaf collection method, sample location in the crown, and leaf evaluator bias on estimates of symptom incidence and severity; 2) how symptom incidence data have been used to estimate natural variation and sample size for Penn State's ongoing research; 3) the comparison of laboratory and field evaluations of symptoms; and 4) the utility of an expert system training module to reduce subjectivity of symptomatology scoring. Dr. Nash emphasized the importance of training to ensure repeatable evaluation of symptoms, and the need to quantify and control measurement error, and to estimate natural variation.

Discussion following Dr. Nash's talk focused on the following issues:

* What is the publication status of the statistical techniques (estimation of natural variation and sample size), and the expert system? Ans: Although documented in internal reports, the work has not yet been published.

* Data on how to estimate the number of leaves to sample, given certain objectives, were presented in the talk; what about the number of trees? Ans: Estimation of sample size depends on the symptom of interest. The natural variation between trees in a given stand or plot can be very high, so one would have to pre-sample a number of trees. Different approaches for estimating sample size could include multi-stage sampling schemes, or a "pilot", e.g., 10 trees, 2 branches per tree. Cost is always a major consideration.

DISCUSSION TOPICS

Guidelines and Precautions When Using Data from Existing Databases

In his presentation on QA principles, Mr. Mickler presented the database for monitoring southern pine beetle as a case study. He discussed concerns with the existing database including inconsistent definitions of beetle "spots", differences between states in methods of data collection and recording, and potential for misuse of the data base. This type of survey/monitoring data can cause concerns when it is summarized in regional maps, so that all areas appear to be similarly sampled. Below are possible approaches to assessing the usefulness of existing databases that were discussed by the workgroup:

1) consider the original objectives of the study; state the specific objectives and intended use of the dataset for the current study;

2) consider the costs and benefits of conducting a new study, collecting additional data, re-analyses, seeking more information on methods, etc. from existing datasets;

3) consider the entire region, and intensively measure or resample selected counties/areas. The intensively sampled areas could be areas of questionable data or borderline outbreaks;

4) build in checks as the program evolves;

5) indicate/identify non-sampled areas in existing databases; be certain to indicate these in all overlay maps produced;

6) collect remeasurement data and calculate estimates of data quality;

7) through the whole process, consider the needs of the states and other groups involved.

The discussion also raised questions regarding the boundary between research and monitoring, and the value of regional pest surveys for detection monitoring.

Goals for Improvement of Forest Pest Monitoring Data

The workgroup compiled the following goals for improving forest pest monitoring data:

1) a common database for forest pest monitoring/survey data;

2) fulfillment of needs of all participants, including states, Forest Service Research, and Forest Health Monitoring; consideration of short and long term data needs;

3) standardized methods for assessing selected pests and/or consideration and evaluation of comparability between methods;

4) development of minimum measurements and methods standards for monitoring a given pest or within individual projects;

5) quantification of data quality;

6) documentation of methods, reporting units, and calculation of percent assessments.

It was pointed out that with increasing political sensitivity, monitoring data may at some point be questioned in court (e.g., ozone damage or point source damage on trees). Legal defensibility will require quantification of data quality.

One of the ways of increasing the usefulness of pest monitoring and survey data sets is to establish standards. The importance of establishing standards, particularly in regional surveys when different states collect the data, was discussed for reporting, methods, and measurements. The dangers of establishing overly rigorous standards were also considered.

Important Components of a Pest Monitoring Program or "How To Proceed"

The workgroup also discussed the "ideal" steps to be taken in planning and implementing a monitoring program that integrates QA/QC principles. These steps, listed below, are iterative and repeated to improve the program over time:

1) Define objectives (knowing they may change and evolve with the program). State intended use of data.

2) Define acceptable error. Provide input into the database and sampling design. Describe uncertainty, and levels of certainty needed to make reasonable policy/management decisions. This step and the first step are similar to the EPA process of developing data quality objectives for collection of environmental data.

3) Decide what you will measure, considering the data needs of the different participants.

4) Decide on methods to be used to collect data. Keep the methods simple and routine. Consider feasibility, monetary constraints, costs, and benefits. Write a workplan; document methods.

5) Train and evaluate crews. Test methods in the field.

6) Start collecting data, regardless of whether data collection activities are called implementation, a field test, a pilot, or a demonstration.

7) Follow up training with a field check early in the season. This should be an "external" or an "expert check." If possible, evaluate performance of field crews quantitatively, i.e., have the expert remeasure a certain number of plots.

8) During the field season, collect remeasurement data.

9) At the end of the field season, hold a de-briefing with an open discussion of what did and did not work.

10) In planning for the next field season, consider all of the above, and implement changes identified as necessary.

The presentations were varied and interesting, and provided a good basis for discussion. Because our workgroup was relatively small, everyone had a chance to participate, contributing different perspectives and personal experiences to our dialogue about data quality and implementation of monitoring programs. The discussions were productive; they summarized concerns about existing data, indicated the need for increased data reliability, and resulted in some guidelines for improving and estimating the quality of pest monitoring data.

QUALITY ASSURANCE PRINCIPLES: AN EFFECTIVE TOOL FOR MANAGERS AND RESEARCHERS ASSESSING REGIONAL PEST MANAGEMENT CONCERNS

Robert A. Mickler[a] and Kathleen Dwire[b]

The application of QA principles to the monitoring and assessment of reduced productivity of forested ecosystems due to insect damage would ensure the accurate quantification of losses to forests reported by state forestry agencies and the U.S. Forest Service. Our ability to detect loss is dependent on the quality of the field monitoring data, which must be documented quantitatively to evaluate of the data based on statistically-supported limits of uncertainty. Uncertainty is defined in terms of accuracy, precision, completeness, comparability, and representativeness.

The lack of accuracy in the assessment of insect damage to forests results from field measurement error. Measurement error can be attributed primarily to the lack of standardized sampling methodology within a region. The limitations of data quality are an obstacle to loss assessment and only allow for the reporting of a "best estimate".

Quality assurance principles implemented in future annual pest surveys can provide more accurate loss assessments and quantify measurement error for use in correlative studies for regional predictive models and other research applications.

DATABASE MANAGEMENT TECHNIQUES FOR QUALITY ASSURANCE/QUALITY CONTROL: FIDSINFOBASE, A CASE STUDY

Stephen D'Eon[c]

There are numerous database management techniques that can be used to improve the quality of data stored in a database. The quality can be improved by controlling data entry, data collection, and survey errors. Techniques to control these three types of errors are discussed using Canada's national forest pest monitoring information system (Fidsinfobase) as an example.

Data entry errors are non-random mistakes usually involving transposed characters, offset keys, and incomplete or offset fields. Techniques to control data entry errors include: entering everything twice, entering important fields twice, checking input against a knowledge base, checking input against a look-up table, and checking input against the database to spot unusual entries.

Data collection errors occur when data are incorrectly collected. These include scribing errors, inconsistent interpretation of field instructions, and modifications of field procedures without proper remarks noted. Database management techniques to control data collection errors include collecting the same information two different ways, checking the logical consistency between fields, and checking data collected by field staff against other field staff.

Survey errors are errors that are generated by the survey guidelines. Survey errors include: non-exhaustive fields, forcing interpretations, combining definitions, and converting measurements to classes, ranges, or midpoints. Survey errors should be controlled in the study design and database design phases.

THE USE OF QUALITY ASSURANCE/QUALITY CONTROL TECHNIQUES TO DEVELOP LABORATORY AND FIELD PROCEDURES FOR FOREST HEALTH MONITORING

Bruce L. Nash, Donald D. Davis, and John M. Skelly[d]

Quality assurance/quality control (QA/QC) is an important component of any forest health monitoring program. At Penn State, QA/QC data have been used to develop research methods, and to ensure the accuracy and consistency of data. In 1987, 6161 leaves were collected from red oak (2284 leaves), white oak (1993), and red maple (1984). The leaves were collected by three different methods (climber with pole pruner, climber with pole pruner/basket, and shotgun) and from each of the four cardinal directions within the outer, exposed portion to the crown. Each leaf was evaluated independently by two trained technicians, who recorded each symptom on each leaf and the percent surface area affected by each symptom (measured as class data with upper limits of: 1, 5, 10, 25, 50, 75, 90, 95, 99, and 100 %).

Data were stratified by leaf evaluator, collection method, and sample location. Analysis indicated that variation between readers was within acceptable limits. Symptoms that presented difficulty to technicians were either dropped from the protocol or more rigorous training was instituted. Incidence and severity varied little by collection method, therefore, we selected the climber/pole pruner technique since it offered advantages over the other two methods. Variation within the crown was generally low; however, this parameter was included in subsequent foliar evaluations. These data, with detailed descriptions of methods, diagnostic information and illustrations of severity standards were summarized in a QA/QC manual.

Evaluations were also conducted in 1988 (14,034 leaves) and 1989 (18,720 leaves) using three and five technicians, respectively. Weekly meetings were held among all evaluators to compare results from sub-sets of leaves evaluated independently by all technicians. Variation due to technician and position within-crown was quantified each year.

A Monte Carlo analysis was used each year to quantify the effect of sample size on estimating the population mean for 12 selected foliar symptoms. This data set is being summarized graphically for four confidence levels by tree species (3 spp.) and year of collection (3 yrs.).

A prototype expert system, Forest Health, has been developed that provides a graphical user interface to train technicians how to estimate 1) the amount of foliar injury on individual leaves and 2) the degree of crown transparency and branch dieback. Conifer and hardwood crowns are produced in three dimensions and can be rotated to view injury from four different viewpoints. Written and electronic output are available for long-term QA/QC data. This system provides a means for standardization among technicians, years and regions. Diagnostic routines for foliar symptoms and casual agents on selected hardwood species are also included in this expert system.

In order to quantify the difference between laboratory and field estimates of foliar symptoms, evaluators used binoculars to estimate several symptoms associated with pear thrips and anthracnose on sugar maple. Incidence and severity of the symptoms were estimated for the upper one-third of 15 sugar maple crowns. Tree climbers then collected leaves from the same portion of the crowns. These leaves were examined in the laboratory for incidence and severity of the same four symptoms. Field evaluations underestimated the incidence of necrotic leaves by as much as 91 percent. Chlorosis, anthocyanescence and leaf crinkle were also greatly underestimated. Estimates of symptom severity differed by as much as three severity classes. This study emphasizes the need for "branch-in-the-hand" evaluations.

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ORNAMENTAL AND SHADE TREE PROBLEMS WORKSHOP

Moderator: E. Alan Cameron[1]

Environmental consciousness is a growing phenomenon in contemporary society. The benefits of the 'good life', specifically including well-landscaped and maintained homes with woody vegetation to provide both beauty and shade, annually come within the economic reach and expectation of more and more families and individuals. Herein lies a paradox, one which creates many challenges and opens many opportunities for professionals with interests in managing insects which occur on ornamental and shade trees in urban and suburban areas. Often, traditional 'forest entomologists' have fielded questions about controls needed for insects perceived to be pests. We have slowly come to recognize that what occurs in a forested situation is not necessarily reflected in an urban environment from either the standpoint of biology and behavior of the pest insect or, more dramatically, from the standpoint of the economics associated with the problem. The same insect, for example, the gypsy moth (*Lymantria dispar*), may be a forest insect pest (as it is throughout much of the northeast and increasingly in the midwest), an ornamental and shade tree pest (as it is in urban and suburban areas within the geographic area where it is common and established), and an insect which is the target of quarantine programs (as it still is throughout much of the United States and Canada). Too often we seem to forget that what is an appropriate response for one kind of situation may be completely inappropriate for another.

The Workshop on ornamental and shade tree problems was given a charge to define the issues, to identify the needs, and to propose recommendations - and ways of achieving implementation of these - that will prepare us for management of ornamental and shade tree problems of the 21st Century. It was deliberately structured to be open and interactive, with only three 'prepared' participants. In turn, the prepared speakers discussed the biology of and a promising control program for the elm leaf beetle, *Xanthogaleruca luteola*, problems associated with introduced pests, and the use of computers in a technology transfer program for gypsy moth management at the level of counties within a state. During the afternoon, many of the those attending contributed to the discussion. Many of the comments and ideas that they presented are incorporated, without specific attribution, in the summary which follows.

It is sometimes difficult to separate 'issues' from 'needs'; one often begets the other. The weakest portion of the summary is that which proposes recommendations to implement programs to address the needs articulated. It is to be hoped, however, that identification of at least some of the issues and needs will provide a foundation on which those interested and committed specifically to working with ornamental and shade tree insects may build.

Perhaps the dominant issue that arose is the fact that ornamental and shade tree entomology is not in the mainstream of forest entomology - or most of entomology of any sort. As a relatively unorganized and unrecognized specialty, it is overlooked and underfunded by too many policy and decision makers. Having said this, it was suggested that there is really more money, but from many and diverse and not always adequate pots, for tree pests in urban areas than there is for the same in forest areas. Problems take time to solve; effective solutions will come through well-conceived pest management programs. These can be built only if sound biological, behavioral, ecological, and economic information is developed for at least the key components of a pest management system. With each perturbation of the system, for example, the introduction of a parasite or predator or changed cultural practice, existing ecological relationships will be changed; research needs tend to develop into loops, not neat straight lines to simple solutions. Too often the target insect is little known or understood, especially if it is an introduced species; its natural enemies are likely to be even less known both domestically and internationally. Dahlsten suggested that the example of eight years needed to develop the elm leaf beetle management program to the

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point that it could be transferred successfully to communities was unusual in that it was accomplished so rapidly. Support of granting agencies must be committed, and commitments honored, for much longer than the two or three year 'quick fix' mentality that is the norm. Before this will happen, though, support of pest management as the driving philosophy underlying 'control' programs must be developed not only among the granting agencies, but also among the user groups. For ornamental and shade trees, a prime target is the decision makers in municipal governments.

Economics and socioeconomics are missing links in both the knowledge and thinking of many working to control insects. Extension services in Land Grant Universities may have individuals who could make significant contributions, but too often these specialists are ignored. In any case, FTE's in Extension are being reduced at University after University (a number of examples were given), and priority accorded to urban programs normally is substantially lower than that accorded programs directed toward traditional farm crops. Urban and suburban programs suffer disproportionate cuts as retrenchments become the operating norm confronting administrators. Turf battles may be fought over roles of 'researcher' and 'extension' faculty. Is it the responsibility of a researcher to stay with a program until it is tested in the field, and see it through to successful implementation? Or is it the job of research to make a handoff to extension as soon as possible and move on to new research? Common sense suggests that those with a vested interest in success of a program (that is, the 'researchers' who may best understand the biological and ecological aspects of a pest management system, at least in the early implementation stages) ought to be involved as long as possible. But artificial divisions between 'research' and 'extension', divisions that have historical roots, continue to exist in too many Universities.

Pesticides have a place in pest management programs. The market, however, seldom justifies the cost of registration in the eyes of manufacturers. IR-4 programs can undertake only so much of this kind of work; there is a void in making and keeping enough effective and appropriate materials available to be used as necessary in pest management programs. Resistance, whether it be detrimental when it is to pesticides or beneficial when it is genetically-based and exists in the plant against a pest insect, needs to be understood. Investigation of the extent of resistance, across specific pesticides or classes of insecticides, or across taxonomic groups of hosts, is costly and time-consuming research, but an avenue that just might provide critical insights necessary to maintenance or improve management programs.

Injury thresholds must be established; these will be different if the plant is located in an urban forest, a recreational forest, or is still in a nursery. Plants in a nursery are potential carriers of pests as they are shipped; tolerance of pests will be much lower than for the same pest in a recreational forest. Exotic pests are being introduced and becoming established with increasing frequency; quarantine programs and procedures, and subsequent eradication programs when quarantine fails, become vital issues.
Public awareness too often manifests itself only after pest populations have increased to the point that they are 'a problem'. Almost inevitably the cry goes up for a quick fix, an instant solution. Limited resources, both monetary and personnel, are diverted to development or implementation of temporary palliatives. At the same time, public opposition to the use of chemical pesticides and concern about personal or environmental contamination complicate programs that may be either necessary on an emergency basis or desirable as a part of carefully structured long term management programs.

There is money to be made in selling services to homeowners, to municipalities, and to other political units. Ethics of practitioners and professionals worthy of the name must be of the highest order, or the good and the bad will be tarred with the same broad brush. There is no consistent and convincing evidence, for example, that parasitoids will control the gypsy moth, yet they are being prominently featured in programs advertised to user groups. There is a fine line between reading the fine print and recognizing that, at least technically, the advertising is not dishonest, and receiving a quick impression that solutions are just a matter of getting enough beneficial insects into the environment. Opportunities for charlatans to make a quick buck and move on abound. We cannot afford to tolerate them under any circumstances. They are a threat not only to the honest and scrupulous practitioners but also to all of us.

Among the needs, that of education overshadowed all others. Over and over again, it was apparent that the general public - and at times even some of us professionals - lack appreciation of the complexities of managing insects, the constraints imposed in urban and suburban situations, the alternatives which are or may become available, and the minor and major differences between forested and non-forested sites and the consequences these have on biology, behavior, ecology, economics, and socioeconomics of insects that may become pests in ornamental and shade tree situations. That not all insects cause injury and are, de facto, a problem must be communicated over and over again. That biological alternatives to the use of chemical insecticides can be successful, and are environmentally compatible, is the kind of message that the public wants to hear and needs to hear in these times of concern for despoliation of our surroundings. Indeed, their receptivity is probably enhanced as a consequence of high profile area-wide aerial pesticide spraying programs that have been used to reduce or to attempt to eradicate some pests. That alternative controls take time to develop and implement, and are not quick and easy solutions, but may be sustainable indefinitely at relatively low cost once established, are equally critical parts of the message that must be communicated.

Target audiences for educational programs run the gamut. Individual homeowners need to be aware of available options, tree maintenance professionals must progress with the times and recognize that the goal of pest management programs is not to put them out of business but rather to change the way they are doing business. City managers and their staffs must learn to appreciate the complexities of programs, and know that the old ways of simply responding reactively to emergency situations are giving way to proactive prevention programs. Professional entomologists, as well as tree care professionals must maintain currency and awareness. One excellent vehicle for such professional maintenance is through certification programs such as the American Registry of Professional Entomologists, a unit of the Entomological Society of America; the International Society of Arboriculture is also developing continuing education and certification programs targeted at practitioners. Not only is technical updating important, but also the continuing appreciation of and demand for adherence to a code of ethics are essential elements of such programs. Consumers and practitioners alike must be educated to the values of certification in pest management specialties in the same way that they have learned, through public education programs, of the value of Board or Bar examinations for physicians and lawyers. Governments, especially at the state level, increasingly are demanding proof of competence. We will be much further ahead if we, the experts, take the lead in developing, maintaining, and enforcing standards through rigorous certification and update training programs than if we abdicate this activity to government bureaucrats.

Injury thresholds have been included as an issue; there is a need to define and establish these for each insect and within the context that the insect is present - a formidable task! This need requires active and expert involvement of specialists from other disciplines. Thresholds will change with time and location based on the economics of the situation if nothing else.

Alternative controls for many insects must be investigated. In some cases, alternatives may involve mechanical activities such as simple sanitation which can eliminate breeding locations for pest populations, appropriately-timed shearing activities to destroy pest habitats at critical stages of development, or the application of traditional silvicultural techniques such as reduction of basal area on a site to improve tree health on heavily forested properties. Conservation, augmentation, or introduction of biological agents such as parasites, predators, and/or pathogenic organisms have potential as integral components of management programs, especially for exotic pests.

If exotic insects become problems, it helps to understand the biology and ecology of regulatory factors in the native home of the pest - if regulation exists. Of at least equal importance is the monitoring and documentation of introduced biotic agents so biological control successes can be reported and publicized. Even more basic is the need to understand the subtle or substantial differences in population dynamics that may arise from moving insects from the forest to an ornamental landscape; knowledge of biology and ecology in the urban environment is important. For example, an increase of 3-4^{o}C in temperature on heated structures in an urban landscape over the normal temperatures experienced in a yard or a park have been shown to enhance overwinter survival of the mimosa webworm. Overwintering sites may be different in urban situations than in 'nature'. Knowledge of these subtle but important factors might suggest management practices such as planting trees at some minimum distance from buildings to minimize the likelihood of either a warmer natural habitat or of the insect moving to a more favorable location which would enhance the likelihood of survival in the face of adverse environmental conditions.

We need continuing research, frequently repeated but not necessarily duplicated at a number of different sites, to enable us to understand variation in biology and behavior of pests. Research costs money. Before we can make progress in research, and in any case to allow maintenance of management programs, suitable sampling methodology must be developed. Samples may be taken purely for research, or they may form the basis of monitoring. Monitoring must become recognized as a component of a program, one which entails costs that are worth incurring whether or not treatments of one kind or another follow. Indeed, substantial payoff is likely when decisions not to treat are taken based on monitoring activity. Monitoring will not be directed only to the pest, but also to the complex of natural enemies that may be present, and also to observed damage. The data gathered should be useful for predictive purposes as well.

Short term solutions will always be required for emergency situations, exotic pests invading new areas, or other special situations. Availability of appropriate alternatives among registered insecticides is critical to both short term and long term programs. Formulation and application technology of pesticides must be improved. For example, systemic materials, especially injectable ones, which can be targeted to precise locations within an individual tree may be key components to solution of problems where substantial values are associated with individual trees that are critical to a landscape design, have historical or botanical significance, or that have other tangible or intangible attributes.

Recognition of resistance which occurs naturally in individual plants could facilitate program success. Paine noted that eucalyptus trees with excessive kino have greater resistance to the introduced eucalyptus longhorned borer, yet these trees were being removed routinely because they were considered to be less aesthetically pleasing than trees not showing evidence of gum. Practitioners must be educated to recognize such situations.

Programs must have tactics which evolve with changing conditions. Ravlin cited an example from gypsy moth when he noted that pheromone-baited traps are vital for survey and detection as the insect invades new geographic areas, but are not working at all once an area is generally infested. They cannot be used to identify areas where egg mass surveys should be conducted but rather at best indicate broadly where populations appear to be increasing or decreasing. And it doesn't take the costs of deployment and monitoring of traps to provide that information.

The program known as 'America The Beautiful' envisions the planting of one billion trees per year - as a start. The needs for maintenance and pest management for this increment to existing trees alone poses tremendous challenges and opportunities if the investment is to pay dividends over time.

All of the knowledge available and educational programs that may be developed have limited value unless they can be combined into working programs and conveyed to solve contemporary problems. Technology transfer becomes vitally important. Elements of importance include aids to decision-making, self-help teaching modules, identification and/or provision of computer hardware and software, and access to needed data bases. All of these are essential if research and technical advances are to be brought on line and into the marketplace. Extension service personnel both at Universities and in the counties, advisors and managers associated with governmental agencies at all levels, commercial tree care organizations, and private consultants all must have access to the latest information, and know what to do with it once they have it. Changing technology to fit changing needs must be available at different stages of an insect gradation in an area, and as the status of a pest changes with time. Systems to guide the identification of priority areas for treatment, for protection, or for monitoring are needed to facilitate maximum return on the investment of always limited available funds. Decision-making must be moved from heavy reliance on politics to heavy reliance on science. Prototype systems are available now and are being refined for a few high profile pests; much more needs to be done for other major pests as well as the almost endless number of minor ones.

Professionals who undertake the challenges of developing management systems for pests of ornamentals and shade trees need time, interest, and dedication. The results may be rewarding and personally satisfying, but the road to success is fraught with frustrations, delays, funding crises, and temporary setbacks.

Recommendations to address issues and needs identified are much harder to develop. A group representing a much broader set of constituencies than was in Denver needs to reconsider the issues and needs, and then tackle difficult questions such as: To whom should recommendations be directed? (For example, should efforts be concentrated on federal decision-makers in agencies? on federal politicians and their staffs? at the state level? or on other targets?) Who should attempt to generate support for what segments of which programs? (Political lobbying is anathema to many individuals; in any case, there are often rigid proscriptions against such activity by employees of taxpayer-supported institutions. Private enterprise may well be accused of lobbying for personal advantage and gain. Tax-exempt charitable, educational and scientific organizations can devote only limited resources, both by law and frequently by member demand, to attempting to influence political decisions.)

Regardless of what is done, decision-makers and influential persons must be the target of educational programs. There are roles here for everyone from Cooperative Extension Service to Farm Advisors to County Agents to research scientists to professional pest managers and anyone else with an interest in solving problems. 'Biocontrol specialist' is a new category of job description appearing at the County and local levels of environmentally aware communities. Implementing training and support systems for these employees will increase the likelihood of their success as they move into unexplored or poorly understood territory.

Development of cooperative programs is facilitated by the long-term development of personal relationships with key people, from the homeowner to the local expert to the decision-makers to the research and technology transfer specialists. Ideally users are involved from the outset of program development. Not only do they build a feeling of ownership in developing programs, but also they can point out practical pitfalls based on their own experience, experience that a contributor more distant from day to day application might overlook. Late awareness of potential problems is a great liability to the success of the ultimate product.

Computer age decision-making tools must be available to all who need them, either on the desks of people such as county extension personnel or easily accessible to individual users. Tapping in to linkable data bases, such as nursery inspection records to gain early warning of potential problems, 911 systems with all of their wealth of information, much of it site-specific, or tree maps for cities which contain detailed records on the species, age, care, and problems associated with individual trees, must become routine. Expert system shells are coming on line; the shells are not very useful, however, until they are used. Training in computer-assisted decision-making is necessary. The liability of high turnover in many county level positions is offset by the benefit that most young employees have had far more exposure to computers, and may hold far less awe or fear of computers, than those older ones whom they replace.

Lower political units, and the individual homeowner, must recognize that they need to pick up more and more of the operating costs of information networks. Knowledge and information becomes power when used; there is a financial cost to acquisition of power that users must be willing to pay. Prioritization of needs will assist in maximizing return on investment of limited resources.

Increasingly, government agencies are wresting authority to legislate conditions under which we, as professionals, can earn a livelihood. It is vital that we not abrogate responsibility for writing laws to politicians and lawyers; they simply do not have the knowledge or insights to write responsible legislation in the vacuum which we create if we are not involved. We must reassert control of the political and legal system as it relates to our professional competence. Similarly, professionals must support mechanisms to vest advising only in those competent to do so. Garden center employees, extension personnel, pesticide salesmen, members of horticulture departments and, yes, entomology departments - all who give advice to the public - must be certified if professionalism is to be upgraded. Certification of biological control expertise and pest management expertise is as easy (or difficult!) to do as it is for chemical pesticide expertise.

There is much to be done. A summary of issues, needs, and possible approaches to meeting the identified needs has been presented. But this is only the beginning. If life in the 21st Century is to benefit to the fullest from what is available with a decade to go in the 20th Century, let alone the knowledge and technology which continue to explode about us every year, significant changes and new initiatives are necessary to harness and exploit opportunities which exist. That is the challenge we face in an expanding arena that we are just beginning to recognize for what it is - an integral component of the good life to which we all aspire.

ELM LEAF BEETLE BIOLOGICAL CONTROL AND MANAGEMENT IN NORTHERN CALIFORNIA

D. L. Dahlsten[a]

The elm beetle, *Xanthogaleruca luteola* (ELB), causes severe damage to many of northern California's English and Siberian elms. Our research program is developing a management system for this introduced pest based on long-term population monitoring for decision-making, and environmentally sound control methods.

From 1985 to 1990 we have sampled English and Siberian elms with ELB populations in 18 locations from the northeast to the central coast of California. Population monitoring has indicated that each ELB generation (2-3 per season) varies unpredictably in its potential for causing foliage damage. Each generation must be sampled, and decisions made for control measures most suitable for that generation. From the data base, we have developed a sampling system in which heat accumulation above 11° C at ELB sites, measured in degree-days, indicates when to sample and, if necessary, when to treat. Sampling elm branch tips for the presence of ELB eggs during the limited time when egg laying is near its peak provides a cost effective means of predicting foliage damage, and thus of deciding whether control actions are necessary.

Several control options have been tested. Banding trunks with Carbaryl kills migrating larvae without disrupting natural enemies, but only reaches a portion of the larvae. B.t. (M-one, Mycogen Corp. strain of *Bacillus thuringiensis*), is being tested as a foliar spray and has potential for reducing numbers of small larvae before they cause significant damage. A number of strains of the egg parasitoid, *Tetrastichus gallerucae*, have been released and at least one strain has survived over winter and reduced the ELB population at one site. When the number of these parasitoids has increased sufficiently, either through same season releases or from overwintering survival, they have exerted substantial control, especially on late season ELB populations.

PROBLEMS OF INTRODUCED PESTS

T. D. Paine[b]

Phytophagous insects introduced into new environments without their natural enemies may develop large and very noticeable populations. Whether they are pests depends, in part, on the location and use of the host plant. Insect damage to ornamental and shade trees is perceived differently than damage to the same tree species in forest or unmanaged systems. The primary reasons may be the use and visibility of the plants. Trees planted in the landscape, or pre-existing trees incorporated into the landscape as urban development continues to expand into forests, are often focal points and subject to a great deal of attention. In addition, the trees are major contributors to the quality of life in those urban areas. Consequently, the perceived thresholds for injury may be very different for ornamental trees in landscapes compared to the same trees not in ornamental settings.

Not only is type of use for a tree critical to determining whether insect feeding is above an injury threshold, the type and the potential risk to the plant are also important. These factors would seem to be relatively simple to evaluate from a biological perspective of reduced photosynthetic area or reduced seed production, but from a social perspective, the problem of thresholds to landscape trees becomes very complex. Highly visible insect activity or damage, regardless of the actual impact of the plant, can become an overriding concern.

Development of an appropriate pest management program for introduced insects depends, in part, on the perception of injury. The use of pesticides may be warranted to reduce real damage, but there are increased exposure risks to the general public if pesticides are improperly applied to landscape plants. In many cases, maintaining the plant in a vigorous growing condition can increase plant resistance or improve the ability of the plant to compensate for injury. Introduction of natural enemies to reestablish biological control if often ideally suited to the urban landscape, particularly if insecticide use on shade trees can be kept to a minimum. However, one of the greatest opportunities for impact but also one of the most difficult to implement successfully, is public education. A public aware of the insect communities and the difference between aesthetic damage and actual risk to the tree should be able to make informed decisions among available pest management options.

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EFFECTIVE TECHNOLOGY TRANSFER AND CONTINUING EDUCATION

Moderators: Nancy J. Campbell[1] and John A. Witter[2]

Panelists: Dennis Neill[a], Jim VanDenburg[b], Robert N. Coulson[c], John A. Witter, Nancy J. Campbell, Julie Weatherby[d]

DEDICATION: To Gary A. Simmons who was devoted to his students, research, and teaching.

The focus of this workshop was the future, and how we as pest management specialists, researchers, teachers, and forest managers can cooperate in developing and implementing technology. Several new ideas/concepts were discussed such as developing a national repository of film on insect and disease identification, ecology, and management. Three case histories of successful technology transfer programs were also presented. The production and use of videos was a recurring theme of the workshop. Several additional topics that were mentioned frequently were: 1) Developing a feedback loop, 2) Involving the target audience from the beginning of the project, and 3) Providing a recommendation system in pest management computer applications. A novel approach to transferring information was used during the workshop. Two of the panelists transferred their information to the audience via a skit. The idea was to demonstrate that there are many ways to transfer technology and that we need to be more creative in our approaches if we want to involve or capture our audience's attention.

SUMMARY OF PRESENTATIONS

Our first speaker, Dennis Neill, discussed technology transfer strategies that are used successfully by marketing experts. He defined marketing as the process of determining what it is your organization is best suited to producing; determining who it is that most wants or needs those goods or services; and finding the most effective means of linking the two. The history of marketing strategies has moved us away from mass marketing, to product differentiation and, finally, we are now moving more towards target marketing. Target marketing is the decision to analyze and separate the different groups making up a market and then offer a range of goods and services focused on each segment of the market. Target marketing corresponds to a carefully aimed rifle shot. Target marketing can save time and money. However, considerable waste of dollars often occurs when "trinkets" (videos, bulletins) are produced for the sake of creativity and not to meet a specific objective.

The main message of the presentation was to know who your audience is. Next, ask yourself: 1) WHAT do they know? 2) WHO gives them orders, inspires them? 3) HOW do they learn? 4) HOW will this new technology make their lives easier? 5) WHAT does your audience think of all this (did they ask for this in the first place)? 6) WHEN is the best time to transfer the technology (morning, night)? 7) WHERE is the best place? and 8) WHY are you doing this, (the objective)? Any technology transfer program should be well thought out in advance and the objective of the program should never be lost in the production of the technology or "trinket".

The next presentation focused on cooperation between research, pest management, and forest managers. Jim VanDenburg discussed how "New Perspectives" will place even a greater emphasis on this continued cooperation. Since the late 1960s, the Flathead National Forest in Region 1 has experienced two severe insect epidemics from two bark beetles that has resulted in around 550 MMBF being removed through clearcut, seed tree, and shelterwood harvesting. Most of the response to managing insects during this time period was re-active versus pro-active. Enter the 1990s with the greater emphasis on forest health and "New Perspectives". The objectives for managing a forest are multi-faceted and can consist of timber, wildlife, and recreation concerns. In many cases this means leaving snags behind, building fewer roads, longer rotations, and less intensive management. This also translates into taking a more pro-active approach to silviculture and building stronger links between forest pest management, research, and silviculture.

The next presentation examined technology transfer and implementation of computer based applications for IPM. Bob Coulson presented a case history on the transfer

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and implementation of the southern pine beetle computer based application. The first effort directed the development and implementation of SPBDSS (Southern Pine Beetle Decision Support System). The developers concluded that the project was not successful because: 1) Developers, managers and users were not included in the planning process, 2) Qualitative information was not considered and essential management guidelines were lacking, and 3) Computer technology was not advanced far enough to accommodate important user-specified facilities. SPBDSS was replaced by ISPBEX (Southern Pine Beetle Integrated Expert System) a knowledge-based task-oriented system. ISPBEX was more readily used because it provided both qualitative and quantitative information, and it was developed in close cooperation with the users. Cooperation was also stressed as an essential ingredient for successful technology transfer and implementation.

John Witter and Nancy Campbell developed and acted in a skit that was designed to show that there are many ways to transfer information. The theme of the skit was the production and use of videos. The main message of the skit was cooperation; cooperation not only between researchers and pest management in one region, but cooperation between regions. The production of videos should involve people from different regions that have different perspectives and expertise and just as importantly, different footage. Footage can come not only from these more traditional sources, but local television stations are often a good source. Over the next 25 years, the demand for and use of videos will greatly increase in natural resource education.

The next presentation examined a case study of effective technology transfer, the Southwide Coneworm Survey. Julie Weatherby discussed the importance of involving users right from the beginning of the program. Again, it was pointed out that users did not want just a lot of information, but quantitative information and management guidelines as well. Developing a user friendly system was also important in a successful technology transfer program. A user friendly system is one that requires minimal training, limited time commitment and little expense.

The final presentation was based on the case history of the Forest Pest Management Technology Transfer Program in Michigan. The program was a cooperative effort between Michigan's universities, the Michigan Department of Natural Resources and the USDA Forest Service and was, in part, initiated by Gary Simmons and John Witter during the 1970s. John Witter discussed 15 items that were extremely important in the Michigan Technology Transfer Program. These included: 1) Determining your target audience, 2) Involving them at the beginning of your program, 3) Developing a feedback loop, 4) Understanding the various institutional forces and constraints within which the program operates, 5) Establishing a small advisory committee of users to oversee project activities, 6) Ideas and practices will be adopted and implemented at different rates; learn who the early adopters are and work with them, 7) Use of the multi-media works well in technology transfer programs, 8) The media used to transfer specific information to user groups should be determined by the size of the audience, and the message being transferred, 9) Information being transferred must be very concise and easy to understand, 10) Intended audience should be known before developing a technology since a common problem is needing more than one technology transfer item because there is more than one audience, 11) Feedback from users is essential and must occur at each step of the program, 12) Packaging the material properly is as important as what you say, 13) In preparing written material for lay people, the text of brochures must be written to engage people, 14) Videotapes are extremely effective in technology transfer programs, and 15) Process and product evaluations must be conducted because it helps you determine what works and what does not work.

RECOMMENDATIONS

1) Create a national repository of film on insect and disease identification, ecology, and management. This would allow several regions to come together and produce videos.

2) At regional and national workshops, plan a session on the development of social skills such as verbal communication.

3) Initiate more joint projects between Forest Pest Management, research, and states. Cooperate at all levels of the project and involve the forests from the beginning. Provide the resource managers with research results as early as possible (don't wait until the results are published).

4) Involve local talent when developing videos or other public relations projects. Often local television or radio personnel are eager to work with us and are often more qualified to do certain jobs such as narrate a video.

5) Continue to strive to make pest management computer applications more user friendly.

6) Know who your target audience is!

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BARRIERS TO INNOVATION IN FOREST INSECT RESEARCH AND MANAGEMENT

Moderator: Donald L. Dahlsten[1]

The objective of this workshop was to look at barriers to innovation in research and pest management. The approach used was to focus on the experiences of individuals from different institutions. It was hoped that a discussion of past barriers would lead to recommendations for the future. The speakers ranged from administrators to researchers and pest managers with both national and international institutions. The six different perspectives presented were as follows: 1) University entomology department head (T. Payne); 2) Univeristy forestry division director (J. Coster); 3) Researcher at an international institute (N. Mills); 4) Researcher and pest manager with the U.S. Forest Service (K. Sheehan); 5) Researcher with a University entomology department (A. Cameron); and 6) Researcher with Forestry Canada (J. Volney).

A number of barriers were discussed during the course of this workshop. The desire for immediate results by industry and granting agencies was identified as one. The current push towards biotechnology was another, not only because of funding, but, at the institutional level, many positions are being filled by biotechnologists rather than forest entomologists or forest pest managers.

Environmental concerns and local and federal regulations often require new pest management practices, but the problems are immediate and there is not the desire to invest the time necessary to develop those practices. The fire-fighting mentality still exists, and this is a major barrier to innovation.

The development of research teams was discussed and one problem identified with this approach is that members of the team do not really understand the other fields represented in the team, because their background is not broad enough. Departmental requirements at the university level could detract from the development of interdisciplinary work in the student's future. Some participants felt that scientists were not bothered by this and would interact on their own. In some cases, departments are reducing the number of required courses for a degree so that classes from other departments can be accepted. However, if this goes too far, there will be no need for departments, and it was felt that this would be detrimental, because students and faculty need a "home." When discussing the issue of scientific teams, it was noted that leadership in a team comes more from a person with a scientific perspective than an administrative one.

Other barriers identified were personal and organizational factors such as the lack of motivation and the need to hire motivated and innovative workers; the climate of the organization should be supportive; informal leadership is needed to promote innovation; clear standards must be set but they must be attainable; and both verbal praise and, if possible, monetary compensation are very important. Also, an organization should allow for some risk in research. Administration should provide good support staff and should try to alleviate rules for purchasing, staffing, and other red tape, particularly for new faculty or researchers. The goal should be to satisfy the basic needs of the researcher.

Barriers in international work may be quite different from those at the national level. A major factor is disparity in funding, as there is extensive support for international work and fewer constraints on spending. This provides for more opportunity, but sometimes the funding is driven more by political than biological needs. Involvement internationally does not necessarily take a lot away from the university. Also, international work tends to give one a better perspective on forestry as a whole. Some of the pitfalls associated with international work are the separation of faculty from their students, development of programs where work is never completed, political instability in some countries, and the lack of credit for international work for those in tenure track positions.

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Some barriers encountered in the Forest Service were identified, but it was emphasized that they did not apply throughout the Forest Service, nor were they necessarily unique to the Forest Service. It was pointed out that not all barriers are bad.

Group laboratories were discussed as a means of getting around the funding crisis and the need for expensive equipment. However, this approach requires creative leadership, because it is often difficult for a new person to break into the group. There are turf problems, too, as the researcher with the most money often takes over the lab. Problems with shared computers has lessened somewhat with the widespread availability of personal computers.

A university entomology faculty member argued that researchers should concentrate on the challenges and not the barriers. One barrier, however, is that research priorities are being dictated by granting agencies which are politically directed. It was stated that one must get congressional attention to get funding. Funding is often for short-term projects and annual review of the projects is used to cut off funds, if necessary. This causes more work for the researcher. Often, those projects that are funded are for a shorter time and for 60 to 70% of asking level, yet the researchers must produce the same product.

Funding at state levels has been reduced, as have McIntire-Stennis funds. The response of deans to these reductions varies from university to university, but often the researcher is hurt the most. It was felt that in many cases internal support is lacking and that the individual researcher has to hustle money, go to meetings, hire personnel, etc. These activities take away from time that could be used to actually do the research.

The primary issue that was identified many times during the session was inadequate funding. Not filling positions and then turning these dollars into support dollars has not worked. Faculty simply have to spend too much time trying to get support, and this takes away from their primary purposes of teaching, research, and public service. Canada has tried to solve the problem by providing operating grants. New faculty can apply for three-year grants which serve as a base which faculty can use to start getting students, etc. Progress is evaluated and the dollars can be extended as well as increased. This povides some security and gives the new faculty member more time to spend on planning and doing the research.

The situation in Canada is much the same as elsewhere, because dollars for research have been reduced. Pest management must compete with all the other forest research disciplines. In Canada, applied research is pushed at the expense of basic research. University, Forest Service research, and Forest Service forest pest management research work against each other when they complain that each is not doing their job, and this occurs more frequently as dollars become scarce.

Research and pest management must be sold to the forester, and researchers do a poor job of telling their clients what they can do for them. All organizations must cooperate to form a long-term plan for pest research. Administrators should allow this interaction to occur.

VIEWS OF A UNIVERSITY RESEARCHER

E. Alan Cameron[a]

Rather than focusing on barriers, let's think of challenges and opportunities. Among our most critical challenges is the need to restore our ability to determine research priorities. All too often, University researchers merely respond to priorities established by granting agencies, which are, in turn, responsive to political and lobbying pressures. Considered decisions, based on the needs of the science, are incidental to funding decisions; micromanagement by bureaucrats is too pervasive. We are being actively encouraged by Congressional Staffers to enter the political system and lobby. Even after decades in the profession, I retain an idealism that has difficulty accepting such behavior. Every moment spent in such activity is at the expense of doing what we are trained and equipped to do - namely, forest pest management research.

Funding is appropriated for the short term, often with annual renewals (and burdensome reporting requirements accompanied by preparation of renewal proposals), and seldom with more than three years' funding allocated. "Hot" areas receive disproportionate funding. The solid, long-term, baseline studies necessary in a crop that has a rotation period of decades, or perhaps more than a century, are rarely considered for more than token support, if that. Funding from individual states is diminishing, which puts increasing pressure on federal funding sources. Hatch and McIntyre-Stennis monies in Agricultural Experiment Stations too often are siphoned off by administrators and do not make their way to researchers to support program activity - e.g., hiring help, travel. Little or no base funding is available to hire permanent technical support; programs rely on transient graduate students and post-doctoral students. Continuity is difficult to establish.

An American counterpart to the Natural Sciences and Engineering Research Council of Canada (NSERC) program, whereby operating grants are awarded competitively to young researchers for three-year periods, and renewed for increasingly higher amounts subject to demonstrated productivity, contribution and accomplishment during a career, would be a significant improvement in our funding approach. This would provide the base upon which significant programs would be built, and it would help to establish the necessary continuity of support funding and personnel over time that is required for continuing programs. Researcher time would be shifted from paperwork to science, and productivity would be expected to increase substantially. The opportunity is there; it will take time and political action to bring it into being.

VIEWPOINT FROM A FORESTRY SCHOOL

Jack E. Coster[b]

From the range of factors that can prevent innovation and creativity in research and teaching organizations, I will limit remarks to Personal and Organizational factors.

Psychologists recognize individuals who might be called "achievers". Achievement, or the need to achieve, is a distinct human motive with environmental origins. Maslow's "Hierarchy of Needs" is a useful theory for understanding personal and organizational achievement behavior. The theory classes needs from basic ones of safety and hygiene, to belonging, to ego and status needs, to self-actualization. Lower needs must be satisfied before an individual seeks a higher level of need satisfaction. Creative and innovative needs are in the highest, self-actualization level of need satisfaction behavior.

Organizations, or even units within organizations, have a climate for tolerance to creativity, inspiration, and innovation. A determining factor in the nature of a unit's climate for creativity is the leadership style of the unit head. How structured (formal-informal) is the leader's style of communications? How are standards set (are they high, but attainable?)? Is praise and recognition appropriately given? Is moderate risk encouraged? Is personal and organizational conflict appropriately tolerated? Are the innovators championed and supported?

Are we (deans, heads, major professors) barriers to creativity? Is our style of leadership and interpersonal behavior a factor in preventing or reducing creativity in our shops?

VIEW OF A RESEARCHER IN AN INTERNATIONAL INSTITUTE

N. J. Mills[c]

From an international perspective, there are four major factors that could constitute barriers for innovation in forest protection. These concern the primary direction or focus of forestry internationally, the knowledge base from which we all work, the extent of international collaboration, and the sources of funding.

From the international perspective, the focus of forestry is on silviculture to the virtual exclusion of forest protection. The widespread replacement of natural forests with highly productive exotics is also resulting in the permanent destruction of the unknown biodiversity of local faunas, representing incalculable losses to scientific innovation in the future. A further constraint is our ability to organize and utilize the overwhelming knowledge base. This emphasizes the need for collaboration both at the national and international levels as well as between disciplines to broaden both the capabilities and the perspective of a research programme. Finally, there is considerable disparity in the extent of funding support for national and international projects. The former are subject to competitive and rigorous peer review for a resultant moderate support. In contrast, the latter are often based on perceived competence and political convenience rather than innovative potential and, yet, result in substantial support.

AN ENTOMOLOGY DEPARTMENT ADMINISTRATOR'S PERSPECTIVE ON BARRIERS TO INNOVATION IN FOREST INSECT RESEARCH AND MANAGEMENT

T. L. Payne[d]

Barriers to innovative forest insect research and management can be seen as stemming from the three broad areas of economics, emphasis, and regulations. The three are not unrelated. Economic climate drives the interests of the timber industry. Because of prices, supply and narrow profit margins, in the absence of certainty that an insect pest problem is eminent, most decision makers in timber management are less supportive of forest insect pest research and associated management efforts. Furthermore, increased emphasis on the business end of things has resulted in all but the elimination of attention to forest protection in the curricula of our colleges and universities. Emphasis on new areas of interest such as biotechnology and global environmental change results in less attention to forest entomology; the resulting impact to our science is two-fold. One, new positions are not being created in forest entomology research, and two, vacated forest entomology positions are generally being directed to the new areas of emphasis. Added to this are the constraints placed on timber managers to deal with environmental regulations and the presence of endangered species. Regardless of the obvious need for research, coupled together, all of these factors tend to draw attention away from research and more toward immediate solutions, more toward a firefighting mentality and approach. Funds for research and management generally are focused on a big bug; there is always urgency, leaving no time to follow promising leads with sufficient replication to judge significance. All too often the rule is take your best shot based on what you have so far. I have little confidence that the situation will change in the near future. Optimistically, we can hope for economic prosperity and a common understanding of the importance of our forests and need for sustained investments in research in forest entomology to the future of those forests.

VIEW OF A U.S. FOREST SERVICE RESEARCHER AND PEST MANAGER

Katharine A. Sheehan[e]

Rolling Stone Syndrome - Often key USDA Forest Service (FS) people move before the results of a project can be evaluated.

Catch-22 Syndrome - Often when we have the funds available to hire someone or do a project, we do not have the authority...and vice versa.

Big Bug Syndrome - Priority funding of "flashy" topics appears to make it tough to find support for less flashy ones.

The-only-good-high-tech-is-my-high-tech Syndrome - Computer-related examples of this syndrome abound: prohibiting the purchase of certain PCs, etc.

This-is-my-turf Syndrome - A fuzzy boundary between Forest Pest Management and Forest Insect and Disease Research sometimes leads to professional jealousy and turf protection.

Image is Everything - Arbitrary limits (not related to funding or other work) are sometimes placed on the number of FS attendees at national meetings.

Crisis Management Syndrome - We tend to focus on short-term treatments that deal with symptoms rather than long-term solutions that address the underlying problems.

Bureau of the Bureaucracy - There is little flexibility to move FS funds from one budget category to another to respond to changing situations.

But we have-always-done-it-this-way Syndrome - There is much resistance to change, and risk-taking is often avoided because of a fear of failure.

Anyone-can-be-an-administrator Syndrome - People with good research or pest management skills are often assumed to be good candidates for administrative positions.

Caveats: These barriers are not totally negative, are not present everywhere within the FS, and often apply to any large organization.

PERSPECTIVE OF A RESEARCH SCIENTIST IN FORESTRY CANADA

W. Jan A. Volney[f]

The obvious barrier, which may be categorized as a lack of adequate funding and resources, may be a result of both research and client agencies being inadequately informed of the benefits to be derived from a specific innovation. This problem can be overcome by demonstrating the benefits and costs of alternatives, relying on sound information on impacts, and projections of pest damage. Lesser obstacles include the institutional culture which resists changes in operations because of unfamiliarity with pest management procedures or a perception that the problems can be solved by other management techniques. There is considerable work to be done in familiarizing decision makers and forest managers (through professional development courses, extension work, and post-secondary programs) on the opportunities to be derived from instituting novel pest management procedures in their operations. In transferring technologies to client agencies much of this resistance to instituting innovations may be eliminated if the personnel of the target agency are involved in the project from its inception and genuinely feel that they are part owners of the new technology. Finally, it is wise to elicit the support of the administrative, financial, and support staff of all agencies involved when significant changes are to be made in operations of the agencies. This will facilitate a clear understanding of the reasons for the change and the opportunities to be derived from the innovation.

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ECONOMICS OF FOREST PEST IMPACTS

Moderator: J.E. de Steiguer[1]

INTRODUCTION

I was delighted when the organizers of the North American Forest Insect Work Conference contacted me about planning a session on the economic impacts of forest pests. It is a subject with a long history in the forestry literature, and one with which I have been involved for a number of years. During our two-hour workshop, the attendance remained at about 30 persons. Very good for a last-morning-of-the-conference technical session. The first order of business was for everyone in the session to introduce themselves telling who they were, where they worked and what their interests were. I was pleased to note that virtually all in the room were either entomologists or forest managers -- practitioners with some apparent interest in the social science aspects of their professional activities.

Summary of the Papers

Each of the papers generated lively discussion, so much so in fact that I was usually forced to cut short the exchanges so we could move on to the next presenter. Tom Holmes, an economist with the U.S. Forest Service, discussed his work measuring the economic consequences of the immense mid-1980's southern pine beetle outbreak in the Four Notch Area of the Sam Houston National Forest in Texas. His work is especially important, because it provides one of the first market-level analyses of a major insect outbreak. Tom employed well-accepted concepts of welfare economics to calculate the economic loses to both timber growers and the subsequent gains by timber mill operators due to the vast level of timber salvaging activity.

Marv Stemeroff, a senior consultant with the Canadian firm of Deloitte and Touche, presented the results of two case studies in Canada dealing with the eastern and western spruce budworms. Mr. Stemeroff, through simulation modeling, calculated the benefits and costs of controlling various levels of budworm infestation and defoliation. The purpose of the study, as with so many pest impact assessments, was to assist government policy makers in prioritizing investments in pest suppression.

Doug Rideout, a forestry faculty member at Colorado State University made the drive from Ft. Collins to Denver to discuss some aspects of the economic theory of pest management. His discussion focused primarily on his work comparing the criterion of maximization of net present value to that of minimization of cost plus net value change. In many respects Rideout's paper represented the central theme of the session -- the need for a unified economic theory of forest pest management.

The paper by Chuck McKinney of Texas A&M University, like that of Tom Holmes, also examined the southern pine beetle outbreak in the Four Notch Area. Mr. McKinney discussed the friction and controversy which exists between the U.S. Forest Service and the environmental community concerning bark beetle management. He advanced the notion that resolution of future conflict can be resolved only through better communication among the conflicting parties. Some new tools for analysis of communication efforts were also suggested.

The Key Ideas

During the two-hour session, a few key ideas emerged from the discussions. First was the notion that the major impetus behind and support for pest economic impact studies has usually come from federal agencies in defense of their insect suppression programs. Embattled agencies often are required to turn to economists in order to demonstrate that their programs are cost/beneficial. And this seems to be the driving force

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behind pest damage studies. Of course, this is certainly not novel within the federal government; agencies continually are required to defend their programs on economic grounds. The point seems to be that the need for pest assessment stems more from policy needs than forest management needs.

Another idea which surfaced at the session was the need for a stronger foundation of economic theory to support pest impact assessments. We lack this better academic base probably for two reasons. First, because policy assessments are always needed very quickly, the analyst is rarely afforded time to develop a sound theoretical underpinning for these studies. Also, financial support for this sort of research is very low and quite erratic and, thus, provides little opportunity to establish a strong theoretical foundation. The lack of a better developed theoretical base is not, however, merely an academic matter. Such information would indeed allow an improved basis for defending those programs found to be worthwhile.

A final point that came from the session was the need for market-level analyses which provide some measure of economic welfare effects on human populations. The principles of economic welfare analysis have been understood and applied by most economists for decades, but forestry economists have been slow to follow suit. Many economic assessments of forest damage instead use methods more suited to the analysis of damage to a single forest stand. Price effects are not taken into consideration, and the damages calculated are usually measures of total revenue losses to timber growers (i.e., an invariant price X total wood volume lost) rather than changes in producer's and consumer's surplus. Past attempts to educate pest program managers on the nature of applied welfare analyses have not been very successful, however continued exposure to studies such as that of Holmes might serve the purpose.

I want to express my appreciation to each of the presenters. It is their work that accounted for the success of our session. My special thanks goes to each of them as well as to the organizers of the Work Conference. Following are the author's abstracts for the four presentations. In some instances, the authors have prepared full-length manuscripts of their work. Interested parties should contact the authors directly to see if reprints are available. (Note: Kenneth H. Knauer, USDA Forest Service, State & Private Forestry, also presented a paper entitled "The role of economics in Forest Pest Management program management," but did not provide an abstract for publication.)

TIMBER SUPPLY IMPACTS OF SOUTHERN PINE BEETLE OUTBREAKS

Thomas P. Holmes[a]

Southern pine beetle (*Dendroctonus frontalis*) epidemics periodically are responsible for catastrophic levels of mortality to southern yellow pine forests. Traditional forest damage appraisal techniques developed for site specific economic analysis are theoretically weak, because they do not consider aggregate impacts across ecosystems and related markets. The traditional model estimates losses only to producers with damaged forests, therefore, it provides misleading information from a distributional standpoint by ignoring impacts on producers with undamaged forests and timber consumers. An economic model of timber supply and demand is introduced and used to develop a new technique for estimating short-run market level impacts of catastrophic forest damages. The null hypothesis that catastrophic disruption of forest ecosystem production has no effect on timber markets is tested using intervention analysis and data on the recent Texas-Louisiana epidemic. Parameter estimates are used to compute short-run changes in economic welfare for producers on damaged forests, producers on undamaged forests, and timber consumers. Principal findings are: 1) changes in social welfare resulting from catastrophic damage to standing timber across forest ecosystems requires market-level analysis, and 2) the net change in economic welfare resulting from insect epidemics is unambiguously negative.

BENEFIT ASSESSMENT OF FOREST PEST MANAGEMENT IN CANADA

Marvin Stemeroff[b]

Benefit assessment of pest management strategies is relatively new in Canada. It utilizes a methodology which quantifies the net economic impacts associated with alternative forest pest management strategies. The result of such analyses are used primarily by policy makers for prioritizing forest management investments and regulating pest management practices, such as the use of pesticides. In the latter case, the benefits of pesticide use are compared to their associated risks within a "risk management" framework.

The basis unit of analysis for a benefit assessment is a "forest management unit", with the critical factor being the impact on long run sustainable timber supply. We begin by utilizing stand growth models to simulate how various forest stand types respond to alternative pest infestation/defoliation levels. From this we aggregate the stand level impacts to a forest with forest timber supply models. In both cases, the selected models are utilized by the respective provinces in their regular timber supply planning processes. In the end, we have a series of sustainable timber harvest levels associated with alternative pest control scenarios.

The costs and benefits associated with each harvest level are quantified using a net present value analysis. Results of two case studies were reported:

* Control of western spruce budworm in British Columbia, and

* Control of eastern spruce budworm in New Brunswick.

For western spruce budworm control, the net present value ranged from $18 to $62 million, with a benefit/cost ratio of between 2.6 and 5.22, using B.t. relative to no controls. For eastern spruce budworm control, the net present value ranged from $79 to $118 million, with a benefit/cost ratio of between 3.4 and 5.3, using B.t. or fenitrothion relative to no controls. In both cases, the wide range in results depended on the assumptions of annual increases in real timber values, extent of infestation, and the level of foliage protection offered with controls.

In response to annual harvest level reductions, the impact on jobs and value added in the economy were also measured. These impacts were estimated using the federal interprovincial input/output model.

CONSIDERATIONS OF THE ECONOMIC THEORY OF FOREST PEST MANAGEMENT

Douglas B. Rideout and Philip N. Omi[c]

The economic theory of forest pest management remains largely undeveloped. Hence, many key issues in the polity and management of forest insects remain unresolved or a matter of speculation. The current economic theory of forest insect management (least-cost-plus-loss) is based on an early forest fire management model developed by Sparhawk (1925). Unfortunately, the Sparhawk model offers little guidance to forest managers, because it does not focus on relevant management decision variables. Our work on the economics of forest fire management (Rideout and Omi 1990) suggests that much could be gained by developing the economics of forest insect management and practice. Such development should focus on the decision variables of most concern to forest managers, relate the theory to the practice, provide for technology transfer, and offer insight to those involved in forest policy considerations. There is potentially much to learn and apply about forest insect management from the fields of fire science and economics.

MEDIATING THE DISPUTE OVER SOUTHERN PINE BEETLE MANAGEMENT ON U.S. FOREST SERVICE LANDS IN TEXAS

Chuck McKinney[d]

If a husband attends to his wife who is sick in the manner that he would want to be treated when he is sick, she might end up in tears. Her needs are usually very different from his. As long as foresters manage natural resources, they are in effect married to environmentalists. Foresters and environmentalists often have very different needs and values, but usually treat each other as though they have the same needs and values. The result is conflict. Both the husband and foresters would benefit from improved communications with the spouse to avoid conflict and avert costly litigation.

A case study of the 1982-86 southern pine beetle epidemic in Texas yielded data on U.S. Forest Service beetle management policies. Some of these management policies were the subject of litigation against the Forest Service by environmentalist groups in Texas. An analysis of court documents revealed the source of the dispute to be objectives, means, and underlying values of the disputants, not technological issues. Communication failures were the primary cause of the conflict.

Research is currently underway that hopes to provide better understanding of the objectives, means, and underlying values of the disputants. Tools typically unfamiliar to foresters are being utilized: ethnography, rhetorical analysis, topoi analysis, stasis analysis, cosmogony studies, etc. The goal is to produce productive communication between foresters and environmentalists (and the public) and generally mitigate the conflict.

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ARTHROPOD PEST ISSUES IN AGROFORESTRY

Moderator: Mary Ellen Dix[1]

In many parts of the world, farmers traditionally have practiced agroforestry. This is especially true in developing countries where farmers practice subsistence agriculture. These farmers traditionally have been keen observers of nature and have designed agricultural systems that mimic natural ecosystems and include trees. The diversity of these systems enables the farmers to survive periods of adverse environmental conditions, minimize impacts of pest damage, and stabilize their income (Olkowski and Zhang 1987). In developed countries, most modern farmers do not practice agroforestry; instead they are interested only in maximizing their economic gain. They have converted thousands of acres of forests, marginal land, and other natural ecosystems to cropland or tree plantations planted with one crop. In the process, they have destroyed the ecological and economic diversity of their operations, and may not have the flexibility to survive adverse environmental conditions.

Recent publicity about widespread erosion, drought, climate change, environmental pollution, and the population explosion has increased awareness in both modern farmers and conservationists of the fragility of the agricultural ecosystem, the decreased diversity in these ecosystems and the farmer's vulnerability to economic disaster. Therefore, interest in agroforestry has increased in North America, and agroforestry is being promoted as a solution or cure for many environmental, economic, and social problems currently associated with agriculture.

Arthropods, both beneficial and harmful, are a major component of all of these ecosystems. Management of both tree and crop pests as well as their natural enemies is a key component of an effective agroforestry system. This paper briefly describes North American agroforestry systems, identifies current and future arthropod pest issues and management concerns, and recommends needed action.

AGROFORESTRY SYSTEMS

Agroforestry is the blending of forestry with agriculture and can be defined broadly as all practices that involve a close economic or ecological relationship between woody plants and crops, livestockk or pastureland. This definition, which is widely accepted internationally, encompasses a wide range of practices that sustain agriculture; protect human, animal, and natural resources; and/or provide economic gain. Typical agroforestry practices include: planting woody plants in contour strips; alley cropping or intercropping; edge plantings of woody plants; planting trees for livestock fodder or protection; planting trees as living fences and fenceposts; establishing windbreaks to protect agricultural land and animals from adverse environmental conditions; and planting trees for timber, nut, and fruit production (Rocheleau et al. 1988).

Although agroforestry systems are well established in many parts of the world, they are still evolving in North America. Model systems that integrate both traditional practices with new ideas and practices are being developed and refined for many parts of the United States. These systems creatively use trees as windbreaks, in riparian zones, energy plantations, and to produce nuts crops.

Windbreaks. Forestry in the Great Plains actually is a form of conservation forestry adapted to dryland agriculture situations. Trees are planted to conserve natural resources, protect the human environment, and increase agricultural production. Most of these trees are planted in windbreaks in a specific configuration and location designed to maximize their benefits.

Reduction of soil erosion is the main reason windbreaks are planted on agricultural land in the Great Plains. Nearly three-fourths of the highly wind-erodible land in the United States can be found in this region. Annual offsite costs of wind and water erosion damage are estimated at \$3.75 to \$6.44 billion dollars and \$3.2 to \$13 billion dollars, respectively; field windbreaks that are designed as long rows of closely spaced trees, can

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significantly reduce this damage (Rietveld and Montrey 1991).

Commonly desired secondary benefits of windbreaks include higher crop yields and improved animal weight gain, enhanced wildlife habitat, improved snow distribution, increased biodiversity, and lower energy costs. Windbreaks can increase grain yields 6 to 44 percent, vegetable and specialty crop yields 6 to 56 percent, hay and forage yields 20 to 100 percent, weight of grazing animals 12 to 25 percent, and survival of newborn livestock 25 percent; they can also decrease amounts of fertilizers and fuel needed. Nonagricultural benefits of windbreaks include a reduction of home heating and cooling costs by 15 to 40 percent, protection of roads from drifting snow, and aesthetic benefits (Rietveld and Montrey 1991).

A frequently unrecognized influence of windbreaks is an increase in arthropod diversity in the crop-tree ecosystem. This influence can be positive, i.e., an increase in abundance of natural enemies of crop or tree pests, or negative, i.e., an increase in abundance of pests themselves (Dix [in press], Heisler and Dix 1991, Stinner and Tonhasca 1991). The abstract by Dix presented below discusses the influence of conservation forestry on arthropod distribution on agricultural land in the central Great Plains.

The concept of using windbreaks to support agricultural production, resource conservation, and human environment protection is still relatively new. Interdisciplinary research is in progress to develop the techniques and guidelines needed to establish and manage the windbreak/crop systems and evaluate their benefits and costs.

Riparian Zones. Trees growing in riparian zones along waterways in the Great Plains can filter out substantial amounts of farm chemicals and sediments, can be used for fuelwood, and can provide cover for wildlife (Rietveld and Montrey 1991). Damming of the waterways is stressing the trees, reducing regeneration, and making them more susceptible to pests (see Antrobius' abstract below). Filter strips of planted trees are being evaluated in Iowa, Missouri, and other states as a method of replacing and supplementing these dying riparian zones (E. Hart pers. comm.).

Energy Plantations. In Iowa, silver maple, poplar, and willow trees are being evaluated as a source of biomass for farm energy. These trees are planted around sewage lagoons and harvested periodically for wood chips. This system is still experimental and final results will not be available for several years. Although potential pests of the trees have been identified, there have been no major pest outbreaks.[a]

Black Walnut Plantations. In Missouri, interplanting black walnut with a series of crops is being evaluated for economic feasibility. The farmer would receive annual income from the crops until they are shaded out, and would start harvesting walnuts within 8-10 years. However, black walnut nut abundance varies radically from year to year because of nut abortion caused by the black walnut curculio and other environmental factors. For more information on this topic, see Linit's abstract below.

ISSUES AND RECOMMENDATIONS

Agroforestry--the management of all aspects of an agricultural ecosystem that contains trees--must be considered when a management plan is being developed or implemented. Likewise, to be effective research programs for evaluating a tree-crop system must be interdisciplinary and solicit input from entomologists, soil scientists, plant pathologists, foresters, agronomists, wildlife specialists, and specialists of other pertinent disciplines. If a team lacks crucial members, its effectiveness is limited. Interdisciplinary teams whose members actively cooperate with each other are the key to the success of research and management efforts.

Because insects play a crucial role in the agricultural ecosystem, entomologists need to function in leadership roles in such teams. Furthermore, pesticide use increasingly is becoming restricted and is no longer the preferred pest control method. Biocontrol, pest-resistant crops and trees, and other alternative control methods need to be developed and implemented.

Many plantings receive little or no care after being established because of insufficient technical support, lack of funding, or landowner ignorance. The few available management specialists cannot meet the demand, and additional specialists need to be trained. Available management information needs to be collected and disseminated to specialists in agroforestry and pest management. Administrators need to provide funding and build political support for programs to train these management specialists. Because technology transfer plays a vital role in training of specialists and education of landowners, it also requires funding and administrative support.

In North America, agroforestry is considered a new discipline that is still evolving. Whereas ten institutions offer one or more courses in agroforestry, only three universities--Michigan State, North Carolina State, and Texas A & M--currently offer graduate degree programs with agroforestry specialization. Internationally, 18 institutions offer courses and training programs in agroforestry, but only four universities offer degrees (Bournes and Huke 1991).

Courses concerning forest pest issues are virtually nonexistent at most schools, because pests and their natural enemies usually have not been identified and little is known about their biology and management. Furthermore, the impacts of species composition, and size and orientation of field windbreaks on pest and natural enemy abundance and distribution is not understood. Research is urgently needed to 1) assess pest and natural enemy abundance in tree windbreak-crop systems, 2) monitor interactions between the ecosystem and the pest, and 3) develop the most effective tree plantings and techniques for managing pest/natural enemy populations.

A Semiarid Agroforestry Center was established at Lincoln, Nebraska by Congress in the 1990 Farm Bill to advance the development, application, and acceptance of conservation forestry practices in sustainable land-use systems. This center and sustainable agriculture centers established at Iowa, Minnesota and several other universities have a common goal of developing systems that attain harmony between agricultural environments and resource conservation. Close coordination and cooperation between these centers is essential to the success of agroforestry regionally, nationally, and internationally. Universities and government agencies must also strive to eliminate political bias in their agroforestry related actions and act as hubs for training and coordinating the transfer of research results and management guidelines to local, national, and international users. Since entomology is an integral part of both agroforestry and sustainable agriculture, entomologists need to play a leadership role in organizing and coordinating research, training, technology transfer, and management activities.

Although verbal administrative support for agroforestry research, teaching, and management has been outstanding, to date funding for most programs has been minimal. Political awareness of problems and needs of agroforestry systems must be increased through innovative educational outreach programs. Administrators need to actively support these efforts by providing the funds necessary to promote cooperation between researchers, teachers, and managers.

CONSERVATION FORESTRY ON AGRICULTURAL LAND IN THE CENTRAL GREAT PLAINS: INFLUENCE ON ARTHROPOD DISTRIBUTION

Mary Ellen Dix[1]

The Great Plains of North America is a semiarid agricultural region characterized by droughts, temperature extremes, desiccating winds, and wind erosion. Tree windbreaks are used primarily to protect the soil, crops, man, and wildlife from adverse environmental conditions. Windbreaks also increase the biodiversity of the agricultural landscape and can influence the distribution of vertebrates and invertebrates. For example, flying insects of many Orders accumulate in sheltered zones near windbreaks. Migrating aphids, cecidomyiids, psychodids, and spiders are deposited in the sheltered areas around the windbreaks. Honeybees and other large insects fly and forage in the sheltered areas around the windbreaks, where windspeeds are lower. Also, pest species and their natural enemies may utilize the windbreaks for food and protection. Cultivated cottonboll weevils in Texas overwinter in the duff and debris of windbreaks. Recent research in Nebraska indicates that spider abundance is higher in windbreaks surrounded by crops than in those surrounded by native grass. However, information on how tree windbreaks and conservation forestry practices in sustainable agriculture systems affect pest distribution and abundance is extremely limited, and is almost nonexistent for their natural enemies. Additional information is urgently needed so that tree windbreaks can be integrated more effectively into sustainable agriculture systems and populations of natural enemies.

WATER AVAILABILITY AND ITS POTENTIAL IMPACT ON TREE PESTS IN GREAT PLAINS FOREST ECOSYSTEMS

William L. Antrobius[a]

Insect and disease processes occur naturally and interactively as forest stands age, and contribute toward a complete cycle of stand regeneration, growth, decline, mortality, and eventually regeneration again. The flood plain ecosystems existing on the Knife River Indian Villages National Historic Site are no exception. The historic site is located in central North Dakota on the Knife River, close to where the Knife and Missouri Rivers meet. These aging ecosystems, consisting of cottonwoods, green ash, boxelder, American elm, and willows, are currently being impacted by both insects and disease-causing organisms. The decline and decay of the historic site's forest resource is most likely representative of processes now occurring on the last remaining hardwood forests existing along the lower Missouri River.

For the fourth year in a row, both the spring and fall cankerworms have been detected at some level on the historic site's green ash, boxelder, and American elm. Heavy defoliation, approaching 100 percent of affected crowns, by cankerworms was recorded in 1989 and 1990. Surveys conducted at the site also indicate that a significant portion of the green ash component is being affected by heart-rotting fungi. Current drought conditions in North Dakota add additional stress to these systems.

Cankerworm populations are usually cyclic, with outbreaks lasting from 3 to 4 years in a particular location. Populations then subside under normal conditions and remain at low levels for the next 12-18 years. Collapse of outbreaks is usually associated with starvation, parasitism and predation, reduced food quality associated with repeated defoliations, and/or adverse weather conditions.

In the past, impacts of spring defoliation by cankerworms and continual stem breakage caused by heart-rot fungi as trees aged, most likely allowed needed light to reach understory regeneration during the critical spring growing period. These processes, in association with seasonal spring flooding, probably contributed to maintaining many sites in woody plant species. The flooding most likely performed at least three major functions: 1) prepared a seedbed for woody plant species through siltation, 2) supplied large amounts of water during the critical spring growing season, and 3) reduced native grass competition by essentially drowning it. The role of fire in these ecosystems is unknown.

The natural process of seasonal, spring flooding along the Knife and Missouri Rivers has most likely been altered by the closing of the Garrison Dam 43 years ago. The effects of this may now becoming apparent. In many areas surveyed within the Historic Site, a lack of woody plant vegetation was evident. Invasion and competition by exotic broome grass may also be a contributing factor to this lack of woody plant vegetation. In light of these realities, the question is raised as to whether or not these ecosystems can be perpetuated for future generations by "natural means." Intervention of some kind may, in fact, be the only way to preserve what is left of these ecosystems, if that is the goal of land managers.

Currently, options available to the Knife River Historic Site are being examined and studied through an interagency, multidisciplinary cooperative effort. Agencies involved are the USDA Forest Service, North Dakota Forest Service, and the USDI Park Service.

BLACK WALNUT AGROFORESTRY: ROLE OF BLACK WALNUT CURCULIO IN NUT PRODUCTION

Marc J. Linit[b]

A pest management program to assess the impact of the black walnut curculio, *Conotrachelus retentus*, is underway at the Sho-Neff Plantation near Stockton, Missouri. Black walnut (*Juglans nigra*) trees within the plantation are planted on either 10 or 20 ft spacings within rows that are spaced 40 ft apart. Agronomic crops such as wheat or soybeans are cultivated in the 40 ft alleys while the walnut trees grow through the sapling stage. Annual crop production can continue until trees attain a height sufficient to reduce light availability. At this time, perennial forage crops can be established in the alleys. This switch coincides with the initiation of nut production. Nut production is economically advantageous, because it offers short-term and annual financial returns from an otherwise long-term investment in timber production, and some hedge against risk through product diversity. The importance of nut production in this management scheme necessitates maximization of the annual nut harvest. The black walnut curculio causes nut abortion on native black walnut trees. However, its impact on nut production in a plantation environment is unknown. Black walnut nut mortality was monitored from 1985 through 1990. Life tables were constructed to follow within-generation nut mortality each year. Overall nut mortality was partitioned to identify the portion attributable to the black walnut curculio. Between 1.9 and 31.9% of the nut crop present at the initiation of curculio oviposition was destroyed by the insect.

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MODELING APPLICATIONS

Moderator: Charles W. Dull[1]

As computers are used more frequently in our profession and the number and complexity of natural resource problems increase, new software in the form of simulation models, artificial intelligence and expert systems will be designed to aid decision makers in making more knowledgeable decisions. New technologies will provide pest management specialists better ways of implementing management techniques and monitoring forest resources. They will also provide a means of informing the public and decision makers about the conditions and the health of our forests. Satellite imagery, aerial photography, and geographic information systems can produce more integrated data and can add to the more comprehensive and faster analysis of forest pest problems over large regions.

During these times of rapid technological development in Forest Pest Management, it is essential to focus on the needs of resource managers and our clients. New technologies not only provide a better way of implementing management techniques and to monitor forest health conditions, but they also provide a means of informing the public and, ultimately, the decision makers who formulate resource policy. New computer technologies and data collection methods provide new ways to compare expected and actual forest conditions, to maintain accurate stand and forest health information, and to help us evaluate the effectiveness of our pest control activities. They provide detailed and consistent information to a broad audience quickly in a clear and readily available format. More widely shared information can increase agreement among individuals, agencies, and organizations on the definition of the problems and on the location and condition of the forest resource. This interaction will enhance our ability to address forest health issues.

It is well recognized that new simulation models must generate accurate, unbiased information on forest health conditions of concern to all interested parties. We have found that the models must be integrated into the management decision making process and must have input from the user community so that users can believe in them and can afford to utilize them. New technologies are advancing faster than forest pest specilalists can absorb it. Training is required to learn user unfriendly software. Many new computer software systems are too big and too complicated for casual software users to learn by themselves. Therefore, a great deal of effort is now being expended on the development of user friendly graphic user interfaces so that models can be integrated into a decision making system. New ways of analyzing and displaying data can lead to improved planning and resource management by reducing controversy about the condition of the nation's forests and increasing our understandings of desired management alternatives.

There will be many opportunities to support forest management in the areas of computer sciences, GIS and data base management, and remote sensing technologies. Forest pest specialists will be using these technologies with increased frequency in the future, and they must learn to utilize these technologies to be effective in their day to day activities. The following abstracts are provided by the speakers in this session which address the previously mentioned topics.

APPLICATIONS OF GIS & FOREST PEST MODELS IN THE PACIFIC NORTHWEST

Katharine A. Sheehan[a]

Several applications involving geographic information systems (GIS) and forest pest models are either currently underway or planned for the near future in the Pacific Northwest.

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Current applications of GIS include the annual aerial detection survey of forest pests and suppression projects. Sketch maps are digitized and overlaid with several ownership maps. Initial tables produced by the GIS system (MOSS) are imported into a relational database (currently Paradox, probably Oracle in the future). Final maps and tables as well as data files are shared among the participating agencies. When suppression projects are planned, a GIS is used to produce maps of project boundaries and spray block boundaries along with key information such as stream locations, road locations, sample points, etc. Eventually, we hope to create hazard and risk rating maps from layers such as pest occurrence and severity, stand boundaries, topographic position, management objectives, etc.

Forest pest models that have been used in this region include the Budworm Damage Model, the Douglas-fir Tussock Moth Model, the Mountain Pine Beetle Model, the Western Root Disease Model, and the Dwarf Mistletoe Model. One "package" for these and other models that is being tested in this region is INFORMS, which will be described by another speaker. All of these models are linked to the PROGNOSIS stand model, and there is great interest in developing procedures for simulating pest complexes.

A pilot project aimed at linking pest surveys with vegetation inventories is currently underway on the Okanogan National Forest. One goal of this project is to incorporate pest information directly into future forest planning efforts.

MODELING IN INFORMS-DG

Patrice Janiga[b]

INFORMS-DG is the Data General based application software for Integrated Forest Resource Management. INFORMS-DG contains several types of models which support project level environmental assessment of multiple resources. Models include those reflecting the processes of sedimentation, fisheries populations, elk habitat, pest impacts (population dynamics and impacts on timber production), timber growth and yield simulation, log transportation costing, and visual sensitivity. What lessons can the INFORMS-DG development pass on to the future of pest management?

To integrate into a system multiple models which support integrated pest management, the following needs to be part of pest management future RD&A:

* Understanding and modeling of pest interactions within ecosystems

* Multi-discipline project teams which represent on-the-ground forest managers, research scientists, systems engineers, and organizational management.

* Existing and new model coding which uses the power of public domain and/or commercial software, including Geographical Information Systems, graphical libraries for user interfaces, Database Management Systems.

* Both heuristic and empirical models suited to the level of reliability and validation required of their role in forest management.

* Long-term model life support which includes initial research, software development, verification, validation, and revisions that focus on the quality assurance as well as practical useability.

* Output displays which enhance interpretation of model behavior that go beyond tabular listings to include charts (histogram, pie, line graphs), 2-dimensional tracking of spread effects, 3-dimensional simulation pests impact on the landscape.

APPLICATION OF GIS IN THE SOUTHERN FOREST HEALTH MONITORING PROGRAM

Robert L. Anderson, Charles W. Dull, Robert J. Uhler and Steve Holzman[c]

In 1990, the National Forest Health Monitoring Program was started in the northeastern United States. In 1991, the program will expand into three southern states; Alabama, Georgia, and Virginia. This part of the monitoring, called "detection", is designed to identify possible forest health related problems. This is done through a series of permanent field plots and field surveys. Realizing that a means was needed to assemble all of this information, manage it, and produce meaningful tabular and spatial data, Forest Pest Management opted for GIS. Forest Pest management in the south was fortunate that the National Acid Precipitation Assessment Program provided funds to produce the Southern Forest ATLAS. The ATLAS provided a GIS system that had many of the needed components in place.

Taking advantage of the availability of this system, Forest Pest Management identified eleven layers to be improved or created in the ATLAS. The layers were identified as crown classifications, weather, ozone, annosus root rot, fusiform rust, littleleaf disease, dogwood anthracnose, oak decline, gypsy moth, southern pine beetle, and spruce-fir damage. For each of these layers, the distribution of the host, distribution of the attribute, and some measure of severity will be mapped. Additionally, a set of tabular data will be produced for each layer. All of these data will be merged with the permanent plot data to assess the health of the southern forests.

USE OF A GEOGRAPHIC INFORMATION SYSTEM FOR INTEGRATED PEST MANAGEMENT IN THE SOUTHERN REGION

B. M. Spears, C. W. Dull, D. N. Rubel, W. A. Nettleton, and R. J. Uhler[a]

A geographic information system is used in the Southern Region for integrated pest management. Forest conditions are monitored and integrated with other data. USGS 7 1/2 minute, 1:24,000 topographic quadrangles are used for base maps. Most resource data are input at this scale; however, data at other scales can be used as 1:100,000 or 1:2,000,000 scale digital line graphs.

Examples of GIS analyses in forest pest management are: 1) interpolation of point data; 2) area overlay, union, and intersection; 3) buffering lines, points, and polygons; 4) flow analysis; and 5) feature extraction from coverages to create subsets. The interpretive products are displayed graphically. This is called spatial or cartographic modeling. Integration between spatial and mathematical modeling is possible with relational data bases. We can expect to see much more integration in the future.

Two important forest pests in the Southern Region are the gypsy moth and the southern pine beetle. In gypsy moth pest management the GIS is used for: 1) defoliation mapping; 2) mortality assessment; 3) tracking the spread of the moth from male moths caught inpheromone traps; 4) using egg mass survey data to plan treatment blocks; and 5) determining treatment efficacy.

In southern pine beetle pest management, the GIS is used to: 1) coordinate and prioritize control, 2) determine control efficacy, 3) hazard rate stands, 4) assist in implementation of the forest plan, 5) estimate losses, and 6) serve as a link to the Southern Pine Beetle Information System (SPBIS). The GIS has proven its value in forest planning already where the southern pine beetle threatened the red-cockaded woodpecker (an endangered species) in the Little Lake Creek Wilderness in Texas.

The GIS has been used for forest pest management in the Southern Region for 12 years. Two GIS's, one on the Homochitto National Forest and one on the Oconee National Forest, have been developed through the Southern Pine beetle Demonstration Area Project. These GIS's can be used for all aspects of forest management in addition to forest pest management. The other 13 forests in the Southern Region are expected to have GIS's by 1996. They are in various stages of development. The George Washington and Jefferson National Forest in Viriginia, the Kisatchie National Forest in Louisiana, and the Ocala National Forest in Florida are currently operational in part or entirely.

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GRADUATE CONCERNS IN FOREST ENTOMOLOGY

Moderator: Tom Eager[1]

The theme of this Conference suits the interests of our audience very well. Perhaps more so than any of the other "age classes" present at this meeting, the topic of the future is of greatest importance to those embarking upon a career in forest entomology.

The very nature of forestry and resource management deals with the conflict of present needs vs. future goals. We as forest entomologists study a unique interface between some of the longest living and some of the most ephemeral organisms.

As can be seen from our agenda, our concerns include both scientific as well as societal topics. The different landscape which forest entomologists will have to face in the near future, as well as some of the prospective tools with which to deal with them, will be discussed first. We will then address a topic near and dear to all young people in forest entomology, the job market.

I would like to thank all of the participants in this session, both the speakers as well as the members of the audience who joined in for some interesting discussion. The encouragement of some of the more experienced participants of this session was quite reassuring to those of us facing an unstable job market. This session led to some animated conversations at the Conference; hopefully it will form the basis for much collaboration in the future.

FUTURE IMPACT OF BIOTECHNOLOGY ON FOREST ENTOMOLOGY

Steven J. Seybold[a]

Biotechnology, the practical application of biological systems and organisms to technical and industrial processes, is an old concept that has been invigorated during the last twenty years by the development of many macromolecular and culturing techniques originating from the human medicine research enterprise. Because of the priorities of human welfare and because of the limited knowledge base in biochemistry and molecular genetics for almost all forest trees and pestiferous insects, the impacts of biotechnology in forest entomology will come slowly.

The effect of biotechnology will most likely be on major forest insect pests in the broad areas of control and biosystematics. Controls based on biotechnology may include genetically improved microbial insecticides, more effective variants of autocidal control, more effective entomological biocontrol agents, and resistant host plantings. In biosystematics, the polymerase chain reaction (PCR) allows minute amounts of DNA (even from curated specimens) to be quickly amplified for direct sequence comparisons. Though the ability to measure sequence differences among taxa quickly and directly makes this a powerful technique, the biologist must have, in hand, specific DNA oligonucleotide priming sequences for the gene of interest to carry out the procedure.

Any new controls derived by biotechnological means will suffer from the same old problems associated with biotype evolution and ecology characteristic of the resilient Class Insecta (i.e., replacement, resistance and resurgence). These control should be carefully applied within the existing pest management framework and not considered as panaceas.

GLOBAL WARMING AND IMPLICATIONS FOR THE FUTURE OF FOREST ENTOMOLOGY

Joel McMillin[b]

Global warming effects and climate change predictions under a doubled carbon dioxide scenario are reviewed. The effects of climate change on U.S. forests and forest insects may be considerable. At the individual tree level, increases in carbon dioxide, temperature and changes in precipitation will be affecting growth rates, water-use

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efficiency, carbon allocation patterns and the overall vigor of trees. These effects are predicated to lead to differences in productivity depending on the species and the geographic region. The natural ranges of many tree species are expected to shift; with some increasing in area and others possibly being pushed into local extinction. Direct effects of climate change on certain forest insects may result in increased growth and reproduction rates. An extended growing season of trees, in combination with direct effects of warmer temperatures, may lead to increases in voltinism for some insect species and hence the possibility for more extensive damage. The plant stress-insect performance hypothesis is questioned and the carbon allocation imbalance hypothesis (Wagner 1990) is suggested as one possible method to predict insect performance on trees of different vigor. There is an apparent need for more basic research pertaining to trees, insects and their interactions in response to climate change before we can accurately predict effects of global warming.

EMPLOYMENT PROSPECTS IN ACADEMIA FOR FOREST ENTOMOLOGISTS

Darrell W. Ross[c]

Employment opportunities in academia are defined here as full-time, tenure track positions in research, teaching, and/or extension at colleges or universities. Job openings of this type for forest entomologists have been scarce in recent years and competition for the few available positions has been intense. There is no indication that this trend will change in the near future.

There are several reasons for the small number of vacancies. There has been a reduced demand for teachers as a result of declining enrollments and changes in curricula at many forestry schools. Also contributing to the lack of job opportunities has been a general decline in funds to support forest biology research.

Historically, many forest entomology positions have been in entomology departments. As these positions become vacant, they are often filled by specialists in fields other than forest entomology, especially high profile fields such as biotechnology. Some recently advertised extension positions have combined forest entomology with horticultural, ornamental, and/or turf entomology emphasizing the latter disciplines.

Because of the small number of opportunities, it would be unwise to consider only academic positions in career planning. In the present economic climate, a more reasonable approach would be to consider all available options including jobs with state and federal governments and private industry as well as academic positions. The greatest number of opportunities will likely be available to those who maintain a diverse background or who specialize in areas of current interest such as biotechnology or climate change.

AFFIRMATIVE ACTION AND ITS ROLE IN FOREST ENTOMOLOGY

Marita P. Lih[d]

Affirmative Action was developed in response to a long history of discrimination against women and minorities. Affirmative Action is based on the concept that we can eliminate discrimination if positive steps are implemented to ensure that all levels of the work force are conducting self-evaluation to identify discriminatory policies and practices, monitoring progress towards a culturally diverse work force, advertising all positions, hiring and promoting on the basis of merit, actively recruiting women and minorities, ensuring facilities are accessible to disabled persons, accommodating disabled employees, and disseminating nondiscriminatory policy statements.

Affirmative Action promotes optimum utilization of the diverse talents and perspectives of each person; a necessary goal if we are to solve the numerous problems facing the world today. Minorities and women represent increasing percentages of our college graduates and our work force. It is no longer practical to ignore their potential contributions.

We are involved in a process of social change. We all must embrace and work for equality at home and in the work place. Employers must develop creative approaches to increasing and maintaining diversity. Universities must train faculty and students to be alert to stereotyping and discrimination. Administrators must give credit to minority recruiting efforts. We must all reach out to our youth. A wealth of resource information is available to support these efforts.

POST-DOCTORAL PROSPECTS FOR FOREST ENTOMOLOGISTS

Robert K. Lawrence[e]

Post-doctoral positions can provide valuable opportunities for recent Ph.D.s to establish their credentials and augment their skills. Post-doctoral associates usually have more time to devote to research interests and are encumbered by fewer non-research responsibilities than are faculty members and graduate students. There are some pitfalls to be aware of when a person starts a "Post-doc", but as is often true, the success of such an experience depends on what the individual makes of it.

Competition in the forest entomology job market is tight, and post-doctoral experience is frequently a prerequisite for obtaining a permanent position. About 70% of persons obtaining Ph.D.s in the life sciences go on to at least one post-doctoral appointment prior to landing a permanent job. It is not uncommon for new Ph.D.s in entomology to spend three to five years in post-doctoral positions. Although openings for permanent jobs in forest entomology are scarce, post-doctoral positions are more readily available. A recent survey of 27 Forest Insect and Disease Research projects in the U.S.D.A. Forest Service revealed that approximately 25 post-docs are currently supported and potentially 10 to 15 more could be hired within the next 12 months. The U.S.D.A. Agricultural Research Service is expected to hire in the near future about 150 post-doctoral associates in the life sciences (molecular biology, plant physiology, entomology and related areas) and engineering.

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RISK AND HAZARD RATING DEVELOPMENT AND FUTURE IMPLEMENTATION

Moderators: David E. Fosbroke and Jack E. Coster[1]

What is the future of forest insect hazard and risk rating? How will changes in technology and in the environment alter current rating systems? How can hazard and risk rating be better decision making tools for future integrated forest managers? These were the questions we had in mind when organizing the workshop in Denver. Inevitably, when we look to see what the future will bring, we first take a closer look at where we are. The workshop participants were no exception to this rule and began by retracing some familiar ground.

There was a lengthy discussion of terms commonly used in hazard rating such as risk, hazard, susceptibility, vulnerability, resistance, tolerance, expert systems, and decision support systems. These terms apparently mean different things to different people depending on their frame of reference. For example, many foresters have training in fire control and bring fire control concepts of risk and hazard to forest pest management. Though a set of unified and accepted definitions would be useful for discussion of hazard and risk rating, they are not likely to be achieved. In fact, Mark Twery suggested that the same definition cannot apply to all forest/insect systems. Because there is no universally accepted definition of these terms, it is important for researchers and managers to carefully define their interpretation of terminology when discussing hazard and risk rating.

In an attempt to prevent further confusion, we present the following definitions for several hazard and risk rating concepts. These definitions are a blend of those given by the workshop speakers. Though there were subtle differences in how participants used hazard rating terminology, we feel that the definitions below are workable for the purposes of the workshop, this article, and each of the abstracts that follow.

* SUSCEPTIBILITY - the probability that a tree or a forest stand will be defoliated given an insect outbreak occurs.

* VULNERABILITY - the probability that a tree or a forest stand will suffer damage given that defoliation occurs. Damage may be in terms of tree mortality, growth loss, reduced acorn production, or some other value loss.

* HAZARD - the probability that damage from defoliation will affect management objectives. Hazard is a stand condition.

* RISK - the probability of a tree or a forest stand sustaining a damaging event. Risk adds a timing factor. In the case of the gypsy moth for example, white oak stands in West Virginia and Georgia might have equal hazard, but the risk of damage to the stand in Georgia is considerably lower than the risk to the stand in West Virginia, because of the proximity of gypsy moth populations.

* DECISION SUPPORT SYSTEM - an information collecting system to help forest managers find a solution to an unstructured (or poorly structured) complex problem.

* EXPERT SYSTEM - a system for finding an optimal solution to a complicated problem using rules based on knowledge gained through experience.

Ray Hicks reviewed the myriad of factors that affect the development of hazard rating systems. Some, such as host preference, host and insect population dynamics, and weather conditions, have been investigated for many pest problems. Others, including individual tree physiology, within species host genetic differences, and long term climatic patterns are less understood.

Each speaker gave examples of hazard rating systems that are currently in use or development. Each system incorporated information on stand composition, stand structure, stand age, past insect population levels, and management objectives.

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Hazard rating models may be traditional in form (e.g. regression equations). Ray Hicks described his experience in applying two regression based systems for gypsy moth to forest stands at the West Virginia University Forest. In contrast, recently developed hazard rating systems made possible by geographic information systems, take the form of map overlays. Mark Twery showed a series of maps of stand composition, defoliation spread, and areas of repeated defoliations. Geographic information systems may also be useful for predicting variables that are key to hazard rating. An example is the prediction of species composition from digital elevation models that is being attempted for gypsy moth hazard rating. Deborah McCullough discussed the on-going development of a Decision Support System for jack pine budworm that actually incorporates hazard and risk rating as an integral part of a larger system.

The effectiveness of any of these rating systems may be influenced by long term changes in climatic conditions. Les Safranyik reviewed potential global climate changes and speculated on how these changes could influence hazard rating systems. As an example, he compared mountain pine beetle outbreaks in lodgepole pine stands in northern British Columbia with outbreaks in the warmer and wetter portions of the beetle's range.

Hazard rating is an attempt to forecast how a stand will respond to insect outbreaks. Mark Twery and Ray Hicks reviewed the framework of this process using the IPM decision process outlined by Mason et al. (1986). This process (see Figure 1.) is a series of decision modules and begins with an assessment of stand susceptibility. If susceptible trees are not present then no action is needed. If they are present, then the process continues with the rating of stand vulnerability. At this point, the manager decides whether the predicted level of damage will adversely affect management goals. If management goals are affected, then insect populations are monitored and defoliation levels predicted. When insect populations reach a predetermined threshold, then an appropriate management option is selected. Integral to the system are the management objectives and values (not necessarily timber values) of the manager and an insect population monitoring system. This implies that two managers with different goals and values may decide on two different paths through the hazard rating process.

Each module in figure 1 consists of one or more predictive models. Two general categories of models are empirical and biological. Empirical models are usually derived from large databases and rely on underlying correlations between hazard or risk and one or more measured variables. Biological models are based on a mathematical description of key biological processes.

Both model types may be further broken down into individual tree models and stand models. Forest managers are likely to have a bias toward using stand level models. This is because it is rarely possible to contemplate managing individual trees.

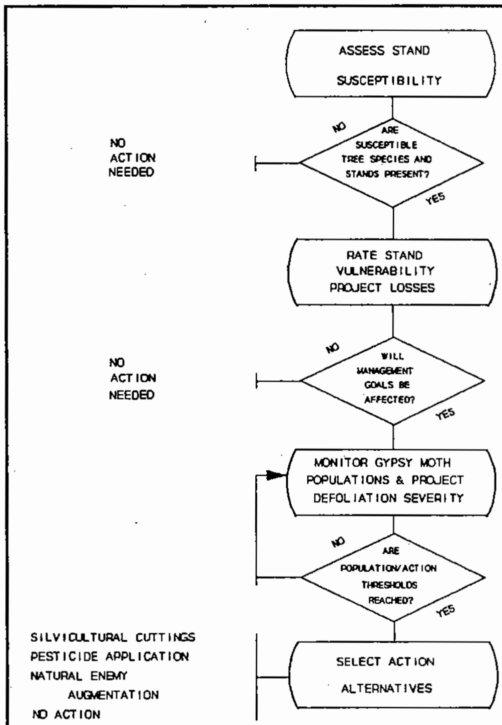

Figure 1. IPM DECISION PROCESS FOR GYPSY MOTH.
Adapted from Mason et al., 1986

Hazard rating is a tool for making decisions about integrated forest management with respect to pest control. The decision-maker must know how assumptions drive a specific hazard rating system. The user also needs to know how good the decisions made from the hazard rating process will be. The two stand mortality models developed for gypsy moth that were used at the WVU Forest gave unexpected results. Ray Hicks traced these problems to differences between stand conditions at the WVU Forest and in the areas where the models were developed. This emphasizes the need for validation of hazard rating systems under real world conditions. This need for validation has been emphasized for at least ten years. Hedden (1980) stated, " This validation phase is potentially the most important in developing hazard-rating systems. Unfortunately, it is the step most often ignored". It appears to us that not enough money and effort have gone into validating existing models.

Several limitations of existing systems were identified by the workshop participants. Commonly, too many stands are rated in the high risk or high hazard category by many systems. In system development an attempt is often made to use data that are readily available or easily obtained. As Les Safranyik noted, "however, if the insects do not view their world in the same way as we classified the forest then it does not matter a hoot how the classification was made." Such biases during the development process may limit the usefulness or applicability of many hazard rating systems.

Visual cues of tree condition (vigor) are relied upon because of a lack of ready field diagnostic tests of tree "health". These cues may be too subjective, introducing variability into classification results. By the time a tree shows a visible decline in vigor the pest problem may be far advanced. Related to this problem is a lack of understanding of the physiological processes that determine a tree's susceptibility or vulnerability. Finally, even those systems that work reasonably well today may not work in the future if the climate changes.

FUTURE DEVELOPMENT RECOMMENDATIONS

Suggestions for future research in the hazard and risk rating of forest stands were made by the workshop participants. These are outlined below:

1) Incorporate management, amenity, and economic considerations into hazard and risk rating development.

2) Involve end users in the design of hazard rating systems.

3) Determine the type of outputs that the end user can and will use.

4) Develop diagnostic tests for tree condition.

5) Remember that management objectives, like forests, are dynamic.

6) Develop an understanding of individual tree processes and their relationship to hazard and risk.

7) Evaluate the quality of management decisions that result from hazard rating systems.

8) Compare insect/host interactions in the warmer and moister part of their range with those in the colder and drier part of their range to determine possible effects of climatic changes on these interactions.

9) Compare vulnerability and susceptibility among different provenances.

10) Use geographic information systems to develop hypotheses about hazard and risk.

11) Investigate surrogate variables to predict those variables which have proven to be important in determining hazard and risk, but which are expensive or difficult to collect.

12) Apply the appropriate system to the situation.

13) Validate existing hazard rating systems.

THE HAZARDS OF HAZARD RATING

Ray R. Hicks, Jr.[a]

Insect hazard rating systems are usually developed from empirical data that document relationships between hazard (probability of attack or damage) and measurable characteristics of the forest. Ideally, hazard rating should be based on causal factors. For example, tree stress is a causal factor, but one that is not readily measurable. Thus, pest managers frequently measure surrogate variables (crown class, site index, etc.) that are related to the causal variable.

At the WVU Forest, we used several existing hazard-rating models to estimate gypsy moth hazard. Because these empirical models were developed in other locations (northeast Pennsylvania, eastern West Virginia), they gave results that were quite unexpected. Now in retrospect, after one year's defoliation we are seeing extensive gypsy-moth-induced mortality in stands at the WVU Forest that were ranked as moderate to low in hazard. Although empirical hazard-rating systems are probably a necessary step in the evolution of insect hazard rating, they must be used with caution and may not work in areas outside where they were developed.

NEW TOOLS FOR HAZARD RATING: GIS AND THE GYPSY MOTH

Mark Twery[b]

The process of hazard rating of forest trees is an important one which has been evolving since long before the formal practice of forestry. Determining which areas of forest may be at risk from damage by insects and related causes is still a difficult task, because of the complexity of the problem. Tools such as geographic information systems (GIS) can provide a means either to make existing tasks easier or to enable new understandings to be gained.

The gypsy moth (*Lymantria dispar*) is a forest defoliator which can cause great damage over wide areas. Its damage is not uniform, however, and understanding which stands are the most likely to suffer damage is important to the efficient management of resources. Specifically, certain types of forest, such as oak or aspen stands are among the most susceptible, or likely to be defoliated given a population of gypsy moths in the area. But not all oak stands will receive equivalent amounts of defoliation, or even given equivalent defoliation will suffer equivalent amounts of damage. The amount of damage which may be expected from a defoliation may be termed a stand's vulnerability. The hazard to which that stand is subjected should be recognized as directly related to the management objectives of the landowner, because what is severe damage to a park operator may be inconsequential in a wilderness area.

A GIS can assist a manager in performing hazard ratings on forest lands by integrating determinations of stand composition, a major component of the susceptibility, with the presence of either insect populations or areas of different management objectives. In addition, techniques can be developed to derive useful information such as stand composition from easily available digital data in areas where collecting data on the ground is prohibitive.

GLOBAL WARMING: POSSIBLE EFFECTS ON HAZARD RATING

Les Safranyik and Terry Shore[c]

The global atmosphere is being enriched with carbon dioxide; a relatively active (greenhouse) gas. This enrichment is mainly a consequence of the combustion of fossil fuels and reduction in forest biomass and soil organic matter. The pre-industrial concentration of 260 ppm by volume is expected to double by the year 2065. This level of enrichment will result in major changes in global climate:

* 3 ± 1.5°C increase in mean annual global air temperature.
* 7.1-15.0% increase in mean annual global precipitation.
* Larger geographic variation in temperature and precipitation.
* Increased interannual, seasonal, and daily variation in the climate of a given area.

As a result of the CO_2 enrichment and consequent global warming, forests are expected to undergo major shifts in geographic ranges, structure, and productivity. During climate change, transient increases in plant stress will likely occur which could predispose forests to increased grazing by insects. In specific forest types or regions, some insect activity/damage scenarios implied by climate change are:

* Outbreaks may increase in frequency and/or severity.
* Outbreaks may occur on atypical sites and/or involve non-susceptible host developmental stages.
* Expansions in geographic range and/or reduction in the length of life cycles may occur.
* Activity by secondary species may increase.

In other situations insect activity might not increase significantly in response to climate change, or may even decline, for a number of reasons:

* Increased host vigour, temperature, or precipitation.
* Reduced habitat suitability (needle hardness, phloem drying, unseasonably high or low temperatures, etc.)
* Insect development/life cycle becomes out of phase with the growing season or the seasonal development of host.

In developing hazard rating systems, we are interested in identifying where, and with what level of incidence and/or severity, damage will occur. We build hazard rating systems for individual trees, stands, or larger areas based on two approaches; biologically-based models, and empirical models. Some of the effects that climate change may have on hazard rating systems are:

* Systems based on understanding of host/insect interactions (biological models) may become increasingly more reliable than empirical models.
* Of the biological models, those based on past climatic history, biogeoclimatic systems, and measures of site quality may become less reliable than those based on current expressions of host and stand conditions, and climatic suitability for insect development and survival.

In some situations, it may be possible to evaluate the main effects of climate change on components of existing hazard rating systems by:

* Comparing the nature and effects of tree, stand and site, and climatic factors affecting insect populations in the southern, drier or lower elevation ranges of their geographic distribution with those in the optimum, northern, wetter, or higher elevation ranges.
* Investigation of insect activity in provenance trials that cover a wide ecoclimatic range.

DECISION SUPPORT SYSTEMS AND HAZARD RATING FOR JACK PINE BUDWORM

Deborah G. McCullough[d]

Jack pine budworm (JPB) is the primary defoliator of jack pine, an important commercial species in the Lake States and Canada. Outbreaks generally occur at 8-12 year intervals and persist 2-4 years, resulting in substantial growth loss, top-kill, and mortality. Jack pine is typically managed for pulp and marginal returns of harvests tend to be low. Measures to control JPB can rarely be justified economically, requiring a long-term, silvicultural approach to JPB management. Identification of high risk stands susceptible to population build-up of JPB, and high hazard stands vulnerable to damage if outbreaks occur, is critical for jack pine managers. The annual allowable cut can be juggled to optimize allocation of harvest, salvage, or sampling efforts to high priority stands.

Several risk or hazard rating systems have been developed independently for JPB. Although most systems are useful, problems have been identified. Often too many stands receive high ratings. Management efforts cannot be prioritized, particularly when the rating systems are not integrated with economic or other components. Also, systems are difficult to apply on a regional basis, since cut-off values for various rating factors vary among agencies.

A cooperative project to develop a jack pine budworm decision support system (JPBDSS) was initiated in 1989 between the US and Canada. Participants include pest specialists, managers, and researchers from several state, provincial, and federal agencies. Stand attributes such as age, density, and vigor interact with JPB population models and rulebases in the JPBDSS, providing each stand with a risk rating. Similarly, stand attributes will be used to determine the ability of trees to tolerate expected levels of defoliation, resulting in identification of high hazard stands. Resource outputs selected by the user will interact with an economics model to estimate impacts of defoliation. Alternative treatment options can be selected and will interface with a growth and yield model. Changes in stand attributes then feed back into risk and hazard rating determinations. Advantages of incorporating risk and hazard rating into a decision support system include the ability to integrate ratings with economic or other management-related factors. The JPBDSS will be linked with a GIS, providing spatial integration of ratings with other factors. Users should also benefit from consolidation of available information from both the U.S. and Canada.

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HOST-INSECT INTERACTIONS

Moderator: Robert A. Haack[1]

In the not-so-distant past, plants were often viewed as passive participants in their interactions with insects and other herbivores. However, that viewpoint has now changed substantially to one that recognizes plants as having complex and variable responses to herbivory, with some responses being nearly immediate while others are more long-term.

One important area of current research addresses the question of how and to what degree do environmental stresses alter "normal" plant-insect interactions. For example, one contemporary conceptual model of plant-stress-insect interaction depicts insect performance responding in a non-linear fashion to increasing plant stress. That is, insect performance generally improves under mild to moderate stress but worsens under severe stress. However, the exact response curve may vary markedly for insects in different feeding guilds. For example, in relative terms, gallers may do best on unstressed or mildly stressed plants, defoliators and sap-suckers may do best on moderately stressed plants, while cambial feeders may be most successful on plants experiencing severe stress.

Considering the future, global climate models project generally warmer and dryer conditions for many areas worldwide, as well as an increased frequency of extreme weather events (e.g., drought, flooding, high temperatures, and UV-B dose). Therefore, in the decades ahead it is even more likely that environmental stresses will have major impacts on host-insect interactions, leading in some cases to an increased frequency of insect outbreaks, while in other cases possibly driving some insects to near extinction.

Many of the above issues were addressed by the seven researchers who spoke at the Host-Insect Interactions Workshop. The purpose of which was to discuss our current understanding and future research needs in this field, and to focus in particular on defoliating, sap-sucking, and cambial-feeding insects. As a secondary theme, some speakers addressed the topic of environmental stress and global climate change in light of their particular plant-insect model system(s). Seven stimulating papers were presented at this well-attended workshop; four dealt with defoliators, one with a sap-sucker, and two with cambial feeders. Because of the lively discussions that followed each individual talk, no time remained to formulate a group consensus on priority research needs in this subject area. Nevertheless, several important research topics in the field of host-insect interactions were identified.

For example, more research is needed in the areas of herbivory in relation to:

1) Tree carbon-nutrient balance; carbon allocation; stress effects on mineral uptake, within-tree distribution, and allocation;

2) Soil fertility; soil acidification (soil pH and Ca:Al ratio); mineral deficiencies and excesses;

3) Host vegetative and reproductive phenology, e.g., the concept of the host's "window of susceptibility;" stress effects on host phenology;

4) Multiple trophic-level interactions, including both parasitoids and insect pathogens; stress effects on these complex interactions;

5) Single and multiple environmental stresses, both abiotic and biotic; the relative importance of the degree of stress as well as the synchrony between the stress event and a particular tree-insect model system;

6) Tree defenses, both inducible and constituitive; biochemistry of defensive responses and variations among different host tissues; mechanisms and genetics of tree resistance to insects; role of gut microbes in detoxification of allelochemicals; the tree's hypersensitive response and the role of microbes in its induction;

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7) Tree age; genotypic differences within a single tree species; and differences within a single tree.

In addition, many participants felt a need for improved techniques to impose single and multiple stresses on trees in field and indoor experiments, as well as further theoretical refinement on how environmental stress is seemingly linked to outbreaks of forest insects.

WHY IS THE GYPSY MOTH DOING SO WELL IN NORTH AMERICA?

Michael E. Montgomery[a]

The gypsy moth, *Lymantria dispar* was introduced to North America from Europe 120 years ago. The species likely originated in Eastern Asia before or during the Oligocene, more than 30 million years ago. At that time, a remarkably homogeneous forest existed across the land mass of the Northern Hemisphere. North America had separated from Europe some 100 million years previously, but was still broadly joined with Asia.

Pleistocene glaciation and the following period of global warming divided this heretofore continuous forest. Europe, with east to west mountain ranges that blocked a southern retreat of flora, lost several tree genera including *Tsuga, Carya, Ostrya, Celtis, Liquidamber, Metasequoia,* and *Nyssa*. Post-glaciation warming left a large arid region in Central Asia that has maintained the Eurasian temperate forests as distinct eastern and western forests.

The genetic homogeneity of the gypsy moth in Europe suggests that it is from a founder population introduced in recent times. In Europe, the gypsy moth is primarily a pest of lowland oak forests where *Quercus robur* and *Q. sessile* are the predominant species. These are late-breaking oak species and resistance of oak forests to attack by gypsy moth is associated with the phenology of budbreak in the European USSR. Extensive, severe defoliation in Europe occurs at irregular intervals with several decades often separating outbreak episodes.

The introduction of the gypsy moth from Europe to North America was more akin to a return home rather than a cast into an alien land. The gypsy moth not only found evolutionarily familiar tree genera, not present in Europe, that it could utilize as hosts, but vast forests of red oak where budbreak is likely better synchronized with egg hatch than in the forests of Europe. In Asia, gypsy moth is cited frequently as a pest in larch and willow stands. Larch and willow break bud earlier than oak and most other deciduous species.

Recent research at the Universities of Georgia, Maryland, and Michigan as well as my laboratory has shown the importance of phenology in gypsy moth host plant relationships. The gypsy moth hatches over a period of 2-3 weeks. Survival of larvae hatching early may often be poor because leaf buds are not open or the weather is too harsh. Larvae hatching late may have higher success at establishment, but often grow less well and have lower fecundity.

The gypsy moth likely encounters the best synchrony between its development and that of its host plant in the forests of Asia. This, plus female flight behavior and strong regulation by natural enemies, could help keep populations more stable in Asia. In Europe, poor synchrony between the host plant and strong delayed density-dependent regulation may explain the occurrence of outbreaks at long intervals of time. The greater frequency of outbreaks in North America may be a consequence of better, but seldom ideal, synchrony between the gypsy moth and its host plants coupled with weaker density-dependent regulation.

INTERACTIONS BETWEEN CONIFERS AND SPRUCE BUDWORMS

Karen M. Clancy[b]

I am investigating the physiological mechanisms of Douglas-fir (*Pseudotsuga menziesii*) resistance to western spruce budworm (*Choristoneura occidentalis*) injury, and determining how water and nutrient stress affects these mechanisms. Some individual trees, populations, or ecosystems of Douglas-fir may be more resistant to damage from the budworm than others, because of the nutritional quality of their foliage, or the timing of bud break and shoot expansion (vegetative phenology).

Experimental evidence from laboratory diet bioassays, that is supported by field observations, indicates variation in levels of several nutrients in host foliage (e.g., sugars, phosphorus, magnesium, manganese, and zinc) may be important in conferring resistance to the budworm. Phenological variation among trees may also be important; Douglas-fir trees putatively susceptible to budworm defoliation had earlier bud break and shoot expansion than paired resistant trees.

The next step in my work will be to experimentally manipulate various "environmental stresses" such as temperature, water, and soil nutrients to determine how the nutritional and phenological characteristics are affected by stress. I plan to do this in greenhouse experiments with clonal plant material from mature Douglas-fir trees. This type of controlled experimentation is the only way to rigorously test how stress affects important plant resistance mechanisms, and how the budworm responds to the stress induced changes.

Once we know the effects of different types of stress on the host plants, and the consequent effects on the herbivore's fitness, we can begin to predict how global climate change may influence interactions between conifers and spruce budworms. One possible scenario is that warmer winter temperatures will delay bud break in conifers, because the trees will not meet their chilling requirements. This could make trees more resistant to budworm attack.

HERBIVORY IN FORESTED WETLANDS AS INFLUENCED BY FLOODING

R.A. Goyer, G.J. Lenhard, and J.D. Smith[c]

A direct effect of an increase in global air temperature may be the rise in sea level and a related increase of water levels in surrounding fresh water ecosystems. Consequently, coastal areas supporting ecologically important wetland tree species may have to endure increased flooding. Forest wetlands in Louisiana are presently experiencing longer periods of flooding and deeper water levels due to subsiding land surfaces and true eustatic sea level rise. This abiotic stress may predispose the wetland forest trees to biotic stress factors. Current research has demonstrated that stressed plants provide better targets for insect herbivory than vigorous plants. Increased stress caused by flooding is implicated in the recently observed outbreak of the fruittree leafroller (*Archips argyrospila*) on baldcypress (*Taxodium distichum*) and continued outbreaks of the forest tent caterpillar (*Malacosoma disstria*) on tupelo (*Nyssa aquatica*) in Louisiana. Additionally, it is hypothesized that direct effects of flooding on survival of herbivores and/or their natural enemies can result in significant fluctuations in herbivore levels.

Comparisons of herbivore and natural enemy survival have indicated that with the forest tent caterpillar and, to a lesser degree, the fruittree leafroller, the direct effects of flooding appear important in their population dynamics. Density dependent mortality caused by parasites and predators is lacking in permanently flooded habitats as compared with seasonally or non-flooded sites. Direct mortality to herbivores (drowning) also appears important. There is a growing body of data that implicates flooding - like drought - as a stress agent that precipitates physiological changes in trees that influence herbivory. The key factors appear to be foliar changes in total carbohydrates as well as levels of lignin plus cellulose. Other interrelated phytochemicals and defensive allelochemicals may also be important.

WHAT IS MISSING FROM OUR UNDERSTANDING OF PONDEROSA PINE STRESS AND PINE SAWFLY PERFORMANCE?

Michael R. Wagner[d]

Population outbreaks of forest insects represent a fascinating ecological phenomenon. There are numerous hypotheses to explain this sudden and dramatic change in insect populations. One of these hypotheses is that environmental stress such as drought modifies plant quality and increases host suitability for insects.

While this hypothesis has wide appeal and general acceptance, the experimental evidence is primarily anecdotal. From 1983 to 1989 our research group attempted to experimentally test this hypothesis for ponderosa pine, *Pinus ponderosa*, and pine sawflies, *Neodiprion* spp. After five years of experimentally induced stress on ponderosa pine we observed that some sawfly population parameters were affected in some years but we were unable to demonstrate changes in key population parameters sufficient to explain outbreaks.

There are several factors that need further consideration to improve our understanding of drought and forest insect outbreaks. First it is likely that there is some level of stress that produces foliage characteristics that are optimum for sawfly survival. Stress above or below that level is probably suboptimum. Response functions need to be developed for each herbivore and host plant that reflect the range of stress a host plant is likely to encounter. Secondly, there is certainly genetic variation in the response of a host plant to stress. Consequently the stress/herbivore response function will likely be dependent on host genotype.

Finally, perhaps the most important missing component in our understanding of the stress/herbivore response is the relevant stress dimension. The plant physiologist's concept of stress is anything that reduces photosynthesis and consequently tree growth. Growth per se is probably irrelevant to most insect herbivores. Perhaps a more appropriate measure of stress is the degree to which a plant is adapted to its current environment. A slow growing plant adapted to its environment is probably less susceptible than a fast growing plant that is not adapted. An adapted plant will allocate its carbon to above and below ground growth in such a way as to maximize survival. An imbalance in carbon allocation can result from a variety of environmental stresses including but not limited to drought. Consequently, the increased performance of herbivores following drought is only likely to occur when the timing of that drought creates a carbon allocation imbalance. A more fundamental understanding of carbon allocation and the degree to which environmental disturbance, like drought, creates an imbalance in carbon allocation will likely improve our understanding of the stress/herbivore response hypothesis.

EFFECTS OF INFESTATION BY THE BALSAM WOOLLY ADELGID, *ADELGES PICEAE*, ON WOOD AND BARK STRUCTURE OF FRASER FIR AND SILVER FIR

Robert G. Hollingsworth and Fred P. Hain[e]

Response of Fraser fir, *Abies fraseri*, to the balsam woolly adelgid (BWA) was evaluated by studying wood cores and bark samples taken from six sites near Mount Rogers, Virginia, and five sites in the Black Mountains of North Carolina surrounding Mount Mitchell. For comparison, samples were also collected from silver fir, *Abies alba*, at four sites in the Black Forest of Germany. Average BWA densities were higher on trees at Mount

Rogers than on Mount Mitchell trees. The proportions of trees producing abnormal wood in response to low or moderate BWA densities was greater for Mount Mitchell trees than for trees at Mount Rogers.

The results from Mount Rogers support observations made for other fir species that BWA infestation induces outer bark formation, leading to tree recovery. Outer bark formation in trees from the Black Mountains and the Black Forest of Germany was not correlated with BWA density. This may indicate that some factor other than BWA infestation is causing outer bark formation in these trees. If so, this may explain why Mount Mitchell trees support generally lower BWA populations. There was indirect evidence that the outer bark measured in Mount Mitchell trees was incompletely formed, with an indistinct boundary layer between living and non-living bark layers.

We suggest that the rapid bark response to infestation by Mount Rogers trees helps explain the relatively slow spread of BWA in that area, as many insects on heavily infested trees might fail to complete development before successfully reproducing.

DYNAMICS OF BARK BEETLE-CONIFER INTERACTIONS WITH THE ENVIRONMENT: CHALLENGES FOR THE FUTURE

James P. Dunn[f]

Bark beetle-conifer associations are very complex, involving reciprocal interactions between plant defensive chemistry, whole tree physiology, behavior of the attacking beetles, beetle associated fungi, and the environment. Recent evidence suggests that normal changes in environmental conditions may influence the resistance of conifers to bark beetle attack by altering the amount of carbon that is partitioned to protective chemicals. A model based on growth- differentiation balance (Loomis 1932) has been proposed by Lorio (1986) to explain changes in conifer resistance against the southern pine beetle (SPB), *Dendroctonus frontalis*. This model proposes that pines partition energy predominantly to growth processes when environmental conditions are favorable (e.g., adequate light, water, nutrients), but partition proportionately more energy to defensive processes (e.g., oleoresin) when environmental conditions limit cell division and enlargement without adversely affecting photosynthesis and translocation of assimilates. I tested this model by regulating soil water by sheltering and irrigating the root systems of 11-year-old loblolly pine in central Louisiana. A consistently significant 2-4 bar difference in pre-dawn and mid-morning water potentials between sheltered and irrigated trees was established for ca. 40 days before beetle attack commenced. A corresponding decline in net photosynthesis (ca. 40%) and defensive resin flow (ca. 50%) was measured between treatments. SPB colonization results showed that higher resin yielding irrigated trees had significantly more attacks and more dead beetles than sheltered trees. Regardless of the differences in tree physiological measurements between treatments, all trees showed considerable resistance to SPB colonization even though it was one of the driest summers in Louisiana history. These results suggest that the purported strong association between drought stress and bark beetle outbreaks may be overstated.

TREE-STRESS-BUPRESTID INTERACTIONS: OUR CURRENT UNDERSTANDING AND FUTURE NEEDS

Robert A. Haack[1]

The buprestids of most notoriety are those that feed in the cambial region of living trees, of which two of the best studied are the bronze birch borer (*Agrilus anxius*) and the twolined chestnut borer (*A. bilineatus*). However, even for these two species, we still know little about their population dynamics and host-plant interactions, and especially aspects of host finding, pheromone production, and host resistance. For example, although many consider that tree-produced chemicals are very important in host location, practically none have been isolated; however, rhododendrol was recently shown to be a short-range attractant for bronze birch borer (Santamour 1990). Since many buprestids preferentially attack stressed trees, we need to identify the stress-induced compounds (or other cues) that buprestids use. Second, although there is evidence to suggest that some buprestids produce pheromones (Wellso 1966; Dunn and Potter 1988), no such compounds have yet been isolated. Identification of host-produced attractants or pheromones would provide useful monitoring tools. And third, in the area of host resistance, what are the physical and chemical changes induced by larval feeding (e.g., Dunn *et al.* 1990)? The bark ridges that develop over larval galleries (e.g., on birch) indicate that trees can respond strongly to such injury. Other questions are why does the attack pattern differ on ring-porous (from the top down) and diffuse porous (entire tree for several years running) hardwood trees? Is it related to differences in xylem translocation, i.e., primarily the outermost growth ring in ring-porous trees (oak), but several of the outer rings in diffuse-porous species (birch)? Also, why has no completely artificial diet yet been developed for a buprestid? As for the future, with successful buprestid attack being so tightly linked to tree stress, these insects would seem to be favored given that global climate models project warmer and dryer conditions, as well as an increased frequency of extreme weather events.

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IMPLICATIONS OF INTENSIVE FOREST MANAGEMENT IN RELATION TO FOREST INSECT AND DISEASE PROBLEMS

Moderator: Roy Hedden[1]

I recently visited a pine plantation in northern Florida that is an excellent example of intensive forest management. The site had been ditched to drain excess water. It was mechanically site prepared and double bedded to further control moisture. It was given preplant phosphorus fertilization. Second generation loblolly pine were planted six feet apart in the beds with the beds spaced ten feet apart. Pre- and post-emergence herbicides were used to control weeds. By the end of the second growing season in the field, the trees were nine to twelve feet tall. Actually, this type of management may have more in common with intensive agriculture than traditional forest management.

This intensively managed plantation is a very vigorously growing pine stand. It is also very susceptible to pests which attack fast growing young pine. Some of these pests, like pine tip moths and fusiform rust, thrive in this environment where the trees have a large surface area of succulent and high nutrient tissue available for attack. In situations such as this we are just feeding the insects. Furthermore, since there are many similar plantations in this area, pest populations are likely to remain high.

This stand is not only susceptible to pests which attack young living pines. It will also become susceptible to bark beetle attack while it is still relatively young. This is due to crown closure occurring at an early age, and consequently, growth declining while the stand is still young.

Since the initial investment in this plantation is high, little loss from pests will be tolerated. One management option increasingly chosen by forest managers is to apply pesticides. A response reminiscent of intensive agriculture. Are there other options? This is the question that is to be addressed in today's workshop. Each speaker will address this issue from their own perspective. Hopefully, this will provide a starting point for future discussions on the implications of intensive forest management for integrated forest pest management.

WHAT IS INTENSIVE FOREST MANAGEMENT?

John D. Walstad[a]

This paper defines the concept of intensive forest management in terms of the degree of managerial attention needed to achieve resource management objectives. In this context, intensive forest management encompasses the conventional "tree farming" approach to silviculture as well as the more natural approach embodied in "new forestry." Both approaches have distinct advantages, disadvantages, and uncertainties associated with their use. The selection of which system to use requires a detailed examination of landowner objectives, management constraints, and the tradeoffs inherent in both approaches. From a pest management perspective, both approaches will likely present challenges to the forest manager as the future unfolds. Thoughtful anticipation of potential pest problems, in conjunction with integrative planning and careful stewardship, will maximize successful ventures in both tree farming and new forestry.

WHAT ARE THE CHALLENGES FOR PEST MANAGERS IN INTENSIVE FOREST MANAGEMENT?

Darrell W. Ross[b]

Plantations are artificial stands of trees grown for the production of commodity or non-commodity values. In North America, most forest plantations have been established primarily for the production of wood and

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wood products. Plantations typically have reduced species and structural diversity in comparison to natural forests. This reduced diversity presents some special challenges to forest pest managers. Plantation management practices may affect pest populations through changes in the physical environment, the abundance of natural enemies, or the quantity and quality of host trees. Because of the high degree of managerial control over stand structure and composition, plantation management also provides opportunities for silvicultural control of pests. However, management objectives and constraints may limit silvicultural options for pest management. Direct control of pest populations becomes increasingly feasible from an economic perspective with increasing value of the crop trees. Effective pest management programs should be integrated within a comprehensive plantation management plan and should consider all the potential pests that may interfere with management objectives. Pest management must be built upon a thorough understanding of the ecological relationships among the crop trees and their associated organisms.

CHALLENGES FOR INTENSIVE PEST MANAGEMENT IN SEED ORCHARDS

Gary L. DeBarr[c]

There are large applied forest tree improvement programs for Douglas-fir in the Pacific Northwest and loblolly pine in the South. There are also improvement programs for tree species of lesser commercial importance. Intensively managed seed orchards, which produce tons of genetically improved seed used to reforest millions of acres of commercial forest land, are key elements of these programs. Insect pests are a very serious problem in seed orchards. In the 1970s and 1980s researchers developed insect control methods that were quickly implemented by pest management specialists and orchard managers. As a result, seed yields exceeded expectations. The 1990s bring new challenges for seed orchard pest management. New challenges include: 1) insuring that insecticides are available for use in seed orchards; 2) reducing insecticide loads in orchards; 3) improving efficiency of control tactics; 4) addressing changing orchard management goals; 5) playing a role in orchard site selection; 6) gaining a better understanding of interactions among species in the seed orchard canopy; and 7) developing noninsecticidal tactics and strategies for controlling insects. Ways of addressing these challenges are discussed.

PROBLEMS WITH USING PESTICIDES IN THE FOREST ENVIRONMENT

R. Scott Cameron[d]

Forest lands account for 32% of the total land area in the United States, but only about 1% of the total pesticide volume used is applied to forest lands. Still, intense controversy and public concern have been associated with the use of pesticides in forest management. There is a general-public perception that all chemicals, especially synthetic pesticides - in any amount, are harmful to the environment. There are risks associated with everything we do, but perception of unacceptable risk does not always agree with fact. There are many things that people are exposed to, such as riding in a vehicle, eating mushrooms, or smoking which pose a far greater life-threatening risk than the usual levels of pesticide residues encountered. On the other hand, there are real problems with the use of pesticides including: short-term effects on pest populations, pest resistance to pesticides, detrimental effects on beneficial insects and other non-target organisms, release of secondary pest problems, chronic effects, worker safety, hazardous wastes, bio-accumulation of some pesticides, and off-site movement. Relatively small amounts of pesticides, especially insecticides, actually reach the target organisms. There is open disagreement among scientists on how to interpret results of pesticide test data. Also, there are concerns which go beyond our knowledge about pesticides which deserve serious consideration. A multitude of laws and regulations affecting the pesticide industry have emerged as a result of the concern and risks associated with the use of pesticides. These regulations have made it much more difficult to register and use any pesticide (including environmentally safer pesticides). The costs associated with pesticide registration and use have increased dramatically in recent years. Registration of each new pesticide compound is estimated to cost companies about $40 million. Factors increasing costs associated with pesticide registration and use include: expensive toxicity and environmental fate tests, registration and re-registration fees, raw materials and manufacturing costs, legal defense costs, liability insurance, monitoring pesticide deposits and movement, etc. For economic and legal reasons, chemical companies have little interest in including or maintaining "minor uses" (including most forestry uses) on pesticides as forest management tools due to the mounting regulations, public concern, litigation, and costs of monitoring pesticide residues. Private forest industry companies are particularly concerned about liability associated with chemical applications and require high (and sometimes difficult to obtain) amounts of liability insurance for contract applicators. Based on current trends it is likely that in the future there will be: reduced pesticide use, fewer pesticide products will be available, reduced application rates per acre will be used, pesticide delivery systems will be improved, costs of pesticides will be higher, silvicultural and biological controls will be emphasized, many areas currently being treated with insecticides will not be treated, pest management costs will increase, forest productivity will decrease and forest products will be more expensive. There is an urgent need to focus public attention and research dollars toward truly high risk problems, improved pesticide application technology, and development of safer pest management tools.

POTENTIAL FOR ENVIRONMENTALLY LOW IMPACT PEST MANAGEMENT STRATEGIES AND TACTICS IN INTENSIVELY MANAGED FOREST SYSTEMS

T. Evan Nebeker[e]

The idea or concept of intensively managed forests has been well outlined by Jack Walstad earlier in this session. As we envision these intensively managed forests we see that they are unique in many ways. The ability to find cost effective, socially acceptable, and ecologically sound means of managing pest populations becomes central to the issue of pest management in such a setting. However, with the demands from society, those practices failing to be cost effective may become cost effective as we are able to place a value on associated environmental and ecological impacts of various pest management strategies and tactics.

Let us define environmentally low impact pest management as - practices that do not (as far as we know) harm the environment and are ecologically sound. That is to say, the management systems are aimed at the manipulation of naturally occurring elements without causing any major instabilities. For example, the use of parasites, predators, pathogens, and chemical cues are part of this management tool kit. Also considered part of this tool kit would be; 1) host selection based on naturally occurring resistance to given pest species; 2) stand modification from a silvicultural basis, i.e. thinning; and 3) gene insertion to increase lethality or resistance to pest populations.

Conservation of our naturally occurring parasites and predators should be at the top of the agenda. Many, if not all, of the current management strategies - such as salvage in association with bark beetle populations - work directly against the conservation of the natural enemy populations. Many of the natural enemies are removed from the forest during salvage operations and only through their powers of dispersal are they able to return and locate suitable hosts.

We also need to identify the mechanisms which cause populations to fluctuate in time and space. Pathogens, with possible emphasis on viruses, need to be considered in more detail. Recent advances in technology removes the past limited possibilities of utilizing such organisms. The same is true for the manipulation of the host (tree) genome or through the insertion of new genetic material. The deployment (mosaics in which they are planted) of such material will be critically important to maintain the desired diversity to avoid problems associated with basic monocultures.

To this point the above mentioned types of pest management options have not been considered, in general, for use in intensively managed forests. As the ecological and environmental awareness of our society continues to grow, these otherwise non-cost effective tools will be considered in a new light. Giving them a real potential for use in future intensively managed forests. The driving variable, as in most systems, will be economic in nature.

WHAT CAN WE LEARN FROM PEST MANAGEMENT IN INTENSIVE AGRICULTURE?

Jane Leslie Hayes[f]

Forest pest management has already borrowed heavily from its agricultural counterparts, and experienced some of the same tactical problems. While some consider efforts in agricultural pest management a model to follow, others feel it is a series of failures to avoid. I argue that agricultural pest management is most aptly described as an ongoing experiment, but one that has progressed by trial and error rather than in a concerted manner; therein lies the most important lesson for forest pest management. In the short-run, agricultural pest management can point to a number of successes; however, a preoccupation with high yield has meant ignoring the long-term impact of current pest management and production practices on natural resources. Chronic pesticide use has resulted in the inevitable development of pesticide resistance and secondary pest problems. Yet, agricultural crop protection remains largely chemically dependent. The answers lie in developing the alternatives and strategic programs that integrate them. Examples are presented of pest management practices and research efforts in cotton production, arguably one of the most intensively managed agroecosystems. Cotton production is a highly mechanized industry and all aspects are intensively managed: Pest (especially insects, diseases, and weeds) management takes place year round and involves all phases of production. Alternative control tactics representing all protection methods (host plant resistance, and chemical, genetic, cultural, and biological control) are under investigation and in some cases in practice, but overall the process is painfully slow; limitations include inadequate data and funding for necessary large-scale studies, and counter-productive efforts. Overall, the lessons are not new: In the development of alternative tactics and strategies, the burden of responsibility is on research/extension to demonstrate significant results. Research efforts should not be limited to, but must focus on compatible, cost effective tactics and strategic approaches. Integrated resource management programs must be developed on a wide-area scale, and require monitoring of both quantitative and qualitative changes in target and non-target components of a system. And because these biological systems are dynamic and evolve, control programs must be developed that anticipate change. Finally, we must educate resource managers that pest management is a continuous process, not a one-time solution.

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GLOBAL CHANGE AND ITS POTENTIAL TO AFFECT FOREST PEST MANAGEMENT

Moderators: Gerard D. Hertel[1] and Dennis Souto[2]

Global Climate Change

The news media have spent a lot of time and space over the last few years on the "greenhouse effect" that leads to global climate change. Believe it or not we get a great deal of our "working knowledge" about the topic from the popular media. No one seems to know what the effects of global climate change will be or where they will occur. Everyone recognizes the large uncertainty/variability in the predictions being made. There is the potential for forest tree distributions to change too quickly for adaptation. Chemical and physical changes will have effects on pest/host interactions in a yet to be determined way. Trees are also important for mitigation, because they use the carbon from atmospheric carbon dioxide.

Forest Health Monitoring

Historically, we have found ourselves in a position of responding to problems after they occurred. A procedure was needed to monitor the status and trends of ecological conditions so that we could anticipate emerging ecological problems before they became crises. To begin the monitoring process a new USDA Forest Service/US EPA initiative on forest health monitoring started last year in New England. By 1995 all States will be involved.

The Workshop

The goal of this workshop was to make forest entomologists more aware of the global climate change issues and forest health monitoring scope and direction. Speakers were invited to provide information and answer questions.

The audience was encouraged to raise issues and make recommendations so the "powers-to-be" could look ahead to determine information needs, research direction, or develop mitigation strategies.

The final section on Issues and Recommendations highlights all the questions raised and recommendations made during the workshop. We were pleased with the willingness of the audience to be involved. The discussions on Climate Change (led by Dr. Fox) (see items 1-14) really emphasized the need for research to reduce the uncertainty in "change" predictions at the regional scale. The Forest Service, through its Global Change Research Program, should provide to the forestry community the state-of-the-knowledge on a regular basis. Other outlet approaches (videos, brochures, newsletters, etc.) besides scientific publications should be used. People (writers-editors) and financial resources should be directed "off-the-top" to get this done. Otherwise, we will continue to use the popular press for our information.

Dr. Smith's talk generated some very specific recommendations for Forest Insect and Disease Research to consider. Items 15, 20, and 23 were considered to be most important by the group.

The forest health monitoring talks by Terry Shaw (substituting for J.E. Barnard) and Margaret Miller-Weeks also generated a lot of good discussion. By far the most significant concern was with indicators of response (numbers 30 and 31). The sense of the recommendations was to move slowly. Make sure that a lot of thought is given to what data are collected and why those data are collected. Also consider how these data will be used in annual reports.

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I. WHAT'S ALL THIS FUSS ABOUT GLOBAL CHANGE?

Douglas G. Fox[a]

The issue of global change will be reviewed from a scientific perspective. Radiation processes, "greenhouse gas" concentrations, General Circulation Models and climate data trends will be used to separate fact from speculation in predicting future global climates. An attempt will be made to translate global predictions into regional and more local questions concerning natural resource managers. Finally the Forest Service Global Change Research Program will be reviewed and it's Interior West component discussed.

What is Global Change?

Global Change is a collection of issues that are global in scope and drive changes in the Earth system. Most notable among these are increases in the amount of relatively active chemicals in the atmosphere. The presence of these chemicals is likely to alter the climate of the Earth. A changed climate presents major challenges to forest resource managers to maintain and increase commodity and non-commodity outputs. However, it may also provide an excellent opportunity to practice responsible ecosystem management.

Fundamentally, global change is a natural resource issue, because terrestrial ecosystems are needed to sustain the human experience. Effects of global change on forests and related ecosystems will need to be assessed and understood. Forests and their management must play the key role in strategies to respond to the challenges of a changing climate. These strategies will be global in scope in as much as the developed world and the developing world must together evolve sustainable resource management.

Global change research requires study of interactions between forest ecosystems and the physically and chemically changing atmospheric environment. Because the climate is being altered in such fundamental ways our empirically based management practices need to be evaluated. Management decisions increasingly will include a climate dimension as forest and related ecosystem values, both economic and social, shift in response to the changing climate.

What Are the Facts?

Climate is influenced by a wide variety of processes operating on different scales. Land surface changes alter radiation inputs and local moisture cycles. Pollutants such as SO_2, NO_x, and volatile organic compounds (VOC) alter atmospheric chemistry and deposition patterns as far as 1,000 km from their source. Greenhouse gases have been increasing globally,and they affect the fundamental energy balance of the Earth system.

Among these increases, concentrations of greenhouse gases have received a great deal of recent attention. This is because: 1) there is excellent documentation of significant increases; 2) the role of greenhouse gases in the global atmosphere and their effect on climate are reasonably well understood; 3) the theoretically predicted consequence of increased CO_2 concentration is a significantly warmer global climate; and 4) the possible consequences of a warmer global climate are altered weather and regional climates which, in turn, can give rise to significant society impacts.

The climate system can be considered as a subset of the Earth system. The Earth system consists of the land, the atmosphere, the cryosphere, and the oceans all linked by hydrologic and by biogeochemical cycles. Within this system physical, chemical and biological processes operate on terrestrial and marine life and on the climate. The climate is an average of the continuously varying weather phenomena that the system generates.

The climate depends upon:

1) Radiation and energy balance.
2) Global General Circulation of Atmosphere & Oceans.
3) Hydrologic cycle
4) Terrestrial Ecosystems

The climate system is very complex. It is impossible to keep track of all the potential effects, all the exchange processes, and all the complex feedback mechanisms that occur in the system without the help of computer models. Similarly, data records are not long enough, nor are they sufficiently unambiguous, to provide clear suggestions about what our future might be like. For this purpose, elaborate computer models of the system must be built. Observations, while useful, are not the answer to issues of climate change. First, we do not have the capacity to measure the system in it's full complexity with sufficient accuracy and, secondly, we do not have sufficient historical records for such measurements to be meaningful.

While climate change itself is a major concern, its effects on global natural resources may be considerably more important to the people of the world. Potential climate changes influence natural ecosystems in a hierarchical fashion. Directly, because as temperature and moisture regimens change the vegetation in equilibrium with the current climate changes and, indirectly, because disturbance phenomena - fire, insects and disease - respond to altered climate, either exacerbating or mitigating the direct climate effect. The effect of increased atmospheric CO_2 concentration, while providing competitive advantage to plants in general and individual species in particular (e.g., C_3 carbon pathway plants will use additional CO_2 more effectively than C_4 plants), may at the same time adversely affect vegetation because of climate instabilities.

International & National Research Efforts

No doubt because it affects all of us, global change has become an international environmental issue and a "Contemporary Resource Issue" in the 1990 RPA Program. Internationally, under the auspices of the United Nations UNEP and WMO, the Intergovernmental Panel on Climate Change (IPCC) has been established. Major objectives of the IPCC activity are: 1) improve scientific understanding; 2) assess potential effects; and 3) develop response strategies. Coordinated with IPCC and under the support of the International Council of Scientific Unions, the International Geosphere and Biosphere Program (IGBP) has been established as "A Study of Global Change." The IGBP is engaged in the development and conduct of large scale international experiments to aid in our understanding of the effects of global change.

The United States Global Change Research Program (USGCRP) represents the United States Government's response to these international scientific and policy issues. The Committee on Earth and Environmental Science (CEES), under the direction of the President's Science Advisor, developed the USGCRP to assure an integrated research approach by all federal research agencies. The CEES is currently establishing a Mitigation and Adaptation Response Strategy (MARS) involving virtually all federal agencies and tasked to ensure coordinated approaches to develop policy responses to the challenges uncovered by the global change research effort.

The Forest Service Global Change Research Program (FSGCRP) is a major component of the USDA Global Change Program and, in turn, a component of the USGCRP. FSGCRP is asking the following questions:

1) What processes in forested ecosystems are sensitive to physical and chemical change in the atmosphere? Or in policy terms: is there a problem?

2) How will future physical and chemical climate changes influence the structure, function, and productivity of forest and related ecosystems, and to what extent will forest ecosystems change in response to atmospheric changes? Or in policy terms: how serious is the problem?

3) What are the implications for forest management and how must forest management activities be altered to sustain forest productivity, health and diversity? Or in policy terms: what can be done about the problem?

The Forest Service will address these questions through the conduct of research that can be grouped into nine distinct program elements. The program elements are:

I. Energy and Biogeochemical Cycles, magnitude, feedbacks and scales;
II. Terrestrial Vegetation, physiology and health;
III. Water, availability and quality
IV. Aquatic Ecosystems and Wetlands, structure, function and productivity;
V. Insect, Pathogens and Microbes, magnitude, frequency and effects;
VI. Fire, magnitude, frequency, and effects;
VII. Wildlife and Domestic Species, adaptability and management;
VIII. Soil, health and productivity;
IX. Economics and Policy, values, tradeoffs and management.

II. HOW CHEMICAL AND PHYSICAL CHANGES CAN AFFECT PEST POPULATIONS

William H. Smith[b]

Global climate change, 2-3^{o}C increase in the annual mean temperature of the earth in association with uncertain perturbation of regional hydrologic cycles, has enormous implication for forest ecosystem structure and function. The effects of global climate change will be greatest in the higher latitudes of the temperate zone. In North America, major responses to global warming could include: a tundra retreat at its southern boundary, northward expansion of the boreal forest, and northward expansion of the northern hardwood forest. Current strategies to predict individual forest tree response to global change include: tree physiological evidence, model (empirical, simulation) evidence, and paleoecological (pollen record) evidence. None of these methods, however, integrates the influence of insect infestation or pathogen infection into their predictions of future forest compositions. Several examinations of the northern hardwood forest dynamics in a warmer climate, using existing strategies, have predicted an expansion of sugar maple. An examination of the dramatic interaction of sugar maple with its large compliment of insect and pathogen stresses and strong interaction with climate, however, illustrates the critical need to systematically and comprehensively integrate insect and pathogen dynamics into predictions of future forests in a different climate. In addition, the potential for stratospheric ozone degradation, with associated potential for increased UV-B exposure at the surface of the earth has important implications for forest tree-forest pest interactions. Forest health professionals, especially entomologists and pathologists, must play a very active role in efforts to predict AND manage the risks imposed on forests by global change.

III. Forest Health Monitoring: Taking the Pulse of America's Forests

Joseph E. Barnard[c]

The health of the Nation's forests has gained increased attention with current concerns about acid rain, global change, and a variety of insect and disease problems. Monitoring of forests to describe their condition and identify changes that may be occurring is needed to provide the factual information base upon which public policy and private ownership decisions can be made. Providing this information is the goal of Forest Health Monitoring.

What is Forest Health Monitoring?

Forest Health Monitoring is the repeated recording or sampling of pertinent data for the comparison of that data to reference or identified baseline information. Monitoring always involves the determination of changes over time and usually also involves interpretation with respect to the reference or baseline. The goal is to answer the "What, Where, When, How, and Why" of forest health. It is a three-tiered approach to collecting, analyzing and reporting information about the health of all forest lands in the U.S. at several levels of detail. The three tiers are:

1) Detection Monitoring (What, Where, When): Records the condition of forest ecosystems, estimates baseline ("normal") conditions, and detects changes from those baselines over time.

2) Evaluation Monitoring (How): Determines the specific nature of detected changes and, if possible, the causes. Provides a basis for corrective actions if they are needed. Hypothesizes causes that can be tested experimentally or by information from Intensive-site, Ecosystem Monitoring.

3) Intensive-site, Ecosystem Monitoring (Why): Provides very high-quality, detailed information to enable a rigorous assessment of cause/effect relationships, to document processes that shape forest ecosystems, and to support experimental research on a small set of sites representing important forest ecosystems.

Research on Monitoring Techniques: This activity, which supports all three tiers, encompasses research on the biological, statistical and analytical aspects of monitoring forest health. This is required to continually improve the effectiveness of Forest Health Monitoring.

How is it Begun?

1990 Implementation

Detection Monitoring was implemented in 1990 in the six New England States (Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island) in close cooperation with the State Foresters. About 260 permanent monitoring plots were established and measured. Forest Health Monitoring has been planned and implemented in close cooperation with EPA's Environmental Monitoring and Assessment Program (EMAP). Through Forest Health Monitoring, the Forest Service will collect all the necessary information for the forest ecosystems component of EMAP.

1991 Activities

In 1991, Detection Monitoring will be continued in New England and initiated in six additional states--New Jersey, Delaware, Maryland, Virginia, Georgia, and Alabama. As in 1991, the State Foresters are fully involved.

In 1991, we are also developing detailed plans for Evaluation Monitoring and Intensive-site, Ecosystem Monitoring, as well as conducting research on monitoring techniques.

Why Monitor Forest Health?

1) The Law Requires It.

*** Public Law 100-521 (the Forest Ecosystem and Atmospheric Pollution Research Act) directs the Forest Service to "increase the frequency of forest inventories in matters that relate to atmospheric pollution and conduct such surveys as are necessary to monitor long-term trends in health and productivity of domestic forest ecosystems...."

*** Public Law 95-313 (the Cooperative Forestry Assistance Act) and Public Law 101-624 (the "1990 Farm Bill") authorize the Forest Service to conduct surveys to detect and appraise man-made stresses affecting trees, to monitor all U.S. forests to determine detrimental or beneficial changes over time, and to annually report the monitoring results.

2) Conservation Demands It.

The Forest Service motto is "Caring for the Land and Serving People." To care for the land, we must know the health of the land and its resources--just as physicians must know the health of their patients. To nurture forests to better serve people, we must know the current ability of the forests to meet people's needs--that is, we must monitor their health.

IV. FOREST PEST MANAGEMENT EVALUATION MONITORING

Margaret Miller-Weeks[d]

In recent years, concerns have been raised over the relative health of our nation's forests. A national initiative is underway to track the long term trends in forest health and productivity through detection, evaluation, and research monitoring. Evaluation monitoring activities are implemented to delineate the extent of identified or perceived problems and provide additional data on tree condition and forest stressors, particularly pests and pathogens.

Forest Health Protection in the Northeast has been actively involved in evaluation monitoring, even before the national initiative was conceived. In the early 1980's, concerns about the status of the spruce-fir and hardwood resources prompted several evaluation surveys. Three major projects that were initiated were the spruce-fir decline and mortality project, the Vermont hardwood tree health survey, and the North American Sugar Maple Project.

The objectives of the spruce-fir project, begun in 1985, were to assess tree crown symptomatology and trends in tree decline, and map the extent of mortality in New York, Vermont, New Hampshire, and western Maine. The symptomatology project was designed to assess visual crown symptoms and the role of historically important damage agents. Permanent plots were established throughout the survey area and visited annually. The mapping project was designed to determine the extent of red spruce and balsam fir mortality by cover type and elevation. The survey was based on color infrared aerial photography and Geographic Information System analysis. A resurvey of a portion of the original survey area was initiated in 1989 to determine any changes in the extent or intensity of tree mortality.

The Vermont Tree Health Survey was conducted in 1985-1986 to determine the area of hardwood decline and mortality and to provide baseline data on crown condition along with stand and site factors. This was a systematic survey of the hardwood resource throughout the state based on color infrared aerial photography and ground plots. The areas are currently being resurveyed to determine trend in tree condition and mortality.

The North American Sugar Maple Project, initiated in 1987, is composed of an international network of plots in the northeastern United States and eastern Canada. The objectives of the project are to determine the rate of change in tree condition in various stands and determine the possible causes associated with observed decline. The plots are visited annually to determine trend in tree condition.

In addition to specific evaluation surveys, Forest Health Protection is responsible for the annual assessment of the distribution and impact of various pests and pathogens. This information is summarized annually in regional forest conditions reports. With the increased emphasis on forest health, it has been decided to prepare regional, as well as national, forest health reports which will include information from the nationwide detection plot network, the evaluation surveys, and assessments of pest distribution and impact. This approach demands long term commitment of resources and incorporation of new technology, such as remote sensing and GIS, into the data management and analysis activities.

Issues and Recommendations:

I. RELEVANT TO GLOBAL CLIMATE

1) Why are insect research funds decreasing?

2) Conflicting opinions in scientific community. (15)[e]

3) How significant are net impacts?

4) Lack of appropriate political response. (4)

5) How good is tree/insect science relative to atmospheric changes? (12)

6) What are practical management options? (3)

7) How do management activities affect climate?

8) How important to entomologists? (4)

9) How do you separate "natural" trends from "abnormal" changes?

10) How will insect/plant interactions change with global changes? (16)

11) How will global warming affect forest ecosystem changes? (16)

12) What about regional changes?

13) Will climate predictions be regional enough? (20)

14) How does North American deforestation in the 1800's compare to current deforestation in terms of impacts? (3)

II. PHYSICAL AND CHEMICAL CLIMATE AFFECTS ON PESTS

15) Research needed on UV, global warming, rising CO_2 effects on pests, pathogens, as well as hosts. (16)

16) Simulating effects beforehand.

17) Movement/dispersal biology needs focus. (1)

18) Animal impacts on species.

19) Changes in natural enemies. (3)
20) Genetic variations' impact/effects. (12)

21) Epizootic occurrences. (1)

22) Influence of flooding stress.

23) Increased multiple-stress experiments. (13)

24) Provenance trial work needed. (2)

25) Differential affects on different pest species. (1)

26) Priority pest list and monitor most important ones. (15)

27) Stresses already happening further south--study it there. (1)

III. MONITORING

28) How much effort is being invested to establish baseline trends? (1)

29) Insect-related research on long-term monitoring sites--compatible? (3)

30) Are we using the right indicators? (35)

31) Is sampling intensity great enough to detect indicator changes? (32)

32) How/who will monitor agroforestry ecosystems?

33) How will monitoring and global change assessments be linked? (8)

34) Are we looking for too much information from plots? (5)

35) How can information be useful at State level? (2)

36) Reconcile management and regulatory agencies' goals.

37) What should be contained in annual reports? (1)

38) Can we use existing activities/information to monitor change? (7)

39) Do we need international monitoring to accomplish goals? (1)

40) Will program last long enough to accomplish goals? (6)

41) Need North American database and coordination. (8)

42) Incorporate review system to adjust as needed. (3)

43) How can we incorporate wildlife indicators when identified? (1)

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[e]The number in parentheses reflects the number of people in the audience who thought the question or issue was important.

BIOTECHNOLOGY - FUTURE OF TREE RESISTANCE AS A PEST MANAGEMENT TOOL

Moderator: Martin Hubbes[1]

Environmental, political and economic concerns are the main driving forces to replace the traditional use of agro-chemicals for pest control. One of the obvious options is the development of tree resistance as a pest management tool. It fulfils best today's environmental concerns. However, breeding trees for pest resistance is not an easy task. The lengthy life cycle and the breeding process of forest trees is a major hinderance.

Another important weakness is our insufficient knowledge of the biochemical mechanisms and the molecular genetic basis of traits that control pest resistance (Hubbes 1990a, 1990b). Recent advances in the field of biotechnology may help to solve some of the above problems, because this technology comprises a number of techniques, such as cell culture, cell fusion, recombinant DNA technology, and bioengineering. With these approaches, greater control over biological processes and a faster pace in developmental changes can be achieved. It provides also the possibility to create completely new gene combinations that otherwise could not easily be obtained with traditional breeding techniques. But as promising as this new technology is, it is also not without concern. Fear exists that some of the newly created combinations may go out of hand and cause detrimental side effects to human health. But with a very rigid and careful testing and monitoring system, the risks that these newly developed organisms may present to human and animal health is very low (Gasser and Fraley 1989, Nutter 1991).

A further problem that hinders the ample application of biotechnology in forestry and the development of tree resistance is the state of cell and tissue culture technology. Once this technology is developed to the point at which seedlings can be grown in large quantities from callus and cell cultures, a major stumbling block will be eliminated and an explosive development in forest biotechnology can be expected.

However, the acceptance of methods of biotechnology in the field of forestry is rather slow, when compared to agriculture or medical sciences. Training of competent molecular biologists within the curricula of the faculties of forestry is not at the point where it should be and, therefore, creates a lack of manpower in forest biotechnology. This will have a negative impact on the progress expected from forestry science. Many opportunities, including funding, which are vital to the scientific progress in forestry and pest management, will be lost. Yet, despite all the excitement generated by gene splicing in medical research, the application of biotechnology in agriculture and forestry could have an impact that may overshadow its success in the medical sciences (Hubbes 1987). The potential to develop tree resistance as a pest management tool is such an important example.

During the present workshop, five papers address the future of tree resistance as a pest management tool. The abstracts of these papers highlight the ongoing research in their respective field and clearly demonstrate that pest resistance as a management tool is not only feasible but a reality. The papers also point out the route that should be taken to accelerate the creation of pest resistance. Needless to say, methods of molecular biology will help us to understand and solve our most urgent problems in pest management. We should be aware that we are at the beginning of a new area of pest management armed with powerful tools that will continue to revolutionize biology.

TARGETING TRANSGENIC TREES RESISTANT TO INSECT PESTS

David I. Dunstan, William L. Crosby, and Fred Constabel[a]

Resistance in plants to insect pests can be achieved by recombinant DNA technology. At the Plant

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Biotechnology Institute, three procedures are being explored: 1) the transfer and expression of heterologous genes encoding a toxic protein (*Bacillus thuringiensis* toxin, 2) the over-expression of genes encoding enzymes catalyzing toxic secondary metabolites (e.g., alkaloids), and 3) the interdiction of biosynthetic pathways leading to metabolites which function as attractants (e.g., glucosino-lates). Model systems use tobacco and rapeseed. Transfer of heterologous genes to trees (spruce) has led to transient expression in cells, so far. Development of improved insertion technology, gene constructs, and plant regeneration protocols will result in stable expression and transgenic trees (spruce, pine), thus transgenic insect resistant trees. Temporal and spatial-specific expression in plants and target specific gene products will safe-guard against undesirable effects on forest ecosystems.

TRANSGENIC EXPRESSION OF BACILLUS THURINGIENSIS INSECTICIDAL GENES AS A MEANS OF PEST CONTROL

Michael A. Harkey, Milton Gordon, and Douglas Bradley[b]

For a variety of economic and environmental reasons, the search for safer, more specific pesticides has become a major effort in forestry. *Bacillus thuringiensis* (B.t.) has emerged as a useful agent in this regard. Several strains of B.t., a common soil bacterium, produce insecticidal protein organisms. A wide variety of B.t. strains exists, harboring a large number of such proteins, which together form a broad arsenal against a variety of insect pests. In addition to the advantage of being highly selective, these insecticides have other useful properties: they are natural products, they are biodegradable, and they can be expressed as part of the natural defence system of transgenic plants.

We, and others have been exploring the feasibility and the effectiveness of producing transgenic plants that express various B.t. insecticidal genes. The major advantages of transgenic expression, as opposed to conventional spraying of insecticidal agents are: 1) controlled uniformity and reproducibility of distribution of the agent among the plants, and 2) elimination of the need for production, transportation, and application of the agent. Major potential disadvantages include: 1) unexpected deleterious effects on the plants vitality, 2) excessive pressure on insect populations to develop resistant strains, and 3) public fears of transgenic "monsters" getting out of control.

A major part of the strategy in producing effective strains of transgenic plants is the design of the gene construct to be expressed. Basically, the construct must contain a regulatory domain that is capable of appropriate expression in the plant, and a structural domain that encodes the protein of interest. The choices made within these two categories must address a number of considerations, such as those mentioned above, that range in scope from technical, physiological, toxicological, and ecological, to public relations and political. In the following paragraphs, we discuss the pros and cons of some of the possible strategies for construction of pest-control transgenes.

Choice of structural Domain. Since each B.t. protein targets a particular group of insects, one can tailor the types and numbers of protein coding domains used to a particular management problem. One could express a combination of genes to broaden the defense of a plant. The development of resistance in the target insect population can be discouraged by expression of combinations of proteins with overlapping toxicity ranges, or rotation and/or mixing of the B.t.-expressing strains in the field. Truncation of the protein coding region (removal of the carboxy-terminal half) may provide two advantages in a transgenic plant. While the smaller peptides retain their insecticidal activity in most cases, they are sometimes more stable than the full length proteins, and their synthesis should impose a lesser metabolic burden on the host plant. Finally, re-engineering of the coding sequence to accommodate the codon usage pattern of the plant, has been shown to greatly increase the rate of synthesis of B.t. proteins in transgenic plants.

Choice of Regulatory Domain. Regulation of B.t. genes in plants has usually involved "non-specific" promoters that express essentially at all times in all tissues. Not surprisingly, the most dramatic results have been obtained with gene constructs with strong non-specific promoters that express B.t. at high levels in test plants. But this approach may have intolerable costs, such as: over burdening the plants metabolic and synthetic machinery, accumulation of large amounts of foreign protein that could interfere with normal physiological processes, and excessive pressure on the target insect population to develop resistant strains. Thus, low level non-specific expression has emerged as a more attractive strategy. An alternative approach is tissue-specific expression; directing the B.t. to the most vulnerable parts of the plant. However, few candidate promoters have been well characterized so far. Another useful approach is the expression of B.t. only in response to intense insect pressure. This would allow the plant to function normally, without the negative consequences of expression of a foreign gene, until such time as the insect burden became intolerable. It would also set up a controllable dynamic equilibrium, allowing the insect population to survive at low density without chronic exposure to B.t. promoters, which have been characterized from a variety of plant defence genes that are expressed in this manner. Using such a promoter, we have generated transgenic tobacco liens that respond to damage to one or a few leaves, by wide spread expression of a test gene within hours of the damage. The use of defence gene-B.t. constructs in transgenic plants provides a useful strategy by which to balance the many conflicting requirements inherent in forest, and agricultural pest management.

USE OF THE PROTEINASE INHIBITOR II GENE FOR INCREASED PEST RESISTANCE IN POPLARS

Harold S. McNabb, Jr., Elwood R. Hart, Richard B. Hall, Scott A. Heuchelin, Ned B. Klopfenstein, Kurt K. Allen, and Robert W. Thornburg[c]

The incorporation of current gene transfer technology in woody-plant insect and pathogen resistance studies has much to offer researchers. We have transferred components of the proteinase inhibitor II gene from potato into three hybrid clones of *Populus*. One component, the wound-inducible promoter was used with the reporter CAT gene. Systemic production of proteinase inhibitor promoter mRNA has shown the promise of using wound-inducible promoters as regulators for other resistance gene constructs. One of our transformed Hansen aspen hybrids with this construct was field planted during the summer of 1989. At the end of the second field season, the total basal diameter growth of the transgenic trees was significantly less ($p \leq 0.05$) than the nontransgenic trees. Another component, the proteinase inhibitor II constitutive part with the cauliflowers mosaic virus promoter is presently being bioassayed, with initial encouraging results, in transformed aspen hybrids and the Ogy hybrid clone of *P. X euramericana*. Gene technology itself does not stand alone in pest resistance development; it is a part of an ongoing forest genetics research program.

INSECT VIRUSES AND THEIR ROLE IN PROTECTION

Basil M. Arif[d]

Insect Baculoviruses are generally highly host specific parasites in that they only infect members of the host's own family. Therefore, they offer a potentially viable alternative to chemicals in the control of forest and agricultural insect pests. One of the major pests of the North American forests is the spruce budworm, *Choristoneura fumiferana*, which destroys large acres of harvestable forests each year. Unfortunately, the baculovirus, a nuclear polyhedrosis virus (NPV), that infects the budworm is not highly virulent and, therefore, is not economically viable on a wide-scale basis. With the advent of genetic engineering and technical capabilities to alter viruses to improve their insecticidal property, several alternatives were outlined to modify the virus to enhance its virulence against the spruce budworm. Several genes that were deemed harmless to non-target organisms were identified for insertion into the baculovirus of the spruce budworm. For example, the B.t. delta endotoxin gene and the synergistic factor (SF) gene could prove to be very useful in this regard. The SF gene codes for a protein associated with the occlusion body protein of a granulosis virus and was found by Tanada and coworkers to enhance the virulence of certain nuclear polyhedrosis viruses. A site, the polyhedrin gene location, on the genome of the budworm NPV was identified as the target site to insert the foreign gene. The polyhedrin gene was isolated, cloned, and sequenced in its entirety. Vectors designed to transfer the synergistic factor gene were constructed based on the polyhedrin gene sequence. We are in the final processes of vectorology to construct recombinant budworm NPV. Other genes that could enhance viral virulence are also being considered. It is hoped that soon there will be a more effective biological control agent against one of the most devastating forest insect pests. Naturally, any recombinant virus will have to be tested stringently for safety to non-target organisms before use in the field.

PEST RESISTANCE BY IDEOTYPE BREEDING

Louis Zsuffa[e]

The ideotype tree is a biological model expected to perform in a predictable manner within a defined environment. The ideotype concept is promoted as a foundation for an operational genetic improvement program for tree crops. A implicit assumption of the ideotype breeding approach is that yield enhancing traits can be manipulated genetically and ultimately assembled in a single genotype.

Pest resistance is an important, yield-enhancing ideotype trait which can be manipulated genetically. The degree and type of genetic control varies with the pests and hosts, and its understanding is important for breeding. Traits controlled by single genes are attractive for manipulation; however, trait correlations are decisive for success. Thus, associated negative effects of gene interactions, which are likely the results of linkage and pleiotropy, may hinder success. The data base on critical aspects for genetic control (such as inheritance, heritability, molecular basis, and gene interactions) for ideotype traits in trees is very incomplete, especially for pest resistance. Construction of ideotypes can assist in generating this knowledge, because it summarizes the current concept of yield-related traits and points to gaps in knowledge.

Ideotype breeding requires the cooperation of a variety of scientific disciplines for progress. In forest trees, this approach is just gaining acceptance. Pest resistance has been treated in most ideotype models only in a very general way. Acceptance of this approach could significantly advance the development of pest-resistant trees. This project could be modelled with poplars and willows - they have shorter reproductive cycles and are easier to clone-manipulate *in vitro* than most other tree species.

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ENVIRONMENTAL EDUCATION IN FOREST ENTOMOLOGY: WHAT IS THE STATUS?

David L. Kulhavy[1]

Environmental education in forestry is currently gaining momentum with increased interest in the forest community and increased environmental awareness. In forest entomology, the major methods of information transfer routinely include refereed journal articles, workshops, symposia, technical reports and papers, project reports and media information, including newspapers, radio and (of course) television and video.

Forestry educators must combine these materials in a factual and practical manner to both stimulate and inform their audience. The combined techniques of environmental education and interpretation increase both the knowledge transfer and the learning process.

Separating environmental education from interpretation is difficult. Comparisons of interpretation and environmental education include:

1) Interpretation is often done in an informal setting, such as a park or recreation area; environmental education is often set in an education setting such as a school of classroom.

2) Interpretation stresses instant acquisition often taking in the "whole picture" in one presentation; environmental education is generally an orderly, stepwise progression over time building from one plateau to another so the audience learns about a particular subject.

3) Interpretation is recreation-oriented; environmental education is learning-centered oriented.

4) Interpretation often occurs over heterogeneous groups varying in age, experience, education and demographics; often times the presenter does not know the audience matrix ahead of time and must readily adapt. Environmental education is often set to a homogeneous audience, such as a sixth grade or college classroom.

5) Interpretation often occurs with a fluid audience that has the choice of staying or leaving; environmental education often occurs in a more structured setting with greater audience control. Environmental education is didactic in its approach, designed to instruct or inform, although entertainment and pleasure may be proffered with a skilled communicator.

(These concepts are adapted from Risk, 1982).

As forest entomology is so all-encompassing, incorporating good communication concepts into teaching increases the audience awareness and the effectiveness of the communication. The importance of the information is enhanced by the credentials of the speaker and the method of presentation.

The following suggestions are helpful in selecting and processing information:

1) Select information that bears directly on the main ideas, issues, and reasoning in completing your topic.

2) Select information that is most appropriate to the listener's background and pertinent to the educator's involvement in the subject.

3) Select information that is timely and real.

4) Select information that summarizes and/or accurately represents the main ideas, issues, or lines or reason you are familiar with.

These steps are critical in both interpretation and environmental education.

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Forest Entomology

I teach forest entomology as a three credit undergraduate course with two hours of lecture and three hours of laboratory each week. Within the framework of the course are the standard requisites for the forest manager, including pest identification, survey and detection, forest insect dynamics, integrated forest pest management, and insect feeding groups. As I teach this course each semester, the challenge is to integrate new and current material while keeping with current concepts and practical information for the forest manager.

To increase audience participation, I use the concept of "Curiosity, Enthusiasm, and Observation" -- I call this my CEO of education, and I use it both as an introduction to teaching and to environmental education. The idea that learning can be fun and a rewarding experience are basic tenets of positive environmental education. There are myriad examples of Curiosity in learning. To best recognize this, go into any classroom from primary through secondary school and carry along your favorite insects, whether they are mealworms, cockroaches, or bark beetles (woodborers inside trees making their sounds are excellent when you can find them). Tell a story or read a book. I use the "Very Hungry Caterpillar" or Nature Scope's "Incredible Insects." The timbre or your voice and your mannerisms will influence your audience and you have captured Enthusiasm. Now, turn this into viewing more material or further identification of insect life forms and you have the third tenet: Observation. Put these together and you have the ingredients for good environmental education in forest entomology.

To increase Observation, I take along a slide projector or combined VCR and monitor when I go to the forest and run them using a generator. The combined effect of first-hand observation of southern pine beetle signs and symptoms, such as pitch tubes, galleries, frass, checkered beetles (*Thanasimus dubius*), loose bark or crown color, combined with reenforcement of slides and/or video provides a longer lasting impression for the students. These materials are keyed to their text and reference material providing yet another stimulus. To further increase learning and retention, discussion sessions are set up to review the material. It is both stimulating and rewarding to watch the students grasp the concepts then use them in a constructive manner.

Increasing Observation leads to increased Curiosity about the forest environment and the ecology and management of forest insects. It is an easy transition to go from slides to the stages of a southern pine beetle infestation. Using technology transfer material, such as the USDA Forest Service Pest Leaflets and pamphlets on forest insects, a natural progression of learning follows.

Enthusiasm is difficult to measure and assess during a semester. It is much easier to see during interpretation where the audience is fixed on a single topic, there is generally one-time learning and you are able to deal with a single concept. The integration of interpretation into environmental education involves treating each lecture and laboratory as a unique interpretive experience, with the bridge between lectures and topics serving as the bridge between interpretation and environmental education. We as educators have the advantage of testing to sharpen our skills as communicators and educators.

With the increased use of video information and the coming of age of computers with video disc technology, optical discs and increased computer storage capacity, comes the concept of integrating "virtual imagery" material with ongoing forest management decisions. It is now possible and practical to record video imagery information of southern pine beetle (*Dendroctonus frontalis*) spots from aircraft and receive real time digital imagery. This imagery can be captured and decisions made on 1) area of an infestation, 2) change over time and, 3) effectiveness of control measures. This is an effective way of integrating current technology with standard methods of survey and detection and pest distribution.

As this technology routinely becomes available, the route to environmental education and increased public awareness of the forest will increase. The forester will need to be an excellent communicator as well as conversant in forestry skills, such as silviculture, mensuration, forest ecology, pest management, and forest resource planning.

Current examples include the impact on forest management recommendations stemming from recent decisions concerning the redcockaded woodpecker in southern forests and the northern spotted owl in forests of the northwest. The controversy and difficult decisions that were made increase public awareness of forest management and brings together many varied and diverse interest groups. This gives the opportunity for increased public education and interpretation of the environment.

It is important to reach all age groups from youth to adult. To do this, effective communication is essential. Combining the knowledge of forest entomology with the precepts of environmental education and interpretation increase both the effectiveness as an educator and the retention of the audience.

Challenges

What are the challenges? It is certainly not enough to just entertain, because material gained in this method is often transient. It is imperative that the interpreter as an educator translates the technical and complex language of the environment into nontechnical form with no loss in accuracy while creating in the listener sensitivity, awareness, understanding, enthusiasm, and commitment (Risk 1982).

It is also important to reach the youth as this group is 1) forming their precepts about the world around them, and 2) they often have the unbridled enthusiasm that stimulates the educator to integrate more material into presentations. Reaching across audiences is more difficult and presents new challenges. The skill of the communicator must be combined with the guile of the interpreter and the knowledge of the educator to teach, stimulate and challenge. The educator in forest entomology must be able to synthesize material and present it in an informative and entertaining format. This will lead to increased participation in our profession and challenges for the next generation of forest entomologists.

CURRENT ENTOMOLOGICAL EDUCATION ISSUES AND TECHNIQUES WITHIN THE COLORADO STATE FOREST SERVICE (CSFS)

David A. Leatherman[a]

The backbone of our efforts is Project Learning Tree (PLT), a national program begun in 1977 and sponsored by the American Forest Council and the Western Regional Environmental Education Council. This program puts professional foresters in touch with professional educators of youth in grades kindergarten through 12th grade. Through two activity guides containing over 170 carefully developed and classroom-tested activities, the structure, importance, and beauty of trees are conveyed to young people. Activities are designed for use within existing curricula in a variety of subject areas - they are not just for science classes.

A summary of PLT activities easily accommodating or dealing with insects was presented and is available from the author.

Another feature of CSFS' environmental education efforts involves classroom visits, mostly to grades K through 6. Insect items that consistently generate interest and enthusiasm are hornet's nests (how they are made, what is the hornet's life cycle, when are nests safe to collect and display, are "spitwads" all bad?, etc.); bark beetles (damage samples showing "tracks", live beetles or model, discussion of pheromones and sex, little insects kill big trees using fungi and strength-in-numbers approach, orientation to hosts, etc.); butterfly metamorphosis puppets (contrast "complete" vs. "incomplete" development, contrast human vs. insect development); butterfly collections (morphos and other tropical forms are a big hit, compare temperate and tropical species, discuss "ethics" of collecting, how do you mount them?, which ones migrate?, etc.).

Other in-class resources that work: USFS insect posters ("Smokey Bear" series); Illinois Natural History Survey "Biodiversity" poster (15 cents each); insect costumes; insect puppets; CSFS-designed, portable "Living Tree" in which a forester operates puppets; insect stickers; pinned insect displays (particularly "big bug" collections); galls of all kinds; cocoons (especially cecropia and polyphemus moths); pheromone traps; any live insects available. In addition, entomologists may want to consider making the most of a bad situation: full arm or leg casts decorated with information about insects (bark beetle signs and symptoms, for example) are ready-made attention-getters.

An additional educational thrust of CSFS has been to incorporate environmental considerations into arborist training, specifically guidelines for minimization of impacts to wildlife. Recommendations include covering concentrations of pollin sources (flower beds in bloom, for example) and small water sources designed for wildlife (bird baths, for example) prior to spraying operations; collecting and freezing in zip lock bags dead animals found near spraying operations (for analysis, if need be); not spraying certain traditional "pests" like hackberry psyllids, which serve as valuable food sources for migrant birds; and consideration of cavities for wildlife-nesting as opposed to automatic elimination for purposes of hazard reduction. Handouts have been prepared listing these guidelines for both urban wildlife and neo-tropical forest migrant birds. A selected list of neo-tropical birds migrating through and/or breeding in Colorado is also available.

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INTERNATIONAL FORESTRY OPPORTUNITIES AND CHALLENGES FOR NORTH AMERICAN FOREST ENTOMOLOGISTS AND PATHOLOGISTS

Moderator: Max W. McFadden[1]

As the title indicates, the organizers of the First National Forest Insect Work Conference were interested in providing a workshop on international forestry that would: 1) bring those attending up to speed on current happenings in international forestry, and 2) to provide a forum to discuss opportunities and challenges for entomologists and pathologists interested in working in international forestry.

In response to this interest, a workshop was organized consisting of panel members who represented many facets of the international forestry community and individuals who had participated in international forestry activities, and who could provide additional insight on challenges and opportunities through their own experience.

In spite of the fact that several panelists had to be replaced at the last minute because of scheduling problems, the workshop was well attended and the question and answer session following the presentations was lively with many members of the audience participating. Although a formal list of recommendations was not prepared, a number of suggestions on how to locate opportunities in international forestry and how to prepare for foreign assignments are included in the individual abstracts.

OPPORTUNITIES AND CHALLENGES IN THE USDA FOREST SERVICE - INTERNATIONAL FORESTRY

Brian Payne[a]

The 1990 Farm Bill (PL 101-624) directed the Secretary of Agriculture to establish an Office of International Forestry under a new and separate Deputy Chief within the Forest Service. Approval of two Senior Executive Service positions has been sought for a deputy chief and an associate deputy chief. A public introduction of the new deputy chief is anticipated in April.

The Deputy Chief for International Forestry will coordinate and expand existing Forest Service international programs and activities, will increase Forest Service leadership in international forest policy making, and will strengthen partnerships with other agencies, non-governmental organizations, and international organizations with interests in international forestry. Examples of Forest Service international programs include:

* Technical assistance and training in tropical developing countries.
* Scientific and technical exchange and cooperative research with other countries.
* Hosting of international visitors for training at Forest Service field locations.
* Bilateral cooperation with other countries in forest management, fire prevention, insect and disease control, and others, especially with Canada and Mexico.
* Representation of U.S. forestry interests in international organizations and meetings.
* Administration of law, regulations, and policies affecting international travel by Forest Service personnel.

OPPORTUNITIES AND CHALLENGES IN THE AGENCY FOR INTERNATIONAL DEVELOPMENT (AID/S&T/FENR)

Carl Gallegos[b]

The Office of Forestry, Environment, and Natural Resources (S&T/FENR) has a staff of four direct-hire professional foresters to promote, support, and guide the expansion of a technically sound forestry program in A.I.D. These are complemented by 12 direct-hire and contract professionals, as well as six AAAS Fellows,

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working in the regional and central bureaus on forestry and related natural resources activities. S&T/FENR's project portfolio includes about $7 million yearly for forestry related projects.

Tropical Forestry

A.I.D. is currently implementing the tropical forestry requirements of Section 118 of the Foreign Assistance Act (as amended) through:

1) implementation of progress and projects in less developed countries (LDCs) that focus on provisions of Section 118, and

2) non-project activities including A.I.D.'s guidance to missions relating to tropical forests.

Project Assistance

In FY 1990, A.I.D.'s tropical forestry program had 182 projects in 47 LDCs in four geographic regions. An additional 21 projects were in the planning stage for implementation during 1990 and 1991. Annual funding levels for tropical forestry assistance projects have increased from $10 million in 1979 to more than $50 million in 1987 and 1988. Currently active and planned projects total 203 and projected funding for FY 91 exceeds $70 million.

A.I.D. has initiated large projects in Central America (Regional Environment and Natural Resources Management, RENARM) and the Philippines (Environment and Natural Resources Management Program), as well as the Africa Bureau Natural Resources Management Support (NRMS) project.

The S&T/FENR Funded Forest Resources Management II (FRM II) project is a follow-on project to the highly successful Forest Resources Management (FRM I) project, which enhances the joint activity between A.I.D., U.S. Forest Service, and Peace Corps in the forestry sector. FRM II is designed to promote the contribution of trees to sustainable development and strengthen the capacity of forestry and natural resources management institutions in tropical and subtropical developing countries through mobilization of the public and private professional forestry and natural resources management community. FRM II will provide: 1) technical assistance; 2) service and support; 3) support for private enterprise development; and 4) facilitation of donor collaboration.

Non-Project Activities

Section 118(c) requires A.I.D. to deny assistance for a range of activities that may have negative impacts on tropical forests. This has been A.I.D. policy for the last three years. A.I.D.'s tropical forestry program is shifting from a heavy emphasis on production to a more balanced approach combining production goals with natural forest protection, preservation, and biological diversity conservation.

Early in FY 90, of all planned tropical forestry projects, over 85% (18 of 21 planned projects) contained specific provision for forest protection and biological diversity conservation.

Past composition of A.I.D.'s forestry program was based upon a recognition of the need to meet local people's needs for fuel wood, fodder, and other products while sustaining agricultural productivity through agroforestry and reforestation as a means of helping to relieve development pressures exerted on remaining natural forests. A.I.D.'s present program continues this basic rationale, but is also giving direct attention to forest protection in two ways:

* increasing direct funding of forest protection measures to conserve biological diversity; and

* focussing of agroforestry and sustainable agriculture activities in buffer zones around forest parks and preserves.

A.I.D. also does a considerable amount of reforestation work and technology transfer through joint efforts among S&T/FENR, the Food For Peace (P.L. 480) program, Peace Corps (PC), and participating overseas Missions. P.L. 480 programs are thought to have accomplished more reforestation and tree planting than all other Agency bilateral projects during the period 1980-1990. Through a collaborative program that started in 1980, A.I.D. and Peace Corps have greatly increased forestry activities with more than 600 Peace Corps Volunteers currently working in forestry and related natural resources. Local currency and food for work resources used each year for forestry and natural resources activities exceed $25 million annually.

Opportunities for Involvement in A.I.D. Activities

There are a number of ways for U.S. foresters to become involved in A.I.D. tropical/international forestry activities including: enrolling in the Forestry Support Program roster - FSP continually seeks specialists with international development experience to work on projects in forestry, natural resources, and related rural development. Interested individuals can obtain information and a "Roster Application" by contacting the Special Projects Coordinator, USDA Forest Service/IF, Forestry Support Program, P.O. Box 96090, Washington, D.C. 20090-6090. Individuals may also call (202) 453-9589.

- As a contractor A.I.D. carries out a majority of its business through contracts that are conducted at the country, regional, and global (Washington, D.C.-based) levels. Private firms and government agencies bid on projects that are announced in the "Commerce Business Daily" (usually available in larger public libraries), and these organizations will hire or assign individuals to implement these projects.

Indefinite Quantity Contracts - A.I.D. has several with private organizations in the field of natural resources and rural development which USAID missions can utilize when necessary. These contracts are set up specifically to provide the missions with quick response assistance for unanticipated needs in project design, evaluation, training, etc.

Work Assignments - U.S. Government employees with desired technical expertise and desired international forestry experience can be detailed to A.I.D. for long term assignments. The type of work that people with technical training in forestry and natural resources might be called upon to do for A.I.D. is usually general in nature; although requests for specific technical assistance are occasionally received. Work assignments may include:

- project design
- project evaluation
- environmental impact statements
- training
- technical trouble shooting
- research design and implementation (e.g., multipurpose tree improvement and management)
- policy/program development (e.g., participation in Tropical Forestry Action Plan forestry sector reviews)

OPPORTUNITIES AND CHALLENGES IN THE USDA FOREST SERVICE, STATE & PRIVATE FORESTRY

Jim Space

No abstract received.

OPPORTUNITIES AND CHALLENGES IN THE UNIVERSITY SECTOR

Robert Gara[c]

The overall objective of working in international forestry is to provide tangible and permanent professional results. Personal benefits also are important. In particular the feeling of accomplishment and gratification felt from working with new colleagues and from the "multiplier effect" in the sense that our working skills are enhanced and our ability to teach our professions at home or in other countries improves dramatically. The improvement comes about because: 1) There often is little literature or experience on the work to be done. Achieving desired objectives, therefore, requires a return to basics. Even before problems can be solved, the planning process and anticipated results must be explained in a clearly understandable and convincing fashion, often in a foreign language. There is no better anvil upon which to forge teaching skills than this experience.; and 2), as often is the case, our specialty in the host country is insufficient or does not exist. Accordingly, we not only provide courses in our respective disciplines, but we also establish curricula at technical schools and/or universities. In this manner, our work provides new services and careers. This is a professional experience useful in ultimately improving our own institutions as well as providing a base for ensuring success in other international assignments.

In less developed countries, there is a greater dependency on establishing programs, projects, and problem solving tasks based on knowledge of the fundamental disciplines. Our working objectives, therefore, should be focused on providing direct and easily understandable solutions to localized problems, e.g., direct and safe suppression of a defoliator. Success would then set the stage for cause and effect problem analysis and ultimately to more sophisticated integrated approaches.

The most demanding challenges in international forest protection involve program or institutional development at a level where a country has a vigorous but unfocused forestry program. The forest resource is serendipitously there and increasing. In these cases, the resource will someday be used and form the basis for an increased GNP. This is the scenario where the country would have the time to establish a strong forest protection program.

The most professionally difficult, but ultimately most challenging work is to solve problems in a country with a mature and sophisticated management/conservation program. Under these conditions forest protection is considered a priori as an essential "insurance policy." It is the obligation of the professional to demonstrate to his/her sponsor that permanent solutions in terms of forest management policies and practices coupled with IPM programs are feasible--and how to proceed!

OPPORTUNITIES AND CHALLENGES IN STATE ORGANIZATIONS

Ronald F. Billings[d]

The knowledge and experience you possess as a professional forest entomologist is in demand in various parts of the world. With increased attention being focused on global warming, tropical deforestation, and other environmental issues, opportunities for short and long term assignments in forest protection are growing, particularly in tropical and subtropical countries. Many third world countries have initiated reforestation programs, but lack the expertise in specialized areas such as forest protection.

Typically, requests for technical assistance in forest protection are precipitated by crises situations some often unidentified insect or disease is discovered damaging new plantations or valuable natural stands. An international "expert" is requested to identify the causal agent, evaluate the impact, and make control recommendations. Cases in point from my personal experience include bark beetles in Honduras, Haiti, Dominican Republic, and Mexico, pine defoliating insects in Viet Nam and root disease problems in the Dominican Republic. In most cases, these problems have no quick fixes; it is up to the expert to suggest and/or initiate more effective long term protection programs. Also, training of the country's professionals or technicians either within the country or via scholarships and travel grants to the U.S. is an essential ingredient.

Unfortunately, it is not easy to break into international forestry without having some overseas experience. Most common routes are via the Peace Corps, Partners of the Americas program, or the USDA Forestry Support Program. Graduate students should consider taking one or more short courses offered by the Organization of Tropical Studies (OTS), based in Costa Rica. Once you gain expertise in a needed field and have overseas experience, short and long term assignments become more readily available through the Food and Agriculture Organization (FAO), the Forestry Support Program, or several private technical assistance organizations. To be informed of job opportunities, submit your name and a current resume to these organizations for inclusion on their rosters of potential consultants.

To be successful in international forest entomology, you should hold and advanced degree (preferably a PhD) and have a least a decade of practical experience in addressing common pest problems. Your educational background should include a wide variety of forestry and entomological subjects. Fluency in a second language (usually Spanish or French) is invaluable and often is considered mandatory in Latin America or Africa. International consultants should be people oriented, have good listening and communication skills, endless patience, and a willingness to work with minimal facilities and equipment. You are often limited to what you can pack in a suitcase. the most challenging assignments are those that require you to come up with practical and sound recommendations for new pest problems you know little about. You must be willing to endure hardships caused by primitive living and working conditions, occasional health problems, and long, arduous field trips to remote locations. Separation from your wife and family for extended periods also is required.

Rewards for participation in international forestry far outweigh any hardships, in my opinion. They include the opportunity to meet and work with people of different cultures and to use your knowledge and innovation to benefit other countries. At the same time, international forestry assignments provide a unique opportunity to travel to foreign places while broadening your experience base. Invariably, you will gain more from each overseas assignment than you give.

R. Scott Cameron[5]

International forestry positions are more numerous in developing countries, especially in the tropics of Africa, Asia, and Latin America. Recent political changes also may open the door to eastern Europe. Much of the financial support for foreign assignments has originated from US AID, FAO, private companies, and international organizations. the US Peace Corps has provided international opportunities for many. Recent USDA Forest Service initiatives may lead to increased activity in international forestry. Candidates for many international assignments are located through the USDA Forest Service, Forestry Support Program (FSP) "roster of expertise." Background and personal attributes helpful for obtaining international assignments include: 1) proficiency in a foreign language; 2) understanding and appreciation of different cultures; 3) ability to work under adverse conditions, without the latest equipment and facilities; 4) good educational training, preferably at the doctorate level; 5) professional experience, recognition as an expert in one's field; 6) strong relationships with colleagues from foreign countries, often developed through attendance at international meetings; and 7) availability employment with an organization supportive of international cooperation. Professionals participating in international assignments enhance their skills and abilities to practice their professions at home through exposure to new cultures and perspectives, and by developing work skills. Visits by foreign professionals often involve highranking officials in government and private organizations. These interactions many times open normally closed doors and channels of communication within the foreign country. Establishment of viable forest management and forest protection programs in developing countries involves longterm incremental development. Important elements in this process include working with national counterparts, education of foreign specialists, curriculum development, and host country commitment of personnel and facilities to the discipline. The level of expertise required of foreign professionals depends on the developmental stage of the forestry sector in the host country. The establishment of a strong forest pest protection program in Chile over the past 20 years paralleled the development of a vigorous and profitable forest industry and serves as a classic example of incremental development.

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FUTURE OF MICROBIAL PESTICIDES

Moderator: M.L. McManus[1]

The purpose of this workshop, "The Future of Microbial Pesticides," is to identify issues surrounding the current use and future development of microbial products in forestry. Although microbial pesticides still account for less than one percent of the total pesticide market, sales of microbials are increasing at a rapid pace, estimated to be between 10 and 25% per year. In forest protection, the importance of microbials is much more pronounced. Commercial formulations of B.t. (*Bacillus thuringiensis*) are being used worldwide to control forest defoliators such as the spruce budworms, gypsy moth, nun moth, and pine processionary caterpillar. In 1990, B.t. was used to control the gypsy moth on more than 60% of the acreage sprayed in State/Federal cooperative suppression projects. The growing interest in microbial products like B.t. are being fueled by environmental concerns over the use of chemical pesticides and the development of resistance by pest species to these chemical products.

However, the sometimes unbridled enthusiasm for using microbial pesticides also must be counterbalanced by considering their limitations and the economic realities of the marketplace. Consequently, the speakers at this workshop were asked to address the various areas of concern that may limit the development, registration, and availability of microbial pesticides for use in forest protection in the decade of the nineties.

William G. Yendol provided an historical review of the development and registration of entomogenous organisms for use against pest species. Although the first microbial product, *Bacillus popillae*, was registered for control of the Japanese beetle in 1947, the development and registration of additional microbials has proceeded slowly, and most of those were registered by the federal government and not by industry. Fungi, viruses, and protozoa are known to cause spectacular epizootics that decimate populations of major forest insect pests; however, many of these pathogens are not candidates for development as commercial pesticides. In most cases, these organisms are difficult to mass produce in culture and their relative specificity to a target pest restricts their marketability and, thus, does not justify the costs associated with their registration. Since 1983, there has been a tremendous increase in the development of new and novel B.t. products and especially in applying genetic engineering technology to improve their efficacy and use against non-lepidopterous pests. However, these and other microbial pesticides are not a panacea, but rather should be viewed as integral components of sound management systems designed for individual pests or crops.

Pamela Marrone discussed the industry perspective on new developments and opportunities for use of microbials in forestry, and noted that never before has there been such interest expressed in B.t. and other microbial products. Although there are currently 21 microbial pesticides registered by the EPA, the agency has reviewed 44 applications for small scale field testing of genetically modified microbial pesticides since 1984. Some of the perceived limitations to microbials, i.e., poor residual activity, slow kill, narrow host range, and patentability, are being addressed by the industry through a number of strategies. Several companies have amassed large collections of B.t. isolates (several thousand) from a wide variety of substrates with the objective of finding strains with enhanced activity against key pests and new activity on other pests. Many of these isolates have novel, unreported crystal types. Molecular techniques are being used to incorporate select genes from various strains of B.t. to increase the product's activity and expand its host range; although narrow host range is an advantage environmentally, it has been cited as a limitation for expanded use of microbial pesticides. In an attempt to improve the residual activity of B.t. on plant foliage, scientists have developed novel delivery systems such as one that incorporates the B.t. protein crystal within the cell wall of a killed species of *Pseudomonas*. Another approach involves incorporating B.t. spores and crystals within either a starch or polymer matrix.

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A number of companies are using biotechnology to engineer B.t. gene(s) directly into plants or plant colonizing microorganisms. Although there are limitations to this approach, industry perceives several advantages that include improved residual activity and efficacy, a reduction in use of chemical pesticides, and an improved proprietary position.

Commercial activity in developing viruses, fungi, and nematodes for insect control has lagged, because of a lack of low cost production systems and, thus, an economic incentive for product development. Marrone also emphasized that the potential for use of microbial pesticides in agriculture is what is driving the industry and that, at best, forestry receives the spinoffs from that technology. She also noted that the fermentation of B.t. products is critical and that the process alone can be responsible for differences in performance among different strains and serotypes.

Although industry recognizes that the delivery of microbial pesticides is critical to their successful performance in both agricultural and forest systems, few breakthroughs have been realized in the formulation and application of these products.

Although B.t. is the focus of most commercial interest, James Slavicek emphasized that several baculoviruses have potential for development as microbial pesticides for forest insect pests. Viruses have been registered for control of the Douglas-fir tussock moth, gypsy moth, and pine sawflies; however, the gypsy moth virus, Gypchek, is receiving the most attention by industry, because this product satisfies the market need for an environmentally safe pesticide that can be used in urban residential areas and in other sensitive habitats. Gypchek is being produced *in vivo* by the Forest Service in cooperation with the Animal and Plant Health Inspection Service; current production is approximately 4000 acre equivalents per year, although the current demand for this pesticide greatly exceeds that which is available. Production of Gypchek in both *in vivo* and *in vitro* systems currently is being pursued by industry. The advantage of *in vivo* production is that large numbers of polyhedra (approximately 10^9 polyhedral inclusion bodies (PIBs)) can be recovered from individual fifth stage larvae; however, this production system is relatively expensive and requires use of a mass-rearing facility and extensive processing/purification of the final product.

In vitro polyhedra production generates a product that does not require extensive purification. Production costs for this method are approximately 2 to 3 fold greater than polyhedra produced in larvae. In addition, a class of viral genomic mutations, termed few polyhedra (FP) mutations, occur at high frequency with viral replication *in vitro*. FP mutants produce very few polyhedra, and those that are produced contain virtually no virions, making them ineffective for insect control. The genesis of the FP mutant necessitates a batch production methodology instead of a more efficient continuous production approach. Further refinement of both *in vivo* and *in vitro* virus production methods is needed to lower overall production costs so that the gypsy moth virus can become competitive with conventional pesticides.

There is heightened interest in improving the potency and efficacy of baculoviruses like Gypchek through genetic manipulation. One approach is to augment or alter viral genes in the current product, since isolates from Gypchek have demonstrated a range of potency that may vary by 150 fold in laboratory bioassays. Another approach being pursued is to insert foreign genes that enhance potency into the viral genome. Among those being considered are toxin genes, insect hormone genes, and genes that code for hormone regulators or that regulate basal metabolism. Improvements in potency and efficacy can effectively reduce the cost of viral products and stimulate their development by industry as microbial pesticides.

After the break, Ada Breaux presented an industry perspective on the requirements for the registration of microbial pesticides. Industry is faced with the challenge to stay competitive in the marketplace and, in order to do so, will need timely publication of guidelines by the regulatory agencies and timely registration of new products, due to the short product life and patentability of microbials. She emphasized the need for good communication between industry and the agencies and stressed that industry must provide the manpower and focus to acquire prompt registrations.

Some of the general issues that concern industry include the issuance of multiple regulations by state, federal, and international agencies. Without standardized guidelines, the cost to industry to obtain registrations will continue to increase. The requirement for multiple agency review, as in the case for registration of transgenic plants, also increases the cost that must be borne by the registrant. Specific registration issues common to conventional microbials include: 1) the need for a standardized analytical methodology to quantify the delta endotoxin content of B.t. products, 2) agreement between the EPA and states on tier I progression for mammalian toxicology requirements, and 3) international harmonization of guidelines for registering microbials. It was suggested that the EPA should take the leadership in working with foreign governments to reduce the regulatory burden on industry.

Specific issues related to genetically engineered microbials (GEMS) were also reviewed. Of paramount concern to industry was a need to finalize 40 CFR 172 experimental use permit regulations, which will define the scope of regulations and the process or product to be regulated. Issuance of guidelines will assist industry in planning its research and development programs on GEMS. There also is a lag in finalizing guidelines for registering insect resistant plants, although several new products are nearing commercialization. The tone of the presentation overall was encouraging, however, because there appears to be a genuine commitment both by the EPA and industry to facilitate the registration of new microbial products. Industry is focusing its concerns to the regulatory agencies through trade associations, and it is interacting in the rule-making process by participating in pre-registration conferences with the EPA and by commenting on guidelines and policy published in the Federal Register.

William Schneider reviewed the current structure within the EPA and regulatory protocols required by the agency for registering microbial products. The Office of Pesticide Programs (OPP) contains three divisions that are involved in the regulatory process. The Registration Division (RD) handles submissions from the registrants and is divided into Product Manager Teams, each with the responsibility of handling a unique group of pesticide products. The initial submissions are passed on to the Science Divisions; Health Effects Division (HED) that deals with toxicology, and Environmental Fate and Effects Division (EFED) which assesses impacts on water, non-target organisms, etc. The Science Divisions perform risk assessments and make recommendations to the Registration Division based on their conclusions. A special biotechnology coordinating group has been formed within EFED to coordinate the review of GEMS, develop policy, and deal with special problems that may arise during the review process.

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) was reviewed along with revisions to the Act that were authorized by the Congress in 1988. The agency currently is reviewing 40 CFR 152.20 to specify how pesticidal transgenic plants will be regulated. Data requirements for Experimental Use Permits (EUPs) and registration of microbials are contained in 40 CFR 158; however, these also are being updated. Regulations for issuing EUPs are found in 40 CFR 172 and were discussed in detail, specifically with regard to notification requirements for testing of non-indigenous organisms and genetically modified organisms. The EPA has registered 21 microbial pesticides, and several other products are close to being registered. Agency review of genetically modified microbials is progressing well and is being closely scrutinized by the public. The agency is eager to work with registrants and encourages frequent and open dialogue prior to and during the process of registration.

Temple Bowen described marketing as "the process of determining who the customers are, what are their needs, how do they purchase, and how do their needs for a product or service change over time." The North American market for microbials used in forest protection has many characteristics that make it challenging if not difficult. The market is relatively large, ca. $7-15,000,000 per year, but is extremely variable from year to year because of the episodic nature of outbreaks of the defoliators that require control. The microbial pesticide market also is highly competitive and commercial development costs are high, estimated at $100,000/year. The choice of product is governed primarily by price, consequently the cost of B.t., for example, has dropped over 400% since 1978 resulting in low unit prices for customers, but low profit margins for the industry. In order for a company to survive, it must diversify and cannot rely on a single microbial product; however, it takes approximately three years to develop and register a new microbial pesticide.

It was suggested that there are several actions that customers could initiate that might enhance corporate interest, commitment, and participation in the forestry market, which is referred to as a "niche market." These include the following: 1) create and enter into multi-year contracts; 2) have the latitude to select a sole source product on the basis of its performance rather than on unit price; 3) make earlier commitments to purchase, and allow public agencies to purchase directly from the manufacturer; 4) modify regulatory procedures for biorationals to expedite labelling of products; 5) provide greater public support in terms of dollars, technical assistance, and research and development of important generic issues, e.g., deposit analysis, equipment development and spray technology; and 6) report promptly and completely on collaborative field, pilot, and research studies conducted with microbial products.

Summary and Recommendations

Despite the increased use of microbial pesticides in forest protection and growing public confidence in their performance, this is a rather fragile market that is dwarfed by the agriculture microbial market. Many companies have entered and then vacated the forestry market, because it was too competitive and profit margins were too low. There is expressed concern that adequate product will be available to managers in the years ahead as the number of suppliers dwindle and the use of chemical pesticides continues to decline.

Federal managers among the audience seemed unaware of the seriousness of the problems faced by industry, but expressed a willingness to work closely with providers to identify and address problem areas. This may entail entering into cooperative agreements with industry to share the costs of research and development activities that are identified as high priority and that will be needed to retain existing registered microbial products and assist in the registration of new products. It was recognized that both industry and federal and state agencies are understaffed, thus, exacerbating the need for collaboration.

During the discussion session, it was suggested that possibly industry could stimulate earlier commitments to purchase by agencies by offering a discount to those who order first. It was noted that the cost of product drops as the period of bidding progresses, which encourages some purchasers to delay making a commitment. A Forest Service representative stated that guidelines for field and pilot testing would soon be published and should improve standardization of how supportive data for microbial registrations are acquired.

Lastly, the benefits of focused research and development programs such as those conducted on the gypsy moth, spruce budworms, and Douglas-fir tussock moth, were discussed. Programs of this nature have accelerated both the evaluation and registration of microbial products and the development of badly needed aerial spray technology. In the absence of these programs, new initiatives are needed to provide the support and impetus to address the needs that have been identified at this workshop. The Appalachian Integrated Pest Management Demonstration Project has been instrumental in supporting these activities in the East. The Forest Service, Forest Pest Management, is developing a strategic plan to provide new directions in forest health protection, and hopefully will facilitate new partnerships with industry to enhance the development of microbial pesticides for the 90's.

EMERGENCE AND CURRENT STATUS OF MICROBIAL PESTICIDES

William G. Yendol[a]

Interest in the development of alternatives to chemical pesticides was stimulated in the 1960's by the publication of "Silent Spring" by Rachel Carson, and by concern over the rapid development of resistance to classes of chemical compounds by economically important insect species. One of the strategies employed searching for entomogenous microorganisms such as bacteria, fungi, viruses, and microsporidia that attack insect pests and might have potential as microbial pesticides. The importance and potential of species of bacteria in the genus *Bacillus* was recognized in the 1940's, when the Federal Government registered the first microbial product (*Bacillus popillae*) to control the Japanese beetle in turf.

Spectacular epizootics caused by fungi, viruses, and protozoa have decimated populations of major forest insect pests such as the spruce budworm and eastern hemlock looper in Canada and the gypsy moth in the U.S., Europe and Asia. However, many of these organisms are not candidates for development as commercial pesticides. Several of the imperfect fungi are registered as mycoinsecticides; however, species of the *Entomophthorales*, which attack many insect species, are difficult to mass produce in culture and require specific meteorological conditions in order to successfully germinate and infect their hosts. Species of microsporidia are naturally occurring pathogens of many forest insect defoliators such as the gypsy moth, budworms, and tent caterpillars. However, they cause only chronic infections, must be produced *in vivo* and, therefore, probably will not be pursued as biological pesticides.

There is growing interest in the development of insect viruses, specifically the nucleopolyhedrosis viruses (NPV), as microbial pesticides. Three NPV's have been registered with the EPA since 1977: TM Biocontrol-1 for control of the Douglas fir tussock moth, Gypchek for control of the gypsy moth and Neochek-S for use against the European pine sawfly. Registration of these and other microbial products also has been either realized or is currently being pursued by the Canadian government. Both *in vivo* and *in vitro* production of Gypchek currently is being developed by commercial interests, however, the potential of this NPV and other candidate viruses has yet to be realized.

Since 1983, the use of *Bacillus thuringiensis* (B.t.) products for control of the spruce budworm in Canada and gypsy moth in the U.S. has increased steadily. During the period 1979-1983, B.t. was used to control spruce budworms on 1-4% of the forested area treated; this figure increased to 20% by 1984 and to 63% in 1988. In 1990, B.t. products were used to control gypsy moth populations on 57% of the 1.5 million acres sprayed in State-Federal suppression programs. In recent years, there has been a switch to neat application of aqueous based formulations of B.t. at higher dose rates (20-30 BIU/A) for control of the gypsy moth.

The application of genetic engineering technology to enhance the efficacy of viruses and B.t. products offers unlimited potential for their future use as microbial pesticides against forest insect pests. However, there is a need to continue the isolation and evaluation of new and more virulent strains of microorganisms that may be candidates for use as microbial pesticides. Microbials are not a panacea, but collectively they will play an important role in an integrated approach to manage forest insect pests.

REGULATORY PROTOCOLS FOR MICROBIAL PESTICIDES

William R. Schneider[b]

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947 directed the Environmental Protection Agency (EPA) to register pesticides and specifies that the agency may grant Experimental Use Permits (EUP's) to potential registrants to acquire the data required for registration. FIFRA was revised by Congress in 1988 to require the reregistration of all previously registered pesticides; this is currently a major ongoing activity within the agency. There are three Divisions within the EPA office of Pesticide Programs (OPP) that are involved in the regulation of microbial pesticides: The Registration Division, (RD); Health Effects Division (HED); and Environmental Fate and Effects Division (EFED).

The Registration Division is responsible for communicating with the customers or "registrants" and is divided into Product Manager Teams. Submissions for registration are eventually passed on to the science divisions (HED, EFED), which in turn perform risk assessments and advise the Registration Division of their conclusions. In addition, a special biotechnology coordination group exists within EFED that is responsible for preparing risk assessments for genetically engineered microbial pesticides and for developing policy for dealing with microbial and biochemical pesticides and transgenic plants.

The EPA intends to modify certain regulations that deal with pesticidal transgenic plants and certain classes of genetically engineered microbial pesticides and non-indigenous organisms. These regulations are identified and discussed. The agency currently has registered 21 microbial pesticides and has reviewed submission for at least 25 other products. The agency is in the process of hiring additional personnel to help with the increased number of submissions for EUP's and registration of new microbial products. Improved communication with potential registrants is being realized through pre-registration conferences. The agency is committed to expediting the timely review and registration of microbial products.

MARKETING PERSPECTIVES FOR MICROBIAL PESTICIDES

A. Temple Bowen, Jr.[c]

Marketing might be described as the process of determining who the customers are, what are their needs, how do they purchase, and how do their needs change over time for a given product or service. The North American market for microbial products used in forest protection has many distinguishing characteristics: 1) the market is highly competitive and relatively large, approximately $10 million/year, but extremely variable from year to year; 2) the commercial development costs are high, yet the unit price and profit margins are low, because the choice of product by consumers is determined largely by price through competitive bidding.

There are several actions that could be taken by customers and responsible agencies that would enhance corporate interest, commitment and participation in this niche market. These include the following: 1) develop multiyear contracts and provide the option to select sole source products on the basis of product performance; 2) allow public agencies to purchase B.t. from the manufacturer and make earlier commitments to purchase products; 3) modify regulatory procedures for biorationals to expedite easier and faster labelling of new products; 4) provide greater public support in terms of dollars, technical support, and leadership for research development of generic issues, i.e., deposit analysis, spray technology, and equipment development; 5) encourage prompt and complete reporting of research and methods improvement studies.

NEW DEVELOPMENTS IN MICROBIAL CONTROL OF INSECT PESTS: AN INDUSTRY PERSPECTIVE

Pamela G. Marrone[d]

Although microbial pesticides still account for less than one percent of the total pesticide market, it is estimated that sales are increasing at between 10 and 25 percent per year. Food safety and other environmental concerns, insecticide resistance, lack of new chemistries, improved efficacy of microbials, and more competitive prices have contributed to the phenomenal growth in microbials, primarily *Bacillus thuringiensis* (B.t.) based products.

Reflection of this growth is evidenced by the proliferation of start-up companies and large agro-chemical companies that are developing B.t. based products. Since 1984, EPA has reviewed 44 applications for small scale field testing of genetically modified microbial pesticides and 40 applications for small scale field testing of transgenic pesticidal plants.

B.t.-based products still possess perceived constraints that are being addressed through a number of strategies that include identification of new strains, development of engineered strains with an expanded host range, developing products with enhanced residual activity and/or improved efficacy, and inserting B.t. genes directly into plants or plant colonizing organisms.

Commercial activity into the use of viruses, fungi, and nematodes for insect control generally has lagged behind the development of B.t., because of the unavailability of low cost production systems for these organisms, and thus poor economic incentive for product development. Microbial pesticides will undoubtedly play a major role in an integrated approach to manage pests in agricultural and forest ecosystems.

BACULOVIRUSES: PRODUCTION STRATEGIES AND PROSPECTS FOR GENETIC ENGINEERING

James M. Slavicek[e]

A number of insect baculoviruses have potential for development as biological insect control agents. The baculovirus formulations Elcar, Tm-Biocontrol-1, Neochek, and Gypchek are registered by the EPA for use against *Heliothis zea*, *Orgyia pseudotsugata*, *Neodiprion sertifer*, and *Lymantria dispar*, respectively. Of these, Gypchek (*Lymantria dispar* nuclear polyhedrosis virus, LdNPV) has been used the most extensively.

Gypchek is produced *in vivo* by a consortium of federal agencies consisting of the Forest Service, Agricultural Research Service, and Animal and Plant Health Inspection Service. Current production and processing is approximately 2500 acre equivalents per year, with a potential capacity of 5,000 acre equivalents annually. The current demand for the product, estimated at 50,000 acre equivalents, greatly exceeds availability. Commercial production methodologies are being developed using both *in vivo* and *in vitro* systems. The advantage of *in vivo* production lies in the number of polyhedra (approximately 10^9 from a fifth instar larva) obtainable from larvae. However, *in vivo* production requires large scale insect rearing and extensive product purification. *In vitro* polyhedra production generates a product that does not require extensive purification. Production costs for this method are approximately 2 to 3 fold greater than polyhedra production in larvae. In addition, a class of viral genomic mutations, termed few polyhedra (FP) mutations, occur at high frequency with viral replication *in vitro*. FP mutants produce very few polyhedra, and those that are produced contain virtually no virions, making them ineffective for insect control. The genesis of the FP mutant necessitates a batch production methodology instead of a more efficient continuous production approach. Further refinement of both *in vivo* and *in vitro* virus production methods is needed to lower overall production costs so that LdNPV can become competitive with conventional insect control agents.

A significant advantage of LdNPV compared to chemical pesticides or *Bacillus thuringiensis* (B.t.) lies in its specificity for the gypsy moth. However, LdNPV is more costly to produce and takes longer to kill gypsy moth larvae compared with other control agents. Genetic manipulation, through the techniques of biotechnology, offers a means of improving LdNPV potency and efficacy. Potency enhancement will allow the application of fewer polyhedra while retaining effective control, thereby decreasing treatment costs. The augmentation or alteration of viral genes is one approach to potency enhancement. We have obtained LdNPV isolates exhibiting approximately a 150 fold difference in potency, and a few polyhedra mutants.

The identification of the gene(s) responsible for an isolate's potency characteristic and of the few polyhedra phenotype, will further our understanding of the basis of viral potency and facilitate the development of a means of enhancing potency. In addition, insertion of foreign genes into LdNPV (e.g., viral enhancing factor) offers another approach for potency enhancement. The insertion of foreign genes with insecticidal effect into LdNPV is a means of increasing viral efficacy (defined as decreasing the time required for viral induced larval death). Potential foreign genes include toxins (e.g., B.t. endotoxin, melittin), insect hormone genes and genes coding for hormone regulators, and insect genes that regulate basal metabolism. Once improvements in LdNPV potency and efficacy have been achieved, LdNPV will become a viable alternative to conventional gypsy moth control agents.

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IS SILVICULTURE THE ANSWER TO OUR FOREST INSECT AND DISEASE PROBLEMS?

Moderator: T. Evan Nebeker[1]

The management of forests in North America has intensified on some ownerships as timber resource value has increased and the need for sustained production has become evident. Increases in demands for wood products, widening price differentials between pulpwood and sawlogs, and greater utilization of both small material and a larger number of tree species have increased the attractiveness of forestry investments.

With this, forest resource protection has become more important. The methods of protection vary dramatically and depend in part on land ownership and the goals of that ownership. The philosophical basis for their management is founded primarily in those goals and objectives and, in part, the dictates of society. The forests of North America are extremely diverse as is their management and protection.

The goal of this workshop was to address one of the many resource protection strategies that is available to forest managers. That strategy involves the utilization of various silvicultural tactics, alone or in combination, to meet the goals and objectives of the owners. If applied properly, the results provide a protection system that is based on sound forestry practices and will be socially, economically, environmentally, ecologically, and silviculturally acceptable. It was also intended that as the workshop unfolded the participants and the audience would become silvicultured. They would go away from the workshop and say "I'm Silvicultured."

To achieve that goal, individuals were selected from various regions of North America that had experience in dealing with forest insect and disease problems which utilized silvicultural techniques. They were asked to address the question - "Is silviculture the answer to our (their) forest insect and/or disease problems?" They were to provide a bit of data to support their conclusions, but most importantly they were to present their philosophy as it relates to the future and a changing forestry perspective within their particular geographic area.

It appears that silvicultural management strategies are going to play a major role in the protection of the North American Forests in the decades to come. It was generally agreed that silvicultural tactics would be in harmony with the "new perspective" issues facing many of the forest managers. With a well educated public beginning to look over the shoulder of public land managers, such as the U. S. Forest Service, a reliance on ecologically sound and environmentally safe principles appears acceptable. In most cases, silvicultural tactics fit into this area. Providing a stable environment for the trees to grow appears to be acceptable from most points of view.

The silvicultural tactic of choice, thus far, has been thinning and the results look very promising in minimizing losses caused by insects and diseases. There also appears to be a place for other tactics such as prescribed burning, as currently utilized in the Southeastern U. S., to reduce the impact of pest species.

Little discussion developed concerning silvicultural systems, especially in intensively managed forests, other than through stand density modifications of existing stands through thinning. It is important that we begin to look at systems from beginning to end. Regeneration methods certainly influence stand structure, for example, either even-aged or uneven-aged. Whether regeneration occurs naturally or through artificial means. As the stands begin to develop, then the decisions concerning precommercial thinning (chemical or mechanical), release or liberation, prescribed burning, fertilization, improvement cuts, commercial thinning, and methods of regenerating the succeeding stand, including methods of site preparation, need to be addressed.

As the decision making process unfolds there appears to be a problem in the area of communication. Trying to

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get pathologists, entomologists, ecologists, and silviculturalists to talk to each other in a meaningful way appears to be a major task. In most cases they have remained within their respective disciplines, acknowledging the existence of the others only in passing, if at all. This certainly could be the result of training; for example, most silviculture texts are void of resource protection considerations. In most entomology, pathology and ecology texts the reverse is also true. For that matter, most ecologists tend to play down the role of insects and diseases in stand dynamics. The current forest managers, researchers, and educators having been trained under such a system have tended to perpetuate the same. There is a need for change in the educational system. Silviculture texts need to include discussions concerning the impact of various tactics on pest populations both from the positive and negative points of view. Forest resource protection courses need to include more forest management and an understanding as to the impact of forest management practices on pest populations and how such systems can be altered to reduce the losses. The public demands that we operate in an ecologically and environmentally sound manner.

There was also a definite sense that we need to put our information into areas where the forest manager is most apt to read and/or run across it. Forest managers do not read entomology or pathology journals. They probably find it boring. We need to aim our efforts toward the journals and other periodicals that they are most likely to be reading to reduce our communication problem. In all, a time for change.

Discussion was good, and we even had some participants taking issue with what had been said. For a minute we thought we were going to go to the parking lot to settle certain issues! Didn't Sherman introduce prescribed burning into the southern U. S.?

IS SILVICULTURE THE ANSWER TO OUR INSECT AND DISEASE PROBLEMS? A STATE AGENCY PERSPECTIVE

Kenelm Russell[a]

While timber has traditionally been the major output of the Pacific Northwest forest resource, profound changes are altering both the forest ecosystem and life styles of forest workers. It is not business as usual in the woods. Old growth forests seemed unlimited; society was busy with material things; and forests of the West were sparsely populated. Today's well educated, involved society places high value on the total forest ecosystem, a dramatic swing away from yesterday's commodity oriented forest.

Two paradigms illustrate positions on the forest resource management continuum. The human management paradigm says that foresters and scientists "know it all" and can solve any ecological problem. The ecologically based world view paradigm says, "Leave it alone," and assumes that humans are incapable of improving on natural forest ecosystems. For example, it is a mistake to abort natural fire cycles which ultimately, through species change, result in repeated cycles of costly insect and disease control problems.

Forest health policies advocating use of integrated pest management principles will promote long term pest protection. Prescribed fire and other tools can reduce pest problems. Bark beetles, defoliators, root diseases, and dwarf mistletoes can be reduced through a more "gentle" silviculture. Deteriorating timber will be allowed for other ecosystem users. Silvicultural pest prevention in the new forest involves the total ecosystem.

MONITORING PEST POPULATIONS FOLLOWING PRECOMMERCIAL THINNING OPERATIONS IN WESTERN FORESTS

Will Littke[b]

Precommercial thinning is employed to achieve multiple stand objectives. These include; stocking control, spacing, and tree selection by diameter and form class. However, pest agents can colonize stumps and slash produced during thinning operations. Pest monitoring is needed to quantify current and future expectations of pest activity levels in thinned stands. The introduction of *Heterobasidion* (*Fomes*) *annosum* root and butt disease into cut-stumps of western hemlock, and the behavior of *Ips pini* (bark beetle) in thinning slash of lodgepole and ponderosa pine are used as specific examples.

Survey results indicate that levels of residual tree infection by *H. annosum* in precommercially thinned western hemlock stands are low (0 to 8%). Stand disease severity 5-10 years after thinning was not correlated with such factors as residual tree diameter, cut-stump density, age of thinning, or soil type. Southwest Washington contains many acres of young overstocked hemlock stands and present recommendations call for precommercial thinning. No disease control measures (Borax stump treatment) are practiced currently, nor appear warranted in precommercial age hemlock stands.

Ips activity varied from 20% to 100% of the stand area, while slash infestation severity ranged from 3% to 34% over eight Oregon thinning sites. *Ips* populations attacking slash increased during June, peaked in July, and decreased through August and September. No residual tree killing by *Ips* was observed on any thinning units at these infestation levels. *Ips* levels may have remained below the damage threshold by factors such as low resident populations, widely spaced thinning layout, progressively larger slash units during peak population periods, and physical dry-down characteristics of the slash.

Silviculture practices when applied to forests need not result in build-up of disease and insect pests. Data provided by pest monitoring can be used as feedback on future decision making when considering stand management activities.

WILL SILVICULTURE REMAIN THE ANSWER TO BARK BEETLE PROBLEMS?

Ken Gibson[c]

Because they kill trees outright, bark beetles are the most damaging group of insect pests in North America. In 1989, an estimated six million trees were killed by bark beetles in the United States. Bark beetles cause the greatest losses in coniferous forests. Most are opportunists -- reaching outbreak conditions as their hosts decline in vigor from one of several factors: competition, drought, defoliation, disease, or overmaturity.

Historically, "control" techniques were aimed at killing beetles. We only recently learned that stand conditions determine the overall effects of bark beetles; and that epidemics can be prevented, or their effects lessened, by maintaining forest stands in a healthy and vigorous condition. Silvicultural techniques which reduce competitive stress, create stand conditions less favorable to beetles, or promote age, size, and species mosaics, can decrease bark beetle-caused losses to acceptable levels. The most applicable alternative -- thinning, sanitation, salvage, species conversion, regeneration, or simply shorter rotations -- vary with bark beetle and host species and management objectives.

Recently-developed pheromone "tools", more environmental awareness, and a better understanding of host/pest interactions, make silvicultural manipulations the most acceptable means of managing bark beetle populations. Whether that will remain true in an era of "new perspectives" remains to be seen.

IS SILVICULTURE THE ANSWER TO NORTHEASTERN FOREST INSECT AND DISEASE PROBLEMS?

Kurt W. Gottschalk[d]

The answer to this question is an unqualified yes AND no. The correct answer depends on a number of factors: the forest type and pest involved, the timing, and the objective of the manager. For two major northeastern pests, silviculture is the only practical answer. These pests are white pine weevil on Eastern white pine and beech bark disease complex on American beech. For the two major defoliators, eastern spruce budworm on spruce-fir and gypsy moth on eastern hardwoods, the answer can be either yes or no depending upon timing and management objective. For eastern spruce budworm, silviculture can be used to increase spruce and decrease fir, resulting in reduced stand susceptibility, but these techniques are of little use during an outbreak.

For gypsy moth, silviculture can be used to change the susceptibility and vulnerability of the stand. The effectiveness of these treatments depends in part on management objectives: to prevent or minimize losses versus preventing outbreaks. Silvicultural treatments can very effectively minimize losses and in some cases prevent losses, but they are not very effective at preventing outbreaks and nuisance to people. Managers need to have realistic objectives for silvicultural treatments and use them appropriately. Silvicultural treatments have the following advantages: 1) they are usually inexpensive (can provide income); 2) they treat the cause of a problem instead of the symptom by creating healthy, mixed forests; 3) they can be used first in high priority areas where they will be most effective; and 4) they are ecologically preferable to chemical insecticides. However, they also have the following limitations: 1) they can be applied to only a limited acreage per year; 2) they require a long time to have a major effect on the pest habitat; 3) they will not prevent outbreaks of many pests; and 4) they can not be used in some areas (i.e., wilderness areas, etc.) where cutting is not allowed. In many forest management situations, these advantages outweigh the disadvantages except when large scale outbreaks result in social pressure for direct control to prevent nuisance to people or non-timber effects.

IS SILVICULTURE THE ANSWER TO THE SOUTHERN PINE BEETLE PROBLEM?

Roger P. Belanger[e]

Southern pine beetle (SPB) outbreaks have increased in frequency, severity, and distribution during the past 30 years. Silviculture offers the most promising and long-lasting means of reversing this trend. Procedures are available for ranking the susceptibility of stands to beetle attack. Silvicultural guidelines have been developed to lower the probability of attack in stands and reduce potential tree losses should outbreaks occur. Regional beetle populations, an assessment of forest health, and possible interactions with other forest pests need to be considered in selecting preventive treatments.

Silviculture is in transition to accommodate changing forestry prospectives in the South. New principles and practices are being developed to realize nontraditional forest management objectives. A concern is that visionaries may overlook the SPB as an important component of these future forests. The author discusses how proposed changes may promote or prevent SPB problems.

Is silviculture the answer to the southern pine beetle problem? It depends on the commitment to that goal.

IS SILVICULTURE THE ANSWER TO WESTERN SPRUCE BUDWORM AND DWARF MISTLETOE PROBLEMS IN THE SOUTHWEST?

Dayle Bennett[f]

Two of the most important pests of Southwestern forests are western spruce budworm (WSB) and dwarf mistletoes (DM). In addition to severely reducing tree growth, these pests also affect visual quality, wildlife habitat, and recreational experiences.

Silvicultural strategies, both as demonstration and more recently as operational timber sales, are being implemented in the Southwest to reduce the adverse effects of WSB, primarily in areas which emphasize timber production. These strategies are based on stand susceptibility and are aimed at improving tree vigor while making stand conditions less favorable to WSB. Longterm effects of these strategies have thus far not been measured.

Silvicultural strategies to prevent and control DM have proven successful and economical in the Southwest. These strategies are aimed at regenerating heavily infected stands or, in lightly infected stands, limiting the spread of DM while enhancing growth and vigor of the host trees.

While silvicultural strategies are an effective means of preventing and/or reducing the effects of WSB and DM, they are usually quite intensive and often result in opposition and close scrutinization. If not properly implemented, or implemented under inappropriate objectives and without public consent, many of these useful strategies may be lost.

PEST INFORMATION NEEDS FOR SILVICULTURAL DECISIONS

F. A. Baker[g]

We have discussed many ways to deal with some of the more troubling pests. Some of these methods have been known for many years. Yet, these pests still cause significant losses. There is a gap between our knowledge of the pest and the application of control methods, between knowing what to do and doing it. If silviculture is to be the answer to our pest problems, we must address several constraints. I would like to approach them from the silviculturist's point of view. My comments are based on talking with several silviculturists, and on evaluations of pest management presentations to silviculture shortcourses.

There are two ways to manage a pest situation incorrectly. First, silvicultural practices can be implemented when they are not justified. This increases inputs, i.e., the cost of stand management. The second is a failure to implement pest management practices when they are needed. This leads to reduced outputs. Both situations arise because of a poor understanding of pest impact - the silviculturist's or the pest manager's!

Pest managers often have a weak credibility with silviculturists. To them, pest managers come in two categories: Chicken Little - the pathologist who finds a pest on every branch. If all the pests he found ate their fill, only the stones would be safe. And then there's Ms. Natural. When asked about insect damage, the response is "That's natural. It's nature's way. No big deal." But pests are a big deal <u>when they impact the ability of stand to meet objectives</u>.

To better understand pest impact, pest managers develop pest models. Silviculturists could care less about pest models. They need to know how pests affect stand management objectives. They manage stands for timber, and also for grazing resources, wildlife habitat, scenic quality , and for people. How do pests affect these various resources? Over the useful life of a stand? Silviculturists need documentation of pest affects, because the public is better informed, and challenges their decisions. Further, they need to better understand the effects of management alternatives on pest damage, and on other pests.

Such models may be helpful, but they rely on information that must be collected from the stand: that is, information not in existing inventories. Who will collect it? And how? The western root disease model requires the number of infected trees, and the proportion of each stump with *Armillaria*. How do we get this information? With inventory data, silviculturists are fortunate to know that root disease is in a stand, let alone how much is on a stump. They need a measure of the pest that is simple, accurate and easily obtained. Data collected by inventory crews for rating dwarf mistletoe is of questionable accuracy - yet that is perhaps one of the easiest pests to see and rate.

Sometimes silviculturists are not aware of recently developed management practices. Pest managers publish technical papers in journals like Journal of Environmental Entomology and Phytopathology. Some silviculturists get the Journal of Forestry, and many see the regional Journals of Applied Forestry. They have a better chance of seeing the Forest Service series in publications. Pest managers must publish their result where silviculturists can see them.

But if we really want to get pest management practices implemented, incorporate them into the silviculture manuals. Then silviculturists would be reminded of pests each time they work through the guidelines.

I have rambled enough. Silviculturists make mistakes, but they manage the forests. Pest managers can help them by considering various objectives, especially non-timber objectives, when we design our management research. We need to make better decision-making rules available to silviculturists, and base those rules on information that already exists or is easy to collect. Then, we need to incorporate this process into the silvicultural decision making framework, where silviculturists will have to deal with it. It will become a part of their vernacular, a part of their doctrine, and they will become better pest managers. Silviculture can answer pest problems only if silviculturists consider pests in each prescription and implement pest management practices when warranted.

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ENDANGERED SPECIES - IMPACT ON FOREST MANAGEMENT

Moderator: Forrest Oliveria[1]

SPOTTED OWL - WHO GIVES A HOOT?

John Stewart[a]

The Deputy Chief of the Forest Service has said that in his 30 years of service he has never been involved with an issue that was so overwhelming and had so much interest in the public eye, the Legislature, and the courts as the Northern spotted owl. It is probably the largest natural resource issue facing the nation today.

The spotted owl lives approximately 15 years. One of the biggest problems with the spotted owl is its low reproductive rate. Individuals reproduce every 2-3 years, with two or three eggs per clutch. Approximately 1 out of 10 owl fledglings survive the first year. Other problems include the great horned owl, a natural predator. Because of threats of predation, we have to find timber stands that have varied structure that is necessary to shelter the spotted owl. The biggest problem facing the owl, however, is removal or alteration of suitable owl habitat. There are three species of spotted owls: the Northern spotted owl found from Canada to San Francisco, the California spotted owl found in the Sierra Nevada Mountains and into Southern California, and the Mexican spotted owl located in the New Mexico, Colorado, Arizona, and down into Mexico.

There are approximately 2400 pairs of Northern spotted owls within five provinces. California has approximately 600 pairs, primarily found on federal ownerships. There are 7.1 million acres of habitat suitable for the Northern spotted owl, down from an estimated 17.5 million acres in 1800, the earliest time for which accurate estimates can be found. The definition of suitability varies from location to location, but it is primarily focused on multi-layer stands that some call "old growth." Twenty-eight percent of suitable owl habitat is protected by Congressional withdrawals, such as wilderness or wild scenic rivers; twelve percent is unsuitable for timber production. The remaining sixty percent is available for timber management and, at current rates, is expected to be harvested within approximately fifty years.

The Pacific Southwest Region's strategy was to designate 1000 acres per Northern spotted owl pair plus 650 acres of replacement habitat. Probably the biggest problem with the existing and future projected condition of the suitable habitat is fragmentation. A lot of fragmentation has been caused by poorly planned and/or poorly placed timber sales.

The principal conservation law to protect the Northern spotted owl is the Endangered Species Act. This act is invoked when the U.S. Fish and Wildlife Service determines that existence of the subject species is threatened or, more seriously, endangered with extinction. The Northern spotted owl was listed as Threatened on July 23, 1990. Under the National Forest Management Act, the National Forests are directed to maintain the viability of the species. Viability is not well defined, no are the elements which contribute to viability of such a wide ranging species as the Northern owl.

In 1990 the Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl (or ISC) produced a report which challenged traditional thinking on spotted owl conservation. The ISC proposed a conservation strategy which called for the reserve of 7.7 million acres for the Northern spotted owl. The ISC report called the existing management plans "a plan for extinction" of the Northern spotted owl. The Forest Service adopted the ISC plan as the new conservation strategy and is currently working in incorporating it into forest management plans.

A principal element of the ISC strategy is to restrict timber management activities within the areas reserved for the owl. No vegetation management activities are allowed until they can be shown to benefit the spotted owl. Even salvage harvest is limited to "special situations where salvage of extensive areas may be proposed," and must be approved by the technical oversight group which reviews implementation of the strategy. This may have significant implications to forest pest management and

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may prove to be the ultimate challenge in maintaining the reserves--and the Northern spotted owl itself.

WILDERNESS, RED-COCKADED WOODPECKER, SOUTHERN PINE BEETLE AND FOREST MANAGEMENT

Timothy R. Bigler[b]

During the early spring and summer of 1990, the Raven Ranger District, Sam Houston National Forest in Texas, experienced a heavy infestation of southern pine beetle (SPB) in Little Lake Creek (LLC) Wilderness area. This area contained red-cockaded woodpecker (RCW), a threatened and endangered species. This presentation reviews the impacts of southern pine beetle suppression when associated with wilderness, threatened and endangered species, and concerns expressed by such groups as the Sierra Club.

Impacts included cut-and-leave activity of mature pine within a designated wilderness, the cutting of pine trees associated with RCW habitat needs, limited RCW habitat availability, the use of insecticide in a proclaimed wilderness, and the public's expressed concern that threatened and endangered species be protected without adversely affecting wilderness values.

Implementation of suppression activities as associated with the National Environmental Policy Act, Endangered Species Act, and the Eastern Wilderness Act were all noted as they impacted the operations to control southern pine beetle in a proclaimed wilderness and to protect threatened and endangered species on the Raven Ranger District.

THREATENED AND ENDANGERED AMPHIBIANS AND FOREST MANAGEMENT

R. Bruce Bury[c]

Old-growth or ancient forests of the Pacific Northwest are productive, diverse ecosystems, and highly specialized habitats that have a wide range of tree sizes and ages, a deep multilayered canopy, large individual trees, many snags, and accumulations of coarse woody debris of large dimension. Old-growth forests provide important habitat for a wealth of plants and associated wildlife.
The Pacific Northwest has many endemic or relict amphibians dependent on forested habitats. Several of these are threatened with extinction or are candidate species for future listing. Preliminary estimates suggest that 25-33% of the amphibian fauna is in jeopardy.

There is high species richness and abundance of wildlife in mature and old-growth forests, because many species are dependent on or associated with features characteristic of late seral stages of forests. For species with sufficient data for analyses, about 44-50% of the Pacific Northwest herpetofauna was associated with mature and old-growth stands. Current evidence suggests that many species and abundant populations of wildlife occur in naturally regenerated forests, particularly the older seral stages. However, the specific habitat requirements of most wildlife are unknown.

Current logging is mostly clearcutting, which removes all trees and snags. Logging is followed by prescribed burning of slash and cull logs, reducing available cover by 50% or more. Often, the end result of current timber harvesting is even-aged stands with little coarse woody debris, especially larger-sized material.

Recent research suggests that managed stands have fewer species and lower abundance of wildlife than old-growth forests. Thus, there likely has been major loss or depletion of biodiversity in the Pacific Northwest, because up to 87% of the old-growth Douglas-fir forests have been subjected to timber harvest over the last 100 years.

There are many types of forests and different communities of species in the Pacific Northwest, ranging from extremely wet coastal temperate forest to interior, dry-adapted mixed stands. Species and communities vary both across the wet-dry moisture gradient, elevation rise (e.g., the Cascade Mountains), and north-south gradients. There is marked geographic isolation of amphibians within these varied biotas, which further leads to jeopardy of their genetic diversity.

The current situation consists of fragmented, older stands surrounded by managed habitats (e.g., second-growth forest). Many efforts and strategies are being discussed on how to protect remnant old-growth forests. At the same time, there is a need to address how to best afford protection of biological diversity in managed forests, e.g., through improved protection of buffer zones and retention of more coarse woody debris in the ecosystems.

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SEMIOCHEMICALS: APPLICATION AND POTENTIAL

Moderator: Kenneth F. Raffa[1]

Insect pheromones represent a powerful and environmentally safe tool for forest pest management. These chemicals are essential to insects for such vital life history processes as reproduction and host finding, and so they provide a vulnerable point of attack from both the direct control and population monitoring perspectives. However, a thorough understanding of the target insect's behavioral ecology, within the context of its distribution, dispersal, and population dynamics is essential for this potential to be realized. Semiochemicals have already achieved implementation in some well characterized systems.

Semiochemicals currently play an important role in the management of several tree pests. In seed orchards, for example, the high value of the crop justifies intensive monitoring efforts. Pheromones can be used to estimate populations and time control treatments for pests. Use of pheromones to disrupt mating seems feasible, but not yet demonstrated, based on recent experiments.

Several important Lepidoptera pests of plantations and managed forests can be monitored and/or suppressed using pheromones. Monitoring allows for detection of introduced pests, pest-free certification, and judicious timing of insecticide sprays. Varying levels of control using mating disruption and/or trap out methods have been achieved against western pine shoot borer, Douglas-fir tussock moth, and ponderosa pine tip moth. Mass trapping and mating disruption have also been effective against gypsy moth populations at their leading edge, but less so within established regions. Likewise, pheromone-based monitoring provides a reliable estimate of gypsy moth populations in new, but not established, areas of infestation.

Major advances have been made in our knowledge of bark beetle pheromone systems. Pheromone-based monitoring and control are used widely against ambrosia beetles for example, and as part of integrated programs against the mountain pine beetle. There is some evidence that combined monitoring of southern pine beetle and its principal predators can be used to predict outbreak proliferation. There is also good experimental evidence that inhibitors such as verbenone can be used to modify normal dispersal behavior, and thereby reduce the spread of infestations. Despite these advances, our knowledge of pheromone chemistry, biosynthesis and individual variation is still only rudimentary. Likewise, our knowledge of how various control strategies will impact natural enemies is only poorly developed.

Further implementation of pheromones is hindered by some problems that are common to both Coleoptera and Lepidoptera management programs. These include practical problems such as a need for better release formulations and dispensors, scientific information gaps such as those listed above, monetary constraints in implementation, and registration issues. Current registration policies seem to bias against highly specific control agents such as pheromones, because of the high development costs relative to the small market potentials involved.

USE OF SEMIOCHEMICALS IN SEED ORCHARD PEST MANAGEMENT

Gary L. DeBarr[a]

Forest tree seed orchards are managed for maximum production of genetically improved seed. Seed orchards have unique characteristics and present interesting opportunities to employ semiochemicals in insect monitoring and control activities. Efforts to identify the behavioral chemicals to which coneworms (*Dioryctria* spp.), seedworms (*Cydia* spp.), seed moths (*Eucosma* spp.), and cone beetles (*Conophthorus* spp.) respond are summarized. Preliminary attempts to use synthetic semiochemicals to monitor and control these insects are discussed. Some limitations on the use of semiochemicals as pest management tools in forest tree seed orchards are discussed.

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OPPORTUNITIES AND HANGUPS WITH SEMIOCHEMICALS OF WESTERN FOREST LEPIDOPTERA

Gary Daterman[b]

Progress in development of semiochemicals as management tools for forest Lepidoptera has continued to move steadily forward. Pheromone-based systems for predictive monitoring are established for Douglas-fir tussock moth, and appear promising for western spruce budworm. Detection monitoring with pheromone-baited traps is in place for European pine shoot moth and some other pests of reproduction. Pest suppression by mating-disruption is registered and in modest use for western pine shoot borer, and is nearing registration for Douglas-fir tussock moth. Lack of adverse effects of mating disruption treatments on natural enemies has been documented in field tests on ponderosa pine tip moth and Douglas-fir tussock moth. Mating disruption appears to be an excellent approach as an environmentally-acceptable method of pest suppression, and should be developed for additional lepidopteran forest pests.

Specific items discussed will include long-term monitoring of forest pests with pheromone-baited traps, pheromone dispensing systems for the mating-disruption method of suppression, and a research approach and initial evaluations of phytochemicals as defoliator feeding deterrents.

Issues identified as "hang-ups" to semiochemical development as pest control agents include regulation and registration concerns; knowledge gaps that hinder development of acceptance of semiochemicals as pest management tools; development technology such as improved aerial dispenser systems; the minor-use characteristic of the forestry pest control market; and limited funding and other resources for research and development. Major opportunities identified include additional pest species for which semiochemical-based pest management applications are appropriate; research gaps for studying pest dispersal, distance responses, pheromone dispenser technology, pheromone plume behavior, phytochemicals as behavior-modifiers, etc.; and for a regulatory entity to become an advocate that actively promotes registration of semiochemicals as the control method of choice.

USE OF PHEROMONE IN GYPSY MOTH MANAGEMENT

Joe Elkinton[c], William Ravlin[d] and Shelby Fleischer[e]

Since its identification in 1970, much research and development has focused on the use of (+)-disparlure for direct control strategies (mating disruption and trap-out) and for survey and detection of populations. Despite successful demonstrations in low density populations, mating disruption remains expensive and technically difficult. It has not been widely employed. Trap-out, in contrast, has become a standard component (along with pesticide application) of efforts to eradicate incipient populations of gypsy moths in the western and southern United States. The detection of such populations has been made possible by a nationwide system of pheromone-baited traps. A sophisticated geographical information system for monitoring gypsy moths has been developed for the Appalachian IPM Project. Pheromone-baited traps spaced at 2 km intervals have been deployed across a large area in Virginia and West Virginia. The distribution of captured male moths is used to plan egg mass surveys and pesticide application. Efforts to develop a pheromone-based monitoring system for established gypsy moth populations in the northeast have not been very successful. The standard milk carton trap baited with 500 μg of (+)-disparlure fills to capacity even in low density populations. Several approaches to development of a low-catch trap, including the use of low-release-rate lures, have been evaluated. However, none have yielded good correlations between male catch and subsequent egg mass counts or defoliation in surrounding forest stands. We suspect that long distance flight of male moths accounts for the poor correlations.

WHAT WE DON'T KNOW ABOUT SEMIOCHEMICAL-BASED COMMUNICATION IN *DENDROCTONUS, IPS, TRYPODENDRON, SCOLYTUS, DRYOCOETES, PSEUDOHYLESINUS, PITYOPHTHORUS, PITYOKTEINES, LEPERISINUS, PITYOGENES, HYLASTES, PHLOESINUS, HYLURGOPINUS, CARPHOBORUS, POLYGRAPHUS, AD INFINITUM.*

J.H. Borden[e]

The study of semiochemicals in bark beetles is a science in its infancy. While we have considerable knowledge about semiochemical-based communication in some species, e.g., *Dendroctonus ponderosae*, and even use semiochemicals to manage such species, our knowledge is still incomplete. For most species, nothing is known about the identity of the major semiochemicals, let alone information on such subjects as: induction and chemistry of biogenesis; geographic variation; maintenance of species-specific communication systems; odor meteorology; transition from aggregation to antiaggregation; dose-response and component-ratio interactions; chirality; and biosystematic relationships. Knowledge on all of these subjects, and others, will lead ultimately to new strategies and tactics for utilization of semiochemicals in the management of populations, as well as to an ability to understand why management tactics do or do not work. With the anticipation of accelerated global warming, and the prospect of increasingly stressed trees, we can expect secondary species to emerge as pests, disrupting established community stability. Therefore, research should be extended to address as many species as possible, so that new semiochemical-based management tools are available when needed.

COMMERCIAL DEVELOPMENT OF PHEROMONES: SOME FOOD FOR THOUGHT

Staffan Lindgren[f]

The main industrial concerns with respect to commercial development of semiochemicals are market factors, and the cost of development including R & D, patent, licensing, and registration costs. Markets have to be sufficiently large to justify the investment risk, but the absolute size of the market may not be the determining factor. Proprietary protection of products, e.g., patents, licensing agreements, and technology transfer agreements, may provide the necessary safe guards to justify the risk.

Markets are very small, with a few notable exceptions, and the development costs are generally high. In forestry expensive large scale operational research is generally required to establish the level of efficacy. Collaborative research with university and government institutions is a critical component of the development.

Especially for smaller companies, registration costs constitute a significant impediment to bringing semiochemical products to market. There is a strong need to develop separate regulatory policies for semiochemicals, rather than relying on modifications of regulations designed to deal with conventional pesticides.

SEMIOCHEMICALS FOR USE IN SOUTHERN PINE BEETLE MANAGEMENT

Thomas L. Payne[g], **C.Wayne Berisford**[h], **Ronald F. Billings**[i]

In the past decade, semiochemical-based suppression tactics have been developed which offer potential for use in management of the southern pine beetle *Dendroctonus frontalis*. The chemicals can be generally classified as attractants or aggregation pheromones (e.g., frontalure, i.e., frontalin plus *alpha*-pinene) and inhibitors, interruptants, or anti-aggregation pheromones (e.g., verbenone and *endo*-brevicomin). Frontalure-baited traps were found effective for use in survey to provide a relative measure of the potential for population increase. However, because of the infestation spot characteristic of southern pine beetle, attractants have not been investigated using an attractant-based, trap-out approach. Instead, attractants were investigated for use in a "Lepidoptera-type confusion technique" and in a concentration tactic. Aerial release of attractant over an infestation to promote "confusion" did not suppress or prevent spot growth. Instead it caused and increased the spread of the infestation. However, when placed as baits on infested trees within the center of an infestation, attractant reduced, and in some cases, halted spot spread by bringing emerged beetles back to previously attacked trees and away from unattacked trees. The tactic was effective under less than epidemic population levels of the beetle and in small spots. When population levels were more epidemic and infestations were large, the technique had little effect. By comparison, verbenone was more successful in suppressing, and in some cases, halting infestation. When placed on freshly attacked and unattacked trees as a buffer along the advancing edge of an active infestation, verbenone was effective in suppressing small infestations in stands with pulpwood size timber. However, in sawlog size timber the tactic was less effective. In combination with the attractant tactic, verbenone did suppress some infestations in sawlog size timber. However, more effective was the combination of the inhibitor tactic with felling all freshly attacked trees to reduce the natural source of attraction. Recent findings suggest that a mixture of (+) and (-) verbenone approaching a 50:50 ratio, is more effective as an inhibitor than the predominantly (-) verbenone used in earlier evaluations of the tactic. Operational use of the tactics is dependent upon the development of an effective elution device for release of the compounds, and ultimately, registration.

PROSPECTS FOR VARIOUS USES OF SEMIOCHEMICALS IN BARK BEETLE MANAGEMENT

David L. Wood[j]

More than thirty-five forest pest management, Canadian and U.S. researchers, State personnel, and semiochemical industry representatives attended a Western Bark Beetle Semiochemical Workshop, January 26-29, 1988, in Lakewood, CO. The purpose of the workshop was to respond to a request from Washington Office, Forest Pest Management for personnel from the Western Regions to develop a Westwide Plan to standardize the use of semiochemicals for bark beetle management in the West and to guide the Washington Office in the allocation of funds for proposals to use semiochemicals in the management of western bark beetles. It had become evident throughout the Forest Service that there was a great deal of interest in the use of semiochemicals, but little consensus on how, when, where, or even if these materials should be used.

At the Work Conference titled, "Attraction and Dispersal of Pine Bark Beetles and Their Associates" held October 16-19, 1989, Mountain Lake, VA, I concluded the following: Semiochemicals are known for most of our destructive bark beetle species, including both attractants and antiattractants. They have been used successfully to aggregate beetles on trees to be removed from the forest. However, the efficacy of the mass trapping tactic has not yet been demonstrated at the population and crop protection level. The efficacy of the interruption tactic at the crop protection level has only been demonstrated for the Douglas-fir beetle and recently for the mountain pine beetle. Without significant interest by land managers in protecting forests from bark beetle-caused tree mortality, progress in developing these tactics will remain slow. Unfortunately, the need for such short-term tactics will occur in the future, but they will not be available. This conference recommended the following: 1) develop survey and suppression tactics and strategies for use of semiochemicals in pest management; 2) economic analyses; and 3) evaluation of pest management tactics and implications to ecology and the environment.

In California I participated in the development of a "Research Proposal for Additional Integrated Pest Management Tools and Strategies to Control Urban and Wildland Forest Pests." This proposal is in response to a resolution passed by the California Forest Pest Council in November, 1989, to increasing mortality to California's timber stands caused by forest pests, and to public concern on the use of pesticides.

The proposal was developed by an interagency steering committee with representatives from the following: California State Board of Forestry, California Forest Pest Council, County Supervisors Association of California, Timber Association of California, University of California, United States Forest Service, Pacific Southwest Forest and Range Experiment Station, Forest Landowners of California, and the California Department of Forestry and Fire Protection.

The proposal focuses on forest management research, technology transfer, and outreach. Annual funding is targeted in the following areas over a period of 10 years:

> Forest Insects: $1,352,000; Forest Diseases: $300,000; Animal Damage: $100,000; Weeds: $350,000; Urban Pests: $470,000; Technology Transfer and Outreach: $455,000; Total Annual Funding: $3,000,000.

In the opinion of the scientists developing this program, the research will produce substantial benefits in excess of the cost. Any one of the specific benefits, such as the trapping of bark beetles during an infestation or limiting root disease, will justify the expense of the program.

Under Forest Insects the following budget was recommended for research and development on behavioral chemicals:

1) Test efficacy of trap-out method for area-wide population reduction. Priority will be given to western pine beetle, mountain pine beetle, and *Ips* spp. $425K; 2) Evaluate efficacy of anti-attractants for single tree protection and to interrupt aggregation over large areas. Priority will be given to western pine beetle and *Ips* spp. $300K; 3) Determine effective dosages of optical isomers of ipsdienol, ipsenol, and verbenone for use as anti-attractants. $75K; 4) Isolate and identify pheromones and anti-attractants for the jeffrey pine beetle and white fir engraver beetle. $75K; and 5) Isolate and identify feeding stimulants from the phloem of host trees. $50K.

AGGREGATION BEHAVIOR OF THE PINE ENGRAVER BEETLE, *IPS PINI* (SAY) IN RESPONSE TO ENANTIOMERICALLY PURE IPSDIENOL

S.J. Seybold, M. Nomura, I. Kubo, and D.L. Wood[j]

The aggregation pheromone of the pine engraver beetle, *Ips pini*, was isolated by extraction of the frass and Porapak trapping of volatiles from male-infested logs and identified as ipsdienol (2-methyl-6-methylene-2,7-octadien-4-ol)Using Propak trapping of volatiles and normal phase HPLC, we have re-isolated ipsdienol and determined its enantiomeric composition from more than ten populations of *I. pini* collected throughout North America. After purifying gram quantities of (R)- and (S)-ipsdienol by preparative HPLC, we have conducted a behavioral dose-response study of *I. pini* to the pure enantiomers at a field site in California.

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MANAGEMENT OF REGENERATION INSECTS

Moderator: Arthur G. Raske[1]

The increased areas of land occupied by young forests in the last 20 years have given opportunity for a new complex of insects to gain pest status and steal attention from the established pest species of mature forests. Insects such as the western pine shoot borer, spruce budmoth, pitch-eating weevil, and seedling debarking weevil have become serious forest pests in sizeable areas of North America. Furthermore, they are likely to be joined by other insect species as new, and sometimes semi-artificial forest conditions, are created through intensive forestry practices.

Fortunately, there are a greater number of options available to combat the damage of pest species in regeneration forests. The relatively small area, the uniform tree size, and the high value of such forests allow us to use some of the newer suppression tools provided by research.

Symposium topics first dealt with some basic processes that affect regeneration forests to a greater extent than forests that are generated naturally, and then switched to examples of specific pests; such as tip feeding moths, defoliators, and several weevil species. The pests of fast-growing hardwoods, so important in tropical climes, are now also becoming serious in the temperate Americas. The last topic of the symposium considered the changing legal ramifications of pest control on young stands.

Forest insects can have a significant influence on nutrient cycling, and this influence needs to be considered before stand establishment. Research in this field is still in its infancy, and more progress needs to be made before the benefits or damages are understood.

The breeding of trees resistant to pest damage has much potential, but is complex. Of the four types of resistance: escape from damage, non-preference, antibiosis, and tolerance; development of tolerance seems to offer the best opportunity in the near future. The work of screening existing genotypes is the most urgent. An advantage is that forests are well suited to this approach.

Several tree diseases have become very important pests of young stands, and insects have become important because they provide the means of spread for some diseases. Thus, the feeding damage of *Pissodes* (weevils), *Rhyacionia* (tip moths) and *Dioryctria* (coneworms) provide the necessary infection courts of two important diseases, pitch canker (*Fusarium subglutinans*) and fusiform rust (*Cronartium quercuum*) in Florida and adjacent states. Reducing damage by these insects, by various means, early in a plantation will prevent many severe pest problems during the whole life of a stand.

Pine plantations in western United States can be severely damaged by pine shoot borers, resin midges, and needle sheathminers. The results of much fundamental research of past years cannot be applied to the changed conditions caused by human intrusion and shifts in climate. Therefore, fundamental research must continue, side by side with applied research, in the years to come.

Loss of increment, reduced height growth, and loss of tree form become important in appraising damage of young stands. Tip moths (*Rhyacionia*) and budmoths (*Zeiraphera*) are examples of pests that have become important in young stands. Interplanting susceptible and resistant trees, planting mixed species, and fertilizing and weed control to increase growth are four silvicultural practices that show promise for reducing damage to acceptable levels.

Defoliation by the spruce budworm in all-aged Douglas-fir stands causes extensive mortality of trees less than 2 cm DBH. However, sufficient numbers of small trees survived 7 years of budworm defoliation, consequently, the ingrowth of trees into the upper DBH classes was not threatened. This is an example of where the do-nothing-option keeps damage within acceptable limits.

The damage of several species of weevils can be reduced by a number of non-chemical means. The use of attractants in flight- or in pit fall- traps is a promising tool to measure population levels. This enables the development of hazard rating indices and control strategies that are very site specific. Strategies

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incorporated into integrated control can include many of the following in the near future: barriers, nematodes, modified planting methods, adjusting harvesting schedules, stump and soil treatments with insecticides, trapping systems, and feeding deterrents.

Fast-growing hardwoods are managed on short-rotation systems. These types of agroforestry system management plans, that include protection measures, must be in place prior to the appearance of pest problems. Such plans also require continuous monitoring for insects and diseases. The use of resistant clones is almost the only way to control disease problems, whereas the integration of several methods can provide acceptable control of problem insects.

The evolving common law and tort law in the southeastern U.S. is fast changing to favor the adjoining land owner (that is harmed), rather than the defendant (the land owner). Thinning and harvesting of pine stands increases populations of weevils, which will disperse to adjoining land and may cause considerable damage to adjoining Christmas tree and other plantations. The legal ramifications of forest practices are giving forest insect problems increased attention, although it is different than that usually given by forest entomologists.

INSECT CONTRIBUTIONS TO NUTRIENT CYCLING AND BIODIVERSITY IN REGENERATING FORESTS

Timothy D. Schowalter[a]

Insect outbreaks in forests are often triggered by changes in nutrient availability that affect plant suitability or susceptibility to insects, or changes in host abundance that affect plant exposure to insects. Resulting tree mortality and growth suppression have been the traditional focus of forest entomological research. However, insect contributions to nutrient cycling and biodiversity may alleviate conditions leading to outbreaks and promote long-term forest productivity and stability.

I manipulated defoliator abundances on regenerating Douglas-fir from 0% to 20% foliage removal during the growing season and measured above-ground growth and foliage production, nutrient turnover from foliage to litter, and litter decomposition for 3 years. Defoliation caused no significant change in plant growth and foliage reproduction, but significantly increased nutrient turnover. Precipitation penetration through the canopy and litterfall were doubled, and nitrogen, potassium, and calcium turnover was increased 20% to 30% during the growing season at 20% defoliation compared to no defoliation.

Selective feeding by herbivores on host trees also promotes development of non-host vegetation and provides food and habitat resources for predators and other associated fauna. Other communities are affected, as well. For example, in the study of folivore effects on nutrient cycling summarized above, three taxa of litter microarthropods, including two oribatid mites, were significantly more abundant under defoliated trees than under non-defoliated trees. The importance of these oribatid species and their response to defoliation is unknown. They may have responded to changes in food resources or to changes in litter microclimate. Litter microarthropods contribute directly and significantly to litter decomposition processes and soil fertility. Therefore, folivores may affect soil fertility and forest health indirectly as well.

Forest insects can influence nutrient cycling and biodiversity even at relatively low abundances. These effects may mitigate changes in plant condition and abundance that often trigger insect outbreaks, and thereby promote long-term forest health. Forest entomological research should progress beyond studies of plant injury during outbreaks to address potential long-term contributions to forest health. These contributions should be considered during forest planning stages, especially during regeneration when management practices can affect forest health and the likelihood of outbreaks over entire rotations.

INTERACTIONS AMONG FOREST INSECTS AND TREE DISEASES IN FLORIDA PINE PLANTATIONS

John L. Foltz[b] **and George M. Blakeslee**[c]

The pine plantations of Florida do not suffer from bark beetles and root diseases like many other coniferous forests of North America. Slash pine, *Pinus elliottii*, the predominant pine species, is highly resistant to infestation by *Dendroctonus frontalis*. During droughts, the aggressive, tree-killing bark beetles are *D. terebrans* and *Ips calligraphus*. Loblolly pine, *P. taeda*, is infested by *D. frontalis*, but the scarcity of old-growth stands and the relatively young age of most plantations apparently keep populations and damage of these two beetle species at very low levels. The major diseases of these two pines are pitch canker and fusiform rust, both of which have numerous interactions with many insects.

Pitch canker (PC) is caused by *Fusarium subglutinans*, a wound parasite. The feeding wounds of *Pissodes nemorensis* provide an infection court for the fungus and contaminated weevils can inoculate the tree during their feeding on new shoots. The resulting dieback of diseased branches and stems provides more brood material for the weevil and results in positive feedback between weevil numbers and PC abundance. The larval galleries of tip moths, *Rhyacionia* spp., also provide infection courts for the PC fungus, but the biology of these moths does not suggest a vector role. Infestation of pine stems by the southern pine coneworm, *Dioryctria amatella*, is another important infection court. Infestations are greater in heavily fertilized stands, and the greater tree mortality may offset the benefits of increased tree growth.

Fusiform rust, caused by *Cronartium quercuum* f. sp. *fusiforme*, is the most damaging pest of Florida pines.

Several recent papers report a positive correlation between tipmoth abundance and the number of rust galls. Secondary shoots produced after tip moths kill the primary shoot may provide more susceptible tissue for basidiospore infection. Other interactions occur when *P. nemorensis* and *D. amatella* infest rust galls and PC develops as described above. These associated pests further reduce tree growth and increase tree mortality. Finally, the regular availability of rust-killed trees supports bark beetles and other decomposers at greater levels than would otherwise occur. Therefore, outbreaks of these insects may develop more rapidly whenever a forest is stressed by other biotic or abiotic agents. Thus, reducing tipmoth and rust levels during the early years of a plantation can reduce pest problems throughout the remainder of the rotation.

RE-DEFINING SOME KEY PESTS OF REGENERATING PONDEROSA AND LODGEPOLE PINE STANDS

Lonne Sower[d]

The western pine shoot borer, *Eucosma sonomana*, has been recognized as a pest of pines throughout the West since about 1973, and this recognition coincided with development of managed pine plantations. *E. sonomana* may infest 40% to 60% of ponderosa pine terminals and cause a 10% to 12% loss of growth potential through half of the crop rotation. Damage symptoms are subtle, however, and trees are not killed outright. Therefore, the shoot borer is easy to ignore.

Infestation levels in lodgepole pine may be even higher, with 65% to 80% of the terminals infested. Symptoms of attack on lodgepole pine, such as short needles, short terminal shoots, dead shoots, and exit holes, were similar to those on ponderosa pine, but even more subtle. However, exclusion of shoot borers with nylon bags in two young lodgepole stands showed that the impact of the insect was profound. Vertical growth of protected trees exceeded that of unprotected trees by 24% per year.

Eucosma infestation levels in lodgepole pine were decidedly higher than in ponderosa pine. Additionally, about half of the infested lodgepole pine terminals had multiple larvae. Also, younger lodgepole pine, often as small as 0.5 m tall, were commonly infested. Larvae in small ponderosa pine usually are killed by resin flooding into larval mines. These characteristics suggest that the shoot borer is more adapted to lodgepole pine than to ponderosa pine.

In the past 50 years, the area of regenerating stands has changed considerably as have the forest habitat and pests. The pine shoot borer and the resin midge are examples of such pests. Both can retard growth of regenerating pines for several years. Needle sheath miners can defoliate 100% of terminals in even-aged ponderosa pine plantations. Human intrusions, along with shifts in climate, have greatly changed western forests in the last 30 to 100 years when most fundamental forest insect research was done. Ramifications of these changes will be forced on us until a new equilibrium is reached. We should respond with more fundamental research in changed and changing forest habitats.

INTENSIVE MANAGEMENT OF LOBLOLLY PINE: RESULTS OF A 5-YEAR STUDY

C. Wayne Berisford[e] and John F. Godbee, Jr[f]

Young loblolly pine stands may sometimes sustain considerable damage from attacks by pine tip moths, *Rhyacionia* spp.; primarily the Nantucket pine tip moth, *R. frustrana*. Although tree mortality is relatively rare, growth loss and loss of tree form are common.

Several studies report positive relationships between site preparation intensity and tip moth attack. Some current management practices include the use of herbicides to control competing vegetation during plantation establishment and sometimes fertilizer to increase early growth. These practices normally increase survival and growth but frequently also exacerbate tip moth infestations.

We initiated a study in 1985, in a newly established loblolly pine plantation in the lower piedmont plateau of Georgia, to evaluate the effects of various combinations of weed control, pine tip moth control, and fertilizer. Treatments were: 1) untreated checks, 2) herbicide for weed control and fertilizer, 3) herbicide, fertilizer, and insecticide for tip moth control, 4) insecticide only, 5) herbicide and insecticide, and 6) fertilizer and insecticide. Tip moth infestations, tree form, heights, diameters and stem volumes were measured for five years after treatment.

Tree growth was generally correlated with the intensity of management. After three years, trees receiving insecticide for tip moth control (TMC) and herbicide were significantly taller and had larger diameters than the other treatments. Those receiving TMC in combination with any other treatment had significantly better form. The same relationships were evident after five years. Then differences were not as great as in earlier years, but total stem volume still showed significant gains from the intensive treatments. A companion study in the Georgia coastal plain showed the same pattern of early growth, but much of the early gains were lost by the fifth year, because trees in plots with the less intensive treatments "caught up" with the early leaders as their growth began to slow; apparently from intense root and crown competition. Stands receiving cultural treatments which produce early rapid growth may require precommercial thinnings or wider initial spacing be maintain the advantage gained.

Early growth and form differences suggest that intensive stand management practices which include some combination of tip moth control, weed control, and fertilizer, may produce higher volumes at harvest. However, only long-term replicated studies carried through rotation on a variety of sites can provide the data on which to base sound management decisions.

INTERACTION BETWEEN WHITE SPRUCE AND THE SPRUCE BUD MOTH: IMPLICATIONS FOR MANAGEMENT

Dan Quiring[g]

The spruce budmoth, *Zeiraphera canadensis*, is the most serious pest of white spruce in plantations in eastern Canada. Larval feeding results in reduced height growth and wood quality. Experimental and life-table studies have demonstrated that budmoth populations attain economically significant levels only on open-grown white spruce trees greater than 1 m in height and decline after crown closure. Thus, plantations are susceptible to this defoliator for approximately 5-15 years.

The susceptibility of young open-grown trees is influenced by female oviposition preference and by host suitability for egg and larval development. Plant genotype has a significant effect on egg and larval survivorship. Egg survivorship was lower on the least susceptible half-sib families due to a higher incidence of egg parasitism and predation. Larval survivorship was also lowest on the least susceptible half-sib families and was inversely related to the date of bud burst.

Possible management options for reducing damage by the spruce budmoth include: planting partially resistant trees; decreasing spacing to accelerate crown closure; or adding fertilizer or growth hormones to accelerate crown closure. Planting susceptible among resistant trees could result in earlier crown closure and should reduce selection pressure on the budmoth to overcome tree resistance. In addition, in areas with high bud moth populations, the bud moth might selectively thin stands by reducing the growth of susceptible trees to such an extent that they are eliminated by competition shortly after crown closure. Intercropping white spruce with other tree species could also reduce susceptibility to bud moth.

EFFECTS OF WESTERN SPRUCE BUDWORM, *CHORISTONEURA OCCIDENTALIS*, ON REGENERATION OF UNEVEN-AGED DOUGLAS-FIR STANDS OF BRITISH COLUMBIA

Rene I. Alfaro[h]

Uneven-aged management is the preferred silvicultural system for Douglas-fir in large portions of the interior of British Columbia. Under this system, foresters attempt to maintain a continuum of age and diameter classes on a given unit of land. The diameter distribution assumes the characteristic J-shaped form with predominance of the smaller diameter classes and gradually lesser numbers of the large tree sizes. Management operates by periodically conducting a selective harvest ensuring a maintenance of the uneven-aged distribution. In theory, regeneration in these stands occurs continuously, with new trees starting under the canopy of the residual stand at a steady rate. In reality, regeneration is patchy and periodic, and depends on factors such as openings created during harvesting, and availability of seed from the upper canopy.

Seven years of western spruce budworm defoliation caused changes in the structure of an uneven-aged Douglas-fir, *Pseudotsuga menziesii*) stand. The stand was overstocked with a total density of 5402 stems/ha. Budworm-caused mortality reduced density to 4018 stems/ha; a reduction of 26%. Mortality was concentrated in the small diameter classes and no trees larger than 25 cm DBH died. Mortality was particularly concentrated among the very small, regeneration trees of 1 cm to 7.5 cm DBH, where 42% of the trees died. This DBH class provides the future merchantable size classes for harvest. Therefore, to ensure sustainability of the unevenage structure it is important to maintain an adequate stock of these small trees. However, because of high initial stocking, the mortality caused by the budworm did not alter the diameter distribution in a manner that would threaten the flow of trees into the upper classes. Calculation of the diameter distribution's diminution quotient "q" indicated a value of 1.63 before budworm and 1.58 after budworm-caused tree mortality. Both quotients are well within the acceptable bounds for sustainable diameter distributions for uneven-aged stands.

USE OF HOST VOLATILES IN MONITORING PINE ROOT WEEVIL DISPERSAL AND ITS MANAGEMENT IMPLICATIONS

Lynne K. Rieske and Kenneth F. Raffa[i]

The pales weevil, *Hylobius pales*, and the pitch-eating weevil, *Pachylobius picivorus*, are part of a weevil complex causing extensive damage to plantation pines throughout the Lake States. Monitoring field populations of the weevil complex is possible using pitfall traps baited with ethanol and turpentine.

Six combinations of ethanol and turpentine were compared for their relative attractiveness to *H. pales* and *P. picivorus*. Both species were more attractive to ethanol/turpentine ratios greater than 1:1. Pales weevils preferred slightly higher ethanol/turpentine ratios than did pitch-eating weevils. Both sexes responded equivalently within each species.

Dispersal patterns of these species were studied using mark and recapture techniques and pitfall traps baited with a 1:1 ratio of ethanol and turpentine. Approximately 17% of the pales weevils and 34% of the pitch-eating weevils were recaptured. Most pales weevils were recaptured in the immediate vicinity of the release point, whereas pitch-eating weevils appeared to disperse further before responding to the baits. Marked weevils were recaptured up to eight weeks following the release date. Pronounced temporal differences in recapture rates were seen, with more weevils responsive in early than late summer.

A separate trap was developed to monitor weevil flight. Total weevil numbers were more commonly caught at 81 cm than 160 cm. Pitch-eating weevils were more responsive to the ethanol/turpentine baited pitfall traps than to flight traps.

The implications of these behavioral responses and dispersal patterns is discussed with respect to host location, niche partitioning, and integrated pest management of the weevil complex.

MANAGING THE SEEDLING DEBARKING WEEVIL IN THE MARITIMES

Bruce A Pendrel[j]

The seedling debarking weevil, *Hylobius congener*, is a new pest of reforested areas in Maritime Canada in the sense that it is now a significant damaging agent where previously it was considered innocuous. This weevil shares a similar life history to two other weevils, the European *Hylobius abietis* and the North American *Hylobius pales*. Pest status for *H. congener* has been primarily caused by a change in reforestation practices to immediate planting following harvest operations.

Management of this weevil has resulted from a number of initiatives and activities; life history studies, damage surveys, analyses of degree of damage occurring on a site, population measurements, the development of a standardized trapping system, and a system to predict the degree of damage on a site. Testing of a variety of control options included pesticides, barriers, nematodes, and planting-site modification. Integration of a site hazard index with control strategies by means of an economic analysis provides a basis for decision making.

PALES WEEVIL: A DIVERSE PEST REQUIRING FLEXIBILITY AND INNOVATION IN MANAGEMENT STRATEGIES

Scott M. Salom[k]

The polyphagous nature of and wide geographical range inhabited by pales weevil, *Hylobius pales*, underscores the ability of this species to adapt successfully to different management systems of its hosts. Not only can *H. pales* feed and develop on as many as 29 species of native and exotic conifers, but they can feed on both live and dead subcoritical tissue. This insect is best known in the southern U.S. as a regeneration pest, and breeds in the roots of stumps and slash on cutover pine sites. Larvae feed on the stems of newly planted seedlings the next year. In the northern U.S. and southern Canada, *H. pales* is principally a pest of Christmas tree plantations, killing seedlings and causing cosmetic injury, such as flagging. At the north/south interface in Virginia, this weevil is a regeneration pest of pine forests and Christmas tree plantations. It is the principal vector of the fungus, *Leptographium procerum*, a deadly pathogen of white pine, *Pinus strobus*.

These different situations require use of varied pest management strategies. For forest plantations in the South, integrated control strategies include: spatial and temporal adjustments of harvesting schedules to help keep weevil populations down; a hazard rating system based on timing of harvesting, to determine when it is safe to plant seedlings; and treatment of seedlings with insecticides. For Christmas tree plantation management, calendar spraying of stumps and soil surrounding the trees is the primary means of control.

Future management considerations should rely on integrated control. The integrated system currently used in North Carolina appears to work successfully, but could probably benefit from accurate forecasting of weevil damage. An effective trapping strategy, modified by researchers in Wisconsin from a system used for *H. abietis* in Europe, should pave the way for developing forecasting capabilities of weevil damage at different sites or different areas within a site. To slow the spread of *L. procerum* in Virginia, alternatives to repeated spraying of toxic insecticides need to be considered. Research that develops methods to inhibit or deter weevil feeding on tree stems may lead to an environmentally safe way of reducing white pine mortality caused by this disease.

MANAGING INSECT PESTS OF FAST-GROWING HARDWOODS

Lawrence P. Abrahamson[l]

Three fast-growing hardwood short rotation management systems will be covered: cottonwood in southern USA, hybrid-poplar, and hybrid-willow in northeastern USA and eastern Canada. Intensive management of these hardwoods involves complete site preparation including killing existing vegetation with post-emergence herbicides, plowing, discing, placing a pre-emergence herbicide "cap" on the site, planting of cuttings, and intensive weed management. This is similar to farming, a type of agricultural forestry.

An intensive management scheme with clonal materials will require intensive pest management. Insect and disease problems will develop and management plans are needed to stay ahead of problems, or plantations could be seriously damaged within a very short time. An integrated pest management approach is necessary and both expected and unexpected insect and disease pests are monitored continously throughout the rotation of the plantation. Disease resistant clones of tree species, developed through genetic selection, are the only way to handle most disease problems. Continuous pest monitoring, genetic selection, resistance to insect and disease, and intensive management control options, including the use of insecticides, are required to stay ahead of insect and disease problems in fast-growing hardwood plantations. Important insect and disease problems of short rotation cottonwood, hybrid-poplar and hybrid-willow plantations were reviewed emphasizing control options and management schemes.

LEGAL RAMIFICATION OF CONTROL

Wayne N. Dixon[m]

The shrinking commercial forest land base in Florida and efforts to control pine reproduction weevils are causing a legal morass. Thinning and clearcut logging operations of pine stands pose a risk of significant weevil damage to conifers on adjoining land. Christmas tree farmers and private non-industrial forestry landowners have filed suits to recover damages caused by pales weevil, *Hylobius pales*, and pitch-eating weevils, *Pachylobius picivorus* dispersing from logged lands.

Case law for this problem has been favorable to the typical defendent, i.e., the party with logging activities. However, our law is evolving to the interests of the plaintiff, i.e., the adjoining landowner.

The defendent claims a right to manage his pine stands, which includes thinning or harvesting. The pine reproduction weevils will inhabit and reproduce in such areas, and eventually will leave it. This is considered a natural occurrence. Therefore, the defendent has no responsibility for what happens to trees on adjoining lands. Indeed, traditional rule under English and American law holds that the owner of land is under no affirmative duty to remedy conditions of purely natural origin upon his land, although they may be highly dangerous or inconvenient to his neighbours. Courts have ruled that a possessor of land is not liable to persons outside the land for a nuisance resulting from trees and natural vegetation growing on his land. Further, use of land in a lawful manner by an owner arguably removes guilt of a nuisance even though it may cause inconvenience or annoyance to a neighbour. According to established law, an owner is exonerated from liability for injuries to an adjoining owner where a reasonable use is made of property.

The plaintiff argues differently. Historically, the immunity from liability for harm outside of owned land caused by a natural condition on that land originated when most land was undeveloped and unsettled. The cost to inspect and remedy natural conditions on owned land was ruled burdensome when measured against the risk of harming others outside that land. Indeed, the low human population densities, the ease of moving to avoid a harmful condition, and the high cost of correction easily established immunity. These circumstances no longer exist. High human population densities, little or no opportunity to move, and less costly control measures are realities of today. A landowner is now held liable for harm occurring outside his domain when it arises from artificial conditions on his land. This has been extended to natural conditions.

Common law is clearly being changed as the trend to reform tort law continues. Courts are deciding for the plaintiff - the harmed adjoining landowner. Modern realities are more likely to reign supreme when pitted against retaining outmoded doctrines.

Pine reproduction weevils will present new challenges to landowners, foresters, pest management specialists, and lawyers. The evolving of common law and tort law promises that this problem insect group will receive increased attention, although it will be a different kind than that usually given by forest entomologists.

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INTEGRATED PEST MANAGEMENT: STATUS OF PROGRAMS AND FUTURE NEEDS

Moderator: F. William Ravlin[1]

For many years the integrated pest management (IPM) paradigm has been taken as an accepted approach to forest pest problems. The paradigm, as given by Waters and Cowling (1976), shows very simply how models, information, and decisions can interact to produce control schemes for the management of pests. In fact today, IPM is usually thought of as a given and that the basic components of IPM (i.e., monitoring systems, models, and appropriate combinations of chemical and nonchemical controls) naturally fall together to create the cost efficient and environmentally sound control systems that universally are desired.

Similarly, the research, extension, and implementation portions of the IPM paradigm are perceived as a means by which new technology is produced, disseminated, and adopted by the management community.

The objectives of this symposium were to summarize and evaluate:

1) The state-of-the-art in information management systems.

2) The state-of-the-art in selected forest insect IPM programs (i.e., southern pine beetle, mountain pine beetle, and gypsy moth).

3) Some mechanisms for research and demonstration of new technologies.

INFORMATION MANAGEMENT AND IPM

S.J. Fleischer, F.W. Ravlin, and L.P. Schaub[a]

The currency of IPM is information. We essentially trade-off pesticide applications for information. As a result of sampling, formating data, interpreting the results, and adding human intuition, experience, and preferences, decisions are made and controls are applied. This is a dynamic process because, as described by Mumford and Norton (1984), decisions made yesterday will affect today's decisions and we must ask how much are decisions determined by history, personal attitudes and abilities, the sequence of information presented to decision makers, or by objective data. Can we learn enough about the decision making process to separate these sources of variability and manage information to arrive at better pest management decisions? The answer to this question is not clear but what is clear are the current attempts to combine different sources of information and knowledge into forest management decision support systems.

The IPM paradigm demands that pest and stand data be collected and information delivered in a timely fashion so management decisions can be based on the state of the ecological system concerned. However, one of the roadblocks to forest pest IPM is data acquisition and delivery. This roadblock stems from the lack of cost effective, precise, and accurate sampling protocols (e.g., sequential sampling schemes) for individual stands, and the ability to sample several stands or adjacent areas with a high enough resolution to present a clear and continuous picture of insect populations from a landscape perspective.

Another roadblock to the successful implementation of IPM is the need for pest managers to interact directly with forest and pest data bases on a real-time basis and to have direct and immediate access to state-of-the-art knowledge about the system in question. The only way this can occur is through the development of computer-aided decision making tools such as data base management systems, geographic information systems, predictive models, and knowledge bases. Examples of systems under development are: GypsES, a gypsy moth management decision support system that integrates each of decision making tools listed above; GypMap, a

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geographic information system also for gypsy moth management at the county level; and ISPBEX a knowledge-based system for southern pine beetle management. Through the development of systems like GypsES and ISPBEX we are are only now beginning to understand the complexity and size of data bases and knowledge bases required to manage forest pests. It is this size and complexity that demands even more robust systems than the ones currently in place or being developed. Further, because we expect that pest managers will spend much of their planning time interacting with systems like these, their acceptance and use will be successful only if pest managers are actually involved in the system development process (Fleischer et al. unpub. manuscript).

SOUTHERN PINE BEETLE MANAGEMENT

W.A. Nettleton[b]

The southern pine beetle (SPB) is the most destructive insect pest of pine throughout the South. While most outbreaks only last about 2 or 3 years in a local area, somewhere in the range of the beetle, epidemic populations can be found in almost any year. Economic losses can be substantial -- the last 5 years have averaged $60,000,000 in stumpage value loss alone.

The South has over 182 million acres of forest and timber products are perhaps the most important agricultural crop in the Region. A big difference about the South compared to other regions is that 90% of the forest land is in private ownership. National forest land comprises 6% of the total.

The forests of the South are dynamic. Growing seasons are long, 220 to 270 days. This favors both the rapid growth of the trees and build up of pest problems. Most pests have high reproductive potentials, leading to overlapping generations. The SPB has 7 to 9 generations/year. We are faced with a variety of insect and disease pests which may interact with SPB at some point in the life of the stand.

Historically, the most common approach to dealing with a sporadic but serious pest like SPB is to respond to the crisis on an ad hoc basis -- often recognizing that long-term preventive management would ultimately be more effective. However, strange as it seems, concern for the SPB often declines faster than the outbreak. This is due to the fact that between outbreaks there are few beetle spots around to trigger one's memory of the devastation of an epidemic.

In the past 17 years, there have been 2 major federally-funded research efforts, ESPBRAP and the IPM Program. This research has led to a better understanding of the beetle. Through this effort we have identified fairly well the components of the IPM approach for dealing with SPB and the associated pests of the pine resource. The basic IPM components that affect forest management include 1) pest population changes over time, 2) susceptibility of forest stands over time, 3) pest impacts on resource values and management objectives, and 4) control strategies and resource utilization. The latter two components are used in the economic justifications of control.

The real integration of IPM is the integration of pest management with total forest management. It is necessary to give great emphasis to early detection, priority setting, loss prediction, and impact assessment. We must continue to strive to provide effective and economical IPM technology needed to protect forest resources from damage.

Problems with implementing IPM for SPB in the South include:

1) Large amount of land controlled by private landowners.

2) A diverse group of managers with a wide range of objectives

3) Timber production is often the primary goal.

4) Multiple use objectives of national forests with longer rotations due to legislation and public wishes.

5) Weak local timber market conditions/prior to and during an outbreak.

Although many solutions in the battle of the beetle are lacking, the potential for implementing IPM is improving. Better education of the public and making foresters aware of opportunities to prevent outbreaks.

IPM OF THE SOUTHERN PINE BEETLE

R. N. Coulson[c]

Since 1972 there have been three major R & D programs directed to SPB/IPM: the Huffaker NSF program, ESPBRAP, and the IPM program. These programs featured a multidisciplinary format and centralized management approach. As research ventures they were successful by virtually any standard of evaluation. In the latter stages of the IPM program, the Forest Service management staff recognized that the traditional methods of technology transfer were not going to be adequate for the computer-based products of research, principally simulation models. In 1979 the IPM program initiated a project designed to integrate and deliver the computer-based products. This investment into the development of the "Southern Pine Beetle Decision Support System" (SPBDSS), ushered the beginning of the computer-based problem solving and decision making applications for IPM. Since this time, the concept and technology of computer-based decision support has changed radically. Continuing efforts by

FPM eventually have resulted in the implementation of a knowledge-based system for SPB-IPM, ISPBEX. The fundamental problem of IPM (how to effectively and efficiently use information for decision making and problem solving) has been and is being dealt with for SPB.

The future of SPB/IPM will involve dealing with a number of technical and institutional problems. The implementation of ISPBEX is clear evidence that the products of forest insect research can have a direct and measurable affect on SPB/IPM decision making and problem solving. As is the case with most forest insect pests, currently there is only a modest research effort under way for SPB. Since financial resources are always going to be limiting, would like to see serious consideration given to three aspects of the way we conduct the SPB/IPM business. First a functional partnership must be developed between the stake-holders in SPB/IPM, i. e., the money changers (funding agents), the researchers, extension foresters, forest managers, and forest users. This partnership would serve several purposes: 1) optimize the use available resource by targeting research to those areas of greatest need, 2) enhance and protect the credibility of the forest entomology research enterprise in that it would be possible to demonstrate that the products of research are influencing forest management practice and 3) minimize the waste associated with a politically dictated research agenda. Second, I would see objective criteria used in the SPB/IPM research planning process. For example, one of the benefits associated with the development process for a knowledge-based system is that it is necessary to define, in a rigorous and formal way, what is known and what is not known. This inventory process is a good mechanism for strategic planning of research. Finally, I would like to see a revival of the systems science/simulation modeling approach. We have demonstrated that simulation models are critical to IPM problem solving and decision making, and that they can be used effectively and efficiently as a component of a knowledge based system.

AN IPM PLANNING PROCESS FOR MOUNTAIN PINE BEETLE MANAGEMENT

J. Borden[d]

If forest IPM programs are to succeed, they must be accepted and used by the management community. Further, much of the development of the management process itself is best done through a "grassroots" effort by managers. For the mountain pine beetle (MPB) problem in the Penticton Creek area of British Columbia, an IPM planning process was developed and implemented by a grassroots-type task force resident in the Penticton district. Much of the basis for the planning process stemmed from the precept that MPB outbreaks behave very much like "forest fires" and that the funding structures and models used for fire management (e.g., cost/benefit models) could apply directly to MPB.

The district was divided into "beetle management units" (BMU) each of which constituted a planning and reporting unit for an operational MPB management program. Each BMU was evaluated relative to a priority rating, a general description, status of adjacent BMU's, other resource issues and constraints, access, available tactics, and funding. With regard to control practices the planning process considered six broad strategies including: suppression, low-level population maintenance, holding, salvage and abandon, abandon and do nothing, and prevention. For each strategy, several tactics could be used including: sanitation and harvesting, single tree treatments, fall and burn, semiochemical baits, removal restrictions, silvicultural treatments, species manipulations, and age-class mosaic manipulations.

The result of the development of this MPB IPM planning process is an effective and responsive system capable of managing MPB under a variety of ecological and economic conditions, and one that is clearly accepted and adhered to by the resource management task force. The process is also flexible enough to transfer to other districts and apply to other types of forest pest problems.

GYPSY MOTH MANAGEMENT IN THE UNITED STATES

M.L. McManus[e]

IPM programs directed at the gypsy moth have undergone a significant evolution beginning in the 1970s. From 1975 - 1978 the USDA, Forest Service used a "Combined Forest Pest Research Program" to develop new IPM technology for managing gypsy moth, Douglas-fir tussock moth, and spruce budworm. For the gypsy moth, this program was directed primarily at control tactics such as parasitoids and predators, chemical (diflubenzuron) and microbial insecticides (nucleopolyhedrosis virus and Bacillus thuringiensis, mating disruption, and mass rearing technology which recently has been adapted for use in sterile insect releases. Also during the 1970s, the "Comprehensive Gypsy Moth Pest Management System" project was undertaken. While the Combined Forest Pest Research Program was directed at producing control technology, the Comprehensive project was directed at a regional gypsy moth management IPM system.

In the early 1980s the "Maryland Gypsy Moth IPM Pilot Project" was implemented in four counties in Maryland. The objective of this project was to evaluate control tactics, develop a standardized approach to monitoring, and to do so in a real world situation. Control tactics could only be examined to a limited extent, because gypsy moth populations remained at very low levels throughout the course of the project. However, monitoring using a standardized 1 km grid system of pheromone-baited traps, larval samplers, and egg mass samples were deployed and represented the first attempt to address large-scale monitoring problems for gypsy moth management. A data base management system together with computerized mapping of male moth, larval, and egg mass populations were also used during the Maryland project. Until this point computer technology was used only on a limited basis in gypsy moth program in the United States (Ravlin et al. 1987).

While the Maryland project evaluated a management system in a real world setting, the so-called "Extramural Gypsy Moth Research program" was designed and implemented to accelerate and complement the more applied aspects of Forest Service research. Examples, of areas of research addressed by the extramural program include: population dynamics, monitoring systems, microbial insecticides, gypsy moth-host interactions, and GypsES, a computerized decision support system.

There is no question that the research and development programs have produced new technology essential for an IPM approach to managing gypsy moth populations, and much of this technology has been transfered to the management community (e.g., monitoring systems, pheromone-baited traps, chemical and microbial insecticides, and an IPM framework). However, for the most part, states and localities in the U.S. rely on loosely defined action thresholds, they lack standard, statistically-based monitoring systems, they still rely on insecticides (B. thuringiensis, diflubenzuron, and carbaryl) as the primary control tactic, and an extensive regulatory program throughout most of the U.S. Part of this situation is because new technologies have not had time to diffuse throughout the management community (e.g., standardized monitoring and the use computers) but part of the situation is also due to the nature of the gypsy moth problem. The problem is extensive and expanding despite regulatory efforts (44 eradication projects were deployed in 14 states in 1990 [C.P. Schwalbe, personal comm.]). Further, there are no new control tactics on the horizon, state programs are constantly being reduced due to funding, and the private sector together with individual and landowner control efforts are increasing in an uncoordinated fashion. So the question of gypsy moth IPM is still elusive and begs for higher level implementation of a program that is capable of slowing the spread to the south and west of leading edge populations and continues to provide research support for states, localities and individuals in generally infested areas.

THE APPALACHIAN GYPSY MOTH IPM DEMONSTRATION PROJECT

R.C. Reardon[f] (Reprinted from Reardon 1990))

The USDA, Forest Service was directed by Congress through the 1987 Supplemental Appropriation to initiate an IPM special project aimed at slowing the spread of the gypsy moth down the Allegheny Mountains in Virginia and West Virginia. Planning for this effort, the Appalachian Gypsy Moth Integrated Pest Management (AIPM) Project, began in late July 1987. The AIPM Project is designed to demonstrate the effectiveness of new and existing management technology in an IPM approach to minimize the spread and adverse effects of the gypsy moth. It will be carried out in addition to the normal County, State, and Federal Cooperative Suppression Program and is not intended to replace that Program in cooperating States.

Initially, the direction and structural components of the AIPM Project were based on those of the Maryland IPM Pilot Project. Protocols within components have been reviewed and modified and will continually be evaluated, updated, and changed as the Project progresses.

The overall objectives of the Project are to: 1) minimize the spread and adverse effects of gypsy moth within the Project area; 2) develop a general prototype IPM structure that can be implemented anywhere in the United States consisting of standardized sampling protocols, decision matrices for low level intervention activities, computer-based geographic information systems, and an educational program; 3) evaluate the use of intervention activities for the management of isolated infestations within the Project Area, and; 4) assess the feasibility of deploying (or implementing) a coordinated County, State and Federal gypsy moth program over a large geographic area.

General AIPM Activities

Project Area. The Project area encompasses all or parts of 20 counties in West Virginia and 18 counties in Virginia, although there was discussion about the feasibility and practicality of expanding the originally defined area.

1) Discussions in late 1988 dealt with expanding the area to include Giles County, VA in order to deal with an isolated infestation located there. Because Giles County had not been included in the AIPM EIS and addition of this area would require an addendum or supplement to the document, it was not added. AIPM instead cooperated with a number of State and federal agencies to evaluate the efficacy of pheromone flakes in eliminating an isolated infestation.

2) In November, 1989, Cleve Benedict (West Virginia Commissioner of Agriculture) requested that consideration be given to expanding the project area to include the northern halves of Grant and Hardy Counties in WV (these counties are bisected by the AIPM Project Boundary). This was of concern, because the counties included both AIPM and non-AIPM lands, resulting in a great deal of

confusion within the counties in terms of funding for treatments in these areas (within the AIPM area, all costs are paid by the project, but outside of the area, normal State/Forest Service cooperative suppression rules are followed for treatment funding). As a result of follow-up discussions, it was decided that the AIPM boundary would not be changed, but that the northern halves of all bisected counties (Grant and Hardy in WV and Shenandoah, Page and Rappahannock in VA) could be treated using 100% federal funds. Selection of treatment area in these areas would be based on gypsy moth populations, land use and management objectives. Further discussions are planned to determine future actions in these areas and areas within the AIPM Project Area.

Project Components. The AIPM Project consists of five major components:

Survey and monitoring for recording quantitative and qualitative observations of gypsy moth and natural enemies, along with other variables indicating changes in the forest environment;

Decision making based on review of survey and monitoring results and supportive data;

Intervention activities used to manage gypsy moth populations at various densities;

Evaluation to determine the effectiveness over the short- and long-term (e.g., annual evaluations; assess the feasibility implementing a regionally-based management system over a large geographical area);

Supportive methods, including cooperative methods improvement evaluations, data base management, and technology transfer.

As above, the general organizational structure of the AIPM Project and specific responsibilities and assignments of various individuals and committees remain the same. A PROGRAM MANAGER provides overall leadership and coordination with a PROJECT LEADER responsible for the development and implementation of the technical aspects of the Project. A STEERING COMMITTEE reviews the overall Project direction, approves the annual work plan, and resolves problems associated with individual agency policy and direction. A PLANNING COMMITTEE, headed by the Project Leader, develops the annual work plan; conducts project reviews; and recommends technical changes to the Steering Committee. A TECHNICAL WORKING GROUP consisting of leaders of subject matter specialties, assists in the development of the annual work plan, and acts as technical advisors to the Planning Committee and Project Leader. The RESPONSIBLE OFFICIAL for this Project is the Area Director, USDA Forest Service, Northeastern Area, State and Private Forestry.

The Project was implemented by field teams at the county level on State and Private Lands in Virginia and at a regional level on State and Private Lands in West Virginia. The three National Forests and the Shenandoah National Park and Blue Ridge Parkway hired field teams to implement the Project on their respective ownerships. A new management unit, the New River Gorge National Scenic River in West Virginia was added to the list of cooperating agencies and has been accorded membership on the Planning Committee.

A FRAMEWORK FOR FOREST IPM RESEARCH

M. W. McFadden[g]

Forest Service research has often been conducted through the use of large research and development programs. These programs can be difficult to manage and will not produce quality results unless there is a basic framework from which large programs can be structured. The objective of this paper is to address the question: "Are we doing research in the best possible manner (i.e., through large programs) to resolve forest IPM-related problems?" This discussion will use the gypsy moth extramural program as an example, but will also borrow from several years of experience from several other programs (e.g., Douglas-fir tussock moth) to put together a framework for research.

"House Rules"

The first aspect to consider are the "house rules" that are associated with all programs. That is, "What are the aspects of programs that are given?". Successful research and development programs must be structured to achieve maximum flexibility in direction and approach for all cooperators and yet maintain the integrity of the program. Program integrity is maintained through directing funding to those areas that will have the highest potential to achieve a set of desired goals. Another aspect to many, if not most, large programs is that in order to achieve flexibility sufficient funding must be available and this funding many times comes through political channels. The results of politically-based funding is often sustained funding over several years, but it can be constrained by local or regional interests and the political environment from which the funding was obtained.

"Crap Detection"

"Crap detection" refers to a process and a framework from which program quality can be maintained. Program quality is here defined in terms of the validity of the research, its relevance of research, and the ability to integrate the results of different research projects into a greater whole than the sum of each of the individual projects. Quality has been achieved in the gypsy moth extramural research program through a well-defined proposal solicitation, review, and research evaluation process. It has also been achieved by encouraging networking, and by supporting projects that focus on synthesis. Examples of projects that are synthetic in gypsy moth program, are the "Gypsy moth life-system model" and "GypsES", a knowledge-based decision support system. With respect to relevance, the Gypsy Moth Extramural Research program maintains close ties with the Appalachian Gypsy Moth IPM Demonstration Project (AIPM). These ties are maintained through joint funding of research projects, review of projects by the AIPM project manager, and by explicit identification of those projects that can directly contribute to the AIPM project.

"Maverick Management"

A significant resource of any research program are those individuals who are highly motivated, creative, and often difficult to supervise ("mavericks"). It is clear that that these individuals can provide some of the more significant research findings, but only through a flexible program environment that facilitates their activities.

Ethics, Trust, and Credibility

Ethics, trust, and credibility are always the standard for every scientist. The Gypsy Moth Extramural Research program continually has been able to maintain these characteristics, and they clearly are the basis for quality science within any program.

Other Aspects of a Large Research Program Framework

Other aspects of the large program framework include maintaining the flexibility to explore research areas that are not directly a part of research proposals, the limited ability to address other important research areas, and managing publication conflicts particularly with such a strong emphasis on networking, integration, and interdisciplinary approaches.

Achievements Through This Program Approach

This discussion began with the question "Are we doing research in the best possible manner (i.e., through large programs) to resolve forest IPM-related problems?" It is a matter of opinion whether or not it is the best approach. However, particularly in the Gypsy Moth Extramural program we have achieved several successes by:

1) Focusing resources on a major problem (gypsy moth).

2) Assisting in education and training of new scientists (i.e., masters and Ph.D. students and postdoctoral scientists).

3) Producing new knowledge.

4) Promoting multi- and interdisciplinary science.

5) Training scientists to work cooperatively and collaboratively.

6) Providing opportunities for continuing collaboration on new programs.

FUTURE PERSPECTIVES

K. Knauer[h]

There is no question that many successes have been achieved in the area of forest IPM, and we have moved science and implementation forward. Interactions with the Forest Service between Forest Pest Management and the research division have never been better despite inherent constraints to intraagency relationships. Even interagency relationships have been facilitated through our work with the AIPM demonstration project and EPA's EMAP program. Our Forest Health program has only just begun, and it too promises to build on the so-called "big bug" programs

This is not to say that problems do not loom in the future. Forest Health for example, is a program that requires large amounts of data concerning pests, trees, and the forest ecosystem in total. Right now several agencies have similar interests (e.g., Forest Health and the EPA's EMAP programs). Agencies like the Forest Service and EPA, together with local governments, should join in partnerships toward some common goal from which knowledge and management can follow on a grander scale. However, this kind of approach has not been successful in the past. The road to success will be a long one and will not be achieved without diplomacy, politics, and resources over a protracted period of time.

The word "technology" occurs in virtually every discussion concerning IPM, Forest Health, or the Forest Service's "New Perspectives" program. To many people, technology equates to the use of geographic information systems, expert systems, models, biotechnology, and new ways to do old task. But, it also means that resources must be obtained from those same sources that are sometimes uncomfortable with even some of the old ways of doing business. Long-standing alliances together with new ones must be encouraged through continued demonstrations that the research, implementation, and educational communities can produce and use the new and old technologies to their benefit and that the benefit/cost ratio is sufficiently high to justify their support.

The end-users of forest IPM-related programs must also be brought into the picture in a more important way than ever. Their input into how we do business as natural resource managers and forest care-takers is essential. Here, end-users relates not just to the national forests, county and city foresters, or pest managers, but to the general public. Forest management programs need support for their very existence. This support will come only from individuals who are sensitive to forest IPM and forest health in general. Education and outreach are essential to our well-being and to our very existence as managers and scientists.

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AERIAL APPLICATION TECHNOLOGY

Moderator: Christopher M. Riley[1]

The purpose of this session was to identify and discuss the problems and weaknesses in current aerial insecticide application strategies, to identify knowledge gaps, and to suggest ways in which these aspects might be addressed in order to develop more effective, efficient, and environmentally acceptable insect pest control operations. It was not the objective of this workshop to produce another wish list of specific topics which need to be addressed, but to serve as a forum at which program managers, researchers, and operators from across North America could discuss ideas and exchange information.

Karl Mierzejewski presented an introductory review of aerial application as a method of controlling forest insect pests. Aerial application technology is not merely a matter of deciding upon the type and number of atomizers to use on available aircraft in order to apply the recommended amount of pesticide to the target area. If the efficacy of aerial pesticide application strategies are to be optimized within the framework of environmental and operational constraints, a multidisciplinary approach must be adopted. Such an approach requires specific knowledge in the areas of entomology, botany, pesticide toxicology, formulation chemistry, liquid atomization, aerodynamics, aircraft performance, particle behaviour, spray physics, meteorology, and operational logistics. A systematic analysis of the entire strategy including spray atomization, spray transport, spray deposition, and toxic dose acquisition is essential if insecticides are to be used most effectively.

Bud Irving presented a users perspective of past and current developments in aerial application technology to control the eastern spruce budworm in New Brunswick.

Current aerial insecticide applications strategies have developed from three fundamental observations: 1) that in all work the incidence of large droplets on balsam fir foliage is rare, 2) that there is a strong positive correlation between spray deposit and biological efficacy, and 3) that for a given volume of liquid the total number of droplets, and hence the potential deposit density, increases with decreasing droplet size.

Early operational trials in which deposition of the chemical insecticides Matacil and fenitrothion was investigated showed that ultra ultra low volume (UULV) sprays applied at 0.4 L/ha using a Cessna 188 fitted with AU4000 rotary atomizers gave similar total deposits to ultra low volume (ULV) sprays applied at 1.46 L/ha using a Grumman Avenger fitted with 11010 Teejet hydraulic nozzles.

With the knowledge that the emitted droplet spectrum produced by a rotary atomizer is dependent upon the rotational speed of the atomizer and the liquid flow through the atomizer, studies in the University of New Brunswick wind tunnel showed that the number of droplets produced for a given volume of liquid increases dramatically for the Micronair AU4000 at a rotational speed of ca. 14000 rpm and a limited flow rate of 2 L/min. Based on this information, replicated operational field experiments were carried out to investigate both the quantitative deposition and biological efficacy of chemical and biological insecticides when applied using conventional strategies at regular dosage and application rates, versus when applied using enhanced atomization strategies at reduced dosage and application rates. Results for fenitrothion applied at 140 g ai/ha in 0.37 L or 0.25 L using a Grumman Avenger equipped with ten AU4000 Micronair rotary atomizers were comparable to those obtained at 210 g ai/ha in 1.46 L using the conventional Avenger/Teejet 11010 configuration. Comparable results were also obtained when undiluted *Bacillus thuringiensis* (B.t.) was applied at 15 BIU/ha in 1.2 L or at 30 BIU/ha in 2.4 L using a Cessna 188 spray aircraft fitted with Micronair AU4000 rotary atomizers operating at maximum rpm with flow rates of 2 L/min/atomizer or 6 L/min atomizer, respectively.

In addition to the positive results of this work, two operationally related problems became apparent. Firstly,

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the Cessna 188 aircraft was fitted with only 4 rotary atomizers. Therefore, in order to apply 15 BIU in 1.2 L using enhanced atomization required a lane separation or swath width of only 25 m. This is obviously unrealistic for large operations, especially at even higher dosages. Secondly, the Grumman Avenger has a nominal flying speed of ca. 170 kts and when contouring the forest, atomizer rotational speeds in excess of 18000 rpm were not unusual. Inducing a climb to reduce the air speed quickly resulted in the aircraft being 150 m or more above the forest canopy. Clearly, neither this nor the continual change in atomizer speed and, hence, emitted droplet spectrum is desirable. Large scale operational implementation of enhanced atomization strategies will be dependent upon the availability of high potency formulations and the development of a constant speed rotary atomizer, both of which are being developed by industry.

Five projects related to aerial insecticide application technology have been funded under the SERG (Spray Efficacy Research Group) umbrella for 1991:

1) The evaluation of key operational parameters influencing B.t. spray efficacy - cost $289,000.
   Operational results with B.t. over the last three years have been variable. In 1988 the results were unacceptably poor. However, in 1989 results were not only good, but comparable to those achieved with the chemical insecticide fenitrothion. In 1990 somewhat poorer, though still operationally acceptable, results were obtained with B.t. In the past five years FPL, Forestry Canada, and RPC have field tested a variety of B.t. formulations under highly controlled experimental conditions. All materials tested have given effective protection, however, this success has not been consistently transferred to operational sprays. The objective of this study will be to investigate various aspects of operational efficacy in an attempt to identify causes of the apparent discrepancy between experimental and operational B.t. performance.

2) Evaluation of three spray systems - boom and nozzle, Micronair AU4000, and Sergonair - cost $99,000. Development of the Sergonair constant speed rotary atomizer is now at a stage where a large injection of capital is required if the unit is to be produced commercially. The objective of this controlled experiment will be to measure both quantitatively and qualitatively the spray deposit achieved with each atomizer in order to assess whether continued development of the Sergonair is justified.

3) A feasibility study of an operational B.t. deposit assessment technique -cost $17,000.
   Deposition of B.t. sprays on foliage is usually assessed using microscopic droplet counting techniques. This method is very labour intensive, and requires the B.t. to be dyed. Even if inexpensive, non-insecticidal, and environmentally acceptable dyes could be obtained, the problems and cost for large scale programs would be prohibitive. The objective of this project is to evaluate the potential of an immunoassay as a low cost and practical technique for the operational assessment of B.t. on foliage.

4) Development of a user friendly PKBW dispersion/deposition model that can be run on a personal computer - cost $40,000.
   The objective of this work is to modify the PKBW model for use by field personnel. Field operations staff must be made aware that they can make decisions and manage the various parameters which effect spray deposition.

5) Laboratory evaluation of optimum droplet sizes for maximum biological efficacy of different B.t. formulations against fifth instar spruce budworm larvae - cost $120,000.
   Sub-lethal dosages of B.t. produce feeding inhibition with subsequent resumption of feeding activity. Current B.t. formulations have only a short period of residual activity on foliage. The question arises as to whether or not the reduced droplet size being employed in enhanced atomization strategies with 48 BIU/gallon or 64 BIU/gallon products causes only sub-lethal effects. The objective of this work is to identify the optimally sized B.t. droplet in terms of biological efficacy. If relatively large droplets of currently resistered formulations are needed for larval mortality, then even higher potency formulations may be required.

Jim Hadfield stated in his presentation on the development of Western spruce budworm and Douglas-fir tussock moth spray operations, that trends in aerial application technology in Washington and Oregon have followed successful developments in other forest insect pest control operations in the United States and Canada. Chemical pesticides are no longer used and B.t. is applied undiluted using rotary atomizers. Elevations in the mountainous terrain of western forests may range from 2000 ft to 7000 ft above sea level on the same project area. From the aspect of operational safety, spray aircraft must be able to sustain a 700 ft/min rate of climb with a 3000 lb load. Turbine aircraft are, therefore, usually required. However, the M18 Dromader piston engined, fixed wing aircraft can meet these requirements. Although western spruce budworm and, to a lesser extent, the Douglas-fir tussock moth are recurrent pests which typically cause problems for several years, none of the operational program budget is reserved for research purposes. Current application strategies have been developed from formal field tests, semi-operational tests, information from other projects, published literature, and advice from Forest Service scientists, pesticide manufacturers, and suppliers.

Dick Reardon, Project Leader for the Appalachian Integrated Pest Management project, started his presentation by saying that it was difficult to ascertain just how and why aerial application technology for gypsy moth control operations in the northeastern US has evolved into its present form.

Developments in aerial application technology of the insect growth regulator diflubenzuron have been minimal. Most of the work has been related to dose and application volume, and in recent years there has been a marked trend towards reduced volumes and reduced amounts of active ingredient.

The 1960s and 1970s was a time of ad hoc trials into the number of applications and timing required for effective control with B.t. Although there was a lot of work going on, very little documentation is readily available. In 1987, Pennsylvania State University became involved and for the first time began a detailed assessment of spray deposition, distribution and penetration of spray droplets into the deciduous forest canopy. This was followed by initial laboratory and field investigations into the biological effects of droplet size and deposit density with B.t. being applied at different dosages in a range of application volumes. Further work examined the effects of application volume on deposit uniformity and compared the biological efficacy of B.t. applied using different atomizers.

Trends in the northeast have been toward increased dosages of B.t. applied undiluted with Micronair rotary atomizers, whereas western programs have developed using Beecomist rotary atomizers. Considering gypsy moth control operations as a whole, there is very little standardization in insecticide rates or application equipment. Different strategies have developed independently in the northeastern US, the western US, and in Canada. It is difficult to document why.

The formation of the NorthEastern Forestry Aerial Application Technology (NEFAAT) Group has led to a much more coordinated research effort in the northeast over the last four years. Areas which need to be addressed in the future include the lack of standardization on swath width, atomizer configuration and formulation types, the limited amount of data on droplet size/deposit density effects and spray accountability, and poor operational efficacy resulting from poor application conditions or timing because of the inadequate supply of aerial applicators.

The cone and seed crop in the US is extremely valuable and control of cone and seed insects is a vital concern of orchard managers across the South. Currently all orchards under good management are treated at approximately one month intervals from March to September with one or more chemical insecticides. At present the most frequently used materials are Guthion and Asana XL.

Over the last three years Larry Barber (USDA Forest Service, Asheville, NC) has been successful in his pioneering use of undiluted B.t. applied using Micronair rotary atomizers to control several coneworm species in cone and seed orchards. The work presented in this session by A. Temple Bowen (Novo Nordisk, Danbury, CT), on behalf of Larry Barber, described the spray deposit analysis of aerially applied B.t. in a mature slash pine seed orchard. The results will be used in the development of equipment and methods to simulate aerial spray deposition for the testing of alternative pesticides.

The activities of U.S. Forest Service, Forest Pest Management in the development of application technology and pesticide testing were described by Jack Barry. Jack is the chairman of the four national steering committees established to identify research requirements and to recommend studies aimed at improving and evaluating the efficacy of aerial pesticide applications.

Committee membership consists of scientists from the USDA Forest Service, Forestry Canada, state agencies, universities, and industry. Collectively, members bring forth needs and the committees sort the list in terms of national importance. The broad-based membership approach promotes cooperation, and empowers members and their constituents in the process of advancing application technology. The four committees are:

1) National Steering Committee for Application of Pesticides - Gypsy Moth and Other Eastern Defoliators;

2) National Steering Committee - Management of Seed and Cone Insects;

3) National Steering Committee for Application of Pesticides - Western Defoliators; and

4) National Steering Committee for Application of Pesticides - Vegetation Management.

Each committee operates according to a set of draft guidelines covering membership, purpose, procedures, and responsibilities. The operating guidelines are supplemented as required. In this regard, the scope of all committees was recently expanded to include the ground application of pesticides. The scope of the Seed and Cone and Vegetation Management Committees was also expanded to include all methods of pest management.

The process of identifying national needs for direct control of forest pests provides a useful tool for researchers who wish to submit proposals for Federal funding. When the process is combined with management priorities, there exists a national basis and rationale for funding projects. Priorities, established by a national group of scientists, thus, are used by management in deciding how best to allocate resources.

Sources of funding include FPM, which has monies for technical development, pest control and research, and individual regions which have operating budgets to address regional requirements. States and universities also are potential contributors through cost sharing and contribution of indirect costs.

The steering committees are useful motivators for research in pesticide application technology. A great deal of progress has been achieved since their formation and, the process of linking projects to address research requirements with appropriate funding is working well. To date three committee reports have been prepared, copies of which are available from Jack Barry.

Of the 50 or so recommendations made concerning aerial application technology in the 1991 report, approximately one quarter were associated with either the development or field validation of mathematical models to predict spray transport and deposition, optimizing application timing or assisting operational planning. Almost one fifth of the recommendations were aimed at evaluating the field efficacy of various products with further recommendations targeted specifically at investigating the biological effects of dosage rate, application volume or application timing. Recommendations falling into the category of operational considerations included the evaluation of aircraft guidance systems, the use of weather data and weather forecasting to improve application timing, the use of spray transport models, and the development of techniques to assess operational spray deposition, to evaluate operational efficacy, and to quantify overall treatment performance. The requirement for guidelines for atomizer characterizations, and measurement of emitted droplet spectra also need to be addressed. Droplet spectra information is needed for operational use and for input into spray transport models. Other topics include the evaluation of application systems in specific contexts, the development of new and improved formulations and products, and studies to examine the effects of *Bacillus thuringiensis* on non-target insects.

The increasing use of the biological insecticide B.t. to control North American forest insect pests was apparent throughout this session. Although the insect growth regulator diflubenzuron is still used on a large part of the gypsy moth program in the northeastern United States, the use of B.t. has increased steadily in recent years. *B.t.* also has given promising results against pests of cone and seed orchards. In Washington and Oregon, chemical insecticides have not been used for several years. Except for New Brunswick, chemical insecticides are prohibited in all Canadian Provinces and B.t. is the only realistic option currently available for large scale spray programs against forest defoliators. Reflecting this trend towards increased reliance on B.t. was the number of Steering Committee recommendations dealing specifically with B.t., a total of 16 recommendations versus only 6 relating to chemical insecticide use.

Unlike chemical insecticides, B.t. must be ingested to be effective and is effective against only certain larval instars. Furthermore, it is generally accepted that the persistence or residual toxicity of currently registered formulations can be measured in days or even hours. Clearly B.t. cannot be used in the same manner as a chemical insecticide. Over the last decade, the success which has been achieved with B.t. has increased tremendously. This is due not only to improved formulations, but also to our increased knowledge of how to use the material properly.

Operational optimization of materials such as B.t. requires accurate timing of applications in terms of larval development and good weather conducive to active feeding for 12 to 48 hours following spray application. The development of optimum use strategies for B.t. in laboratory and field studies is of limited operational value if the materials cannot be applied in the most suitable conditions for spray deposition and biological efficacy. Inevitably, this will mean increased numbers of aircraft and, therefore, increased application costs. However, when approximately 50% of the treatment cost is the cost of the material there is little sense in spraying at a time when conditions are marginal for good spray deposition, when the insect population is of limited susceptibility, or when adverse weather conditions are anticipated within a few hours and the treatment has only limited potential for success.

It is obvious from the information presented during this session that the scope and requirement for research in aerial pesticide technology is immense. Topics which must be addressed range from the very specific to generic problems which are of concern throughout North America. Throughout this meeting opportunities for joint US and Canadian cooperation were encourged and discussed both at research scientist and adminstrative levels. The advantages of pooling Canadian and US resources and expertise in spray technology to address topics of mutual concern are obvious. It is hoped that the enthusiasm generated during this meeting will lead to the development of agreements within which collaborative projects can be undertaken in the future.

THE DEPOSITION OF AERIALLY APPLIED FORAY 48B IN A SLASH PINE SEED ORCHARD

Larry R. Barber and Jose Negron[a]

Spray deposition on seed orchard trees is vitally important to the success of spray projects and to the operational success of insecticide treatments. It is the objective of many of our seed orchard evaluations to look at new or unregistered pesticides. We are developing methods to simulate aerial application for various pesticides. This work has given us the opportunity to evaluate carefully the deposition of a pesticide on slash pine trees. Additional work will be done on loblolly pine at a later date.

In this study, we determined that spray droplets impinged on the upper surfaces of needles located on top of a branch more than on the upper surfaces of needles positioned beneath a branch. Needles from the top of a branch showed a higher top of needle:bottom of needle spray drop ratio than needles from beneath a branch.

Penetration of spray into the interior of the crown or lower canopy was not determined, but will be examined in future studies. Also, no attempt was made to look at deposition on conelets or cones. The spread factor for this spray mixture is unknown for this receptor surface (pine needles), therefore, no relationships are established between stain sizes and spray cloud descriptive data such as vmd.

FOREST PEST MANAGEMENT PESTICIDE TESTING AND DEVELOPMENT ACTIVITIES

John W. Barry[b]

Four national steering committees have been established by the Chief, USDA Forest Service for pesticide application. Since 1988 the committees have met at least annually to identify needs and other issues related to testing and advancing our ability to manage forest defoliators, seed and cone insects and vegetation using direct control technology. Committee membership is represented by scientists from the USDA Forest Service, USDA - Animal Plant Health Inspection Service, Canada, States, Universities, and industry. The steering committee approach has been successful in identifying national needs, encouraging proposals to address the needs, and assisting management by ranking proposals for funding allocations. Cooperation from a broad sector of the forest pest management community is essential to maintaining the steering committee process.

THE EVOLUTION OF PESTICIDE APPLICATION TECHNOLOGY IN EASTERN CANADA

H. J. Irving[c]

In New Brunswick and elsewhere in Eastern Canada, conventional dosages of insecticides and application practices were inadequate for coping with the extremely high and vigorous populations of budworms encountered in 1974 and 1975. The practice of cutting the "spray suit" to fit the cloth was used extensively without a good understanding of spray physics or population dynamics. The situation was exacerbated further by a worldwide shortage of insecticides along with a growing public awareness that excessive use of chemical insecticides posed potential risks to both human health and the environment.

In response to regulator's demands for quantification of off-target drift and New Brunswick's need for more effective application technology, Forest Protection Limited provided support for the voluntary cooperative formation of a multi-disciplinary group of scientists from federal departments, universities, and other research organizations. This group was later formalized and is now known as SERG - Spray Efficacy Research Group - and includes as sponsors and users the Provinces of Ontario and Quebec, along with New Brunswick.

Results from R&D carried out mainly by SERG participants indicated that release height above the forest canopy and "enhanced atomization" are key factors in achieving more effective use of both chemical and biological insecticides for protection of conifer forests from spruce budworm. The "enhanced atomization" technique is based on Micronair AU4000 rotary atomizers operated at high rotational speeds and flow rates of 2 litres per minute per atomizer.

CONTROLLING FOREST PESTS BY AERIAL APPLICATION: PRESENT AND FUTURE STRATEGIES

Karl Mierzejewski[d]

In using aerial application as a method of controlling forest insect pests, a theoretical systematic approach must be made initially, followed by a consideration of operational factors. Biological considerations such as the distribution and behaviour of the likely susceptible stages of the pest in space and time would be the first aspects considered. Physical considerations, such as spray target dimensions, weather factors, droplet size, and material properties must then be addressed. Consideration of these biological, physical, and meteorological factors will define the physical spray target. Material choice is very largely determined by legislative bodies. Selection of materials, and knowledge of target stage and plant phenology will enable the likely spray window to be established. The period between droplet formation and deposition is the most complex and the most critical component of the aerial application process, and therefore, has been the most extensively studied aspect in the lab and in the field. Laboratory and field experimentation has led to a considerably improved understanding of the processes involved in aerial application, and its development as a science.

Once a theoretical plan of action has been established, operational factors must be considered. Aircraft choice depends on the size of treatment areas and required productivity. Atomizers available today are not efficient in producing droplets in size ranges which are most effective biologically, and this constitutes one of the main areas needing improvement. Equipment to provide pilots with better tracking guidance of aircraft would minimize areas of over and under treatment, and this also is an area requiring development.

THE DEVELOPMENT OF AERIAL APPLICATION TECHNOLOGIES FOR WESTERN SPRUCE BUDWORM AND DOUGLAS-FIR TUSSOCK MOTHS CONTROL PROGRAMS

James S. Hadfield[e]

In 1947 the Forest Service first used aerial spraying to control the Douglas-fir tussock moth (DFTM) in Oregon and Washington. DDT was applied at the rate of 1 lb per acre in one gallon of solvent and fuel oil. From work done in 1948 against the western spruce budworm, the basic specifications for subsequent suppression projects were developed.

Fixed-wing aircraft were used exclusively from 1949 to 1962. Starting in 1965, helicopters were specifically required. In 1974, DDT was sprayed for the last time by the Forest Service for forest defoliator suppression in the Pacific Northwest. Chemical insecticides were phased out entirely in 1983. Commencing in 1984 all aerial application contracts were negotiated rather than awarded only on low bid.

In 1985, a turbine powered airplane was evaluated and found to provide acceptable application. A nearly undiluted application of B.t gave very good control of budworm. This operation showed it was possible to reduce budworm populations to less than 1 surviving budworm per 45 cm branch tip with B.t applications. In 1988, the Forest Service treated almost 600,000 acres for western spruce budworm suppression in Oregon. Both helicopters and fixed wing aircraft were used to apply undiluted B.t at 16 BIU per acre. Undiluted B.t was pilot tested at 1/3 gallon per acre and found to provide acceptable results.

The spray specifications now used on R-6 WSBW and DFTM suppression projects include: Undiluted B.t. applied at 16 BIU per acre in at least 1/3 gallon of product.. Turbine powered helicopters and fixed-wing aircraft equipped with rotary atomizers are required to apply a droplet spectrum with a $D_{v\ 0.5}$ of 75 μm to 150 μm.

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EXPERT SYSTEMS WORKSHOP

Moderator: Michael C. Saunders[1]

Applied aspects of artificial intelligence (AI) are becoming increasingly commonplace in modern society. The most obvious of these AI-based applications is computer software that employs pattern-matching and object-oriented methodologies to simulate the reasoning and decision making behaviors of human experts. The simplest of these systems is the so-called expert system which embodies the qualitative and quantitative heuristics of a single human expert to assist in solving problems within a single, bounded problem domain. The applications now being developed for agricultural and natural resource management greatly expand on the expert system approach and include object oriented and/or mathematical simulation models, spatial analysis tools (i.e., geographic information systems), large database management systems, and integrated knowledge bases derived from multiple experts from diverse scientific and management disciplines. The nomenclature for these types of software includes object oriented simulations (OOS), intelligent geographic information systems (IGIS), knowledge system environments (KSE), and integrated expert systems (IEX).

Two systems were presented during this workshop that dealt with major forest pests that must be addressed at the landscape scale. Dr. Robert N. Coulson of Texas A&M University presented the Integrated Southern Pine Beetle Expert System (ISPBEX) for managing the southern pine bark beetle (SPB), *Dendroctonus frontalis*, in national forests. This pest is particularly problematic in the southern states due to: 1) extensive monocultures of pine forest; 2) difficulty in projecting the growth and spread of SPB infestations; 3) difficulty in projecting the occurrence and severity of SPB infestations; and 4) suppression tactics that infringe on cultural resources (e.g., archaeological sites) and protected habitats of rare and endangered species (e.g., red cockaded woodpeckers).

ISPBEX will include knowledge bases for assisting in decision making relative to SPB management. In many cases, these knowledge-bases will execute mathematical models in order to more accurately predict and evaluate aspects of the SPB management domain. These include stand hazard and risk models, stand growth and yield models, and population dynamics models. The spatial analyses are performed with a GIS and spatial analysis routines. The GIS capabilities enable users to spatially reference the locations of important landscape elements such as SPB infestations, high hazard stands, and red cockaded woodpecker colonies. The population dynamics model coupled with the GIS and spatial analysis routines are used to forecast SPB infestation growth and encroachment on cultural resources and red cockaded woodpecker colonies. The knowledge bases then use this spatial information to help determine the legality of control operations in protected areas. A version of ISPBEX without the spatial analysis capabilities has been implemented on 12 ranger districts in the southern United States.

Dr. Michael A. Foster of Penn State University presented the gypsy moth expert system (GypsES). The gypsy (GM), *Lymantria dispar* is the most important defoliator of deciduous forests in the northeastern United States. The current status of GM management programs is ad hoc due to: 1) lack of coordination among research, extension and implementation units; 2) no standardized management packages or population monitoring protocols; and 3) inadequate, or absent database management systems, including GIS. Previous computerized approaches, such as operations research techniques and simulation models, have been inadequate, because they are not good at handling the qualitative information and unstructured problem solving typical of management problems. To address these issues, the United States Forest Service, in cooperation with Penn State University, Virginia Tech, and West Virginia University, initiated funding in 1988 for development of a computerized decision support system for GM called GypsES (Gypsy Moth Expert System).

The development platform for GypsES is currently high-end Macintosh computers running the AU/X UNIX

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operating system. The software components of the system are generally C-language based and run under UNIX to insure portability across a variety of hardware platforms when it is completed. The software architecture of GypsES combines conventional and artificial intelligence computer science approaches for knowledge based problem solving. Its components are knowledge based advisors (KBAs) that package several kinds of expertise about gypsy moth management, a geographic information system (GIS) for managing spatial information (e.g., landscape and forest units, topographic features, GM populations), a graphical user interface (GUI) for user interaction with the system, a database management system (DBMS) for managing nonspatial information, and a connection management system (CMS) for integration and communication among the various components. The knowledge based advisors (KBAs) are expert system modules which package both current GM management expertise and new practices developed by researchers. There are 5 KBAs for: 1) MONITORING activities (pheromone traps, egg mass sampling); 2) DEFOLIATION PREDICTION from egg mass counts; 3) PHENOLOGY PREDICTION to time sprays based on historical weather and GM simulation models; 4) HAZARD/RISK ASSESSMENT based on forest information and projected defoliation; and 5) a TREATMENT ADVISOR which assigns treatment priorities to areas based on land use priority and risk. The treatment advisor can handle management scenarios both for National Forest and for State cooperative suppression programs at the county and local levels. The GIS in GypsES is currently the C-language based, public domain GRASS (Geographic Resources Analysis Support System) developed by the Army Corps of Engineers Construction Research Laboratory (CERL). It is 'intelligent' by virtue of rulebases which emulate an expert cartographer and GIS user in order to facilitate use by those unfamiliar with GIS. The Graphical User Interface (GUI), based in X Windows, includes a system of windows, icons, menus, and pointers (WIMPs) for a flexible and intuitive interface consistent throughout all components of the system.

The GypsES system is now being ported to INTEL 386 machines for field-testing an alpha version in Prince William County, VA, and the Monongahela National Forest, WV, in Fall 1991. A beta version will be developed from refinements based on these field tests, and further field testing will occur in 1992 on a wider range of sites.

The third software system was presented by Dr. Bruce N. Nash of Penn State University. This system is called ForestHealth, and it is an amalgam of object oriented simulations, knowledge-based diagnostics modules and training/evaluation routines. The intent of ForestHealth is to address the fact that there are several major nation-wide initiatives designed to evaluate and monitor forest health. These initiatives include: 1) USDA Forest Service Forest Health Monitoring Program; 2) EPA's Environmental Monitoring and Assessment Program (EMAP); 3) USDA Forest Service Global Change Projects; and 4) the National Park Service's ongoing forest assessment efforts. Each of these efforts rely on intensive, on-site data collected largely by seasonal technicians. These data include basic stand parameters, crown conditions and general diagnostic information.

Assessment of tree health requires accurate estimates of crown condition and identification of specific biotic and abiotic agents which may affect crowns, stems, or roots. ForestHealth, an expert advisory system written in C language for the Macintosh platform, provides a diagnostic module and two training modules. The diagnostic module provides guidance in identifying foliar symptoms and the common insects, diseases, and abiotic disorders found on leaves of sugar maple, red maple, black cherry, northern red oak, and white oak. Graphical user interfaces are central to both training modules. The Foliar Severity routine trains users to categorize injury (percent leaf area) on single leaves using a modified Horsfall-Barrett scale. The Crown Dieback routine displays different types and degrees of crown injury which users must identify and classify. Each crown is a unique object oriented simulation generated in "real time" using tree/branch parameters selected by the user. Since the crowns are created on a 3-dimensional basis, multiple views are possible. Written output from training sessions or periodic checks provide quantitative information for quality assurance/quality control (QA/QC). ForestHealth provides diagnostic assistance, training, QA/QC data, and standardization for research or survey projects involving forest health. At the present time, elements of ForestHealth are being used by four different federal research or management units.

The final speaker was Dr. Patrice Janiga, Program Manager for the U.S. Forest Service's Systems Development Program in the Methods Application Group. Dr. Janiga spoke to the issues related to the implementation of decision support software. Her presentation focused on issues associated with the development cycle of software and the relationship of software authors with target agencies. Although there are no hard and fast rules that ensure a software product will be accepted by an agency, there are certain approaches that may enhance its probability of adoption. Among the most important of these approaches are: 1) identify the potential user community at the outset of the development cycle; 2) involve the prospective users of the software as co-developers as early in the development cycle as possible; 3) develop the software to run on machines already in place at the delivery sites; and 4) develop an implementation plan that ensures not only that the end users are thoroughly trained in the use of the software, but that upgrades to the software are anticipated and provided for by the developers. These general guidelines are intended to ensure that the user community accepts and assumes ownership of the software package, and provides for a continual dialogue between them and the software developers.

As discussed in this workshop and elsewhere at the North American Forest Pest Work Conference, expert systems and their offshoots are rapidly gaining recognition as the most viable integrating medium for research products, and the most promising vehicle for bridging the gap between research and implementation. This recognition will undoubtedly lead to more AI-based systems being initiated for other forest pest management problem areas, and it will lead to higher level discussions concerning the bureaucratic infrastructures that need to be created and nurtured to support adopted decision support tools during their productive life cycles. Those in the forest pest management community are fortunate that the AI-based applications being developed for managing forest insects and diseases are at the forefront of the technology, and, given the energy and talent of the various development teams in North America, we can look forward to leading the way in this important area for the foreseeable future.

MODELLING II - DEVELOPMENT

Moderator: Frederick M. Stephen[1]

This workshop focused on development of simulation models. Approaches to building models of biological systems vary considerably. The schemes used for classifying models vary also. Robert May in his 1973 book "Stability and Complexity in Model Ecosystems", used the terms tactical models and strategic models. Tactical models being highly detailed, pragmatic descriptions of specific systems, while strategic models may be those that sacrifice precision in order to grasp general principles. May stated that in ecology, tactical models of the systems analysis kind, applied to specific problems of resource and environmental management, have proved more fruitful than general theory. He speculated that, in the long run it is likely that future "ecological engineering" will draw on the entire spectrum of theoretical models. He further stated that "sympathetically handled, tactical and strategic approaches mutually reinforce, each providing new insights for the other." In the sometimes vigorous spirit of discussion encountered in our workshop, these somewhat differing approaches were not always handled with sympathy, but certainly each approach had its advocates.

Several speakers stressed the significance of various approaches to modelling. A synopsis of the evolution of computer technology and simulation systems was presented. Processes being used in the development of models for specific forest insect pests served as examples of those techniques currently in use. Much of the discussion focused on the benefits of simple versus complex models.

SUMMARY OF ISSUES DISCUSSED

Robert Coulson described the evolution of computer decision aids, from file management systems (1970s) to the knowledge systems environment (1990s). Early systems in forest entomology abstracted only quantitative data about pest insect species, but not the qualitative knowledge that managers use in making decisions and solving problems. Today's advanced knowledge systems environment permits the integration and interpretation of various types of information, and allows us to treat problems that do not have algorithmic solutions.

Lukas Schaub addressed prediction of gypsy moth phenology on a landscape-wide basis. Phenology models are used to understand the system to be modelled, e.g., gypsy moth developmental rate is affected by temperature, temperature decreases with rise in elevation, therefore, elevation affects any prediction related to the developmental process. Simulation of grid cells is used to identify phenologically similar areas. The model can be re-initiated with observed egg hatch data to get a more accurate prediction. These models are incorporated into GypsES, an expert system that assists management in solving problems such as timing of intervention to control gypsy moth.

Joe Elkinton adapted existing models to simulate nuclear polyhedrosis virus (NPV) epizootics in gypsy moth larvae. The models examined included a simple differential equation model of Anderson and May, and the complex Gypsy Moth Life System Model (GMLSM) of Valentine. NPV is transmitted through a surface contaminant of the egg. Larvae die over time, providing inoculum for a second wave of infection. Eggs were collected in winter and reared to determine the first wave, and the second wave was predicted based on the first wave. The Anderson and May model predicted well at high larval densities but not at low densities. GMLSM consistently under-predicted mortality, and, at high densities, predicted that the population consumes all the foliage so is not able to sustain an epizootic. Elkinton concluded that we can benefit from families of models from the simple to the complex, depending on the models and the biology to be modelled.

Nick Crookston presented the Prognosis Model for Stand Development, which simulates cutting and the effects of pests on individual trees, and estimates tree size, growth, and mortality. Most of the complexity is in the housing rather than in the model itself. The model, its

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uses, and inventory methods have grown together since 1970. Currently there is a need to increase the model's sensitivity to weather, climate, and tree vigor, and to add details of the mechanisms of growth processes. The pest/host interactions will then be rebuilt to take advantage of these changes in the model. The model is operational on about 15 different systems. The model's job is simulation of growth, not housing system-dependent graphics.

Alan Berryman considered the use of simple versus complex models. The appropriateness (integrity, credibility) and practicality (cost to build, run, and initialize) of the model must be examined. Berryman felt that large models are often a vice because: 1) the user cannot tell if they are appropriate or what they are doing; 2) they are expensive to build, run, and initialize; and 3) they are not necessarily more precise. Given that we are going to have large models, we must work to eliminate redundancy and non- contributing components from these models. Berryman believes that in the future large models will be purely research devices; essential processes will be in simple models, which will be used and applied.

As moderator, Fred Stephen elected to forfeit his presentation time in order to permit conclusion of an animated discussion that evolved during and after Alan Berryman's presentation. Stephen's remarks were to be directed toward the objectives, development, and usage of an infestation-level model of southern pine beetle population dynamics and tree mortality. The model contains both complex and simple elements, and is constructed with the intent of providing optimum predictive reliability combined with ease of use for pest managers.

Some of the major points made during discussion periods follow:

* Model complexity is not necessarily a virtue, but it is not necessarily a vice. The art lies in how much complexity to incorporate.

  Complex models may allow exploration of new areas that cannot be done with a simple model. Models also can be used to identify areas where knowledge is inadequate.

* Large models need not be opaque. Some phenomena need complexity to be accurately represented.

* Berryman felt that models can be kept simple by using separate models for separate functions, and that simple models can be evaluated whereas complex models cannot or will not be evaluated.

* The question is not large versus small models, but building good models. We have to look at the question to be answered in determining what type of model is appropriate.

* It is important to examine the cost of building and running the model versus the benefits derived; the benefits may be worth the costs!

* There are many ways of doing analytic processes. We have to develop new techniques for analysis in order to simplify models.

* The opinions of researchers and managers may differ as to the practicality and workability of a model. If input requirements become too cumbersome, the model may not be used. On the other hand, if the model is practical and it works, then managers will use it. The question becomes what is considered practical in terms of required input by the intended users of the model?

* What is complexity in relation to model development? This is an integral question. It is not adequate to consider only the number of dimensions in the model.

* Heuristic systems such as the knowledge based systems may not be able to be simplified.

* Sensitivity analyses can help determine which processes in the model have little effect on model performance. These processes can then be eliminated in an effort to shrink the model.

* Is science based on trust, or conflict? Can we trust the builders of models to know their own creation? Can we trust the builders to adequately test the model? How can we ensure that these practices occur?

RECOMMENDATIONS:

The debate over the usefulness and advisability of constructing simple versus complex models will likely continue. The intended uses of the model as well as the system being modelled are integral elements of the model building process. Allowances may have to be made by both the developers and users of models in order to build practical systems without sacrificing model reliability.

There is not currently a clear understanding of the distinction between a simple and a complex model. Is complexity determined by the number of lines of code, or by the number of required input variables, or by other factors?

It is important to engage in debate over the issues surrounding model development, so that the processes of model design and construction can progress. This is a rapidly evolving area, and should benefit greatly from diverse outlooks. It is essential that we all be open to new ideas so that the best models for the system at hand can be developed.

MODELING THE APPLICATION OF KNOWLEDGE FOR SOUTHERN PINE BEETLE IPM

Robert N. Coulson[a]

The initial approaches of the forest entomology community to systems analysis and modeling emphasized use of tools from mathematics, engineering, and computer science, which are suitable for abstracting quantitative information that scientists traditionally deal with. Missing from the initial models was the qualitative, or heuristic knowledge, that guides the decision making process of managers. The Knowledge System Environment (KSE) represents the most advanced approach to problem solving and decision making currently being used today in forestry and natural resource management. A KSE consists of six fundamental components: user interface, knowledge-base interpreter; management information system (domain-specific information); database management system (domain-independent information), geographic information system (analysis and display of spatially referenced data); and a connection management system (software system that integrates the various components of the KSE). Advantages of the KSE approach include: 1) integration of the various types of information that form the knowledge base for a particular subject [published research results and reports, spatial and tabular databases, simulation models, and observations and experiences of human experts]; 2) knowledge-based interpretation of these different types of information; 3) blending of surface knowledge [which describes correlative relations] with deep knowledge [which describes causative relations]; 4) use of site specific spatially referenced information; and 5) treatment of problems that do not respond to algorithmic solutions.

LANDSCAPE WIDE GYPSY MOTH PHENOLOGY PREDICTION

Lukas P. Schaub, Jesse A. Logan and F. William Ravlin[b]

Our goal is to extend the use of simulation models and predict phenology over the landscape and to make this technology readily available to managers. Describing temperature over a mountainous landscape is a complex issue and is highly dependent on the scale of interest. We are interested in the resolution of 0.1 to 1 km. The most important landscape features influencing temperature at this level are elevation and slope position. Currently we calculate temperature at a given elevation by decreasing the temperature at a base elevation by 0.6^{o} C for every 100 m of ascent. Our approach is based on combining information from local weather data (e.g., from NOAA) and the USGS Digital Elevation Model. Simulations of date of emergence for 50% of second instars at various elevations reveal that the phenology-elevation relationship is linear and is used in the geographic information system to calculate a new layer based on the elevation layer. Gypsy moth managers are interested in knowing which areas can be managed identically. We define a phenological window as a duration in days within which the phenology is considered the same within a management perspective. The phenological window is dependent on the duration of susceptible instars and the degradation of the insecticide. At this early stage in the project, elevation is the only variable used to describe temperature. Our approach is incorporated into GypsES (Gypsy moth Expert System), a computer-based environment that will provide managers with an integrated set of decision making tools.

MODELING THE DYNAMICS OF NUCLEAR POLYHEDROSIS VIRUS (NPV) IN GYPSY MOTH POPULATIONS

J. S. Elkinton and G. Dwyer[c]

We used a modified version of the simple differential equation model of Anderson and May and the complex Gypsy Moth Life System Model (GMLSM) to simulate the within-generation dynamics of NPV in gypsy moth populations. We tested the models against data from field studies that measured the week by week progression of mortality from NPV in nine gypsy moth populations of varying density. Both models exhibited the characteristic bimodal temporal pattern of mortality from NPV evident among larval gypsy moths and a population density threshold effect. At densities below the threshold, mortality from NPV declined to very low levels among late instars. At densities above the threshold, high late-instar mortality occurred. The Anderson and May model predicted lower mortality at low population density than was observed in the field. The GMLSM, in its current form, predicted lower mortalities than was observed in all populations. Work with simple models may help identify artifacts that may be difficult to uncover in complex simulations.

THE PROGNOSIS MODELING SYSTEM: USE, DEVELOPMENT, AND FUTURE FOR SIMULATING FOREST GROWTH AND PESTILENCE

Nicholas L. Crookston[d]

An overview of the Prognosis Model for Stand Development is presented. Emphasis is given to the linkages to pest extensions to the Prognosis Model. Extensions exist that represent mountain pine beetle, Douglas-fir tussock moth, western spruce budworm, *Armillaria* and *Phellinus*, mistletoe (built into tree growth equations), and stem rusts (under development). The model is used by silviculturists for evaluating stand prescriptions, planners for estimating forest-wide growth and yield and some non-commodity outputs, pest managers for evaluating pest treatments, and wildlife and other non-timber managers for evaluating habitat management programs. Variants of the Prognosis Model cover most of the forested area of the western U.S. and part of British Columbia. Growth equations within the Prognosis Model represent tree vigor and site conditions. However, the techniques used to predict growth are insensitive to weather and climatic change, and crudely represent tree vigor. Using the present growth models, pest and host tree interactions are modeled indirectly using model elements that are surrogates for the underlying controlling mechanisms. Future work will be focused on including more of the mechanisms of growth and rebuilding models of pest and host interactions to more directly represent important processes. This work will be done incrementally to maintain the Prognosis Model's usefulness and so that the effectiveness of new techniques can be measured in respect to current capabilities.

WHAT IS AN APPROPRIATE AND USEFUL MODEL?

Alan A. Berryman[e]

I address the problem of choosing an appropriate model to describe a particular set of ecological data and then consider what makes a model practical or useful. First, models must be selected for their theoretical credibility, or for the logic of their underlying structure or assumptions. It makes no sense to select models that make ridiculous assumptions or that violate established theoretical principles; e.g., I have seen regression models that predict an oviposition rate of 50 eggs per female when the density of females is zero! For models to be practical, or useful, they need to have easily estimated initial conditions (input variables), should be transparent so that the user can understand why the model predicted such and such, should be relatively accurate, and should be cheap to build and operate. Simple models built around sound theoretical principles seem to be generally more appropriate and practical because: 1) large models are more expensive to build and operate than simple models; 2) large models are often less accurate than simple models because redundant equations amplify the errors; 3) large models are so complicated that the user, and often the creator, cannot see why they do what they do (they are opaque!); and 4) large models often require so many inputs that, for logistical or financial reasons, the user cannot measure all of them. A more detailed discussion of simple theoretical models and their application to forest insect prediction and management will appear in the American Entomologist in the near future.

DEVELOPMENT OF FUNCTIONAL MODELS FOR SOUTHERN PINE BEETLE POPULATION PREDICTION

Frederick M. Stephen and M. P. Lih[1]

Approaches selected in building models of biological systems or processes vary for many reasons, including the specific problem being addressed; the mathematical and biological skills of the the modelers; the intended use or needs of the users; the accuracy required in prediction; the computing tools or skills available; and the data available for the modeling effort. We have been interested in why southern pine beetle spots grow and die, and have built a model of that process to predict, over a relatively short time frame (ca 3 mos.) numbers of currently infested trees and total tree mortality in an existing infestation. A central focus has been the requirement that intended users (i.e., forest pest managements specialists) not have to climb trees or intensively sample beetle populations, but rather perform simple surveys of infested trees and stands, gathering standard data that are familiar to foresters. Currently the model is used for justification of control decisions in National Forest management and in Wilderness Areas where the Red-cockaded Woodpecker, an endangered species, is threatened; also as a component of the integrated SPB expert system; and for comparative analysis of spot growth in research evaluations, e.g., pheromone or pesticide trials. Performance evaluations on 70 infestations in 5 states over 5 years revealed an average absolute error for number of dead trees over time of 16.7% and an average error for number of dead trees over time of -2.8%. Tests by the U.S. Forest Service with 27 infestations showed that "actual values were within 30% of predicted values 78% of the time".

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IS THERE A NEED FOR LONG-TERM DATA SETS?

Moderator: W.J.A. Volney[1]

Insect populations and the damage they cause to forests are known to vary through time. The nature and characteristics of these variations are often described in very general terms and processes which cause these fluctuations are usually unknown. Opportunities to assess and manage damaging forest insect populations improve materially if the nature of the processes underlying population behavior are known. The degree to which pest management objectives are realized depends on the extent to which processes influencing the damage caused by insect populations are known and can be manipulated.

Knowledge of a natural phenomenon is created by progressing from observing the phenomenon, extracting and postulating plausible hypotheses from the observational data, testing these hypotheses by experiment or using controlled observations and, finally, updating the hypotheses as a result of the foregoing step. This can be an iterative process. Eventually hypotheses verified by independent observation and experiment become theories and, eventually, laws. This process is called the scientific method. If our management procedures are to be based on scientific principles, we have no alternative but to invest in long-term observational data sets, at least initially.

Some cultures seek to manipulate nature through other means. In the initial development of a discipline, before hypotheses are elevated to the stature of laws, management based on scientific principles may be as effective as procedures based on other principles such as superstition.

There can be little question about the need for long-term data sets, because the discipline of forest pest population dynamics is in its infancy. The controversial part of this question is what type of data are required to improve our understanding of pest population behavior. Furthermore, one may ask: what constitutes a long-term data set? Most importantly, one may ask: what information can be obtained from the study of long-term data sets that can not be obtained from short-term studies or an experimental program in population dynamics. And there is always the question as to whether long-term studies are the best investment of scarce research resources, not the least of which is the commitment of the scientist or agency undertaking such a study.

Long-term data sets are available for a variety of forest pest systems that can shed some light on these questions. Five speakers presented prepared talks that sample the wide range of systems that have been studied. The list of systems discussed is far from exhaustive. The sixth speaker described procedures which could be used to search for principles governing the dynamics of the system being studied.

This summary is an attempt to capture the salient points of their addresses and provide a synopsis of the discussions arising from their comments. The abstracts of the speakers' presentations are also provided.

TREE-RING RECORDS

Dr. Anne Lynch[a] presented a paper co-authored with Dr. Tom Swetnam[b] on the use of proxy data in the form of tree-ring records to describe the long-term history of western spruce budworm outbreaks in the Southwest. By using tree-ring series from both host and nonhost trees in a variety of forest stands they were able to discuss the variation in western spruce budworm outbreaks in time and space.

The western spruce budworm defoliation signature is characterized by a depression in radial increment and reduced height growth in host trees of defoliated stands. No such depression in growth is evident in nonhost trees. The more recent outbreaks evident in the tree-ring

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record were coincident with the historical records of outbreaks in the region.

The most recent outbreak was the most severe and widespread, occurring in all four sites from which tree rings were examined. Previous outbreaks were not synchronous over the area examined. The land practices of European settlers, such as harvesting non-host species, fire protection and cattle grazing, all in the twentieth century, created stand conditions that are conducive to wide spread outbreaks.

A 1200 year chronology developed from limber pine trees in the area also illustrated the dramatic shifts in climate that have occurred. Prior to 1550 the pattern of rainfall was quite variable and oscillated at a high frequency. After 1550 there was a period of drought, which lasted for approximately 400 years. It is only in the last 25 years that the rainfall pattern typical of the area prior to 1550 returned.

The long-term record of proxy data on the behavior of western spruce budworm populations is unique in its length. Most importantly, it illustrates the difficulty we may have in basing our understanding on too short a record. The record also demonstrates that anthropogenic and climatically driven shifts in the environment can have dramatic effects on the behavior of the western spruce budworm populations.

DOUGLAS-FIR TUSSOCK MOTH RECORDS

Dr. Roy Shepherd[c] described an analysis of Douglas-fir tussock moth defoliation records accumulated over 70 years in western North America.

Several features of the outbreaks are evident. The populations appear to be periodic in the northern parts of the range but less so in the southwest. The initiation of outbreaks seem to be sporadic, but the population crashes seem to be synchronous over large areas.

The differences in outbreak behavior, north to south, and observations on the impact of natural enemies of the tussock moth may shed some light on significant aspects of outbreak epidemiology. Virus epizootics appear to be important in mediating declines in the Douglas-fir tussock moth populations in the dense, largely contiguous host stands of the north. It is believed that wind, movement of larvae within the stand, especially from the soil to the foliage, and attenuated dispersal losses are important in enhancing the transmission of virus in northern forests. The sparse, spatially isolated forests of the southwest may not be conducive to this form of horizontal transmission within populations. Other natural enemies may be more important in contributing to population collapse in the forests of the southwest.

The spatial distribution of outbreaks was also analyzed with respect to biogeoclimatic regions in the northern areas. The long-term record would suggest that outbreaks occur in the more xeric regions where degree-day accumulations are intermediate between the extremes experienced in interior British Columbia. These observations, if nothing else, provide an empirical basis for forecasting shifts in the regions where outbreaks may be expected under a variety of climate change projections.

HISTORICAL RECORDS

Dr. Robert Campbell[d] presented the view that information collected to assess pest control operations may be of some value in elucidating population processes.

By systematically comparing the population dynamics research on the western spruce budworm, the jack pine budworm, and the spruce budworm in the east, general theories on the functioning of each population system may be formulated. Because the three pest species are so similar, processes observed in one population may be identical, or similar to those in the others.

A considerable volume of information is collected on the budworm species when control operations are undertaken, because these species are also commercially important. This information, coupled with the research information, may be invaluable in evaluating processes operating in populations. Opportunities exist in operational programs to acquire data relatively inexpensively. Whereas most operational programs collect information on egg mass densities, the added cost of 15 to 20 cents per plot may justify having the number of rows and egg mass length measured to determine the mean egg mass size. From a limited number of operational assessments where egg mass size was determined, there appears to be a positive correlation between egg mass size and egg mass density. The significance of this counter-intuitive result is puzzling.

Over time the accumulation of operational assessments will represent an important source of long-term data. If the right variables are observed, these data sets also become important sources of information. There is a need, on the part of the research community to periodically review this information and assess its utility for furthering our understanding of the pest's life system.

SPACIO-DYNAMIC DATA SETS

Dr. Andrew Liebhold[e] discussed the utility of long-term forest insect population data that incorporate geographical information on outbreaks. Much of the information collected for forest insect surveys is not properly archived. In some cases, information may exist but can only be found in obscure documents catalogued with miscellaneous information collected by various Government departments.

One example of such information is the data on gypsy moth infestations in Massachusetts which were "rescued" by Dr. Campbell and known as the Melrose data. Analysis of this information and a comparison with current infestation records reveal a distinctively different behavior in population spread prior to 1965. The difference is attributed to the effect that early control efforts had in retarding population spread. When these efforts were curtailed population spread accelerated.

A second use of long-term data on outbreaks was to describe the characteristic pattern of gypsy moth spread. Models of this process would allow managers to anticipate the spread of the pest and plan for its arrival in uninfested areas.

Outbreak information coupled with geographical information could also be analyzed with geostatistical models to predict the future occurrence of defoliation in currently infested areas. Three dimensional models, employing a process known as "krigging", could be used to extrapolate beyond the region for which data exist and forecast population behavior over the landscape.

It is unfortunate that no systematic means of cataloguing the census data represented by aerial sketch maps was employed. Such a methodology is now available in the several geographic information systems available. The quantity of information that can be dealt with on such a system, if it were archived systematically, would materially improve the forecasting capability of the models already available.

LONG-TERM STUDIES OF NATURAL ENEMIES

Information on the behavior of natural enemies is uncommon. Unique in this regard are the studies carried out by Dr. Donald Dahlsten[f]. In addition to the study of cavity nesting birds, Dr. Dahlsten has also recorded the abundance of both urban and forest tree pests in a variety of localities.

The techniques used in assessing defoliator populations and comparing these indexes to direct assessments of populations have resulted in accurate yet inexpensive methods to assess population change. The elm leaf beetle, which is multi-voltine, can have different population behavior in different years at the same site. Consequently, rapid assessment techniques were developed to allow managers to choose among alternative management options. Considerable data on the population dynamics of the Douglas-fir tussock moth in California have been accumulated by using artificial pupation shelters in susceptible stands. Information on pupal densities, generation survival, and egg and cocoon parasitism can be obtained from these shelters.

The provision of nesting cavities for the mountain chickadee and monitoring these boxes over the past 25 years have yielded extremely valuable information. These data allow an examination of the reciprocal interactions between the insectivorous birds and certain forest insect populations. By banding fledglings, recording fledgling success, determining the cause of mortality in the nests, and observing the feeding of nestlings, hypotheses on the role of weather as it determines the success of overwintering and season of egg laying can be investigated. In addition, the effects of insect variety and abundance on the success of mountain chickadee populations can be evaluated.

One of the astonishing observations about these studies is that the equipment and procedures required to obtain the observations are inexpensive, yet very little of this work has been emulated in other systems where secondary cavity nesters and caterpillars that wander to seek cocoon sites are important. Similarly, in life-table studies of forest insects avian predation is often neglected. Yet the studies described by Dr. Dahlsten provide a means of obtaining an index of avian predation, provided secondary cavity nesters are involved.

THE ANALYSIS OF LONG-TERM DATA

Dr. Allan Berryman[g] described the opportunities available for analyzing long-term time series of population data. His abstract gives a list of five applications that employ long-term data sets in describing the system studied and searching for underlying processes.

Most importantly, he observes that there already exist a considerable number of data sets that have not been fully analyzed. Despite the investment they represent, it is unfortunate that the agencies that collected the long-term data have not had the commitment to analyze the historical records. Dr. Berryman argued that the precision with which this information was collected would be adequate as long as they indicated order of magnitude changes in population densities, because pest populations typically fluctuate over several orders of magnitude. Not surprisingly, he also proposed that the information to be collected need not be costly. The cost of these observations was really in the long-term commitment of the agency funding the work.

CONCLUSIONS AND RECOMMENDATIONS

All speakers considered the need for long-term information as prerequisite for analyzing processes that drive populations. The length of the records accumulated in the studies described varied, but it is quite apparent that the longer and more extensive the observational data base the richer it became. There was some debate as to the need for extreme precision in the data acquired. The resolution of this issue may be approached through sensitivity analyses using the procedures employed in examinations of the data sets.

The following is a synopsis of recommendations arising from the issues dealt with by the panel.

1) Pest management information should be collected and archived in well defined filing systems.

2) The information from operational projects form a valuable source of data and should be reviewed by the research community periodically.

3) Institutions concerned with pest management should invest, if they do not already do so, in the acquisition of long-term data over extensive areas if our understanding of the processes governing pest damage is to improve.

4) Observations should not only be limited to pest populations, but should include the natural enemy complex as well as the reaction of the host stands.

5) Any specific piece of information collected need not be costly if there is sufficient investigation of suitable technologies to acquire pest related information inexpensively.

6) Existing data bases should be made machine readable and available for analysis.

7) Analytical techniques available for analyzing long-term ecological data should be improved and applied to pest management related information.

8) Opportunities exist to incorporate both extensive spatial and temporal information in expert systems to improve pest management decision making.

By integrating the results obtained by the analysis of long-term data sets in pest management decision making, we shall move along the "credibility continuum" giving the pest manager tools based more on scientific principle than on tenets based on superstition. Long-term data bases thus provide an empirical data base on which scientifically based decision making can be developed.

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APPROACHES TO TEACHING UNDERGRADUATE COURSES IN FOREST PROTECTION

John Witter and Jennifer Stoyenoff[1]

In the last 40 years, forest protection courses have undergone a number of significant changes. Previously, fire, entomology, and pathology were typically taught as separate courses and often housed in separate departments; students enrolled in these courses were usually forestry majors. Today, many universities have shifted to teaching combined courses covering two or more disciplines, and they often serve students that come from a wide variety of backgrounds.

Forest protection courses currently offered fall into three different categories: integrated protection course (fire, entomology, and pathology); integrated pest course (entomology and pathology); and separate protection courses. The integrated pest course is the most highly recommended course structure; it exposes students to two disciplines at the same time and leads to development of better diagnostic skills. The integrated protection course is not recommended, because it greatly restricts coverage in each area and creates more confusion for the students. The separate protection courses are often not taken by students, because of lack of time in their schedules. Key topics all forest protection students should be exposed to are insects, diseases, fire, weeds, and animal pests such as deer and rabbits.

Problems related to students in forest protection courses include weak biology backgrounds, weak observational, analytical, and communication skills, and initially high frustration levels in integrated courses. Problems related to the courses include lack of a single textbook that spans the needed range of material, high cost of textbooks, amount of field training that can be offered, and applying appropriate lab work and testing procedures to the course.

Universities must give thought to preparing students adequately for forest protection jobs and to continuing to help alumni out in the job market with workshops, training sessions, and lifelong learning programs.

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INTRODUCTION

This workshop met in two different sessions, totalling six hours. Approximately 30 people participated, including instructors, researchers, and managers. These people represented both the disciplines of forest pathology and entomology. Four formal presentations were made during the course of the workshop. Most of the workshop time was spent on short discussions of how forest protection courses are taught at various universities, approaches that are working, and problems associated with forest protection courses. Key areas emphasized included: 1) changes in forest protection courses over time; 2) strengths and weaknesses of various course models; 3) minimal concepts that should be covered in a forest protection course; 4) student backgrounds; 5) textbooks and supplemental materials; 6) laboratory formats; 7) testing procedures; and 8) students beyond the classroom.

OVERVIEW OF FOREST PROTECTION COURSES

Changes in Forest Protection Courses Over Time

From the late 1920s until the early 1980s, fire, entomology, and pathology were typically taught as separate courses. Although it varied somewhat among universities, the fire course was normally administered by the forestry department, while the entomology and pathology courses were each housed in their respective departments. Over the last ten years, there has been a gradual shift from separate courses in each discipline to a combined course that includes two or three of the disciplines. This has come about because the undergraduate forestry curriculum has expanded to include more economics, policy, communications, business, and computer science, leaving less time for forest biology courses.

The types of students that are enrolled in forest protection courses has also gradually changed over the years. Almost all students who took forest protection courses from the 1940s to the early 1970s were majoring in forestry. This shifted considerably at some universities during the 1970s and 1980s. Presently, forestry students are in the minority in forest protection courses that are taught in some areas of the country. In these areas, students from wildlife, horticulture, urban forestry, recreation, landscape architecture, and other disciplines make up the majority of the students.

Numbers of students enrolled in forest protection courses has likewise experienced a shift over the last 40 years. During the 1970s, student enrollment in many forest protection courses doubled or tripled. However, enrollment began to decline in the late 1970s. It stabilized during the mid 1980s, and then began to increase again.

Present Day Forest Protection Courses

Upon reviewing courses offered in forest protection throughout North America, we found that there is a wide variety in what is available to undergraduate students. At a few universities, almost no forest protection courses are required. At others, three courses are offered (fire, diseases, and insects), with students required to take two of the three. In some cases, there are only two protection courses taught, one covering fire and the other covering both insects and diseases. Finally, some universities teach a single general course that covers all three areas. These various permutations are possible because of relaxation of Society of American Foresters' requirements in forest biology. At most land grant universities, advanced level forest protection courses are also offered. The number of advanced level courses available at non-land grant institutions varies from none to a range comparable to that found at land grant universities.

Differences in forest protection education are also apparent today at the regional level. In some parts of the country, courses have a much stronger emphasis on urban forestry. This tends to be especially true in the east and midwest. Likewise, fire tends to be a much more important forest protection component in certain areas, notably the south and west. The breadth of the forest protection course varies considerably in different parts of North America also; forestry schools and their courses are regional or national in scope depending on the geographic area over which the students are drawn from and in which they are later employed.

STRUCTURES OF FOREST PROTECTION COURSES

Workshop participants agreed that almost all forest protection courses taught in North America fall under three models. These are: 1) the integrated protection course (fire, entomology, and pathology); 2) the integrated pest course (entomology and pathology); and 3) the separate protection courses.

Integrated Protection Course

In recent years a few universities have developed a general forest protection course that combines the three areas of fire, entomology, and pathology into a single course. This has been done to alleviate the difficulty of having to fit so many separate requirements into the four year undergraduate program. Such a combined course may be taught by a single individual or by two or three instructors together. In some cases, the course is taught as three separate modules with no integration among them. In other cases, it is taught using a highly integrative format. The evaluation of the combination course presented in Table 1 is based on the assumption that a highly integrated format is followed. Most professors who are currently teaching a course which combines all three forest protection areas do not recommend it to others, because it leads to great dilution of material and lack of adequate forest biology coverage.

Integrated Pest Course

Several universities have combined only two of the disciplines, entomology and pathology, into a single course while leaving fire as a separate course. Several schools have used such a model for five or more years, and many others are considering switching to it. This format seems to be working well for the institutions that follow this approach; it is highly recommended despite the fact that there are still some difficulties associated with it. One of the strong points in favor of such a course structure is the fact that students appear to acquire better diagnostic capabilities in the combined course. They are exposed to both insects and diseases at the same time and, therefore, can learn the subtle differences of distinguishing between them. Also, because only two areas are combined rather than three, less confusion and more in-depth coverage are possible than is the case with the fully combined model.

Separate Protection Course

The traditional model used in forestry schools was to offer three separate protection courses. This has generally been done, because most faculty are trained in a single discipline and prefer to teach only in that area. Also, a separate course approach allows plenty of time for covering background information, presenting case history examples, and introducing life history information and subsequent organism ID. This approach is slowly being replaced, however, by courses featuring a combination of disciplines, because students do not have time in their schedule to take undergraduate disciplinary courses in all three areas.

MINIMAL CONCEPTS IN FOREST PROTECTION COURSES

Workshop participants in general felt strongly that all students should be exposed to certain basic forest protection topics, regardless of the course format in which they are covered (separate courses, partially combined, or fully integrated). These areas should include insects, diseases, fire, weeds, and animal pests such as deer and rabbits. Unfortunately at many universities students have not been receiving exposure to all of these areas. The reasons for this lack of exposure are varied: these subject areas are covered in separate courses at many universities, but students are not required to take classes in all of these areas; professors teaching integrated courses are often trained only in one discipline and may stress this discipline to the detriment of other areas; the backgrounds and interests of students in the course may lead to strong emphasis in certain subject areas and little or no emphasis in others; the regional nature of instruction at some universities may lead to non-coverage of certain subject areas; and the amount of lecture time available in the course may limit topic coverage.

Within each of the five key subject areas, certain basic concepts should be presented. There should be some level of forest biology coverage, including discussion of ecological conditions that are conducive to the various damage agents. Secondly, silviculture should be well integrated with each of the areas. The signs, symptoms, and conditions of the various damage agents should be emphasized. Basic IPM concepts, including monitoring, evaluation of impact, selection of treatment alternatives, and determination of control effectiveness, should be stressed. Finally, students must be taught where to go to get additional help with and information about each of the five key damage areas.

STUDENTS IN FOREST PROTECTION COURSES

The type of student enrolled in forest protection courses today varies greatly. At some universities, most of the students are forestry majors. At other universities, the students come from a wide variety of disciplines. In either case, a number of key problems were identified that revolve around students.

The workshop participants felt very strongly that in most cases the biology background of students enrolled in forest protection courses is much weaker today than it was twenty years ago. This is due to several factors. First, gradual course credit inflation at many universities has led to a reduction in the number of basic biology, chemistry, and physics courses that students take. Also, since the emphasis in many general biology courses is placed on molecular rather than organismal biology, there has been a reduction in students' knowledge of organism-level biology and ecology. One exception to this is found in the Canadian universities, where the students continue to get good training in both basic biology and ecology. It is imperative that students have strong backgrounds in general and forest biology if they are to make the appropriate management decisions in the future; managers are today being forced to manage for multiple resources and to take into account biological diversity, old growth forests, and conservation biology, all of which requires excellent biological understanding on the part of the manager.

Strong observational and analytical skills are another area in which many students are somewhat lacking. Instructors participating in the workshop continually pointed out that many students in their classes had poor observational skills, trouble in delineating problems, and difficulty with creative problem solving. We need to provide students with greater opportunities for observation and description in forest protection courses. After taking such a course, the student should be able to look at particular signs and symptoms, figure out what the problem is, and apply biological information to prescribe appropriate silvicultural and management options.

Lack of adequate communication skills is also a difficulty with many students. Some universities now highly recommend that professors incorporate communications training into some or all of their courses to increase student abilities in this area. Forest protection professors have used a variety of approaches to do this, including term papers, take-home exams, having students develop a fact sheet or extension bulletin, or building problem solving exercises into laboratory work. One should consider trying to increase students' communication skills when determining testing procedures in forest protection courses.

Instructors of integrated courses report that many students initially have high frustration levels due to their weaknesses in basic biological and ecological background, weak observational and reasoning abilities, weak analytical skills, and needing to deal with different vocabularies for each of the disciplines in the combined course. If the material becomes too much, instructors must be willing to back off on details. It is important to cover the concepts well, but it is also important to make the course fun, keep the students curious, and keep enthusiasm high. There are many ways to do this. Some of the techniques used by different instructors include various kinds of visuals (slides, videos, movies, computer programs, overheads), use of live insects, interesting guest speakers, field trips, and use of local examples.

READING MATERIALS ON FOREST PROTECTION

There have been many textbooks written on the subject of forest protection. However, many of these are of limited scope, covering only certain pests or certain regions of the country or are otherwise incomplete. Additionally, many of them are out of date or out of print. Those books that are available tend to be disciplinary in nature, covering only fire or insects or diseases. The workshop participants strongly agreed that no one book was available which spanned the needed range of material for an integrated forest protection course.

There is a further problem with textbooks in addition to that of scope; textbooks are expensive. There are several ways of dealing with this difficulty. Some instructors simply use two different disciplinary textbooks and do not worry about expense. Others use only a single text or no text at all and supply reading materials in other forms. They may place items on reserve in the library for students' use. They may obtain multiple copies of books covering regional problems and make them available to students. Free leaflets and handouts from cooperative extension and state or federal agencies may be utilized. Finally, they may provide handouts or photocopied course packs, although this is becoming more difficult and requiring more advanced planning as the problems with the copyright laws become greater. Students' feelings about textbooks vary. When books are used they often complain of the expense, but when no book is used they often criticize the lack of a text.

Workshop participants strongly recommended that a single integrated textbook on forest protection should be prepared. After lengthy discussion, it was decided that there was no one individual who could successfully complete this project. Rather, it was recommended that the USDA Forest Service Forest Pest Management should organize an advisory committee to put together a group of individuals who would write a truly integrated concept book that would also include key case history examples presented by region. This book could be used for a college textbook, as a manual for pest management training sessions, or as a required textbook for the silviculture certification program of the USFS. Such a book would need to be updated frequently, and would need to be readily available to all who would use it. It is important for the USFS to sponsor this book to ensure that it would truly get done; private publishers are not usually willing to take a risk on such a jointly written book. Canadian scientists participating in the workshop also were interested in this project, and there may be a possibility of cooperation between the US and Canadian agencies to produce the book.

LABORATORY AND FIELD TRAINING

Instructors of forest protection courses feel that laboratory and field experience are very important for students to properly understand their subjects. The amount of field training that can be offered varies greatly among courses, based on the time of the year the course is taught, proximity to appropriate outdoor areas, and whether or not the school has a summer camp program. Instructors reported that in course evaluations, students always asked for more field time. It is important to schedule as many field trips and outdoor activities as possible, although the time of the year at which the course is taught greatly influences the possibility of this. It may be possible in some instances to offer a field trip as part of another course at a more appropriate time of year if the forest protection course is taught in the winter.

Laboratory training in forest protection courses generally stresses signs, symptoms, and identification, although specific topics covered vary by course. Many innovative techniques have been used to increase students' interest and ability in laboratory work. These include having students prepare a dichotomous key of a group of specimens, use of live insects for behavioral study, placing and collecting from pheromone traps and various other types of traps, use of freeze-dried specimens, and specimen display boxes showing the life cycle of the pest along with related foliage, predators, and parasites of the pest. Many instructors have students prepare insect, disease, and/or damage collections themselves to help the students better learn about the organisms involved. If local infestations are available, field trips to such areas will make the pest experience much more real for students. Many instructors also successfully use computer simulation and modelling programs to excite the students. Pest managers at the regional level often can supply good information on programs to use.

There was general agreement from workshop participants that there is no need for a generic lab manual to be written. Such a manual would not be useful because professors tend to stress regional and local problems in lab and therefore wish to supply their own material as handouts or course packs to the students.

One of the problems with having a laboratory for the class is the necessity of constantly needing to repair and upgrade the collection. There are several ways to handle this difficulty. One way is to use specimens from students' class collections to replenish the teaching collection. Occasionally, it is also possible to hire a student on an hourly basis to collect specimens for the lab. Alumni or pest specialists from state or federal agencies may be sources of certain specimens. Finally, permanent displays in which the students can not directly handle the insects may be used.

TESTING TECHNIQUES

There are a variety of ways to test students in forest protection courses, both in lecture and lab. Since different students perform differently on various types of tests, it is important to vary testing methods. Instructors use written in-class exams, take home exams, and oral exams. Some faculty stress problem solving skills on their exams; they may give students a large problem to work on which could even be presented as a project for the student. Other types of projects include term papers, assignments to write fact sheets or extension bulletins, computer simulation exercises, pest/damage/disease collections, photography projects, or research projects.

STUDENTS BEYOND THE CLASSROOM

Once students have completed a forest protection program, they should be able to go out into the real world and perform successfully at a forestry related job. This goal, however, is not always attained. While employers feel that some students have received good training, they feel that others are lacking in basic skills, notably basic biological and ecological knowledge and written and oral communication skills. Agency personnel attending the workshop expressed the desire for new employees to have a better foundation in the basics; knowledge of specific insect or disease problems is not as important, because agencies provide short courses to new employees on the key pest problems of a given region. Detection, evaluation, and management of specific forest damage agents can be easily learned on the job either in the field or through training sessions if employees already have a solid background in fundamental concepts and principles. Participants felt that students may not receive enough fundamental information if a totally combined protection course (fire, insects, and diseases) is taught, because of lack of time to adequately cover the main portions of each area.

Various universities have surveyed alumni from their forest protection programs and found that these alumni wish that they had taken more entomology and pathology while they were in school. Unfortunately, forest biology courses are often shoved into the background of the curriculum and treated as electives by faculty and students alike. Instead of having strong forest biology requirements, many programs today are focusing on economics, computers, and business classes as requirements. Exacerbating this is the problem that only so many classes can be fit into a four year program; universities can not lengthen the program duration to correct this, because they will then not remain competitive in the market. One solution is to re-evaluate the academic schedule and restructure forest protection degree requirements. Another move that universities should make is to become involved in workshops, training sessions, and lifelong learning programs, either as sponsors or participants. Such programs would greatly aid alumni by providing them with a source of further information and training once they have moved from the classroom to the job market.

RECOMMENDATIONS

* Do not elect to teach a totally combined protection course (fire, insects, and diseases together); such a course has extremely limited time to cover each subject area and leads to great dilution of material, lack of forest biology coverage, and confusion on the part of students.

* An integrated pest course (covering insects and diseases together) is a highly recommended course structure; students are exposed to two disciplines at once in such a course and acquire better diagnostic capabilities, because they learn to distinguish subtle differences between insects and diseases when shown both at the same time. Because only two subject areas are combined here rather than three, less confusion and more in-depth coverage are possible than is the case with the fully combined course model.

* All students should be exposed to certain basic forest protection topics. The key topics are insects, diseases, fire, weeds, and animal pests such as deer and rabbits.

* Within each of the five key subject areas, certain basic concepts should be presented. First, there should be some level of forest biology coverage, including discussion of ecological conditions that are conducive to the various damage agents. Secondly, silviculture should be well integrated with each of the areas. The signs, symptoms, and conditions of the various damage agents should be emphasized. Basic IPM concepts, including monitoring, evaluation of impact, selection of treatment alternatives, and determination of control effectiveness, should be stressed. Finally, students must be taught where to go to get additional help with and information about each of the five key damage areas.

* Avoid high student frustration in integrated courses by backing off on details and instead providing a solid coverage of underlying concepts and principles.

* It is very important to vary testing methods. Make use of written in-class exams, take home exams, and oral exams. Stress problem solving skills and communication skills. Provide students with projects such as term papers, assignments to write fact sheets or extension bulletins, computer simulation exercises, pest/damage/disease collections, photography projects, or research projects on which you can evaluate their performance.

* Laboratory and field experience are very important for understanding forest protection issues properly. Instructors reported that in course evaluations, students always asked for more field time. It is important to schedule as many field trips and outdoor activities as possible, although the time of the year at which the course is taught greatly influences the possibility of this. Other innovative techniques should also be employed to increase students' interest and ability in laboratory work.

* The biology background of students should be strengthened as much as possible; avoid course credit inflation and other situations that lead to students acquiring weaker biological backgrounds.

* Encourage students to take more entomology and pathology courses while they are in school.

* Restructure forest protection degree requirements to reflect the importance of forest biology to the forester.

* Build strong observational and analytical skills in students; provide students with greater opportunities for observation and description in forest protection courses. After taking such a course, the student should be able to look at particular signs and symptoms, figure out what the problem is, and apply biological information to prescribe appropriate silvicultural and management options.

* Incorporate training in communication skills whenever possible. Forest protection professors have used a variety of approaches to do this, including term papers, take-home exams, having students develop a fact sheet or extension bulletin, or building problem solving exercises into laboratory work. One should consider trying to increase students' communication skills when determining testing procedures in forest protection courses.

* Provide students with training in the basic skills, notably biological and ecological fundamentals and written and oral communication skills, that they need to be successful in a forestry related job.

* Sponsor and participate in workshops, training sessions, and lifelong learning programs. Such programs greatly aid alumni by providing them with a source of further information and training once they have moved from the classroom to the job market.

* There is no need for a generic lab manual to be written. Such a manual would not be useful, because professors tend to stress regional and local problems in lab and therefore wish to supply their own material as handouts or course packs to the students.

* Workshop participants strongly agreed that no one book was available which spanned the needed range of material for an integrated forest protection course and strongly recommended that a single integrated textbook on forest protection should be prepared. USDA Forest Service Forest Pest Management should organize an advisory committee to put together a group of individuals who would write a truly integrated concept book that would also include key case history examples presented by region. This book could be used for a college textbook, as a manual for pest management training sessions, or as a required textbook for the silviculture certification program of the USFS. Such a book would need to be updated frequently, and would need to be readily available to all who would use it. It is important for the USFS to sponsor this book to ensure that it would truly get done; private publishers are usually not willing to take a risk on such a jointly written book. Canadian scientists participating in the workshop also were interested in this project. There may be a possibility of cooperation between the US and Canadian agencies to produce the book.

THE INTEGRATED PEST COURSE: A CASE STUDY AT THE UNIVERSITY OF MICHIGAN

John Witter and Harrison Morton[1]

Forest protection courses taught at different universities vary greatly. This is due, among other factors, to differences in backgrounds and interests of the students and of the professors, goals of the school, the number of lecture and lab sessions available in the course, and the geographic range over which students come from and in which they will be employed. At the University of Michigan a single course is taught, entitled Ecology of Landscape Pests, which integrates insects and diseases into one curriculum. It features heavy emphasis on urban problems and multiple use resources, linkages with other courses, heavy use of slides and videos, and less emphasis on timber than is found in certain other regions of the United States.

The Ecology of Landscape Pests is taught by two professors (one entomologist and one pathologist) in such a manner that the disciplines of entomology and pathology are completely integrated in both lecture and lab. The first twelve lectures deal with integrated pest management (introduction, 2 lectures; IPM concepts, 1; population dynamics, 3; control, 5; and impact, 1). The next 26 lectures cover insects and diseases by the tree module attacked (foliage, 6 lectures; buds and shoots, 1; roots, 2; seeds and cones, 1; twigs and boles, 6; phloem, 4; cambium and xylem, 5; biting and stinging insects, 1). The last four lectures look at interactions of abiotic and biotic factors. The goals are to teach students to recognize potential pests of urban and rural environments and to give the students ecological training so that they are capable of planning and carrying out sound forest and forest pest management practices in the future. The course is structured so that it may be taken for anywhere from one to four credits; students taking less than four credits do not take the lab. Allowing variable credits is important, because students taking the course come from a wide variety of backgrounds and majors; some, such as landscape architecture students, do not have time in their schedules to take the full four credit lecture and lab sequence.

Several advantages accrue from teaching a course that combines insects and diseases. First, material in these two subject areas is compatible and integrates well. Students have an easier time understanding the interactions between the two, and when exposed to both at the same time, they see the subtle differences that exist in symptoms of insects and diseases. Also, having two instructors provides a system of checks and balances. Each instructor must be concise and well organized in order to present material without overflowing into the other instructor's time, instructors can play off one another by asking questions and providing comments and interactions, and students can become exposed to two different viewpoints within a single course. Such a team teaching system also provides flexibility; although both professors try to attend all lectures, if one professor must be out of town for a short while the other instructor can cover for him.

Among the disadvantages of such a course is the fact that when insects and diseases are combined into a single course, the student must deal with an enormous amount of material and must cope with learning the language of two different disciplines at once. This is often difficult at first, because many students have weak biology backgrounds. Additionally, less overall lab time is available for each discipline when they are taught together in a single course. Because of the large volume of material covered, testing the student becomes more difficult. Another problem in addition to coping with two disciplines is that the students must also deal with two professors who have different teaching styles, and they may have to face high cost of books and course packs if both entomology and pathology texts are utilized. Professors must handle upkeep and cost of slides and lab materials for both entomology and pathology areas rather than just one or the other.

Some possible solutions to these problems include requiring students to have prerequisite courses in their background, using handouts to cover weaknesses in students' backgrounds, providing study questions that emphasize concepts, reducing emphasis on organism identification, and placing lab materials in an open lab so that students may have 24 hour access for study. The high cost of multiple textbooks can be alleviated by placing books on reserve in the library or lab, using course packs or handouts, or this cost might be lowered by encouraging the development of a new textbook covering the necessary range of material. Difficulties with collection and slide upkeep could be handled by sharing collecting responsibilities, tapping outside resources such as alumni and state and federal agency pest managers, and making use of slide collections that some work conferences have.

Despite the fact that there are some disadvantages, we have found that the integrated pest course works well for us at the University of Michigan, and it will continue to be taught in this fashion in the future.

FOREST ENTOMOLOGY IN THE UNDERGRADUATE CURRICULUM IN THE FACULTY OF FORESTRY AT THE UNIVERSITY OF BRITISH COLUMBIA

John A. McLean[a]

The forest entomology component of the "protection" courses in the undergraduate curriculum at UBC is a 13-week, 2-credit course (=2 x 1h lectures plus 1 2h lab per week). Pathology is also a 2-credit course, but in addition to the 2 1h lectures, it has a 4th lab every alternate week. Both courses are taught in third year.

The students have already had first year courses in biology (6 credits) and dendrology (6 credits), second year courses in soils (3 credits), ecology (4 credits), meteorology (3 credits) and, perhaps most significantly, an 8-day field school at our forest at Gavin Lake, near William's Lake in the interior of British Columbia. This field school is important as 4 days are devoted to 5 or 6 of the biogeoclimatic zones that are found in the area. Most Forest Science Department members participate in the course. All attend every day and contribute where appropriate during the day. In this way, the whole biological component of the curriculum is brought together for the students <u>and the faculty</u> so that everyone shares in the experience of the whole forest. The entomology, pathology, and small mammal pest problems are dealt with concurrently. Other challenges, such as the maintenance of mule deer winter range in overmature Douglas-fir forests, are also dealt with on site. An underlying unifying theme is the formulation of a preharvest silvicultural prescription for each of the areas (a detailed consideration of all the factors that would impinge upon the successful regeneration of the area should be logged).

The entomology course itself includes an introduction to the structure, function, and life history strategies of (forest) insects. Various groups are considered in parallel to the laboratory sessions - seed and cone insects, nursery insects, insects in young plantations, leader and shoot feeders, defoliators, bark beetles, green wood borers, and insects affecting wood in service. A basic theme is judging impact in terms of height or volume over age curves. Basic biological processes and control strategies are discussed at appropriate stages. Examples of integrated pest management systems are included where possible.

Laboratory sessions introduce students to about 50 insects, 30 of which are emphasized as representative of their groups. Each insect of interest is displayed in as life like a manner as possible (freeze drying of foliage and insects, especially immatures) along with parasites and predators. An important part of the displays is the damage samples and other diagnostic features. After all, 95% of the time the forester sees only the damage symptoms.

TEACHING FOREST PEST MANAGEMENT AT THE UNIVERSITY OF ARKANSAS AT MONTICELLO

Lynne Thompson[b]

The University of Arkansas at Monticello (UAM) is an undergraduate campus serving primarily the people of southeastern Arkansas. It has about 2,000 students and 100 faculty. The Department of Forest Resources has the only forestry school in the state. There are about 70 undergraduate foresters, most are white males. We graduate about ten foresters per year and forest industry is the principal employer.

The Forest Pest Management course was created in 1984 from separate insect and disease classes. When I came to UAM in 1980, students were required to take a course in either forest insects or forest diseases. Most students took insects. Therefore, we considered our graduates to be deficient in pest science knowledge. In 1982, we decided to combine the classes. So the 6 hours of insect and disease material was condensed to 4 hours. Most of the deleted material dealt with life history details and non-southern pests. The course, thus, became regional in nature, covering the concepts of forest pest management and the major southern pests, especially those of pines. Silvicultural management is emphasized, especially the use of hazard ratings. Laboratory exercises stress using printed materials to identify and diagnose pest problems (e.g., Insects and Diseases of Trees in the South, Diseases of Arkansas Forests, and Insects of Eastern Forests).

The lecture outline includes: damage, losses, and benefits of insects and diseases; introduction to insects; introduction to diseases, emphasizing fungi; principles of forest pest management; management strategies and methods, emphasizing silviculture; pests of major tree modules; loblolly pine pest management; introduction to herbicides; and arthropods attacking foresters. The major pests covered are bark beetles, rusts, trunk and root decays, tip moths, and borers.

Three collections are required: insect damage, adult insects to order and disease damage. Several field trips are scheduled to evaluate pest situations or to look for signs and symptoms on plants.

Major course advantages include: integration of insect, disease and weed materials from beginning to end; consistency of presentation and philosophy, which is important in undergraduate courses; applied nature of the material; and regional pest coverage. Disadvantages include: no integrated textbook; insufficient time to develop some ideas, such as population dynamics and epidemiology; and loss of other viewpoints with only one instructor.

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INTERACTIONS BETWEEN FOREST INSECTS AND TREE DISEASES

Moderator: David L. Wood[1]

SUMMARY

Insect, microbe, and tree interactions have received increased attention from the scientific community over the past two decades. Root pathogens have been found to predispose trees to bark beetle infestation. Insect-caused defoliation may predispose trees to bark beetle infestation or to infection by root pathogens. Nematodes may predispose trees to infestation by bark beetles. Fungi carried by bark beetles during host colonization are implicated in causing death of trees. The activities of insects and microbes are all conditioned by the physiochemical status of the tree as influenced by environmental and genetical variables. These interrelationships appear to be infinitely complex and thus require a multidisciplinary approach to research on these systems. Many of the above associations have been established in the past two decades. However, the behavioral, physiological, and biochemical processes have, in general, not been well studied. Increased understanding of these multi-organism interrelationships will be critical to meeting some of the major challenges facing forest entomology, in particular, conversion to high production, intensive management systems, introduction of exotic organisms, and numerous forest declines that may result from air pollution and global warming.

CONSEQUENCES OF PINEWOOD NEMATODE-BEETLE INTERACTION

Marc J. Linit[a] and Donald N. Kinn[b]

The consequence of pinewood nematode interaction with its insect vectors (*Monochamus* spp.) varies with the susceptibility of host trees to nematode infection. Mortality of susceptible species such as Scots pine and Japanese black pine has been documented. Native pine species appear to be resistant to nematode infection; however, sublethal effects may predispose native pines to bark beetle attack. We report on the impact of nematode infection on loblolly pine oleoresin flow.

Loblolly pines on the Catahoula Ranger District, Kisatchie National Forest, LA, were monitored during three years, 1988-1990. Each year, 30 trees were inoculated with 30,000 to 50,000 pinewood nematodes. Thirty additional trees were inoculated with distilled water. Oleoresin was collected over a 24 h period on a monthly basis. The inoculation site was at a height of 3 m and oleoresin collected at 1-2 m above ground level. In 1988 and 1990, oleoresin flow was significantly reduced in the nematode inoculated trees one, two, three, four, and five (1990 only) months after inoculation. Differences disappeared during subsequent months. In 1989, no significant reduction in oleoresin flow was observed.

The expression of differences in oleoresin flow seems dependent, in part, upon environmental conditions of the season during which the tests were undertaken. This was noted when differences in oleoresin flow were observed during 1988 and 1990, both dry years, while no differences were observed during the wet summer of 1989. Dry conditions are known to favor the development of pine wilt disease and would presumably affect the sublethal impact of nematode infection as well.

RESISTANCE OF WHITE FIR PROVENANCES TO THE FIR ENGRAVER (*SCOLYTUS VENTRALIS*) - *TRICHOSPORIUM SYMBIOTICUM* COMPLEX

William J. Otrosina[c] and George T. Ferrell[d]

In 1988, following 2 years of drought, four 28-year-old white fir (*Abies concolor*) provenance plantations in the central Sierra Nevada of California sustained considerable mortality caused by this bark beetle-fungus complex. Two ("low diversity") plantations each contained only 4 local provenances, 2 from 30 mi., and 2 from 60 mi., away. The other 2 ("high diversity") plantations each contained 39 provenances from throughout most of this fir's range in the West.

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Mortality differed by plantation and provenance, being: 1) 4-fold higher in the low diversity plantations; 2) 2-fold higher in provenances 30 miles away compared to those 60 mi., away; and 3) higher (14%) in provenances from Oregon and northern California than in those from southern California, Arizona, Nevada, and Utah, all with virtually no mortality. Judging by numbers of pitch streamers on bole surfaces of surviving trees, provenances with the most mortality had been heavily attacked while those with little or no mortality had been attacked lightly or apparently not at all. In cage tests with local beetles given a choice of bolts cut from local (nearest the plantation-site) and exotic (Arizona) trees, much higher densities of attacks were initiated in local bolts and attacks in these bolts were more often successful reproductively. Results suggest local strains of these pests may be adapted, or conditioned, to local strains of their host trees. Preliminary results of isozyme analyses of geographic samples of the beetle and fungus support this hypothesis, as do results of inoculations of surviving plantation trees with local and exotic isolates of the fungus. Research continues on the mechanisms involved.

INTERACTIONS AMONG FOREST INSECTS AND TREE DISEASES IN FLORIDA PINE PLANTATIONS

John L. Foltz[e] and George M. Blakeslee[f]

The pine plantations of Florida do not suffer from bark beetles and root diseases like many of the coniferous forests of North America. Slash pine, *Pinus elliottii*, the predominant pine species, is highly resistant to infestation by *Dendroctonus frontalis*; during droughts, the aggressive, tree-killing bark beetles are *D. terebrans* and *Ips calligraphus*. Loblolly pine, *P. taeda*, is infested by *D. frontalis*, but the scarcity of old-growth stands and the relatively young age of most plantations apparently keep beetle populations and damage at very low levels. The major diseases of these two pines are pitch canker and fusiform rust, both of which have numerous interactions with many insects.

Pitch canker (PC) is caused by *Fusarium subglutinans*, a wound parasite. The feeding wound of *Pissodes nemorensis* provides an infection court for the fungus, and contaminated weevils can inoculate the tree during their feeding on new shoots. The resulting dieback of diseased branches and stems provides more brood material for the weevil and results in positive feedback between weevil numbers and PC abundance. The larval galleries of tip moths, *Rhyacionia* spp., also provide infection courts for the PC fungus, but the biology of these moths does not suggest any role as a vector. Infestation of pine stems by the southern pine coneworm, *Dioryctria amatella*, is another important infection court for pitch canker. Infestations are greater in heavily fertilized stands, and the higher tree mortality may offset the benefits of increased tree growth.

Fusiform rust, caused by *Cronartium quercuum* f. sp. *fusiforme*, is the most damaging pest of Florida pines. Several recent papers report a positive correlation between tip moth abundance and the number of rust galls. It is speculated that secondary shoots produced after tip moths kill the primary shoot provide more susceptible tissue for basidiospore infection. Other interactions occur when *P. nemorensis* and *D. amatella* infest rust galls, creating additional infection courts for the PC fungus, and PC develops as described above. These associated pests further reduce tree growth and increase tree mortality. Finally, the regular availability of rust-killed trees supports bark beetles and other decomposers at greater levels than otherwise would occur. Thus, outbreaks of these insects may develop more rapidly whenever a forest is stressed by other biotic or abiotic agents. Reducing tip moth and rust levels during the early years of a plantation may reduce pest problems throughout the remainder of the rotation.

INTERACTIONS AMONG ROOT BEETLES, FUNGI, AND BARK BEETLES IN PROMOTING FOREST DECLINES: DYNAMICS OF INFECTION AND MORTALITY IN LAKE STATES RED PINE

Kenneth F. Raffa[g], Kier Klepzig[h], and Eugene B. Smalley[i]

Increased understanding of insect-fungal complexes will be critical to meeting some of the major challenges facing forest entomology. For example, the conversion to high production, intensive management systems is often conducive to insect-fungal associations. In addition, numerous forest declines have been observed worldwide, but these are usually complex and multifactoral. Strictly epidemiological approaches are not sufficient to determine the role of such processes as acidification, global warming, and atmospheric alteration in these declines, and so a more mechanistic understanding and baseline data are required. Insect-fungal relationships also provide an opportunity for multidisciplinary basic research, to which forest entomology must contribute if it is to survive as a subdiscipline.

Bark beetle-fungal complexes involve two separate feeding guilds, scolytid-*Ophiostoma* associations in the main stem, and root organisms that predispose trees to attack. Bark beetle reproductive success, maintenance during nonoutbreak periods, and conversion to outbreak behavior are regulated by factors that reduce tree resistance to attack. A variety of environmental stresses can reduce tree defensive capability.

Host resistance to bark beetle-fungal complexes can be manifested at three levels: deterrence of beetles from entering, resin flow from wounded ducts that mechanically impede beetles and interferes with their communication, and accumulation of toxins that inhibit beetle and fungal development. These defenses act in a cohesive fashion to interrupt the colonization process at several stages. Each of these can be circumvented by mass attack, however.

Red Pine Decline is the most damaging condition affecting mature plantations in the Lake States. Although the final cause of tree death is the *Ips pini-Ophiostoma ips* complex, infection by root fungi predisposes trees to successful attack. *Leptographium terebrantis* and *L. procerum* are vectored by a group of root- and lower stem-infesting beetles. This guild does not kill trees, but the fungi progress through root grafts, and, thus, provide a zone of susceptible hosts for *I. pini/O. ips*. Possible control recommendations include severing root grafts by removing stumps during sanitation, and preventing extensive grafting by planting several species in staggered blocks.

GIRDLING BLUESTAIN INOCULATIONS FAIL TO KILL YOUNG PONDEROSA PINES

J. Richard Parmeter, Jr.[j], Gary W. Slaughter[j], David L. Wood[l]

Despite much discussion and speculation, the role (if any) that bluestain fungi might play in the death of conifers attacked by bark beetles is still uncertain. We attempted to kill small (15-30 cm dbh) ponderosa pines by making breast-high, girdling cuts with a chain saw to a depth just barely scoring the sapwood. Cotton cord colonized by *Leptographium terebrantis*, an aggressive bark beetle associate, was tied around the cut in 8 trees, spores of the fungus were sprayed into the entire cut on 6 trees, and 5 girdled trees were left untreated. All girdles were wrapped with duct tape. By 9/26/89 (19 weeks after inoculation), two cord-inoculated trees had been killed by *Dendroctonus ponderosae*, the remaining trees were green. Dye flow patterns in cord or spore inoculated green trees showed nearly continuous, resinous wedges of non-conduction in the outer sapwood, with unobstructed flow in inner sapwood zones adequate to maintain crowns. Flow in uninoculated trees was essentially unobstructed. Occlusion induced by inoculation did not resemble that accompanying bark beetle attack.

ENVIRONMENTAL STRESS AND WHOLE-TREE PHYSIOLOGY

Peter L. Lorio, Jr.[k]

In the study of interactions between forest insects and tree diseases, it is most important that one consider interactions among trees, environment and the invading organisms. Kramer (1986) strongly emphasized the importance of understanding how environment and genetics affect the physiological conditions of trees through their control of physiological processes. Without such understanding, the interpretation of interactions between forest insects and tree diseases is extremely difficult. For example, the seasonal ontogeny of pines involving reproductive and vegetative growth and development processes brings about dramatic changes in physiological conditions that greatly influence the nature of interactions with bark beetles and associated fungi apart from influences of environment (Lorio et al. 1990). Environmental conditions can, in turn, alter physiological conditions in ways that will increase or reduce tree resistance to invading organisms depending on the timing, severity, and duration of the deficits. Many past studies of insect and disease interactions have been carried out without adequate consideration of these relationships, thus, preventing the best interpretations of results. The concept of plant growth-differentiation balance (Loomis 1932, 1953) provides a very sound and useful basis for forming and testing hypotheses of tree, insect, and disease interactions. Our research on pine interactions with *Dendroctonus frontalis*, guided by application of Loomis' concept, has led to development of a conceptual, testable model of seasonal variation in tree resistance to beetle attack, which clearly complements knowledge of *D. frontalis* seasonal behavior.

HOST REACTIONS TO MICROORGANISMS AND "HAMMERING": MOUNTAIN PINE BEETLE AND SOUTHERN PINE BEETLE EXPERIENCES

Evan T. Nebeker[l], Richard F. Schmitz[m]

Trees (lodgepole pine - LPP) infected with: 1) Armillaria root rot (AM) - evident at the root collar; 2) lodgepole pine dwarf mistletoe (DMT) - > level 6; 3) Comandra blister rust (CBR) - evident on the main stem in the upper crown; and 4) apparently "healthy" trees (CK) were selected for study on the north slope of the Uinata Mountains in northeastern Utah during 1989 and 1990. Parameters of interest were radial growth (last 10 yrs divided into 5 yr intervals), resin flow (total and rate), xylem terpene chemistry, and phloem nutrient status.

There were no significant differences in ages of the trees selected for each of the four groups listed above. Within the CK trees, there was a significant difference in radial growth between the north and south aspects. Average radial growth over the past 10 yrs for CBR infected trees was significantly less than AM, DMT, and the CK trees.

Oleoresin flow follows similar patterns in LPP and loblolly pine (LP). In LPP over 65% of the total flow occurs by the 6th hour after wounding. In LP nearly 80% of the flow occurs by the 6th hour. LPP is a much "drier" species than LP where considerable more resin is produced. In both tree species, the constitutive defensive system could be shut down (no resin flow) by simulating bark beetle attacks by hitting the trees with a radial increment hammer leaving a wound slightly larger in diameter than an adult bark beetle Once the hammering was discontinued the resin flow returned to pre-treatment levels or above depending on the intensity of "hammering." Flow nearly doubled within a week after hammering was terminated in the more intensively hammered trees. This demonstrates the similarity in reaction by the host and the importance of the physical processes associated with the attacking adults.

The following represents only a few of the significant differences observed while investigating LPP resin and phloem tissue. DMT infected trees had significantly more α-pinene than in the AM, CBR, and CKs. The CKs had significantly more camphor than AM, CBR or DMT infected trees. The CKs also had significantly higher levels of myrcene than DMT and CBR infected trees. DMT and CBR infected trees had significantly less nitrogen in the phloem than the CKs. CBR and AM infected trees had significantly lower amounts of sugar (reducing) than the CKs. CBR trees had significantly lower levels of non-reducing sugars than DMT, AM, or the CKs.

The goal of this project is to unlock the relationship between the mountain pine beetle and potential hosts during endemic periods. Similar types of information need to be collected from diseased trees in the southeastern U.S. to explain the potential role of root rots, etc. in maintaining a host population for endemic populations for the southern pine beetle to colonize.

A BARK BEETLE/*CERATOCYSTIS* ASSOCIATION: A PARADOX

Eugene B. Smalley[1], Kenneth F. Raffa[2]

Hickory bark beetle, *Scolytus quadrispinosus*, outbreaks reached epidemic levels in the early 1960s in the North Central U. S. and were especially destructive to stands of bitternut hickory, *C. cordiformis*. More recently, Wisconsin outbreaks have been observed on *C. ovata* in Dane Co. (1986), and on *C. cordiformis* in La Crosse, Vernon, and Lafayette Counties (1986 to 1990). A new, heterothallic species of *Ceratocystis* (tentatively *C. caryae sp. nov.*) was isolated from sunken bark cankers associated with beetle attack on *C. cordiformis*. Brood galleries typically were lined with perithecia. Pure cultures were isolated from larvae, bark lesions, and discolored xylem, but not from free flying adult beetles. Perithecia were produced in abundance from mass ascospore transfers to potato dextrose agar (PDA), while single ascospore cultures developed only the Chalara anamoph. Cultures were highly aromatic and had a fruity odor similar to that produced by other *Ceratocystis* species. In field and greenhouse pathogenicity studies, *C. caryae* proved to be highly pathogenic to *C. cordiformis*, *C. ovata*, *C. illinoensis*, *Juglans cinerea*, and *J. nigra*, and it could be readily reisolated from xylem lesions 40 days after inoculation. These results present a paradox, in that virtually all *Ceratocystis sensu stricto* species are associated with sap or fungus feeding beetles such as nitidulids, but rarely bark beetles. The failure to isolate *C. caryae* from *S. quadrispinosus* adults might have been due to masking by faster growing fungal associates, especially *Fusarium* and *Gliocladium*, or it may suggest the presence of other insects such as nitidulids in the complex.

BLUESTAIN FUNGI AND THE XYLEM OCCLUSION ENIGMA

Kenneth R. Hobson[1], J. Richard Parmeter, Jr[1], David L. Wood[1]

A close, symbiotic mutualism between tree-killing bark beetles and their associated bluestain fungi has been surmised for more than 50 years, although the means of tree death has never been explained. Microbial isolations across conducting and non-conducting sapwood of *Pinus ponderosa* attacked by *Dendroctonus brevicomis* (WPB) did not support the hypothesis that failure of the xylem was associated with the penetration of tracheids by hyphae of the vectored fungi. Other microbes or perhaps as yet undescribed physiological mechanisms may be responsible for xylem failure. It has been demonstrated that the bluestain fungi can cause necrosis of the phloem. Hyaline hypomycetous fungi found in the mycangium may also produce this result in the absence of bluestain fungi. The rapid death of the tree is brought about by the cessation of water flow to the crown, but bluestain fungi are generally not present at the boundary of xylem dysfunction. Instead they appear to invade xylem after it has been debilitated and has dried beyond some threshold value.

Trees baited and attacked by WPB were cut sequentially at roughly two-week intervals until crown discoloration was evident. For each tree, the xylem function of sample bolts was tested by dye assay. Xylem chips were taken for microbial isolations across the interface of occluded to functional sapwood. The association of xylem occlusion with the presence of any individual fungus was highest for an unidentified yeast (26%); but in 33% of the occluded xylem sampled there were no fungi. Bluestain fungi were isolated from only 18% of occluded samples. It appears unlikely that the penetration of xylem tracheids by fungi can explain the observed occlusion of xylem. The production of intercellular gas bubbles, plant hormones, toxins, or degradation products from wounded phloem where adult beetles are feeding may spread through the xylem via the ray tracheids and/or living ray parenchyma producing embolisms in advance of the growth of the bluestain fungi. These observations and others reporting beetle-killed trees lacking bluestain, inhibition of beetle reproduction and development in infected phloem, and absence of bluestain fungi from mycangia indicate that the bark beetle/bluestain mutualism paradigm currently prevalent is questionable and a reconsideration of these relationships as a whole is needed.

STUDIES OF INSECT/PITCH CANKER RELATIONSHIPS IN CALIFORNIA

Joseph W. Fox[1], Mark E. Schultz[1], Kelli Hoover[n], David L. Wood[1], Thomas R. Gordon[1]

Pitch canker disease is found more often on pines planted in poor soil and is generally limited to pine species used as ornamentals. The fungus probably was introduced into California, because we found that it had limited genetic variability. It probably is insect-vectored, because our studies have shown that there are few wind-blown spores. We have found the pitch canker fungus on: 1) cones, cone beetles (*Conophthorus radiata*), dry cone beetles (*Ernobius punctulatus*), and twig beetles (*Pityophthorus carmeli*); 2) twigs, twig beetles, and pine weevils (*Pissodes radiata*); and 3) branches and mainstems, engraver beetles (*Ips mexicanus* and *I. paraconfusus*). Our field caging experiments confirmed transmission to cones by cone beetles, and, by using pheromones, we demonstrated transmission to mainstems by engraver beetles. Intraspecific (vertical) transmission of the fungus to progeny was demonstrated for *Ips* species with no effect on insect survival, development, and fecundity. Interspecific (horizontal) transmission among insects cohabiting the same host was suggested when higher numbers of emerged cone beetles were carrying the fungus when the host cone was invaded by contaminated dry cone beetles. Seedlings and ramets of mature pines were susceptible to inoculations of 25 conidial spores per μl. Juvenile tissue was most susceptible to this fungus. The fungus can grow (at slightly reduced rates) in the presence of *Ips* species' native symbionts. Monterey pine cones were the main source of new infections during the recent drought. The disease complex may reduce Monterey pine distribution, because the disease kills tree parts which increases colonization and abundance of tree-killing bark beetles.

THE ROLE OF PREDISPOSITION BY DISEASES IN THE MANAGEMENT OF BARK BEETLES

Fields W. Cobb, Jr[j]

For several decades, there have been increased interests and research relative to predisposition of forest trees to bark beetle infestation by tree diseases. Although several aspects of the phenomenon have been investigated, the question receiving the most attention has been, "Do diseases often predispose their hosts to bark beetle infestation?" Many of us believe that the question has been answered with an unqualified "yes." As predisposing factors, root diseases probably lead the pack, but dwarf mistletoes, rusts, abiotic diseases such as air pollution damage, and foliage diseases can be important agents as well.

Some good efforts have gone into answering the above question. Although there is more work to be done, we have enough knowledge of the system to move to the next level. As a naive forest pathologist, I perceive the population dynamics of bark beetles as being influenced by three major factors: 1) the weather; 2) the so-called natural enemies; and 3) the availability of food. The first two factors I must leave in the hands of entomologists to study. Pathologists can help you with the third, however. The question immediately arises, "What indeed is food for bark beetles?" We can state that it is the right tree species of the appropriate size, sometimes with other characteristics such as bark thickness thrown in. We know, though, that under "normal" conditions this is not enough. The trees must be stressed before they become food for beetles.

In the absence of a serious drought or fire, bark beetles may be dependent upon diseased trees to maintain a population high enough to expand and become damaging during periods of tree stress that are limited in duration. If beetle populations in an area are high because of a high incidence of diseased trees, those populations may be able to surpass the populations of their natural enemies during an early phase in a drought and cause much more loss (impact) than would occur if the beetle populations were low initially. To construct predictive models that can be used to assess costs and benefits and to develop strategies and management tools, we need reliable data on the interactions between diseased tree and insect populations and how these interactions influence impacts when the whole system is stressed by factors such as drought or fire.

MODELING INTERACTIONS AMONG BARK BEETLES, ROOT PATHOGENS, AND CONIFERS

Charles G. Shaw III[o]

Interactions among bark beetles and root diseases affect the dynamics of both pests in the forest, as well as overall ecosystem structure, function, development, and productivity. The Western Root Disease Model is the only pest model that currently deals with these interactions. Although far from complete, the current model simulates both pest dynamics and impacts. It provides a dynamic representation of the spatial and temporal epidemiology of pathogenic species of *Armillaria*, *Phellinus weirii*, or *Heterobasidion annosum*. The model simulates spatial relationships among locations of infected stumps and infected and uninfected live trees to predict disease spread as well as the persistence or "carry-over" of disease between rotations. The major relationships captured in the model are: the susceptibility of trees to infection by root disease; the vulnerability of trees to death once infected; disease related reductions in stem growth; disease spread to previously uninfested areas; inoculum dynamics in infected dead trees and stumps; and the effects of windthrow and attack by bark beetles. Four types of bark beetle interactions and their effects on tree mortality may be simulated, including one that interacts with windthrow events (i.e., certain outbreaks of Douglas-fir beetle). In the model, bark beetles interact with root disease fungi primarily by changing inoculum levels and potential for disease spread. For example, trees killed by bark beetles can become *Armillaria* inoculum only if they were infected by the fungus prior to death. Thus, beetles that kill uninfected trees near disease centers could potentially slow disease spread because the model assumes that these root systems will not become inoculum sources. In all 4 bark beetle types, infected trees that are killed by bark beetles do act as root disease inoculum sources. With two of the bark beetle types, an outbreak occurs only when the density of a given tree species with sufficient size and proportion of their root systems infected by root disease exceeds a user-defined minimum. That is, these types of bark beetle events are dependent on root disease infection, tree species, and their size and density. The difference between the two types comes in the impact of the event, as the probability of a tree dying depends on its location relative to that of root disease centers. Three types of tree conditions and locations are recognized: 1) uninfected trees "well" outside of root disease centers; 2) uninfected trees within or very near root disease centers; and 3) infected trees inside of root disease centers. Based on experience or local knowledge, model operators can use these relative locations to assign trees different probabilities of attack. A recent model enhancement to deal with *Annosus* root disease allows trees that died within the current simulation time step (usually 10 years) to be counted in the density requirements necessary for a bark beetle attack to occur - a logical change as weakened trees destined to die within the simulation time step are prime candidates for attack by bark beetles. The model is currently undergoing an analysis of its sensitivity to changes in the various parameters that control it and, thus, the assumptions and hypotheses under which it was developed. The items to which the model is most sensitive (i.e., type, quality, and quantity of input data) are the ones where additional resources could most likely be best put to improve performance.

INTERRELATIONSHIPS BETWEEN DEFOLIATION AND ROOT DISEASE IN WESTERN TRUE FIR STANDS

Gregory M. Filip[2]

Root diseases, particularly those caused by *Armillaria* spp., have a history of association with stressed hosts including those defoliated by insects. In northeastern Oregon, I have been studying a stand of *Abies grandis* that has been defoliated for over 10 years by *Choristoneura occidentalis* and is infected by *Armillaria* NABS 10, a weakly parasitic species. Over this 10-year period, 10% of the trees have died and all were infected by *Armillaria* sp. Normally, one would expect a much higher incidence of tree mortality given the severity and longevity of defoliation and the abundance of stump infection (63%) in the stand.

To further study the interrelationships among host, defoliation and root pathogens, potted *A. grandis* seedlings were annually defoliated (new foliage) and inoculated with *Armillaria* (NABS 10 or *A. ostoyae*, a strong pathogen). After six years, none of the seedlings became infected. Replication of the study including a drought stress scenario was done in the greenhouse under more controlled conditions. After one year, almost all of the seedlings that were not defoliated or received adequate watering became infected by *A. ostoyae*. None of the defoliated seedlings or seedlings without adequate watering became infected (Catherine Parks, pers. comm.). We hypothesize that *A. grandis* seedlings under stress by defoliation or desiccation (grown outdoors in exposed pots) are not infected by *Armillaria* spp. because of biochemical alterations in the host, the fungus, or both.

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III. POSTER ABSTRACTS

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GYPSY MOTH LIFE SYSTEM MODEL: THE STAND-DAMAGE MODEL

J.J. Colbert[a]

The gypsy moth, *Lymantria dispar*, does significant damage to mixed hardwood stands in portions of North America. Since its introduction into the United States near Boston in 1869, it has continued to spread, albeit slowly at first, through most of the northeastern states and portions of Canada. It feeds on a number of hardwood species, but prefers the oaks. The Gypsy Moth Life System Model was constructed to organize the available knowledge and ascertain the needs for additional information on gypsy moth population dynamics. It was designed to simulate the dynamics of the gypsy moth and its natural enemies in a single stand over periods of time ranging form a few to 100 years. The model, originally conceived in a series of workshops in 1984, has evolved significantly to include most of the currently available research on gypsy moth, and it has been enhanced by the additional development of a user-friendly control system. A number of direct gypsy moth management and indirect stand management options may be simulated.

The Gypsy Moth Life System Model is composed of three major components: the stand described as a vector of tree counts by diameter size classes for each tree species; the gypsy moth is described as a number of cohorts, partitioned to canopy strata by host tree species; and the natural enemies of the gypsy moth. Natural enemies consist of predator, parasitoid, and virus pathogen submodels that predict the amounts of gypsy moth mortality as functions of the previous dynamics of the gypsy moth and the natural enemy. Background mortality (that not attributable to specific causes), larval cohort and foliage development, feeding, and defoliation are followed in the gypsy moth subsystem. The stand submodel calculates tree growth and mortality, produces annual estimates of potential foliage available for each host-canopy strata. It uses the reductions in potential foliage caused by defoliation, received from the gypsy moth submodel to decrease growth and foliage production, and increase tree mortality rates.

The stand submodel is available as a stand-alone system. Along with the poster display, this Stand Damage Model was demonstrated. It will permit a user with no experience in computer programming to access the model, its full set of parameter options, and run simulations, save input data and simulation output, through a system of menu-accessed control and edit screens. Users may specify defoliation scenarios, weather patterns, and stand management prescriptions for simulation, as well as choose from twenty tree species in creating the stand that they are interested in following.

SUMMARY OF A THREE YEAR STUDY OF RED PINE DECLINE IN WISCONSIN

K.D. Klepzig, K.F. Raffa, and E.B. Smalley[b]

Red pine decline is characterized by an expanding circular area of dead and declining trees and is becoming increasingly prevalent in Lake States plantations. A three year study was conducted to determine whether any insects, fungi, and/or soil parameters were associated with this syndrome. The root collar weevil - *Hylobius radicis*, the pales weevil - *Hylobius pales*, the pitch-eating weevil - *Pachylobius picivorus*, the red turpentine beetle - *Dendroctonus valens*, and *Hylastes porculus* were significantly more abundant in declining stands than in healthy *Pinus resinosa* stands. These root- and lower stem-infesting insects consistently carried *Leptographium terebrantis* and *Leptographium procerum*. Higher soil organic matter, pH, and K levels were also associated with areas of mortality. Intensive root sampling revealed high levels of root mortality, staining, infestation with *Leptographium* species, and extensively grafted root systems in declining red pine stands. This advancing belowground mortality precedes the aboveground symptoms of reduced radial growth, thin crown structure, and infestation by the pine engraver - *Ips pini* and its fungal associate *Ophiostoma ips*. Colonization by the latter two species is always associated with and/or is responsible for ultimate tree death. A sequence of interactions among this complex of organisms and abiotic factors is proposed as the cause of red pine decline.

ETHYLENE AND INDUCED HOST RESISTANCE OF SOUTHERN PINES

J.D. Johnson, T.L. Massey, and M.M. Popp[c]

Our model for host defense to southern pine beetle (SPB) and the blue stain fungi they vector is based on our observations that ethylene plays a key role in triggering an inducible resistance response including a rapid increase in terpene flow (manuscript in press). The role of ethylene in controlling induced host resistance in slash pine (*Pinus elliottii* var. *elliottii*) was investigated in one-year old seedlings. Ethylene stimulators and inhibitors were injected into seedling stems using either a probe or by drilling a small hole. Seedlings were treated with a stimulator or inhibitor 24 hours before inoculation with sterile water or a suspension of *Ceratocystis minor* = (*Ophistoma minus*) spores. A third set of seedlings with no prior treatment was sampled for ethylene 0.5, 1, 2, 3, and 5 days after inoculation. Using two different inhibitors that have distinct points of suppression, aminoethoxyvinylglycine (AVG) at 100 uM and $CoCl_2$ at 50 uM, we found that AVG had little effect on ethylene production while $CoCl_2$ consistently reduced ethylene for up to 6 days after treatment, suggesting that the ethylene-forming enzyme (EFE) is the limiting step in the process. Two stimulators, 1-aminocyclopropane-1-carboxylicacid (ACC) at 100 uM and ethephon at 1 ppm, increased ethylene production, but in different ways. Ethephon produced a burst of ethylene on day 2 with a gradual increase beyond day 5, whereas ACC resulted in an increase either on day 1 if EFE had been induced in the presence of *C. minor* spores or later on day 2 if inoculated with sterile water. We have developed the means to experimentally manipulate the timing and amount of ethylene in pine, which will allow us to stimulate host defense to SPB and vectored fungi prior to attack.

DEGREE-DAY MODELS FOR TWO PINE SEED BUGS, *LEPTOGLOSSUS CORCULUS* AND *TETYRA BIPUNCTATA*

J.C. Nord, G.L. DeBarr, and M.W. McGuinness[d]

Leaffooted and shieldbacked pine seed bugs (*Leptoglossus corculus*) and *Tetyra bipunctata*) were reared in the laboratory under a range of constant temperatures. Rate of development was regressed on temperature, and threshold temperatures were determined. Degree-day (DD) models were constructed to predict seed bug development in pine seed orchards. The DD model for *L. corculus* was verified under variable temperature conditions in an outdoor insectary. Additional validations of models for both species will be done in programmable laboratory temperature cabinets and in the field.

MATING DISRUPTION FOR CONTROL OF WEBBING CONEWORM, *DIORYCTRIA DISCLUSA*, IN LOBLOLLY PINE SEED ORCHARDS

G.L. DeBarr[d], J.C. Nord[d], L.R. Barber[e], J.F. Negron[f], and C.G. Niwa[g]

The webbing coneworm, *Dioryctria disclusa*, is one of four sympatric *Dioryctria* species that destroy cones of loblolly pine (*Pinus taeda*). The sex pheromone of *D. disclusa* is (Z)-9-tetradecenyl acetate (Z9-14:Ac). During 1989 and 1990 USFS entomologists evaluated the concept and technology of mating disruption (MD) and the potential of MD for controlling *Dioryctria* in seed orchards. Synthetic Z9-14:Ac was released at a rate of 5 g/acre in orchards in Georgia, Louisiana, and North Carolina. Releasers were placed in the middle and upper crown of each tree. Efficacy of MD was evaluated by comparing trap catches, female mating, and cone attacks in treated and control plots. Trap "shutdown" occurred in all MD plots. Trap catch was reduced by 99.5 percent in 1989. Trap catch along transect lines was reduced similarly in 1990 and indicated that little pheromone drifted from the MD plots into control plots. Pretreatment and posttreatment measurements of *D. disclusa* infestations in MD and control plots will be used to evaluate damage reduction.

MAIN FOREST INSECT PESTS OF WESTERN VENEZUELA

A.J. Briceño-Vergara[h]

A record of insect pests of the main tree species in the forests of western Venezuela is being carried out. Data on the type of damage, frequency, natural enemies, and life cycle is given for most important insect pests, as well as a list of the most common insect pests found in both natural forests and plantations.

PROTECTING DOUGLAS-FIR CONES AND SEED USING SYSTEMIC IMPLANTS

L.E. Stipe and J.E. Dewey[i]

Douglas-fir infested with western spruce budworm, *Choristoneura occidentalis*, were treated with a systemic insecticide to protect the cone and seed crop. Potential cone bearing Douglas-fir trees were selected and assigned to one of two treatment groups: 1) Acecap implants, 2) control. The Acecap implants were applied during mid-April just prior to cone bud growth. Implants were placed in holes drilled into the sapwood at four inch intervals around the base of the tree. Data collected from each sample tree were as follows: tree height and diameter; external cone damage and infestation rate just after pollination; host tree defoliation caused by budworm, external damage on mature cones; green cone weight; and mature seed per cone classified as full, hollow, and insect damaged. Cone data were collected from 25 mature cones from each tree.

No significant difference existed between tree height and diameter among the treated and untreated groups. The initial rate of budworm infestation and damage in the small cones was the same. Foliage protection averaged 74 per cent better in the treated trees. Mature cone weight increased by 67 per cent, while external damage was 18 per cent for the Acecap group and 67 per cent in the controls. Seed yield per cone was 20.9 for the Acecaps and only 3.7 for those not treated. This represents an 82 per cent increase for all seed. X-ray analysis showed only minor differences in seed condition.

Systemic implants are an effective treatment when used to protect Douglas-fir foliage, cones, and seed from budworm damage.

POPULUS CLONAL EFFECTS ON FOREST TENT CATERPILLAR POPULATIONS

D.J. Robison and K.F. Raffa[b]

Forest tent caterpillar, *Malacosoma disstria*, population changes and characteristics were monitored for two consecutive years on two hybrid poplar clones, caged in the field. The clones were NC11382 (=NE27, *Populus nigra* x *P. berolinensis*) and NE332 (*P. simonii* x *P. berolinensis*). In a series of laboratory and greenhouse studies with 15 hybrid poplar clones, NC11382 had been found to be a superior clone behaviorally and developmentally for the forest tent caterpillar, and NE332 a poor clone for this insect. These two clones were caged separately (n=6) in field plots in cages 4 ft wide x 8 ft long x 4 to 20 ft high (expandable with tree growth). Forest tent caterpillar populations were started in each cage with two egg bands and the populations allowed to develop for two years. After one year the mean number of egg bands per clone was 14 and 2, for clones NC11382 and NE332, respectively. After two growing seasons the mean number of egg bands per clone was 22 and 1, for clones NC11382 and NE332, respectively. The same pattern was true for pupal populations during the study. These differences were statistically significant. These results represent the linkage between laboratory and greenhouse plant-insect interaction and resistance studies and the effects of host differences on population dynamics. Thus, differences among clones (varieties) in their suitability for pest species can significantly effect pest populations and their impact. Silviculturally promising clones should be screened for pest suitability as a routine part of their evaluation. A productivity (clonal growth and tolerance of defoliation characteristics) and suitability (insect preference and performance) matrix was derived for making these evaluations. The matrix facilitates the selection of clones for further improvement or for outplanting. Findings from this study do not suggest that pest resistance requires a tradeoff in growth potential. Coupling plant-insect interactions with population dynamics is integral to effective tree improvement for pest resistance, for evaluations, and for devising outplanting deployment strategies to minimize pest impacts. Concern for potential pest impacts and the development of new pest biotypes will effect the use of clones in plantation establishment. Clonal mixtures which maximize the diversity of resistance factors should counter these negative effects. Mosaics of clonal blocks should accomplish this and facilitate management options. In general, resistance to a suite of probable pests should be integrated into intensive forest plantings. This will require a thorough understanding of the interrelationships among the pests and their hosts. Pest surveys in hybrid poplar have indicated that clonal resistance to one pest may not be correlated with resistance to others.

EFFECTS OF HOST SPECIES ON DEVELOPMENT AND OVIPOSITION OF THE FOREST TENT CATERPILLAR (*MALACOSOMA DISSTRIA*)

D. Parry[j], J.R. Spence[k] and W.J.A. Volney[k]

Larval survivorship, development time, pupal mass, and sex ratios of forest tent caterpillars were compared among populations fed on trembling aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), Alaska birch (*Betula neoalaskana*), Saskatoon service berry (*Amelanchier alnifolia*) and wild rose (*Rosa acicularis*). Observations were made on larvae reared from the first instar and on wild-caught fourth instars that had developed on aspen, but were transferred to an experimental food treatment at the fifth molt. Early instars were highly selective in host species requirements, but later instars were more catholic feeders and did not suffer reduced survivorship from feeding on other hosts. Fecundity was related to host, even in the transfer experiments. Although field egg band surveys suggested that females oviposited preferentially on aspen in central Alberta we were unable to demonstrate a preference for aspen in laboratory oviposition tests.

THE DECISION SUPPORT SYSTEM FOR THE EASTERN HEMLOCK LOOPER IN NEWFOUNDLAND

P. McNamee[l], A. Raske[m], C. Wedeles[n], L. O'Brien[o], G. Sutherland[n], and J. Hudak[m]

LOOPER, a Decision Support System for the Eastern Hemlock Looper in Newfoundland was developed by Forestry Canada, and Environmental and Social System Analysts. The System consists of six linked and user-

friendly computer models that present a menu of options, and guides the user through the various scenarios of simulated events.
The six coupled prediction models called LOOPER are:

1) Island-wide Outbreak Risk Model -- provides a general risk of an impending outbreak of the looper on the Island of Newfoundland, giving two to three years advance warning to enable managers to prepare control strategies or initiate preventative treatments.

2) Initial Defoliation Risk Model -- provides the risk of No, Light, Moderate, and Severe defoliation during an outbreak, under various spray regime options, for forest stands not defoliated the previous year.

3) Continued Defoliation Risk Model -- provides the risk of No, Light, Moderate, and Severe defoliation, under various spray regime options for forest stands defoliated the previous year.

4) Volume Tree Mortality Model -- provides the risk of volume of timber mortality for forest stands, given the historical and predicted defoliation category, modified by various spray regime options.

5) Volume Timber Decay Model -- provides the risk of volume of decay in looper-killed timber in each forest stand, given the historical and predicted defoliation category.

6) Larval Development Model -- Provides the probability of looper being in the egg or a given larval instar in 23 regions of the Island.

Outputs can be either read from the computer screen, or produced as hard copy. LOOPER can produce digital maps of risks of: outbreaks, defoliation intensity, timber mortality, decay, and looper development; or stand by stand lists of these predictions. Both maps and lists can be produced for one or a group of map sheets (13.9 x 9.2 km), a Forest Management Unit, or for the entire Island. LOOPER is now being used to plan surveys and treatments. Modifications to the System will include linkage to a timber supply model and economic analysis modules.

FOLIAR BIOMASS ESTIMATES FROM SATELLITE IMAGERY FOR BALSAM FIR STANDS DEFOLIATED BY THE HEMLOCK LOOPER

J.E. Moulton[p], S.E. Franklin[q], and J. Hudak[m]

Optical sensors of the LANDSAT and SPOT satellites provided spectral response patterns that were closely related to forest conditions. We used satellite imagery to delineate hemlock looper, *Lambdina f. fiscellaria*, defoliation in balsam fir, *Abies balsamea*, stands and to estimate foliar biomass per pixel based on multispectral reflectance ratios.

Field biomass estimates were used to calibrate satellite vegetation indices. Regression models were used to compute biomass at each pixel in the study area. Biomass estimates were spatially and temporally analyzed to determine changes related to light, moderate and severe levels of defoliation from 1987 to 1989.

A high correlation ($r = .96$) existed between field measures for the defoliation classes in 1988 and the satellite vegetation index estimates. Total foliar biomass for balsam fir stands decreased from 40.6 million kg in the study area in 1987 to 36.3 million kg in 1988 and increased by 1.2 million kg from 1987 to 1989.

CLASSIFICATION OF HEMLOCK LOOPER DEFOLIATION FROM SATELLITE IMAGERY

S.E. Franklin[q] and J. Hudak[m]

Defoliation by the hemlock looper, *Lambdina fiscellaria fiscellaria*, in balsam fir, *Abies balsamea*, forests in Newfoundland was classified from satellite imagery. High resolution SPOT images were acquired before and after defoliation in 1987 and 1988. The image analyses included visual inspection of colour composites, unsupervised and supervised classifications, and application of general linear models. Results were compared to both field checks and sketch maps generated from helicopters by the Forest Insect and Disease Survey of Forestry Canada. The unsupervised classification showed one class of defoliation, but supervision of the classifier enabled separation of three levels labelled as light (less than 30%), moderate (30% to 60%), and severe (greater than 60%). The classification was at least 90% accurate as determined by a combination of random sampling, discriminant analysis, and field verification. The digital map of defoliation classes was transferred to the provincial forest inventory ARC/INFO GIS to calculate area and volume statistics for individual stands.

A TECHNIQUE FOR USING MICROENCAPSULATED TERPENES IN LEPIDOPTERAN ARTIFICIAL DIETS

K.M. Clancy[r]

I have developed and tested a technique to microencapsulate terpene compounds by forming gelatin-walled microcapsules around the terpene essential oils. Five monoterpenes (-pinene, β-pinene, camphene, myrcene, and limonene) and three oxygenated monoterpenes (bornyl acetate, linalool, and β-citrocellol) that are common constituents of Douglas-fir

(*Pseudotsuga menziesii*) oleoresin were encapsulated and mixed into artificial diets to determine the effects that the terpenes had on western spruce budworm (*Choristoneura occidentalis*) survival and reproduction, using a three generation bioassay. I describe the technique and present data from preliminary bioassays with seven of the terpenes. The technique is useful, because it helps to reduce the rate at which terpenes volatilize from the diets and it "packages" the terpenes in a manner more closely resembling the way they are present in plant foliage (i.e., restricted to the resin canals).

ECOPHYSIOLOGICAL PARAMETERS ASSOCIATED WITH LOBLOLLY PINE RESISTANCE AGAINST THE SOUTHERN PINE BEETLE

J.P. Dunn[s] and P.L. Lorio, Jr[f]

A conceptual model based on growth-differentiation balance (W.E. Loomis. 1932. Proc. Amer. Soc. Horticult. Sci. 29:240) has been proposed to aid understanding of tree susceptibility to the southern pine beetle (SPB). This model proposes that pines partition energy predominantly to growth processes when environmental conditions favor growth (e.g., adequate light, water, nutrients), but partition proportionately more energy to defensive processes (e.g., oleoresin) when environmental conditions limit cell division and enlargement (growth) without adversely affecting photosynthesis and translocation of assimilates.

We regulated soil moisture availability by sheltering or irrigating root systems of juvenile loblolly pine. Water stress, photosynthesis, radial and vegetative growth, and resin flow (defense) were measured between treatments. We hypothesized that trees under moderate water deficits would show reduced growth, but not reduced photosynthesis, therefore, more energy would be partitioned to defense. Resistance to beetle attack would increase during times of moderate water stress.

High rainfall throughout the spring prevented establishment of moderate water deficits relative to non-sheltered trees, and planned SPB attacks were delayed until August. A consistently significant ($p \leq 0.05$) 0.2-0.4 MPa difference in pre-dawn water potentials between sheltered and irrigated loblolly pine was established by mid-July. A corresponding significant decline in net photosynthesis (ca. 40% drop in carbon gain), and radial growth of sheltered trees relative to irrigated trees was measured by early July. Resin flow (defense) was also significantly lower from the more water stressed sheltered trees. Colonization results showed that irrigated trees had significantly more attacks, more dead beetles in resinous galleries, and more galleries than sheltered trees. No significant differences in successful beetle attacks were detected between treatments, but a higher percentage of beetles attacking sheltered trees were successful (22%) than those attacking irrigated trees (14%). Regardless of the differences in physiological parameters between treatments, all trees showed considerable resistance to SPB colonization, even though it was one of the driest summers in recorded history in central Louisiana.

TRANSPORTATION OF AMBROSIA BEETLES IN THE INDUSTRIAL MILIEU OF COASTAL BRITISH COLUMBIA

J.A. McLean[t], D.K.W. Lam[t], and B.J. Sauder[u]

Ambrosia beetles bore into the clear high value outer layers of logs and greatly reduce the value of lumber products cut from infested logs. An Ambrosia Beetle Task Force has been formed by the Department of Forest Sciences at the University of British Columbia, the Wood Harvesting Section of MacMillan Bloedel (MB) Research, and Phero Tech Inc, to determine the amount of ambrosia beetle infestation on logs leaving MB logging divisions around coastal British Columbia.

Four crews are presently checking all log booms produced by logging divisions to determine the present proportion of logs infested by ambrosia beetles. Average infestation levels vary among the three MB regions being surveyed. Most infested logs were attacked by *Trypodendron lineatum* and as these attacks occurred in April/May 1990, MacMillan Bloedel has already received valuable information on log inventory management in the woods.

The log bundles sampled in each of the log booms will be monitored closely during this year's ambrosia beetle attack flight to determine the additional amount of infestation that can occur on the way to mills. An analysis of the time that booms are stored in temporary tie up locations on the way to the mill is being conducted. Logs infested with *T. lineatum* will be followed closely to determine where brood beetles emerge and seek an overwintering site. These data will be linked with the results of semiochemical-based mass-trapping services that are provided to MacMillan Bloedel by Phero Tech Inc.

SOUTHERN PINE BEETLE DEMONSTRATION AREA PROJECT

B.M Spears, R.A. McKinney, C.W. Dull, W.A. Nettleton, D.C. Kahle, and R.J. Uhler[v]

Southern pine beetle (SPB) continues to be the most serious insect pest of forests in the South. In 1988, at the request of the Chief of the Forest Service, Forest Pest Management and Region 8 established a major demonstration area project on the Homochitto National

Forest in Mississippi and the Oconee National Forest in Georgia. The primary objective is to demonstrate how pine stands can be managed effectively using sound practices and control strategies to minimize SPB and other pest caused damage of the pine resource while achieving other management objectives. The philosophy of the project is "sound forest management is good southern pine beetle prevention".

Several major databases and other sources of information have been integrated into a geographic information system (GIS) to assist in the management of these national forests. The development of the GIS for these demonstration area forests has been consistent with the database development on other national forests as outlined in the Region 8 GIS Implementation Plan. Using the GIS has enabled the analysis of SPB spot locations in relation to other geographic information. Comparing each spot identified from each series of serial surveys is done by linking the relational databases to the spatial data. SPB hazard ratings were developed through links between the stand and compartment themes and the forest inventory data. A soils database has also been included for these national forests.

Numerous cartographic outputs have been produced by analyzing the forest inventory and SPB data. Use of this geographic database has also assisted in meeting the administrative, operational, and logistical requirements of the project.

FOREST HEALTH MONITORING APPLICATIONS FOR THE SOUTHERN FOREST ATLAS

C.W. Dull[v], R.L. Anderson[v], S. Holzman[v], D.H. Marx[d], R.J. Uhler[v], D.N. Rubel[v], and H.D. Brown[v]

The Forest Service has designed a national system to annually monitor the health of the Nation's forests. The purpose of the Forest Health Monitoring system is to provide long-term data that will advance our understanding of forest ecosystems so that changes can be understood and predicted. Concerns regarding forest health have led to the development of the Southern Forest Atlas, a geographic information system comprised of five major components used in the Forest Health Monitoring Program. This database was compiled to help demonstrate relationships between measured forest conditions and atmospheric deposition, and to help determine if there are any long-term relationships between the two while considering the other natural and man-made factors that affect forest health. The major components of the database are atmospheric deposition, weather, soils, pest and fire, and forest distribution.

Air quality, wet deposition and visibility data were characterized from 1973 to the present. Information on hourly mean concentrations of ozone, sulfur dioxide, and nitrogen dioxide were collected from several different agencies. Weather data since 1950 were collected from all airway and precipitation stations in the Southeast. A soils database with a variety of values attached to soil associations was compiled for the Southeast. The pest component contains information on the spatial distribution of forest insects and diseases. Forest surveys conducted by Forest Inventory Analysis (FIA) units supplied forest distribution data. The data are used to quantify natural stresses that may predispose forests to damage by pollutants. Otherwise, damage might be attributed to pollutants alone.

Performing spatial analysis and displaying data variables within and between various databases is essential for analyzing the relationships between tree growth and stress factors. The Southern Forest Atlas provides this capability. Analyzing these relationships spatially will help develop sampling strategies, surveys, and control activities to support the Forest Health Monitoring Program.

GIS APPLICATIONS FOR GYPSY MOTH INTEGRATED PEST MANAGEMENT

B.M. Spears, C.W. Dull, D.N. Rubel, and R.J. Uhler[v]

A geographic information system (GIS) for gypsy moth management is used by Forest Pest Management (FPM) staff in Region 8 of the Forest Service and several state and federal cooperating agencies. The poster shows products that have been developed to support gypsy moth programs.

GIS analytical capabilities are used to evaluate activity of the gypsy moth in the Southern Region. They include: 1) overlays of defoliation boundaries on county boundaries to determine the area of defoliation by county; 2) overlays of defoliation on spray block boundaries to produce spray efficacy determinations; 3) computing total acres of defoliation and total acres within spray blocks; and 4) determination of defoliation by ownership class. The GIS was used for tracking defoliation which occurred in successive years at the same location and for solving the logistical problems of determining which areas had been treated from year to year. These GIS capabilities are needed for making mortality assessments.

The Appalachian Integrated Pest Management (AIPM) Gypsy Moth Project Area covers thirteen million acres in Virginia and West Virginia. The primary objective of the AIPM Project is to retard the southward progression of the gypsy moth through the Appalachian Mountains. Many GIS products illustrating gypsy moth movement and proposed control actions were produced.

Gypsy moth population levels are measured annually by placing pheromone traps on two and three kilometer grids in Virginia and West Virginia, respectively. The number of male gypsy moths per trap is collected as point data. We than intrapolate the point data to produce a polygon coverage showing ranges of male gypsy moth numbers for the AIPM Area. Male gypsy moth trend and isoline maps are produced to show trap catch results, to illustrate trends in gypsy moth levels from one year to the next, and to plan egg mass surveys. Egg mass survey maps are produced and used to plan gypsy moth treatment efforts.

The Region 8 Forest Pest Management GIS is used to incorporate remotely sensed data with other data to produce maps showing damage, past trends, and steps taken to control the gypsy moth. It is used also to make predictions of future gypsy moth movement and damage. These interpretive products convey valuable information to the public and to resource managers.

THE EFFECTS OF FERTILIZATION ON SPRUCE BUDWORM AND HOSTS

R.M. Muzica, B.E. Wickman, R.R. Mason, and A.R. Tiedemann[W]

The Blue Mountains of Oregon have been experiencing a western spruce budworm (*Choristoneura occidentalis*) outbreak for at least 10 years. In an attempt to minimize impact of defoliation, 4-ha (10-acre) plots were fertilized with one of three fertilizer treatments in October 1988; two combination treatments, and nitrogen alone. Four plots were assigned to each of five 16.2 ha (40-acre) blocks in a randomized block design. Responses in 1989 included a significant foliage nutrient response, particularly nitrogen, with all fertilization treatments. Both male and female pupal weights were significantly lower on the control (unfertilized) plots, but there were nominal differences among the different fertilizer regimes. In both 1989 and 1990, larval weights and density appeared to be unrelated to fertilization and foliage quality. As an index of defoliation, end-of-season foliage weights for 1989 were significantly greater on plots fertilized with a combination fertilizer, regardless of concentration, than on plots fertilized with nitrogen alone, or unfertilized. These data may suggest that despite comparable feeding by spruce budworm on all plots, those fertilized with a combination of nutrients may provide compensatory foliage growth to maintain tree vigor.

IMPORTANCE OF PREDATOR DIVERSITY IN INSECT OUTBREAK PREVENTION

T.R. Torgersen and R.R. Mason[W]

Birds and predaceous arthropods, including spiders and ants, are important components in the complex of natural enemies that have a critical role in constraining populations of major defoliating insect pests in the Pacific Northwest. A diverse assemblage of birds prey on western spruce budworm and the Douglas-fir tussock moth. Spiders are the most abundant arthropod predators in the forest canopy, and prey on a wide variety of insects. Ants are not only important predators of insect pests, they are also a major dietary component for the pileated woodpecker, which is an 'indicator species' of the ecological health of western forests. A 23-minute video illustrates features of natural and biological control, as well as population dynamics of the western spruce budworm, Douglas-fir tussock moth, and larch casebearer. Diseases, parasitoids, arthropod predators, and insectivorous birds and mammals are shown, and their beneficial roles in insect control are described. The video explains studies to quantify insect mortality from predation. These studies demonstrated that insectivorous birds and foliage-foraging ants could have a marked effect on mortality of western spruce budworm at innocuous population levels. Guidelines are presented for conserving natural enemies and enhancing their role as pest-regulators through maintaining and increasing spatial and structural diversity in managed stands.

DISPERSAL AND FLIGHT ACTIVITY OF BARK BEETLES IN NORTH CAROLINA

S.P. Cook and F.P. Hain[X]

Dispersal and flight activity of three conifer-infesting bark beetles (*Dendroctonus frontalis, Ips grandicollis*, and *Hylastes porculus*) currently are being investigated by our research group at North Carolina State University. Mark-recapture experiments with *D. frontalis* are being emphasized with recapture points ranging from 2 to 20 m from the release site. Flight activity of all three species is being investigated with an emphasis on attraction, seasonal patterns, and preferred height of flight. A brief summary of work being conducted will be presented along with a discussion of how differences in dispersal and flight activity of these species may be related to several aspects of beetle biology including: preferred host material; host location; beetle mating strategy; and semiochemicals.

IS THE GYPSY MOTH ESTABLISHED IN FLORIDA?

J.L. Foltz[Y] and W.N. Dixon[Z]

The number of *Lymantria dispar* males captured in pheromone detection traps in 1990 in Florida was 469, up dramatically from the annual captures of 64 to 99 males in the preceding 5 years and 49% greater than the 1982 record of 315 males. Solitary larvae were found in tarpaper traps at several campgrounds on 20, 26, and 30 March and 14 and 30 May. The first male moth was detected on 8 May. By 8 June, well before males were flying in the northern states, 194 males were recorded. Weather station data from Plant City, Florida and the phenological model of Casagrande *et al.* (Environ. Entomol. 16:556-562; 1987) indicate hatching dates of early March and mid-April for males maturing on 1 May and 1 June, respectively.

Because most males were collected in close proximity to campgrounds and RV (recreational vehicle) parks, the most probable source of the moths is from egg masses and pupae imported on RVs and outdoor equipment coming from northern infested areas. Zip code data from several RV parks in Zephyrhills showed the majority of the "winter Floridians" were from Michigan, New York, Pennsylvania, and Ohio, all but the latter having suffered considerable gypsy moth defoliation in recent years. These same states are also major sources of summer tourists who might import pupae; males imported in this manner would fly at essentially the same time as their siblings in the northern states.

To date there is no evidence of an established gypsy moth population in Florida. Bottlenecks that must be passed through to become established include: 1) low mating success due to sparse numbers of males and females; 2) reduced hatch due to high temperatures prior to diapause; 3) reduced hatch due to lack of winter chilling; 4) high mortality of newly eclosed larvae due to the scarcity of preferred hosts and the paucity of host foliage of the proper phenological state; 5) and the high mortality of all life stages from the many natural enemies of foliage-feeding Lepidoptera. If the gypsy moth should become established, these same factors would likely restrict outbreaks to levels much lower than now common in the northern United States.

INFLUENCE OF A BEETLE VECTOR ON WITHIN-TREE POPULATIONS OF PINEWOOD NEMATODE

J.E. Warren and M.J. Linit[aa]

The dispersion pattern of the pinewood nematode, *Bursaphelenchus xylophilus*, in beetle infested and non-beetle infested logs was investigated to determine the effect of *Monochamus carolinensis* on within-tree pinewood nematode populations. Two, 30-cm bolts were removed from each of seven Scots pine, *Pinus sylvestris*, trees. Each bolt was inoculated with *Ophiostoma minus* and 1000 pinewood nematodes of varying life stages. One bolt was selected randomly to receive beetle oviposition. The other bolt was not subjected to oviposition and served as a control. After oviposition, the bolts were held at 27°C until beetle emergence began. Each log was then sliced into fifteen, 2-cm disks. Three, 1.57-cc wood samples were taken from each disk for a total of 45 samples per log. Beetle larvae, pupae, and callow adults were removed where possible from each disk. The total number of pinewood nematodes and the number of pinewood nematode dauer juveniles was determined for each sample using the modified Baermann funnel technique. The number of nematodes carried by each insect and the number of nematodes in the wood adjacent to the gallery from which the insect was taken was determined. Taylor's power law was used to determine the within-tree dispersion pattern of pinewood nematode in both beetle infested and non-beetle infested logs. The dispersion of the pinewood nematode was aggregated in both log treatments. The degree of aggregation did not differ between the two treatments. Dauer juveniles were found in low numbers in non-beetle infested logs, but were found in high numbers in the beetle infested logs. Thus, dauer juvenile formation rarely occurs in the absence of its vector, suggesting the importance of a beetle associated factor in dauer juvenile formation.

Wood samples taken around areas of insect activity had a significantly higher nematode density than samples taken away from insect activity. Although not statistically significant, the highest nematode density was found in wood surrounding the pupal gallery. Additionally, callow adults carried greater numbers of dauer juveniles than either pupae or larvae. This could be due to nematode aggregation that begins around the larval gallery then builds as the insect develops into a pupa. Upon adult eclosion, nematodes contained within the wood surrounding the pupal chamber migrate to the adult insect.

THE ROLE OF PESTS IN THE ECOLOGY OF PINE-FIR FORESTS AT SOUTH LAKE TAHOE, CALIFORNIA

R.F. Scharpf[bb]

In 1971, Jeffrey pine forests in South Lake Tahoe, California were infected by an outbreak of Elytroderma disease caused by the fungus *Elytroderma deformans*. A year after the outbreak, several experimental plots were established to determine tree mortality over time and the causes of death. In 1973 the USDA Forest Service reported that 11 percent of the dead Jeffrey pines on 800 acres had died of Elytroderma disease, 11 percent from Jeffrey pine beetle, *Dendroctonus jeffreyi*, 44 percent from Elytroderma disease and Jeffrey pine beetle, and 34 percent from unknown causes. The disease persisted as systemic infections in many trees for years after the outbreak. From 1972 through 1978, pines on the experimental plots continued to die at a more or less steady rate; by the end of 1978, 32 percent of an original 607 Jeffrey pines were dead. And since then additional Jeffrey pines have died, but were not recorded.

Noticeable ecological changes have taken place on the experimental plots since 1972. Small white firs in the understory were released after the pines died, and have become the predominant species in what were mixed pine-fir stands with pine as the dominant overstory. In the 20 years since their release, many firs have replaced the dead pines and become the larger, dominant trees. Since 1987, the study area has experienced a prolonged drought. Many of the white firs have suffered extreme moisture stress, are severely weakened, and have been successfully attacked by fir engraver, *Scolytus ventralis*. Consequently, the white fir component of the stands is now dying at an alarming rate. What the tree composition of these stands will be in the future is not known. A disease outbreak in 1971 (along with an infestation by the Jeffrey pine beetle) seems to have changed what were predominantly overstory Jeffrey pine stands with understory firs, to rapidly developing white fir stands. Thereafter, the prolonged drought since 1987 and the fir engraver beetle outbreak have killed a large part of the fir component. These stands appear destined to remain in a dynamic state of change indefinitely if elytroderma disease outbreaks and droughts become regularly reoccurring events.

EVALUATING IMPACT OF GENETICALLY TRANSFORMED *POPULUS* ON DEVELOPMENTAL BIOLOGY OF THE IMPORTED WILLOW LEAF BEETLE

K.K. Allen and E.R. Hart[cc]

In an attempt to enhance host-plant resistance against folivorous herbivores, hybrid aspen clones Hansen and Crandon (*Populus alba* x *grandidentata*) have been genetically transformed with pin 2, a proteinase inhibitor gene from potato. The product of this gene is a protein molecule that binds and inhibits the action of trypsin and chymotrypsin. To investigate the impact of this gene, bioassays are performed with the imported willow leaf beetle, *Plagiodera versicolora*. Beetle larvae have been raised through one larval generation on whole, excised poplar leaves and data collected on leaf area consumed, mortality, development rate, and pupal weight. Beetles also have been reared for three successive generations (egg to adult) on a single transformed clone to examine chronic exposure effects. Finally, beetles will be raised in a whole-tree environment to examine behavioral differences on selected clones.

AN EXPERT SYSTEM FOR MOUNTAIN PINE BEETLE UNDER ENDEMIC CONDITIONS IN WESTERN LODGEPOLE PINE FORESTS

D.L. Bartos[dd] **and K. Downing**[ee]

Expert Systems are an excellent way to organize existing knowledge for use by land managers or research scientists. Our objective was to develop an expert system that would deal with endemic (low) levels of mountain pine beetle in the lodgepole pine type of the Intermountain West. Initially, a knowledge acquisition program was written to aid in obtaining knowledge from the experts on the functioning of the system. This information was then fed into KnowledgePro (an expert system generator) which produced the expert system. Users provide parameters (e.g., dbh of the stand and infested trees, stand elevation, and various temperature values) pertinent to the stand in question. The expert system uses this information to determine if the mountain pine beetle population will increase, decrease, or remain static for the coming year. The developed system mimics the current knowledge closely.

AN ADVISORY SYSTEM FOR MOUNTAIN PINE BEETLE MANAGEMENT

B.J. Bentz[ff]

Mountain pine beetle (*Dendroctonus ponderosae*) is responsible for the loss of economic benefits on millions of acres of lodgepole pine in the western United States. Unsuccessful efforts to eradicate this native pest have resulted in investigations to ascertain methods for prevention of population buildup. Toward this goal, recent research endeavors have identified conditions within the forest stand which are favorable to beetle population increase. If resource managers can identify stands with these conditions in a timely manner, they will be able to minimize future impacts caused by the mountain pine beetle. Silvicultural treatments which alter the stand conditions may be prescribed, thereby making the environment less favorable for beetle population growth. The expert system being developed will incorporate these and other strategies for mountain pine beetle management into the current decision process used by Forest Service silviculturists. Included in the system is knowledge representing the managers decision network, and quantitative models for identifying the susceptibility of a stand to mountain pine beetle impact, and the loss expected.

BIOLOGICAL CONTROL OF FOREST INSECT PESTS USING TRICHOGRAMMID EGG PARASITOIDS

S.M. Smith, E. Forsse, R. Bourchier, Z. Wang, N. Maheswaran, and K. Strom[gg]

Egg parasitoids of the genus *Trichogramma* are being investigated for their use against forest insect pests such as the spruce budworm (*Choristoneura fumiferana*), the forest tent caterpillar (*Malacosoma disstria*) and the spruce budmoth (*Zeiraphera canadensis*). The propensity, timing, and temperature threshold for flight by *T. minutum* held under varying environmental conditions has been established in the laboratory. These studies are now being linked to parasitization levels under semi-field conditions. Shifts in fecundity, longevity, and flight of parasitoids reared continuously at high laboratory temperatures (25°C) has been related to changes in biochemical patterns (isozymes) in order to predict the efficiency of parasitoids released in the field. Biological and biochemical characterizations of parasitoids collected from within and between different field sites show a high degree of variability, suggesting that only small localized collections of *Trichogramma* need to be made when establishing colonies for mass-rearing and release. Preliminary studies also have been initiated to determine the susceptible period for parasitization by *Trichogramma* on eggs of the forest tent caterpillar and the spruce budmoth. This will enable release programs to be developed in the future against these forest pests.

SPIDER ABUNDANCE ON PONDEROSA PINES IN WINDBREAKS

M.E. Dix[hh] and D. Jennings[ii]

Ponderosa pine is commonly planted in windbreaks in the central and northern Great Plains, because it can tolerate temperature extremes, low moisture levels, and alkaline soils. Larvae of *Retinia metallica* and *Rhyacionia* spp. (Lepidoptera: Tortricidae) mine the growing shoots of ponderosa pine, killing the buds and stunting branch and terminal growth. Severely damaged trees may die. In 1988 and 1989, trees in six infested windbreaks in eastern Nebraska were sampled monthly for possible arthropod predators of these moths. Spiders were the most abundant predator on the trees. The abundance of spiders was influenced by sample height, surrounding vegetation, and sample date. Most spiders were found in the lower two-thirds of the tree. Windbreaks surrounded by field crops had more spiders than those surrounded by turf or native grass.

PHENOLOGY PREDICTOR, DEFOLIATION PREDICTOR, AND MONITORING SYSTEM DESIGNER COMPONENT OF GYPSES (GYPSY MOTH EXPERT SYSTEM)

L.P. Schaub, F.W. Ravlin, J.A. Logan, S.J. Fleischer, J.A. Young, S.L. Rutherford, and E.A. Roberts[jj]

GypsES is a computer-based environment that will provide forest managers with an integrated set of decision making tools. It will assist managers in dealing with complex problems of gypsy moth control, resource allocation, and program implementation with state-of-the-art technologies including data base management systems, geographic information systems, knowledge based systems, and statistical and simulation models.

The Phenology Predictor uses temperature data from one NOAA weather station, an algorithm describing the elevation dependency of temperature and a simulation model to construct a function between the timing of the target event and the elevation. USGS digital elevation model data and this function are used to predict the phenology in the landscape. Cells within the same target window are aggregated to provide a more comprehensible description of gypsy moth phenology. The Defoliation Predictor produces maps of the estimated level of defoliation. The Hazard Component of GypsES needs defoliation projections to estimate risk rating. The Monitoring Designer of GypsES designs monitoring programs by interpreting data about gypsy moth populations, site/stand characteristics, and management objectives. The system assists users in prioritizing management units and delimits areas to be monitored. The system suggests a sequential sampling plan for egg masses dependent on the hazard rating of the sampling areas. Depending on the risk rating of the management unit, male moth pheromone trap grids are proposed.

GypsES is being developed on a MacIntosh IIci11[R] running under the operating system A/UX[R]. The geographic information system we are using is GRASS. A graphical user interface is being developed in XWindows. The choice of software was directed by the goal of maximum portability and affordability to allow as many delivery platforms as possible. The way problems can be solved is currently implemented in as simple, yet fully functional, a form as possible. GRASS commands are currently invoked by the C program through system calls and calls to the GRASS libraries. In the final version, system calls will be replaced by calls on the object level.

AN OBSERVATION OF DIFFERENTIAL MORTALITY CAUSED BY THE SOUTHERN PINE BEETLE WITHIN 11-YEAR OLD RUST-RESISTANT LOBLOLLY PINE FROM DIFFERENT GEOGRAPHICAL SEED SOURCES.

H.R. Powers[d], Jr., R.P. Belanger[d], and W.D. Petter[d]; F.L. Hastings[kk]

A field study in Coastal South Carolina comparing disease resistance and growth potential of fusiform rust-resistant loblolly and slash pine was prematurely terminated at age eleven by southern pine beetle mortality. The incident of mortality appeared to be related to seed source. Is this coincidental or is there reason to suggest that insects should be considered when disease resistance is being studied?

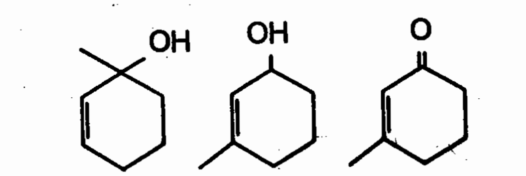
LANIERONE: A NEW PHEROMONE COMPONENT FROM IPS PINI (COLEOPTERA: SCOLYTIDAE)

S.A. Teale, F.X. Webster, A. Zhang, G.N. Lanier[ll]

A new pheromone component, lanierone, (2-hydroxy-4,4,6-trimethyl-2,5 cyclohexadiene-l-one) was isolated and identified from a Porapak Q collection of volatiles from male *Ips pini* from New York through a GC fractionation and bioassay sequence. In both the laboratory and the field, synthetic lanierone, in a 1:100 ratio with synthetic ipsdienol, was as attractive as male-produced pheromone. Synthetic ipsdienol alone was not attractive to females in the laboratory and only weakly attractive in the field. Varying the ratio of lanierone to ipsdienol in the field from 10-4:1 to 1:1 in ten fold increments resulted in an increased number of beetles trapped at the three lower ratios, but also in an increase in the proportion of males trapped. In the field, all combinations of lanierone to ipsdienol attracted proportionately fewer males than did pheromone-producing male beetles. GC and GC-MS analyses of Porapak Q-trapped volatiles from males and females revealed that lanierone is produced in an amount equal to about 0.1% to 0.2% of that of ipsdienol and is produced exclusively by males. The small amount of lanierone produced, together with a GC retention time similar to that of ipsdienol on a nonpolar column, probably confounded its detection in earlier studies.

1-METHYLCYCLOHEX-2-ENOL, 3-METHYLCYCLOHEX-2-ENOL AND 3-METHYLCYCLOHEX-2-ENONE AS PHEROMONES IN THREE SPECIES OF *DENCROCTONUS* BARK BEETLES

E.A. Dixon[mm], H. Wieser[mm], H.F. Cerezke[k], E. Begin[nn], G. Gries[oo], R.A. Werner[pp], and A.T. Whitehead[qq]



1-methylcyclohex-2-enol (MCOL) **3-methylcyclohex-2-enol (seudenol, Se)** **3-methylcyclohex-2-enone (MCH)**

The three title compounds, MCOL, Se, and MCH, appear to play significant roles in the communication system of at least three species of *Dendroctonus* bark beetles. Confirmed previously by others were MCOL for *D. pseudotsugae* (Douglas-fir beetle), and Se and MCH for *D. pseudotsugae, D. rufipennis* (spruce beetle), and *D. simplex* (eastern larch beetle). MCOL and Se were identified as aggregants, while MCH clearly acts as antiaggregant for all three species. Attempts have been made to answer questions concerning cross-attraction between *D. pseudotsugae* and *rufipennis*, and of speciation between *D. pseudotsugae* and *simplex*. A general scheme for the rearrangement between MCOL and Se, and the oxidation of the latter to MCH has also been suggested.

In recent field bioassays we have identified MCOL as an effective attractant for both sexes in combination with frontalin and -pinene for *D. rufipennis* and *pseudotsugae*, and in combination with α-pinene alone for *D. simplex*. MCOL was shown to be present in the frass of female *D. rufipennis*, and produced significant EAG responses in females and males of the same species. *In vitro* laboratory experiments demonstrated unequivocally that MCOL and Se are subject to acid-catalyzed interconversion reaching an equilibrium favoring the latter. This interconversion takes place readily also in a mulch of spruce phloem, suggesting the likelihood of spontaneous interconversion in the beetles' natural habitat.

Current knowledge suggests that there is an ecological sequence of events involving the three semiochemicals; MCOL attracting both sexes, Se attracting primarily males, and MCH, although being generally antiaggregative, showing some tendency to preferentially repel males. Intriguing questions remain unanswered concerning the biosynthetic origin of MCOL, and the mechanism of cross-attraction or speciation among the three species.

FORECASTING INFESTATION TRENDS OF THE SOUTHERN PINE BEETLE

R.F. Billings[rr]

A practical method to forecast annual infestation trends of the southern pine beetle, *Dendroctonus frontalis*, has been developed by the Texas Forest Service and pilot tested in selected areas throughout the southern United States. Multiple funnel Lindgren traps baited with the synthetic aggregation pheromone "frontalin" and a rapid-release dispenser of turpentine from loblolly pine (*Pinus taeda*) are deployed during the early spring to monitor dispersing populations of *D. frontalis* and a major predator, *Thanasimus dubius*. Two variables derived from mean trap catches from three pheromone traps deployed per county or National Forest Ranger District are used to predict infestation trends in the current year. These variables are mean numbers of *D. frontalis* trapped per day and the proportion of *D. frontalis* to total catch of *D. frontalis* plus *T. dubius* over a two-four week trapping interval. Five years of trapping data (1986-1990) from 11 southern states showed that these variables have predictive value for forecasting whether southern pine beetle infestation levels at the county, ranger district, or state levels are likely to increase, decline, or remain static compared to the previous year. This forecast system represents an innovative, simple, and reliable means to predict short-term infestation trends for this destructive forest pest throughout its range in the southern United States.

UTAH GYPSY MOTH ERADICATION PROGRAM 1990 GYPSY MOTH REPORT

S. Munson[SS]

Since the gypsy moth was first detected in July 1988, treatment and detection efforts have continued to expand as gypsy moth populations have been discovered in remote areas within the Wasatch mountains of Utah. In May 1989, 1190 acres were treated in the Mt. Olympus Cove area of Salt Lake City. As new populations were discovered during the 1989 detection and delimitation survey, the treatment area expanded in 1990 to include 13 blocks encompassing 20,064 acres in three counties (Davis, Utah, and Salt Lake).

1990 Eradication Program

The only egg masses found during the fall 1989 egg mass survey were in the Mt. Olympus Cove spray block. All block boundaries were based on male moths captured during the 1989 flight period. All multiple catches and/or clusters of traps with single catches were placed within 1990 treatment block boundaries. Isolated single catches were often not included in spray block boundaries.

Aerial applications of *Bacillus thuringiensis*, (B.t.) were applied over the 20,064 acres in 1990. Each spray block was treated three times at 5-7 day intervals. Aerial application was made using three rotary wing aircraft, one Hiller 12E Soloy and two Bell 206B3s. All aircraft were equipped with four electronic rotary atomizer Beecomist nozzles calibrated to deliver 64 oz. per acre. Foray 48B at 24 BIUs was applied neat for all applications. Application costs, which include the cost of the B.t. and aerial application was $9.23 per acre. Total project costs are approximately 1.1 million which, based on 60,072 acres treated, represents $18.31 per acre.

Mass trapping was conducted within residential sections of each spray block. Approximately 2200 traps were placed within these residential sites. Preliminary estimates of the cost of trap placement and retrieval for mass trapping is $5.06 per trap. Detection trapping was conducted by APHIS personnel. Using the new detection trapping guidelines developed by APHIS, 169 detection traps were placed throughout the state. No moths were captured in the detection survey.

Approximately 6,000 traps were placed in the delimitation survey within and surrounding the 1990 spray blocks. Of these, 2,000 traps were placed on Forest Service land in mountainous terrain. This represents an increase of 1,500 traps compared to the 1989 delimitation survey in this type of terrain. Only 5 percent of the traps placed in the mountains were missing in 1990, compared to 30 percent not found in 1989. In 1990, 527 moths were caught in the delimitation traps. Of these, 286 moths were captured outside of the treatment blocks. Most of the increase is due to additional traps placed in remote terrain and the high percentage of traps retrieved. Within the treatment blocks, only 241 moths were captured compared to 2,239 positive catches in 1989.

In 1991, 14 blocks totaling 29,925 acres will be treated in a four county area (Davis, Salt Lake, Utah, and Summit) of northern Utah. B.t. at 25 BIU's will be applied neat in 3 applications spaced 5-7 days apart.

THE GYPSY MOTH ERADICATION PROGRAM IN UTAH

J. Anhold and S. Munson[SS]

A summary of the gypsy moth eradication program conducted in Utah from 1989-1991 focused on three primary areas; treatment, quarantine, and detection-delimitation trapping. Maps, graphs, tables, and photographs provide information on the success and problems associated with treatment of gypsy moth in mountainous terrain. Egg mass densities have been reduced from 4,000 egg masses per acre to non-detectable levels. The application program has grown from 1200 acres treated in 1989 to 30,000 acres scheduled for treatment in 1991. Although egg mass densities have decreased dramatically, low level populations have been discovered in remote mountainous areas along the Wasatch Front, necessitating treatment of large areas of host type.

TREATMENT MONITORING DATA BASE

H.A. Machesky and D.B. Twardus[tt]

The Treatment Monitoring Data Base (TMDB) was implemented in 1986 in response to an identified gap in knowledge about gypsy moth suppression effectiveness or parameters associated with effectiveness. The TMDB was developed to: 1) provide information about the results of operational projects, and 2) provide information about conditions contributing to those results. In 1985, when the TMDB was being designed, no record of project results of operations existed. More importantly, the effectiveness of USDA cooperative suppression programs was not documented. Effectiveness, at that point in time, had not been defined. TMDB offers a way to define and quantify project effectiveness and also evaluate operations. This is done with minimal impact upon project logistics. The TMDB focuses upon project effectiveness -- that is, how are we doing in terms of project objectives.

A part of the usefulness of TMDB lies in its record-keeping and data summary aspects. Aerial application projects are very complex, requiring attention to numerous variables. The TMDB, as a data management system, provides a way to track variables that may be related to project results or are needed to summarize project operations.

The TMDB contains data collected from individual treatment blocks. The TMDB consists of three main components: data collection, a data base, and summaries of the data. Data include information about the site or block, about the treatment and conditions during treatment, about the aircraft performing the treatment, and results after treatment. At present, the TMDB contains data spanning 5 years and over 4,000 blocks in 8 states and 2 national forests. The TMDB is particularly suited to large projects with numerous treatment blocks where record-keeping and data analysis are difficult. The TMDB is also useful in helping to focus attention upon aspects of aerial application that are important in achieving success. In this aspect, it is also a training tool.

DECISION SUPPORT SYSTEM FOR THE HEMLOCK LOOPER, *LAMBDINA FISCELLARIA* (GUEN.),IN NEWFOUNDLAND

J. Hudak[m] and A.G. Raske[m]; P.J. McNamee[l] and G.D. Sutherland[n]; L. O'Brien[uu]; C.H.R. Wedeles[vv]

The System, called LOOPER, consists of six linked and user-friendly predictive models that presents a menu of options and guides the user through the various scenarios of simulated events. The six models are: General Outbreak Risk Model, Initial Defoliation Risk Model, Continued Defoliation Risk Model, Volume Tree Mortality Model, Volume Timber Decay Model, and Larval Development Model. LOOPER produces digital maps or stand lists of all outputs.

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IV. WORKSHOP EVALUATION

IV. WORKSHOP EVALUATION

We include in this section a reproduction of the evaluation form that was completed by participants at the end of the Conference. In the space preceding each question, is the average response of 101 (out of 375) responses to the survey instrument. Selected additional comments that best describe how most of the respondents felt about the Conference also are included.

A vast majority of the respondents felt that the Conference was effective, timely and held in a convenient place. Both the city (Denver) and the hotel (Radisson Hotel) received excellent reviews. The theme was timely and relevant, although it could have been better advertised prior to the Conference. Most felt that the Conference itself was of appropriate length and well-organized, although there was some disagreement on how long concurrent sessions should be. Many attendees did not like concurrent workshop sessions, because they had to make difficult choices. However, most agreed that this was the only way to handle the topics covered, given the number of Conference participants. Participants could not agree on the appropriate length of workshop sessions; however, it was recommended that all of them should be the same length. As indicated by the selected comments, it is difficult to obtain a consensus on how to conduct workshops. Many people believed that sessions should have been informal and open (similar to workshops at Western Forest Insect Work Conferences), and others favored more formality, with scheduled participants. Scheduling allows people to move between workshops. Perhaps a mixture of the two types of sessions is best, with each type offered at the same time; e.g., formal sessions in the morning and informal sessions in the afternoon. An arrangement like this would satisfy most concerns regarding concurrent workshops. The participants felt that the subject matter in most sessions was adequately covered, regardless of the type of workshop they preferred.

Another area that could be improved is more judicious use of Keynote speakers to set the theme for the conference. Most respondents felt that there were too many Keynote speakers, and they did not adequately cover the topics assigned. It was suggested by many that the number of Keynoters be reduced, and that applicable keynote talks be presented just prior to the appropriate workshops.

The Poster Sessions were well received, and the set up and viewing was readily accessible. Although most respondents agreed that the poster session should be a part of future conferences, many felt that the poster topics should be more relevant to the conference theme.

When selecting Steering Committee members and moderators for future conferences of this type, we should encourage broader representation in terms of cultural diversity and professional interest. To be most effective, participation and attendance at this meeting should include people who represent a range of user groups, research interests, forest management, entomology, and pathology. Similarly, we feel that a truly North American approach is desirable. Many colleagues in South America and Mexico wanted to attend, but lacked financial means. We suggest that during the budgeting process for future conferences an attempt be made to secure travel funds to help defray expenses for some of these people.

Overall, most felt that the Conference was timely, well-organized and that we should hold another in the future. Every three to five years was the most commonly suggested length of time between North American Forest Insect Work Conferences. Most participants felt that a central location is good, but that if a regional Forest Insect Work Conference was putting on the North American Conference, it should be held in the region sponsoring it to keep costs down. We hope a Regional Forest Insect Work Conference volunteers to hold another national meeting in the next three to five years. Just remember, it takes at least 2 years to adequately plan and obtain financial support for a conference of this type. We (Abrahamson and Allen) would be glad to do it again (if no one else volunteers), but suggest that the Steering Committee formed for this conference meet in the near future and decide when, how and where the next North American Forest Insect Work Conference should be held. We believe the Conference was worthwhile, and hope that it will continue on a regular basis.

CONFERENCE EVALUATION FORM AND RESPONSES

We have been very pleased with the interest and enthusiasm shown for this first North American Forest Insect Work Conference. The Steering Committee hopes that you leave Denver with a feeling of accomplishment and time well spent.

Hopefully, the group's enthusiasm will encourage others to repeat this effort at an appropriate time in the future. If this comes to pass, we would like to identify ways to improve future meetings. Please take the time to assist us in this regard.

Please rate the following aspects of the conference using the scale below:

Excellent		Average	Poor	
5	4	3	2	1

If you wish to provide written comments, please do so at the end or in the space that follows each question. Return this form to the designated location at the registration/information desk in the Terrace Level Foyer. Thank you.

1.	4.25	Overall, do you think the meeting was effective?
2.	4.32	Was the theme (i.e., looking ahead, planning for the future, etc.) relevant?
3.	3.57	Was the theme communicated well prior to the conference?
4.	4.21	Was the length of the conference appropriate?
5.	3.51	Were sessions too long?
6.	3.38	Were sessions too short?
7.	4.43	Was the site appropriate for the conference?
8.	3.95	Were mailings timely?
9.	3.72	Were mailings informative?
10.	4.85	Was the location of the Poster Session accessible and convenient?
11.	3.78	Did the Poster Session contribute to the conference purpose?
12.	3.84	Was the time available for the Poster Session adequate?
13.	4.23	Was registration handled efficiently?
14.	0.79	Were American Airlines conference travel arrangements handled efficiently?
15.	3.52	Was information provided about the Conference useful?
16.	4.29	Should this type of a conference be offered in the future?
17.	3-5 yrs	In five years? Ten years? Other ________ (circle or indicate preference)
18.	2.93	Did the Keynote Speakers effectively set the stage for the workshops?
19.	3.96	Was the meeting well organized?
20.	3.88	Were the subjects covered appropriate?

Additional comments? Use space below please.

SELECTED ADDITIONAL COMMENTS

- This was one of the BEST scientific conferences that I have ever attended. CONGRATULATIONS! Let's do it again in 4 years.

- You did an outstanding job, congratulations.

- Steering committee is to be commended. A huge task for the most part well done.

- Because of the airfare, it is better to start meetings on Sunday afternoon. Amtrak should have been mentioned or another means of transportation with the station location given in reference to the hotel.

- My concern is that this gathering was predominately self-serving. If the intent was for forest protection researchers and forest pest managers to gather and address each other, then the conference is a resounding success; however, if we wanted to get our messages out to others(??), I'm not at all sure that we have advanced our cause. Who did we communicate our messages to? Who were the intended audiences? What specific messages do we want the audiences to come away with anyway. These questions were not particularly well dealt with, in my estimation.

- Excellent session. Our knowledge changes too quickly, and these integrated regional conferences should be no longer than 3-4 years apart. Just the contact is very important.

- I would have liked to see less time spent on keynote speakers and more time spent on concurrent sessions. I could not attend all the sessions. I would have liked to but it was impossible, because so many sessions ran at the same time. All-in-all I thought the meeting was excellent. The wide scope of the meeting was quite enlightening -- I hope it happens again.

- I commend the organizers for their extensive and important efforts. Commentary here is in the spirit of fine tuning a good machine. Too many of the keynote speakers were stale and boring platitudes. Quality control in workshops varied enormously. We are under attack from major NGO's, such as wilderness society. Such groups should be charged with directing a workshop.

- Lunch flowed very smoothly and staff was very helpful. During breaks please serve fruit and juices instead of pastries and cakes.

- Forest entomology ignores certain agencies as contributors to its meetings. ARS and APHIS were not represented, and in some cases were unaware of the meeting. Granted, these agencies do not confine themselves to forest pests, but they both include scientists and projects that work with forest pests.

- Conference should be titled North American Forest Insect and Disease Work Conference. Pathology interactions are important and should have not been left out of the title.

- Please give us a "vegetarian" choice for lunch. Even many of the carnivores among us prefer to eat less fat, high cholesterol meals.

- I believe a better job could have been done in getting media coverage of the meeting. There were many interesting topics at the meeting and, if invited, media would have brought good publicity. Otherwise this was an EXCELLENT meeting. Well planned and organized.

- Make explicit provisions to receive evaluations by mail.

- Lunch together was a GREAT idea.

- Maybe the conference should have lasted another half day so there would be more time for the Work Conference. Also the 8-hour sessions were too long. I think the sessions should have been limited to 4 hr. The 2-hour sessions were too short.

- Too few poster presentations available at poster session. To many talks in sessions. Too much emphasis on lecture, not discussion. Too many topics attempted -- 3-4 concurrent sessions is ample. Too many keynoters - one per day would be plenty. Still an excellent meeting.

I suggest another session in 5-10 years, organized by "realists" (foresters for example) so that fringe groups (entomologists, for example) can prove their worth and value for a change. This is the ultimate challenge to the next Work Conference, in my opinion.

Stress hands on results "case histories" in the future (success/failure stories). Also, appreciated letter sent encouraging attendance by state person through National Association of State Foresters.

Great mix of people from all parts of the USA, in particular, as well as some participants from neighboring countries.

There was a lack of participation on the part of management folks (state people and forest pest management) as speakers and moderators.

Everyone expresses the need for communication and collaboration with other disciplines. How about a forest management conference that includes entomologists, silviculturists, soils, hydrologists, wildlifers, etc. It would be tough but it needs to be done if we want to improve forest management in the future.

This was a good idea. I very much appreciated being able to "circle the continent" in a single workshop. I would like to see the pathology conferences do the same thing. I was adverse to concurrent workshops at first, but after attending, I give this idea enthusiastic support.

This was a great conference. It should be continued every 4-5 years. To ease the travel time and cost restraints, we could cancel regional work conferences during National Work Conference years. Two suggestions: 1) start the meeting Monday a.m. and have one keynote and one plenary speaker. Begin the workshop sessions Monday after lunch, so we can attend more sessions; 2) It might be nice to have a Memorial reading for our colleagues who have died since the last meeting.

Particularly enjoyed the National scope. My state has concerns that cross regional boundaries and are not adequately addressed in regional workshops.

Workshops could have been better organized, but that really is the responsibility of the moderator. Some were well planned and organized. Other moderators were very unorganized and altered the schedule of speakers, which was a great mistake. Keep the schedule as planned.

I like the interdisciplinary topics and suggest this be continued and include more areas. This was equally good for pathologists.

Less topics to allow more participation in areas of interest. I felt deprived of information and discussion from sessions I was equally interested in, but could not attend because of so many conflicting times.

I feel that most workshops should have had more opportunity for discussion and fewer prepared talks.

The sessions that had about 20 peopld or less were the most effective. In these sessions, the discussions were much better and more effective.

Too many concurrent sessions. Should limit to only three.

I felt the program could have been better. Many workshop moderators listed speakers only and not the focus of their talk. Also, approximate times for each of the talks to begin would have been useful. Otherwise, a great conference.

Most sessions tended to be a series of formal presentations followed by a question and answer session. I would rather see an ongoing discussion with each presenter. The informal structure has been useful in past western regional conferences that I have attended may be a bood model.

Occasionally, too many talks in each session and not enough discussion time. It was frustrating but a very good idea not to publish the times of individual talks, because people would have moved around a great deal and stifled the discussion.

I really liked the variety of workshops on the program. There was opportunity to address a range interests. A big plus. The program covered all possible aspects of forestry.

The rooms, no matter the site or shape, should be arranged in a semi-circle to facilitate discussion, the lecture type arrangement facilitates exactly that. Good job. great to see you all!

Many workshops conducted with too many formal talks and not enough discussion. This was a serious problem.

Concurrent sessions necessary, but overlapping not a good idea (some starting in the middle of others). When a person wanted to take in a particular discussion, there was no way to tell what time a particular theme was being presented. No sure-fire solution offered, but programmed times might be necessary for more formal presentations.

Very good selection of topics for workshops. My only complaint is that most workshops were too formal -- I think that slides and overheads should be banned from workshops, and that prepared speeches should take up no more than 50% of the total time allotted.

Too many similar concurrent sessions. Should not have microbials, semiochemicals, and biotech sessions all being held at the same time. Developing sessions of similar interest detracted from the general usefulness.

Each speaker should be assigned a particular time and this scheduling should be listed on the program to allow access to other speakers in other sessions.

When concurrent sessions are used, papers and presentations need to be scheduled so participants can be sure to hear those presentations of great interest. Times need to be published and adhered to, so one can plan.

The only comment I have is that there were perhaps too many workshops of "likeness" themes scheduled concurrently, perhaps too many scheduled for one period. Perhaps with the size of attendees interest, there was no other way to plan efficiently to suit everyone.

Regarding the length of the sessions and meeting organization, two points: 1) I felt the sessions were a bit too long, but this impression would have been negated if so much time had not been devoted to keynoters; 2) It would have been helpful if the times of each speaker were listed in the program or at least posted outside the room. Lastly and most importantly, the format was not really a true workshop. The emphasis of formal presentations lasting roughly 30 minutes is really not conducive to exchange and discussion. Workshops should be looser and less formal and the speakers should stimulate discussion.

Too many concurrent workshops with themes with would attract the same individual.

Although a workshop format should be flexible in time periods, I still think that an Entomol. Soc. Amer. type scheduling would be beneficial. That is, strict time keeping by moderators, so that attendees can switch between sessions for specific speakers. To keep flexibility time arrangements per speaker should be generous. If interchange is not stimulated people would just sit and read, or wander around for the next speaker.

Keynote speakers not particularly stimulating. Would have preferred a wider range of topics or viewpoints. Also, an opportunity for a panel discussion and/or questions or discussion from the audience.

Too many keynote addresses.

AUTHOR INDEX

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Allen, Douglas C.; Abrahamson, Lawrence P., tech. eds. 1992. Proceedings: North American forest insect work conference; 1991 March 25-28; Denver, CO. Gen. Tech. Rep. PNW-GTR-294. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 182 p.

A proceedings of a conference held to stimulate interaction among people working in areas of forest protection and silviculture and on issues of national and international concern relative to forest insect and disease management, education, and research. National issues addressed were forest productivity, stewardship, biological diversity, and new perspectives and how these issues affect environmentally sound management of forest pests.

Keywords: Forest pests, forest insects, forest diseases, entomology, entomology (research), entomology (education), pathology, pest management.

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