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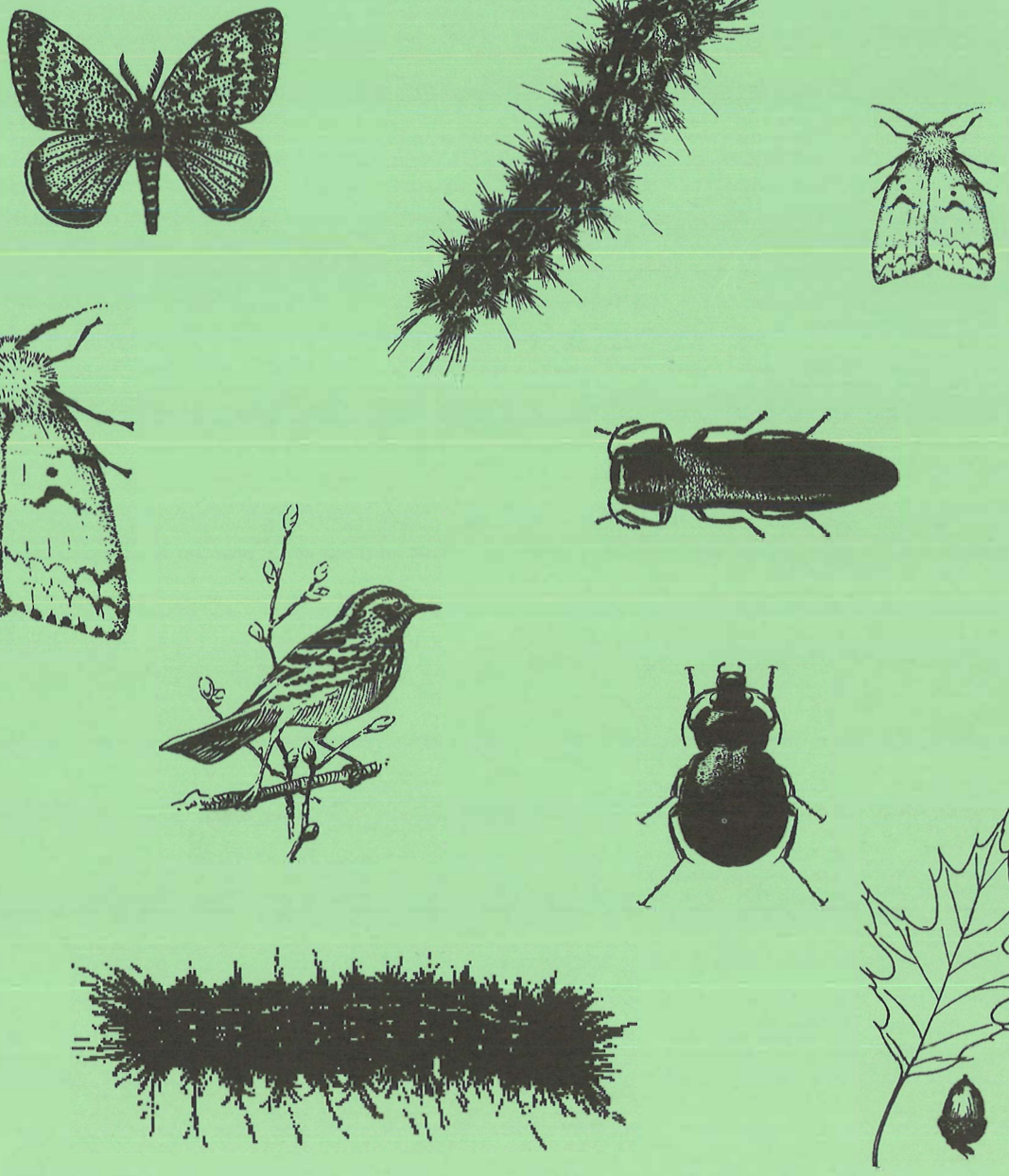

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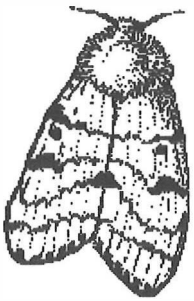
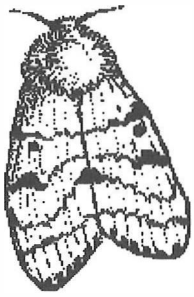
Interagency Gypsy Moth Research Forum
1997





January 14-17, 1997
Loews Annapolis Hotel
Annapolis, Maryland

Edited by
Sandra L. C. Fosbroke and Kurt W. Gottschalk

Sponsored by:

Forest Service Research

Forest Service State and Private Forestry

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USDA

FOREWORD

This meeting was the eighth in a series of annual USDA Interagency Gypsy Moth Research Forums that are sponsored by the USDA Gypsy Moth Research and Development Coordinating Group. The Committee's original goal of fostering communication and an overview of ongoing research has been continued and accomplished in this meeting.

The proceedings document the efforts of many individuals: those who made the meeting possible, those who made presentations, and those who compiled and edited the proceedings. But more than that, the proceedings illustrate the depth and breadth of studies being supported by the agencies and it is satisfying, indeed, that all of this can be accomplished in a cooperative spirit.

USDA Gypsy Moth Research and Development Coordinating Group

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USDA Interagency Gypsy Moth Research Forum
January 14-17, 1997
Loews Annapolis Hotel
Annapolis, Maryland

AGENDA

Tuesday Afternoon, January 14

REGISTRATION
POSTER DISPLAY SESSION I

Wednesday Morning, January 15

PLENARY SESSION ..... Moderator: M. McFadden, USDA-FS

Welcome
Michael McManus, USDA-FS

Introductory Remarks
Max McFadden, USDA-FS

Coordination of USDA Biological Control: Removing Bottlenecks to Achieve Delivery
Sally L. McCammon, USDA-APHIS

The Seventh American Forest Congress: Process, Results, and Implications for Research on Forests
William R. Bentley, Salmon Brook Associates

Spore Wars: *Entomophaga maimaiga* versus Gypsy Moth in North America
Ann E. Hajek, Cornell University

POSTER DISPLAY SESSION II

Wednesday Afternoon, January 15

GENERAL SESSION ..... Moderator: K. S. Shields, USDA-FS

Characteristics of Exotic Defoliators
Presenters: Y. Baranchikov, V.N. Sukachev Institute of Forest, Russia; J. Hilszczanski, Forest Research Institute, Poland; A. Schopf, Institute of Forest Entomology, Austria; A. Battisti, University of Padua, Italy

GENERAL SESSION (CONTINUED) . . . . . Moderator: K. W. Gottschalk, USDA-FS

GypsES: Decision Support for Gypsy Moth Managers: Demonstration and Interactive Session
Presenters: K. W. Gottschalk, USDA-FS; J. J. Colbert, USDA-FS; S. Thomas, USDA-FS; J. Ghent, USDA-FS

Thursday Morning, January 16

GENERAL SESSION . . . . . Moderator: E. Dougherty, USDA-ARS

Progress in Molecular Aspects of Biocontrol Agents
Presenters: A. Valaitis, USDA-FS; N. Dubois, USDA-FS; S. Hiremath, USDA-FS; D. Gundersen-Rindal, USDA-ARS; E. Dougherty, USDA-ARS; J. Slavicek, USDA-FS

GENERAL SESSION (CONTINUED) . . . . . Moderator: D. Eggen, Del. Dept. Agric.

Research Reports
Presenters: F. Hérard, European Biological Control Lab., France; W. Wallner, USDA-FS

POSTER DISPLAY SESSION III

Thursday Afternoon, January 16

GENERAL SESSION . . . . . Moderator: M. Montgomery, USDA-FS

A Case Study of Managing the Gypsy Moth Using Silviculture
Presenters: K. W. Gottschalk, USDA-FS; P. M. Wargo, USDA-FS; R.M. Muzika, USDA-FS; A. Liebhold, USDA-FS; S. Grushecky, West Virginia University

GENERAL SESSION (CONTINUED) . . . . . Moderator: R. C. Reardon, USDA-FS

Research Reports
Presenters: P. Zolubas, Lithuanian Forest Research Institute, Lithuania; R. Williams, Oak Ridge National Laboratory; G. Ramaseshiah, FERRO, India

Friday Morning, January 17

GENERAL SESSION . . . . . Moderator: P. M. Wargo, USDA-FS

Forest Health/Forest Decline: Perception, Reality, Resolution
Presenters: W. Martin, Commissioner of Natural Resources, Kentucky; O. Loucks, Miami University, Ohio; S. Horsley, USDA-FS; W. Shortle, USDA-FS

GENERAL SESSION (CONTINUED) . . . . . Moderator: R. Fuester, USDA-ARS

Entomophaga maimaiga
Presenters: R. Webb, USDA-ARS; L. Bauer, USDA-FS; A. Hajek, Cornell University

CONTENTS

PLENARY PRESENTATIONS

ABSTRACTS AND PAPERS OF PRESENTATIONS AND POSTERS

THE SEVENTH AMERICAN FOREST CONGRESS: PROCESS, RESULTS, AND IMPLICATIONS FOR RESEARCH ON FORESTS

William R. Bentley[1]

Salmon Brook Associates, 17 Hartford Ave., P.O. Box 748, Granby, CT 06035

The Seventh American Forest Congress was a truly remarkable event. Over 1,500 people participated in the Forest Congress, and thousands more participated in the local roundtables and collaborative meetings that preceded it. The participants developed a vision for the future of America's forests and principles to guide us toward the vision.

A Personal Version of the Vision

In the future, our forests will have a variety of owners with their rights and objectives respected, and these owners will accept their responsibility as stewards;
In the future, forests will be enhanced by policies that encourage public and private investment, sustainable production of a wide variety of values--goods, services, and experiences;
In the future, the current area of forests will be maintained and the area expanded where appropriate;
In the future, forests will be shaped by a wise mix of natural forces and human actions; forests will be sustainable and diverse; forests will be highly productive;
In the future, forests will contribute to strong urban and rural communities;
In the future, forests will be managed in ways sensitive to global implications, watersheds and aquatic systems, and local needs.

Source: adapted from vision elements listed in Bentley and Langbein 1996

The Forest Congress participants strongly agreed with a vision of science-based forest policy and management and two specific principles for achieving the vision:

[1] The author is President of Salmon Brook Associates and Senior Research Scholar, Yale University. He served as executive director of the Seventh American Forest Congress, and currently chairs the Forest Congress Research Committee.

1. *Science-based information is accessible and understandable, distributed in a timely manner, and contributes to forest policy and management.* (80% agreement)

2. *Comprehensive, integrated, and well-organized research is well funded. It is designed and conducted in collaboration with stakeholders to ensure for society the countless benefits of our forest ecosystems. Knowledge and technology products are effectively distributed, tested, and implemented.* (76% agreement)

The Forest Congress Research Committee is building on these principles. The committee did considerable work before and during the Forest Congress, including reviews of earlier assessments of America's forest research system. The committee performed a diagnostic analysis of the performance, successes, and failures of the current system. The general conclusion is that the system in aggregate is not meeting America's needs. The causes include the current relationships between clients for science-based information and the research community. The low impact of client voices in setting the research agenda affects the demand for science-based information as well as the levels of funding.

PRINCIPLES OF THE SEVENTH AMERICAN FOREST CONGRESS

The 10 principles with the highest levels of agreement:

1. An open and continuous dialogue is maintained and encouraged among all parties interested in forests. (88% agreement)

2. Voluntary cooperation and coordination among individuals, landowners, communities, organizations, and governments is encouraged to achieve shared ecosystems goals. (85%)

3. Cohesive and stable policies, programs, and incentives should be available to allow forest owners to sustain and enhance forests. (84%)

4. Natural resource issues should be resolved by peaceful means.[2] (81%)

5. Create financial and non-financial incentives for long-term forest stewardship. (81%)

6. Science-based information is accessible and understandable, distributed in a timely manner, and contributes to forest policy and management. (80%)

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[2] Note that a very similar principle received 71% agreement, but is not listed among the top 10 because of the overlap. It states, "Conflicts over forest issues will be resolved through nonviolent processes."

7. Comprehensive, integrated, and well-organized research is well funded. It is designed and conducted in collaboration with stakeholders to ensure for society the countless benefits of our forest ecosystems. Knowledge and technology products are effectively distributed, tested, and implemented. (76%)

8. All differences in goals and objectives of public, private, and tribal forest owners are recognized and respected. Forest owners, including the general public, recognize and embrace both the rights and responsibilities of ownership. All forest owners acknowledge that public interests (e.g., air, water, fish, and wildlife) exist on private lands and private interests (e.g., timber sales, recreation) exist on public lands. (75%)

9. Urban and community forest ecosystems will be valued, enhanced, expanded, and perpetuated. (74%)

10. People's actions should ensure that the management of forests should sustain ecosystem structure, functions, and processes at the appropriate temporal and spatial levels. (70%) *(Source:* Bentley and Langbein 1996)

BACKGROUND

The Seventh Forest Congress began with concerns about the poor use of scientific information in America's forest policy and management. Although the frame of reference rapidly grew beyond research and the use of information, research policy is a continuing focal point. The Forest Congress Research Committee (FCRC) was among the first formed.

Forest research subcommittees reviewed the status of research on forests by regions. Each subcommittee recommended broad areas of future research emphasis. A concurrent dialogue session during the Forest Congress summarized the results of the committee's work. The diversity of funding was reviewed, including the work supported by NASA, the Department of Energy, and other non-traditional sponsors. The session explored means for stronger client involvement in supporting research and actual citizen involvement in some research work. Also explored were general strategies for improving the funding base and developing a more responsive institutional framework.

The Forest Research Committee is one of five that has continued post-congress (the others are policy, management, education, and communities). It is building on several previous reviews and recommendations, such as *Mandate for Change* (National Research Council 1990) sponsored by the National Academy of Science. The recommendations for stronger applied science go back to the 1974 Resource Planning Act and 1976 National Forest Management Act. Included are several U.S. Department of Agriculture reviews and the current efforts by the American Forest & Paper Association.

The FCRC includes leaders from the public and private forest research communities and several client groups. The committee will take the lead on comparing current research with the Forest

Congress vision and principles, identifying gaps in forest research needs and diagnosing the causes of these gaps. In dialogue with the local roundtables and the broad Forest Research Committee, the committee will make recommendations. These will include solutions to meet overall information needs and improve the interface between forest research and American forest policy and management. The committee will complete its work by fall 1997.

The committee held three meetings to date. The first was of the full Forest Research Committee, which includes both researchers and users of science-based information. It was in Portland, Oregon, on September 26-27, 1996. It focused on identifying gaps in research performance, doing diagnostics of the causes of these gaps, and designing possible solutions. Although the results were less than conclusive, the general picture emerged that America's forest research system was not performing up to expectations. The causes included funding levels, but all agreed that the problems were more fundamental. Considerations of causes included structure -- both the current organizations and their relationships with clients and with one another. Mechanisms for setting the agenda, and levels of funding, also are important.

The second meeting was with researchers from the Forest Service, universities, industry, and NGOs. It was in Washington DC on October 23-25, 1996. The Forest Service, Cooperative State Research Extension and Education Service, Pinchot Institute for Conservation, and Yale Forest Forum co-sponsored the meeting. The breakdown in communications between the Forest Service and several universities about partnerships prompted the meeting, but the discussions ranged over a broad array of issues. Again, the symptoms point to gaps in overall research performance. Again, declines in funding are an obvious part of this picture, but they are not the primary causes. Relationships with clients or customers are critical. Exploration of several structural issues shows promise, but no conclusions so far.

The third meeting of the Forest Research Committee was January 7-8, 1997, in Charleston, South Carolina. The starting points were the results of the two previous meetings plus some suggestions on new client relationships for agenda setting, new funding mechanisms, and new structures. The results included a work plan that will lead to a draft report and recommendations.

The goal is a clear set of results to take to state roundtables by late spring 1997. By fall 1997, it should be clear what levels of agreement we have for major changes in forest research policy and the nature of the constituency supporting these changes. A final meeting, perhaps of a subcommittee, will review the results from roundtable and collaborative meetings. The final report and recommendations will be delivered to the U.S. Senate and House of Representatives, the White House, and the state-level counterparts. The results also will be sent to collaborators, such as the environmental coalitions, AF&PA, the Forest Service and other federal agencies, and NAPSFC, soliciting their review of the recommendations. Hopefully, the on-going involvement of all these parties will lead to their support because they participated in and influenced the process.

DIAGNOSTICS

The Forest Research Committee is using the vision and principles of the Forest Congress and, more importantly, the process of the Forest Congress. Five key diagnostic questions are being considered.

1. ***Are we working on the right things?***

   So far two general answers have emerged. First, many agree with the overall agenda, but not the priorities. The two most obvious disagreements are with the low priority given to Forest Inventory and Assessment with regard to frequency of updates and quality of information. Second, the balance of Ecosystems Management research compared to research focused on specific management problems (e.g., timber production, recreation user needs) seems skewed to many, especially outside the West. Some feel that the agenda is not practical enough, and many are not satisfied with the extension and other outreach linkages between clients and researchers.

2. ***Are we allocating our resources in a way that matches both client and national priorities?***

   The answer to the client part of this question depends on who you are. The National Forest System may be satisfied with the current allocations, but other public agencies are not. We do not have an adequate assessment of environmental organization views, but outdoor recreation clients, community-based groups, small owners, and commodity producers have expressed their concerns with the current allocations.

   Unfortunately, the same may be true of the national interest part of the question. Some clients place higher values on biodiversity and other non-market services, which leads them to advocate a different mix as being in the national interest than groups who are more concerned with market or market-like values (e.g., outdoor recreation, timber, wildlife, and range).

   Except for leaders in the research community (e.g., *Mandate*), we see few clients articulating arguments for allocations that lead to improved understanding of the underlying ecosystems or human interactions in ecosystem contexts.

3. ***Are we devoting adequate resources to research on forests given the values at stake?***

   With no notable exceptions, everyone agrees that too few resources are devoted to research on forests. However, many observers articulate arguments that the starting point should be improving the allocations of current resources and the results from these allocations. This would be sound advice, especially as a political strategy, if there were no fundamental disagreements on the priorities.

4. ***Are we implementing research results rapidly and well?***

A consistent answer in past evaluations of America's forest research system is that the technology transfer mechanisms need improvement. Many suggestions are made to further this improvement, but the two lessons learned in forestry, agriculture, and many other fields that stand out are:

a. Demand-pull by clients who are involved in setting priorities and identifying applied problems leads to much more rapid adoption of results compared to transfer to clients who are unaware of the research or its possible value to them.

b. Effective applied research systems are staffed by researchers who identify with and like to work with their clients. While less critical in basic research, it is not surprising that basic research done by people with strong interests in ultimate application by clients seems to be more on target and more rapidly converted to applied technology.

5. ***Are research results used appropriately by the policy system?***

This question prompted the initial dialogues that led to the Seventh American Forest Congress. The answer was, "No!" Both forest policy and management are replete with decisions and implementation based on little, if any, real science-based information. This characteristic can be found on a wide variety of issues; for example:

a. The ban on use of 2,4,5-T, which was based on risks to human health, was first implemented for forest applications, a context where relatively few people were at risk. The ban was later extended to range and pasture contexts, and finally to crops, which are most directly in the human food chain. However, 2,4,5-T is still allowed in rice production regimes. This suggests political power, not scientific information, is the important basis for this policy.

b. In the many clearcutting controversies on public and private forestlands, scientific arguments have been made by both sides to the effect that only their view is correct. In most of these controversies, both clearcutting and some kind of selection systems will work. The real reasons for favoring one over the other are values--dollars, aesthetics, wildlife, and so forth--not science.

c. Recent arguments regarding endangered species--spotted owls, merlets, and anadromous fisheries--are often based on little scientific information. The risks are real, but often the arguments are a cover for a power struggle among various interest groups and professional specialties. This has diverted attention from the common need for better information.

In summary, the diagnostics point to the need for improvement in current relationships between researcher organizations and clients. Funding is inadequate and falling slowly in real terms, and relationships among research organizations can be improved.

VISION AND MISSION

The roundtables at the October 23-25, 1996 meeting of researchers worked on a vision statement. The following is a restatement of their efforts:

> *A comprehensive, well-organized system of forest research organizations that are directed by the clients (stakeholders) and produce information useful to the formulation of policy and management decisions.*

This vision can be used as a mission statement for the aggregate system and for specific forest research units.

PRINCIPLES

A few draft principles for implementing the vision or mission emerged from the Forest Congress and the October meeting; for example:

1. Research strategies and plans are designed and conducted in collaboration with stakeholders.

2. Knowledge and technology products are understandable and effectively distributed, tested, and implemented in a timely manner.

3. Science-based information contributes to forest policy and management.

4. Research funding should be adequate considering the values at stake for forest owners, consumers, and the general publics.

5. Users pay for and set the priorities for most applied research on forests.

6. The national interest in improving the knowledge base about how forests function is the responsibility of the U.S. Congress through its authorization and appropriation processes.

7. Researchers should be independent in selecting their methods and the answers they reach to questions posed by clients.

8. A mix of funding sources and setting the agenda for basic research on forests is desirable; i.e., no one federal agency should have the sole responsibility for basic research on forests.

Refinement of selected principles will be done for the draft report that will circulate to the roundtables and collaborators.

KEY ELEMENTS OF THE FCRC ACTION PLAN

The Charleston meeting produced an action plan with several goals:

1. ***Developing a design for how to do an inventory of research projects.*** The inventory is reasonably well done for research funded by USDA dollars with state matching funds. The current inventory is very uneven for industrial, foundation, and other federal agency dollars. A workable system should include topics, scientist-years, and dollars, with frequent updates.

2. ***Mapping who is doing what.*** Closely related to inventory is a "map" of the organizations funding and conducting research, the topics, and the users of the results. One element of the solution probably will be a virtual community on the Internet of researchers concerned with forests.

3. ***Short-term update for Mandate for Change.*** *Mandate* generally is viewed as the most important of recent reviews of forest research. Many of its recommendations are still valid. A critical restatement of these at this time will help guide our efforts.

4. ***Design a research council and benchmarking the concept.*** The general concept of a Forest Resource Research Council (FRRC) emerged from the meetings to date. This council will bring together both research producer and user interests. It would be an effective mechanism for generating the on-going agenda and priorities, and for advocating both increased funding and new funding mechanisms. The "benchmarking" exercise is twofold in purpose. First, it provides ideas from other nations on forestry and within America in other areas of applied science (e.g., support for agricultural research). Second, it is a means for judging the potential of any FRRC design for actually dealing with the causes and alleviating symptoms observed.

5. ***Manual for local roundtable reviews of recommendations of FCRC.*** To make an impact on policymakers, the draft report and recommendations of the committee must be reviewed by state and local roundtables and interested collaborative groups (e.g., AF&PA, NAPFSC, "Gang of 10" environmental organizations). The most effective reviews would use the Forest Congress process to discuss the recommendations, then reach levels of agreement on each.[3] We will prepare a manual similar to the guidelines for pre-congress roundtables and collaborative meetings. The manual will help

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[3] The focus on levels of agreement is important. Agreement, which was represented by the color **Green**, is the simple statement, "I agree!" The color **Yellow** is used to represent ambiguous feelings. "I am uncomfortable, but I will go along," or "I have mixed feelings," or "I just don't know." **Red** means disagreement, but the reasons may be ambiguous rather than a simple "I do not agree!" **Red** can mean, "This is not a principle," "This is redundant with a principle I just agreed to," or it can mean "I disagree with the folks supporting this idea!"

organizers and participants have fruitful 4- to 8-hour discussions that yield results of use to the FCRC.

The manual will clearly state the purpose of the meeting with regard to reviewing the recommendation and identify important research needs. Avoiding reinvention of wheels and making sure research will help specific clients and regions is especially important. Possible relationships to regional discussions will be explored, and a strategy and plan for regional gatherings developed.

6. ***Develop an understanding of participatory research in this overall strategy.*** The words, "*[Research] is designed and conducted in collaboration with stakeholders to ensure for society the countless benefits of our forest ecosystems*" suggests a level of participation that is uncommon in American research on forests. Participatory research is becoming more common in some overseas settings using methodologies like *farming systems* and *participatory rural appraisal*. Various levels of participation have been used in public health, water, and other fields, and the Forest Congress Communities Committee advocates more trials with this approach in forestry. The advantages and disadvantages will be explored.

RECOMMENDATIONS

It is too early to suggest what specific recommendations might be made beyond establishment of the Forest Resource Research Council. However, several ideas have been explored that reflect the seriousness of both the problems and the possible solutions. The alternatives include:

1. Shift toward user-pay mechanisms for funding most applied research and some basic research, from fees based on area, products, services, and other measures of the values at stake (i.e., the Pittman-Robinson and Dingle-Johnson models for funding fish and wildlife research).

2. Expand the FRRC idea to be a national research funding foundation with state-level research funding foundations to handle the allocation of user-pay and appropriated funds.

3. Create a set of operating research foundations, each focused on the production, environmental, and social problems of specific ecoregions or national-level problems, that would replace part or all of the current system of federal, state, and industrial research units.

At the present time, none of these is likely to be strongly recommended, but support could surface as the action plan yields more information or the state and local roundtables respond to the draft report.

SOME PERSONAL OBSERVATIONS

I have worked in and with the community of researchers on forests for over 35 years. It was my good fortune to begin my career during a golden age of applied science in America. My experience includes work with the Forest Service and several state agencies, an industrial firm, many universities, and some foundations. In each case, I have seen first hand wonderful people doing first class science and equally gifted people using science-based information to help improve our private and social performances. These experiences were rewarding, and they reaffirmed my faith in science as a base for the betterment of humankind. We have helped all members of society, including the poorest, and we have moved toward realistic understanding of our global ecosystem.

My optimism is tempered, however, by several negative factors at play in American today. Citizens have less trust of science than was true a generation ago, and they are more prone to ideological strategies for addressing our forest and environmental problems. Some of this reflects over promising in the past; some is simply the malaise of Americans as they lower their expectations in a highly competitive global marketplace. Some of the distrust comes from poor education about science, especially the scientific method and philosophy, among both general citizens and professionals. No doubt environmental pollution, often caused by misapplied technology, with the attendant health hazards and possible species extinction, adds to this distrust.

The arrogance of the scientific community contributes to this distrust and the alienation of research clients from researchers. The very success of science since World War II has created a scientific elite that often is out-of-touch with the users of science-based information. In a populist democracy like America, self-proclaimed elites soon elicit negative responses from the "peasants," however defined.

In forest science, an often cited conflict within research organizations is provision of technical services. The need to do this in close juxtaposition with quality science may seem odd to many Forest Service and university scientists. Most industrial research mangers will testify, however, that effective technical services make their internal clients a supportive constituency for continuing to invest in research.

The current controversy over the Forest Inventory and Analysis (FIA) in the Forest Service, especially in the southern states, is an example. It appears that the agency is not being sensitive to a critical need. Several important clients and stakeholders want scientifically credible estimates of forest parameters like growth and standing volumes. The observation by some that FIA is not research misses the point. Provision of this service, with quality and credibility, helps maintain a strong constituency that supports the Forest Service research branch. Similar observations about extension, service forestry, and technical services are heard in other organizations. To ignore the needs of stakeholders is both arrogant and fool hardy.

The focus on clients or stakeholders by the Forest Congress throughout may seem odd to some professionals and scientists. I think it is the fundamental reason why the Forest Congress process has been reasonably successful to date and it continues to hold promise for new forest policy directions. For similar reasons, I believe that a client focus is necessary if research on forests is to flourish and meet the principles stated by the Forest Congress participants.

LITERATURE CITED

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SPORE WARS: *ENTOMOPHAGA MAIMAIGA* VERSUS GYPSY MOTH IN NORTH AMERICA

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ABSTRACT

The Asian entomophthoralean fungal pathogen *Entomophaga maimaiga* was first discovered causing epizootics in gypsy moth populations in seven northeastern states in 1989. It had not previously been reported from North America although Harvard researchers had attempted to release it in the Boston area in 1910-1911 and numerous pathogen surveys had been conducted in the northeast between 1911 and 1989. We now think that (1) this pathogen was accidentally introduced from Asia relatively recently, or (2) there is the possibility that the weakly virulent strain of *E. maimaiga* introduced in 1910-1911 remained relatively inactive in the soil and gradually adapted to North American conditions and the European strain of gypsy moth present in North America (for full discussion see Hajek *et al.* 1995). The extensive epizootics that occurred in 1989 were associated with an extremely rainy spring and increasing gypsy moth populations. This pathogen and gypsy moth were therefore unique among gypsy moth natural enemies in North America due to such high levels of mortality at low host densities.

During 1990, the distribution of this pathogen appeared to increase since *E. maimaiga* was recovered in 10 northeastern states but *E. maimaiga* occurred only far from the leading edge of gypsy moth spread. Rainfall during 1990 was relatively abundant in May but June was dry. To evaluate whether this pathogen could be introduced to new locations, *E. maimaiga* resting spores were released at 41 locations in MD, PA, VA, and WV during 1991 and 1992. 1991 was an extremely dry spring but fungal establishment was recorded in the majority of release plots, with spread of up to 350 m from release sites. During 1992, *E. maimaiga* was found in almost all release and control plots at very high levels and it had also spread across most of the contiguous distribution of gypsy moth in the northeast. Studies have demonstrated that conidia of this fungus are airborne and we hypothesize that airborne conidia both from 1991 and 1992 release plots as well as from areas to the north where *E. maimaiga* was already established were responsible for the seemingly simultaneous spread during 1992. Although many methods of spread by *E. maimaiga* are also possible, the only other method investigated to date is movement of *E. maimaiga* resting spores in mud on soles of footwear, which could account for more localized spread.

From 1990 through 1994, *E. maimaiga* was released at numerous sites in the northeast and Michigan. Although it had been confirmed that this pathogen was specific to Lepidoptera, we needed more detailed information about potential infection of non-targets. Bioassays were

conducted to test *E. maimaiga* specificity in the laboratory; of the 78 species challenged, while optimizing conditions for infection, about one-third became infected but all at low levels except one of two sphingids tested and all lymantriids. During 1994, non-targets were collected from 7 areas during *E. maimaiga* epizootics but only two individuals were infected out of > 1500 larvae reared, yielding 0.4% *E. maimaiga* infection in *Malacosoma disstria* and 1.0% *E. maimaiga* infection in *Catocala ilia*.

Epizootics have been reported in gypsy moth populations each year from 1994-1996, somewhere within the gypsy moth range. Land managers, researchers, and the public are wondering what the overall impact of this fungus on gypsy moth will be. Can it cause population crashes? What will happen to the other natural enemies of gypsy moth? Numerous field researchers have suggested that *E. maimaiga* might be shortening the duration and lessening the extent of gypsy moth outbreaks. At present, it is too early to be able to substantiate such suggestions regarding general long-term trends. To provide an example of *E. maimaiga*/gypsy moth interactions over six years, we present results from central New York from 1991-1996. *E. maimaiga* was first seen in this area in 1990. During the dry spring of 1991, in gypsy moth populations from 4,000-40,000 egg masses/ha, the gypsy moth nuclear polyhedrosis virus (LdNPV) was the predominant pathogen with the characteristic bimodal abundance as epizootics developed; however, *E. maimaiga* was also detected in all plots but at lower levels. Gypsy moth populations did not collapse in 1991. In 1992 when rainfall was slightly greater than normal during the period that larvae were present, *E. maimaiga* was the most abundant pathogen with lower levels of infection in early instars, especially in lower density plots. LdNPV was also present in all plots although more abundant in higher density plots. At the end of the 1992 season, gypsy moth egg masses were almost totally absent and no defoliation had occurred. From 1993-1996, gypsy moth populations have remained at extremely low densities. *E. maimaiga* was recovered infecting larvae throughout this time although infection levels varied, but LdNPV was almost not found at all. In summary, from plots in central New York, during a year with approximately normal levels of rainfall, *E. maimaiga* and NPV were both active during an epizootic resulting in a population crash. Needless to say, further examples of the long-term dynamics of *E. maimaiga* in association with gypsy moth and other gypsy moth natural enemies are needed before we can derive an overview of the potential changes in gypsy moth dynamics after establishment of *E. maimaiga* in North American gypsy moth populations.

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IMMEDIATE IMPACT OF BACTERIOLOGICAL AND CHEMICAL CONTROL OF *DENDROLIMUS SUPERANS* IN CENTRAL SIBERIA ON NON-TARGET INSECTS

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ABSTRACT

In September 1996, a 3-year study was initiated to compare the impact of the bacterial insecticide, DIPEL 8L, with the intensively used deltametrin pyrethroid, DECIS, on native non-target insects in *Dendrolimus superans sibiricus* Tschtvrk.-infested Siberian forests.

Two 120-ha experimental areas in the Lower Angara region of the Krasnoyarsk Kray were used for this study. The areas were forested with 35% to 95% fir (*Abies sibirica*) and with aspen (*Populus tremulae*) and birch (*Betula pendula*). Ten sample plots were established within each area and in each plot, five 2x2 m linen collection cloths were placed under randomly selected trees. An Antonov-2 aircraft equipped with Micronair AU5000 was used to treat one area with DIPEL 8L at a rate of 3.0 L/ha and the other with DECIS at a rate of 75 g(a.i.)/ha. Twenty collection cloths were placed in untreated (CONTROL) forest stands adjacent to and north of the treated areas. Pesticides were applied on September 9-12 when *D. superans* larvae in fir crowns were at instar 2 and 3. Dead insects were collected in the DECIS and CONTROL areas one day after treatment and in all areas 3 and 7 days later.

Laboratory analysis showed that the *D. superans* larvae were especially susceptible to the CryIAa toxin, followed by the CryIAb and CryIAc toxins in DIPEL 8L. Siberian moth mortality at DIPEL sites was lower (66%) then at DECIS sites (93%). Insects of five orders dominated among arthropods dropped from crowns at DECIS-treated plots: Lepidoptera (mainly Geometridae, Noctuidae, Notodontidae, Drepanidae, Arctiidae), Coleoptera (Curculionidae, Coccinellidae, Chrysomellidae), Hymenoptera (Formicidae, Ichneumonidae, Braconidae, Tenthredinidae), Heteroptera, and Diptera. It is obvious that DIPEL is ecologically a relatively safe insecticide: its immediate impact on non-target insects was registered nearly exclusively among autumn Macrolepidoptera (mainly Geometridae and Noctuidae), and was 2-3 times lower then that of DECIS. Detailed identification of the collected insects is in progress.

OUTBREAKS OF SIBERIAN MOTH, *DENDROLIMUS SUPERANS SIBIRICUS* TSCHTVRK., IN CENTRAL SIBERIA

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ABSTRACT

Dendrolimus superans sibiricus Tschtvrk. is the major defoliator of coniferous forests in Asian Russia. It is widely distributed in the Urals, Siberia, the Far East, Mongolia, northwest and northeast of China. Outbreaks occur in *Abies sibirica, Pinus sibirica, Picea* spp., and *Larix* spp. forests, though larvae feed on most conifers in the family Pinaceae.

The larvae are up to 110 mm long. The number of larval instars and the width of the head capsule for each instar can be different, depending on the length of the life cycle (two, three, or four calendar years). Male larvae have 5 to 9 instars, those of the females 6 to 10; typically males have 5 and females 6.

Moths fly and lay eggs from the end of June to the beginning of August. Eggs are deposited on needles or branches. Commonly two winters are spent in the larval stage; second to third instars and fifth to sixth instars overwinter coiled up, under the forest litter. Pupation occurs from mid-June to late July in cocoons in tree crowns. The length of the *D. superans* life cycle depends on the population density. During outbreaks, some portion of excessively dense populations has a two-year life cycle. As a result, the adults of two generations emerge simultaneously and the population increases sharply. At the depression phase, some portion of the population has a four-year life cycle, where three winters are spent as larvae.

The administrative region of Krasnoyarsky Kray covers all the territory of Central Siberia on both sides of the river Yenisej. In the fir-dominated forests of this region there were 10 outbreaks since 1873; the last five were carefully documented. They occurred in 1935-1947, 1950-1959, 1962-1969, 1978-1985, and 1989-1997 defoliating 0.7, 2.6, 0.9, 0.1, and 1.1 million ha, respectively. Pesticides were applied during the last four outbreaks: 13,000 and 190,000 ha were sprayed with DDT and 462,000 ha with pyrethroids in 1958, 1968, and 1996, respectively. Domestic bacteriological insecticides were used in 1968 (1,000 ha) and 1984 (1,500 ha). In 1996, the *Bacillus thuringiensis* formulation DIPEL 8L (Abbott Laboratories) was used on 116,400 ha. Ultra low volume applications were made using MICRONAIR AU5000 atomizers. The Global Positioning System for aircraft navigation was used for the first time in Russia.

THE PINE PROCESSIONARY CATERPILLAR, *THAUMETOPOEA PITYOCAMPA*

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ABSTRACT

The pine processionary caterpillar (PPC), *Thaumetopoea pityocampa* (Denis et Schiffermüller), has been a pest of pines in the Mediterranean region for about 2,000 years. Three aspects of its bionomics are discussed in both old and recent reports: the gregarious behavior of the caterpillars and the building of a large silk nest during the winter; the intense, repeated defoliations over vast territories; and the urtication caused to man and cattle by poisonous larval hairs.

The distribution of the PPC is the result of an interaction between climate and the distribution of its preferred host plants. Climate is the predominant factor defining the upper latitudinal and elevation limits. For example, the PPC occurs at 48°N at sea level in Central Europe, 45°N and 800 m in the Southern Alps, and 32°N and 2,000 m in Northern Africa. On the other hand, only the presence of suitable host trees defines the southern limit of the pest range which includes pine plantations near the desert in Northern Africa.

The PPC is a polyphagous defoliator of species of Pinaceae native within the pest range, though it has a strong preference for some species of pines such as *Pinus nigra*, *P. halepensis*, and *P. sylvestris*. However, exotic pines, such as *Pinus radiata* from California and *P. canariensis* from the Canary Islands, that have been introduced into Europe and occur in plantations are, by far, more heavily attacked than any other native species of pine.

The timing of the life cycle changes dramatically within the host range of this pest as a result of an adaptation to the conditions of both local climate and host plants. There are two main reasons for this: first, the variability of the time period spent by the larvae on the tree over winter (longer in the cold regions, shorter in the warmer ones); and second, the prolonged diapause of pupae that occurs in the soil. These two parameters seem to be correlated, that is, the effect of a prolonged diapause may split a given population into cohorts that are characterized by different emergence times.

Natural enemies are numerous and well adapted to the host, but they do not play a decisive role in the population dynamics of the PPC. Almost all the available types of pest control have been attempted, but a standard, acceptable method has not yet been defined. The main difficulties encountered in managing the PPC are caused by the flexibility of the life cycle and by the variety of damage the pest may cause. Currently, the microbial pesticide *Bacillus thuringiensis* (*Bt*) is

applied against larvae in autumn or early winter. However, additional research is needed to define both the optimum dose of *Bt* and the timing of its application against PPC larval stages.

An assessment of the risk for the spread of PPC outside its natural host range must consider the probability that various life stages can be accidentally transported with plant material. The egg mass, and especially the pupa, seem to be stages with higher probability of being transported with pine needles and soil, respectively. On the other hand, the territories at risk of introduction can be identified according to their climatic features and the presence of the potential host plants, especially species of pine.

IS *ENTOMOPHAGA MAIMAIGA* RESPONSIBLE FOR COLLAPSE OF GYPSY MOTH IN MICHIGAN?

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ABSTRACT

During the 1980's, the contiguous hardwood forests of Michigan's lower peninsula became infested with the gypsy moth. This infestation was not contiguous with that of the eastern states. As a result, Michigan's outbreaks were highly volatile and frequent since few of the biological control agents introduced into New England over the last century were present in Michigan.

In 1989, *Entomophaga maimaiga*, a virulent pathogen of gypsy moth from Japan, was discovered causing epizootics in several New England states. The presence of this fungus was presumed from introductions near Boston in 1910-11 by Speare and Colley. Pathogen surveys of gypsy moths in 1989 found *E. maimaiga* limited to the surrounding states, suggesting a slow spread rate since its initial introduction. Researchers were surprised with results from a 1990 survey that suggested a comparatively higher rate of spread than expected.

We were interested in determining if *E. maimaiga* were present in Michigan, and in 1991 surveyed gypsy moth larvae for pathogens in 11 counties in Michigan's lower peninsula. We also established research plots in Lake, Crawford, and Grand Traverse counties to compare the efficacy of two inoculative-release methods. Larval and cadaver samples were made throughout the season each year, as well as defoliation estimates and egg mass counts at release sites and along transects to determine establishment, monitor spread rate, and quantify the impact of *E. maimaiga* on host populations.

Entomophaga maimaiga was not found in Michigan in 1991, except at the epicenter of one of our research plots. By 1992, however, *E. maimaiga* was collected at all of our research plots, and defoliation and egg mass counts were lower in and around these plots. The following year, the fungus had spread to three adjacent counties. Surveys of all known release sites, as well as our initial survey sites, revealed the fungus spread to 13, 20, and 37 counties in 1994, 1995, and 1996, respectively.

Gypsy moth defoliation in Michigan had increased annually since 1979 with 11 acres to >700,000 acres by 1992. In 1993, however, defoliation declined to 400,000 acres, and decline

occurred annually with 97,000 in 1994, 86,000 in 1995, and only 3,200 acres in 1996. The mechanism(s) of gypsy moth collapse in Michigan are unknown; however, the initial decline in 1993 appears correlated with above average rainfalls in June of 1993 and 1996. High rainfall is well correlated with the high spread rate of *E. maimaiga*, and fungal epizootics were observed in many localities in 1996. However, cold winter temperatures, implicated in overwintering egg mortality, are also correlated with population declines in some areas. In 1997, researchers will begin to quantify the role of abiotic and biotic factors involved in the collapse of Michigan's gypsy moths.

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BROWNTAIL MOTH, *EUPROCTIS CHRYSORRHOEA*, IN CASCO BAY, MAINE

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ABSTRACT

While Maine has historically experienced severe impacts from the browntail moth since its introduction to the State in the early 1900's, only remnant populations of the browntail moth were found on a few offshore islands in the 1980's. A recent upsurge of the population within the Casco Bay region of Maine which began in 1989 has caused heavy defoliation of trees and shrubs and severe discomfort to people living in or visiting the region. Toxic hairs found on the integument of the larval stages of this insect cause a severe dermatitis on contact with the skin and may also cause respiratory problems. Mechanical removal and destruction of the overwintering webs is efficacious against low population levels, but at outbreak levels aerial control using Dimilin 4L is necessary. Environmental concerns over the use of insecticides adjacent to marine waters has raised the need for development of less disruptive control techniques. Dr. Norman Dubois of the USDA Northeastern Forest Experiment Station is currently working on studies to find an efficacious B.t. strain against the browntail. Dr. Victor Mastro of the USDA APHIS has developed an effective pheromone for survey use. Maine Forest Service personnel, with the assistance of Dr. Ronald Weseloh of the Connecticut Agricultural Experiment Station, have been releasing *Calasoma sycophanta* adults to augment local predation since 1995.

TEMPORAL CHANGES IN HEMOLYMPH LEVELS OF DIACYLGLYCEROLS AND TREHALOSE: POTENTIAL FLIGHT FUELS OF ASIAN GYPSY MOTH FEMALES

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ABSTRACT

We are attempting to assess the flight dispersal capability of Asian gypsy moth, *Lymantria dispar* (L.), females by determining how much fuel, in the form of lipids and trehalose, that females have available for flight. Gypsy moths do not feed or imbibe water as adults. They therefore must rely entirely on energy stores accrued during the larval stage to provide energy for flight, mating, and oviposition. Thus, to use an analogy, the distance that females can fly is limited by the amount of fuel they have on board just as an automobile can only travel so far on a tank of gas. Knowledge about the dynamics of lipid utilization during flight will allow us to estimate the maximum distance that gravid AGM females can disperse. This information will, in turn, help dictate the temporal and spatial placement of monitoring devices and sampling efforts. We report here baseline information concerning the temporal fluctuations in hemolymph lipid and trehalose in AGM as affected by female age, time of day, and mating status.

In moths and other insects, carbohydrates or lipids are the major energy sources for flight. Insects that do not eat as adults or those that undertake long uninterrupted flights (both are traits of AGM females) use lipids as their primary energy source. The major form in which lipids are transported through the blood from fat body storage sites is as diacylglycerols (DAG). We used a sensitive radioenzymatic DAG assay to measure changes in hemolymph DAG levels of mated females during the first photophase and scotophase of their adult life. Hemolymph DAG levels of resting, mated females were relatively stable throughout the day (8.4 - 9.1 μmole/ml). After the onset of darkness, however, DAG levels rose rapidly during the first 15 minutes of scotophase (the females begin wing fanning preparatory to flight during this time interval) and then appeared to plateau at ca. 13 μmole/ml.

Hemolymph trehalose titers were determined by the anthrone colorimetric assay. Trehalose profiles during the daylight hours were essentially the same for mated and virgin females: trehalose levels increased for several hours after eclosion then stabilized around 10 mg/ml for the remainder of the photophase. Both virgin and mated females showed an abrupt but small decline (from 10 to 8 mg/ml) in sugar concentration immediately after lights-off. Soon thereafter,

however, sugar levels in mated females rose rapidly until nearly 30 minutes after lights-off, coinciding with wing fanning and flight in these individuals. After females stopped flying, at ca. 30 minutes into the dark period, blood sugar levels dropped precipitously. By contrast, blood sugar concentrations of virgin females remained relatively stable at ca. 8 mg/ml during this same interval.

PREDICTING POTENTIAL LOSSES FROM GYPSY MOTH DEFOLIATION AND DESIGNING MANAGEMENT ACTIONS TO AMELIORATE LOSSES

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ABSTRACT

The Wayne National Forest in southeastern Ohio has heavy concentrations of forest types that are highly preferred gypsy moth habitat. This area is expected to have significant increases in gypsy moth populations in the coming decade. The Gypsy Moth Stand-Damage Model was used to predict potential losses from probable future gypsy moth outbreaks and to assess the effects of silvicultural alternatives. Following an initial survey to determine the distribution of high hazard oak-dominated stands on the Forest, forest inventory histories were reviewed and additional stands were inventoried to provide a balanced sample across the four predominant forest types and six compartments. These data were transferred to the GypsES Decision Support System that was used to maintain the input data and manage output data from simulations. Three simulation scenarios were considered: heavy, moderate, and no defoliation over 10 years starting in 1997. These three sequences were repeated for each of three silvicultural alternatives: standard presalvage thinning to the B-line (60% relative stocking in the residual stand), a light presalvage thinning (to 80% relative stocking), and no thinning. Stem counts, basal areas, board-foot volumes, and dollar value of the residual stands were summarized by species within stands and stand totals. Tests done to examine differences among compartments determined that there were no significant differences and data were pooled across compartments. Results indicate that tree mortality losses due to defoliation can be reduced by presalvage thinning of heavily stocked stands.

INTRODUCTION

The Wayne National Forest, located in southeastern Ohio, is expecting to see considerable increases in gypsy moth populations, to outbreak intensities, in the coming decade. Much of the area in and around the National Forest is currently considered to be on or very near the advancing front or leading edge of the generally infested area (Liebhold *et al.* 1997). To provide estimates of the potential losses from gypsy moth defoliation and the effects of management, we sampled

six compartments on the Wayne National Forest, selecting stands that are dominated by oak for this analysis.

METHODS

To ascertain what losses might result from future defoliation, we chose simulation trajectories that paralleled those used in the analyses for the national gypsy moth Environmental Impact Statement (Anonymous 1995). There were two consecutive 5-year episodes of either moderate or heavy defoliation and a 10-year, no-defoliation scenario used as a control. Table 1 contains the defoliation levels expected by feeding preference class.

Table 1. Percent defoliation patterns for the 5-year outbreak periods by feeding preference class (Liebhold *et al.* 1995), canopy position, and outbreak intensity.

Feeding Preference	Year 1	2	3	4	5
			Heavy Outbreak		
Preferred					
overstory	40	90	100	50	0
understory	60	100	100	30	0
Acceptable					
overstory	0	25	50	30	0
understory	30	40	70	15	0
Immune					
overstory	0	0	10	0	0
understory	0	10	25	0	0
			Light Outbreak		
Preferred					
overstory	30	50	0	0	0
understory	40	70	0	0	0
Acceptable					
overstory	0	15	0	0	0
understory	10	30	0	0	0
Immune					
overstory	0	0	0	0	0
understory	0	10	0	0	0

Thirty eight stands were used in this analysis. They were drawn from four forest types that are oak-dominated and are representative of six compartments. There are six forest types that are dominated by highly preferred hosts of the gypsy moth but only four of these were found

suitably stocked in sufficient number to warrant their inclusion in the analysis. The four forest types used in these analyses are: the Black Oak - Scarlet Oak - Hickory Type; White Oak Type; Yellow Poplar - White Oak Group - Red Oak Group Type; and the Mixed Oak Type.

To calculate the potential dollar losses, local stumpage values ($/MBF) for the most commercially important species were determined. All other species were set to $35.00/MBF as the default 1997 value. Net present values (1997) for final 2007 stumpages were calculated using a 5 percent discount rate.

Species Codes		Price	Species Common Name
Alpha	Numeric	1997-$	
WA	541	240.00	White Ash
BWA	602	240.00	Black Walnut
YP	621	60.00	Yellow Poplar
BC	762	240.00	Black Cherry
WO	802	150.00	White Oak
SO	806	55.00	Scarlet Oak
CO	832	55.00	Chestnut Oak
RO	833	195.00	Red Oak
BO	837	195.00	Black Oak

Using tree inventory data from these stands, we set up criteria for management. First, if a stand was greater than 70 percent of fully stocked in 1997, it was selectively thinned to the 60 percent line. Second, if a stand was stocked to greater than 90 percent in 1997, we also simulated a lighter removal to 80 percent residual relative stocking. Finally, the third alternative was on entry. The removal was weighted to take 20 percent more stems in the smallest 2-inch diameter class than in the largest diameter class present. These algorithms tend to remove more suppressed stems and we further assumed that this removal would also be a selection following Gottschalk's rating system and Silvicultural Guidelines (Gottschalk 1993, Gottschalk and MacFarlane 1992). We assumed that removal of the most susceptible stems would not reduce defoliation but would remove the low-vigor trees, those with highest probability of being killed during subsequent defoliation episodes. Each of these three management alternatives takes place in 1997 and is followed by the execution of a 3-simulation set of model runs: none, light, and heavy defoliation 10-year simulation scenarios.

For each 3-simulation set, the initial conditions (1997) and three final conditions (2007) and two sets of differences were stored as 18 tables by species and five diameter ranges with marginal statistics. The 54 tables were further summarized to stand totals in the five categories: stem count, relative stocking, basal area, standing board-foot volume, and dollar value. Differences between final values were calculated to determine the effects of defoliation and management actions. These data were used in the statistical analysis that assessed the similarities and differences among stands across compartments and forest types.

RESULTS

Final stand summary values were subjected to analysis of variance techniques to look for differences among the compartments and forest types being considered. No significant differences were found among the compartments included in this analysis. Data were pooled to the forest type for further analysis.

Of the 38 stands selected for this analysis (Table 2), 31 were sufficiently stocked to warrant some management considerations (Table 3) while 24 were heavily enough stocked to consider two removal levels (Table 4). Estimates of losses due to defoliation are exhibited in Table 2. Here it is evident that heavy defoliation resulted in a pronounced decrease in relative stocking, basal area, and volume. Basal area losses from moderate outbreaks averaged 7.8 ft^2/ac and ranged from 1.5 to 22.3 ft^2/ac. Heavy defoliation caused an average drop of 52 ft^2/ac, a 46% loss in basal area; losses ranged from 19.5 to 84.1 ft^2/ac. Smaller board-foot (0.45 MBF/ac) and dollar losses ($22.10/ac) were associated with light outbreaks, whereas heavy outbreaks caused dollar losses as high as $381/ac and averaged more than $245/ac, or a 52% dollar loss in standing timber.

Table 3 shows the means, standard deviations, and ranges for the same 30 variables considered in Table 2, but here there were 31 stands that were sufficiently stocked to warrant some entry. This includes stands that were marginally stocked in 1997; relative stocking levels were between 70% and 90% in seven of these stands. Another important fact to recognize with this and the following table is that the data presented is that of the residual stand and does not include the count, basal area, volume, or value of the material removed during the simulated silvicultural entries. In stands subjected to light defoliation following management, the basal area loss was cut by almost fourfold from 7.8 to 2.0 ft^2/ac. Under heavy defoliation episodes, a 32.4 ft^2/ac loss occurred in the residual basal area. Similar savings were found in terms of board-foot volumes and dollar values of the residual stands, ranging from about 20 to 55%.

When less substantial removals were considered and stands that were heavily stocked were reduced to only 80 percent of fully stocked, the savings in the residual stands were not as large but were still consistent with the alternatives (Table 4). Average dollar losses ranged from 3.7% following light outbreaks to 52.6% for heavy outbreaks. Basal area differences were similar: heavy outbreak losses averaged 50.3% while light outbreaks averaged just 4.0%.

Under the no-action alternative, the average losses from a heavy outbreak were 52.0 ft^2/ac of basal area, 3.1 MBF/ac, or $245/ac, while light thinning reduced these losses to 43.5 ft^2/ac of basal area, 2.9 MBF/ac, or $228/ac. A full presalvage thinning to the B-line further reduced losses to 32.4 ft^2/ac of basal area, 2.2 MBF/ac, or $171/ac, for an average savings of about 20 ft^2/ac of basal area or $75/ac.

Table 2. Summary data on a per-acre basis; 38 stands were used from six compartments and four forest types highly susceptible to gypsy moth defoliation. No management was applied.

Variable	Mean	Std Dev	Range Minimum	Range Maximum
STEM COUNTS AND RELATIVE STOCKING				
Initial Conditions (1997)				
Stem Counts	355.44	215.6	109.0	928.0
Relative Stocking	97.97	28.2	34.0	139.0
End of 10-Year Simulations (2007)				
No Defoliation				
Stem Counts	302.0	166.5	96.0	761.0
Relative Stocking	95.7	28.3	38.0	156.0
Light Defoliation				
Stem Counts	282.6	158.7	93.0	746.0
Relative Stocking	88.8	25.5	36.0	147.0
Loss from Light Defoliation = Difference: Light - None				
Stem Counts	-19.4	30.4	-179.0	0.0
Relative Stocking	-6.8	5.2	-21.0	-1.0
Heavy Defoliation				
Stem Counts	246.1	118.5	73.0	587.0
Relative Stocking	50.5	16.7	19.0	95.0
Loss from Heavy Defoliation = Difference: Heavy - None				
Stem Counts	-55.9	80.5	-383.0	44.0
Relative Stocking	-45.2	17.6	-79.0	-19.0
BASAL AREA				
Initial Conditions (1997)				
Basal Area	115.7	27.0	38.2	157.4
End of 10-Year Simulations (2007)				
No Defoliation				
Basal Area	113.9	28.3	41.7	182.3
Light Defoliation				
Basal Area	106.2	25.8	39.5	170.0
Basal Area Diff.	-7.8	5.7	-22.3	-1.5
Heavy Defoliation				
Basal Area	61.9	19.4	22.2	108.8
Basal Area Diff.	-52.0	17.5	-84.1	-19.5

Table 2 (cont.).

Variable	Mean	Std Dev	Range Minimum	Range Maximum
		STAND VOLUMES AND VALUES		
		Initial Conditions		
Volume (MBF)	6.0	1.7	1.3	8.8
Dollar Value	468.9	159.5	86.0	737.9
		End of 10-Year Simulations (2007)		
		No Defoliation		
MBF	5.9	1.5	1.5	8.2
Dollar Value	474.7	147.1	88.0	719.4
		Light Defoliation		
MBF	5.5	1.4	1.4	7.6
Dollar Value	452.7	143.7	86.6	704.0
MBF Difference	-0.45	0.39	-1.5	0.0
Dollar Val. Diff.	-22.1	14.2	-56.9	-1.4
		Heavy Defoliation		
MBF	2.8	0.9	0.8	4.5
Dollar Value	229.5	75.0	44.2	345.8
MBF Difference	-3.1	1.2	-5.1	-0.7
Dollar Val. Diff.	-245.2	79.7	-381.0	-43.8

Table 3. Summary data on a per-acre basis; 31 stands with relative stocking over 70 percent fully stocked were treated by removal to 60 percent relative stocking in 1997. All data here represent conditions following these simulated silvicultural manipulations.

Variable	Mean	Std Dev	Range Minimum	Range Maximum
STEM COUNTS AND RELATIVE STOCKING				
Initial Conditions (1997)				
Stem Counts	75.3	16.3	51.0	117.0
Relative Stocking	58.4	0.8	58.0	62.0
End of 10-Year Simulations (2007)				
No Defoliation				
Stem Counts	170.7	35.0	97.0	247.0
Relative Stocking	55.7	2.9	46.0	60.0
Light Defoliation				
Stem Counts	167.9	35.0	94.0	251.0
Relative Stocking	54.1	3.2	45.0	59.0
Stem Count Diff.	-2.8	2.2	-7.0	4.0
Rel. Stocking Diff.	-1.6	0.7	-3.0	-1.0
Heavy Defoliation				
Stem Counts	200.2	50.4	83.0	300.0
Relative Stocking	28.0	5.6	19.0	43.0
Stem Count Diff.	29.5	21.3	-14.0	80.0
Rel. Stocking Diff.	-27.7	5.2	-39.0	-15.0
BASAL AREA				
Initial Conditions (1997)				
Basal Area	70.7	7.7	61.8	94.3
End of 10-Year Simulations (2007)				
No Defoliation				
Basal Area	68.3	7.7	56.6	92.6
Light Defoliation				
Basal Area	66.3	7.9	54.6	91.3
Basal Area Diff.	-2.0	0.75	-3.8	-1.1
Heavy Defoliation				
Basal Area	35.9	10.7	21.6	67.6
Basal Area Diff.	-32.4	4.4	-41.3	-22.0

Table 3 (cont.).

Variable	Mean	Std Dev	Range Minimum	Range Maximum
		STAND VOLUMES AND VALUES		
		Initial Conditions (1997)		
Volume (MBF)	4.2	0.75	2.6	5.9
Dollar Value	325.6	86.8	109.9	550.6
		End of 10-Year Simulations (2007)		
		No Defoliation		
MBF	4.2	0.6	3.0	5.9
Dollar Value	331.8	78.4	124.3	521.8
		Light Defoliation		
MBF	4.0	0.6	2.9	5.9
Dollar Value	321.9	77.8	121.3	512.1
MBF Difference	-0.2	0.1	-0.3	0.0
Dollar Val. Diff.	-9.9	3.2	-17.1	-3.0
		Heavy Defoliation		
MBF	2.0	0.7	0.8	4.4
Dollar Value	160.6	46.5	37.8	255.2
MBF Difference	-2.2	0.30	-2.7	-1.5
Dollar Val. Diff.	-171.2	36.6	-266.6	-86.5

Table 4. Summary data on a per-acre basis; 24 stands with relative stocking greater than or equal to 90 percent fully stocked were treated by removal to 80 percent relative stocking in 1997. All data here represent conditions following the simulated silvicultural manipulations.

Variable	Mean	Std Dev	Range Minimum	Range Maximum
STEM COUNTS AND RELATIVE STOCKING				
Initial Conditions (1997)				
Stem Counts	95.00	15.50	68.0	128.0
Relative Stocking	77.75	0.44	77.0	78.0
End of 10-Year Simulations (2007)				
No Defoliation				
Stem Counts	103.91	15.51	69.0	136.0
Relative Stocking	73.12	3.81	61.0	78.0
Light Defoliation				
Stem Counts	105.54	15.98	70.0	136.0
Relative Stocking	70.33	4.18	59.0	75.0
Stem Count Diff.	1.62	2.36	-1.0	10.0
Rel. Stocking Diff.	-2.79	1.10	-5.0	-1.0
Heavy Defoliation				
Stem Counts	164.00	28.56	95.0	213.0
Relative Stocking	35.08	5.92	23.0	44.0
Stem Count Diff.	60.08	21.83	26.0	106.0
Rel. Stocking Diff.	-38.04	6.20	-53.0	-30.0
BASAL AREA				
Initial Conditions (1997)				
Basal Area	90.82	6.00	82.3	100.8
End of 10-Year Simulations (2007)				
No Defoliation				
Basal Area	86.45	6.38	73.8	95.2
Light Defoliation				
Basal Area	83.02	6.78	71.4	92.8
Basal Area Diff.	-3.43	1.14	-5.7	-2.0
Heavy Defoliation				
Basal Area	42.96	9.54	27.5	58.6
Basal Area Diff.	-43.49	5.72	-56.4	-34.9

Table 4 (cont.).

Variable	Mean	Std Dev	Range Minimum	Range Maximum
		STAND VOLUMES AND VALUES		
		Initial Conditions (1997)		
Volume (MBF)	5.48	0.77	3.5	7.0
Dollar Value	432.08	101.31	147.4	596.9
		End of 10-Year Simulations (2007)		
		No Defoliation		
MBF	5.39	0.60	4.0	6.4
Dollar Value	434.21	94.70	165.0	606.9
		Light Defoliation		
MBF	5.08	0.61	3.8	6.0
Dollar Value	417.96	94.52	156.0	589.4
MBF Difference	-0.30	0.11	-0.5	-0.1
Dollar Val. Diff.	-16.25	4.31	-23.7	-9.0
		Heavy Defoliation		
MBF	2.46	0.64	1.0	3.7
Dollar Value	205.90	57.04	48.7	293.7
MBF Difference	-2.92	0.33	-3.6	-2.4
Dollar Val. Diff.	-228.31	40.56	-313.2	-116.3

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THE EUROPEAN GYPSY MOTH IN COASTAL PLAIN PINE-HARDWOOD STANDS:

OVERSTORY DEFOLIATION AND TREE MORTALITY

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ABSTRACT

As gypsy moth (*Lymantria dispar* L.) populations have expanded their range into the southeastern United States, outbreaks in previously undefoliated forest types have become more frequent. Recent laboratory studies have revealed that sweetgum (*Liquidambar styraciflua* L.) and loblolly pine (*Pinus taeda* L.) are potential hosts for the gypsy moth. Both of these species occur in pure and mixed stands throughout the Southeast, therefore the potential for defoliation by advancing populations appears to be great. Unfortunately, we cannot extrapolate the results of laboratory feeding studies to the field. Designed field experiments are needed to adequately address forest management issues. Thus, in 1992 we initiated a study to determine the effects of gypsy moth defoliation on the growth and mortality of loblolly pines and hardwoods growing in mixed stands.

Between 1992 and 1993, 141 research plots were established in 47 mixed stands in the Coastal Plain of Virginia and Maryland. Two stand types were selected for study: mixtures of loblolly pines and oaks, and mixtures of loblolly pines and sweetgum. Individual stands were selected in order to achieve a representative sample of a range of stand conditions, from relatively pure pine stands to relatively pure hardwood stands.

In both stand types studied, the proportion of susceptible species present at the time of plot establishment appeared to influence the intensity of defoliation. Stands with a larger proportion of hardwoods had greater annual defoliation levels. Oaks and sweetgum were both heavily defoliated on a wide scale. Individual pines were observed to experience some defoliation, however, even in areas where the susceptible hardwoods had been completely stripped, large-scale defoliation of pines did not occur. Pine-oak stands lost more total basal area than pine-sweetgum stands. The majority of this mortality consisted of susceptible hardwoods, mainly oaks. Conversely, while the defoliation of sweetgum was intense, mortality was negligible indicating that this species may be less vulnerable to mortality than some of the common oak species. Mortality in both stand types was also influenced by factors unrelated to defoliation. The combined effects of defoliation and a wildfire in 1993 produced some of the highest levels of mortality that were observed among pine-oak stands. Also, although some stands did suffer mortality of individual pine trees it was not clear that this mortality was a result of defoliation. In one of the stands examined, pine mortality occurred prior to any defoliation as a direct result of a southern pine beetle (*Dendroctonus frontalis* Zimmerman) outbreak.

ON UNDERSTANDING THE MECHANISM OF *BACILLUS THURINGIENSIS* INSECTICIDAL ACTIVITY

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ABSTRACT

Bacillus thuringiensis (*Bt*) strains are entomopathogenic to species within Lepidoptera, Diptera, or Coleoptera depending on the type of delta-endotoxins (also referred to as the Insecticidal Crystal Proteins or ICP) they produce. They are classified on the basis of the DNA homology of their toxin genes and the insecticidal activity spectrum of the ICP. Briefly, the CryI class is specific for Lepidoptera and the crystal is bipyramidal. The CryII class is Lepidoptera-Diptera specific and the crystal is cuboidal. The CryIII class is specific for the Coleoptera and the crystal is rhomboidal. The CryIV class is specific to Diptera and the crystal of this group can be bipyramidal, ovoid, or bar shaped. The site of action of these Cry classes of toxins is the membrane of the midgut cells of susceptible insects. A fifth class is the Cyt class; its crystal is amorphous and is cytolytic to susceptible Diptera.

Although there is only about a 25% amino acid sequence similarity between the different Cry ICPs, their three-dimensional structure is similar and organized into three domains. Domain I, a bundle of six amphipathic and one hydrophobic alpha-helices, is involved in membrane insertion and pore formation. Domain II is three antiparallel beta-sheets terminating in three loops at the apex of the molecule; they are probably responsible for recognizing and binding to receptors on the midgut columnar cells. The Domain III is a tightly packed beta-sandwich in which the conserved C-terminus is buried within its center. This domain is resistant to further proteolysis and maintains the structural integrity of the molecule. The structural similarity between ICPs may be due to five identical conserved regions; two are located near the C-terminus of Domain I and the N-terminus of Domain II and three are located in Domain III.

After ingestion, the ICP is solubilized by high pH to a protoxin in the midgut of the larva. The protoxin is activated by midgut protease, reducing it to a protease-resistant toxin. The active toxin binds to the receptor (identified as Aminopeptidase N), and inserts the helices in the apical membrane of the columnar cell, resulting in pore formation and disruption of the channel functions (potassium (K^+) transport). Exchange of alanine and serine with glycine and leucine in the alpha-8 loop or asparagine with either glycine or alanine in loop 2 significantly increased the toxicity of the CryIAb against gypsy moth larvae. Combining both mutations in a single CryIAb

further increased the toxicity of the ICP. These increases in toxicity correlated with increases in binding efficiency and with disruption of the K^+ transport (measured by increased short circuit inhibition across the midgut membrane). Deletion of the amino acids in loop 2 resulted in complete loss of toxicity, decreased binding, and K^+ transport inhibition. None of these alterations had an effect on the structural stability of the ICP. The disruption of the K^+ transport causes depolarization of the columnar cell apical membrane; this is followed by closure of the junction gap between the goblet and columnar cells and collapse of the transepithelial potential. Osmotic events (Donnan Effect) occur whereby water is taken up by the columnar cell, causing it to swell and lyse. This final event leads to loss of midgut integrity. These reactions occur within 30-40 minutes after ingestion followed by death 48-72 hours later from starvation or septicemia. This sequence of events generally is common in most susceptible larvae, especially in lepidopteran larvae.

THE OCCURRENCE OF GENETIC MARKERS IN THE CANADIAN GYPSY MOTH POPULATION

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ABSTRACT

To distinguish among varieties of gypsy moth, two genetic markers are presently used: (a) mitochondrial: based on the amplification of a segment of mitochondrial DNA followed by restriction digests (*Nla*III and *Bam*HI) (Bogdanowicz *et al.* 1993), and (b) FS1: based on the amplification of a segment of the genomic DNA (Garner and Slavicek 1996). In 1993, 618 specimens trapped around Eastern Canadian ports were analyzed using the genomic FS1 marker and 58 specimens were heterozygous (N+A) for both the Asian and North American bands while 560 were homozygous (N) for the North American band (P. Covello, Agriculture Canada). In 1994, we analyzed 198 specimens using the mitochondrial test and 6 were N+/B- (mostly seen in Europe and part of Asia) while 192 were N-/B- (mostly seen in North America and sometimes in Europe). This suggests that the genetic background of North American gypsy moth is not homogenous. In 1995, we initiated a survey within the area of Canada generally infested with gypsy moth to: (a) determine the occurrence and distribution of the FS1 and mitochondrial markers in the Canadian gypsy moth population, (b) determine if the genetic make up is different around ports and military bases (high risk of introduction of exotic gypsy moths) than in other areas (low risk of introduction), and © establish a reference collection to evaluate the diagnostic potential of new markers. Traps were placed in 18 chosen sites with a grid of 40 x 30 km. The distance between traps was 5 km for a total of 63 traps per site. More than 14,000 specimens were collected from the traps. A subset of ~2,100 insects (equivalent to 15%) was dissected and DNA was extracted. The DNA extracts were then analyzed using both the mitochondrial and FS1 genomic markers.

Results showed no significant differences between low and high probability sites within the same province or area. The differences were more pronounced between different parts of the infested area. Ontario had a mitochondrial N+/B- average of 3.62% and FS1 heterozygous (N+A) average of 6.59% and the Eastern part of the Canada (Nova Scotia, New Brunswick, and Québec) had a mitochondrial N+/B- average of 0.200% and FS1 heterozygous (N+A) average of 1.67%. The FS1 and mitochondrial markers are able to detect most cases of introduction of exotic gypsy moths. However, more markers are needed to distinguish the North American subpopulation that

displays either heterozygous FS1 (N+A) or N+/B- markers from exotic moths with similar genetic typing.

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BLEPHARIPA SCHINERI (DIPTERA: TACHINIDAE), A PROMISING NATURAL ENEMY OF GYPSY MOTH

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ABSTRACT

The tachinid fly *Blepharipa schineri* (Mesnil) is a Palearctic species that holds promise as a natural enemy of gypsy moth. Significant levels of gypsy moth parasitism have been reported from different temperate regions of Eurasia. It has a number of biological characteristics that are of interest: (1) it is univoltine, having an obligate diapause, and does not require an alternate host; (2) it has a high biotic potential (≈5,000 eggs per female); (3) parasitism is likely to be biased toward female gypsy moths; and (4) it is well adapted to xeric habitats favored by gypsy moth. Initial indications are that host specificity is high, but more information is needed. *Blepharipa schineri* appears to be fairly host specific; only two other hosts, *Endromis versicolora* and *Dendrolimus sibiricus*, are mentioned in literature. While this information is encouraging, we need to challenge *B. schineri* with some representative North American Lepidoptera to acquire more information on the risk it presents to non-target species.

Oviposition cues were tested by offering females of *B. schineri* bouquets of red oak with (1) intact leaves, (2) simulated feeding, leaf edges notched with a cork borer, (3) leaves previously fed upon by larvae of *L. dispar*, and (4) tethered feeding caterpillars of *L. dispar*. After 24 h, bouquets were examined for eggs of *B. schineri* and the numbers tabulated. The results suggested that oviposition by females was biased with 7% of the eggs on intact leaves, 14% on leaves with simulated feeding, 39% on leaves with feeding by *L. dispar*, and 40% on leaves with tethered larvae of *L. dispar*. The data suggested that host feeding was the important stimulus, whether or not a host larva was present.

Gypsy moth populations in Alsace (France) had collapsed in 1995, so it was not possible to collect large numbers of parasitized hosts in 1996. Nevertheless, it was possible to collect adults of *B. schineri* at some sites. Females placed in sleeve cages over branches of trees infested with lab reared hosts oviposited on the leaves, and parasitism was obtained when the leaves were shipped to Newark, DE, and offered to gypsy moth larvae in quarantine.

GYPSES: A DECISION SUPPORT SYSTEM FOR GYPSY MOTH MANAGEMENT

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ABSTRACT

GypsES is a computerized decision support system for gypsy moth management being developed by the USDA Forest Service Northeastern Forest Experiment Station and State & Private Forestry (both the Northeastern Area and Region 8). GypsES provides decision support to gypsy moth managers by identifying areas of concern; recommending areas to monitor; recommending areas to treat using either silvicultural alternatives, direct suppression for established populations, or eradication of localized spot infestations; providing treatment support options for modeling losses with and without treatment; uploading and downloading of spray block and spray line information through Global Positioning System files; and spray deposition modeling. The system is based on GRASS, a public domain set of GIS routines. It can handle all geographic data and features spatially referenced databases as well as a full-featured map creation and edit facility using topographic backgrounds. The system was designed and created with a user-friendly interface programmed in C under Unix X-windows/Motif. Rule-based logic and independent models are also integrated to support users' management decisions. The system can produce reports, create maps, and export graphics files for use in other programs. The basic objectives of GypsES are to model the sequence of evaluations necessary for gypsy moth management decisions and to provide active managers of a gypsy moth problem (or other pest) with useful tools to make their work more efficient and enable better decisions. Version 1.0 is now being finalized.

MANAGING FORESTS FOR GYPSY MOTH USING SILVICULTURE:

INTRODUCTION AND OVERVIEW

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ABSTRACT

A large-scale study was established at the West Virginia University Forest in 1989-90 with the following objectives: (1) to evaluate the effectiveness of two silvicultural treatments (presalvage and sanitation thinnings) in minimizing gypsy moth effects on forests, and (2) to determine the mechanisms involved in silviculture-gypsy moth interactions. Four replicates of each thinning and adjacent unthinned treatment stands were installed prior to gypsy moth defoliation. The study areas were large enough that the dynamics of gypsy moth populations would be only partially affected by dynamics outside of the plot. The mechanisms included in the study were: vegetation dynamics (both overstory and understory), secondary mortality agent dynamics, seed production, litter fall and leaf area index, dendrochronology/growth analysis, gypsy moth population dynamics, small mammal predation on gypsy moth, ground-dwelling invertebrate predator dynamics, bird community predation, gray squirrel habitat, hazard-rating evaluation, and economic feasibility of harvesting gypsy moth silvicultural treatments. Stands were thinned during the winter of 1989-90. Six of the 16 study stands were defoliated in 1990 and 1991. Six other stands were accidentally sprayed with Dimilin during 1990 which prevented further defoliation from occurring. Other factors influencing the study were: droughts in 1988 and 1991; defoliation of yellow-poplar by the yellow-poplar weevil, *Odontopus calceatus*, in 1992-94; defoliation of red maple by the lesser maple spanworm, *Itame pustularia*, in 1995-96; and an ice storm in 1995.

The two silvicultural treatments, presalvage and sanitation thinning, are used in different types of stands and have different objectives. Presalvage thinning's objective is to reduce damage (mortality primarily) by removing trees with higher probabilities of dying before they are defoliated and die and leaving trees with lower probabilities of dying, i.e., to reduce stand vulnerability. It is applied to stands that contain predominately susceptible species (greater than 50 percent of basal area), have sufficient stocking to be thinned, are greater than 15 years from maturity, and are 1 to 3 years or more before gypsy moth defoliation. Sanitation thinning's objective is to prevent the spread and establishment of gypsy moth by reducing gypsy moth habitat via removing preferred food (host) trees, removing structural features or refuges for larvae, and by promoting predator and parasite habitat. It is applied to mixed stands (less than 50 percent basal area in susceptible species) that have sufficient stocking to be thinned, are greater than 15 years from maturity, and are 1 to 3 years or more before gypsy moth arrival.

MANAGING FORESTS FOR GYPSY MOTH USING SILVICULTURE: OVERSTORY SEED PRODUCTION AS INFLUENCED BY DEFOLIATION

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ABSTRACT

As part of the evaluation of the effectiveness of silvicultural treatments to minimize gypsy moth effects on forests at the West Virginia University Forest, two treatments, sanitation thinning and presalvage thinning, are being tested. Estimates of defoliation, growth, and mortality were measured on permanent plots. As part of the evaluation of defoliation patterns and silvicultural treatments, seed traps were used to measure the annual seed fall. Seed fall was analyzed for the influence of silvicultural treatment, defoliation, stand composition, and year effects. Year had a highly significant effect for total, oak, and yellow-poplar seed falls. Seed fall was highly variable from year to year with good and poor years occurring for total, oak, and yellow-poplar seed fall, and year was generally the most important variable affecting seed fall. Oak seed fall was the major component of total seed fall, so they had similar patterns. Defoliation had a highly significant negative effect on total and oak seed falls, but not on yellow-poplar seed fall. Stand composition had a highly significant effect on yellow-poplar seed and was the most important variable for yellow-poplar seed fall where defoliation was not important. It was also significant for oak seed fall, but not for total seed fall. Silvicultural treatment had no effect on total, oak, or yellow-poplar seed fall. Significant interactions between year and defoliation, year and composition, and composition and defoliation are all plausible and can be explained by the relationships between gypsy moth feeding preference and stand seed source and contribute to understanding the seed fall produced in these stands.

MANAGING FORESTS FOR GYPSY MOTH USING SILVICULTURE: TESTING THE EFFECTIVENESS OF SILVICULTURAL TREATMENTS IN REDUCING OVERSTORY DEFOLIATION AND MORTALITY

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ABSTRACT

Invasion of eastern forests by the exotic insect, gypsy moth (*Lymantria dispar* L.), has resulted in defoliation and subsequent tree mortality. Disturbance from these factors varies widely across the landscape. In our study of the management of gypsy moth using silviculture, this presentation focused on the first objective: to evaluate the effectiveness of two silvicultural treatments (presalvage and sanitation thinning) in minimizing gypsy moth effects on forests. Six of 16 stands were defoliated for 2 years by gypsy moth. Three years after defoliation ended, mortality was evaluated. Host preference class had a significant effect on defoliation patterns but thinning did not. Mortality was strongly influenced by defoliation patterns and by thinning. Thinning and defoliation had a significant interaction: in undefoliated stands, thinning had no effect on mortality, but in defoliated stands, it reduced mortality. Defoliated sanitation thinnings did not have a significant effect on mortality, but thinned stands did have lower mortality rates. Defoliated presalvage thinnings had significantly lower mortality rates than unthinned stands.

This study was the worst case test of these treatments as there was no time between the completion of the thinning treatments (April 1990) and defoliation (May-June 1990) for the residual trees to adjust to the treatments and increase in vigor. The sanitation thinning treatment was not effective in reducing defoliation, but did reduce mortality some (not statistically). The presalvage thinning treatment was effective in reducing mortality and has potential for even better results if given more time between treatment and defoliation. These results support the use of silvicultural treatments prior to gypsy moth defoliation to minimize gypsy moth effects on tree mortality.

GYPSY MOTH POPULATIONS OF DIFFERENT ORIGINS CAN BE CLASSIFIED USING HEAD-CAPSULE COLORATION

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ABSTRACT

Spectral frequencies from digitized color images of gypsy moth head capsules were obtained using Imagepro software. The gypsy moths were from 28 populations of larvae collected from field locations in Russia and the United States and from laboratory colonies. Discriminations between populations were done in sequential fashion to derive 26 variables. The usefulness of these 26 variables for distinguishing individuals according to population was verified for the original 28 populations.

A study was designed to assess the reliability of these variables in classifying populations by geographic origin. Gypsy moths were collected from 23 locations in Europe, the United States, and Russia. The 26 variables were used to discriminate among these 23 populations and the classification matrix was used as a measure of similarity. A 2-dimensional projection was produced. When populations from the same country were grouped on this projection, their relative position was consistent with their corresponding location on a map of Eurasia. The position of populations on the projection also reflects similarities in their biological and physical characteristics assessed in separate studies.

A second study examined head capsules from 16 laboratory-reared crosses to determine the reliability of the method to classify populations by genetic origin. The projection for the 16 crosses between Russian and North American strains resulted in a distribution that conformed to genetic relatedness. Backcrosses were located closest to the corresponding parental strain, while the F_1 and F_2 hybrids were located between the backcrosses.

With the introduction of flighted females into the United States from Europe and Asia, a method of distinguishing populations is needed to plan and evaluate suppression and eradication programs. The procedure described is inexpensive and could prove useful in formulating management decisions.

EFFECTS OF FOREST THINNING ON SMALL MAMMAL ABUNDANCE AND PREDATION ON GYPSY MOTH LARVAE AND PUPAE

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ABSTRACT

Silvicultural manipulations may be used to reduce forest susceptibility or vulnerability to defoliation by the gypsy moth. The effects of this management strategy on small mammal abundance were determined by pitfall-trapping small mammals one year prior to silvicultural thinnings and for three years following logging on the West Virginia University Forest. Survival rates of gypsy moth larvae and pupae were monitored in three types of exclosures placed at three heights in the forest strata. The small mammal community sampled on our study site varied in their response to silvicultural manipulation. We found little change in total small mammal, *Sorex cinereus* and *Clethrionomys gapperi* abundance as a result of thinning. *Peromyscus* spp. abundance increased significantly after thinning. They may have responded to increasing amounts of understory vegetation which could provide cover, as well as an increased invertebrate food supply. Thirty-seven percent of larvae and 25 percent of pupae were killed by predators over the 3 days of observations each year. Thinning did not influence the proportion of larvae or pupae killed. Survival of larvae and pupae on the ground was significantly lower than that found on tree boles or in the foliage. Differences in survival among exclosure types indicated that invertebrates were the major predators of larvae and small mammals were the major predators of pupae.

ENTOMOPHAGA MAIMAIGA: WHERE DO WE GO NOW?

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ABSTRACT

During 1996, larval mortality due to the entomophthoralean pathogen *Entomophaga maimaiga* was abundant in many gypsy moth populations across the northeastern distribution of this pest as well as in Michigan. The repeated epizootics caused by this fungal pathogen in North America since 1989, when it was first found in North America, provide convincing evidence that *E. maimaiga* is well established. However, we have much yet to learn about this Asian endemic; I envision two major types of information needed: (1) information about the ecology of *E. maimaiga,* and (2) the use of this pathogen for gypsy moth control.

Knowledge of the interactions of *E. maimaiga* with the biotic and abiotic environment will allow a better understanding of this fungus and hopefully will lead to some ability to predict *E. maimaiga* activity. In considering the biotic environment, we could use more information about the impact of this obligate pathogen on gypsy moth populations and the extent of resulting host population decline under differing conditions. Recently, there has also been interest voiced in the impact of this fungus on other natural enemies of gypsy moth. Fungal entomopathogens can potentially impact other natural enemies directly (within the same host) and/or indirectly (by decreasing host density). We know little about either direct or indirect interactions of *E. maimaiga* with the suite of other gypsy moth natural enemies although recent data suggest that both *E. maimaiga* and the gypsy moth nuclear polyhedrosis virus (LdNPV) can co-occur within cadavers and can both be active in populations at the same time. Extensive studies have been conducted investigating the impact of *E. maimaiga* on non-target Lepidoptera. In field studies of the effect of *E. maimaiga* on non-targets (Hajek *et al.* 1996a), field populations of the most potentially susceptible group, the lymantriids, were extremely low; while no infection was found, due to the small sample size the impact of *E. maimaiga* on non-target lymantriids in the field should be investigated further. Since epizootics of *E. maimaiga* first occurred in North America in 1989, during an exceptionally rainy spring, there has been an assumption that extreme levels of rainfall are necessary for this fungus to cause high levels of infection. Data since 1989 have demonstrated conflicting results regarding whether rainfall in May or June is associated with levels of *E. maimaiga* infection (Weseloh and Andreadis 1990, Hajek *et al.* 1996b), while additional studies have provided further data on the positive association between *E. maimaiga* activity and rainfall (Weseloh and Andreadis 1992, Smitley *et al.* 1995). However, we have seen that *E. maimaiga* can also be active during relatively dry years, e.g., in 1991 (a dry spring) *E. maimaiga* epizootics occurred at one site in Virginia where populations subsequently collapsed and sites in Connecticut (Weseloh and Andreadis 1992) and central New York. It is clear that we have more to learn about the associations between *E. maimaiga* and moisture in the field. In

actuality, the interactions among host, pathogen, **and** the environment (both biotic and abiotic) determine disease transmission and research programs should attempt to evaluate all three using a holistic approach.

Studies of the use of *E. maimaiga* for gypsy moth control have almost entirely been directed toward introduction of this fungus to areas where it does not occur. We know that this fungus can spread on its own but, at present, we are unable to predict how quickly it will independently move into leading edge populations. Thus, land managers in leading edge populations are generally eager to introduce *E. maimaiga* to these areas. Studies have also begun on the use of this fungus for inoculative augmentation in areas where it already exists, in order to initiate epizootics earlier than they would naturally occur. One stumbling block to use of *E. maimaiga* for gypsy moth control is acquisition of this fungus for release. The potential for in vitro production of hyphal bodies by *E. maimaiga* exists but production using this technology is not presently being investigated and it is not known whether hyphal bodies produced in this manner will be able to survive and initiate disease cycles in the environment after release (this stage occurs within infected insects). *E. maimaiga* can be grown in laboratory colony insects but, at present, this methodology is only suitable on a small scale. At present, almost all control-based studies have been conducted using field-collected resting spores. To acquire resting spores, one can either collect cadavers of late instars from trees during or shortly after an epizootic or one can collect soil contaminated with resting spores. While cadaver collection is preferable to moving soil, this can only be undertaken shortly after epizootics and care must be taken regarding storage of cadavers containing resting spores prior to their release at a new location. In order to collect soil bearing resting spores, one must know the exact locations where epizootics have occurred in the recent past, permissions for collecting and moving soil must be obtained from both state and federal agencies, soil must be collected from locations with the greatest possibility of having high titers of resting spores and, optimally, resting spore content of the soil should be confirmed and quantified (Hajek and Wheeler 1994).

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DO CLIMATE AND TIMING DURING THE OUTBREAK-LATENCY SEQUENCE AFFECT GYPSY MOTH PARASITISM IN THE NATIVE RANGE ?

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ABSTRACT

Gypsy moth (*Lymantria dispar* (L.)) parasitism was studied between 1994 and 1996, during the last year of the outbreak phase in two areas climatically very distinct, Corsica and Alsace (Northeastern France), and during the first year of the latency phase in Alsace.

During the last year of the outbreak phase, young larvae were mainly attacked by the braconid *Glyptapanteles porthetriae* Muesebeck in both regions. Collapse of populations during the second half of gypsy moth larval development was due to the tachinid *Blepharipa pratensis* (Meigen) alone in the warm climate, and to the combined actions of NPV and the tachinid *Parasetigena silvestris* (Robineau-Desvoidy) in the cool climate. *Blepharipa schineri* (Mesnil) attacked a good proportion of gypsy moth larvae during the last year of outbreak in the cool climate site, but its parasitism was masked by multiparasitism with *P. silvestris,* and competition that was very favorable to *P. silvestris*.

During the first year of the latency phase at the cool climate site, *Phobocampe disparis* (Viereck) replaced *Glyptapanteles* as the most abundant parasitoid of young larvae, but *P. silvestris* was still the most abundant parasitoid of old larvae. Its persistence and efficacy in finding targets in low host densities is noteworthy. Predominance of *P. silvestris* was repeated during the first year of the latency phase, although presence and evidence of egg laying by *Blepharipa* was shown.

THE NUN MOTH, *LYMANTRIA MONACHA* L.

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ABSTRACT

The nun moth is a species that is widely distributed in the Palearctic region. In Europe, it occurs in the area located between Sweden and Finland and northern Spain, Italy, Greece, and Bulgaria. In the east, the nun moth can be found in isolated locations as far as Japan. The region of nun moth outbreaks in Europe comprises Poland, Germany, the Czech Republic, and Austria. During the last 100 years, more than 60 outbreaks were recorded in Scots pine and Norway spruce stands characteristic of that area (Bejer 1988).

Host Plants

The nun moth is a polyphagous species. Scots pine, Norway spruce, and European larch are the most preferred coniferous host plants, while among broadleaved species, it prefers European beech, European birch, and species of oak. During the outbreak from 1978-1984 in Poland, the nun moth also attacked exotic American species, such as Jack pine, blue spruce, and Douglas fir.

Biology

The nun moth is closely related to the gypsy moth, so the biology of both species is very similar. Adults of the nun moth appear at the beginning of July and can be observed until mid August. Unlike the gypsy moth, the adults of the nun moth are active at night and they are often attracted to light. The adults of both sexes fly long distances; the males may even fly over a distance of more than 100 kilometers (Sliwa 1987). The males are attracted by a sex pheromone which many be advantageous in monitoring nun moth populations. The similarity of the nun moth and gypsy moth sex pheromones is such that in the traps used for monitoring nun moth males in Poland, 10-20% of the individuals trapped are male gypsy moths.

After mating, the females lay 70-300 eggs that are hidden in bark crevices or under lichens (Sliwa 1987). After embryonation, the larvae overwinter within the eggs, and during that time, they exhibit high tolerance to low temperatures (to -40◦C). Hatching takes place at the end of April and at the beginning of May. After having emerged, the larvae remain for a few days on the bark surface grouped in so-called "little mirrors." This unexplained behavior is important for the survival of the larvae. Young larvae begin their feeding on new foliage or on the male inflorescences of coniferous host plants. It is very important for further population success that there is synchrony in the time of larval hatch and the time of development of young leaves or flower shoots; the older larvae feed on old foliage. The larvae have 5-6 moults in their life cycle

and during that time may damage about 300 pine needles or 1,000 spruce needles. They pupate in June and July, usually on stems and branches of host trees.

Factors Limiting Nun Moth Populations

Spring frosts are an important abiotic factor affecting nun moth populations because the newly hatched larvae are very susceptible to low temperatures. Heavy rains also wash away the youngest larvae from the trees, and thus also may cause high mortality. Winds facilitate the dispersal of first instars, but may sometimes be an unfavorable agent when it deposits them on arable lands. The flying adults are sometimes drifted to the sea or large water reservoirs where they may perish (Sliwa 1987).

Microorganisms, mainly viruses, that cause so-called "tree-top disease," are the major biotic factors that limit nun moth populations. There are many insect predators that attack nun moth life stages. Insect predators include the carabids, coccinelids, raphidids, pentatomids, formicids, and forficulids. The most numerous insect parasitoids include parasitic wasps (about 100 species) and dipterans (sarcophagids and tachinids) of which *Parasetigena silvestris* is the most important species. Other natural enemies of the nun moth include representatives of spiders and birds, such as the genera *Parus* and *Sturnus*, as well as mammals, such as bats and mice.

Potential Risk to North America

The polyphagous nature of the nun moth, its dispersal capabilities, and its concealed placement of eggs on bark suggest that it is a potentially dangerous species to American forests. West coast forests dominated by coniferous stands may be most favorable for the establishment and development of the nun moth. Taking into consideration the success of the related gypsy moth in North America, it may be assumed that the nun moth could also become a serious forest pest.

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CLONING AND SEQUENCING OF ACTIN cDNA FROM THE GYPSY MOTH MIDGUT CELLS

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ABSTRACT

Actins are highly conserved proteins which are found ubiquitously in all eukaryotic cells, from fungi and protists to mammals. They form a major component of the cytoskeleton, and are involved in many forms of cellular and organismal motility. Amino acid sequencing of several actins has revealed the presence of several distinct actin isotypes in vertebrates which can generally be classified as either "cytoplasmic" or "muscle" actins. Cytoplasmic actins are found in non-muscle cells where they are utilized to form cellular microfilaments which function in cell motility and mitosis. The variation among actin isotypes (proteins) is limited to only a few amino acid substitutions. However, at the nucleic acid level, there are significant differences with respect to size of genes, location and number of introns, and length of 5'- and 3'-untranslated regions in the mRNA.

Isolation of actin genes has revealed that in most species these proteins are encoded by multigene families. The high degree of sequence conservation between actin proteins from diverse group of organisms argues strongly that this multigene family arose by duplication and subsequent divergence from a common ancestral gene. Due to their ubiquity and evolutionary conservation, actin genes seem ideal for comparative studies.

Our interest to clone and characterize actin gene sequences from the gypsy moth was based on the following reasons: (1) We had identified a protein in the brain of gypsy moth embryos whose expression was diapause related. Partial peptide sequence analyses indicated that the protein was actin. We wanted to confirm this by northern analyses using cloned actin sequences as probe. (2) Cloned actin sequences are very useful as positive controls in monitoring and standardizing conditions for Southern and northern analyses.

We used oligonucleotide primers (based on peptide sequences) in rTh polymerase-mediated polymerase chain reactions to obtain a 930 bp cDNA fragment complementary to gypsy moth midgut actin mRNA. This fragment was cloned into pNotA vector (5'-3 Prime Corp., Inc., CO) and its nucleotide sequence was determined. Since this cDNA did not contain sequences corresponding to the terminal regions of actin mRNA, 3'- and 5'-RACE reactions were performed and products were sequenced. The gypsy moth actin mRNA was 1,387 nt long which included a 36 nt 5'-untranslated region and a 223 nt 3'-untranslated region. There was a single open reading

frame coding for a protein of 376 amino acids. The conserved polyadenylation signal was present at position 1397-1402. Comparison to actin protein sequences of *Manduca sexta*, *Bombyx mori*, *Aedes aegypti*, *Anophales gambiae*, and *Drosophila melanogaster* (Genbank) indicated that the gypsy moth actin was almost identical to other insect actins. The only significant differences were at positions 140 (a threonine instead of an alanine) and at 199 (a serine instead of a glycine). However, the high degree of conserved sequence indicates that the gypsy moth actin and actins from other insects are derived from a common ancestral gene.

DEVELOPMENT OF GENETICALLY ENGINEERED ECTOMYCORRHIZAL FUNGAL DELIVERY SYSTEM FOR BIOLOGICAL CONTROL

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ABSTRACT

We are pursuing a novel strategy of utilizing genetically engineered ectomycorrhizal fungi as (1) biological control agents against insects and other plant pests, and (2) for providing beneficial factors essential for plant health and vigor.

Nearly all vascular plants establish mutually beneficial interaction with specific soil-borne, root colonizing fungi such as ectomycorrhizal fungi. Although naturally occurring ectomycorrhizae have been used for a long time, very little effort has been made to genetically engineer them for expanded use in agriculture and forestry. Since mycorrhizal fungi are closely associated with the roots and form a mantle around the roots, foreign gene expression in these fungi could have a profound effect on the root system and on the microenvironment around roots.

Our long-term goal is to develop genetically altered ectomycorrhizal fungi as a novel delivery system for: (1) biological control of root damaging insect pests by expressing insect toxins; (2) improving tree growth by increasing the efficiency of mycorrhizal synthesis of phytohormones; (3) changing adverse microenvironments around the root system due to acidity or other pollutants; and (4) biological control of bacterial and fungal diseases of trees through expression of specific genes engaged in reducing/purging the virulence of the pathogens. Initially we plan to develop and test the system mentioned in goal (1). For this, we have selected two plant/insect systems, one involving coleopteran pests (white grubs) and the other a lepidopteran (*K. gracilis*).

We have strains of *L. bicolor* and *P. involutus* that have been isolated from red pine plantations and shown to form effective mycorrhizal association with several conifer species. We have developed a particle gun-mediated transformation system for these fungi and used it successfully to insert genes for hygromycin resistance (selectable marker), beta-glucuronidase (GUS, reporter gene), and a DNA fragment encoding BtCryIIIA, a coleopteran specific insecticidal protein. The genes were stably integrated and functioning properly in transformed fungi. The presence of

introduced genes did not have any adverse effect on the ability of these fungi to form mycorrhizae on pine roots.

While BtCryIIIA is not very effective against scarabs such as white grubs, bioassays with transformed fungi expressing this toxin on susceptible insects will allow us to standardize conditions such as determining the efficiency of expression of toxin, etc. Once these experiments are successful, we plan to introduce other Bt genes such as Bt buibui gene (known to work on several scarab pests) and BtCryIA (lepidopteran-specific).

In order to increase the environmental safety of these genetically engineered fungi, we plan to use symbiosis-specific promoters to drive the insecticidal gene expression in the transformed fungi. In this situation, the engineered fungi will not express insecticidal proteins except when they are in association with host roots. We have identified five such genes from *L. bicolor* that are induced by host plant signals. A cDNA clone of one of them has been sequenced and gene encoding it has been isolated. Experiments to identify and characterize the promoter of this gene are currently in progress.

FACTORS CONTRIBUTING TO REDUCED SPECIES DIVERSITY IN THE THIRD-GROWTH ALLEGHENY HARDWOOD FOREST

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ABSTRACT

The cherry-maple or Allegheny hardwood forest is located on the Allegheny Plateau in northwestern Pennsylvania, southwestern New York, and adjacent areas of Maryland and West Virginia. The type is composed primarily of black cherry (*Prunus serotina* Ehrh.), red (*Acer rubrum* L.) and sugar maple (*Acer saccharum* Marsh.), and American beech (*Fagus grandifolia* Ehrh.). Important associates include white ash (*Fraxinus americana* L.), yellow-poplar (*Liriodendron tulipifera* L.), black (*Betula lenta* L.) and yellow birch (*Betula allegheniensis* Britton), cucumber (*Magnolia acuminata* L.), and eastern hemlock (*Tsuga canadensis* (L.) Carr.). During the past 15 to 20 years the northern Pennsylvania portion of the type has experienced unusual levels of overstory mortality. Some of this mortality has occurred rapidly and can be attributed to a succession of native and exotic defoliating insect/disease outbreaks of unusual intensity and duration combined with unusual or untimely climatic events. Sugar maple has been the most severely affected species; unusual levels of sugar maple mortality have been documented across northern Pennsylvania since the early-mid 1980's. Much of it has been characterized by slow deterioration of radial growth and crown vigor, particularly on unglaciated sites above 2000 feet in elevation, and fits the definition of a decline. Recent research has shown that declining sugar maple had significantly lower foliar concentrations of calcium and magnesium and significantly higher concentrations of potentially toxic aluminum and manganese than healthy trees and that crown vigor, health, and foliar nutrition of sugar maple were significantly altered by addition of dolomitic limestone. Slope position and glaciation also influenced sugar maple health and foliar nutrition. Trees on glaciated sites and on the lower slopes of unglaciated sites were healthier and had higher foliar calcium and magnesium concentrations than those on unglaciated, upper slope sites. Work to evaluate the effects of *Armillaria*, changes in soil and soil leachate chemistry, aluminum and manganese toxicity, and accelerated base cation leaching is underway.

The situation is made worse by the fact that sites where mortality has occurred often lack advance seedlings of the species that were present in the overstory. Long-term herbivory by white-tailed deer (*Odocoileus virginianus* Boddaert) has been one of the most important factors influencing vegetation development in the hardwood forests of Pennsylvania in this century. Not only have deer affected the abundance and rate of growth of forest vegetation, but due to the selective nature of browsing, the species composition as well. Browsing has affected species

composition directly through species removals and indirectly by setting in motion a series of plant-plant interactions which over time result in altered species composition and regeneration failure. Deer density interacts with lighting and seed supply to determine whether established advance seedlings are present on the forest floor.

The species composition of the Allegheny hardwood forest has changed from domination by beech and hemlock in the pre-settlement forest to domination by black cherry, red and sugar maple, and other less shade tolerant species in the second-growth forest. The third-growth forest is likely to be less diverse than those which preceded it. Present research suggests that defoliating insects and insect/disease complexes, drought and other climatic events, species and site-related nutritional factors, herbivory by white-tailed deer, lighting, and seed supply are the principal factors influencing health, regeneration, and diversity of the Allegheny hardwood forest.

COMPARISON OF FEMALE FLIGHT CAPABILITY OF *LYMANTRIA DISPAR* L. REARED ON ARTIFICIAL DIET VERSUS FOLIAGE

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ABSTRACT

We compared the flight capability of female gypsy moths from Far East Russian (RM) and North American (CT) colonies and from reciprocal F_1 hybrids (RM x CT or CT x RM) reared on two larval food sources (high wheat germ artificial diet and black oak foliage). Two laboratory techniques, a free-flight test and a flip test, were used to assess flight capability of < 2 day old, mated females. The free-flight test allows the female to initiate flight at will in a dimly lit room and the flip test evaluates the ability of the female to right herself.

In the free-flight test, all of the RM females reared on foliage exhibited sustained flight compared with only 77% of those reared on artificial diet. Of the North American females reared on foliage, 13% were able to glide for a short distance, while none of those reared on artificial diet exhibited gliding behavior. A greater percentage of reciprocal F_1 hybrid females reared on foliage exhibited gliding behavior than siblings reared on artificial diet. Additionally, 8% of the CT x RM cross females reared on foliage exhibited sustained flight; none of the reciprocal F_1 hybrid females reared on artificial diet demonstrated sustained flight.

The slopes of the linear regression of female front wing length on female weight were similar for all strains when reared on artificial diet, and for the RM and CT strains reared on foliage. However, the slope of the linear regression of wing length on weight was steeper for F_1 hybrids reared on foliage than for those reared on artificial diet. A greater percentage of females reared on foliage were able to right themselves in the flip test than siblings reared on artificial diet. A female that can right herself easily with one quick wing beat generally is able to glide or sustain flight. This suggests that the greater flight capability of foliage-reared females than females reared on artificial diet may be due to more than a change in the ratio of wing length to weight.

Our data suggest that the female flight capability of a gypsy moth strain may be underestimated when reared on artificial diet. Thus, if flighted females are introduced and become established in the generally infested area of North America, more flight capability than originally predicted may be retained with hybridization. These results also emphasize the need for caution when using laboratory data for gypsy moths reared on artificial diet to predict behavior in their natural habitat.

ACTIN GENE EXPRESSION DURING DIAPAUSE IN THE GYPSY MOTH

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ABSTRACT

Diapause of the gypsy moth, *Lymantria dispar*, is obligatory as a pharate first instar larvae, and a long period of chilling is essential for its termination. Like most late-embryonic diapauses, the mechanism of gypsy moth diapause is poorly understood, largely due to the experimental challenges posed by working with the small early stage larvae. Knowledge of changes in gene expression regulated specifically by diapause is useful not only for understanding the physiological processes of diapause, but also for identifying developmental markers that can be used to probe regulatory mechanisms of diapause. In our search for such markers, we focused on changes in gene expression in the gypsy moth brain.

Newly deposited gypsy moth eggs were kept at 25°C for up to 34 days to allow completion of embryogenesis and the entry into diapause as pharate first instar larvae. The brain and subesophageal ganglion (CNS) were dissected from dechorionated pharate larvae at different developmental stages and subjected to *in vitro* protein synthesis experiments. The reactions were pulse-labeled with ^{35}S-methionine for 1 h at 25°C to label newly synthesized proteins. SDS-PAGE analysis of labeled proteins revealed significant variations during development among which a 45 kDa protein appeared to be specifically diapause-related. Expression of this protein decreased gradually from day 10 to day 16, which coincides with the time of diapause initiation in the gypsy moth. After chilling for 60 or more days and transferring to 25°C, conditions required for termination of the diapause, expression of the 45 kDa protein was stimulated again. Amino acid sequences of two peptides derived from this protein suggested that the 45 kDa protein was actin. This was confirmed by using anti-actin monoclonal antibody (Sigma) in immunoprecipitation analyses. In order to test whether regulation of actin gene expression was at the transcriptional level, we attempted northern analyses using gypsy moth actin cDNA clone as a probe. However, northern analysis was not sensitive enough to detect actin mRNA in small amount of brain samples that were available. Therefore, we used rTh polymerase-mediated polymerase chain reaction (PCR) to reverse transcribe and amplify actin mRNA sequences present in RNA isolated from brain at different developmental stages. Results obtained were consistent with the protein data described above, indicating that regulation of actin gene expression was at the transcriptional level. Our work has identified actin as one of the diapause-regulated proteins in the central nervous system of the gypsy moth. Furthermore, it demonstrates that actin can serve as a reliable marker to monitor the diapause status.

A CASE STUDY OF MANAGING THE GYPSY MOTH USING SILVICULTURE:

GYPSY MOTH POPULATION DYNAMICS

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ABSTRACT

Within the northeastern United States there is considerable variation in the susceptibility (defoliation potential) and vulnerability (tree mortality) of forests to gypsy moth (*Lymantria dispar* (L.)). Silvicultural thinnings have been suggested to reduce susceptibility and/or vulnerability. We evaluated how these practices affected the dynamics of gypsy moth populations by experimentally thinning half of each of 8 oak-mixed hardwood stands in the Central Appalachians of West Virginia. The population dynamics of gypsy moth were monitored using yearly counts of egg masses, numbers of larvae hatching per mass, estimates of larval density, and weekly collections of larvae and pupae which were reared to quantify mortality due to parasitoids and disease. During the 8-year study, 3 stands were heavily defoliated by outbreak populations of gypsy moth, 3 were sprayed accidentally with pesticides, and 2 were undisturbed. Egg-mass populations appeared slightly lower in the thinned portions of the undisturbed stands, but thinning seemed to have little or no effect on densities in the defoliated and sprayed stands. Variation in mortality of gypsy moth due to parasitoids and disease was related to variation in egg-mass densities in the current and/or preceding years. After adjusting for these effects of gypsy moth density, thinning had no significant effect on mortality caused by any parasitoid or pathogen. Our results indicate that these types of silvicultural manipulations do not directly influence the effectiveness of the natural enemies of gypsy moth. We conclude that it is more likely that the effect of thinnings on gypsy moth dynamics are related primarily to a reduction in foliar biomass.

SPATIAL AND TEMPORAL PATTERNS IN POLLUTANT DOSE THAT EXPLAIN FOREST HEALTH ENDPOINTS

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ABSTRACT

Many different forest health measures, or expressions of "forest decline," can be understood as important ecological or regulatory end points, but the mortality data reported by the USDA FS Forest Inventory and Analysis (FIA) remeasurements since the 1950's have many long-term advantages (see Powel *et al.* 1992). Measures of growth often are used to express forest health, but the growth rates of surviving trees are stimulated by the loss of competing trees (by decline or death), leading to an overstatement of health with growth data. On the other hand, tree death is readily defined in the plot remeasurements from years ago, and can inform us reliably about long-term trends. But, in addition, we want to look at tree mortality and its potential causes to see whether it could be evaluated hierarchically, i.e., long-term and at a large scale, as well as short-term and locally, to determine whether potentially significant influences on forest health exist at these large scales, in addition to the local tree and stand influences.

Using data from all the states with four consecutive measurements (a 10-state area of the montane east), we find a significant upward trend in tree mortality over the period 1960-1990, ranging from a doubling (for oak) to nearly a tripling (for hickory) in annual death rate of trees. We asked what are the processes that, over multiple decades, and at this large scale, would produce a trend toward higher mortality. We considered many possible explanations, including aging, stand dynamics, drought, defoliations, the invasion by gypsy moth, and air pollutant loads. All fail to explain the data except for the regional air pollutant loads. Indeed, the correlations between the average state-wide pollutant loads and mortality rate in all the sub-regions examined (25 states in all), for each of three wide-ranging tree species groups (red oaks, white oaks, and hickories), are highly significant ($p < .01$). For data from a recent survey of oak decline (Bechtold *et al.* 1991), the geographic pattern of pollutant loads (for ozone, wet sulfate, and wet nitrate) accounts for 92% of the variation in decline. There is abundant literature on mechanisms by which these pollutant loads alter tree metabolism, particularly the effects of pollutants on the trees' insect and disease defense mechanisms. For the tree and stand level, we conclude that pollutants increase the susceptibility of many trees species to insects and disease during modest droughts, defoliation events, and major changes in stand structure. Despite the death of individual trees having multiple causes, we find the 30-year, large-scale **change in tree mortality rate** has only one underlying cause, the air pollutant load in the rural eastern U.S. In this context, the U.S. Forest Service would serve its state and local clients well, and facilitate gypsy moth control, by publicly supporting the late-1996 proposals by the U.S. EPA to lower the standard for ground-level ozone.

DEVELOPMENT AND DYNAMICS OF MIXED MESOPHYTIC FORESTS OF THE SOUTHERN APPALACHIANS

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ABSTRACT

The Mixed Mesophytic Forest Region occupies the unglaciated portion of the Appalachian Plateau physiographic province as defined by E. Lucy Braun and A.W. Küchler. The region does not follow the prevailing trend in declining forest cover and early successional development as experienced in other deciduous forest regions. In spite of intensive and extensive use in the last 200 years, it remains the most forested area in the eastern United States and one of the most forested in the temperate world. Mixed mesophytic forests (also known as cove hardwood and Appalachian mixed forests) are found throughout the southern Appalachians in cool, moist environments of well-drained, dissected uplands.

Major characteristics of the regional forests include (1) forests of high species diversity in all strata; (2) shared dominance by at least 10 commercially important deciduous species; (3) an all-deciduous character; and (4) indicator species of yellow buckeye (*Aesculus flava*) and white basswood (*Tilia heterophylla*). Although Lucy Braun and others considered these forests to be millions of years old and the seed source for other modern forests, we now know that the region has developed with changing climates, retreating glaciers, and in conjunction with human culture. Human influence has dramatically increased from the millennia of use by Paleo-Indians and historic Native Americans into the few decades of intensive use in the 20th century.

The most significant changes have occurred in mixed mesophytic forests since 1870: extensive and intensive logging of the region from 1890 to World War II; death of American chestnut prior to World War II; suppression of fire, elimination of livestock grazing, and land abandonment since World War II; and subsequent forest development following these changes in forest composition and varying land uses. Predicting future change is complicated by a number of extrinsic factors such as invasion of exotic pest and disease species including gypsy moth, impacts of air and other pollutants, climate change and other shifts in the physical environment, and demands for a number of forest products ranging from timber and medicinal plants to selected animal species. Intrinsic factors that affect the future forest include continued composition changes in response to death of American chestnut; responses in growth and composition with changes in age structure and human use; and compositional responses to acute and chronic natural disturbances and disasters such as flooding, drought, and storms.

The economic, ecological, and recreational values of this large block of continuous forest cannot be overestimated. Maintaining ecological health of the Mixed Mesophytic Forest Region is essential to sustaining regional posterity and the numerous goods and services provided by these renewable resources.

SPECIES OF *DENDROLIMUS* (LEPIDOPTERA: LASIOCAMPIDAE) IN CHINA

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ABSTRACT

There are 25 known species in the genus *Dendrolimus* and all but two occur in the People's Republic of China. The most destructive species in China are *D. punctatus*, *D. spectabilis*, *D. tabulaeformis*, and *D. superans*. The latter species also is an important pest in Asian Russia. The only species in this genus not found in China, *D. pini* and *D. benderi*, are important pests in Europe and Pakistan, respectively.

The biology of species in the genus varies greatly. Most species are univoltine, but at least one is multivoltine and one is biennial. Depending on the species, overwintering occurs as eggs, young larvae, or mature larvae. Eggs are laid, without a hair covering, on needles in chains or loose masses. Newly hatched larvae congregate on the shoot tips and suspend themselves on silken threads for dispersal by wind. All species feed on conifers, with most preferring species in the pine family. Pupation takes place at the base of needle clusters. Adults of both sexes can fly.

The most serious defoliator of forests in China is *D. punctatus*. It is distributed widely, occurring in 17 provinces. It is multivoltine, with 2-3 generations per year in the Yangtze River drainage area, 3-4 in South China, and 5 on Hainan Island at the southern tip of China. The preferred host of *D. punctatus* is horse-tail pine (*Pinus massoniana*), though subspecies have developed that specialize on other native pines. Recently, its host range has expanded to the introduced wetland and torch pines, on which it often is a severe pest. It prefers to feed on older foliage but will feed on young needles after all of the old needles have been consumed. Infestations occur most frequently below 200 meters along railroads, highways, and rivers, and in monoculture pine plantations.

Egg parasites, primarily *Trichogramma dendrolimi*, *Telenomus dendrolimusi*, and *Anastatus* spp., are the most important natural control agents. *Exorista* spp. are the most effective of the larval parasites. Birds, especially cuckoos and even a falcon, are reported to feed frequently on the larvae. The most important disease is cytoplasmic polyhedrosis virus (CPV). The chemical pesticides used most often are deltametrin and diflurobenzuron. These often are applied from beneath the canopy using foggers. Biological pesticides include eggs of *T. dendrolimi*, spores of the fungi *Beauvaria bassiana* and *Pacilomycetes* spp., and CPV. *Bacillus thuringiensis* is not used widely because of its cost.

A CASE STUDY OF MANAGING THE GYPSY MOTH USING SILVICULTURE:

SECONDARY MORTALITY AGENTS: *AGRILUS BILINEATUS*

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ABSTRACT

Population densities of twolined chestnut borer, *Agrilus bilineatus* (Weber), adults were sampled over a 6-year period in a mixed hardwood forest in West Virginia. We were interested in understanding populations dynamics of *A. bilineatus*, for little is known about this species, despite its obvious importance as a mortality agent to stressed *Quercus* spp. Sixteen stands (average size 10.5 ha) were used in the study; eight of these were silviculturally thinned in 1989, the remainder were uncut. During 1990 and 1991, populations of gypsy moth, *Lymantria dispar* L., reached outbreak levels. Densities of *A. bilineatus* adults peaked in 1992, the year following the second defoliation year (1991), and were always greater in thinned stands than unthinned; however, overstory mortality was greater in unthinned stands. Correlations between twolined chestnut borer and tree mortality were not strong, nor were the relationships between defoliation and twolined chestnut borer.

A CASE STUDY OF MANAGING THE GYPSY MOTH USING SILVICULTURE:

UNDERSTORY: EFFECTS ON GROUND-DWELLING INVERTEBRATES

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ABSTRACT

The ground-dwelling arthropod communities of a mixed hardwood forest dominated by oak (*Quercus* spp.) in West Virginia, USA were sampled for four years in a study designed to examine the efficacy of silviculture for reducing *Lymantria dispar* L. populations. Spiders, carabid beetles, opilionids, and ants were collected from pitfall traps and identified to species. These groups were of interest because each has members which are known predators on some life stage of gypsy moth. During the sampling period, portions of the forest were defoliated by gypsy moth and some areas were selectively logged using silvicultural treatments designed to reduce forest susceptibility to and/or to reduce the vulnerability of the stands. The effect of canopy-opening disturbance was noticeable for both carabids and ants: total abundance decreased, but diversity increased. The dominant ant species, *Aphaenogaster picea*, decreased nearly 50% over the four-year period, particularly in defoliated areas. For spiders, the effect of either defoliation or logging was dampened by natural variation in the populations in terms of overall abundance and diversity. Individual family and species level variation, however, was detected. For example, the Linyphiidae, a family of web-spinning spiders, was positively related to abundance of fern understory, and fern coverage increased significantly in areas that were both logged and defoliated. Two spider families were significantly inversely related to fern abundance. The overall abundance of opilionids increased immediately after the disturbances, but decreased in subsequent years. Composition and abundance of ground-dwelling arthropod assemblages may be modified by and are sensitive to both 'natural' biotic disturbance and to forest management practices.

A CASE STUDY OF MANAGING THE GYPSY MOTH USING SILVICULTURE:

UNDERSTORY VEGETATION DYNAMICS

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ABSTRACT

Ground flora, both regenerating woody species and herbaceous vegetation, are significant components to consider when attempting to understand resilience and recovery of a forested ecosystem. With this study we were able to examine the influence of both disturbance (gypsy moth defoliation) and management practices (silvicultural thinnings) on vegetation in the lowest structural layers. Regenerating species were identified, measured, and counted in 1989, (pre-defoliation and pre-thinning), 1990, 1991, 1992, 1994, and 1996. Herbaceous vegetation was identified and coverage was estimated in 1992, 1993, and 1995. In four of the six defoliated stands, woody species regeneration was clearly dominated by *Acer rubrum* (red maple). This species dominated the larger size classes and also dominated in actual number of seedlings. Two of the defoliated stands, however, were dominated by *Prunus serotina* (black cherry). Although these stands were dominated by *Quercus* (oak) overstories, there was little evidence of adequate oak regeneration.

No pre-disturbance herbaceous vegetation data were collected, so it's not possible to examine changes due directly to defoliation and thinnings, but the data does provide the opportunity to look at temporal changes and contrast the stands that had been defoliated or thinned with those that had not. Using ordination techniques, it appears that disturbance plays a significant role in distinguishing the stands in multi-dimensional space. The species turnover is great, i.e., there are some stands that have few if any species in common, therefore variation among stands at the WVU Forest is great. Within a given stand, species richness did not change from 1992 to 1995.

A significant management and ecological implication of thinning in stands that have been or will be defoliated is the increase in competing vegetation with canopy opening. In stands that were either thinned or defoliated there were significant increases over time in ferns, *Rubus* spp., and grasses, any of which can interfere with woody species regeneration. In stands that were both thinned and defoliated the increases in these types of competing vegetation were even greater.

FAMILY STRUCTURE AND HABITAT RELATIONSHIPS OF SPIDERS IN AN APPALACHIAN FOREST

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ABSTRACT

Spiders of 24 families were collected by pitfall traps in an oak-mixed hardwood forest in north central West Virginia during an 11-week period in early summer of 1989--1992. All trapped individuals were identified at least to the family level. Quantitative vegetation data allowed assessment of spider habitat associations on a finer spatial scale than previously reported. The Lycosidae dominated each year despite great annual variation in abundance for each family. Percentage of fern coverage on a plot basis was related inversely to abundance of Thomisidae and Gnaphosidae, but related positively to abundance of Linyphiidae, a reflection of the strategies of the families. There was a strong positive correspondence between abundance of the Thomisidae and percentage of oak basal area in the overstory. Pitfall-trap catches were biased slightly toward capture of male spiders; the average sex ratio (male:female) for hunting-spider families over the 4 years was 8.1:1, and for web-spinners was 2.5:1. Abundance of juvenile spiders (over all families) varied temporally and was related inversely to total abundance.

DENDROCHRONOLOGY OF INTENSIVE PLOT SYSTEM (IPS) DATA

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ABSTRACT

Outbreaks of the gypsy moth, *Lymantria dispar* L., are sporadic and typically result in extensive defoliation of the preferred host species, *Quercus, Populus*, etc. Historical increments of host and non-host species from 1952-1976 were measured from samples collected in 6 sites located in Massachusetts, New Jersey, and New York. During that period, the gypsy moth expanded its range through these areas and several outbreaks occurred. Defoliation levels were recorded at sample locations from 1972-1976; outbreaks occurred at each location during this period. Standardized chronologies for each species were averaged by year at each location. All host tree species exhibited a decrease in increment associated with defoliation levels recorded from 1972-1976. While some non-host species exhibited increased growth during outbreaks, others did not. These differences may reflect the extent to which growth of different species is limited by light and nutrients. A difference series, i.e., subtraction of the non-host standardized chronology from the host standardized chronology, performed well as a measure of gypsy moth outbreak intensity. Examination of difference chronologies prior to 1972 indicated the occurrence of historical outbreaks in certain areas and these episodes appeared to coincide with historical outbreaks in the region. The use of difference chronologies appears to be a useful method for quantifying historical gypsy moth outbreaks when no other records exist.

PATTERNS OF TREE GROWTH IN FORESTS DEFOLIATED BY GYPSY MOTH

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ABSTRACT

Extensive mortality occurred at the WV University Forest in 1990, 1991, and 1992 following two years of severe gypsy moth defoliation. Dead trees were cored and ring-widths were measured to evaluate the occurrence of a 'signal' indicating suppressed growth and eventual mortality following the stress of defoliation. We also looked at increments of live trees for comparison and eventually to determine growth loss through defoliation. Most standardized chronologies extended to at least 1930. We found no evidence of a signal sufficient to differentiate trees that survived defoliation from those that did not. Live and dead standardized chronologies were similar for all oaks. Chronologies of non gypsy moth host species, such as red maple, reflected a distinct growth, i.e., increasing in growth as a result of mortality of oaks.

INFLUENCE OF PARASITIZATION BY THE SOLITARY PARASITOID *GLYPTAPANTELES PORTHETRIAE* (HYMENOPTERA: BRACONIDAE) ON THE DEVELOPMENT AND JUVENILE HORMONE DEGRADATION OF ITS HOST *LYMANTRIA DISPAR*

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ABSTRACT

Under natural conditions *G. porthetriae* attacks mainly first and second instar gypsy moth larvae. Depending on the time of parasitization the parasitoid emerges from 3rd or 4th instar hosts. In both groups the endophagous developmental time takes 14 days but it takes significantly longer if gypsy moth larvae are parasitized in the 3rd instar. The older the host larva is at the time of oviposition the lower is the percentage of truly parasitized larvae; pseudoparasitism also occurs more often.

Larval development and molting are dependent on the juvenile hormone titer in the hemolymph of the host. JH in the blood of gypsy moth is degraded by juvenile hormone esterase (JHE). JHE activity in control larvae, especially at the beginning of the instar, is significantly higher than in parasitized larvae where hardly any JHE activity was detected. This blocking of JHE activity by the parasitoid might be the reason for a high JH titer in the host's hemolymph which subsequently causes disruption of development.

JHE was purified with affinity chromatography and partial aminoacid sequence was obtained. The sequenced peptides showed high homology with JHE from H. virescens but no similarity with previously published peptides from JHE of *L. dispar* could be found.

GYPCHEK: A SURVEY TO DEFINE CUSTOMER NEEDS AND PRODUCT MARKET

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ABSTRACT

Representatives of both the gypsy moth management community and environmental and extension organizations were surveyed to determine the near-term product market for the Forest Service-produced microbial pesticide Gypchek and to ascertain how the product might be improved to meet user needs. Questionnaires mailed to administrators, mid-level managers (e.g., state pest control specialists), local-level managers (e.g., county coordinators, district rangers), industry representatives, and researchers with either an immediate or a potential interest in gypsy moth management resulted in 355 responses. Also, 33 representatives of environmental interest and extension organizations responded to a telephone survey.

Gypsy moth managers indicated that the number of environmentally sensitive acres infested with gypsy moth would likely increase to at least 375,000 acres in the near future. However, unless the cost of Gypchek could be reduced to between $5 and $10 per acre (excluding application costs), probably less than 20 percent of those acres would be treated with the product. Even though many recognized that the product's formulation could be improved and that the need for two applications was undesirable, cost and availability seemed to be the primary reasons for non-use. As expected, Gypchek was viewed in a more favorable light by environmental and extension organizations than by managers, presumably because of its positive environmental attributes. In the absence of a similar commercial product, managers (67%) and environmentalists (75%) favored continued Forest Service production and distribution of Gypchek at a reduced cost through cooperative suppression programs.

FURTHER NOTES ON THE DISTRIBUTION, HOST PLANTS, AND PARASITOIDS OF *LYMANTRIA OBFUSCATA* WALKER (LEPIDOPTERA: LYMANTRIIDAE)

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ABSTRACT

Lymantria obfuscata Walker (Lepidoptera: Lymantriidae) is known to cause considerable damage, often denuding alder, false acacia, oaks, poplars, willows, and several temperate fruit trees (apple, apricot, cherry, pear, peach, plum, and walnut) in India. Its confines in Himachal Pradesh, Kashmir, and Uttar Pradesh are widely separated from one another by the barriers of unsuitable hosts, climate, and topography. Since the 1960's, partly with the sustained interest of the USDA to obtain natural enemies of allied species to contain the related pest, *Lymantria dispar* (L.), an exhaustive study on the parasitoids of *L. obfuscata* was made in these regions. The research was biocontrol-oriented, seeking information on their identity, bioecology, life history, and host range. Further search for more suitable natural biocontrol agents of *L. obfuscata* elsewhere culminated in the author's recent exploratory survey in Nepal. In Nepal, several species of *Alnus, Populus, Quercus,* and *Salix* occur, but plantations of the preferred hosts of *L. obfuscata* viz., *Alnus nitida* and *Quercus incana,* are rare due to unfavorable conditions there. The site characteristics also are not favorable, lacking protected niches for concealment of large larvae, pupation, and oviposition by adults. Previous studies on the head capsule of *L. obfuscata* in Nepal were based on specimens misidentified as such. The author could neither locate specimens of *L. obfuscata* at the original collection site (Indrayani Village) nor elsewhere on any of the possible hosts available in Nepal. The record of it from Nepal is indicated as apparently erroneous.

Seasonal parasitism, based on pooling larval collections across dates at each site, by the parasitoids of *L. obfuscata* encountered in the Kullu Valley (Himachal Pradesh) was low in 1995, ranging from 0 to 5.5% and averaging 2.96%, but much higher in 1996, ranging from 4.0 to 55.2% and averaging 16.95%. Activity of the braconid parasitoids *Glyptapanteles flavicoxis* Marsh (23.3% at Khokhan Rd in 1996) and *Rogas indiscretus* (43.5% parasitism at Banogi in 1996) was more pronounced in the low density areas associated with apricot in the Kullu Valley. Live material of *Glyptapanteles indiensis*, *G. flavicoxis*, *Rogas indiscretus,* and tachinids was sent to the USDA quarantine facility at Newark, DE, for further study. Further exploration for any suitable parasitoids of other allied lymantriids occurring in Nepal, Sikkim, and Bhutan is suggested for their possible use against *L. dispar* in the United States or elsewhere.

ELECTROPHORETIC PATTERNS IN PROTEINS OF GYPSY MOTH DIFFERING FOR FLIGHT CAPABILITY

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ABSTRACT

Increased shipments of materials to the United States and Canada from Western and Central Europe and the Far East have resulted in new introductions of Eurasian strains of gypsy moth, *Lymantria dispar* (L.) into North America. These strains are considered more destructive than the strain already established in North America because larvae have broader host ranges and adult females are capable of flight. Analyses of variability in protein loci of gypsy moth indicate greater genetic diversity in populations from western to eastern Eurasia (Harrison *et al.* 1983, Arduino *et al.* 1994), but no genetic linkages with flight have been shown. In this study, allozymic markers were surveyed in the gypsy moth to investigate relationships with flight capability and to provide information for constructing a linkage map.

Populations of *L. dispar* that originated in Germany, Romania, Siberia, and a laboratory culture (NJSS), and for which flight capability data were available, were surveyed electrophoretically. Thoraxes were homogenized in tris buffer, analyzed using standard horizontal starch gel electrophoresis, and stained at 8 enzymatic loci. Measures of genetic diversity were compared with (1) flight behavioral data from free-flight estimates of sustained flight (W. Wallner and P. Grinberg, personal communication), and (2) data from a flip test relating a female moth's ability to upright itself as an indicator of flight capability (M. Keena, personal communication).

Among field populations, genetic diversity was highest in gypsy moth from Siberia, though overall diversity was highest in the NJSS sample. If NJSS is considered an outlier, an unpaired group mean weighted analysis with Nei distance measures affirmed greater genetic diversity in gypsy moth populations approaching the eastern Palearctic. Genetic heterozygosity in field populations of gypsy moth might indicate flight capability; however, whether genetic markers correlate with behavioral characters for flight remains to be determined. Ongoing research seeks to increase the number of loci available for scoring population diversity and to develop a linkage map for gypsy moth.

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THE PINE MOTH, *DENDROLIMUS PINI*

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ABSTRACT

Data about the biology, diapause behavior, and the population dynamics of the important pest on pine in Europe, the pine moth *Dendrolimus pini*, are presented. The pine moth is distributed throughout the whole Euroasian continent from the Atlantic coast up to the Altai-mountains in the west of Mongolia. It prefers extensive pine stands on dry soils of low quality. Scots pine is the most favored host tree, but you can also find the caterpillars on *Pinus nigra* and other pine species as well as sometimes on spruce and fir. During the last 290 years, 80 outbreaks of the moth were recorded in the area of northern Germany and Poland, of which the heaviest one was from 1869 to 1872, when more than 1.7 million ha of pine stands were infested by the moth. Most of the heavily defoliated trees died.

During its univoltine cycle, which is common for most parts of middle and southern Europe, the pine moth larvae hibernate in the 3rd or 4th instar. The overwintering of the larvae, which is induced by short-day photoperiods, shows all physiological characteristics of a real facultative diapause, although there is no fixed manifestation stage of the diapause. The high phenotypic variability in its diapause behavior may be an advantage for the pine moth to disperse the risks during periods of low population density. Furthermore, it enables the moth to develop both in a univoltine or a two-year cycle which might be important for its existence in areas of more northern latitude. However, this phenotypical plasticity also reduces the synchronizing effect within a population which might have an influence on the population dynamics of the moth during outbreak periods. Factors regulating the extreme non-cyclic fluctuations with long periods of very low abundance and the sudden increase of its population are discussed.

BIOECONOMICS OF MANAGING THE SPREAD OF PEST POPULATIONS WITH A BARRIER ZONE

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ABSTRACT

Area-wide pest-management projects often require long-term economic planning. In this paper, we apply bioeconomical concepts initially developed for managing fish populations to the management of spread rates of invading exotic pest species via barrier zones. Exotic pests are serious threats to North American ecosystems, and thus, economic analysis of their management is important for making decisions about eradication, or stopping or slowing their spread. The rate of population expansion (which may be positive or negative) is considered a control function. The present value of net benefits from managing population spread is maximized using the calculus of variations. As the area already occupied by the population increases and/or the negative impact of the pest species per unit area decreases, the optimal strategy changes from eradication (by forcing the population front to retreat back) to slowing the spread and finally to doing nothing. The model shows that slowing population spread may be a viable strategy of pest control even when a relatively small area remains uninfested. Stopping population spread is not an optimal strategy unless natural barriers to population spread exist. The model was applied to the spread of gypsy moth (*Lymantria dispar* L.) in North America. Expected costs of the barrier zone were derived from the optimization model of slowing gypsy moth spread (Sharov and Liebhold 1997). Damage caused by the gypsy moth, $380 per 1 km^2 per year, was estimated from Leuschner *et al.* (1996) assuming that residential impacts occurred only in defoliated areas (i.e., ca. 5 times less often than it was assumed by Leuschner *et al.*). The model indicates that the optimal strategy of managing the expansion of large gypsy moth populations is slowing the rate of spread to 3.4-4.1 km/yr. Eradication of isolated small gypsy moth populations located far from the generally infested area is economically justified if their radius is >45-195 km.

MODEL OF SLOWING GYPSY MOTH SPREAD WITH A BARRIER ZONE

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ABSTRACT

The USDA Forest Service is currently conducting a Slow-the-Spread (STS) pilot project to evaluate the feasibility of slowing the spread of the gypsy moth (*Lymantria dispar* L.) in several areas along the population front. To predict the effect of the STS on the rate of gypsy moth spread, we developed a model that assumes establishment of isolated colonies beyond the expanding population front. These colonies grow, coalesce, and thereby contribute to the movement of the population front. The model estimates the rate of spread from 2 functions: (1) colonization rate as a function of the distance from the population front, and (2) population numbers in a colony as a function of colony age. Eradication of isolated colonies was simulated by truncating the colonization rate function beyond a specific distance from the population front. Model parameters were estimated using data on moth capture in pheromone-baited traps in the Appalachian Mountains in Virginia, West Virginia, and North Carolina. The rate of establishment of isolated populations declined with increasing distance from the population front and reached almost zero at a distance of 250 km from the boundary of defoliated areas. The intrinsic rate of population increase was estimated as $r = 1.706$ per year. The model predicts that the STS project will result in a 54% reduction in spread rate. The actual rate of gypsy moth spread in the Appalachian Mountains decreased from 20.1-26.5 km/yr before 1990 to 8.6 km/yr after 1990, which is a 59-68% reduction. The decrease in the rate of spread may have resulted from eradication of isolated colonies just beyond the expanding population front that started in 1990. Thus, model predictions were close to the observed reduction in the rate of population spread.

COMPARISON OF THORACIC MUSCULATURE OF ASIAN AND NORTH AMERICAN GYPSY MOTHS

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ABSTRACT

Female gypsy moths, *Lymantria dispar*, of the Asian race are capable of sustained flight, but females of the gypsy moth population established in North America are not. To gain insight into factors that might limit flight capability, we compared the anatomy, histology, and ultrastructure of the flight muscles of North American (NAGM) and Asian gypsy moths (AGM) and their F_1 and F_2 hybrids. We also compared the anatomy of flight muscles of F_2 hybrids that exhibited various degrees of flight capability.

The thoracic muscle mass of female AGM was greater than that of female NAGM. We found no significant differences in dry weight of either intact bodies or thoracic exoskeletons of AGM and NAGM. However, the thoraxes of female AGM weighed significantly more than those of female NAGM, and the thorax represented a greater proportion of the total body weight for female AGM than female NAGM. The thoracic weights of female F_1 hybrids were in the intermediate range between the parents, as were the ratios of thorax weight to total body weight. The body weight, thorax weight, and ratio of thorax weight to total body weight of female F_2 hybrids were highly variable, but covered the entire range between AGM and NAGM. The fibers that comprise the dorsolongitudinal flight muscles were larger in diameter in AGM than in NAGM, but there was no consistent difference in diameter of myofibrils within the fibers, or in diameter and configuration of actin and myosin filaments.

Female moths that are able to right themselves from an inverted position with one quick wing beat are generally able to glide or sustain flight. We found that female F_2 hybrids that can right themselves easily have flight muscle fibers that are similar in diameter to those of AGM; female hybrids that right themselves with difficulty have flight muscle fibers of intermediate diameter compared with AGM and NAGM; female hybrids that cannot right themselves have flight muscle fibers that are similar in diameter to those of NAGM. These findings suggest that flight capability in female gypsy moth is related to thoracic muscle mass and specifically to diameter of flight muscle fibers.

ALUMINUM MOBILIZATION, CALCIUM DEPLETION, AND VITALITY OF RED SPRUCE IN NORTHEASTERN FORESTS

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ABSTRACT

Dendrochemical and biochemical markers link stress in apparently healthy red spruce trees to acidic deposition. Dendrochemistry of spruce stemwood indicated a period of Ca, Mg enrichment consistent with cation mobilization in the root zone during the 1960's when acidic deposition to spruce forests in the northeastern U.S. increased sharply. As high levels of deposition continued, Al mobilized in mineral soil became available for interaction with Ca, Mg on cation exchange sites in soil and absorbing roots. At some locations, the interaction of Al with Ca, Mg induced strain and contributed to the death of mature trees. At most locations, increased Al has only induced stress as indicated by elevated concentrations of the biochemical stress marker, putrescine. Trees under high stress are at greater risk of declining health than those at low stress levels.

OAKS AND GYPSY MOTHS: AMELIORATION OF THE EFFECTS OF DEFOLIATION THROUGH ORGANIC BIOSTIMULANTS

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ABSTRACT

The effect of organic biostimulants on the growth and physiology of non-defoliated and chronically defoliated seedlings was monitored for three years. Organic biostimulants are vitamin-humic-algal mixtures which promote plant growth and vigor. Treatments of organic biostimulant, organic biostimulant with added casein hydrolysate, and a control were compared to assess ameliorative effects. The following parameters were measured: height increment, diameter increment, chlorophyll content, photosynthetic rate, chlorophyll fluorescence, and total leaf phenolics. Seedlings that were not defoliated or that were minimally defoliated had significantly greater height and diameter growth, photosynthetic rates, chlorophyll content, and chlorophyll fluorescence than heavily defoliated plants. Total leaf area and total plant photosynthesis were highest in plants treated with organic biostimulants with added casein hydrolysate, while photosynthetic rate per unit leaf area was highest in plants treated with organic biostimulants alone. Total phenolics was significantly higher in heavily defoliated plants than in plants that experienced little or no defoliation. Plants treated with the organic biostimulant Roots• with added casein hydrolysate showed greatest increments in diameter and height, and had the highest amounts of chlorophyll. Organic biostimulants caused a relatively greater increase in diameter as than in height of seedlings tested.

DEVELOPMENT OF IMPROVED STRAINS OF THE *LYMANTRIA DISPAR* NUCLEOPOLYHEDROVIRUS

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ABSTRACT

During propagation of baculoviruses in cell culture a class of viruses with an altered plaque phenotype, termed few polyhedra (FP) mutants, arise at high frequency. FP mutants exhibit the characteristics of formation of few polyhedra, the occlusion of few or no virions in polyhedra, and the synthesis of greater amounts of budded virus compared to wild type (many polyhedra, MP) virus. The enhanced production of budded virus is thought to be the basis for FP mutants becoming the predominant virus type during serial passage in cell culture. The rapid formation of FP mutants during propagation in cell culture is an impediment to the production of baculoviruses in this system on a commercial scale.

The *Lymantria dispar* nucleopolyhedrovirus (LdMNPV) rapidly mutates to FP mutants during serial propagation in *L. dispar* Ld652Y cells. After only three serial passages of LdMNPV in 652Y cells greater than 90% of the virus present exhibited the FP phenotype (Slavicek *et al.* 1995, Biological Control **5**:251-261). Development of LdMNPV viral strains refractory to mutation to the FP phenotype would facilitate production of virus in cell culture systems. Several LdMNPV strains were developed, and the stability of polyhedra production by these isolates was assessed through serial passage in the *L. dispar* 652Y cell line.

One of the new viral strains exhibited stable polyhedra production levels through 14 serial passages in the Ld652Y cell line. In contrast, FP mutants were formed and become the predominate virus type after only 3 to 5 serial passages of wild type virus. The stability of the new LdMNPV isolate suggests that FP mutant formation would not occur or pose a problem during production of this viral strain in cell culture bioreactors.

In addition to development of viral strains for production in cell culture bioreactors, we are trying to develop viral strains with increased potency. We have identified a LdMNPV gene homolog to the enhancin gene present in granuolviruses. The enhancin protein is able to increase the potency of AcMNPV polyhedra. A genetically engineered strain of the LdMNPV is being constructed that overexpresses the LdMNPV enhancin gene. The potency of this engineered virus will be assessed.

ATTEMPTS TO ESTABLISH A GYPSY MOTH LIFE TABLE IN A SUBURBAN SETTING

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ABSTRACT

In 1996, an attempt was made to construct life tables for the gypsy moth at two residential sites, one with a high population and the other, a low population. Each site had a conventional yard and an adjoining woodlot. Calibrated frass collections and burlap counts were used to obtain weekly estimates of gypsy moth density following hatch, and samples of larvae and pupae were monitored in a screened, unheated outdoor insectary to identify causal agents and to obtain mortality estimates between census intervals. Survivorship trends differed between the two sites, collapsing at the low density site before late instars were present, and diminishing less dramatically at the high density site. Trends in the yard and woodlot were similar at each site. Sampling error most likely contributed to a case of apparent recruitment at the low density site. On several sampling dates, mortality in samples collected for analysis exceeded that reflected in differences between density estimates on successive sampling dates. These anomalies were expressed as unexplained negative mortality for the purpose of balancing the life table, so mortality estimates for those weekly intervals were considered approximate.

Nuclear polyhedrosis virus was the most important mortality factor at the high density site, whereas the fungal pathogen, *Entomophaga maimaiga*, was most important at the low density site. The larval parasite, *Cotesia melanoscela*, was recovered at both study sites, but parasitism was variable. The imported carabid, *Calosoma sycophanta*, was fairly abundant at the high density site, and destroyed many gypsy moth pupae there. Because of the high incidence of disease at both sites, none of the parasites that habitually attack large larvae (e.g., *Parasetigena silvestris*) was recovered. It remains to be seen whether *E. maimaiga*, which causes spectacular epizootics resulting in the sudden collapse of gypsy moth populations, will have long-term adverse effects on the complex of imported larval parasites.

COSTS ASSOCIATED WITH URBAN GYPSY MOTH CONTROL BY ARBORISTS

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ABSTRACT

The European gypsy moth, *Lymantria dispar* (L.), is an introduced forest pest that has significantly impacted hardwood forests and urban environments in the northeastern United States. In urban settings, high density gypsy moth populations generate enormous public concern. This is primarily due to the loss of aesthetic value after defoliation, the nuisance created by the presence of large numbers of insect larvae, and the fear of losing highly valued shade trees. The objective of this study was to provide a cost analysis of residential gypsy moth management programs.

Time, or number of man-hours required to spray the property, is a major cost factor. Due to the extreme variations in the size and foliar surface of urban trees, no specific guidelines exist for calculating the man-hour estimate. The time estimate is simply based on the salesperson's past experience with similar situations. The factors which influence this estimate include: (1) number and size of trees, (2) size of property, (3) physical layout of the property, and (4) proximity of the property to sensitive areas. Travel time to and from each job site is another factor that may influence the required number of man-hours.

Cost data were obtained from two large commercial tree care companies in the Northeast. On average, pest suppression services in the eastern region cost the residential property owner $104.70 per hour (does not include materials). This cost per hour was broken down into six major components: (1) labor, (2) administrative overhead, (3) equipment, (4) materials, (5) mobilization, and (6) profit.

Total actual cost for pest management (without profit) was $65.90. Labor accounted for approximately 30% of this cost, equipment for 11%, administrative overhead for 36%, and mobilization (travel and job set-up time) for 23%. Materials cost varied depending upon the treatment alternative chosen. Total costs for one treatment cycle of carbaryl, B.t.-low rate, B.t.-high rate, and diflubenzuron were $114.58, $256.20, $271.80, and $115.69, respectively. Material cost for one complete treatment cycle ranged from 12% to 62% of the total cost. An average profit figure was calculated for the two companies.

IDENTIFICATION AND CHARACTERIZATION OF THE GYPSY MOTH MIDGUT MEMBRANE RECEPTORS FOR THE LEPIDOPTERAN-SPECIFIC *BACILLUS THURINGIENSIS* DELTA ENDOTOXINS

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ABSTRACT

Bacillus thuringiensis (*Bt*) has become the most effective biopesticide used for the control of the gypsy moth and a large number of other insect pests. Although *Bt* is relatively specific and is very attractive from environmental and health standpoints, its effect on non-target insect species remains a serious concern. To facilitate the design and development of new *Bt*-based insecticidal proteins that are more toxic against target insects and that affect fewer non-target insect species, an understanding of the molecular mechanism of the insecticidal action of *Bt* and of the biochemical basis of the insect host specificity exhibited by different *Bt* toxins is needed.

Bt is a group of spore-forming soil bacteria that produce insecticidal proteins known as the Cry delta-endotoxins which are selectively toxic to insect midgut epithelia. The insecticidal activity of different *Bt* strains is dependent on the type of *Bt* toxins that are produced by the different *Bt* strains. The lepidopteran-specific *Bt* toxins are designated as the CryI proteins. They are produced as large protoxins which are activated by midgut proteases to yield active toxins that penetrate the peritrophic membrane, and then bind to specific receptors on the gut membranes. The binding of *Bt* to specific receptors in the gut membrane catalyzes the insertion of the insecticidal protein into the membrane, leading to ion channel formation and insect larval death. Isolation and elucidation of the functional role of the *Bt* receptors in insect larvae has become an area of intense interest because the binding of the activated *Bt* toxin to specific receptor sites on the brush border membrane of midgut cells in insects is considered to be the key step in the pathogenic process of the insecticidal activity of *Bt*.

In the gypsy moth two distinct receptors for the CryIA delta-endotoxins of *Bt* have been identified: a 120 kDa aminopeptidase (APN) which is a specific receptor for CryIA(c), and a 210 kDa epithelial membrane molecule which recognizes CryIA(a) and CryIA(b). Protein sequence obtained from the purified APN is currently being used to isolate and clone the receptor of the gypsy moth. Isolation, cloning, and characterization of the gypsy moth receptors will lead to genetic mapping of the *Bt* toxin recognition and binding sites, and should facilitate the structure-based design of new and improved *Bt*-based biopesticides.

RESPONSE OF ASIAN AND NORTH AMERICAN GYPSY MOTH POPULATIONS TO A FOOD SHORTAGE

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ABSTRACT

Gypsy moth larvae from North America (Massachusetts, United States) and Asia (Bellyk, South Siberia, Russia) were reared on different amounts of leaves of birch (*Betula pendula*) in a laboratory in Krasnoyarsk, Russia. Starting at the molt to fourth instar, larvae were kept individually in petri dishes, weighed, and fed fresh leaf disks daily. There were four groups of larvae in each population and 50 to 70 larvae per group. The control group was fed disks ad libitum, and the average consumption rate (number of 1-cm dia. disks per mg body weight) was estimated for particular weight of larvae. The other groups received an amount of food to provide 70%, 50%, and 30% of the control consumption rate. The number and duration of instars, daily weight of larvae, weight of pupae and emerging moths, and span of forewings were recorded for each insect. Female moths were dissected within 24-36 hours of eclosion and the number of fully formed eggs with vivid chorion sculpture was determined. The data are based on 454 larvae, 343 pupae, and 215 male and 126 female moths from the two populations.

As the food shortage increased, Asian larvae of both sexes produced one additional instar. Starvation of larvae from N. America gave an inconsistent reaction, from a decrease of one instar to an increase of two instars. Food shortage caused mortality in both populations, mainly at the molt to the pupal stage. The level of mortality was: 0, 2, 12, and 49% for Asian and 2, 33, 46, and 62% for N. American populations under full, 70, 50, and 30% of the food supply, respectively. Although the starting weight of fourth instar N. American larvae was less than the Asian, N. American female moths that survived the treatments were heavier than their Asian counterparts. American females had a shorter forewing span, higher relative fecundity, and a higher moth/pupae live weight ratio. The rate at which the wing span, pupal and higher moth weight, and fecundity declined with the increasing food shortage was not different between the Asian and American populations.

The Asian population was more resistant to food shortage only in higher survival rates. Food shortage affected the adult weight and female fecundity of both populations equally. Regardless of the amount of food available, N. American female moths were heavier and invested more of the gains in biomass into fecundity instead of muscles and fuel for migration.

PEST RISK ASSESSMENT AND INTERNATIONAL FOREST RESOURCES

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ABSTRACT

A risk assessment procedure for evaluating pest introductions on unprocessed logs into the United States from Russia, New Zealand, Chile, and Mexico is described. This generic process has been used to identify potential serious pest risks and provide estimates of economic and ecological impacts.

To meet demands for fiber, U.S. timber companies have increased their intention to import unprocessed wood from offshore. Such importation presents the risk of introducing plant pests that are regulated by the USDA's Animal and Plant Health Inspection Service (APHIS). The complexity of the biological analysis of risks associated with this activity prompted APHIS to ask the USDA Forest Service to provide technical assistance. This has resulted in risk assessments for the importation of logs from Russia (1991), New Zealand (1992), Chile (1993), and, more recently, from Mexico. To provide permanent technical assistance to APHIS, the Chief of the Forest Service and administrator of APHIS chartered the Wood Import Pest Risk Assessment and Mitigation Evaluation Team (WIPRAMET).

It is difficult to determine whether an organism will become a pest if introduced inadvertently. Certainly, if the host plant genera in the native country are comparable to those of a potential receiving country, the pest should be considered a serious threat. However, even benign organisms in their native habitat can become pests when introduced into a new environment. To address this uncertainty, a generic risk assessment process was used that analyzes potential pest introductions based on a specific commodity or pathway (Orr *et al.* 1993). The process begins with literature surveys and the opinion of international entomologists and pathologists to select an initial list of potential pests. From this list, individual pest risk assessments are conducted for exemplars for those found in the pathways of, on or under bark, or in wood.

Each risk assessment is divided into two components: probability of establishment (composed of four elements), and consequences of establishment (three elements). Information used by the assessor(s) is organized under each element and succinctly describes the raw material and how it led the assessor(s) to make a risk judgment. This judgment may be qualitative, quantitative, or a combination of both. By using a rating system for each element of high, medium, or low, the assessor must justify each conclusion with analytical biological statements. Detailed biological statements for each element are crucial to peer reviewers because of their transparency.

These seven elements and their characteristics are as follows:

ASSESS PROBABILITY OF PEST ESTABLISHMENT

Pest With Host At Origin: Probability of temporal and spatial association with the pathway.

Entry Potential: Ability of the organism to be transported and survive transit.

Colonizing Potential: Ability of the organism to contact adequate hosts and reproduce in the new environment.

Spread Potential: Propensity of the organism to spread beyond the initial colonized area.

In all evaluations, the first element carries greater weight than the remaining three.

ASSESS CONSEQUENCES OF ESTABLISHMENT

Economic Damage Potential: Impact on forests, subsidiary industries, and control costs.

Environmental Damage Potential: Impact on biodiversity, ecosystem description, and effects of control measures.

Perceived Damage: Political and social impacts, including consumer and aesthetic influences.

Estimating overall risk entails assigning a value to each of the seven elements and then combining them into a final pest risk potential. Such evaluations serve as recommendations for APHIS to consider when making decisions on mitigation. In general, APHIS considers mitigatable those organisms with moderate to high risk potential.

Estimates of long-term economic impacts of forest pest introductions easily exceed $100 billion. Ecological impacts also are recognized but difficult to assess due to complex interactions. However, major shifts in global wood production and transport portend an escalation of pest risk assessment internationally. Researchers are encouraged to acknowledge the biological requisites of risk analyses and the crucial role they can play in view of expanding global trade.

LITERATURE CITED

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A CASE STUDY OF MANAGING THE GYPSY MOTH USING SILVICULTURE:

SECONDARY MORTALITY AGENTS: *ARMILLARIA*

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ABSTRACT

Colonization of defoliation-weakened trees by *Armillaria* spp. (predominantly *A. gallica*) is a dominant cause of mortality in mixed-oak forests defoliated by the gypsy moth. The incidence of *Armillaria*-induced mortality may be related to the inoculum-potential (abundance and aggressiveness of rhizomorphs) of the fungus in the soil. Abundance of *Armillaria* rhizomorphs in the soil in cut and uncut stands was measured in 1989 at the time of initial cutting. It was remeasured in 1995, six growing seasons after the initial cut.

Three of the eight stands in each cutting regime were defoliated by the gypsy moth in 1990 and 1991. Abundance of rhizomorphs in the uncut stands in 1995 compared to 1989 decreased in all but one stand (a defoliated stand). Abundance of rhizomorphs in the thinned stands increased in four of the five undefoliated stands and one of the defoliated stands. In general, abundance in 1995 was proportional to abundance in 1989 regardless of whether there was an increase or decrease in 1995. Rhizomorph abundance in defoliated stands was generally reduced. In 1995 the abundance of rhizomorphs of a competitive decay fungus, *Megacollybia platyphylla*, was measured on all stands. In general, there was an negative relationship of the two fungi. When *Armillaria* abundance was high, *Megacollybia* was low and vice versa. No causal relationships can be inferred yet from this data.

FUNGAL-INDUCED COLLAPSE OF A LEADING EDGE GYPSY MOTH POPULATION IN SOUTHWESTERN VIRGINIA

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ABSTRACT

In 1995 and again in 1996, we monitored 10 woodlots near Lexington, VA, for the presence of gypsy moth nuclear polyhedrosis virus (NPV) and the fungus *Entomophaga maimaiga* Humber, Shimazu, & Soper (fungus). Gypsy moth (*Lymantria dispar* (L.)) populations in the woodlots varied from very sparse to high (potentially defoliating levels). NPV was strongly density dependent, being confirmed only from the woodlots with higher gypsy moth populations. In contrast, presence of the fungus was confirmed from gypsy moth cadavers found in woodlots containing very sparse (less than 1 life stage found per burlap band larval trap) gypsy moth populations. Monitoring was most intense in the 5 blocks with the highest gypsy moth populations, where, beginning in the early season, larvae were collected weekly, with those dying within 7 days of collection examined by light microscopy to identify cause of death. Beginning in mid-season, weekly counts were also made from burlap band larval traps. In 1995, perhaps due to (1) fewer inoculative resting spores from 1994, (2) weather events, and/or (3) earlier gypsy moth population development, the fungal epizootic developed late in the season, with most larvae succumbing during instars 5-6, producing primarily resting spores (azygospores). Estimated mortality due to fungus averaged 81% in high-density plots, and 84% in low-density plots. Due to the lateness of the fungal attack, NPV occurred in a normal two-wave epizootic, although second-wave NPV mortality was undoubtedly reduced because of loss of late-season caterpillars due to fungus. Estimated mortality due to NPV averaged 6% in high-density plots and <1% in low-density plots. In 1996, perhaps due to (1) the large number of overwintering resting spores produced in 1995, (2) weather events, and/or (3) somewhat later gypsy moth population development, high levels of fungal-induced mortality occurred earlier in the gypsy moth season than in the previous year. Most gypsy moth larvae died in a mid-season wave of fungal-induced mortality, with necropsied cadavers containing only conidia. This resulted in relatively few larvae surviving to late instars. At this time, a second, late-season, wave of fungus-induced mortality occurred, with over half of the necropsied cadavers now containing resting spores. The depletion of the gypsy moth population by the early appearance of the fungus apparently suppressed the second wave of NPV, which virtually disappeared from late-season larval collections from all plots.

RANGE SHIFTS IN GYPSY MOTH OUTBREAKS AND OAK FOREST DISTRIBUTIONS IN THE NORTHEASTERN UNITED STATES UNDER CLIMATE CHANGE

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ABSTRACT

Rising global temperatures over the next century resulting from the greenhouse effect may profoundly affect the distribution and abundance of insect populations. One general hypothesis is the poleward shift of species distributions. We investigated potential range shifts for *Lymantria dispar* in the northeastern United States under several climate change scenarios. We analyzed maps of historical outbreaks, climatic variables, and the distribution of oak-hickory and oak-pine forests in a geographic information system. We developed linear discriminant function models of the occurrence of defoliation as a function of climatic and forest type variables and of the distribution of oak forests as a function of climatic variables. Using the models, we extrapolated range changes in gypsy moth defoliation and oak forests under three temperature increases, 2°, 4°, and 6° C, and the projections of three general circulation models (GCMs).

The basic responses of both forest and defoliation distributions to rising temperature were increases in the areas projected as forested by oak and defoliated by gypsy moth. Oak forest was projected to occupy nearly 29% of the study area under ambient conditions and increased rapidly with higher temperatures, reaching 100% at +6° C. The pattern for defoliation was nearly identical. The oak forest and defoliation projections exhibited a northward shift with increasing temperature. Projections for the GCM scenarios were generally more extreme than those for simple temperature increases, reflecting their more extreme temperature changes. Projections of oak forest distribution varied among the GCM scenarios, ranging from 79-100%. Those for defoliation were uniform and extreme, with the entire study area predicted to be defoliated in all cases. To understand the patterns of change in the distribution of defoliation, one must consider that defoliation requires both a defoliator population and a forest population to be defoliated. It seems likely that the projected changes in defoliation reflect primarily the redistribution of oak forests under rising temperatures and that these changes are on a time scale of centuries.

GLOBAL CHANGE AND GYPSY MOTH-TREE INTERACTIONS: ARE CHANGES AHEAD?

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ABSTRACT

There is considerable interest in how the predicted rise in global atmospheric CO_2 concentration and temperature may affect terrestrial ecosystems. Research shows that coniferous and deciduous tree species respond to elevated CO_2 atmospheres with increases in biomass production and alterations in leaf phytochemical constituents. Observed reductions in leaf nitrogen content in tree leaves, along with increases in non-structural carbohydrates and carbon:nitrogen ratios, have the potential to affect folivorous insects which feed on trees. For example, because nitrogen is essential for insect growth and reproduction, we might expect elevated CO_2-induced reductions in leaf nitrogen to alter insect growth, consumption, and development. Because leaf feeding insects, especially forest pests, have substantial impacts on forest productivity, tree survival, and forest management practices, the role of both increasing global atmospheric CO_2 and temperature has important ramifications for future forest health. We present here a brief overview of research addressing how global change scenarios may alter various tree-forest pest interactions, giving particular attention to research with the gypsy moth.

Reductions in leaf nutritional quality have been documented for several tree species grown under CO_2 enrichment, including loblolly pine (*Pinus taeda* (L.)), white oak (*Quercus alba* (L.)), quaking aspen (*Populus tremuloides* (Mich.)), paper birch (*Betula papyrifera* (Marsh.)), and sugar maple (*Acer saccharum* (Marsh)). When insects are presented elevated CO_2-grown foliage of these species several responses have been observed. These include increased consumption of needle biomass to compensate for reduced nutritional quality of foliage (*Neodiprion lecontei* (Fitch) - *P. taeda*) and reductions of larval growth and prolonging of instar development (*Malacosoma disstria* (Hübner) - *P. tremuloides*). Studies investigating responses of the gypsy moth, *Lymantria dispar* (L.), to elevated CO_2-grown tree saplings have produced mixed results. While larvae fed quaking aspen leaves grown under CO_2 enrichment consume more foliage than those fed ambient CO_2-grown leaves, insects consuming either paper birch or sugar maple do not. Similarly, the growth of larvae declines on some host trees and increases or remains unchanged on others. Although one of the preferred host trees of the gypsy moth, white oak, does have CO_2-induced reductions in leaf quality, this does not adversely affect the growth or development of F_1 sterile larvae. Current research efforts suggest that larvae feeding at an elevated temperature consume more sugar maple foliage than those feeding at ambient temperature and that this response is independent of plant CO_2 growth concentration. More long-term experiments using natural insect populations over several generations are necessary to understand how potential changes in global CO_2 concentration and temperature may alter important host tree-gypsy moth interactions.

LITHUANIAN GYPSY MOTH POPULATION: FEMALE FLIGHT POTENTIAL

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ABSTRACT

The gypsy moth population in Lithuania was assumed to belong to the European race of *Lymantria dispar*, in which female moths do not fly. However, no one had ever questioned this assumption or checked for evidence of flight by females. In 1995, gypsy moth females were noticed on the beach along the seacoast, cast ashore by waves. The nearest birch trees could be found located within pine stands 200 m away from the coastline. The nearest forest edge was 60-80 m from the sea. We believe that the females must have been elevated above the canopy (15-20 m) to have been driven by wind.

We observed eclosion and subsequent behavior of female moths and found that if mating was not allowed for 1-3 days after emergence, 45.5 ± 5% of females were flying, 15.2 ± 6.2% were walking, and 39.4 ± 8.5% were waiting. After mating, 53.8 ± 9.8% of the females were flying before egg laying, 23.1 ± 8.3% were walking, and 23.1 ± 8.3% started laying eggs immediately. If normal mating (within 24 hrs) was allowed, only 14.3 ± 6.6% of the females were flying prior to mating, 46.4 ± 9.4% were walking, and 39.3 ± 9.2% were waiting. When mated within 24 hrs, 50.0 ± 11.2% of females started laying eggs immediately after mating, while 35.0 ± 10.7% were walking and only 15.0 ± 8.0% were flying.

INSECT PARASITES OF GYPSY MOTH IN LITHUANIA

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ABSTRACT

To determine the natural enemies (insect parasites) regulating gypsy moth populations in Lithuania in 1995 and 1996, we collected gypsy moth life stages during the periods of gypsy moth development. Twenty larvae or pupae were collected each week from each of eight plots (5 ha) within damaged areas. Larvae were reared separately on artificial diet under laboratory conditions until death or eclosion. The gypsy moth population at the sampling sites was declining (in a naturally ceasing outbreak) with a density of 831 ± 281 egg masses/ha in 1995 and 3 ± 1 egg masses/ha in 1996. Defoliation reported at these sites was <20% in 1995 and none in 1996. Host tree species were birch (*Betula* spp.) and alder (*Alnus* spp.).

Insect parasites killed 37.1 ± 0.9% of reared larvae. Mortality at different life stages was: L1 = 4.1 ± 1.0%, L2 = 20.1 ± 1.7%, L3 = 40.1 ± 1.7%, L4 = 40.2 ± 2.1%, L5 = 55.1 ± 2.4%, L6 = 74.9 ± 2.9%, pupae = 54.8 ± 7.7%.

The dominant species of gypsy moth parasites and their occurrence have been determined to be:

Parasetigena silvestris R.D. - 58.8%
Phobocampe disparis Vier - 25.4%
Meteorus pulchricornus Wes. - 5.4%
Blepharipa spp. - 2.8%
Apanteles melanoscelus Ratz. - 1.8%
Glyptapanteles liparidis Bon. - 1.1%
Rogas spp. - 0.5%
Sarcophagidae - 0.3%
Chaldidoidea (Hym.) - 0.3%
Palexorista spp. - 0.1%

STATUS OF GYPSY MOTH IN LITHUANIA

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ABSTRACT

Lithuania is reported to be the northern boundary of gypsy moth occurrence. The insect was found in southern and western parts of the country and cold temperatures causing egg death in winter are assumed to be the main limiting factor in northern spread.

The first historical record of a major gypsy moth outbreak in southern and western Lithuania was in 1854-56 (which was part of a 1852-58 outbreak extending from Germany and Poland to western Latvia). Outbreaks later took place in 1898-99 and 1908-09 and a small local outbreak was recorded in 1914. Historical records indicate that only spruce stands were damaged. Insufficient data exist for the period of 1930-45. After World War II, gypsy moth was recorded only in the birch stands of Kursiu Nerija – a relatively small area of narrow sand spit along the coast of the Baltic Sea. A severe outbreak occurred there in 1971-75 and 1992-95 (with heavy defoliation in some smaller areas in 1982-83). Control measures have been very limited because of the protected status of this particular territory. Surprisingly, a new outbreak was recorded in 1996 in the southwestern part of Lithuania, and 2,500 ha of mixed spruce-birch forest is predicted to be totally defoliated in 1997. Also, there are indications of a gypsy moth outbreak in the southwestern part of Latvia. Causes of these new outbreaks are unknown and no research is currently underway in these areas.

Gypsy moth populations have been encountered regularly since 1968, but they have been limited to sites of previous outbreaks. No country-wide monitoring of gypsy moth presence and/or abundance has ever been performed. No special research on gypsy moth in Lithuania had been carried out until 1994 when a two-year cooperative research project was launched with the USDA Forest Service. This project was targeted toward research on gypsy moth natural enemies – insect parasites and pathogens in a naturally declining outbreak area.

USDA Interagency Gypsy Moth Research Forum
January 14-17, 1997
Annapolis, Maryland

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Contains 60 abstracts and papers of oral and poster presentations on gypsy moth biology, molecular biology, ecology, impacts, and management presented at the annual U.S. Department of Agriculture Interagency Gypsy Moth Research Forum.

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