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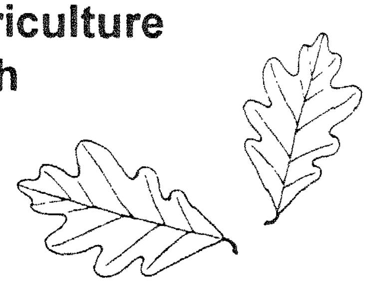
Forest Service

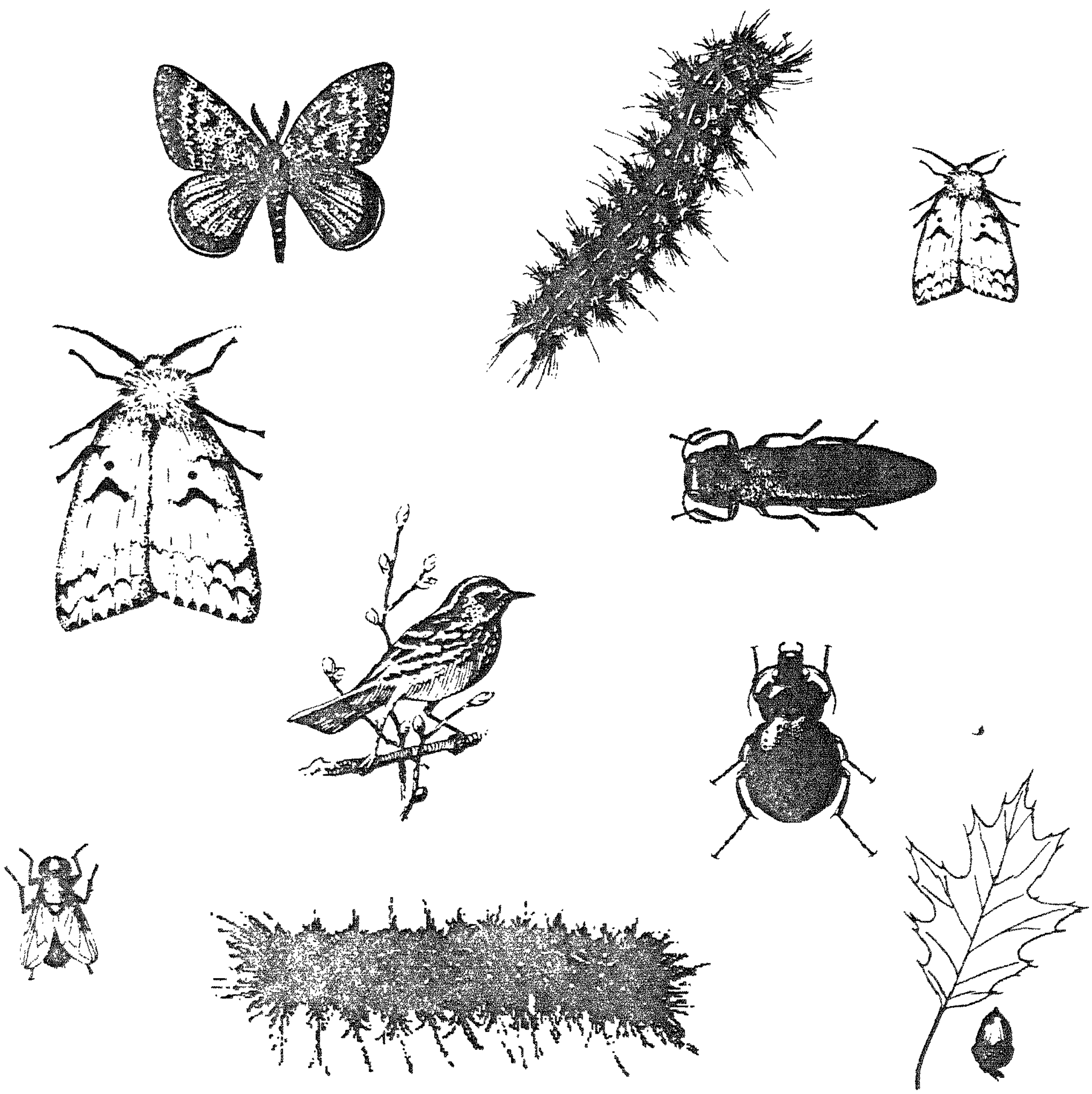
Northeastern Forest Experiment Station

General Technical Report NE-240

PROCEEDINGS

U. S. Department of Agriculture Interagency Gypsy Moth Research Forum 1997





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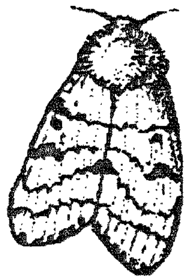
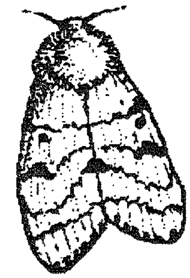
ACKNOWLEDGMENTS

Thanks to Dr. Mark J. Twery for providing the cover and title page design.

Proceedings
U.S. Department of Agriculture
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:

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Cooperative State Research Service

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

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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%)

---

[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.

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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