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Northeastern Research Station

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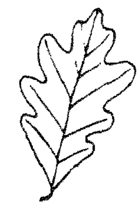
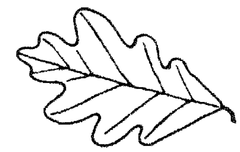
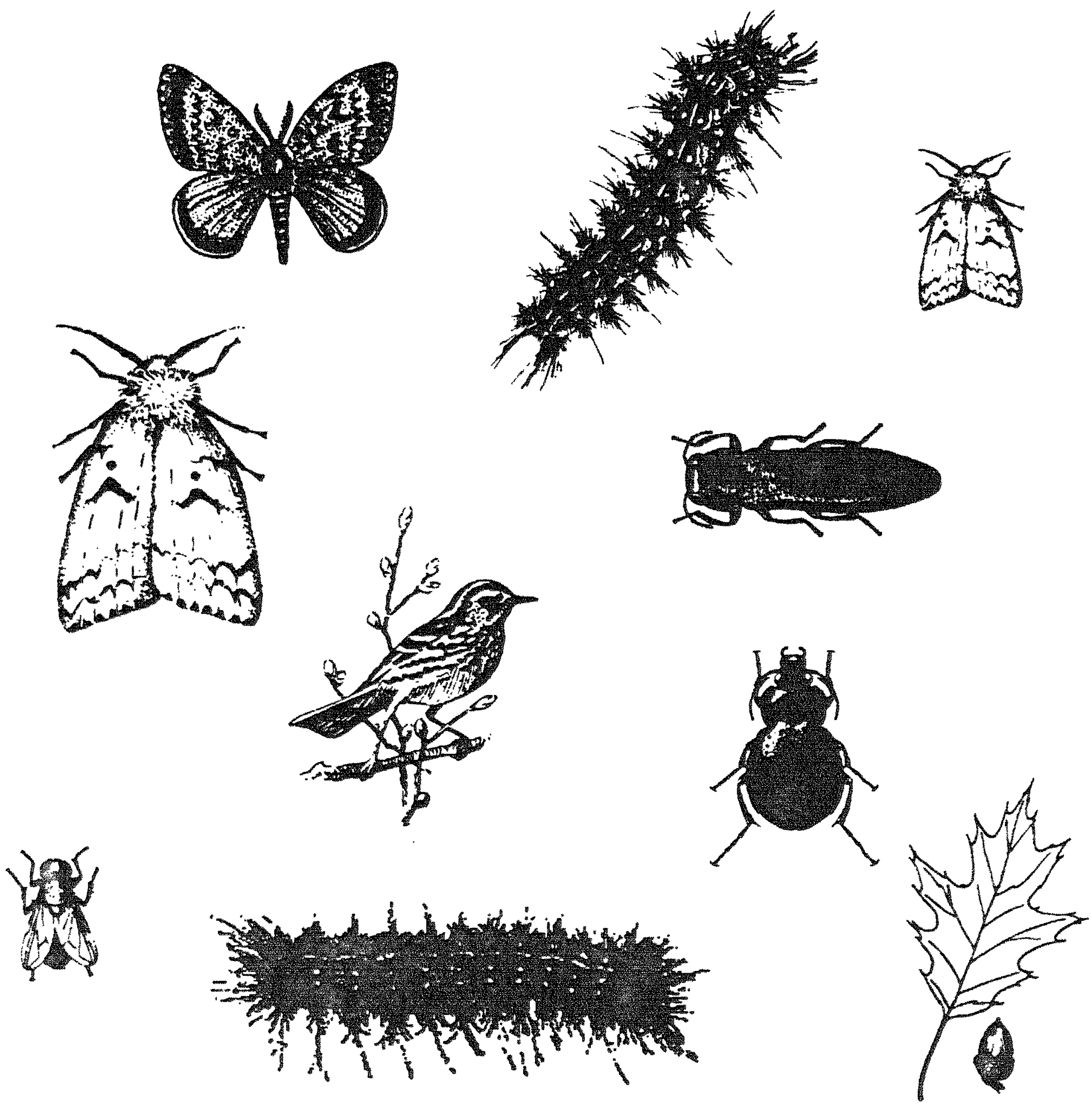
PROCEEDINGS

U. S. Department of Agriculture Interagency Research Forum on Gypsy Moth and Other Invasive Species 1999







ACKNOWLEDGMENTS

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

Proceedings
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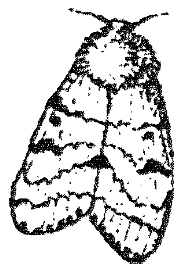

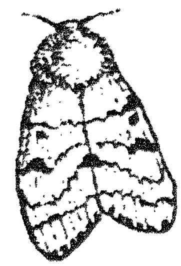

January 19-22, 1999
Loews Annapolis Hotel
Annapolis, Maryland

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

Sponsored by:

Forest Service Research

Forest Service State and Private Forestry

Agricultural Research Service

Animal and Plant Health Inspection Service

Cooperative State Research, Education and Extension Service

USDA

FOREWORD

This meeting was the tenth 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 title of this year's forum reflects the inclusion of other invasive species in addition to gypsy moth. 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 l 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

Ernest S. Delfosse, Agricultural Research Service (ARS)
Vic Mastro, Animal and Plant Health Inspection Service (APHIS)
Tom Hofacker, Forest Service-State & Private Forestry (FS-S&PF)
Steve Yaninek, Cooperative State Research, Education and Extension Service (CSREES)
Robert Bridges, Forest Service-Research (FS-R), Chairperson

The program committee would like to thank Abbott Laboratories; USDA, Cooperative State Research, Education, and Extension Service (CSREES); and USDA, Animal and Plant Health Inspection Service, National Biological Control Institute (NBCI), for their support of this meeting.

USDA Interagency Research Forum on Gypsy Moth and Other Invasive Species
January 19-22, 1999
Loews Annapolis Hotel, Annapolis, Maryland

AGENDA

Tuesday Afternoon, January 19

REGISTRATION
POSTER DISPLAY SESSION I

Wednesday Morning, January 20

PLENARY SESSION .... Moderator: J. Robert Bridges, USDA-FS

Welcome
Michael McManus, USDA-FS

Introductory Remarks
J. Robert Bridges, USDA-FS

Northeastern Forests - Winds of Change
Daniel Twardus, USDA-FS

New Initiatives on Non-native Invasive Species
William Sommers, USDA-FS

GENERAL SESSION .... Moderator: R. Fuester, USDA-ARS

Research Reports
Presenters: P. Schaefer, USDA-ARS; D. Leonard, USDA-FS; C. Schwalbe, USDA-APHIS; S. Munson, USDA-FS

Wednesday Afternoon, January 20

GENERAL SESSION .... Moderator: V. Mastro, USDA-APHIS

Asian Longhorned Beetle
Presenters: P. Eggert, USDA-APHIS; J. Cavey, USDA-APHIS; M. Smith, USDA-ARS; S. Lingafelter, Cornell University; B. Wang, USDA-APHIS; A. Hajek, Cornell University; S. Teale, SUNY College of Environmental Science & Forestry; V. Mastro, USDA-APHIS

POSTER DISPLAY SESSION II

Thursday Morning, January 21

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

Current Research on Hemlock Woolly Adelgid
Presenters: D. Orwig, Harvard University; F. Santamour, Jr., U.S. National Arboretum; B. Steward, Bayer Corporation; S. Salom, Virginia Polytechnic Institute and State University; M. Wallace, North Carolina State University; M. Montgomery, USDA-FS

POSTER DISPLAY SESSION III

Thursday Afternoon, January 21

GENERAL SESSION .... Moderator: A. Diss, Wisconsin Dept. of Natural Resources

The Pine Shoot Beetle
Presenters: J. Pasek, USDA-APHIS; S. Teale, SUNY College of Environmental Science & Forestry; T. Poland, USDA-FS; C. Sadof, Purdue University; D. McCullough, Michigan State University; T. Scarr, Ontario Ministry of Natural Resources

GENERAL SESSION .... Moderator: V. D'Amico, USDA-FS

Research Reports
Presenters: H. Gossenauer-Marohn, Hessian Agency of Forest Management Planning, Forest Research and Forest Ecology, Germany; K. Thorpe, USDA-ARS; J. Slavicek, USDA-FS; G. Hoch, Institute of Forest Entomology, Forest Pathology, and Forest Protection, Austria; R. Fuester, USDA-ARS; R.M. Muzika, University of Missouri

Friday Morning, January 22

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

The Eurasian Invasion: Plant Pathogens Past, Present, and Future
Presenters: W. MacDonald, West Virginia University; D. Houston, USDA-FS, retired; D. Bergdahl, University of Vermont

GENERAL SESSION .... Moderator: K. Gottschalk, USDA-FS

Panel Discussion: Gypsy Moth Management in North America: A Metamorphosis
Panelists: J. Elkinton, Univ. of Massachusetts; A. Liebhold, USDA-FS; K. Raffa, Univ. of Wisconsin

Closing Remarks

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NORTHEASTERN FORESTS - WINDS OF CHANGE

Daniel B. Twardus

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The northeastern forest - including all of New England and the Mid-Atlantic States - extends as a nearly unbroken canopy from Maine to West Virginia. Within this region two broadly defined forest types can be described: the laurentian mixed forest of northern New England consisting of northern hardwoods, montane spruce-fir, and lowland spruce-fir; and a vast eastern broadleaf forest of southern New England to West Virginia consisting of northern and central hardwoods, and the northeastern oak-pine and oak-hickory forests.

Today, the northeastern forest extends over 85 million acres and by most accounts can be described as a healthy, productive, and resilient natural resource.

Here are 10 statistical facts about today's northeastern forest that help characterize its present condition. These statistics are based, in part, upon data summaries provided by the USDA Forest Service, Forest Inventory Analysis, and can be found in Powell et al. 1993.

(1) Forestland occupies 67% of the land area whereas nationally, 32% of the land area is occupied by forestland.

(2) The forest classified as "urban" is increasing.

(3) Privately owned forestland accounts for about 90% of the 85 million acres of forestland in the Northeast.

(4) The amount of forestland has increased slightly across the region since the 1970's.

(5) Softwood timber volumes have increased since 1952 by 67%. Hardwood volumes increased since 1952 by 104%.

(6) Softwood sawtimber volume (big trees) has increased since 1952 by 114% while hardwood sawtimber volume increased by 156%.

(7) In 1992, the greatest amount of conifer timber volumes were found in (1) spruce and balsam fir, (2) white and red pines, and (3) eastern hemlock. And, for hardwood species, (1) soft maples, (2) hard maples, and (3) red oaks.

(8) Annual mortality as a percent of growing stock was 0.6% in 1992. This is relatively unchanged since 1952.

(9) In 1991, the ratio of annual growth to mortality was 3.9 to 1, while the ratio of growth to removals was 2.3 to 1 again reflecting substantial increases in timber inventories.

(10) Since 1976, harvesting has remained relatively constant at 1.3 billion cubic feet, annually. In 1991, National Forests in the Northeast contributed about 2% of the volume.

These statistics paint a generally favorable view of the northeastern forest. However, beneath the surface of these statistics lie some changes that have and are now taking place. Some of these changes have been dramatic while others are more subtle yet nevertheless significant.

Change Number One: The Red Maple Invasion

- In Connecticut, red maple (*Acer rubrum*) growing-stock volume has increased 55% since the 1970's. More importantly, red maple replaced northern red oak as the number one species and accounts for over 21% of the growing stock volume.

- In Vermont, red maple volume increased 119% since 1966 and has risen from a sixth place in volume to 2nd place. Results are similar in New Hampshire and Massachusetts.

- In New York, sugar maple is the leading species in growing stock volume, barely edging out red maple. In Pennsylvania and New Jersey red maple is the leading species.

- In West Virginia and Maryland yellow poplar is the predominant species in terms of volume but red maple experienced a 74% and 56% increase respectively, since 1975. In Delaware, loblolly pine retains its rank as the number one species but red maple volumes increased 60% since 1972, far exceeding any other hardwood species and generally at the expense of hickory and beech.

The increase in red maple is one of the most dramatic changes occurring within the forests of the Northeast. This change can be attributed to several factors but of most significance is the effect of forest management both in terms of harvesting and fire prevention.

- In Connecticut, between 1971 and 1984, 52% of the average annual hardwood growing stock removal was oak species.

- In West Virginia, between 1975 and 1989, 44% of the total hardwood average annual removal was oak.

- In Maryland, 42% of total hardwood annual average removal was oaks (1976-1986), and in Delaware, 55% for the same time period.

Consistently from New England south to West Virginia, oaks have been preferred in harvesting giving rise to canopy openings that the generalist red maple species has filled.

Along with the impact of logging has been the exclusion of fire. Red maple is more sensitive to fire than many other northeastern tree species, and the lack of fire will allow for an increase in red maple that otherwise may not have occurred.

A third factor related to the species composition change taking place is white-tail deer management.

Change Number Two: The Impact of White-Tail Deer

Prior to colonization of eastern North America by European settlers, deer (*Odocoileus virginianus*) density in the eastern forests was approximately 7 to 10 deer per square mile (Witmer and deCalesta 1992). By the end of the nineteenth century much of the forest had been cut over, and the deer herd was nearly eliminated (Redding 1995). Due to a combination of vast amounts of forage available in a regrowing forest, hunting regulations, and predator extinction, the deer population exploded.

Throughout the Northeast, deer populations today are at record levels - 30, 40, and even 60 per square mile. In general, deer densities in excess of 20 per square mile decrease vegetative species richness, species abundance, and species composition (deCalesta and Stout 1997).

In northwestern Pennsylvania in an old-growth forest known as Hearts' Content, 27 different woody tree species were recorded in the understory in the 1920's. By the 1990's, after 70 years of deer browse by a herd that has averaged over 40 per square mile, only 11 woody species are left in the understory (Jones et al. 1993). In some areas of the Allegheny National Forest in northwestern Pennsylvania, deer browsing has completely prevented the reestablishment of forest trees following cutting.

In oak forests in central Massachusetts, deer populations of 25-40 per square mile interrupted the understory growth and, in some cases, prevented regeneration. At these deer densities, maturing oak stands developed an open, park-like structure with poorly developed understory and mid-story layers. Future stands will be dominated by fewer species, notably red maple, and sweet birch. Oaks will be less abundant (Healy 1997).

Forest stands cannot be harvested if advance regeneration is inadequate to produce replacement trees. McWilliams et al. (1993) reported that only 4-20 percent of forested lands surveyed across Pennsylvania in 1990 had advance regeneration sufficient to provide adequate regeneration of diverse woody species. Overabundant white-tailed deer populations were theorized as the primary cause for the regeneration failure.

The effect of this regeneration failure may be reflected in the change in the diameter distribution particularly of hardwoods since 1952. The percent of growing stock volumes in the smaller size classes (less than 9.0 inches) shows a consistent downward trend since 1952.

In 1952, 16% of the hardwood growing stock volume consisted of trees less than 9.0 inches; today, they represent only 10%.

Complicating this issue, of course, is that income generated by deer-hunting activities generates millions of dollars throughout the Northeast each year. In Maryland, in 1991, more than 124,000 deer hunters spent almost $122 million on transportation, food, equipment, lodging, and other related hunting expenses (Lynch 1997) This equates to $2,600 per deer killed in 1991 in Maryland.

Change Number Three: An Invasion of Diseases

For this forest, no discussion would be complete without reference to the single most devastating impact of an introduced species - the Chestnut blight. At one time, American chestnut (*Castanea dentata*) comprised about 25% of the canopy of the forests we now refer to as the oak-hickory forests of the Northeast (Braun 1950). Today, chestnut is a minor understory component. The chestnut blight fungus spread from an introduction in New York about 1900 throughout the range of chestnut killing trees as it spread. Forests once referred to as chestnut oak are now known as oak-hickory, as both species filled in the gaps left by the spread of the disease.

The largest concentrations of American beech (*Fagus grandifolia*) are found in New York, Pennsylvania, and West Virginia. In New England, however, the average percent of beech volume in trees less than 15 inches is 77%. In Maine, where beech is a decreasing forest component, 87% of the volume is in trees less than 15 inches (Twardus et al. 1995). Where larger beech is found, it is often severely deformed and defective in the aftermath of beech bark disease.

The dramatic effect of beech bark disease has become evident throughout New England, Pennsylvania, and West Virginia. The disease, first introduced into the US from Canada in the 1930's, has a killing front that now extends as far south as West Virginia. Beech bark disease mortality in West Virginia now encompasses more than half a million acres.

Eastern white pine (*Pinus strobus*) extends from Maine south through the Appalachian Mountains. The lumber industry of the Northeast was for many years based upon white pine. Today, however, (and due in part to exploitive logging) eastern white pine is only locally important. Reestablishing white pine to an ecological and economic place of importance has been complicated by white pine blister rust, a parasitic fungus that requires two different host species to complete its life cycle - white pines and currant or gooseberry (*Ribes*).

The introduction of white pine blister rust from Europe into New York in 1909 launched an historic battle to save white pine - the Blister Rust Control Program. The discovery of a few small trees infected with blister rust triggered a fight to protect white pine; a battle waged coast to coast and lasted for over 70 years. The irony of the battle, of course, was that the blister rust did not decimate the white pine forests of the Northeast before logging did.

American elm (*Ulmus americana*) graced eastern city streets and was a significant component of four forest types throughout the Northeast and Midwest. Then in 1930, a fungus introduced on elm logs imported from Europe reached the Northeast. The fungus grows in living elms as a parasite but also thrives in dead wood as a saprophyte spreading from tree to tree largely by bark beetles or root grafts. Early in 1933, control efforts began. By the 1940's thousands of elms were dead; by 1952, over 400,000 dead elm were reported. To date, at least 50 million elms have succumbed, significantly reducing the canopy diversity of a large portion of the northeastern forest and decimating one of our more magnificent urban shade trees.

These are four of the more dramatic disease introductions into the northeastern forest. Another disease, but one of less prominence, in terms of knowledge about its impact, is the butternut canker.

The historical range of butternut or white walnut (*Juglans cinerea*) extends from Maine south to Arkansas. Never a predominant tree in the forest, it has been most valued for its nut production for wildlife and a limited use in the furniture industry. Today, however, it is difficult to find a healthy butternut due to a disease known as butternut canker. Butternut is being killed throughout its range by a fungus of unknown origin but theorized to be introduced. It causes branch and stem cankers that eventually girdle the tree. Sprouts if they develop are also infected. The disease was first reported in Wisconsin in 1967 (Ostry et al. 1994). Recent forest inventory data show dramatic decreases in the number of living butternut - in some areas 90% of the butternut are diseased. Butternut is a lesser known component of the forest but one which may be virtually eliminated over the next few years, and in fact, has been proposed as a candidate for listing as a Federal threatened and endangered species.

Change Number Four: Acid Deposition

Acid deposition has contributed to a regional decline in available calcium in spruce-fir forests of New York and New England. These changes have resulted in impaired mineral nutrition in some red spruce forests. There is also evidence that acid deposition has contributed to reduced cold tolerance of high elevation red spruce in the Northeast. Acid deposition has also contributed to a depletion of calcium from soils of northern hardwood forests on some soils and some experimental studies indicate that these soils are close to nitrogen saturation which would result in additional calcium losses (Eagar and Adams 1992).

There has not been sufficient time to evaluate the role of clean air legislation on these trends nor to determine how easily these trends might be reversed.

Change Number Five: Landownership

According to USDA estimates in 1992, nearly 393 million acres of timberland, or about four-fifths of the nation's total, was considered to be non-federal timberland. The Northeast region contains 20% of that total.

Private businesses and individuals are the primary owners of the nation's nonfederal forest. In the Northeast, non-industrial private ownerships account for roughly 63% of the forest ownership (Birch 1996). More importantly, 88 percent of these private forest landowners own less than 50 acres and control 33% of the resource (Birch 1996). Throughout the Northeast, ownerships in the less than 50-acre category have increased dramatically since 1978 (Birch 1996). In general, Birchs' private forestland study indicates a shift toward more owners of smaller forestland parcels.

The implication of a changing ownership pattern is significant. The transition to many new forest owners will mean a more diverse pool of forest management objectives, if forest management is even a consideration for many in this group. In addition, smaller forest parcels change ownership more often negating the possibility of long-term forest management planning. A recent report by the National Research Council of the National Academy of Sciences (1998) focuses upon the emerging environmental issues related to the non-industrial private forestland owner. These include forest fragmentation, biodiversity, timber supplies, and urban-rural interfaces. Paramount in their conclusions is the need to develop national policies and programs for nonfederal forests grounded in a comprehensive ecological policy.

Recognition of the role of the non-industrial private forestland owner in the overall well being and long-term sustainability of the northeastern forest may well be the most significant challenge facing us today. It will affect our perception of forest management, how we deliver information about forest management, and the nature and condition of the future northeastern forest.

Forest inventory statistics, especially those related to productivity, suggest that the northeastern forest has recovered from past abuses and is resilient. But these statistics belie several important considerations.

(1) The forest has changed dramatically from what it was just 200 years ago.

(2) The ecological significance of American beech, American elm, and American chestnut, once prominent species in the forest, has changed dramatically, due to introduced diseases.

(3) Introduced plants and diseases continue to threaten the condition of the forest.

(4) Acid deposition has contributed to regional declines in the available calcium from soils in the Northeast.

(5) A species composition change is taking place allowing red maple to occupy a larger ecological niche at the expense of oaks, hickory, and other species, thereby reducing diversity.

(6) The future forest is being affected by deer browse causing regeneration failure, or at the least, contributing to species composition changes.

(7) The forest is being fragmented into an increasing number of smaller ownerships which will influence forest management options.

The challenge is two-fold. The first challenge is the recognition of the changes that have and are now taking place throughout the northeastern forest and the effect these changes have upon the long-term sustainability of the forest. We have a tendency to not only accept change but also to assume that all change is natural and unavoidable. This simply is not true. We have the ability and the knowledge to control white-tail deer herds, to stop high-grading, to minimize air pollution, and to control the importation of insects, diseases, and plants.

The second challenge is the development of comprehensive policies and programs that reflect ecological sustainability and are directed towards the non-industrial private woodland owner. This is a good example of "think globally, act locally."

Private landowners certainly have a responsibility to be good stewards of the land, while society has a responsibility to encourage them to fully exercise these responsibilities. In both situations, the issue involves agreement on acceptable standards of forest stewardship that apply not only at the woodlot level but just as importantly are reflective of the sustainability and health issues for the forest as a whole.

Numerous federal and state programs already exist to provide financial and technical assistance to private woodland owners. What is lacking is an ecological coordination of these programs especially in terms of connecting the actions of the individual landowner with the health and sustainability of the forest.

Addressing the sustainability of the northeastern forest requires the broad-based social and political desire to do so. Furthermore, it is dependent upon:

- recognizing the condition of the forest and changes taking place,
- the rights and responsibilities of private landowners,
- the coordinated implementation of programs from an ecological basis,
- research and information directed towards non-federal forests,
- and the levels of investment available for the non-federal forest landowner.

The northeastern forest stands, today. But it is not the same forest and nor should we expect it to remain unchanged. However, the ill winds of change that have acted upon this forest and are today acting are to a large extent of our own making. Our investments in recognizing these changes and counteracting those changes we see as debilitating will represent our gift of sustainability for the future.

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NEW INITIATIVES ON NON-NATIVE INVASIVE SPECIES

Dr. William T. Sommers

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Scope of Problem

Travel and trade dramatically increase biological introductions

- Increasing human travel and global trade have resulted in an increasing transport of biological organisms from their native ranges to new areas lacking natural regulating factors. As a result, non-native invasive species infestations are increasing at a dramatic rate - with severe impacts to recreation, wildlife habitat, biodiversity, wetlands and waterways.

- NIS (non-native invasive species) are the second leading contributing factor in the decline of 42% of US endangered and threatened species.

- Opportunities for non-native invasive species increase with global climate change.

Severe impacts to forest and rangelands (grasslands) and associated waterways

- An estimated 6-7 million acres of National Forest Service lands are currently infested with noxious weeds and non-native invasive plants, increasing at an estimated rate of 8%-20% per year. This has resulted in 60-80% loss of land values in some western range states, and an increased susceptibility of these lands to erosion and fire.

- Conservative estimates on control costs of NIS and economic loss due to NIS infestations on U.S. forest, range, and croplands increase are $20 billion annually.

- Non-native invasive pathogens such as chestnut blight and Dutch elm diseases have dramatically altered the composition of the forested landscape. Seventeen species of non-native forest insects are highly invasive. $20 million was spent in one year alone to eradicate Asian gypsy moth in Washington and Oregon states; and a $41 billion dollar forest products and tourist industry in the NC and NE U.S. is at risk if the recently introduced Asian Longhorned beetle has been introduced into natural forests and successfully colonizes. On average, 12 new NIS insects colonize in HI per year.

Similar impacts are occurring nationwide, prompting a call for action from the scientific community in March 1997 to Vice President Gore for a coordinated national effort against NIS.

- The San Francisco Bay is invaded by a new exotic species on average once every twelve weeks.

- Zebra mussel spread can decrease species richness in the Mississippi drainage basin by 50% over the next decade.

- At least 1.5 million acres in FL have been invaded by non-native invasive plants, leading to dramatic loss of native habitat.

The U.S. Response - A National Campaign against Non-native Invasive Species

- These and other examples of NIS impacts convey the need for well-integrated Forest Service planning and program execution, along with federal and non-federal partners. Solutions to non-native invasive species (NIS) problems require aggressive research, control and technical assistance efforts across Federal, State and private lands, using a collaborative, multi-faceted approach to control and eradication.

- The Dept. of Agriculture, along with the Departments of Interior and Commerce, will lead in the implementation of a government-wide response beginning in fiscal year 2000.

- This government-wide response and federal duties have been enhanced in a pending Executive Order on Invasive Species. In brief, the E.O. requires all federal agencies (more than 20) to combat NIS via preventing entry, detection and rapid response, enhanced control, restoration of species and habitat conditions and public education. Research and technology development for these purposes will be an explicit federal duty.

- The convergence of concern and mandates for action are remarkable - as also the demand for a greater investment in science.

FS R&D's participation in the national campaign against NIS extends a sound history of research and development of technology.

- This forum, now in its 10th year, signals the commitment and value that FS R&D places on collaboration with other U.S. and international research organizations -- to network information and increase scientific opportunities on NIS. Such fora that encourage partnerships have never been more important, and in fact are fundamental to the U.S. national campaign.

- The shape of current and past FS research is aligned with government-wide R&D goals. the Committee on Environment and Natural Resources (CENR) initiative, which FS helped to develop, highlights the increased emphasis given to an NIS effort within USDA and the Forest Service. With this increased emphasis comes greater opportunities--and responsibilities--for coordination, collaboration and program support.

- The FS R&D program to be enhanced focuses on:

  (1) Understanding the biology of NIS organisms and their interactions within ecosystems

  (2) Developing control options, especially biologically based technologies, for more established populations

  (3) Monitoring and analysis of population dynamics, and to understand impacts of NIS on ecosystem structure and function

  (4) Science to support restoration of species and habitats

- The proposed President's Budget for FY 2000 increases FS R&D funding for invasive species research to $13.6 million dollars, an increase of $5 million over FY 99 appropriations. In addition to this amount of funding for ecologically based research, additional support has been requested for FY 2000 to enhance collection of monitoring data on invasive species at a number of LTER sites.

- Current FS R&D program on NIS focuses primarily on ecosystems common to FS lands, and is coordinated with ARS, NRCS, CSREES and APHIS, Interior, other federal and non-governmental organizations.

- Examples of research in progress includes study of:

  (1) NIS plant ecology, plant community dynamics and alternative control strategies for high elevation and grassland weeds in the Rocky Mountain and Southwestern regions

  (2) Ecological studies to support restoration of sites after treatment of exotic weeds

  (3) Genetic selection of trees resistant to Dutch Elm Disease, and research to develop more resistance to butternut canker

  (4) Biological studies of the nun moth, a species of high risk of introduction to the U.S.

  (5) Biological control research on Hemlock woolly adelgid

  (6) Improvements in biologically based controls for gypsy moth

- NIS of key concern for increased study in FY 2000 for the FS include: Hemlock woolly adelgid, gypsy moth, kudzu, cheatgrass and other NIS plants in western states, pink hibiscus mealybug in Puerto Rico, *Miconia* and other invasive plants in Hawaii, among others.

There are a number of challenges that FS R&D will address in our expanded program of work in FY 2000, in partnership with others.

- *FS R&D will be contributing to a government wide effort to enhance information management and risk assessment for NIS.*

  Towards this goal, we participated in a 1997 workshop to evaluate current databases for non-native invasive plants and helped sponsor a December 1999 workshop on other taxa. Featured at the 1998 workshop was the Forest Insect and Disease Information System, a collaborative product under development by FS R&D, FS S&PF, and APHIS -- along with research and regulatory organizations in Canada and Mexico. This information system has a number of important features: it's web based; interactive; contains a risk assessment as well as basic information on biology, geographic distribution and control; and, has QA/QC provisions.

- *FS R&D will seek to balance short and long-term research, such that studies vital for ecologically based management solutions are maintained along with shorter-term studies, technology development and evaluations that strengthen early detection, eradication and control.*

  As examples of shorter term efforts, FS scientists are working with technical experts in S&PF and with APHIS on evaluations of pathways for wood infesting insects. FS scientists will continue to participate in development and evaluation of monitoring protocols at intensive sites and FHM evaluation monitoring sites. And, FS research will be targeted at aspects of NIS biology that provides information essential to effective detection surveys and control.

- *FS R&D will support more effective prediction of invasiveness through study of invasive species ecology and biology, and habitat/site characteristics associated with vulnerability to invasion. Additionally, such studies can increase our current understanding of the relationship between disturbance (fire, land use practices, etc.) and NIS invasions; and, the impacts of NIS on ecosystem structure and function.*

  A number of ranking systems are under development by scientists outside the FS, wich correlate various biological attributes with invasiveness. Systems for woody plants, for example, consider such characteristics as native range, incident of successful invasion elsewhere, leaf longevity, vegetative reproduction, length of flowering and fruiting period, dispersal mechanism, seed size and germination requirements.

Success of NIS insect invasions are associated with characteristics that include geographic range, abundance in original range, range of host preferences, habitat available for development, absence of natural enemies, generation time, high growth rate, dispersal behavior and association with human populations that increases ease of transport.

Though these and other attributes can be used in assessment of potential invasiveness, there remains much to larn about biotic and abiotic interactions that trigger invasions and/or the incident of wide-spread outbreaks from populations after introduction. Better anticipating the timing of, and likely sites for, invasions requires study of NIS biology and ecology. This knowledge, in turn, can be applied to: development of management options that protect uninfested ecosystems, development of management practices and technologies to mitigate NIS damage, and for the refinement of risk assessment systems.

FS R&D is participating in a number of partnerships to enhance planning and collaborative actions:

(1) FS R&D continues a jointly funded effort with FS S&PF to accelerate the movement of research findings to field operations for control of NIS (ca. $500,000 in leveraged FS funding).

(2) FS R&D participates in a newly established FS team on invasive species, as a way to ensure coordinated agency actions.

(3) FS R&D participates in a number of intra- and interagency coordinating groups, such as the Federal Interagency Committee for Management of Noxious and Invasive Weeds, the NST Committee on Environment and Natural Resources, the USDA Biological Control Coordination Council and Action Team, among others.

(4) FS R&D is participating and leading in regional efforts to more effectively focus and coordinate research and operational efforts aimed at NIS--such as planning for kudzu control in the southern U.S. and a Northeastern Station - North Central Station - Northeastern Area team on invasive species.

(5) FS R&D continues, and seeks to enhance, international exchanges and scientific collaboration, especially for development of biological control options, identification of pathways, and enhancement of risk assessment information systems.

Other Forest Service Responsibilities

USDA Forest Service program of work is an important component of the national campaign.

- FS program of work on invasive species supports the Natural Resource Agenda for Sustainable Forest Management and healthy watersheds.

The National Forest System Program

- Focused on operational activities related to prevention; rapid detection and assessment; control and restoration; and partnership, education and outreach activities which are coordinated with other similar programs in other Federal land management Departments (Interior, Defense, and Transportation) as well as other Federal agencies within the Department of Agriculture providing technical advice and assistance to state and private landowners (NRCS, CSREES).

- This campaign will incorporate implementation of the *Stemming the Invasive Tide: Forest Service Strategy for Noxious Weed and Non-native Invasive Plant Management* and coordinate interagency implementation of the *Pulling Together: National Strategy for Invasive Plant Management* and the *USDA Strategic Plan for Noxious Weeds* with other participating agencies.

The State and Private Forestry Program

- S&PF activities are carried out on other Federal lands in cooperation with several other Federal land management agencies (DOI, DOD, BLM, FWS, BIA, NPS).

- S&PF will increase the federal capacity to address non-native invasive species throughout the United States in cooperation with State Foresters, Tribal governments, private landowners and other Federal agencies.

NFS and S&PF Partnerships

- Partnerships are essential in developing ecosystem-based, cross jurisdictional approaches.

- Forest Service is a member of both the National Invasive Species Council and the Federal Interagency Committee for the Management of Noxious and Exotic Weeds, a 16 agency technical committee, which will serve to coordinate Federal agencies as well as public outreach and education.

- Partnership programs, such as the *Pulling Together Partnerships* managed by the National Fish and Wildlife Foundation, have been found to be most effective when structured in a cross-jurisdictional, multi-disciplinary program with community based decision-making.

The Forest Service has a strong partnership with the Animal and Plant Health Inspection Service (APHIS) in the eradication and suppression on non-native invasive insects and diseases. Partnerships are currently established through challenge cost-share programs as well as with other Federal agencies and State governments and Tribes.

Integrated Science and Technology Development for Non-native Invasive Species: Research & Development Program Elements

Assessment of Ecological Risks; Impacts on Ecosystem Structure and Function

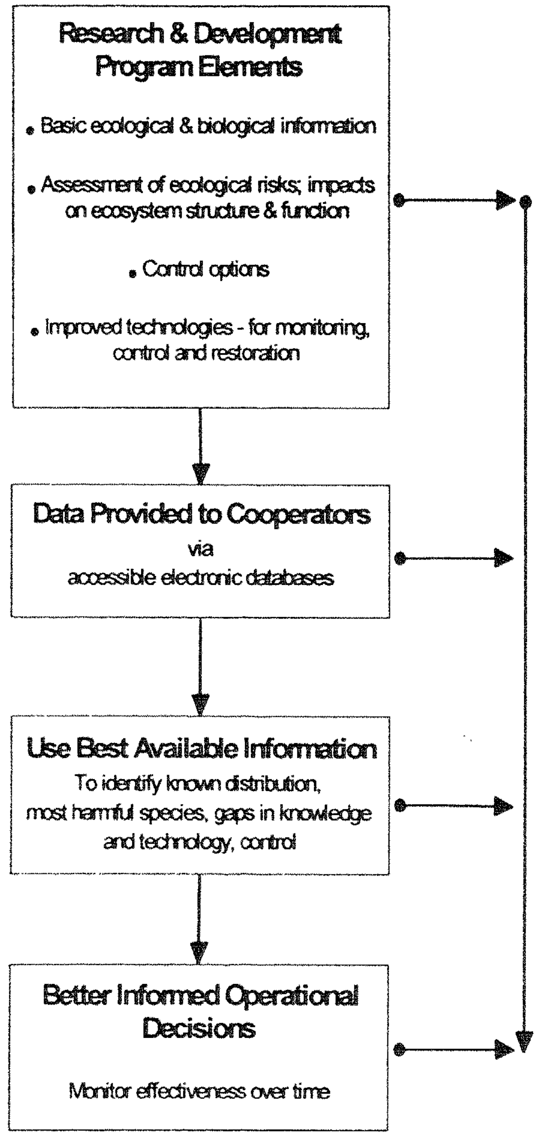
- Ecological requirements of NIS, including interactions among physical, chemical, climatic and biological factors facilitating establishment and spread
- Processes whereby NIS displace native species
- Data on economic and environmental costs/benefits from NIS introductions

Control Options

- Ecosystem manipulations with mechanical, chemical and biological control methods
- Genetics research - for improved resistance to NIS and identification of NIS

Improved Technologies

- Quantify contribution of natural and anthropogenic vectors of transport
- Early documentation of new infestations of established invaders
- Technology, protocols and monitoring systems that more accurately define NIS distribution and rates of spread
- Technologies that aid in restoring habitats and species


Research & Development Program Elements
• Basic ecological & biological information
• Assessment of ecological risks; impacts on ecosystem structure & function
• Control options
• Improved technologies - for monitoring, control and restoration
Data Provided to Cooperators via accessible electronic databases
Use Best Available Information To identify known distribution, most harmful species, gaps in knowledge and technology, control
Better Informed Operational Decisions
Monitor effectiveness over time

PHEROMONE MONITORING OF *DENDROLIMUS SUPERANS* BUTLER: EVALUATION OF THREE TRAP DESIGNS IN SIBERIAN TAIGA

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ABSTRACT

The Siberian moth, *Dendrolimus superans sibiricus* Tschtvrk., is a major defoliator of conifers in Northern Asia and it could have a serious impact on native forests should it become established in North America. The objective of this study was to test the main types of pheromone traps to be used in detection surveys in the U.S. and population monitoring surveys in Russia. We tested two types of sticky traps: a large delta trap (INRA), and the wing trap (Trece Inc.). The non-sticky trap used was the "Otis live-catch trap" constructed from two standard gypsy moth milk-carton traps with larger entrance holes and a plastic funnel inside. A line of traps, each baited with a live two-day-old virgin female in small plastic net chamber, was placed along a logging road that ran through a Siberian larch forest. Traps were positioned ca. 1.5 m from the ground on trees with 100 m between traps in A-B-C-A-B-C sequence. Each trap was rotated daily to the next trap location. During this procedure, the position of chambers with females was also rotated, so, for example, on the second day of the experiment female from the trap A was moved to the trap B, which in its turn replaced the trap C. The sticky sheets were changed daily, male moths captured in the traps were removed and counted. The experiment had 5 replicates that were observed over 3 days. For statistical analysis, the daily catch of each trap was considered an independent variable. Numbers of captured moths were transformed by $\log_{10}(x+1)$ to insure equal variance before analysis of variance by ANOVA. Significant differences in mean trap catches were identified by the least significant difference (LSD) test at $a = 0.05$. During this experiment, the population density of the moth was low and all three kinds of traps were equally effective with an average of 3.1, 2.8, and 3.3 males/trap/day for the wing, delta and Otis traps respectively. Our observations in other habitats though not so carefully designed showed that at average population densities the sticky traps were not able to catch and retain all moths that visited them. The maximum number of moths trapped per trap in one night was 6 for the wing trap and 5 for delta trap. The Otis trap caught a maximum of 115 moths per night and there was still plenty of space inside the trap.

SIBERIAN MOTH FEMALES' ATTRACTIVENESS TO MALES:

DAY TIME AND MOTH AGE EFFECTS

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ABSTRACT

There is limited information on the diel periodicity of female attractiveness to males in the Siberian moth *Dendrolimus superans sibiricus* Tschtvrk. (Rozhkov 1965; Kupressova et al. 1982). Our work was done in July 1998 in the larch forest situated on the eastern slopes of Kuznetskiy Alatau Mountains in Southern Siberia (Shira Region, Khakass Republic). In spring, density of Siberian moth in these plots was low, averaging 0.05 larvae per tree. Thirty-two Otis live-catch traps each baited with a virgin female in a plastic net chamber were put in line along a logging road in larch forest. There were females of 7 age groups: from 1 to 7 days old with 2-7 females in each group. Traps were positioned ca. 1.5 m from the ground on the periphery of larch tree crowns with 50 m between traps. They were in the field from 14th to 26th of July and were checked daily; except when they were checked hourly from 16.00 July 14th until 15.00 July 16th. Females attracted males only from 22.00 till 06.00 with maximum attraction in the interval from 23.00 till 02.00. During this study (average day temperatures 16.2±0.5°C) individual females attracted as long as 14 days with average period of 9 days. All females were alive at the end of the test, and each female chaotically laid 10-40 sterile eggs in its cage. The dynamics of changes in females attractiveness (S) with their age (T) for each female was approximated with the equation: $\ln S_{(i)} = a_{(i)} - b_{(i)}*T$, where (a) and (b) were calculated by the lowest squares method using the data on each (i)th female. Parameter (a) in the equation was the logarithm of attractiveness of individual female at the day of hatching (T=0). Parameter (b) estimated the rate of change in attractiveness as a function of female age. It was observed that for each individual female there was significant decrease in attractiveness with age. The significant correlation between the calculated starting attractiveness (a) and attractiveness decreasing rate (b) was found. The higher the starting level of attractiveness, the faster it decreased with the females' age.

BUTTERNUT: IS IT REQUIEM OR RECOVERY?

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ABSTRACT

Butternut (*Juglans cinerea* L.) is considered a minor component of the hardwood forests of eastern North America, yet it is highly valued as a commercial wood with a diversity of uses. This species also provides mast for wildlife and adds significantly to the biodiversity of our forests. However, during the past 30 years, the butternut canker fungus (*Sirococcus clavigignenti-juglandacearum* Nair, Kostichka, and Kuntz) has decimated butternut throughout its range in eastern North America. This fungus kills trees of all ages and also has been found to infest nuts. Recent forest inventory data indicate that butternut canker has had a major impact on butternut survival. For example, in North Carolina and Virginia, 77% of the butternut trees were lost between 1966 and 1986, and Michigan has reported an 84% reduction in the species. A recent Wisconsin survey revealed 91% of live butternut trees were diseased and 27% of the total population surveyed were dead. Butternut canker has been found on 94% of trees in the Lake Champlain Basin of Vermont and approximately 25% of the trees surveyed were dead. Due to crown dieback, nut production is limited and regeneration in the Vermont surveyed stands appears lacking. Because of concern for butternut, several states have placed a moratorium on cutting healthy trees growing on state lands, and the USDA Forest Service has introduced butternut harvesting guidelines for National Forest lands. Also, the Forest Service, in cooperation with several state and academic institutions, has initiated a tree selection program based on phenotypic disease resistance. Some selections have been made and they are now being propagated by grafting.

The origin of *S. clavigignenti-juglandacearum* remains unknown, but it is believed to be a recently introduced exotic pathogen. Butternut is currently listed as a category 2 species and it soon may be placed on the federal government's threatened and endangered species list because of the impact of butternut canker. The threat to butternut is real and the fungus is on the verge of eliminating this tree species from the forests of eastern North America. The species already has been eliminated from the standpoint of sustainable wood production, and the future of butternut remains in serious question. Will there be a "requiem or recovery?" We may know the answer to that question within our lifetime.

SATELLITE IMAGERY USED TO CLASSIFY HEALTH OF EASTERN HEMLOCK IMPACTED BY HEMLOCK WOOLLY ADELGID

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ABSTRACT

We used satellite imagery to classify at the landscape level the health of eastern hemlock, *Tsuga canadensis* (L.), stands within an 110,000-ha area in the lower Connecticut River Basin impacted by hemlock woolly adelgid, *Adelges tsugae* Annand. We obtained Landsat Thematic Mapper images of the study area and selected images with the least cloud cover from images captured prior to leaf expansion to avoid foliar reflectance of deciduous trees interspersed among hemlocks. A landcover classification was performed on an April 1985 image to locate the maximum extent of hemlock stands prior to adelgid infestation, which was first reported in Connecticut in 1985. Four sites with relatively large, undisturbed stands of eastern hemlock were identified within the study area. Radiance normalization and non-hemlock masking techniques were applied to a May 1995 image to locate current stands of hemlock and remove reflectance data for non-hemlock portions of the image. The Normalized Difference Vegetation Index, the Tassled-Cap Transform, and the Modified Soil Adjusted Vegetation Index-2 were used to transform the 1995 image. Each transform was followed by cluster analysis to separate hemlocks into four health classes.

The techniques described in the USDA Forest Service Crown Condition Rating Guide were used to evaluate the health of 600 eastern hemlock trees, 4 each at 150 locations within the study sites. Five indicators of tree vigor were used to measure tree health: live crown ratio, crown density, diameter, dieback, and foliar transparency. Average indicator values were calculated for the four trees measured at each location; these values were combined to determine the visual crown rating, or health class, at each location. Four levels of tree health were identified: good, average, poor, very poor. A GIS was used to measure the accuracy of the imagery classification of health by comparing the field data with the classified images. The Modified Soil Adjusted Vegetation Index-2 transform provided the most accurate classification of hemlock health, with an overall accuracy rate of 82.1%. We conclude that remote sensing and GIS can be used to classify the health of eastern hemlock stands and monitor at the landscape level changes in tree health from insect infestation or other stressors.

SHUTTING THE BARN DOOR - A HISTORICAL OVERVIEW OF APHIS REGULATORY EFFORTS TO REDUCE PEST RISK FROM IMPORTED WOOD PACKING MATERIALS

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ABSTRACT

Solid wood packing materials (SWPM) imported with foreign cargo present considerable pest risk to U.S. natural resources. However, these materials are so pervasive in shipments that strict regulation to prevent pest introduction could severely impact international trade. In light of this knowledge, APHIS traditionally regulated SWPM by requiring only freedom from quarantine pests when found during inspection - a practice commonly used by most countries. But in recent years, increased restrictions were warranted by the nature and numbers of pest interceptions made from imported cargo. APHIS has incrementally increased restrictions on SWPM from the traditional approach to requiring freedom from bark and pests (in 1995) and, most recently for any wood from China or Hong Kong, to a certificate of treatment at the origin (in December 1998). The restrictions on wood from China and Hong Kong comprise an interim emergency rule resulting largely from reaction to infestations of Asian longhorned beetle (ALB), *Anoplophora glabripennis* (Motschulsky), in New York and Illinois and from repeated detections of ALB and other exotic wood pests in domestic warehouses. As the next effort designed to shut the barn door on forest pests arriving with SWPM, APHIS will propose a rule to regulate SWPM from all origins. APHIS published an Advanced Notice of Proposed Rulemaking soliciting comments from the public on this new rule, on January 20, 1999.

LONG-TERM HEALTH MONITORING OF SESSILE OAK IN NORTHEASTERN HUNGARY

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ABSTRACT

The sessile oak (*Quercus petraea* Matt. Liebl) is one of the most important tree species in Hungary both from an economical and ecological point of view. The widespread and large scale decline of this species was first observed in Hungary in the late seventies. Experimental plots with individually numbered trees (ca. 200-300 trees/plot) were established in 1982 all over Hungary in order to study the process of the decline. Twenty seven of these monitoring plots are located in northeastern Hungary. The health status of the sample trees at these plots has been scored on a 4-degree scale (5-4-3-2), twice a year (late May and mid September) since 1983. The social status of the sample trees (Kraft classes) was also recorded.

This survey evaluates the autumn health scores of more than 4,500 sample trees at these 27 experimental plots in the period between 1983 and 1998. The following indices were calculated based on the health scores recorded tree by tree (averaged for all the sample trees): mortality index, mortality trend index, health index, health trend index. (Definitions can be found on the poster). These indices were correlated with the drought index, and the yearly damage of the geometrid caterpillars. The drought index is defined as the average temperature of the growing season (in C°) divided by the weighted sum of the precipitation in the growing season (in 100 mm).

It is evident that the drought index and the mortality index follow a highly similar pattern. Between 1983 and 1989, when the drought index showed a decreasing trend, the mortality index also decreased. The rates of mortality between 1989 and 1992 were hardly more than 1%, and occurred mainly among the suppressed trees, so it can be considered as natural self-thinning. After 1991 when several seriously dry years followed each other the mortality index started to increase significantly, and mortality was recorded among the dominant trees too. The mortality index reached its peak in 1995 with a value of 4.6%. Following 1995, when the drought index decreased significantly again, the values of the mortality index dropped too. This is also evident that the mortality index shows a delayed (ca. 2 years) response to the change of the drought index. There are highly significant positive correlations between the yearly values, 2-, 3- years moving averages of the drought index, and the yearly values of the mortality trend index. In other words, the degree of tree mortality always increased in extremely dry years. Reverse correlation

was found between the drought indicating variables (yearly values, 2-, 3-years moving averages of the drought index) and the health index. When a given year or a 2-3 year long period was extremely dry the health conditions of the sample trees got significantly worse. Significant positive correlation was found between the population level of geometrids (yearly values, 2-, 3-years moving averages) and both the mortality index/mortality trend index. In the years when the geometrid population was high in the spring higher and increasing tree mortality was recorded in the autumn. Significant negative correlation was found between the population levels of the geometrids and both the health index and the health trend index. When the geometrid population level was high in spring, the health status of the sample trees got significantly worse in autumn.

Considering these results it can be concluded that both the drought and the defoliating caterpillars were major stress factors in the process of sessile oak decline in NE Hungary during the last two decades.

BIASED SEX RATIOS IN THE GYPSY MOTH:

LABORATORY EXPERIMENTS AND FIELD OBSERVATIONS

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ABSTRACT

Sex ratios in field populations of the gypsy moth, *Lymantria dispar* (L.), can be highly variable, ranging from <5% to >90% females. This is of practical significance because, male-biased sex ratios tend to be associated with collapsing populations, and female-biased sex ratios, with building populations. Laboratory experiments were conducted using the New Jersey strain of *L. dispar*. The first, performed using two types of rearing containers (individual and group) and progeny of 10 females, indicated that overall sex ratios were slightly but significantly male-biased, but did not differ among container types or progenies of different females. Mortality, which was significantly higher in group rearings and differed among female progenies, might have been higher in female progeny, contributing to the overall male-biased sex ratio. In the second experiment, progenies of 10 different females were reared individually at 15, 20, 25, 30, and 35°C. No progeny survived at 35°C, and high mortality was seen at 15 and 30°C. Sex ratios at 30°C were strongly male-biased but about 50:50 at the remaining temperatures. Sex ratios among progenies of different females were heterogeneous, being male-biased in three cases, female- biased in one case, and approximating 50:50 in the remainder. There was a significant negative correlation between incidence of mortality and the sex ratio for different combinations of temperature and progenies, suggesting that differential mortality was affecting the sex ratio. We conducted an exploratory analysis of environmental factors affecting pupal and adult sex ratios of the gypsy moth at Belleplain State Forest, from 1982 to 1996. Gypsy moth abundance appeared to be the most important factor, and significant negative correlations were observed between pupal sex ratios and all indices of density. Relationships between pupal sex ratios and natural enemies seemed to be a consequence of the latter's responses to gypsy moth abundance. For example, sex ratios of pupae were positively correlated with parasitism by the larval parasites, *Cotesia melanoscelus* (Ratzeburg) and *Parasetigena silvestris* (Robineau-Desvoidy), which are low density specialists. On the other hand, they were negatively correlated with incidence of NPV and abundance of adults of the predator *Calosoma sycophanta*, both associated with high gypsy moth populations. Adult sex ratios were influenced in large part by pupal sex ratios, but parasitism by the introduced pupal parasite *Brachymeria intermedia* (Nees), which exhibits bias towards male pupae, tended to elevate the adult sex ratio. Both pupal and adult sex ratios were negatively correlated with precipitation during the Spring of the current year.

CLONING OF A PUTATIVE CRY1Aa/CRY1Ab *BACILLUS THURINGIENSIS* TOXIN RECEPTOR FROM THE GYPSY MOTH

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ABSTRACT

Bacillus thuringiensis (Bt) is a Gram-positive bacterium which is widely used as a biopesticide for the control of lepidopteran insect pests. Bt toxins bind specifically to receptor molecules on the surface of insect midgut cells. The binding of Bt toxin to its receptor plays a key role in eliciting the insecticidal activity of Bt. Toxin binding leads to membrane pore formation which is followed by midgut cell lysis and insect mortality. However, the exact mechanisms involved in toxin binding and pore formation remain unclear. To advance our understanding of the mode of action of Bt from a toxin/receptor interaction perspective, we are pursuing cloning and development of tissue culture expression systems to produce Bt receptors *in vitro* for detailed molecular analyses.

Four cDNA fragments encoding a putative Cry1Aa/b toxin receptor from the gypsy moth, *Lymantria dispar*, have been cloned and characterized. Sequence analyses show that this cDNA is similar to Bt Cry1A toxin clones from *Manduca sexta* and *Bombyx mori*. The amino acid sequence from the *L. dispar* clone is approximately 60% identical to the corresponding sequences from *M. sexta* and *B. mori*. The function of this Bt toxin receptor molecule in the midgut is unknown, but the amino acid sequence is related to the cadherin family of proteins.

GYPSY MOTH IN HESSE:

AN ENDANGERED SPECIES IN A CHANGING ENVIRONMENT?

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ABSTRACT

Outside the optimal natural range in the Mediterranean and Balkans area GM outbreaks in central Europe up to now differ in intensity and timely succession. There is still no evidence for the fact that the endemic German populations are subject to a strict long-term periodicity as the ones in Serbia. Favorable weather conditions, especially drought, seem to have a decisive influence. For the recent 4 decades on average every 7 - 8 years an outbreak was recorded in the southern part of Germany. They lasted 3 - 4 years each.

The latest outbreak in the state of Hesse, from 1992 - 1995, which has been the severest one in this century, offered the challenge to develop strict rules for counter measurements. They resulted from an analysis of host tree vitality and the expected intensity of larvae attacks.

- Up to a mean egg mass density of 1/tree only NPV applications took place.
- Between 2 and 10 eggs masses Btk was used.
- More than 10 egg masses triggered a Dimilin treatment.

With all three variants we achieved an effective foliage protection.

In 1997 a permanent survey net, based on a 1 to 1 km-grid with pheromone baited milk carton traps, was installed as an early warning system.

First results for host tree vitality, catch rates and GM vitality are reported: Despite favorable climatic conditions and a neglectable impact of defoliators, the latest annual crown survey showed that more than 15% of old oaks had leaf losses between 65 and 100%. Since 1991 the mortality rate of oaks in the area is plainly higher than on the average of the state.

Based on 247 defined trapping sites an increase in male moth catches of 165% in total from 1997 to 1998 was registered. In none of the 12 local survey areas the numbers decreased. The highest absolute trapping results are localized in the northern part, especially around the Frankfurt airport, in the northern boundary of the county capital Darmstadt and in the south west of the hessian reed. The highest mean trapping rates were recorded in the north and south of the Rhine-

Main-plain. Especially in the forest district of Lampertheim the catches doubled. These regional herds coincide with those from which the recent outbreak started in 1992.

The pathogen impact actually is on a low level. Pupae and adult moths were vital; the highest percentage of virus-infested individuals have been detected in older larvae instars, but only with a mean percentage of 0.9%. The microsporidia impact is even lower. *Nosema lymantriae* was only found in 2 traps. Fungi infections with *Beauveria bassiana* and *Paecilomyces farinosus* only appeared sporadically at one trapping site.

The genetic screening of south German populations, using RAPD and AFLP analysis, showed that only 2 populations had the European marker form, while at the other 14 sites a mixture of Asian, North American and hybrid marker forms were noticed with varying proportions between the sites. Genetic similarities were found between GM fullsiblings, although a comparatively high amount of genetic variation was detected between the European populations. Clustering of isolates from neighbored German populations fitted well with the region they originated from. German isolates could mostly be distincted from Asian genotypes. The only exception was an isolate from the forests near Frankfurt. It had a deeper genetic similarity to an isolate from Nara/Japan than the later one to isolates from Northern Honshu/Japan.

Flight experiments with individuals from 4 different origins showed a correlation between characteristic Asian RAPD-markers and flight ability.

In respect to the high level of susceptible forest types the impact of defoliators, especially GM, locally in coincidence with other insects like the forest cockchafer remains an irrefutable risk factor for forest policy.

PHOSPHATIDYLINOSITOL SPECIFIC PHOSPHOLIPASE C TREATMENT OF *LYMANTRIA DISPAR* MIDGUT EPITHELIAL CELLS DOES NOT REDUCE THE CYTOTOXICITY OF *BACILLUS THURINGIENSIS* INSECTICIDAL CRYSTAL PROTEINS *IN VITRO*

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ABSTRACT

Isolates of *Bacillus thuringiensis* (*Bt*) produce insecticidal crystal proteins (ICPs) in conjunction with sporulation. Currently, ICPs are believed to act as follows: (1) The protein crystal, a protoxin, is consumed by a susceptible insect and solubilized by the insect gut fluid. (2) Proteases from the midgut fluid process the protoxin into an active toxin. (3) Toxins diffuse into the extra-peritrophic space and bind to receptor molecule(s), on columnar cells of the midgut epithelium. (4) An as yet poorly understood series of cytotoxic events, usually hypothesized to involve toxin insertion and pore formation in the cell membrane, leads to cell, and ultimately, insect death. In this model, the ability of the cells to specifically bind the toxin is crucial. Several reports have identified glycosyl-phosphatidyl inositol (GPI)-anchored aminopeptidase-N (APN) enzymes in the midgut brush border membranes of certain Lepidoptera, including the gypsy moth, *Lymantria dispar* (L.), as specific receptors for activated *Bt* toxins. We therefore hypothesized that enzymatic removal of GPI-anchored proteins from midgut epithelial cells (MECs) harvested from gypsy moth larvae would reduce their sensitivity to *Bt* as measured by adenosine triphosphate (ATP) depletion from toxin-treated cells. Phosphatidylinositol specific phospholipase C (PIPLC) pre-incubation of MECs released 35% of the APN activity and 65% of the activity of a second GPI anchored marker enzyme, alkaline phosphatase (AP). However, PIPLC-incubated and mock-incubated cells responded identically to three Cry1 ICPs, each of which reportedly binds to a GPI-anchored APN from *L. dispar* or other lepidopteran larvae. Thus, PIPLC sensitive, GPI-anchored proteins may not be a necessary component of functional *Bt* intoxication in *L. dispar*.

MORTALITY OF GYPSY MOTH PUPAE CAUSED BY PREDATORS IN EASTERN AUSTRIA

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ABSTRACT

Mortality of gypsy moth pupae was investigated in two oak stands near Eisenstadt, Burgenland, Austria in 1998, when gypsy moth populations had been at innocuous levels for four years. Laboratory reared *L. dispar* pupae were exposed by mounting them on burlap bands fixed on tree boles at different heights at two study plots, Klingenbach and Siegendorf. Six hundred pupae were exposed on 25 trees located on a square grid at each site. The number of destroyed pupae was recorded after three days of exposure, the cause of mortality was determined, and all pupae were replaced by new ones. This procedure was repeated eleven times. Mouse and *Calosoma* (Coleoptera, Carabidae) populations were studied by trapping. Snap traps baited with *L. dispar* pupae and tree-trunk traps mounted around tree boles were used.

Mortality of the exposed *L. dispar* pupae by predators was high. After a steady increase since the beginning of host exposure, it reached about 100% at Klingenbach from the fourth sampling period on. Total mortality over the exposure period was 92%. Mortality stayed lower at the other site, Siegendorf, and reached 100% only during three exposure periods; total mortality was 67%. Judging from remains of destroyed pupae, most of them were killed by mice (46% mortality at Klingenbach, 36% mortality at Siegendorf). The impact of *Calosoma* spp. was markedly lower (1% mortality at Klingenbach, 4% mortality at Siegendorf). A large number of pupae (40% at Klingenbach, 23% at Siegendorf) was missing after the three days period, probably removed by small mammal predators.

Not only mortality of pupae, but also mouse populations differed between the two study plots. In a total of eight trap-nights, 13 mice were caught at Siegendorf and 38 mice at Klingenbach in 60 snap traps on each plot. *Apodemus flavicollis* (Rodentia, Muridae) was the species captured most frequently on both study plots. *Apodemus sylvaticus* was found in lower numbers. *Clethrionomys glareolus* (Rodentia, Arvicolidae) was only captured at Klingenbach. The higher mortality caused by small mammal predators as well as the higher trap catches of mice at Klingenbach correspond with the higher density of ground cover at this site. Trap catches of *Calosoma* were very low. At Klingenbach no carabid beetles were captured. Six *Calosoma* were caught at Siegendorf in the beginning of the investigation period. None of these specimens was recaptured.

EFFECTS OF *ENTOMOPHAGA MAIMAIGA* ON LEPIDOPTERA IN THE LITTER

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ABSTRACT

Due to the virulence of the gypsy moth fungal pathogen *Entomophaga maimaiga* and its ability to cause epizootics in low density host populations, there has been abundant interest in its potential applications for biological control. As part of extensive non-target testing, field studies demonstrated that infection in any insects other than gypsy moth larvae is rare. However, these field studies examined only macrolepidopteran larvae in the foliage. We know that gypsy moth larvae are very mobile and later instars can spend long periods of time resting near the soil where *E. maimaiga* inoculum is abundant. In the present study, we sampled lepidopteran larvae around the bases of oak trees to determine whether other lepidopteran species spending time near the soil become infected by *E. maimaiga*. In addition, bioassays were conducted by exposing a species whose larvae feed on dead oak leaves in the leaf litter (the herminiine noctuid *Zanclognatha laevigata*) to *E. maimaiga* inoculum to determine susceptibility in comparison with gypsy moth.

From 2-26 June 1998, areas of 200 cm in diameter at the bases of 20 red oak trees in Yellow Barn State Forest, NY were sampled. The sampling procedure consisted of thoroughly examining the area including the soil surface, leaf litter, understory vegetation, and tree boles, with particular attention to the many layers of leaf litter. All lepidopteran larvae, prepupae and pupae found were collected and reared. As in previous studies, we consider production of spores as positive evidence for infection. We collected and reared 358 larvae of Lepidoptera (including 7 families of Macrolepidoptera and 5 families of Microlepidoptera) many of which were in the litter. Among all of these individuals, we found only one gelechiid larva (1.2% of all gelechiids) and one noctuid, *Sunira bicolorago*, (5% of total individuals collected of this species) infected by *E. maimaiga*. Among the 67 gypsy moth larvae collected and reared, 37% were infected by *E. maimaiga*, demonstrating that *E. maimaiga* was present and active. These results are in agreement with our previous findings from foliage feeding Lepidoptera that *E. maimaiga* is highly host specific.

Bioassays were conducted by exposing third instar larvae of *Z. laevigata* or gypsy moth to resting spore-containing soil. No *Z. laevigata* larvae were infected although 60% of the gypsy moth larvae became infected.

THE USE OF ENTOMOPATHOGENS FOR CONTROL OF CERAMBYCIDS IN JAPAN AND CHINA

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ABSTRACT

Numerous cerambycids are important pests in orchards and forests in China and Japan and the pests have been the focus of control efforts using entomopathogens. In preparation for studies of pathogens for control of *Anoplophora glabripennis* in North America, we reviewed the Asian literature and discussed progress with Asian researchers.

A greater effort has been directed toward targeting adult cerambycids compared with larvae and fungi have been the most successful pathogens. During field trials, the hyphomycete fungus *Beauveria brongniartii* has been applied against *Anoplophora malasiaca* (a citrus borer in Japan), *A. glabripennis* (Asian longhorned beetle; a forest borer in China that does not occur in Japan), and *Psacothea hilaris* (a mulberry borer in Japan) while *Beauveria bassiana* has been tested in Japan against the pinewood nematode vector, *Monochamus alternatus*. The application methodology used against *A. malasiaca* and *P. hilaris* began as culturing the fungus on wheat bran and applying it around the bases of trees in field cages and evolved to culturing the fungus on non-woven pulp sheets that are stapled around trees. This latter tactic is aimed at self-inoculation of adults after emergence when they wander around tree boles during the ca. 14 d period of maturation feeding. A Japanese company (Nitto Denko, Tokyo) now produces and sells the non-woven pulp sheets containing cultures of *B. brongniartii* (isolate originating from *P. hilaris*) as a product named Biolisa Kamakiri. In Japan, these strips are applied against both *A. malasiaca* and *P. hilaris* and, since 1995, have been registered for application in mulberry, tangerine and fig. Extensive studies have demonstrated that this product yields very high levels of infection for at least 30 d after application. We know that this same isolate of *B. brongniartii* has been found to be very virulent against *A. glabripennis* in China and studies are under way testing the non-woven pulp sheets containing cultures of *B. brongniartii* in Ningxia Province, central China. Studies targeting cerambycid larvae with pathogens have investigated application of *B. bassiana* against *M. alternatus* larvae in dead trees and logs. Researchers in China have investigated the use of entomopathogenic nematodes (espec. *Steinernema feltiae*) to control larvae of *A. glabripennis* in wood. While these nematodes could be valuable because they can search for host larvae, it proved difficult to apply nematodes close enough to take advantage of this behavior. In trials, 61% infection was found, with mortality ca. 5 d after application and it is assumed that the majority of infection occurred when larvae visited holes to discard frass.

EFFECTS OF MICROSPORIDIAN INFECTION OF GYPSY MOTH LARVAE ON THE HOST-PARASITOID-SYSTEM, *LYMANTRIA DISPAR* (LEP.: LYMANTRIIDAE) - *GLYPTAPANTELES LIPARIDIS* (HYM.: BRACONIDAE)

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ABSTRACT

Interactions between *Glyptapanteles liparidis* (Bouché) (Hym.: Braconidae), a larval endoparasitoid of the gypsy moth, *Lymantria dispar* L. (Lep.: Lymantriidae) and the microsporidian pathogen *Vairimorpha* sp. (Protista, Microspora) were investigated.

Gypsy moth larvae were experimentally infected with *Vairimorpha* before and after parasitization by *G. liparidis*. Development of hosts, parasitoids, and microsporidia was observed by rearing larvae, and dissections at certain intervals, respectively. *Vairimorpha* infection of the host affected the performance of the braconid negatively, both when inoculation took place before or after parasitization. In many cases parasitism by *G. liparidis* was not successful, because of premature death of the host. This happened frequently when *L. dispar* larvae were parasitized after infection. Lethal time of gypsy moth larvae was shorter in infected and parasitized hosts than in only infected hosts. When *G. liparidis* was able to complete its endoparasitic development, the time of development was longer in infected than in uninfected hosts, mortality of parasitoids after emergence from the host was higher, weight of adult wasps was lower, and the longevity of adults was reduced. A negative effect of the host's microsporidiosis was detectable from the beginning of parasitoid larval development on. *G. liparidis* was not systemically infected by the host's microsporidium, but braconid larvae did ingest microsporidian spores at the end of their endoparasitic development and accumulated them undigested and ungerminated in their blind midgut. Intensity of *Vairimorpha* infection, measured as number of spores produced per mg fresh weight of gypsy moth larva, was higher in parasitized and infected hosts than in unparasitized and infected hosts.

The possibility of mechanical transmission of *Vairimorpha* by the ovipositing female parasitoid was investigated. *G. liparidis* females were allowed to sting heavily infected gypsy moth larvae and afterwards several uninfected larvae. No transmission was ascertained, neither at a stage of the infection when the fat body of the host was filled with environmental spores, nor at an earlier

stage, when vegetative forms and primary spores of the microsporidium were present. Furthermore, *G. liparidis*, that had developed in infected hosts, did not transmit *Vairimorpha* to uninfected hosts by oviposition.

Host selection experiments revealed that *G. liparidis* females did not discriminate between healthy and infected *L. dispar* larvae for oviposition when groups of infected and uninfected larvae were exposed to wasps in cages. Usually, the percentage of parasitized larvae did not differ between infected and uninfected gypsy moth larvae.

BEECH BARK DISEASE

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ABSTRACT

Beech bark disease (BBD) causes defect and mortality in American beech (*Fagus grandifolia*). The disease results when fungi (*Nectria* spp.) attack and kill bark tissues infested and altered by the beech scale, *Cryptococcus fagisuga*. The scale, and probably one of the fungi (*N. coccinea* var. *faginata*) entered North America sometime before 1890 at Halifax, N.S. A second pathogen, *N. galligena*, is native to North America on many hardwood hosts (but rarely on beech uninfested by scale). The introduced causal complex has spread west to northeastern Ohio, and south through Pennsylvania. Isolated outbreaks occur in West Virginia and on the North Carolina / Tennessee border. Outbreaks in first-affected forests killing front can result in severe mortality (> 50%) of the large trees. Openings in such stands often regenerate to dense thickets of beech which, as they become infested and infected by the now resident causal complex, are rendered increasingly defective, slow in growth, lose vigor and may die (aftermath forests).

Invertebrate predators of the beech scale, and mycoparasites of the *Nectria* spp. adversely affect populations on individual trees, but appear ineffective at the stand level. Host resistance to the beech scale offers most promise for long-term control of the disease. Scale resistant trees, singly or in groups, occur in some long-affected forests in low numbers (< 1% of beech stems). Resistant trees in groups usually are closely related. Genetic studies have shown them to be members of clones, half- or full-sib families, or mixtures of clones and families.

Results of past studies suggest that (1) scale populations will find increasingly favorable environments as they spread southward into ever-warmer climates (and in the north, also, as climate warming ensues); (2) other *Nectria* spp. may become part of the causal complex as beech trees become infested in new areas; (3) today's killing-front forests will, eventually, come to resemble the long-affected aftermath forests of northern New York, New England, and the Maritimes; and (4) resistant trees will be revealed in most affected forests, but will remain a minor component unless measures are taken to exploit them.

COMPARISON OF SURVIVAL AND DEVELOPMENT OF *LYMANTRIA MONACHA* (LEPIDOPTERA: LYMANTRIIDAE) ON A BROAD RANGE OF NORTH AMERICAN PLANT HOSTS

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ABSTRACT

Lymantria monacha (nun moth) is an Eurasian pest of conifers (spruce, fir, larch and pine) not known to be established in North America, but could be introduced accidentally because of its biology and behavior. *Lymantria monacha* larvae feed on and kill primarily conifers (*Picea*, *Pinus*, *Abies*, and *Larix* spp.) but can also defoliate deciduous trees and shrubs (*Fagus*, *Carpinus*, *Betula*, and *Quercus* spp.). In Europe *L. monacha* prefers and most often damages *Picea abies* (Norway spruce) and *Pinus sylvestris* (Scots pine). To predict the potential for establishment of *L. monacha* in North America, I compared its development and survival on 15 conifer and 19 broadleaf tree species. Seven Eurasian species were included for comparison.

Several North American conifers (*Abies concolor*, *Picea pungens*, *Picea glauca*, *Pseudotsuga menziesii*, and *Tsuga canadensis*) and broadleaf species (*Betula populifolia*, *Quercus rubra*, *Q. lobata*, *Q. velutina*, and *Prunus serotina*) were suitable for *L. monacha* development and survival. When compared to its preferred European hosts, other North American hosts (*Quercus alba*, *Carpinus caroliniana*, *Carya ovata*, *Tilia cordata*, *Larix occidentalis*, *Pinus strobus*, *Pinus ponderosa*, *Pinus taeda*, and *Pinus nigra*) were marginally suitable as hosts due to slower larval development, lower survival or both. I observed little or no evidence of larval feeding on *Populus* spp., *Acer* spp., *Fraxinus americana*, *Liriodendron tulipifera*, *Morus alba*, and *Juniperus virginiana*.

Successful development and survival of *L. monacha* larvae on some host plants were influenced by host phenology, specifically timing of bud break, presence of flowers, and quality changes in foliage as it matured. During the first two instars, larvae required new foliage (*Picea* spp., *Abies* spp., *Pseudotsuga* spp., *Pinus ponderosa* and *Pinus taeda*), male cones (*Pinus sylvestris* and *Pinus nigra*) or flowers (*Carya ovata*) to survive and develop successfully. Larval survival and growth was poor on *Quercus alba* foliage expanded and turned green. *Lymantria monacha* established well on *Larix kaempferi*, but after reaching the fourth instar, larvae refused to feed on it and eventually died. Fourth through sixth instar larvae had difficulty utilizing *Fagus grandifolia* foliage. This resulted in slowed growth, increased mortality, and smaller adults.

UPDATE ON CHESTNUT BLIGHT RESEARCH

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ABSTRACT

The devastation of the American chestnut (*Castanea dentata*) by the fungus *Cryphonectria parasitica* represents one of the greatest recorded changes in natural plant populations caused by an introduced organism. American chestnut once comprised 25% of the eastern hardwood forest, an area that included 100 million acres of land. The term blight was applied to the disease to describe the gross foliar symptoms that developed as individual branches and eventually the main stem died from the cankers that typify infection. Despite early efforts to control the disease by sanitation, the invading fungus spread on average 25 miles a year, encompassing the entire range of the species within a period of 40 years. The success of this fungus was insured by the availability of a uniformly susceptible host population. Today, American chestnut survives as an understory tree by producing a succession of sprouts that in time also became infected and die.

Within 20 years of the discovery of chestnut blight, researchers shifted their attention to their only hope for control, breeding blight-resistant trees. Early breeding programs were designed to preserve the most desirable traits of the American chestnut while incorporating resistant germplasm from Chinese and Japanese chestnuts. The research primarily relied on making large numbers of crosses but there were few second-generation trees developed from first-generation hybrids. Further, most of the F_1 hybrids were backcrossed to a resistant parent, typically one that lacked the desired traits of the American chestnut. These early undertakings met with limited success and were never designed to control chestnut blight in North American forests. There has been renewed interest in breeding resistant trees using another breeding approach; the well established backcross method. With this method, American cultivars that are susceptible to blight are crossed with Asiatic species. The first generation hybrids then are backcrossed to American chestnut rather than to the source of resistance. Resistance plants are selected from the progeny as successive backcrosses to American chestnut are made.

A second approach to blight control came in the 1950's when natural abatement of the disease was observed in Italy. This change in the disease eventually was attributed to the development and/or transmission of cytoplasmically-transmitted double stranded RNA viruses that infect *C. parasitica*. Strains of the fungus debilitated by these viruses have been termed "hypovirulent" the "hypoviruses" they carry and appear to be responsible for the biological control of blight that has occurred in most chestnut growing regions of Italy. A similar phenomenon has been observed in Michigan among populations of American chestnut that grow outside the natural

range of the species. Comparable spread of hypoviruses has not been observed when they have been released into sprout populations that exist in the natural range. The restricted spread of hypoviruses may be linked to a complex system of vegetative compatibility that limits the strain-to-strain contact that is necessary for hypovirus transmission to occur. Currently, genetically modified strains of *C. parasitica* are being field-tested that may help overcome the barrier imposed by vegetative compatibility by permitting hypovirus transmission to many different strains via the sexual reproductive cycle. The long-term fate of the American chestnut may reside with the natural or artificial development of a hypovirus epidemic and/or the introduction of American chestnuts that possess high levels of resistance to *C. parasitica.*

EFFECTS OF ABIOTIC FACTORS ON GYPSY MOTH EGG SURVIVAL IN MICHIGAN

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ABSTRACT

Gypsy moth (*Lymantria dispar* L.) suppression program decisions are based primarily on counts of egg masses obtained during autumn surveys. These surveys are often conducted over large areas and require considerable time and expense. Unfortunately, in some years, the number of acres designated for aerial application of Bt exceeds what is actually needed. Overspraying can occur because of substantial egg mortality and is undesirable for environmental and economic reasons.

The purpose of this research is to evaluate factors that cause gypsy moth eggs to die. Our goal is to develop an improved method of predicting defoliation, particularly in late winter or early spring, allowing adequate time for possible adjustments in suppression plans. A better understanding of the effects of winter weather on egg survival is needed in the Great Lakes region and adjacent North Central states where cold temperatures, variable snow depth, and extensive areas of oak or aspen cover type occur. Objectives of our overall project include assessment of egg mortality in relation to weather factors, egg parasitism rates, potential effects of maternal vigor on winter egg survival, and mortality of young larvae due to pathogens. Here, we specifically address how egg mass location, in terms of aspect and height, may affect egg survival.

Methods: An intensive study was initiated in two sites in 1997 to evaluate the effects of temperature, radiation, snow depth, and aspect on the microclimate experienced by gypsy moth eggs and subsequent egg survival. The first site is a relatively warm location in southwestern Michigan at MSU's W.K. Kellogg Experimental Forest in Kalamazoo County. The second site is a private woodlot located in Roscommon County in north central Michigan, the "frost pocket" of the state. At each site, we selected a white oak tree, 22-25" in diameter, growing in an oak-

dominated stand. Freshly laid egg masses were obtained from the Otis AFB rearing facility in August 1997, placed into individual screen pouches and attached to the stem of the 2 trees in late August. Egg masses were placed on each of the trees in a 4x8 grid array, with 32 egg masses on each cardinal direction at each of 3 heights: 0-30 cm (below snowline), 1 m (variable snowline) and 2 m (above snowline). Temperatures experienced by eggs were monitored at 30 sec intervals from August 1997-April 1998 using microthermocouples inserted into the middle of 2 egg masses on each aspect and at each height on both trees. Temperatures recorded by the microthermocouples were connected to a multiplexing data logger. Weather monitoring instruments were deployed at both sites in August 1997, within 3 m of the selected trees. Climatic variables including air temperature, wind speed and direction, total incoming and net solar radiation, and relative humidity, were downloaded from the multiplexor at each site weekly through April 1998. In spring of 1998, a portion of the egg masses from each height and aspect were collected at 3 wk intervals and returned to the lab. A subsample of eggs were reared to eclosion or examined to determine cause of death.

Results: We found that egg masses experienced dramatically different microclimates because of aspect and differential solar loading, despite El Nino conditions in 1997-98 that led to the warmest winter on record. Both height and aspect strongly affected temperature variability, and in some cases, the minimum and maximum temperatures experienced by egg masses. Egg masses on the southern side of trees experienced the highest maximum temperatures, the greatest deviation from ambient air temperature, and the greatest variability in temperature gradient, followed by egg masses on western and eastern aspects. Temperatures inside egg masses at the base of the tree on the southern aspect were up to 12 °C warmer than air temperature, compared with differences of only 1 °C on the northern aspect. Highest maxima occurred in egg masses on the southern and western aspects, especially near the tree base where solar loading levels were highest. On a sunny September day, temperature of southern-aspect egg masses exceeded temperatures in northern-aspect egg masses by 30 °C. Snowfall was lower than normal in 1997-1998. Minimum temperatures were only slightly warmer when egg masses were under snow, but snow cover appeared to damp out maximum temperatures, especially on the southern side of trees.

Warm fall temperatures had a greater effect on egg survival than winter temperatures. Egg masses on southern exposures had the highest egg mortality, while egg mortality was consistently lowest on the northern exposures. Egg survival on the eastern aspect was similar to the northern aspect, and survival on the western aspect was midway between northern and southern aspects. Egg masses near the ground sustained greater mortality than egg masses at 1 or 2 m on all but the northern aspect, where height had little effect. Although egg masses near the ground may be insulated by snow, especially at the northern site, the high solar radiation and resulting temperatures killed many eggs.

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