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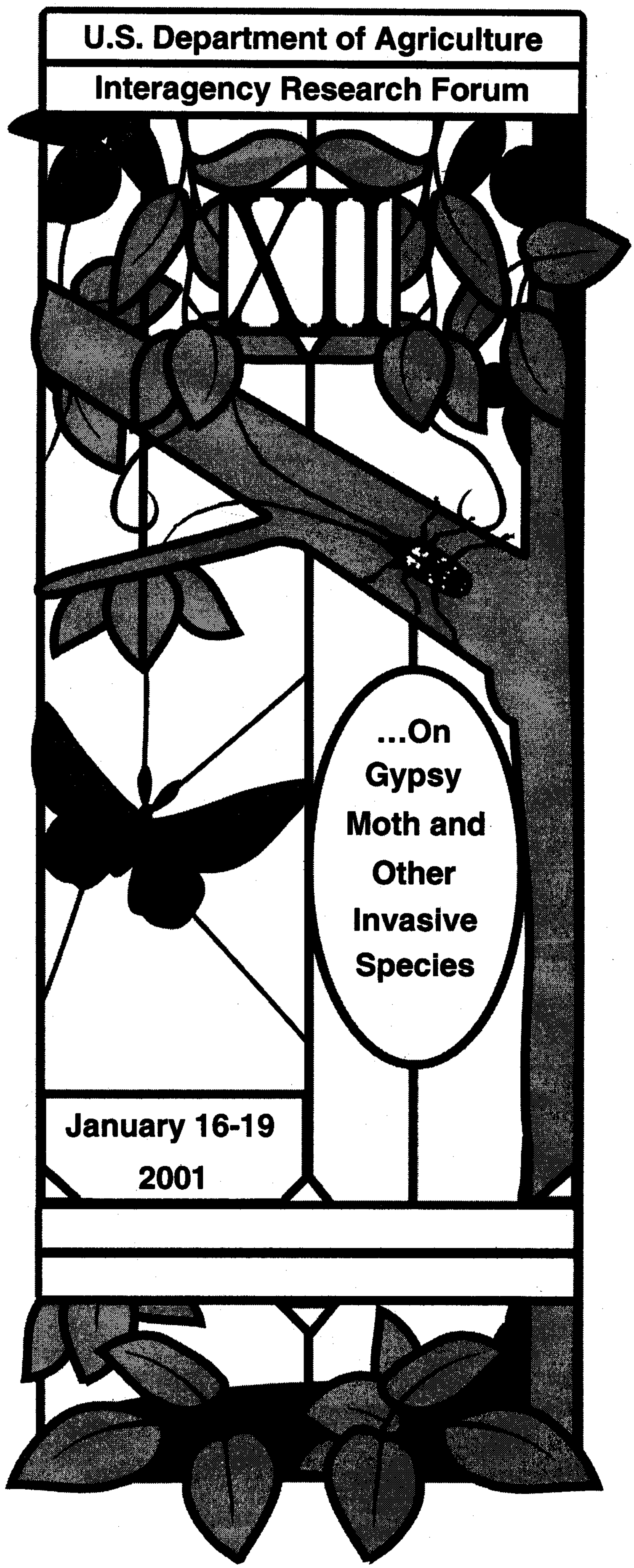

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USDA Interagency Research Forum on Gypsy Moth and Other Invasive Species
January 16-19, 2001
Loews Annapolis Hotel, Annapolis, Maryland

AGENDA

Tuesday Afternoon, January 16

REGISTRATION
POSTER DISPLAY SESSION I

Wednesday Morning, January 17

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

The Siege of Invasive Species in Midwestern Ecosystems
Robert N. Wiedenmann, Illinois Natural History Survey

The Brown Spruce Longhorn Beetle in Halifax: Pest Status and Preliminary Results of Research
Jon Sweeney, Natural Resources Canada

PLENARY SESSION .... Moderator: Robert Mangold, USDA-FS

The National Council on Invasive Species
Lori Williams, Department of the Interior

A Multi-year Project to Detect, Monitor, and Predict Forest Defoliator Outbreaks in Central Siberia
Max McFadden, The Heron Group, LLC

Wednesday Afternoon, January 17

GENERAL SESSION .... Moderator: Cynthia D. Huebner, USDA-FS
Invasive Plants: Organismal Traits, Population Dynamics, and Ecosystem Impacts
Presenters: E. Nilsen, Virginia Polytechnic Institute & State University; D. Gorchov, Miami University of Ohio; F. Wei, State University of New York at Stonybrook; K. Britton, USDA-FS; C. D'Antonio, University of California at Berkeley

GENERAL SESSION .... Moderator: Kathleen Shields, USDA-FS
Research Reports
Presenters: J. Colbert, USDA-FS; J. Elkinton, University of Massachusetts; J. Cavey, USDA-APHIS

POSTER DISPLAY SESSION II

Thursday Morning, January 18

GENERAL SESSION .... Moderator: Victor Mastro, USDA-APHIS
Asian Longhorned Beetle
Presenters: M. Stefan, USDA-APHIS; D. Nowak, USDA-FS; S. Teale, SUNY College of Environmental Science and Forestry; B. Wang, USDA-APHIS; R. Mack, USDA-APHIS

GENERAL SESSION .... Moderator: Kevin Thorpe, USDA-ARS
Research Reports
Presenters: S. Frankel, USDA-FS; B. Geils, USDA-FS; D. Gray, Natural Resources Canada

Thursday Afternoon, January 18

GENERAL SESSION .... Moderator: Vincent D'Amico, USDA-FS
Gypsy Moth in the Midwest
Presenters: D. McCullough, Michigan State University; A. Liebhold, USDA-FS; W. Kauffman, USDA-APHIS; A. Diss, Wisconsin Department of Natural Resources; L. Solter, Illinois Natural History Survey; K. Raffa, University of Wisconsin

GENERAL SESSION .... Moderator: Vincent D'Amico, USDA-FS
Research Reports
Presenters: B. Hrašovec, University of Zagreb, Croatia; E. Burgess, Hort-Research, Auckland, New Zealand; C. Maier, Connecticut Agricultural Experiment Station

Friday Morning, January 19

GENERAL SESSION .... Moderator: Sheila Andrus, USDA-FS
Asian Longhorned Beetle: Detection and Monitoring Panel Discussion
Panel Participants: J. Aldrich and A. Zhang, USDA-ARS; R. Haack, USDA-FS; D. Lance and B. Wang, USDA-APHIS; D. Williams, USDA-FS; S. Teale, SUNY College of Environmental Science and Forestry; M.T. Smith, USDA-ARS; K. Hoover, The Pennsylvania State University

GENERAL SESSION .... Moderator: David Lance, USDA-APHIS
Asian Longhorned Beetle: Control Options Panel Discussion
Panel Participants: V. D'Amico, USDA-FS; T. Poland and R. Haack, USDA-FS; A. Hajek, Cornell University; L. Hanks, University of Illinois at Champaign-Urbana; M. Keena, USDA-FS; B. Wang and W. McLane, USDA-APHIS; Z. Yang, Chinese Academy of Forestry; M.T. Smith, USDA-ARS

Closing Remarks

CONTENTS

PLENARY PRESENTATIONS

The Siege of Invasive Species in Midwestern Ecosystems 1
R.N. Wiedenmann

The Brown Spruce Longhorn Beetle in Halifax: Pest Status and Preliminary Results of Research 6
J. Sweeney, G. Smith, J.E. Hurley, K. Harrison, P. de Groot, L. Humble, and E. Allen

A Multi-year Project to Detect, Monitor, and Predict Forest Defoliator Outbreaks in Central Siberia 11
M. McFadden, A. Sharov, and Y. Baranchikov

ABSTRACTS AND PAPERS OF PRESENTATIONS AND POSTERS

Modeling dispersal of the Asian longhorned beetle. 15
J.S. Bancroft and M.T. Smith

Siberian moth sex attractant: tests in different geographic populations 21
Y.N. Baranchikov, J.A. Klun, V.C. Mastro, V.M. Pet'ko, I. Ragenovich, G.I. Turova, R.A. Tur'yanov, and G.I. Yurchenko

Gypsy moth insect predators and parasites in Central Siberia 22
Y.N. Baranchikov, Y.P. Kondakov, P.W. Schaefer, and R.W. Fuester

Invasive terrestrial slugs in forest ecosystems in North America 23
G. Bernon

Potential biocontrol agents for kudzu from China 24
K.O. Britton, J. Sun, D. Orr, Z. Yang, C. Ping, T. Mingyi, and J. Zi-de

Pest resistance genes for the control of gypsy moth and other forestry pests 28
E.P.J. Burgess, B.A. Philip, L.A. Malone, and H.S. Gatehouse

Hemlock woolly adelgid impact assessment: how big of a threat is this critter? 33
J. Colbert and B. Onken

Invading forest insects in Central Europe 39
G. Csóka

Nonlinear transmission of the gypsy moth NPV 40
V. D'Amico, J.S. Elkinton, and J.D. Podgwaite

Ecosystem impacts of invasive exotic plants in wildlands - characterizing the culprits 41
C.M. D'Antonio

Assisted and natural spread of parasitoids and diseases in newly established populations of gypsy moth: the Wisconsin experience 46
A. Diss

Control of *Anoplophora glabripennis* with entomopathogenic fungi 48
T.L.M. Dubois, H. Jiafu, Z. Li, M. Fan, and A.E. Hajek

Assessing the impact of Norway maple on natural forest communities 49
W. Fang

The Phytosanitary Alert System of the North American Plant Protection Organization: www.pestalert.org 53
D.A. Fieselmann, W.D. Bailey, R. Favrin, R. Santibanez, I. McDonell, and L.C. Millar

Technologies for preventing introductions of exotic wood-boring insects into the United States 54
M. Fleming, K. Hoover, Y. Fang, D. Agrawal, V. Mastro, J. Shield, Y. Wang, and R. Roy

Relationships between endogenous juvabione in Fraser fir and balsam woolly adelgids 55
G.A. Fowler, J. Zhang, and F.P. Hain

Development of odor-based monitoring systems for exotic pests 56
J.A. Francese, D.R. Lance, and V.C. Mastro

Sudden oak death in coastal California 57
S. Frankel

Male-biased sex ratios in *Glyptapanteles flavicoxi* (Marsh) (Hymenoptera: Braconidae) parasitizing gypsy moth (Lepidoptera: Lymantriidae) 58
R.W. Fuester, K.S. Swan, K. Dunning, and P.B. Taylor

Review and prospect of research on *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in China 59
R. Gao and G. Li

Impacts of white pine blister rust 61
B.W. Geils

Entomophaga maimaiga at the southern edge of the gypsy moth range 65
H. Gillock and F.P. Hain

Effects of the invasive shrub, *Lonicera maackii*, Amur honeysuckle, on native plants in eastern deciduous forests 66
D.L. Gorchov and K.E. Miller

Assessing gypsy moth seasonality and risk of establishment using a geographically robust model of phenology 69
D.R. Gray

Acoustic detection of *Anoplophora glabripennis* and native woodborers (Coleoptera: Cerambycidae) 74
R.A. Haack, T.M. Poland, T.R. Petrice, C. Smith, D. Treece, and G. Allgood

Asian longhorned beetle (*Anoplophora glabripennis*) in the United States: historic timeline of key detection/interception events 76
E.R. Hoebeke

The gypsy moth in Croatia 77
B. Hrašovec

Comparisons of natural enemy populations in eastern and midwestern gypsy moth populations 80
W.C. Kauffman and D.J. Nelson

Anoplophora glabripennis (Coleoptera: Cerambycidae) flight propensity in the laboratory 81
M. Keena and W. Major, III

Anoplophora glabripennis (Coleoptera: Cerambycidae) development on cut logs of four species of *Acer* 82
M. Keena, S. Ulanecki, and L. Lazarus

Systematics of Asian longhorned beetles of the genus *Anoplophora* 83
S.W. Lingafelter and E.R. Hoebeke

Characterizing the response of artificially inserted Asian longhorned beetle larvae in three host tree species under greenhouse conditions 84
S. Ludwig, S. Montero, K. Hoover, and J. Sellmer

Methods development for the exclusion of Asian longhorned beetle 86
R.G. Mack, Jr. and A.V. Barak

Distribution, hosts, and seasonal activity of the exotic Japanese cedar longhorned beetle, *Callidiellum rufipenne* (Coleoptera: Cerambycidae) 87
C.T. Maier

Studies on multiparasitism of *Glyptapanteles porthetriae* and *Glyptapanteles liparidis* (Hym., Braconidae) on the host larva, *Lymantria dispar* (Lep., Lymantriidae) 90
R.C. Marktl and A. Schopf

Factors affecting the success of the gypsy moth biological control *Entomophaga maimaiga* in Michigan 91
D.G. McCullough, N.W. Siegert, A.E. Hajek, M. Wheeler, R.C. Venette, and W.C. Kauffman

Intercept™ Panel Trap, a novel trap for monitoring forest Coleoptera 93
J.R. McLaughlin, D. Czokajlo, D. Ross, and P. Kirsch

Attract and kill technology for management of European pine shoot moth, *Rhyacionia bouliana*, and Western pine shoot borer, *Eucosma sonomana* 94
J.R. McLaughlin, G. Determan, A. Eglitis, D. Czokajlo, C. Sack, and P. Kirsch

Novel new attractant and formulations for control and monitoring of tephritid fruit flies 95
J.R. McLaughlin, C. Sack, P. Kirsch, G. Booysen, and D. Czokajlo

Attractants for the larger pine shoot beetle, *Tomicus piniperda* 96
J.R. McLaughlin, S. Teale, D. Czokajlo, T. Poland, P. deGroot, J. Staples, R. Haack, and P. Kirsch

Field evaluation of a Chinese lady beetle for biological control of the hemlock woolly adelgid 97
M.E. Montgomery and N.P. Havill

Adaptive physiological traits and constraints on the distribution of invasive legumes 98
E.T. Nilsen

Important genera of longhorn beetles native to Slovakia: pest status and natural enemies . . . 102
J. Novotný M. Turčáni, and G. Csóka

Potential effect of an Asian longhorned beetle (*Anoplophora glabripennis*) on urban trees in the United States 104
D.J. Nowak, J.E. Pasek, R.A. Sequeira, D.E. Crane, and V.C. Mastro

Evaluation of systemic insecticides to control *Anoplophora glabripennis* (Coleoptera: Cerambycidae) 105
T.M. Poland, R.A. Haack, and T.R. Petrice

The use of molecular genetics to identify and monitor invasive pests 107
D. Prasher, J. Molongoski, P. Elder, and D. Winograd

Exotic ambrosia beetles in the southeastern United States 108
R.J. Rabaglia

Recent studies on midgut bacteria of the gypsy moth 109
K.F. Raffa, N. Broderick, R. Goodman, and J. Handelsman

The New Pest Advisory Group: A component of safeguarding U.S. agricultural and natural ecosystems 110
S.C. Redlin, L.G. Brown, W.D. Bailey, R.A. Schall, L.C. Millar, and D.A. Fieselmann

Automated recording traps to assess gypsy moth flight phenology along the advancing front 111
A.J. Sawyer, D. Leonard, V. Mastro, J.G.R. Tardif, E.S. McKinstry, G. Pelletier, and D.M. Pitta

Distant effect of pheromone used for mating disruption of gypsy moth 112
A. Sharov, K. Thorpe, and K. Tcheslavskaia

Anoplophora glabripennis antennal sensory receptors: a research update 113
K.S. Shields

Olfactory responses of antennal sense organs of the female sphinx moth (*Manduca sexta*) to host-associated plant odorants 115
V.D.C. Shields and J.G. Hildebrand

A mutation in ORF 134 of the LdMNPV causes production of abnormally large polyhedra 116
J.M. Slavicek, M.E. Kelly, N. Hayes-Plazolles, and M. Mercer

Dispersal potential of *Anoplophora glabripennis* Motsch. 117
M.T. Smith, J. Bancroft, R. Gao, and G. Li

Comparison of the reproductive potential of *Anoplophora glabripennis* (Motsch.) among host tree species 123
M.T. Smith, J.S. Bancroft, and J. Tropp

Pathogen-host and pathogen-pathogen interactions: microsporidia vs. the gypsy moth 129
L.F. Solter, M.W. Henn, J.P. Siegel, D.K. Pilarska, and M.C. Higgs

Infectivity of rhabditoid nematodes to the Asian longhorned beetle 131
L.F. Solter, M. Keena, J.R. Cate, M.L. McManus, M.C. Higgs, and L.M. Hanks

Influence of male and female mating ages on the percentage of embryonated eggs in gypsy moth egg masses 132
J.A. Tanner, S.E. Lane, and D.L. Melcher

Testing mating success of gypsy moth females in Wisconsin 133
K.S. Tcheslavskaia, A.A. Sharov, and C.C. Brewster

Toxicity and efficacy of imidacloprid to *Anoplophora glabripennis* (Coleoptera: Cermabycidae) 134
B. Wang, R. Gao, V.C. Mastro, W.H. McLane, and R.C. Reardon

Integrating a biological control program into education and outreach 135
R.N. Wiedenmann, D.J. Voegtlin, M.R. Jeffords, and S.L. Post

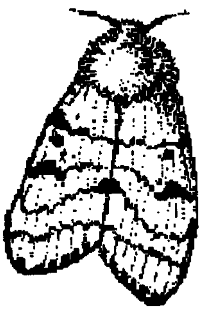
Observations on *Anoplophora glabripennis* in South Korea in Summer 2000 136
D.W. Williams, H. Lee, I. Kim, and P.W. Schaefer

Investigations of natural enemies for biocontrol of *Anoplophora glabripennis* (Motsch.) 139
Z. Yang and M.T. Smith

Progress on ALB semiochemistry 142
A. Zhang, J.E. Oliver, and J.R. Aldrich

LIST OF ATTENDEES 143

Proceedings
U.S. Department of Agriculture
Interagency Research Forum on Gypsy Moth and Other Invasive Species
2001



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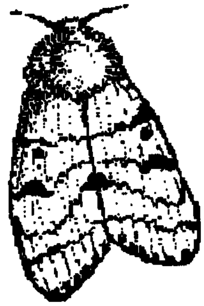

Edited by
Sandra L. C. Fosbroke and Kurt W. Gottschalk

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USDA

THE SIEGE OF INVASIVE SPECIES IN MIDWESTERN ECOSYSTEMS

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ABSTRACT

Although coastal regions of North America are heavily invaded by exotic species, invasive species are not limited to the Atlantic or Pacific coasts. Here, I show that the midwestern U.S., as exemplified by ecosystems in Illinois, is equally predisposed to invasions, often by the same means. I cite traits of invasive species and the habitats they invade, offer some reasons why the Midwest is easily invaded and details about a few of the worst invasive species in the Midwest, then summarize our efforts to fight back by using biological control against purple loosestrife.

The recent publication by Pimentel et al. (2000) estimated that invasives cost the U.S. over $137 billion per year. Invasive weeds and insects alone were estimated to cost over $26 billion and $16 billion, respectively. Calculating similar estimates of the ecological costs of invasive species is more difficult, but would be equally alarming. In the United States, approximately 40% of the species listed as threatened or endangered are thought to have been imperiled by the effects of invasive species (Wilcove et al. 1998). Other regions of the world fare even worse – as many as 80% of species endangered in some regions are thought due to invasive species. As many as 42% of vertebrates whose causes of extinction are known are attributed to invasive species.

In addition to directly affecting native species, invasive species can alter basic ecological processes in invaded habitats. Exotic plant species can displace native plants, affect nest sites for birds, alter nutrient cycles, or increase frequency of fires. Exotic animal invaders prey on beneficial organisms, disperse seeds that change landscapes, or have different grazing patterns that increase soil erosion. The aquatic invader zebra mussel (*Dreissena polymorpha*) actually increases water quality through filtration, predisposing the habitat to new invaders, such as the Eurasian fish, round goby (*Neogobious melanostomus*). In reverse, increased turbidity by common carp (*Cyprinus carpio*) alters water habitats needed by native plants and fish. Finally, the duration and extent of the effects of invaders may be felt long after the initial wave of invasions occurs, the so-called "ghost of invaders past." Species that can persist in invaded habitats, the interactions among those species, and subsequent new invasions leave communities far different than they were originally. Consider the invasion of the Great Basin of the American West by European cheatgrass (*Bromus tectorum*). Large stands of cheatgrass enhance frequent fires, thus changing the shrub-steppe habitat to a near monoculture of the exotic grass (Kurdila 1995, Vitousek et al. 1996). Crossing that habitat now, one may not encounter many of the species that evolved in the shrub habitat. Instead, those plant and animal species that can persist in the new frequent-fire regimen will continue to structure this altered community.

What is special about the midwestern U.S.? Though geographically far from ocean coasts, we are easily reached by invasives. Economic trade has brought many invaders to the Midwest. Once the Great Lakes were isolated from oceans, but now are connected through the St. Lawrence Seaway. The opening of the Seaway brought goods via ocean-going vessels to ports on the Great Lakes, but also brought aquatic invaders in ballast water in the ships' holds. Sea lamprey (*Petromyzon marinus*) decimated Great Lakes fishing in the 1960s. Later invaders include zebra mussel and round goby, both considered native to the Black and Caspian Seas. Two species of tiny waterfleas (*Daphnia* spp.) are among the most recent invaders found in the Great Lakes and are impervious to predatory fish, giving them a leg up (figuratively, at least) on native species and reducing food for predaceous fish. Nor are these invaders of the Great Lakes confined to the lakes. Once, the Great Lakes and the Great River systems of the Midwest (Illinois, Mississippi, Ohio, Missouri, and Platte Rivers) were isolated. Not now. The Sanitary Ship Channel near Chicago connects Lake Michigan with the headwaters of the Illinois River. Some 250 miles downstream, the Illinois River joins the Mississippi. Once zebra mussel moved through the Great Lakes and into the Illinois River, the rest of the Great Rivers were open for invasion. Likewise, exotic fish that have found new homes in the river systems are poised to move the opposite direction, into the Great Lakes.

Land habitats are equally prone to invasion. Air traffic through major airports (e.g., Chicago's O'Hare Airport) connects the Midwest with the rest of the world in a few hours. Rail and truck traffic pass through the Midwest in all directions. A direct rail link from Nova Scotia in far-eastern Canada to Chicago may permit movement of brown spruce longhorned beetle (*Tetropium fuscum*) into the Midwest. Asian longhorned beetle (*Anoplophora glabripennis*) is one of the more notorious trade-enhanced invaders to threaten urban and rural Midwestern forests. The Chinese soybean aphid (*Aphis glycines*), first discovered in 2000, likely found its way into the U.S. through trade of bonsai plants from Asia. Once escaped (or moved through re-shipment of infested plants), the aphid found soybean habitats to invade, from Minnesota to Kentucky.

Invasion of Midwestern communities – whether aquatic or terrestrial – is enhanced by several factors. Many of our invasive pests are longitudinal migrants; that is, they arrived from a similar area of the world in a similar latitude and climate, traveling east to west, or vice versa. Invasible communities also often have some sorts of disturbance that predispose the habitats to invasion. Development, altered hydrology, siltation, fire, and grazing are all disturbances that contribute to invasion conditions. Or, communities may be early successional with a low diversity of native species, especially ecologically similar species. Illinois' remnant prairies can be considered early successional, and the Great Lakes were glaciated as recently as 10,000 years ago, thus having a fairly simple natural fauna. Thus, the Illinois landscapes and lakes were prime for invasion.

The other aspect of invasions relies on characteristics of the invaders themselves. Lists of traits associated with invasive species include high reproductive and dispersal rates, resistance to native natural mortality, and being a habitat or resource generalist. The perennial plant purple loosestrife, for example, produces >2.5 million seeds per year. Likewise, gypsy moth produces up to 1,000 eggs in a mass. Some Midwestern invasives have high dispersal abilities. Round goby was discovered in the St. Clair River in 1990. Within five years, the fish could be found in all of the Great Lakes. Although gypsy moth females are flightless, the early instars can balloon on winds, and egg masses are especially prone to accidental movement by humans. Invasive plants, such as purple loosestrife or garlic mustard, are largely untouched by native herbivores.

The list of invasive species in the Midwest knows no taxonomic bounds. In Illinois, the diverse list of exotic invaders includes plants, insects, terrestrial vertebrates, aquatic organisms (both vertebrate and invertebrate), and even plant pathogens. Illinois has plant invaders such as garlic mustard (*Alliaria petiolata*), purple loosestrife (*Lythrum salicaria*), kudzu (*Pueraria lobata*), and teasel (*Dipsacus laciniatus* and *D. sylvestris*). Garlic mustard can reach densities of 2,000 plants/m^2 in many Illinois forests, displacing native spring ephemerals. Kudzu, whose infamy is known from the southeastern U.S., has over 90 known populations in Illinois. Teasel species apparently are increasing along roadsides and rights of way, also making incursions into pasture and prairie. I say apparently increasing, because any perceived increase in density and spread is anecdotal – due to a lack of economic cost, this species has not been monitored closely in the past (but the monitoring is beginning now). In addition, both common reed (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*), which are distributed throughout both Old and New Worlds, are represented in the state by apparently exotic genotypes with invasive properties. Several plants planted extensively along roadsides, either to stabilize hillsides (e.g., crown vetch, *Coronilla varia*) or as part of a wildflower mix (e.g., Dame's rocket, *Hesperis matronalis*), are now spreading and invading other areas. Finally, several species are either just arriving, such as Chinese yam (*Dioscorea oppositifolia*) moving northward, or anticipated to arrive soon, such as mile-a-minute weed (*Polygonum perfoliatum*) moving westward.

Insect invaders are equally diverse. Asian longhorned beetle in Chicago has become the poster-child for invasions due to trade. More than 1,500 trees in the Chicago area have been cut down to slow the spread; whether this has kept the beetle out of the area forest preserves is not yet certain. Gypsy moth was first detected in Illinois in 1973, but is acknowledged to have become far worse in the past decade. Another consequence of open trade, the Asian tiger mosquito (*Aedes albopictus*) invaded the state in used tires shipped from Asia. These cavity-nesting mosquitoes found the water that collected in tires and tree cavities to be perfect for their populations to increase. This mosquito can vector several kinds of encephalitis – themselves exotic species. Whether Chinese soybean aphid becomes one of the bad offenders is yet to be seen. Lacking many natural enemies, dispersing readily, and overwintering on another exotic species, buckthorn (*Rhamnus cathartica*), this aphid has many of the right (or wrong) traits. It also can vector soybean viruses, which may put this species toward the top of the list.

Aquatic invaders in the Midwest are more than adequately represented. Zebra mussel was first detected in the Great Lakes in 1988, but now reaches densities of >700,000/m^2 (Griffiths et al. 1991), often completely covering native mussels and clams, and clogging water intake pipes, causing an estimated $100 million in damage and control costs. Round goby has been found at densities >50/m^2 along the littoral area of southern Lake Michigan – and this for a fish that can grow to 25 cm in length. Gobies also prey on many small fish and – in a quirk that is one of the few rays of hope – will feed on zebra mussels (as well as native mussels). Other fish that threaten native mussels include the yet-to-arrive black carp, a species grown for aquaculture in nearby states. This species can grow to 1 m in length and as much as 36 kg – traits good for a food fish, but terrifying for an invasive predatory fish. Interestingly, black carp is only one of an array of six exotic carp species threatening invasion that occur at three trophic levels – herbivores, plankton feeders, and predators.

Invasive feral hogs (*Sus scrofa*), well established in southern Illinois, are poised to transmit livestock and human diseases. Even the seemingly benign Eurasian collared dove (*Streptopelia decaocto*) has been implicated in reductions in other native bird species. Finally, exotic, invasive plant pathogens have transformed the Illinois landscape. Cities once lined with American elms now are home to few, if any, after arrival of Dutch elm disease. And the Prairie State, though located on the edge of the eastern deciduous forest, still has felt the effects of chestnut blight fungus, though not so severely as the rest of eastern North America.

As bad as the picture seems, we are fighting back. Cutting trees and injecting insecticides seems to be slowing the spread of Asian longhorned beetle. Nearly all kudzu populations have been treated repeatedly with herbicides; many appear to be controlled. A barrier is planned for the Sanitary Ship Channel near Chicago to slow movement of round goby into the Illinois River (except that the fish has been found downstream of the barrier). Garlic mustard biological control agents are being studied in Switzerland and we hope to have some of them by 2002. And finally, we seem to be winning the fight against purple loosestrife in our wetlands. Since 1994, Illinois has been rearing *Galerucella* spp. beetles for biological control of the weed. Nearly 2 million beetles have been distributed to approximately 130 wetland sites in the state. At several sites, signs look promising. We have seen severe defoliation of loosestrife, followed by an increase in the native plant species, at one monoculture in northwest Illinois. At a more-diverse sedge meadow nature preserve in northeast Illinois, flowering and height of loosestrife plants have decreased, coupled with an increase in the native plants that defined the nature preserve. In 2000, there was no loosestrife flowering within a mile of the beetle releases. We also have engaged over 200 educators in understanding the value of Illinois wetlands and the problems of exotic species, and helped them grow loosestrife and rear *Galerucella* beetles in their classrooms for release. Educating the next generations of citizens about invasive species is part of our long-term plan for combating invasives in the state.

Though invasive species will continue to arrive in the Midwest – through trade bringing invaders via water, land, or air – we will continue to fight back. Statewide management plans are being developed to try to stem the threats imposed by current or future invaders. Whether we win the war (or at least a few battles) remains to be seen.

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THE BROWN SPRUCE LONGHORN BEETLE IN HALIFAX: PEST STATUS AND PRELIMINARY RESULTS OF RESEARCH

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ABSTRACT

In March 2000, it was determined that the brown spruce longhorn beetle (*Tetropium fuscum* Fabr.) (Coleoptera: Cerambycidae), a native of Central Europe and parts of Asia, had become established in Point Pleasant Park, Halifax, Nova Scotia, where it was killing red spruce (*Picea rubens* Sarg.) trees. The risk the beetle poses to the health of North America's forests resulted in the formation of the Brown Spruce Longhorn Beetle Task Force, comprised of members of several federal, provincial, and municipal agencies. In this presentation, we briefly describe the beetle's biology, the chronology of events leading to its discovery in Halifax, current efforts to eradicate it and contain its spread, and preliminary results of some of our research.

LIFE CYCLE AND BIOLOGY

In its native range, *T. fuscum* attacks mainly Norway spruce (*Picea abies* (L.) Karst.) but has also been reported infesting *Picea sitchensis* (Bong.) Carr. (Franke-Grosman 1954), *P. pungens* Engelm., *Abies alba* Mill., *Pinus sylvestris* L., and *Larix* spp. Mill. (Juutinen 1955 and references therein). While it is considered a secondary pest in Europe, usually infesting windthrown or living trees under stress from other factors such as root rots, drought, or bark beetles, *T. fuscum* occasionally appears in trees "weakened so negligibly that they are virtually the same as healthy trees" (Juutinen 1955). Throughout most of its range, *T. fuscum* is univoltine and overwinters as a larva. However, it can have two generations per year in the southern part of its range and can require 2 years per generation at its northern range limit. Adults emerge sexually mature from May to August, mate soon after emergence, and mate more than once. Females lay an average of 80 eggs, singly or in clusters, well hidden beneath bark scales (Schimitschek 1929). Larvae feed in the phloem and cambium and produce an extensive network of wide, irregular tunnels. Infestation eventually leads to girdling of the stem and increases the tree's susceptibility to other pests; once infested by *T. fuscum*, a tree usually dies within 1 to 5 years (Juutinen 1955). Mature larvae typically form a hook-like pupal cell 1-2 cm deep and 2-4 cm long in the sapwood, but may also pupate between the wood and bark or entirely in the phloem. The adult beetle makes an oval to round exit hole about 4 mm in diameter (Wettstein 1951).

CHRONOLOGY

Events leading to the discovery of *T. fuscum* in Halifax began in July of 1998 when representatives of Natural Resources Canada (NRCAN) and the Canadian Food Inspection Agency (CFIA) observed a large number of dying trees in Point Pleasant Park, located adjacent to a container port in the city. Surveys of the park in the fall of 1998 found many dead and living red spruce with copious resin flow down the trunk. During the winter of 1998-1999 and winter-spring of 1999-2000, more than 70 bolt sections were collected from the stems of 17 live, green spruce trees with copious resin flow and no evidence of attack by *Dendroctonus* spp., and incubated in containment facilities for insect rearing and fungal culturing (Pegler and Hurley 2001). A total of 125 adult specimens of *Tetropium fuscum* emerged from 14/17 trees and were confirmed by regional (NRCAN), national (AAFC and CFIA), and European experts. Other insects that emerged were native to North America, not known to cause tree mortality, and were found in only a few samples. In February 2000, examination of *Tetropium* specimens from the Nova Scotia Museum of Natural History revealed that 17 specimens of *T. fuscum* had been collected in Point Pleasant Park, Halifax, in 1990 and misidentified as a native species, *Tetropium cinnamopterum* Kirby. Morphological characters useful for distinguishing *T. fuscum* from *T. cinnamopterum* are available (Smith and Humble 2000). By March 2000, *T. fuscum* was considered established in Point Pleasant Park (Smith and Hurley 2000).

In parallel to the insect rearing studies, there were investigations into the incidence of root disease in the park's red spruce. Fungal culturing in February 1999 and field surveys in September 1999 found little evidence of root rots. However, pure cultures of an *Ophiostoma* sp. wood stain fungus were isolated from beetle-infested trees in April 1999 and confirmed by AAFC in March 2000. This *Ophiostoma* was isolated from infested trees again in April 2000. The species and pathogenicity of the *Ophiostoma* is unknown. Studies of *Ophiostoma* systematics and molecular methods for species identification are currently underway (NRCAN and AAFC).

On 30 May 2000, Point Pleasant Park was placed under federal plant quarantine by the CFIA and movement of wood from the park was restricted. On 5 June 2000, the Brown Spruce Longhorn Beetle (BSLB) Task Force was established with the main objective of eradication. The Task Force is led by the CFIA with representatives from Natural Resources Canada, Halifax Regional Municipality (HRM), Nova Scotia Department of Natural Resources (NSDNR), New Brunswick Department of Natural Resources & Energy (NBDNR&E), Maritime Lumber Bureau (MLB), and Dalhousie University. An intensive survey, beginning in the park and expanding outwards, was launched by the CFIA and NSDNR in which more than 52,000 conifers were examined on over 47,000 residential properties covering more than 170 km^2. Surveys were also conducted within an 18- to 20-km radius of the park. Based on surveys, the CFIA expanded the BSLB quarantine zone on 13 October 2000. Trees suspected of BSLB infestation were felled and burned and bark was peeled from the stumps to the soil line. Cutting was halted by a court injunction in August 2000 but was overturned on appeal in December 2000. To date, about 3,100 infested trees have been removed: 2,200 within Point Pleasant Park and about 900 outside the park. No BSLB infested trees have yet been found outside of a 15-km radius from Point Pleasant Park.

RESEARCH

We present preliminary results from research on: (1) susceptibility of selected North American conifers to *T. fuscum*; (2) development of a trap for detection surveys; and (3) trap logs for containment of infestations. We also list other studies, proposed or underway, that are part of an overall research plan to increase our knowledge of the beetle's biology, behavior, and ecology, and to develop effective methods of detection and control.

Host susceptibility was investigated using: (1) small cage laboratory bioassays to compare the numbers of eggs laid on native spruce species in forced and choice tests; (2) a field experiment comparing infestation of 1-m vertical bolts of *P. rubens*, *P. glauca* (Moench) Voss, *P. mariana* (Mill.) B.S.P., *Abies balsamea* (L.) Mill., and *Larix laricina* (Du Roi) K. Koch; and (3) the rearing of insects from bolts collected from trees found displaying signs of *T. fuscum* infestation during field surveys. Given no choice, female *T. fuscum* laid eggs on *P. rubens*, *P. glauca*, and *P. mariana*; in choice bioassays, *P. rubens* was preferred to *P. mariana*. Lifetime fecundity averaged 85 eggs (0-151) and increased with female size. Adult *T. fuscum* successfully emerged from bolts of *P. rubens*, *P. glauca*, and *P. mariana* collected in field surveys; thus, all northeastern spruce species are susceptible. The results of the field experiment will be known when rearing is completed in late spring of 2001.

In an effort to develop a survey tool, we tested an unbaited control plus five combinations of α-pinene, ethanol, and the 3-component aggregation pheromone for *Ips typographus* (as a potential kairomone) in Lindgren funnel traps for attraction of *T. fuscum*. The traps were placed about 1 m above the ground in Point Pleasant Park on 28 June 2000 and checked weekly until 24 August. Eight *T. fuscum* adults were captured and no lure was more attractive than the unbaited control. Twenty other species of cerambycid beetles were captured in the traps, including one specimen of *T. cinnamopterum.*

Because *Tetropium* spp. will attack freshly cut logs (Post and Werner 1988), trap logs were deployed operationally as a means of attracting ovipositing female *T. fuscum* in an attempt to reduce infestation in living trees. Over 100 log decks were spaced about 50 m apart along roads and pathways in Point Pleasant Park on 20-22 June 2000. Each deck consisted of six, 2.4-m long by 15- to 35-cm diameter red spruce logs stacked, parallel, three on the bottom, two in the middle, and one on top. All logs were cut from uninfested trees that were felled in late May to early June. We conducted two experiments. In the first, we baited 30 log decks with the same five combinations of host volatiles (plus unbaited control) that were tested in the funnel traps (five replicates per treatment). In the second, an unbaited, 6-log deck was compared with a: (1) spoke of 6 logs, each laying directly on the ground; (2) line of 6 logs, oriented vertically and braced between two trees; and (3) three freshly girdled, live red spruce trees. The remaining operational log decks were baited with high release rate lures of ethanol and α-pinene (Phero Tech Inc.). Six of these log decks (=36 logs) were processed in November 2000 by milling the logs into 7- to 8-mm thick slabs using a portable bandsaw and counting the numbers of pupal cells. We found a mean of about nine *Tetropium*-like (i.e., L-shaped) pupal cells per log. Logs on the bottom of the deck were infested more heavily than those exposed on top. From a subsample of 47 undamaged larvae, 46 were cerambycids and 38 (81%) were *Tetropium* spp. Infestation levels and the ratio of *T. fuscum* to native *Tetropium* will be determined in January 2001 by milling trap logs to count pupal cells and by rearing adults from bolt subsamples.

FUTURE AND ONGOING STUDIES

In addition to the studies described above, research is underway in the following areas:

- Survey and diagnostic tools
  - morphological and molecular methods of identifying juvenile stages of native and non-native *Tetropium* spp. (NRCAN, CFIA, and AAFC)
  - comparative diagnostics of damage by *T. fuscum* and native *Tetropium* spp. (NRCAN, CFIA, and AAFC)
  - trap bolts/slabs as surveillance tools (NRCAN)
  - determining an effective trap and lure for detection of adult *T. fuscum* (NRCAN and NSDNR)
- Phytosanitary treatments
  - efficacy of chipping (NRCAN)
  - heat treatment protocols (UNB Wood Science & Technology Centre)
- Biological controls
  - microbial control through autodissemination of *Metarhizum anisopliae* (NRCAN and Anhui Agricultural University, China)
  - identity, origin (native vs. exotic), and impact of parasitoids/predators exploiting *T. fuscum* domestically; feasibility of classical biological control (NRCAN and CABI)
- Stem injection of systemic insecticides (NRCAN)
- Plant-insect interactions
  - adaptations of *T. fuscum* to new host species (NRCAN)
  - role of tree stress and host quality in host choice (NRCAN)
  - role of visual cues in short/long-range foraging and host selection (NRCAN)
- Chemical ecology
  - determining host-volatile composition from healthy and stressed red spruce (NRCAN)
  - screening of host volatiles in behavioral bioassays and field trials (NRCAN)
- Phenology of adult emergence, oviposition, and larval development (NRCAN)
- Identity and insect-fungal association of *Ophiostoma* sp. (NRCAN and AAFC)
- Current and potential socio-economic impacts of *T. fuscum* (UNB and NRCAN)
- Testing of feasible laboratory rearing protocols for *T. fuscum* (NRCAN)

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A MULTI-YEAR PROJECT TO DETECT, MONITOR, AND PREDICT FOREST DEFOLIATOR OUTBREAKS IN CENTRAL SIBERIA

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In 2000, the U.S. Agency for International Development (USAID) initiated a new Russia Forestry Resources and Technologies (FOREST) project which is planned for 5 years and has a budget of $20 million. From the USA side, this project is implemented by Winrock International, Chemonics International, and The Heron Group, LLC, a group of international consulting companies who won the competition of proposals. Other cooperators include the new Ministry of Natural Resources of the Russian Federation which includes the former Russian Federal Forest Service, the World Bank, the Institute for Sustainable Communities, Sukachev Institute of Forest in Krasnoyarsk, Russian Far East Forest Research Institute in Khabarovsk, Regional Forest Service Centers in areas of project implementation, regional government offices, and other organizations.

The principal objectives of the project are to: (1) strengthen regional forest policy and legislation, (2) preserve and expand Russia's carbon sink (fire awareness and pest management), (3) more effective use of timber and non-timber forest products, (4) raise public awareness to reduce forest fires, and (5) promote the use of renewable biomass energy.

There are four technical components of the project (#1-#4) and three cross-cutting components (#5-#7):

1. Forest Fire Prevention
2. Pest Management
3. Secondary Wood Processing and Non-Timber Forest Products
4. Renewable Energy Alternatives
5. Forest Policy and Legal Reform
6. Applied Forestry Research (Carbon Cycle)
7. Forestry Grant/Loan Program

In this paper, we present only the Pest Management component, which is implemented by The Heron Group in cooperation with the Sukachev Institute of Forest and the Russian Fo-- Service. The goal of this component is to optimize the system of monitoring of major forest pest species based on their habitat preferences, intensive use of geographic information systems technology, and combined use of contemporary sampling methods. Pest monitoring will be funded by the FOREST project in the first 5 years, and later it will be continued by the Russian Forest Service.

The Pest Management component is focused on monitoring of the following major target pest species. The Siberian Moth (*Dendrolimus superans sibiricus*) is the most devastating defoliator in Siberia. Normally, each generation takes 2 years to develop, but during an outbreak, the population switches to a 1-year life cycle, which increases the population growth rate. This insect has a distinct outbreak cycle with a period of about 11 to 14 years. Between outbreaks, the population density is extremely low; it then gradually increases and finally leads to defoliation of millions of hectares of forests. The Siberian moth feeds on many coniferous host species but most economic damage occurs in fir and Siberian pine stands. After the last outbreak in 1993-1996, tree mortality occurred on 136,000 hectares despite an intensive treatment campaign.

Forest stands killed by the Siberian moth lose all their economic value; also, they are extremely flammable and often become sources of devastating forest fires. It appears that dead stands not only stop accumulating carbon dioxide from the atmosphere, but they also emit a large amount of carbon dioxide in the first 2 to 5 years after defoliation (Baranchikov and Kondakov 2000).

A second species is the gypsy moth (*Lymantria dispar* L.) which damages deciduous trees and larch. Its outbreak cycle is less pronounced than the Siberian moth.

The fir sawyer beetle (*Monochamus urussovi*) is mostly a secondary pest of firs. It often reaches a high population density in areas initially damaged by defoliators (e.g., Siberian moth) or fire. The beetle is a vector of several phytopathogenic fungi from genera *Leptographium* and *Ophiostoma*. It infects healthy firs with fungus during its maturation feeding on crown shoots. At high population densities, firs quickly become weakened by fungi and then become susceptible to beetle oviposition. Thus, the area of moth-killed fir stands is often doubled due to *Monochamus* activity.

One of the biggest problems in forest pest management in the Asian part of Russia is the ineffective pest monitoring system in most areas. In Krasnoyarskiy Kray, a set of permanent sampling plots was established in 1997 for monitoring of the Siberian moth and other pests. In these plots, the abundance of Siberian moth larvae is determined by cutting sample trees or shaking trees with a log and collecting fallen larvae. This is a very labor-intensive procedure because many trees in each site must be sampled to get a reliable estimate of larval density.

To reduce sampling efforts and to monitor larger areas of Siberian forests, we propose to use pheromone traps. Pheromone traps are routinely used in the U.S. for monitoring gypsy moth populations (Schwalbe 1981, Leonard and Sharov 1995). The technology of pheromone traps is well developed and is ready to be transferred to Russian Cooperators. Pheromone components are identified for the gypsy moth and recently for the Siberian moth (Klun et al. 2000) and can be synthesized in Russia.

Monitoring forest defoliators with pheromone traps has the following advantages. (1) Trapping is less labor intensive than sampling of other life stages; thus, more sites can be sampled. (2) Moth counts in traps represent an average population abundance in the area. Thus, traps work well even if they are not placed in the most favorable habitats, which are often difficult to access. (3) Traps capture a large number of individuals, thus, population trends can be determined with greater precision than with larval sampling.

But pheromone traps can not solve all problems with pest monitoring because they have several limitations. (1) Traps often get saturated with moths. This problem can be addressed, however, by increasing trap size, reducing the number of entrance holes, reducing attractiveness of the bait, or by electronic detection of moth counts. (2) Moth counts in traps do not represent local population abundance at a small scale. Thus, they can not be used for delineating areas for treatment. Additional sampling of other life stages may be necessary at high population densities. (3) Moth counts in traps do not represent additional population parameters (e.g., sex ratio, parasitism), but these characteristics can be determined using additional sampling methods.

We propose to develop a regional approach to forest pest monitoring in the area of Yenisey Siberia. This includes delineation of large-scale regions where monitoring is recommended for each target pest species, and specifications for monitoring activity in each region depending on climatic zone, vegetation patterns, and organizational structures of forest pest management. At a smaller scale, we will delineate areas with various risk of defoliation by the Siberian moth in individual forestry units. Maps will be generated with GIS technology to be used for optimizing placement of sampling areas that have to be located in the most favorable habitats. In post-outbreak periods, monitoring will be based mostly on pheromone traps. Larval sampling will be initiated only after a consistent increase in pest abundance has been determined with pheromone traps.

The pest monitoring program is a part of a larger decision-support system. Our draft version of a decision-support system for Siberian forests follows (Fig. 1). Based on historical records of pest outbreaks, areas are selected for large-scale pheromone monitoring. In areas where population numbers increase consistently, a denser grid of traps can be used. At high population density, it is important to sample life stages to evaluate the risk of defoliation. Treatments are approved based on information on pest abundance, landscape characteristics (tree species composition and terrain), and forest value.

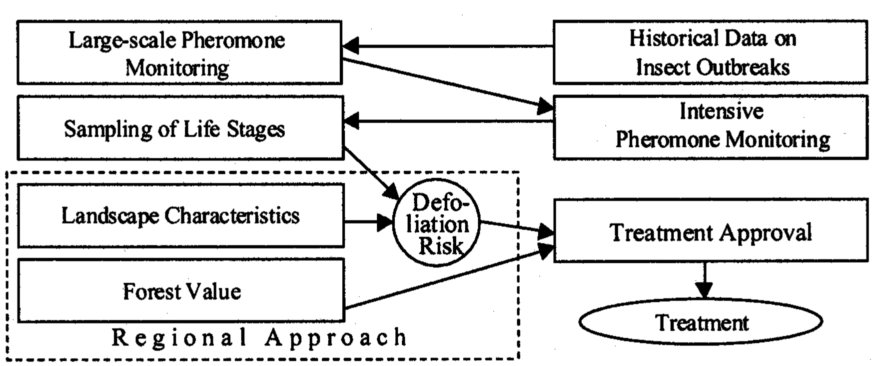

Figure 1. Proposed decision-support system for forest pest management in Russia.

Another important component of the project is the use of information technology that includes database software, GPS recorders, GIS software, and presenting project results on a web site which will be available to all project participants and to the general public.

The Pest Management component will be implemented first in Krasnoyarskiy Kray, and then we plan to expand it to the Irkutsk and Khabarovsk regions. In 2001, we have the following tasks (some of which will continue through the life of the project).

1. Facilitate the production of pheromones and traps in Russia.
2. Use a grid of pheromone traps to monitor the abundance of Siberian moth and gypsy moth on the left bank of the Yenissey River to the south from Krasnoyarsk.
3. Develop a database on the abundance of forest pest insects accessible via the Internet. This objective will require training of Russian personnel. Initially the database will be set at the Sukachev Institute of Forest and later transferred to the Russian Forest Service.
4. Develop an algorithm for delineating regions with various habitat quality for the Siberian moth.
5. Compare captures of the Siberian moth in pheromone traps in various habitats. Traps will be placed in favorable, moderately favorable, and unfavorable habitats to test the effect of habitat on moth counts in traps.
6. Compare counts of the Siberian moth in pheromone traps with larval density.
7. Compare effectiveness of an attractant of the Siberian moth produced in Russia with one produced in the U.S..
8. Organize a workshop on methods for forest pest monitoring.

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