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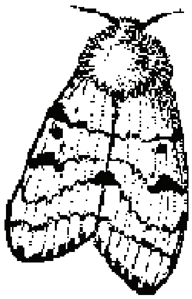
2003



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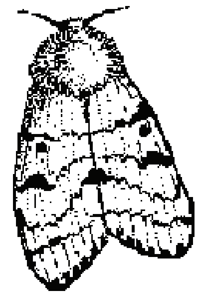

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Foreword

This meeting was the fourteenth 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 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 by the agencies and it is satisfying, indeed, that all of this can be accomplished in a cooperative spirit.

USDA Gypsy Moth Research and Development Coordinating Group

Kevin Hackett, Agricultural Research Service (ARS)
Vic Mastro, Animal and Plant Health Inspection Service (APHIS)
Bob Nowierski, Cooperative State Research, Education and Extension Service (CSREES)
Robert Bridges, Forest Service-Research (FS-R), Chairperson

The program committee would like to thank The Heron Group, LLC, Valent BioSciences Corporation, and the Management and Staff of the Loews Annapolis Hotel for their support of this meeting.

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Contents

Steps to Minimize Exotic Pest Damage to U.S. Forests

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The United States has magnificent and varied forest resources, home to thousands of species. Unfortunately, that variety translates to ample opportunities for imported pests and diseases to find suitable hosts. We believe that the appropriate response to a pervasive threat such as that posed by exotic species is to adopt the best countermeasures that scientists can devise.

As Dr. Thomas Ledig (1992) warned us a decade ago, "Introduction of exotic diseases, insects, mammalian herbivores, and competing vegetation has had the best-documented effects on genetic diversity [of forest ecosystems], reducing both species diversity and intraspecific diversity."

One example is white pine blister rust (*Cronartium ribicola* J.C. Fisch). This introduced pathogen has had a severe impact on important timber resources as well as high elevation ecosystems. Populations of whitebark pine from British Columbia to Yellowstone National Park have been heavily damaged, with mortality reaching 90 percent (Schmidt 1992; Campbell and Antos 2000). Whitebark pine occupies a critical niche in western ecosystems by producing large seeds that are extremely nutritious and important in food chains of 110 animals. Whitebark pine seeds are especially important components of grizzly bear, black bear, red squirrel, and Clark's nutcracker (Kendall and Arno 1989; Schmidt 1992; Reinhart et al. 2001).

Hemlock-shaded stream valleys shelter unique plant and animal communities in the Appalachians. Introduction of a single species, the hemlock wooly adelgid (*Adelges tsugae* Annand) is leading to the disintegration of an otherwise long-lived, stable, native ecosystem.

While both the science and policy of exotic species have come a long way in the decade since Ledig wrote his warning, the problem is demonstrably not yet under control. Furthermore, we are increasingly aware of impacts from other types of introduced species, such as exotic earthworms. These organisms are changing soil chemistry and structure (Dennis Burton, pers. comm. November 2002) as well as disrupting the food chains of salamanders and facilitating invasion by alien plants (John Maertz, Cornell University, pers. comm.; Gundale, 2002).

In summary, both species-specific and broad-impact exotic species are cause an ever-growing cumulative direct affect as well as a cascade of secondary damage that is resulting in radical changes in America's forests.

As we noted earlier, we believe the appropriate response to the invasive species challenge is to adopt the best countermeasures that scientists can devise. In contrast, however, the actual response has been a series of partial measures that are falling short.

The problem is that our government's policies reflect other values such as free trade, unrestricted commerce, and shrinking government. There is still widespread ignorance about the impact of bioinvasion. Scientists in government and academia have raised the alarm — but your efforts are not yet supported by other important constituencies, particularly environmentalists and wood product companies. We hope that all stakeholders can work together to educate decision-makers and key agenda-setters — the press — about the costs arising from current policies, and the policy changes that will enable us to succeed in minimizing impacts of intro forest pests and diseases.

Prevention

The challenge of preventing introductions of additional exotic forest pests is increasing due to rising trade. Import volumes have grown 28-fold since 1970; they have nearly doubled just since 1994 (U.S. Office of the Trade Representative 2002).

Those of us are focused on forest pests are especially concerned about rising imports of the three principal pathways for forest pests: solid wood packaging, logs and lumber, and living plants. Imports of plants present a double threat, since the plants themselves can be invasive as well as vectors of pests and diseases. Plant imports rose from about 456 million in 1993 to about 694 million in 1999 [APHIS Federal Register July 23, 2001 (Volume 66, Number 141)]. The wide variety of plants imported — 863 genera in 2000 — creates opportunities for many types of pests and diseases to reach America (Meghan Thomas, APHIS, personal communication).

The United States is the world's largest importer of forest products. During the 1990s, imports of softwood logs rose by a factor of 17; imports of hardwood logs and lumber both more than doubled. Imports of softwood lumber rose by 29 percent. The vast majority of this wood — 70 percent of the hardwood lumber, 90 percent of the other categories — is from Canada; this wood poses little risk. However, America annually imports approximately 3 million cubic meters of logs and lumber from countries other than Canada. In recent years, Europe has supplied about one-third of these imports; other major suppliers are Argentina and Brazil. Among these suppliers, a risk assessment has been completed only for New Zealand. (Trade data are from USDA Foreign Agricultural Service, www.fas.usda.gov/ustrade) It seems likely that the risk will grow in future if importers rely more on non-Canadian suppliers in response to the tariff recently imposed on Canadian suppliers and the expansion of supplies from maturing plantations in New Zealand and South America.

Imports of solid wood packaging (SWPM) are also rising commensurately with growing trade volumes. SWPM has been documented as a major pathway for introduction of potential forest pests (Haack 2002; Haack and Cavey 1997). According to the interception data compiled by these authors, more than one-third of interecepted pests are found in crates; between a quarter and one-third are found in dunnage; and only about five percent are found in pallets.

The policy response to the risk from these pathways has been adoption of half measures dictated by trade policy. The U.S. Department of Agriculture and the Congress are focused on the benefits of trade, while ignoring the substantial costs. While U.S. agriculture exports earn about $50 billion per year (U.S. Office of the Trade Representative 2002), costs associated with introduced plant pests and diseases, weeds, and livestock diseases total about $90 billion annually (Pimentel et al. 2000). These costs will rise substantially as a result of such recent introductions as the Asian longhorned beetle (*Anoplophora glabripennis* Motschulsky) and emerald ash borer (*Agrilus planipennis* Fairmaire). We call for a re-examination of these policies, so as to assign a higher priority to preventing introductions of alien species.

We believe that phytosanitary measures must be effective and minimize dependence on inspection. The inspection-detection model is too labor-intensive and time-consuming to be applied to more than a tiny fraction of incoming shipments. Furthermore, tiny organisms and microscopic pathogens are too likely to be missed by even the best trained and most highly motivated inspector (USDA APHIS and Forest Service 2000; National Plant Board 1999) Finally, phytosanitary measures must be easy to verify. Ease of verification is particularly important now that the inspectors are being transferred to the Department of Homeland Security, which will probably have priorities other than plant pests.

Unfortunately, the phytosanitary safeguards currently applied to the three major pathways for forest pests fall far short of these criteria. We have suggested specific changes to improve their effectiveness and ease of administration.

First, history demonstrates that imported plants have been a major pathway for introduction of forest pests, especially for pathogens. Our proposed solution is to limit plant imports to in vitro plantlets and small shipments of seed. Both types of imports would be subject to strict post-import testing and controls to ensure that they are free of pathogens and diseases. To maintain the flow of new cultivars, we recommend expanding USDA Plant Introduction Stations, the National Germplasm Repositories, National Arboretum, and other programs. They could work with State and private botanical gardens and arboreta both to develop promising native plants and to "bulk up" those exotic plants found to be both free of disease and not likely to be invasive.

We applaud the initiative of the North American Plant Protection Organization (NAPPO) Forestry Panel. In February 2003, the Forestry Panel will meet jointly with the NAPPO Fruit Tree and Grapevine panels to begin documenting the risk of pest introduction via plant imports and developing a North American guideline intended to close this pathway.

Wood packaging is already the subject of an international standard, adopted by the International Plant Protection Convention (IPPC) in April 2002 [www.ippc.int/cds_ippc_prod enter "wood packaging" in the search box]. We are disappointed by its very weak goal or efficacy target: "to practically eliminate risk for most quarantine pests and significantly reduce risk from a number of others". The IPPC standard calls for one of two treatments of packaging made from solid wood: heating to wood to a core temperature of 56°C for 30 minutes; or fumigation using methyl bromide. The IPPC claims that these treatments will "practically eliminate"insects in the Anobiidae, Bostrichidae, Buprestidae, Cerambycidae, Curculionidae, Isoptera, most Lyctidae, Oedemeridae, Scolytidae, Siricidae, as well as the nematode *Bursaphelenchus xyolphilus.*

However, APHIS concedes that these treatments might not kill some deep wood borers, fungi, rots, and wilts (USDA APHIS 2002). While Eric Allen (Canadian Forestry Service, pers. comm.) has found the heat treatment to be effective against seven types of pathogens, further testing would be prudent. In the meantime, both heat treatment and fumigation will be difficult for inspectors at our ports to verify. Finally, widespread adoption of the IPPC standard could lead to tripling global use of methyl bromide. Such a step would contradict the goal of the Montreal Protocol on Ozone-Depleting Chemicals.

Our proposal is to implement the IPPC standard now to reduce the risk of pest introductions on wood packaging but simultaneously specify a deadline by which shippers must convert from packaging made of solid wood to packaging made from particle and fiberboards, plastic, metal, fiberglass or other materials that will not harbor forest pests.

To curtail pest introductions in imported logs, lumber, and chips, we recommend requiring heat treatment prior to importation for wood from all suppliers except Canada.

We believe that the USDA will not adopt adequately protective phytosanitary measures until the Department leadership commits to achieving a strong efficacy target (called in trade jargon a "level of protection"). While the USDA Animal and Plant Health Inspection Service (APHIS) rarely defines what it means by its preferrred term "negligible risk", it has been explicit in two cases that apply to wood. In the supplemental impact statement covering wood imports from New Zealand and Chile (USDA APHIS 1998a) and in the environmental assessment prepared for the emergency regulation pertaining to wood packaging from China (USDA APHIS 1998b), APHIS accepted a risk level of 3 to 5 percent. However, a risk of 3 to 5 percent is not "negligible"; it is, in fact, quite high: 10 to 14 times greater than the risk of dying from cancer incurred by a cigarette smoker (Botkin 2001). When a 3 to 5 percent risk is applied to the large volume of imports making up the three forest pest pathways, it translates to the probable arrival on our shores of between hundreds of thousands and tens of millions of quarantine pests. We urge APHIS to aim for a truly minimal risk — and to involve stakeholders in an explicit discussion of the impacts of choosing a less protective goal.

Finally, regulations cannot be effective if they are not enforced. Unfortunately, APHIS has apparently not found an effective way to ensure that foreign exporters comply with current regulations governing wood packaging. These regulations require that bark be removed from the wood. However, Italian exporters of marble and other heavy materials often violate this requirement. When APHIS inspectors detect SWPM with bark, they fumigation of the shipment and charge the cost to the importer. The importer is expected to pressure the exporter to be more careful in future. However, interception data and reports by APHIS staff clearly show that Italian exporters continue to ignore the bark removal requirement.

What will be the impact of transferring the inspection duties to the Department of Homeland Security? If the new department takes a "zero tolerance" approach to violations of any regulation, enforcement could improve substantially. However, if the Department places such a high priority on searching for potential terrorist materials that it downplays discoveries of unrelated violations, enforcement could deteriorate further.

Since no border control measure is completely effective, early detection of pests that evade the controls and rapid response to such introductions is widely recognized as an essential part of any prevention system. We therefore are pleased by initiation of the joint Forest Service - APHIS detection program. Unfortunately, funding for responding to the introduced pests is insufficient and is too hard to obtain. In 2000, APHIS and the Forest Service together spent just $26 million responding to newly introduced forest pests or those spreading into new regions (GAO 2001). We support calls for providing substantially more funds, through a mechanism that ensures the funds will be available quickly.

Funding across the board is inadequate. In fiscal year 2001, the entire federal government spent approximately $1 billion on all aspects of its exotic species programs (data compiled by the National Invasive Species Council). This sum is less than 1 percent of the costs arising from these species, as calculated by Pimentel et al. (2000). We are concerned particularly by the declining capacity in the Forest Service research program, which should provide the knowledge base for an effective response to both newly introduced and well-established invaders. Funding for Forest Service research has fallen 8.4 percent since 1980. The key forest-protection research program fell by 56 percent during this period (NRC 2002b). As a result, the number of entomologists and plant pathologists on staff have fallen to fewer than 40 (Terry Shaw, USDA Forest Service, pers. comm.) We do not believe that states, universities, or industry are likely to carry out the long-term research formerly conducted by the Forest Service program. Therefore, we support the National Research Council's recommendation that the Forest Service restore its expertise in the core disciplines of traditional biology (NRC 2002b).

We believe that an effective response to introduced forest pests should incorporate the full range of measures, including breeding to incorporate resistance into host plants and restoring species to forests. Vital germplasm preservation efforts for regional populations and genotypes of forest trees should begin as soon as a threat from an exotic arthropod or disease is identified. Unfortunately, the Forest Service and states' genetic improvement program have also suffered declining funds and staff. State efforts could perhaps be revitalized through funding from the State and Private Forestry program. Private industry remains focused primarily on the few species that are the foundation for timber production.

Success in overcoming the damage caused by established exotic pests and diseases requires that those organisms not be continually reintroduced. Such continuing introductions could spread the invader to new areas or inject genetic variations that make the pest or disease more virulent or harder to control. Unfortunately, the World Trade Organization's Agreement on the Application of Sanitary and Phytosanitary Standards (SPS Agreement) and the International Plant Protection Convention (IPPC) impose severe restraints on efforts to prevent reintroductions of established pests.

Under these trade agreements, APHIS may impose phytosanitary measures to prevent introduction of only those organism that meet the definition of a "quarantine pest". Regarding exotic species already in the country, APHIS must regulate movement of the organisms inside the U.S. as strictly as it does their conspecifics at the border. Furthermore, this "official control program" must be established, authorized, or performed by APHIS, not some other agency.

Between 6,000 and 9,000 introduced plant pests and diseases and exotic weeds are established in the United States (USDA APHIS and Forest Service 2000; Kartesz 1999; USGS 1998). APHIS will never have sufficient staff and resources to implement an "official control program" targetting more than a tiny fraction of these organisms. Even well-recognized, highly damaging exotic species do not meet the definition of "quarantine pest". The hemlock woolly adelgid is an example. This species is quite arguably "widespread" since it occupies half of the U.S. ranges of its eastern hemlock hosts. In addition, the efforts to mitigate it impacts, while substantial, do not meet the definition of "official control". In consequence, APHIS is prohibited from applying phytosanitary measures to prevent reintroduction of this aphid should it be found on some incoming shipment of horticultural plants from Asia.

The severe constraints imposed by the trade agreements' provisions might be partially reversed by the pending "environment standard" now under consideration by the IPPC. This standard, expected to be adopted in April 2003, recognizes that "official control of pests presenting an environmental hazard may involve agencies other than the NPPO [national plant protection organization, e.g., APHIS]." However, it is not clear whether the clause allows the Forest Service or some other federal agency to substitute its efforts for those of APHIS. If such a substitution is allowed by subsequent interpretation, this standard may allow the U.S. to continue taking actions to prevent future re-introductions of such confirmed damaging exotic species.

As we stated earlier, funding for exotic species programs should be expanded. We support higher appropriations from general tax revenue. We also support Peter Jenkins' (2002) suggestion of charging a user fee for those whose activities inherently raise the risk of introducing exotic species. We suggest adopting a somewhat higher fee than Jenkins proposes, and allocating the receipts to all stages of responding to alien species, not just early detection and rapid response.

In early 1999, President Clinton issued Executive Order 13112, which established the National Invasive Species Council and eventual adoption of the nation's first invasive species management plan. Promulgation of the order and the efforts of the Council have resulted in some improvements in the government's programs and, especially, in spurring greater involvement by a rising number of stakeholders. However, an executive order can be cancelled by any president at any time. Furthermore, the Council lacks independent authority; it must instead persuade each department or agency to act. Consequently, we do not believe this structure can bring about the fundamental changes needed to minimize exotic species' damage to U.S. ecosystems.

When a newly detected problem is considered serious, new governmental agencies are created to address it. Therefore, we call for creation of a national Center for Biological Invasion. This concept was first advanced by Schmitz and Simberloff (2001). Our proposal, however, goes farther in that it would assign some regulatory and research responsibilities to the Center.

The effectiveness of America's response to introduced forest pests and diseases depends on decisions made by the highest administrative levels and the Congress. If we are to convince these decision-makers to alter current policies and provide sufficient resources, we need to engage the two principal missing constituencies: the wood products industry and environmentalists. I can only speculate on reasons why the wood products industry is not more concerned about the potential impacts of exotic pests on their future profitability.

Environmentalists are also not yet heavily involved, especially as regards exotic forest pests. The reasons are complex. One factor appears to be old saw, "Out of sight, out of mind." A particular tree species is severely depleted as the result of attacks by exotic species, but then the gaps in the forest are filled by other trees. Most visitors to the forest don't see the missing element. Environmentalists also don't understand the loss of this single species to the broader overall causes of bioinvasion; they see each exotic species as an isolated incident. Many environmentalists also do not appreciate the cascade of ecological effects that follows removal of one species from the forest ecosystem. These gaps in understanding can be corrected, I believe, if scientists, policy makers, and environmental education practitioners will themselves try harder to explain the linkages. It is especially important to distribute information about the ecological impacts of exotic species in forests.

Trade activists in the environmental community should also correct the general lack of awareness of the impact of new international trade agreements on our government's ability to protect our forests from new introductions.

Forest pest experts have been less involved in federal policy formulation compared to weed scientists. As a result, both government policies and public perceptions of the bioinvasion problem tend to neglect forest pests.

Environmentalists who are working on invasive species have formed a coalition and are making other efforts to raise the profile of invasive species issues, spur more activity, and coordinate our existing efforts to ensure they are as effective as possible. A major hurdle to expanding the community's involvement is the difficulty we have experienced in persuading foundations and individual funders that policy solutions to the problem exist.

Our forests deserve the best protection all of us working together can muster. I conclude by reiterating my hope that by working together, we can be more successful.

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Siberian Moth Monitoring System in the Asian Part of the Russian Federation

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Abstract

Forest protection in Siberia and the Far East is oriented on timely detection of pest outbreaks being developed. The monitoring system for the main Siberian forest pest - Siberian moth (*Dendrolimus superans sibiricus* Tschetv.) includes ground and air inspection, as well as systematic sampling of caterpillars along fixed routes and sample plots by shaking and felling sample trees. High labor intensity and the cost of this work points out the need to optimize monitoring by developing and introducing new technologies.

The Russia Forest Resources and Technologies (FOREST) Project, funded by the U.S. Agency for International Development (USAID) is introducing an efficient and cost-effective system to monitor Siberian moth populations and predict their outbreaks over time. Synthesis of Siberian moth sex pheromone in 1998-1999 (Baranchikov et al., 2000; Pletnev et al., 2000; Klun et al., 2000) opens new opportunities for optimization of the existing monitoring system for this species. Within the FOREST Project the monitoring system for Siberian moth populations is well described and widely used. It is based on an original approach to sample plot selection and subsequent application of pheromone traps and existing monitoring techniques. The work is carried out by project partners - research institutions of the Russian Academy of Sciences together with local branches of the Russian Centers of Forest Protection in Krasnoyarskiy, Primorskiy and Khabarovskiy Krays, Tomsk, Irkutsk and Sakhalin Oblasts', Tyva and Khakassia republics using the available ground monitoring experience.

The project objective is to optimize the Siberian moth monitoring system based on regional specificity of pest populations, wide use of geoinformational technologies and combined application of modern sampling methods.

During project development, forest protection zoning of Siberia and the Far East was completed. Specific monitoring techniques were then suggested for every region taking into account specificity of pest complexes and their biology. In the area of leskhoses – individual forest enterprises - located in regions of potential Siberian moth outbreaks, forest stands with different outbreak risk were selected. Maps were made using GIS technologies that allow optimizing the location of permanent sample plots by relating them to sites of potential outbreaks. During the inter-outbreak period, monitoring is implemented in these plots using, mainly, pheromone traps, which greatly reduce both labor and financial costs. The fixed-route ground inspections with shaking and felling sample trees is intensified only when pest numbers increase and are detected by pheromone traps.

The results of Siberian moth population density monitoring after 2 years are compiled in the data bank of the Project and are available on the Internet. Current work with specialists on forestry and forest pathology as well as annually organized seminars make it possible to train interested personnel in the monitoring methods, compiling and processing data, and peculiarities of approaches to understand in the decision support system in pest density control. Stage-by-stage transmission of the monitoring system to Roslesozaschita – the Russian agency for forest protection – is planned.

The FOREST Project also provides research in further optimization of sex attractant structure of Siberian moth and technologies for its application. Under support of the Project in Russia, the industrial production of dispensers and cheap pheromone traps were set up. The Project also is funding preparation of a 4-volume handbook on methods of forest pest and disease monitoring. Within the FOREST Project grant program, the development and introduction of the principles of how to organize forest protection in individual leskhos and in the Subject of Russian Federation have been started.

All information (in English and Russian) on this activity can be found on the FOREST Project web site www.forestproject.ru as well as on the web site of the Pest Monitoring Component of the Project: http://forest.akadem.ru/projects/c2

Attraction of Siberian Moth Males by Different Dispensers and Pheromone Concentrations

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Abstract

This work was carried out during July 2002 in sparse populations of Siberian moth in the park larch forests of the Khakass Republic. Two types of dispensers were used: rubber dispensers (pieces of rubber tubing saturated with an attractant) and the three-layer laminated dispenser made of folgaplene where attractive substances are issued through the polyethylene membrane. The mixture Z-5, E-7- dodecadienol and Z-5,E-7-dodecadienal in the ratio 1:1 is the attractant. Both pheromone and dispensers are manufactured by the Institute of chemical tools for plant protection in Moscow (Pletnev et al. 2000, 2002). The work was supported by the USAID FOREST Project.

In experiment 1 the rubber and folgaplene dispensers, saturated with 200, 20 and 0.2 mkg of attractant/lure were compared.

In experiment 2 the folgaplene dispensers with 600 and 200 mkg of attractant were compared. Some dispensers were kept for 26 days in an uninterrupted air flow at 22°C before transporting them to the forest.

In both experiments all dispensers were tested in 10 replicates in the modified milk-cartoon trap produced in Russia for Siberian moth monitoring (Baranchikov et al. 2000). The traps were placed in a line 100-250 m apart, in the larch forest of the park type. Samples were taken once every 3 days. During sampling each trap was moved to the place of the following one. Thus, the catch of traps did not depend on their location. Sampling was started at July 7- 9 and was continued till all flight of Siberian moth males had ceased.

The results from experiment 1 have shown that dispensers of both types with all three attractant concentrations were attractive to Siberian moth males. We found that both attractant concentration and the dispenser type effect the amount of moths caught. Independent of the type of dispenser, the most attractive concentration turned to be 200 mkg/lure – 1.4±0.25 and 0.8±0.07 males/trap/day; compared to 20 mkg/lure – 0.5±0.2 and 0.03±0.01; and to 0.2 mkg/lure – 0.2±0.1 and 0.02±0.01 males/trap/day for the folgaplene and rubber dispensers, respectively. On the average, the folgaplene and rubber dispensers with 200 mkg of attractant attracted moths during, respectively, 14.4±1.3 and 15.0±1.2 days after the experiment was initiated. Within the lower concentrations, the differences were associated with the type of dispenser but not the concentration: for 20 mkg/lure – 9.8±2.1and 2.2±2.2 days; for 0,2 mkg/lure – 10.0±2.9 and 0.9±0.9 days for the folgaplene and rubber dispensers, respectively.

The second experiment revealed that the folgaplene dispensers which were subjected to the blow ("old") attracted males during the same period of time as dispensers without the blow ("new"): 13±2 and 15±1 days, accordingly. The differences in males between them were large: 0.4±0,1 and 1.0±0.2 males/trap/day for the "old" and "new" dispensers, respectively. The attractiveness of "new" dispensers with 200 mkg/lure was equal to 0.5±0.2 males/trap/day and did not differ from the "old" dispensers with 600 mkg/lure. The dispensers with 200 mkg/lure did not lose attractivity for 16±3 days and are comparable with both dispenser with 600 mkg/lure.

These studies show that both the rubber and folgaplene dispensers with high concentrations of attractant are able to attract Siberian moth males during the entire flight period. At lower concentrations the folgaplene dispensers show a higher efficiency as compared with the rubber ones.

Thus, the folgaplene dispensers worked equally well with any concentration of the sex attractant and we recommend them for monitoring Siberian moth populations.

Using Gypsy Moth Artificial Diet for Studies of Invasive Species: Terrestrial Slugs

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Abstract

The gypsy moth artificial diet was tested as a food source for rearing species of invasive terrestrial slugs. Over the last 200 years, at least 20 species of slugs, mostly from Europe, have established throughout North America (Bernon 2001). Unlike the indigenous fauna, the invasive species are generalists and can be agricultural pests. Although they can be reared on a variety of natural diets, it is difficult to standardize experiments.

Two invasive species, *Limax maximus*, and *Limax flavus*, were reared on a lettuce diet and the gypsy moth artificial diet. The artificial diet was an optimal food source for both species. Colonies were easy to maintain and either species would be suitable as models for experimentation. *L. maximus* copulates while suspended on a strand of mucus, and would not mate in the laboratory. However, both species reproduced without mating, (hermaphrodism) when reared on either diet in the laboratory. Although self-fertilization is known to occur in slug species, no record was found for *L. maximus* (Bernon 2002).

Arion lusitanicus is the most serious slug pest species in many areas of Europe (Grimm 2001). Surprisingly, the range of this slug has only recently expanded in Europe (von Proschwitz 1997), and it is therefore a high risk species to invade North America. Preliminary studies in a quarantine laboratory verified that *A. lusitanicus* can also be reared on the gypsy moth diet; this slug will be a serious pest if it becomes established.

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Status of the Brown Marmorated Stink Bug, *Halyomorpha halys*, (Heteroptera: Pentatomidae), New Invasive Species

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Abstract

Origin

The Brown Marmorated Stink Bug, *Halyomorpha halys*, is a pest of soybeans and fruit trees in China, Japan, Korea, and Taiwan. Specimens were identified by E. Richard Hoebeke in 2001; adults were collected as nuisance pests when seeking over-wintering sites in homes and buildings in Allentown, PA. However, the county extension had been receiving similar reports for several years (Bernhard, pers. comm.). Over-wintering adults can easily hitch-hike in commodities from Asia; the origin of the PA population is unknown but molecular diagnostics is in progress (Carter, pers. comm.)

Delimiting survey

Surveys were conducted in 2002, relying on random host plant observations, adult flight activity, and publicity from the local media. The distribution is mostly limited to an area in and around Allentown, PA. Specimens were collected in five PA counties and in Warren County, NJ (additional collections were reported from NJ by Rutgers University). No isolated populations have been reported, but adults are mobile and commonly found in vehicles.

Host Specificity

Although still limited to mostly urban areas, *H. halys* was found to be polyphagous, with a patchy distribution and occasional dense populations. The most common host plants were *Pawlonia tomentosa*, and *Buddleia* (butterfly-bush), with noticeable leaf damage. Several nymphs were found on soybeans, and this crop will be monitored in 2003. A backyard peach grower in Allentown reported losing his crop to "cat-facing" feeding damage to fruits; specimens of *H. halys* were collected at the site, but this infestation will need to be confirmed in 2003. Organically grown apples within the infested area will also be monitored in 2003.

Risk Analysis: Case History of *Puccinia jaceae* on Yellow Starthistle

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Abstract

This research concerns evaluation of a foreign plant pathogen, *Puccinia jaceae*, for use in biological control of yellow starthistle (*Centaurea solstitialis*, YST), a major, invasive weed pest of the western United States. Although plant pathogens can be very damaging to plants (risk awareness) and, for various reasons, may be perceived as dangerous, *P. jaceae* was selected for evaluation because it is most likely safe to use in the U.S. Host specificity is a characteristic of the rust fungi. It is a foreign accession and not fully understood or tested, so the risk analysis must be conducted in a containment greenhouse facility until clear judgment of risk is possible. All tests in this facility are conducted under controlled conditions (dew period and temperature, inoculum load, etc.). Judgment of risk either is facilitated or complicated by the fact that disease response is usually greater under greenhouse conditions than in the field. If a non-target species does not develop symptoms under optimal greenhouse conditions, it is clear that it will not be diseased by the pathogen in the field. If, however, infections occur on hosts not normally infected under field conditions, the question becomes one of whether this is a greenhouse phenomenon or a realistic possibility in the field. Predicting field performance (either beneficial or not) based on greenhouse data, therefore, is challenging. Side-by-side comparison of *P. jaceae* and a related indigenous U.S. pathogen in the greenhouse can improve judgments about field performance.

Risk is hazard x exposure (R = H x E). For U.S. releases of classical agents such as *P. jaceae*, exposure of other plants is assumed. Risk management involves controlling hazard by documenting a very high level of host specificity. Risk assessment, therefore, begins with identification of potential hazards. For example, *P. jaceae* caused limited infection of safflower in greenhouse studies, but *P. jaceae* could not be maintained if safflower was the sole source of inoculum. Support of these findings came from direct, side-by-side greenhouse comparisons using *P. carthami* from North American, cause of safflower rust, and a disease that is manageable in California. Also, unlike *P. carthami*, *P. jaceae* teliospores did not initiate safflower seedling infections. Tests in Greece showed that safflower was not susceptible to *P. jaceae* in the field. Risk communication included meetings with safflower growers, California Department of Food & Agriculture scientists and regulators, the Technical Adivsory Group, APHIS-PPQ personnel, and notice in the Federal Register about the proposed action to release *P. jaceae* in California.

The Effects of Natural Disturbances Caused by Siberian Silkworm (*Dendrolimus superans sibiricus*) and Fire on Regeneration and Radial Wood Growth of Boreal Woody Plants in Krasnoyarsk Krai, Russia

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Abstract

This research considers the effects of damage by Siberian silkworm, *Dendrolimus superans sibiricus* (Tschetverikov), and fire in mixed stands of Siberian spruce, *Picea obovata* Ledeb., and Siberian fir, *Abies sibirica* Ledeb., in Krasnoyarsk Krai, Russia. This study specifically investigates the role of insect outbreak and, in combination, fire disturbance effects on forest dynamics, specifically post-disturbance regeneration, overstory canopy density and structure, understory composition, and annual radial wood growth. The sampling protocol for this research is adapted from the USDA Forest Inventory Analysis Program.

This sampling design employs stratified random sampling with identical parameters for treatments and control plots. Treatments consist of two temporal periods of disturbance, three combinations of disturbance, and two control treatments at two separate study areas. Treatment 1 is a spruce-fir ecosystem that endured a significant outbreak of silkworm from 1956-1957. Adjacent to this is Treatment 2 that also was severely defoliated and subsequently burned in the 1960s. Treatment 3 is a control plot, an old-growth stand that has incurred only minor disturbances in the last century. Treatment 4 endured severe silkworm defoliation 5 years ago and exhibits significant tree mortality. Treatment 5 includes this same outbreak, but also includes a large post-outbreak fire scar. Treatment 6 is an 80-year-old relatively undisturbed fir-spruce control plot. Treatment 7 is a fir-spruce stand with a 5 year-old fire disturbance and no silkworm history.

Five replicates for each treatment were selected to reduce variance of measurements. Replication within treatments is being accomplished by identifying five separate stands within each treatment. An intensive sampling plot is being installed in each stand. Each sample plot consists of four subplots, each with a 7.3 m radius tree subplot and 17 one-meter radius regeneration plots.

In addition, tree cores are being collected and will be analyzed to determine growth rates and how these are affected by disturbance. Sampling occurred during the 2002 summer field season and will continue during the 2003 summer field season.

Results of this research should prove valuable in answering the following questions:
Are there specific interactions between insect infestation and fire as related to conifer regeneration?
Are there specific changes in forest structure as a result of combinations of insect infestation or fire?
How do single or multiple disturbances affect the composition of Siberian conifer forests?
What is the response of radial wood growth in pre-outbreak and post-outbreak conditions?

Case History: *Cactoblastis cactorum* on *Opuntia* spp. in the U.S.

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Abstract

The unintentional arrival of the cactus moth, *Cactoblastis cactorum,* in Florida in 1989, following its release against *Opuntia* species on several Caribbean islands in 1957-1960, has raised concerns for the safety of native and rare *Opuntia* species in the Florida Keys and the potential spread of *C. cactorum* to the *Opuntia*-rich areas of the western U.S. and Mexico. In addition to threatening the biodiversity of these native ecosystems and the forage and vegetable *Opuntia* industries, the negative publicity from such non-target effects could heighten public concern over the use of exotic natural enemies and jeopardize future biological control programs against weeds. The arrival of *C. cactorum* in North America is useful as a case study to evaluate our risk analysis process for the introduction of biological control agents, and for our response to newly established exotic pests. The case study of *C. cactorum* suggests that risk perception is higher for species being considered for release as biological control agents than for species that have recently established as exotic pests.

As part of the risk analysis process, *C. cactorum* is being used in a proof of concept study in which reproductively inactivated insects aid in the risk assessment of potential biological control agents for invasive weeds. Low doses of radiation can cause treated moths to produce sterile offspring. This type of induced-sterility is called inherited (F_1) sterility. The production of sterile progeny allows developmental and behavioral observations to be made under actual field conditions without the concern of establishing a breeding population. These observations allow confirmation of oviposition behaviors and host associations, field-testing of larval feeding preferences, and studies of larval development and survival on related plants that are of concern in various geographical locations.

Preliminary Analysis of mtDNA Sequence Data for *Anoplophora*: Implications for Identification of Species Boundaries and Source Population Determination of Asian Longhorned Beetle (*A. glabripennis*) in the United States

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Abstract

It is important to both define the origin or source population(s) of ALB that have been introduced into the United States and to determine whether more than one introduction has occurred. Mitochondrial DNA sequence data can potentially yield insights into the history of ALB introductions, and we present very preliminary data that bear on the question of origins. Sequence data from mitochondrial COI were edited and trimmed to 926 characters. Data analysis was carried out with PAUP 4.0b10 using neighbor joining and maximum parsimony with the heuristic search option - confidence in the trees was estimated from 100 bootstrap replicates. All characters were weighted equally. These preliminary results support recognition of a separate clade for the *A. nobilis* form of *A. glabripennis,* and the *A. malasiaca* form of *A. chinensis*. More informative morphological characters, or a second independent molecular data set, are needed to resurrect these species from synonomy. For beetles analyzed thus far, individuals from the New York and New Jersey populations of *A. glabripennis* show little variation in mtDNA sequence and the North American haplotypes are very similar to a haplotype from China. Asian populations exhibit much greater genetic diversity. These data suggest a single introduction event in New York and New Jersey. The identical haplotypes from a New Jersey specimen and a specimen from Gansu Province, China supports the accepted theory that China is the source of the American introduction to the East Coast.

Location of Early Instar Gypsy Moth (*Lymantria dispar*) Larvae: Implications for Monitoring

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Abstract

The gypsy moth is a major forest defoliator in the USA, Europe, and parts of Asia. Gypsy moths hatch from egg masses on the boles of trees in the spring. If an egg mass is contaminated with LdNPV (gypsy moth virus) from the previous year, some of the larvae hatching from the egg mass will be infected as they eat their way out of the egg. The assumption has been that early instars, as opposed to later instars, spend daylight hours on foliage eating. This assumption, if true, has important implications for the current method of aerial spray treatment of formulated LdNPV (Gypchek).

We decided to test this assumption by making detailed daytime observations on trees that were small enough to allow complete visual coverage. We planted a simplified, miniature forest in Ansonia, CT near the Forest Service quarantine lab. The 32 trees in this stand were small enough so each tree could be thoroughly examined, but large enough (3+ m high) to allow larvae to behave naturally. Surface sterilized and LdNPV-contaminated eggs were released on half of the 32 trees chosen at random, in an attempt to roughly replicate the manner in which eggs are laid in real forest situations. A 30x30 cm board was put at the base of each tree to simulate ground refugia, and a small rectangular piece of burlap was attached to the bole of each tree as a "bark flap". Trees were divided into sectors by height and compass direction. For field observations, we used a mobile platform to access every part of each tree. Larvae from different parts of the trees were also collected and reared, and their mortality quantified, to determine whether or not LdNPV infection had an impact on larval location and behavior.

First and second instar larvae were found in far higher densities under the burlap flap than anywhere else on trees. As a whole, larvae were not found feeding on foliage during daytime hours. Of a sample of 28 larvae found on foliage during the day, 25 were dead of LdNPV infection within 2 days. This data leads us to believe that infection does have an effect on some aspects of larval location. However, the location of LdNPV-killed cadavers was not significantly different at different heights within a tree, nor did infected and uninfected larvae disperse (balloon) at different rates.

Tests of Bt Toxins and Formulations Against the Asian Longhorned Beetle: Problems and Implications

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Abstract

Bacillus thuringiensis (*Bt*) is an entomopathogenic bacterium that has been used successfully as a biopesticide against a variety of insects. Bt toxins bind to insect midgut receptors and form ion channels, disrupting potassium flux in midgut cells and paralyzing and killing the target insect. *Bt* var. *tenebrionis* and *Bt* toxins were assayed against larval and adult Asian longhorned beetles, *Anoplophora glabripennis* (ALB). The ALB is a large wood-boring cerambycid native to parts of mainland China and Korea. The ALB is a polyphagous feeder, with a marked preference for poplar, maple and willow. Damage resulting from larval feeding can be sufficient to render large trees unsound, creating hazardous conditions in populated areas.

Three basic methods were used to test *Bacillus thuringiensis* and related toxins against ALB. 1) Voltage Clamping: larvae were cut open longitudinally, and an 2 cm length of midgut tissue was removed. This tissue was placed between two chambers containing an electrolytic solution of saline. Current flow across the membrane was measured while a solubilized toxin was added to the solution in the lumen-side chamber, and changes in current flow noted. 2) Diet Incorporation: larvae were placed in a cup containing a modified version of artificial red oak borer diet. Those in the test group were placed in a cup containing diet into which was incorporated the *B. thuringiensis* var. *tenebrionis* product Novodor®. 3) Droplet Feeding: adult beetles were held by the thorax, and a 4 microliter droplet of a solubilized toxin and distilled water solution was placed directly on their mouthparts using an Eppendorf pipette.

Preliminary *in vitro* assays showed some toxins to be active on whole midgut preparations in voltage clamp assays, and in assays on brush border membrane vesicles formed from midgut epithelial cells. For *in vivo* tests, the commercially available product Novodor was incorporated into artificial diet, upon which larvae were allowed to feed *ad lib*. In other tests droplets of solubilized *B. thuringiensis,* toxins were fed to larvae and adult beetles using a micropipette. None of the *in vivo* assays showed significant negative effects on either larvae or adults. We believe that some aspect of ALB midgut chemistry may be incompatible with toxin activation or mode of action.

Overview of the Ecological Risk Analysis Process

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Abstract

There are five components of risk analysis (RA) that many risk analyzers use: awareness, perception, assessment, management, and communication. There is a high degree of relatedness among these components. The purpose of this abstract is to provide a conceptual model for RA that can be used in complex systems analysis. The scope of coverage herein is just for impact on nontarget species in biological control–RA procedures can be quite different for other subjects.

Risk awareness leads to *risk perception*. Because there is likely to be incomplete information when analyzing potential risk from a biological control agent–hence uncertainty–the perception of risk tends to "the worst-case scenario" and the actual risk is very often overestimated. A key input to the *risk assessment* component for biological control agents is host-specificity testing, that estimates physiological (or laboratory) host range of an agent. Results of host-specificity testing are, ideally, used by regulators prior to issuing a release permit. However, risk assessment does not tell regulators what to do, it simply provides objective data to inform the regulatory process, and an objective decision analysis process should then be employed. Post-release research should focus on determining the ecological (field or realized) host range of an agent. *Risk management* can take many forms, but for biological control, it tends to be confined to testing pesticides in the laboratory, to be used to eradicate the agent "if something goes wrong." The potential value of this information is questionable, because, once released, an agent cannot normally be eradicated. *Risk communication* is often the weakest element of RA for biological control. It should take place at every step in the process, but often occurs only after a problem is discovered, such as the involvement of a threatened or endangered species.

Risk can be expressed as hazard x exposure, but the difficulty is in defining and measuring these terms. I define hazard as *the ability to cause harm*, and propose that it is an innate characteristic of the taxon, including factors such as potential host range, toxicity, basic biological features, capacity to interact with the environment, etc. I define exposure as *potential harm*, mediated by environmental factors ("sieves"), such as susceptible hosts in the environment, bridging species, distribution, phenology, ecology; and climatic conditions. Importantly, exposure acts upon hazard. Laboratory testing favors the biological control agent, and factors in the environment favor the potential host, whether target or nontarget species.

Thus, risk becomes not only hazard x exposure, but the interaction of innate characteristics of a taxon and environmental sieves that mediate the interaction, a measure of the completeness of information, and a measure of uncertainty.

Invasive and Exotic Species of North America: www.invasive.org

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Abstract

Proper identification of invasive species and associated biological control agents are important for adequate monitoring and detection activities, as well as to support proper management decisions. Inclusion of quality, identified photographs in educational and training materials, presentations and publications significantly increases their value and impact.

Invasive.org (www.invasive.org) is a web-accessible archive of high quality images driven by a fully-searchable taxonomic database with accompanying overview “Fact Sheets”. Images in the system are there to be used, and can be used with no royalties and no fees for all educational applications. The images can be located through several search and menu options, and can be downloaded in the desired resolution, format and file size needed by the user. The system was developed as a portal to high resolution images with links to species-based information. The images are tools that users can retrieve and incorporate into training, educational and outreach materials as needed.

Invasive.org is part of the ForestryImages system (www.forestryimages.org), and is one of eighteen (18) websites maintained by the Bugwood Network (www.bugwood.org) on a broad range of topics, including invasive species, forestry and forest health, and entomology dealing with both natural systems and more directly managed systems.

Invasive.org and the associated ForestryImages system are being used: Hundreds of images taken by dozens of photographers on more than 180 pest and 150 biological control agent subjects are available through the system. From January through September 30, 2002, over 79,000 users retrieved nearly 500,000 pages of information through the system. The content of the systems and the user base continues to expand.

Evaluation of Browntail Moth Suppression with a Baculovirus

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Abstract

We field tested *EcNPV*, a baculovirus that is a naturally occurring pathogen of browntail moth, (*Euproctis chrysorrhoea L*) as a potential biopesticide and an alternative to chemical pesticides. We applied the virus in May 2002, soon after budburst to small plots consisting of clumps of black cherry saplings or individual apple trees at two sites in the Casco Bay region of Maine. Application occurred during a week of heavy rainfall. Approximately 50 percent of the larvae from one site and 20 percent of the larvae from the second site died from *EcNPV* in subsequent weeks. Mortality peaked 3-4 weeks after application, a time period that allowed substantial defoliation. A major epizootic of *Entomophaga aulicae*, a fungal pathogen native to N. America, was observed at both sites at the end of the larval stage.

Generation of American Elm Trees with Enhanced Tolerance/ Resistance to Dutch Elm Disease through Genetics

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Abstract

Dutch elm disease (DED), caused by the fungi *Ophiostoma ulmi* (Buisman) Nannf. and *Ophiostoma novo-ulmi* Brasier, has devastated North American species of elm, nearly eliminating the use of American elm (*Ulmus Americana* L.) as an urban shade tree. There is a need for multiple, genetically diverse American elm cultivars with superior tolerance to DED to be used by arborists and nurseries for urban plantings as shade trees and for the restoration of the American elm in forests. American elm clonal selections with significant tolerance to DED include 'Valley Forge', 'New Harmony', Delaware 2, and R18-2. These clones were crossbred to generate progeny with potentially enhanced levels of DED tolerance or resistance. The four crosses carried out were R18-2♂ x 'Valley Forge' ♀, 'New Harmony' ♂ x Delaware 2 ♀, 'New Harmony' ♂ x R18-2 ♀, and 'New Harmony' ♂ x 'Valley Forge' ♀. A field plot consisting of the progeny, ramets of parents, and unselected seedlings was established in 1995. Trees were inoculated in June 2002 with a mixture of the DED pathogens. The total percentage of the crown showing DED foliar symptoms, which can include wilting, chlorosis, and necrosis, was visually assessed for each tree at 4 weeks and at 8-9 weeks. Significant numbers of progeny were identified as potential candidates for propagation as DED tolerant elms. Several progeny showed few symptoms even at 8-9 weeks: 38 of 321 progeny at 5% or less, 73 of 321 progeny at 10% or less. Progeny of the R18-2 ♂ x 'Valley Forge' ♀ cross had a significantly lower mean percentage of foliar symptoms compared to progeny of the other three crosses at both reading dates. The numbers of ramets for the parents were low, compromising comparisons of progeny to parents. Crown dieback (absence of foliage), to be assessed in 2003, will be used to narrow down the promising candidates with potentially enhanced DED tolerance for subsequent propagation and retesting.

Invasive Insect Pests: How Many are Needed to Establish a Pioneer Population?

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Abstract

The process of pest risk analysis (PRA) is concerned principally with determining whether an organism presents a hazard, whether pathways exist for the organism to move to a new area and, finally, whether conditions exist to enable establishment in the receiving country. Taking bark and wood boring beetles as examples, this paper examines proof of pathway for initial transfer between the countries of origin and a number of other countries worldwide. Within this assessment, the Coleoptera have been divided into five groups, although the demarcation between them is not precise. The figures for each category represent either the number of genera or species that have been recorded as incursions of invasive exotic species by various plant protection organizations globally:

- Ambrosia beetles: Secondary wood borers in weakened, dying or recently dead trees (9 genera)
- Xylophagous bark and longhorn beetles: Mainly in weakened, dying or recently dead trees but some attack healthy trees (19 genera)
- Secondary bark feeders: Weakened, dying or recently dead trees (23 genera)
- Primary but non-aggressive tree killers: Relatively low mortality by attrition rather than mass attack (11 species)
- Primary aggressive tree killers: Mass attack strategies with well-developed pheromone systems and usually accompanied by fungal associates to overcome tree defenses (7 species)

There is proof of pathway (i.e. the organisms have been intercepted in the receiving countries) in all these categories, particularly for secondary bark feeders (23 genera). The two categories of tree killing beetles included both North American and European species. The high interception rates are not surprising in relation to the ability of bark and wood boring beetles to survive either under bark, if it is present, or within the wood. Packaging wood is regarded as the highest risk pathway for these pests and the plant protection organizations in the receiving countries regularly intercept many species of beetle either by inspection or by use of pheromone traps.

A key question arising from the known capacity of bark and wood boring beetles to move internationally is whether they have been able to establish in the receiving countries. Analysis of proof of pathway for establishment (i.e. breeding populations of the pest in the receiving country) reveals an interesting and intriguing picture. The numbers of genera or species known to have established in the five categories are 8, 8, 17, 5 (species, including *Dendroctonus micans* which has never been intercepted in transit) and 0, respectively. The surprise from this listing is the absence of establishment in new geographic regions of the most aggressive, mass-attack tree killers including, for example, *Ips typographus* from Europe and *Dendroctonus ponderosae*, *D. rufipennis*, etc. from North America.

What are the reasons for the apparent inability of the most aggressive bark beetles to establish outside their home ranges? There is no simple answer to this question and it is likely that a number of biological, ecological and environmental factors act in concert to determine whether the arrival of beetles with wood shipments actually translates to subsequent successful establishment. A potential factor is proximity to host trees after arrival, which is a probability event involving numbers of emerging adults, sex ratios and distance to hosts. Non-aggressive species have made it; are aggressive species different? A further important factor could be the numbers of beetles required to establish a pioneer population, even on weakened trees. If the number required is relatively large (say >10 m^{-2}), this translates to a much larger emergent population when taking account of the inevitable dilution over space and time after a population emerges from imported timber.

Clearly, more research is needed to understand whether the finding that aggressive tree-killing beetles are less able to establish isolated pioneer populations is biologically determined or whether it is an artifact. International collaboration is essential to address the intriguing questions raised by this analysis. I would be happy to develop an international collaborative project and would welcome comments and expressions of interest in such a program.

Effect of Entomopathogenic Nematodes on *Plectrodera scalator*

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Abstract

Entomopathogenic nematodes (EPNs) of the families Steinernematidae and Heterorhabditidae were screened for efficacy against the cottonwood borer (CWB), *Plectrodera scalator,* a model host for the Asian longhorned beetle (ALB), *Anoplophora glabripennis*. Two heterorhabditids and four steinernematids were screened against three cohorts of CWB third and fourth instars. A filter paper bioassay using a 24 h nematode-to-insect exposure identified three isolates effective against CWB: *Steinernema feltiae* SN, *S. feltiae* argentensis, and *S. carpocapsae* Sal applied at 100 IJs / larva. *Steinernema feltiae* SN was the most effective isolate, killing 58 percent (mean value) of the larvae. Insect mortality by *S. carpocapsae* Sal and *S. feltiae* argentensis was 50 percent and 38percent respectively. *Steinernema glaseri* and *Heterorhabditis indica* failed to kill any larvae. Preconditioning IJs to aqueous ALB frass for 1 hour did not affect nematode pathogenicity or infectivity to CWB. Nematode infectivity to CWB was low; the number of IJs penetrating the host was approximately 1 IJ per larva. In many cases, dissected larvae exhibiting symptoms of bacterial infection by the symbiont did not recover nematodes. The LC_{50} for *S. carpocapsae* Sal using a filter paper assay was 88 IJs per insect, and for *H. marelatus* IN was 475 IJs per insect. *Plectrodera scalator* is a good model host to use where *A. glabripennis* is unavailable; larvae are susceptible to attack from similar nematode species resulting in comparable insect mortalities.

Effect of Entomopathogenic Nematodes on *Anoplophora glabripennis*

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Abstract

Entomopathogenic nematodes (EPNs) of the families Steinernematidae and Heterorhabditidae were screened for efficacy against the Asian longhorned beetle (ALB), *Anoplophora glabripennis*. Two bioassays were used to screen nematode effects on ALB: a filter paper assay using a 24 h exposure of nematode-to-target-insect, and a feeding-pot bioassay using a 72 h nematode exposure of infective juveniles applied to the bore hole in the nutritional media. EPNs tested were *Steinernema feltiae* SN, *S. glaseri*, *S. riobrave* TX, *S. carpocapsae* Sal, *Heterorhabditis indica* MG-13 and *H. marelatus* IN applied at 100 IJs / larva. Neonate larvae were susceptible to all isolates screened using a filter paper bioassay, mortality ranged from 97 percent by *S. feltiae* SN to 39% by *H. marelatus.* Third instar larvae were susceptible to all isolates screened in the filter paper bioassay; *S. feltiae* SN and *S. carpocapsae* Sal were the most effective causing 100 percent mortaliy. In the feeding-pot bioassay, only *S. feltiae* SN and *S. carpocapsae* were effective, killing 100 percent of the larvae, sixth and seventh instars were similarly susceptible to *S. feltiae* SN and *S. carpocapsae* Sal, but the remaining isolates screened were ineffective. Nematode preconditioning to aqueous ALB frass did not enhance larval mortality. However, *S. feltiae* SN juveniles were positively attracted to ALB frass-extracts favoring its use in locating ALB larvae in cryptic environments like bore chambers or bark. Our results demonstrate the potential use of *S. feltiae* SN and *S. carpocapsae* as control agents for ALB.

Painted Apple Moth Eradication Project in New Zealand

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Abstract

Painted apple moth (*Teia anartoides)* is a native of Australia. It was first identified in Auckland in 1999, and has consequently spread to other west Auckland suburbs. It has the potential to seriously impact on our conservation estate, horticultural industry, parks and the nation's exotic forests. The Ministry of Agriculture and Forestry are managing an eradication campaign that includes the aerial spraying of Foray 48B. Foray 48B has a proven record for use in urban eradication programs and has been used over urban populations in Canada and the USA. As part of its eradication program the Ministry of Agriculture and Forestry are managing a communications strategy and providing a dedicated health service with those with health concerns related to the eradication program.

Potential Susceptibility of Eastern Forests to Sudden Oak Death, *Phytophthora ramorum*

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Abstract

Sudden oak death is caused by the fungus-like organism, *Phytophthora ramorum*, and was first discovered in central coastal California in 1995. Greenhouse tests of eastern oak species pin oak (*Quercus palustris*) and northern red oak (*Q. rubra*) have shown these species to be just as susceptible to sudden oak death as their west coast relatives. We developed a preliminary map of the potential risk to eastern forests in order to prepare for quarantine and management actions should the pathogen be introduced or move naturally to the eastern U.S. The map was developed using FIA periodic inventory plot data from the Eastwide database. Median indicator kriging was used to develop a surface of red and live oak relative density from the point data. A forest density layer was used to mask the surface to remove nonforest areas and to reduce the proportions based on forest density. The northeastern states conducted a shrub inventory during these periodic inventories. This shrub data was recently obtained and binary classifications were used based on presence or absence of *Phytophthora ramorum* shrub hosts, primarily evergreen ericaceous species. Indicator kriging was used to generate a two probability surfaces: one of shrub host presence and one of overstory host presence. These probability surfaces were multiplied to create a probability surface of host presence in the overstory and understory. The eastern oak forests of the U.S. appear to have plenty of susceptible hosts, both overstory and understory, that would make the establishment of *Phytophthora ramorum* in these forests a very serious threat.

Risk of Gypsy Moth Establishment in Canada and Continental U.S.: Estimating the Risk Based on Temperature Requirements for Seasonal Development

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Abstract

Among the requisites of each insect is the availability of food during its feeding stage(s) and suitable temperatures to complete its life cycle. This can be summarized as a requisite seasonality: the coincidence of particular life stages with particular seasonal events. For the gypsy moth (*Lymantria dispar* L) this means that first instar larvae will hatch coincident with the emergence of new foliage of host plants, that the cold-hardy and low-temperature-requiring diapause phase will coincide with winter, and the high-temperature-requiring prediapause and postdiapause phases will coincide with late summer and spring, respectively.

A physiologically-based phenology model can help estimate the probability that an introduced population can become established in a location by assessing the degree to which local temperatures satisfy developmental requirements and maintain insect seasonality. Presented here is an assessment from the Gypsy Moth Life Stage (*GLS*) model of the risk of gypsy moth establishment in North America under historic climate conditions (1961-1990) and a hypothetical climate change scenario of an average increase of 1.5°C .

The *GLS* model is a physiologically-based model of gypsy moth phenology that links egg, larval, pupal and adult development to create a full life-cycle model.

GLS does not rely on an arbitrary starting date for any particular life stage (a common problem with many phenology models). *GLS* is initiated in a location using a very broad oviposition period to establish a likely hatch pattern for the location. Subsequent oviposition patterns are the end product of simulated larval-adult development; egg hatch patterns are the end product of simulated egg development.

After 100 generations an index of climatic suitability is calculated as the average proportion of each generation that successfully completes its life cycle.

Climatic suitability may be low because diapause requirements are not satisfied (too few days of sufficiently low temperature; e.g. Florida); or because a late spring hatch, coupled with a short summer with low temperatures, causes late oviposition, and subsequent failure of eggs to complete prediapause before winter (e.g. much of Canada). Thus, in the north, the climate change scenario increases suitability; in the south suitability is reduced. A color map of suitability is available by contacting the author.

The individual life stage components of *GLS* were developed by Gray, Logan, Sheehan and co-workers.

2002 Studies on the Asian Longhorned Beetle, Pine Shoot Beetle, and Emerald Ash Borer

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Abstract

***Anoplophora glabripennis* (Cerambycidae).** Work focused on acoustic detection, insecticide trials, and natural enemies of the Asian longhorned beetle (ALB). A "Generation II acoustic system" was assembled, incorporating refined discrimination algorithms and additional input channels. The new system incorporated smaller, lighter and more portable components that can be worn in a mesh belt around the user's waist. Two new systems were assembled in 2002 for USDA APHIS to use in New York. In a lab study, adults fed twigs dipped in a 15 ppm solution of imidacloprid, started to die within 1 week, and all were dead within 3 weeks. In China, we injected trees with systemic insecticides and then counted the number of dead ALB adults under each tree daily. Overall, the highest numbers of dead adults were found beneath trees treated with imidacloprid, and in fact some started falling from the trees on the same day they were injected. In a 2002 survey of ALB natural enemies at two sites in China, we collected 4845 ALB individuals, including 1135 eggs, 3560 larvae, 42 pupae, and 108 adults. The most common natural enemy encountered was the ectoparasitoid *Dastarcus longulus* (Colydiidae). We also isolated 13 strains of *Beauvaria bassiana* from ALB larvae.

***Tomicus piniperda* (Scolytidae).** In 2002, we conducted studies on pine shoot beetle (PSB) attractants, inhibitors, and mortality during debarking. We found that *trans*-verbenol increased PSB trap catches over alpha-pinene alone. Verbenone and various 6- and 8-carbon, non-host alcohols inhibited PSB attraction to alpha-pinene. Using *Ips calligraphus* as a surrogate for PSB, we noted that more than 99 percent mortality occurred to parent adults during the debarking process.

***Agrilus planipennis* (Buprestidae).** The emerald ash borer (EAB) was discovered in 2002 in Michigan (Haack et al. 2002). As of March 2003, EAB was found in 6 counties in Michigan, 1 in Ohio, and 1 in Ontario. So far, only ash (*Fraxinus*) has been attacked. We initiated studies on insecticide, seasonal development, within-tree distribution, survival in firewood, natural enemies, and laboratory rearing. We tested two insecticides (imidacloprid, bidrin) and three injection methods (Mauget and Wedgle, trunk injection, Kioritz soil injection). So far, Mauget imicide resulted in the highest EAB larval mortality. Most larvae were 2nd instars by late July, 3rd instars by early August, and 4th (last) instars by late August 2002. Larvae were first found in pupal cells on 20 August. Overwintering occurred in both the outer sapwood and outer bark. We found that the oldest galleries were generally along the upper trunk and major branches, indicating that oviposition begins there and then spreads to the lower trunk and upper crown in subsequent years. In studies of natural enemies, we encountered clerid beetles, chalcid wasps, and various fungi (*Beauveria bassiana*, *Metarhizium anisopliae, Paecilomyces* sp., and *Verticillium* sp.) A species of braconid wasp in the genus *Spathius* is a common parasitoid of EAB in China. Field-collected larvae were reared successfully to adult on a modified *Prionis* diet; chill of prepupae is not required.

Haack, R.A.; Jendek, E.; Liu, H.; Marchant, K.R.; Petrice, T.R.; Poland, T.M.; Ye, H. 2002. **The emerald ash borer: a new exotic pest in North America.** Newsletter of the Michigan Entomological Society. 47(3-4): 1-5.

The Use of Fungal Bands for Control of Asian Longhorned Beetle

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Abstract

The fungal entomopathogen *Beauveria brongniartii* is grown in nonwoven cellulose bands and sold for control of four orchard-infesting cerambycids, including *Anoplophora malasiaca*, in Japan. This product is manufactured by Nitto Denko and sold under the name Biolisa. Wandering beetles self-inoculate themselves with fungal spores when walking on bands and can then transfer spores when mating. Bioassays (in labs in China and in quarantines in the U.S.), caged trials (in China) and non-caged trials (in China) have all demonstrated that this fungal pathogen and delivery system can be effective for control of *Anoplophora glabripennis*, the Asian longhorned beetle (ALB). However, although nine citations had been found reporting this fungal species in North America, none can be confirmed; either isolates are not available or identifications are incorrect. Molecular studies have shown that *B. brongniartii* is not one cohesive group and, in fact, the Japanese isolate used for producing fungal bands in Japan is quite different from North American isolates available to date.

Because we are not certain how long it would take before *B. brongniartii* could be used in North America, if this species was approved by the EPA, we have shifted focus to North American entomopathogenic fungi. Isolates of *Metarhizium anisopliae* and *Beauveria bassiana* from ALB from Chicago are at least equal to, if not superior to *B. brongniartii* in virulence during bioassays. Both of these species are common in North America and both have been registered previously with EPA as microbial insecticides. During the 2002 field season in Bengbu, Anhui, China, we compared activity of *M. anisopliae* with *B. brongniartii* using five replicate plots for fungal bands of each species and five control plots. More ALB adults were infected by *M. anisopliae* than controls over the first 30 days that bands were on willows; results appeared equivalent with *B. brongniartii* treatments. We have not yet analyzed data on emergence and oviposition.

M. anisopliae and *B. bassiana* were both grown in bands on the Cornell campus and placed around trees in Queens, NY to evaluate persistence of activity of bands. Bands of both fungi exceeded the lower limit for effectiveness over the entire 63 days of our study. This is significantly longer than *B. brongniartii* has been shown to be active in bands in Japan.

Activity of *Entomophaga maimaiga* Resting Spores

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Abstract

Resting spores are produced by *Entomophaga maimaiga* within cadavers of late instar gypsy moth larvae killed by this fungal pathogen. After the occurrence of epizootics in gypsy moth populations, *E. maimaiga* resting spores are present in the soil and constitute an inoculum reservoir so this pathogen persists in an area. Sites that have been followed in central New York demonstrate this persistence, with abundant infection in the very low density of gypsy moth larvae present 11 years after an epizootic.

Resting spores are the stage of *E. maimaiga* with the greatest potential for biological control use. There is a continual demand for *E. maimaiga* for release when gypsy moth moves into new areas as well as for inoculative augmentation. Resting spores can be produced in vivo as well as in vitro, but development of mass production has not proceeded further due to our lack of understanding of resting spore dormancy and the difficulty in studying these long-lived spores. Dormancy in resting spores of closely related species of fungi often requires several months of chill before resting spores are germinable. *E. maimaiga* resting spores collected in cadavers in the field in late spring/early summer never germinate and, when these resting spores have been collected from the field monthly, infection was only found the following spring beginning in April, with peaks in May and June. We assumed these spores were dormant after production, and our focus has been on developing methods to break this dormancy.

When resting spores are produced, as they mature, the double wall becomes thicker and the interior of the spore changes from a granular appearance to only one or a few lipid droplets (a stage we refer to as C5). Because resting spores germinate slowly and germination plates easily become contaminated, our standard method for evaluating resting spore activity is to expose gypsy moth larvae and quantify infection. Resting spores of a Japanese isolate of *E. maimaiga* were produced in protoplast-injected gypsy moth larvae in the laboratory and stored on water agar at room temperature after host death. By chance, as a control, we exposed gypsy moth larvae to these resting spores at 15°C 3 weeks after they had matured to C5s, and we found infection; these samples did not need a prolonged period of chill to yield infection. When this study was repeated, we found the same 3-week lag after maturation of resting spores before infection began. We were very surprised when infection increased to 100 percent after 2 months, and larvae exposed to these resting spores continued to be infected for 215 days after resting spore maturation, with this study ending only due to lack of resources, not due to lack of continued infection. These same resting spores were stored in the cold, and this study was repeated using resting spores stored in the cold for 1-8 months and a similar pattern occurred. However, when resting spores were stored in the cold for longer periods, once bioassays commenced, the lag period before infection occurred decreased so that after 8 months of cold storage, infection was seen in the first larval exposure after samples were brought from 4°C to 15°C.

We hypothesized that perhaps this lack of dormancy was a function of the origin of the isolate, and these studies were repeated using a Japanese isolate, but no differences were detected among three Japanese and two North American isolates. We next hypothesized that some environmental cue during resting spore maturation caused initiation of dormancy, and our laboratory-produced resting spores were not receiving this cue. To test this hypothesis, we injected gypsy moth larvae with protoplasts of a New York isolate and placed some of these larvae in sleeves on oak branches in the field while others remained under laboratory conditions. In the field, after larvae died, cadavers remained in sleeves for two more weeks to allow maturation of resting spores. Resting spores produced in the laboratory were maintained on water agar. There were no differences when field-produced versus laboratory-produced resting spores began infections. Samples were also stored at 4°C for 2 or 4 weeks and then assayed, but, once again, exposure to cold did not induce dormancy. Therefore, we have not identified any environmental cues received during resting spore maturation that delay activity.

We have learned that infection without a delay or cold period requires that the resting spores are fully mature (C5s). Studies demonstrated that maintaining resting spores on a substrate of 5:10 water:clay yielded C5s much faster than when cadavers were at 9:10 or 15:10 or on water agar. These studies also demonstrated that there

is considerable variation among fungal isolates in resting spore maturation.

In summary, while we have more to learn about induction of dormancy in *E. maimaiga* resting spores, our present findings of activity of this fungus without dormancy clearly facilitates progress toward development of methodology for mass production of *E. maimaiga* for biological control.

Molecular Diagnostic Tools for ALB

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Abstract

We proposed to use molecular techniques to study the genetic structure of Asian longhorned beetle (ALB) populations in Asia and North America, allowing us to assess the dispersal behavior of the adult beetles, the extent to which populations have spread in urban areas, and the potential for future spread. We have extracted and sequenced DNA from individuals of six populations; four from China, one from New York and one from Chicago. Three regions of the mitochondrial genome have been assessed for variation among populations. Sequenced gene regions include cytochrome oxidase I and II, and a portion of the large ribosomal subunit of the 16S rRNA. Unfortunately, screens of over 500 base pairs of sequence from each of these gene regions either showed little variation (telling us little about population structure) or were unreadable when sequenced due to heteroplasmy.

We now are examining genetic structure of populations using random amplified polymorphic DNA (RAPD) analysis. We screened 20 RAPD primers for variation among the six populations, scored 11 loci from two primer sets, and subjected these data to discriminant function analysis. These data indicated that the Gansu population from China shares a portion of its band variation with Illinois and New York, and Illinois and New York populations share some similarities among individuals.

Our studies confirm that there is genetic structuring among ALB populations in China, and suggest that this variation could be used to identify the locations of populations that were the source of North American infestations. In the future, we will extend our genetic analysis to include additional locations within Asia. This information will be valuable for evaluating international quarantine practices and preventing introduction of other invasive pest species.

Host Suitability and Utilization by Asian Longhorned Beetle

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Abstract

Anoplophora glabripennis (ALB) is an invasive wood-boring cerambycid beetle that kills hardwood trees. The host range of this species is unusually broad but is not well defined in the available literature and may include tree species that have not been reported as hosts because they have not previously been exposed to the beetle. We evaluated oviposition by *A. glabripennis* offered a choice of four common eastern North American forest and landscape hardwood tree species, and performance of the resulting larvae, under greenhouse conditions in two different sets of trials. In the first trial, choices consisted of sugar maple *(Acer saccharum)*, red maple *(A. saccharum)*, green ash *(Fraxinus pennsylvanica)*, and red oak *(Quercus rubra)*. In the second trial, choices were goldenraintree (*Koelreuteria paniculata)*, river birch ((*Betula nigra)*, London planetree (*Platanus* x *acerifolia*), and callery pear ((*Pyrus calleryana* cv. Aristocrat). Significantly greater numbers of oviposition sites were found on sugar maple than on red oak with intermediate numbers on red maple and green ash. Similarly, significantly greater numbers of living larvae were found in sugar maple than in the other tree species; however, more were found in red oak and fewer in green ash than expected, considering relative numbers of oviposition sites. After 90 days, mean mass of living larvae did not differ significantly among tree species. These results suggest that all four tree species may be suitable hosts for *A. glabripennis*. Most importantly, although larval establishment was poor in green ash and larval growth may have been retarded in red oak, larvae did survive and grow in both species.

In the second trial, adult *A. glabripennis* fed more on goldenraintree and river birch than on London planetree or callery pear. Oviposition was highest in goldenraintree but larval mortality was also high and larval growth was lowest in this tree species. Oviposition was lowest in callery pear and larvae failed to survive in this tree species, whether they eclosed from eggs laid in the trees or were manually inserted into the trees. Larval survival was also very low when larvae were placed on artificial diet containing powdered callery pear bark and wood. Adult beetles feeding on callery pear had reduced longevity and females feeding only on callery pear failed to develop any eggs. Resistance of goldenraintree against larvae appears to operate through the primarily physical mechanism of abundant sap flow. Resistance of callery pear against both larvae and adults appears to operate through the chemical composition of the tree, which may include compounds that are toxic or otherwise interfere with normal growth and development of the beetle. Unlike river birch or London planetree, both goldenraintree and callery pear originated in the native range of *A. glabripennis* and may therefore have developed resistance to the beetle by virtue of exposure to attack during their evolutionary history. We suggest that all tree species tested in this study, with the exception of callery pear, be considered potential hosts when surveys are conducted to detect infested trees or when replanting infested areas. However, we are still evaluating whether ALB can complete development in red oak or goldenraintree.

Searching for the Origins of Two Invasive Pests – *Anoplophora glabripennis* and *Tomicus piniperda* – by DNA Fingerprinting

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Abstract

In the last decade phylogeographic studies gained importance as they help to understand population structures and ecological findings. Further they can support pest management strategies by obtaining information on the origins of invasive species. In the last years we performed studies on two important invasive forest insects.

The pine shoot beetle, *Tomicus piniperda,* is a main pest on pine trees in Europe and for a decade has been found in the USA where it spread quickly. For a phylogeographic analyses, the mitochondrial COI from different European, Asian and USA populations was analyzed. Eighteen haplotypes were found which could be divided into three groups doing a nested clade analysis: group 1 contained most of the European and the U.S. populations, group B contained the Chinese population and group 3 contained the Spanish populations. Surprisingly, the sequence divergence between the Spanish group and group 1 (Central European and U.S.) was high compared to the one of the Chinese population and group 1. Searching the postglacial history of the main host, *Pinus sylvestris,* it is likely that the Pyrenees formed a barrier for gene flow, whereas gene flow seems to be continuous between the geographical distant locations China and Europe. Further we can conclude that the American populations originated from Central Europe, however, markers like microsatellites are needed to resolve that question more specifically.

Due to the detection of the Asian longhorned beetle (ALB), *Anoplophora glabripennis*, in Austria, molecular investigations were started to differentiate ALB from other *Anoplophora* species and other European long horned beetles. Furthermore a phylogeographic analysis of the introduced *A. glabripennis* in Austria and *A. glabripennis* populations in Asia was an additional aim of this work. Therefore ALB from China and Austria, *A. chinensis*, *A. malasiaca*, A. *macularia*, *A. davidis*, and *A. elegans* were collected. DNA was amplified with mitochondrial primers and PCR products were either sequenced or digested with restriction enzymes (PCR-RFLP). Both investigations led to results which could not be interpreted due to double peaks in the sequence chromatogram or incomplete digestion. The mitochondrial DNA is normally inherited maternally and the phenomenon found in ALB can be explained by additional paternal inheritance or by nuclear copies of the mitochondrial sequences. Latter phenomenon called Numts, occurs quite frequently in a variety of organisms, including insects and other invertebrates, vertebrates, fungi and plants. The occurrence of Numts complicates the employment of mitochondrial DNA in evolutionary studies like that of *Anoplophora*.

Predicting Early Plant Invasions in Forests of West Virginia

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Abstract

West Virginia public forests have experienced comparatively less invasion than forests in more urban regions and may serve as an optimal landscape for modeling early establishment of exotic invasive plants. Documentation of the importance of disturbance and environmental variables as predictors of invasion is lacking. I sampled the understory (herbs, shrubs, vines and tree seedlings) of 24 undisturbed (80 or more years old) and 24 disturbed (15-year-old clearcuts) sites in the Monongahela National Forest Cheat Ranger District. Sites were randomly selected such that three common ecological land types were equally represented in both undisturbed and disturbed sites. Species were grouped into exclusive types: exotic invasive, exotic noninvasive, native invasive, native noninvasive weed, and native noninvasive nonweed. Eleven environmental and seven disturbance variables were measured. Data were analyzed using logistic regression analysis. In all sites, exotic invasive weeds ranked low in relative importance values. High richness and diversity values and high levels of native noninvasive weeds and exotic noninvasive weeds best predicted invasion by exotic invasives in the undisturbed forests; only high herb richness was a reliable predictor of invasion in disturbed sites. Undisturbed sites were more likely to be invaded the closer they were to a paved road. In the disturbed sites, northeast-facing slopes, low moss/lichen cover, high bare ground cover, shallow slopes, low light levels, and shorter distances to gravel and paved roads best predicted invasion. A combined analysis showed that disturbed sites and sites with northeast-facing slopes were most likely to be invaded.

Quarantine Surveillance: Lure Trials for Scolytidae in Northeastern China

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Abstract

At least 550 species of Scolytidae are known to occur in China and the adjacent regions of eastern Russia, Japan and Korea. Half of the 46 species of Scolytidae currently recognized as introductions in North America, including three recently discovered species, *Tomicus piniperda* (Linnaeus), *Hylurgus ligniperda* (Fabricius) and *Hylurgops palliatus* (Gyllenhal), as well as numerous other species of quarantine concern occur in east Asia. Our collaboration has initiated field testing of commercially available pheromones and kairomones of Scolytidae to determine the potential of such lures to detect bark and ambrosia beetle species occuring in NE China and of quarantine significance to Canada.

The objectives of our ongoing studies include determining which species can be detected with commercially available lures, obtaining voucher material to aid in identification of nonindigenous Scolytidae and development of collaborative research projects for the detection of bark beetles of quarantine significance which do not respond to existing lures. Results from trapping experiments conducted in 2002 for *T. piniperda, Ips subelongatus* (Motschulsky) and *Pityogenes chalcographus* (Linnaeus) are presented.

Distribution, Abundance and Host Range of Exotic Ambrosia Beetles in Southwestern British Columbia

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Abstract

Five previously unrecognized nonindigenous ambrosia beetles (Coleoptera: Scolytidae), *Trypodendron domesticum* (Linnaeus), *Xyleborus pfeili* (Ratzeburg), *Xyleborinus alni* (Niisima), *Xylosandrus germanus* (Blandford) and *Xyloterinus politus* (Say) have been discovered in the urban forests of British Columbia since 1995. Within urban forest sites, the recently introduced scolytid fauna, along with other previously introduced taxa, now comprise the largest component of trap captures. Three of the recently introduced taxa have successfully invaded both urban forest habitats and adjacent managed forest lands. The introduced species are now a major component of the scolytid diversity in some forest systems and may impact the diversity of native plant and animal species. Preliminary results from studies on the abundance, diversity and host ranges of native and nonindigenous ambrosia beetles attacking recently dead or dying coniferous and deciduous trees in southwestern British Columbia are presented.

Effects of Temperature on the Biology and Behavior of *Anoplophora glabripennis* (Coleoptera: Cerambycidae)

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Abstract

There is a critical need for information on the basic biology and behavior of *Anoplophora glabripennis* (ALB) to provide the biological basis for predicting potential dispersal, developmental phenology, timing of exclusion and eradication methodologies and attack rates in different environments. Published information on its life history and behavior at different temperatures regimes is very limited.

Fecundity, longevity and mating success for mating pairs of ALB from the Chicago, IL strain were assessed at 5 temperatures (15, 20, 25, 30, and 35°C and $\geq$ 50%= percent RH) in rearing jars with *Acer saccharum* twigs provided as food and a bolt as an oviposition substrate. Larval development and survival on artificial diet were investigated at 8 temperatures (5, 10, 15, 20, 25, 30, 35, and 40°C). Adult preflight behavior, time of flight initiation, and type of flight were observed for periods of 45 minutes at 15, 22, and 30° C (60 $\pm$ 20 percent RH).

Males lived longer than females at all temperatures. Survival, fecundity, and percent hatch were highest at 20-25°C and declined above and below this temperature range. Adults of both sexes did not initiate flight at 15°C but propensity for flight tended to increase with temperature. The lower developmental threshold for instars 1-8 was estimated to be slightly less than 10°C. The upper threshold for development (i.e., the temperature at which development stops and death occurs) was 40°C for instars 1-3 and 35°C for instars 4 and subsequent instars. First instar larvae reared at 35°C survived an average of 40 days and molted once or twice, whereas larvae held at 40°C never molted and survived an average of only 9 days. Data on development to adulthood are incomplete at this time.

These results suggest that adults surviving into the fall in the field will fly less and lay fewer eggs and that those eggs may not hatch until spring. Larval development at a constant 15°C suggested that beetles may take two or more years to complete development in colder climates. Exposure to temperatures $\geq$35°C for several days may increase mortality of all stages and cause at least a temporary cessation of egg oviposition. Given the deleterious effects of higher temperatures, the beetle is unlikely to complete more than one generation a year even in warmer climates. However, beetles are more likely to disperse at higher temperatures which could make detection more difficult in warmer climates.

The Horse Chestnut Leaf Miner, an Invasive Pest of Unknown Origin in Europe

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Abstract

The horse chestnut leaf miner, *Cameraria ohridella* Deschka and Dimic (Lep.: Gracillariidae) is a small moth that was first discovered in 1984 in Macedonia and in 1989 in Austria. It is now found from Northern Italy to Denmark and from Ukraine to UK. The fast spread of the moth in Europe is explained by the transportation of adults and pupae in dead leaves, by car, train, truck, etc. Adult moths emerge in spring from overwintering pupae. Eggs are laid on the upper epidermis of the leaves. There are usually six larval instars. The first instar larvae are sap-feeders and the next three feed on leaf tissue. The last two instars spin a cocoon in the mine, in which they pupate. There are two to four generations per year, depending on the climate. Pupae overwinter in dead leaves. The damage is produced by the larvae that mine in leaves of horse chestnut (*Aesculus hippocastanum*). In the regions where the moth is present, nearly all horse chestnut trees are attacked, and most become brown and lose their leaves in summer. Heavy defoliation is observed nearly every year. The pest is causing much concern in Europe where horse chestnut is an important ornamental tree in streets, parks and gardens. The few endemic forests of horse chestnut in the Balkans are equally threatened. The real impact on trees is not yet clear. Trees are surviving, but horse chestnut is no longer planted in Central Europe because of the moth. Recent observations suggest that the pest affects fruit production and seedling survival in natural stands.

Natural enemies are presently studied. Over 20 polyphagous parasitoid species were found attacking *C. ohridella* in Europe, both in urban areas and in natural stands. However, in general, parasitism is much lower than for other Gracillariidae. Predation by birds and invertebrates is usually low. The main mortality factors are intraspecific competition in the summer and autumn generations, and winter mortality through leaf destruction.

The origin of *C. ohridella* is unknown. It may come from the Balkans, where it was first found and where the host tree originates, but several indications suggest that it rather comes from another continent. Its original host tree may be another *Aesculus* species in Asia or North America, but another tree genus cannot be ruled out, since it can develop on some *Acer* spp. in Europe. The area of origin is presently searched, using surveys, pheromone trapping, host tree screening, and molecular analyses.

Beech Bark Disease: Identifying and Enriching for Resistance in the American Beech

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Abstract

Beech bark disease begins when bark tissues attacked by the scale insect (*Cryptococcus fagisuga* Lind.) are rendered susceptible to infection by fungi of the genus *Nectria,* leading to the weakening and eventual death of the tree. Some American beech trees remain disease free in stands long-effected by beech bark disease and challenge trials have shown that they are resistant to the scale insect (Houston 1982, USDA Forest Serv. Res. Pap. NE-507).

Increasing the number of resistant beech trees while reducing the proportion of susceptible trees is currently thought to be the best management approach to minimize the overall impact of beech bark disease [Mielke ME; Houston DR; Bullard AT (1986) In: Proceedings, Integrated Pest Management symposium for northern forests: 272-280]. Even in heavily infested areas, trees that remain clear of scale may be "escapes" and not truly resistant. Previous work by David Houston (1982), reported an artificial inoculation technique that confirmed the resistance of older, scale-free trees and successfully infested 1-year-old seedlings. We are currently setting up experiments designed to determine if this technique will be an effective tool in distinguishing resistant from susceptible American beech trees. To directly compare resistant and susceptible individuals we are using three different tree sources: 1) root sprouts, both naturally occurring and artificially induced through wounding, 2) grafted material, and 3) seedlings, both from open-pollinated sources (half-sibs) and from controlled cross-pollinations (full-sibs). Our initial efforts have resulted in the collection of 1200 seeds from controlled-cross pollinations and 5000 open-pollinated seeds. Insect collection traps have been set to confirm the resistance of the parent trees, to confirm the resistance of clusters of clonal trees, and to collect eggs for use in challenge experiments of seedlings and grafted trees.

Our long-term goal is to use this artificial inoculation technique as a way to screen cross-progeny for their resistance phenotype, giving insight into the genetic basis and mechanism(s) for resistance. Molecular techniques will also be applied in efforts to identify DNA-based markers for resistance. Eventually, superior resistant progeny will be selected and used to develop seed orchards to provide an enriched source of resistant American beech for plantings ahead of the disease front to minimize the impact and in aftermath forests to restore healthy, productive beech to the forest landscape.

Male (Gypsy) Moth Trapping in Minnesota

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Abstract

Release-recapture trials were conducted to assess the sensitivity of gypsy moth detection trapping grids in northern Minnesota. Square plots of 23.3, 5.8, and 4.6 km^2 were established with densities of 1, 16, and 36 disparlure-baited delta traps per 2.59 km^2 (= 1 mi^2), respectively. Grids were arranged so that each corner of a plot's "core" 1.6 X 1.6 km area fell at a trap site. Lab-reared gypsy moths were sterilized (150 Gy), dusted with Day-Glo powder, and placed in waxed cardboard release containers at central points between traps. Approximately 1000 pupae were placed weekly per plot for 12 weeks; emergence and capture were monitored.

Weekly emergence ranged from 1 to 77 percent of pupae (average = 44 percent) and was positively correlated with accumulated degree-days (15° C base) during the emergence period (F = 11.3; *d.f.* = 1, 23; P = 0.003). Weekly recapture of males ranged from 0 to 6.7 percent (average =3.2 percent), but relationships between recapture and temperature-related variables were not significant in initial analyses. Overall recapture was 1.0, 3.5, and 4.6 percent for trap densities of 1, 16, and 36 per mi^2, respectively (F = 5.09; *d.f.* = 2, 23; P = 0.015). Recapture rates observed in this test were in general agreement with results of other similar studies, suggesting that the sensitivity of gypsy moth detection trapping grids should be roughly comparable between northern Minnesota and more the southern areas in which grid sensitivity has been evaluated in previous tests.

Additional release-recapture tests were run in Massachusetts. Marked males were released on 16 days at the center of two concentric rings of traps (6 and 12 traps at 30 and 60 m, respectively, from the release point). In these tests, recapture did increase significantly with increases in values of several temperature-related variables, although (surprisingly) minimum temperature on the morning of adult emergence produced the best fit (r^2 = 0.361; F = 7.91; *d.f.* = 1, 14; P = 0.014). Additional testing is needed to better define effects of weather- and climate-related variables on the sensitivity of gypsy moth detection trapping systems.

A Multiple Scale Assessment of *Ailanthus altissima's* Invasion Potential

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Abstract

The current distribution, historic rate of spread, and reproductive potential of *Ailanthus altissima* suggest that it is poised for significant additional expansion into suburban and rural areas in the near future. We are beginning a multiple spatial scale study of *Ailanthus*' current distribution in a representative landscape in the mid-Atlantic region of the eastern U.S. By combining remote sensing and GIS techniques with field-based studies of seed and ramet dispersal into several common habitat types, it will be possible to describe current invasion potential and gauge future invasion probability in similar urban, suburban, and rural landscapes.

Methodology Assessment for Injecting Systemic Insecticides in Trees

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Abstract

The Asian longhorn beetle programs in New York and Chicago annually inject tens of thousands of trees with systemic insecticides using a method that requires personnel to guard an injected tree for 4 hours post application. In 2002, the current method (Mauget capsules) was compared to 5 other injection systems that immediately deliver insecticide into the tree. Five formulations of imidicloprid were also compared, using several of the injection systems: Imicide 10 percent, Imicide 25 percent, Pointer 5 percent, Pointer 10 percent and Imajet 5 percent (when using this formulation, a 2x dose was injected). Systems were evaluated based on insecticide residue comparisons, time required to inject, field-worthiness of the system, and damage ratings as a result of the injections. The systems compared to the Mauget capsule injection method were: Quik-inject System (by Mauget, 3/8" hole, 2" deep), Arborsystem's wedgle and wedgechek (cambium layer injection method), ALB injector (7/32" hole ½" deep), and two high pressure systems, Sidewinder (15/64", 1" deep, with a 0.28" plug), Arborjet's VIPER (18/64", 0.63" deep, with a 0.33" plug). For statistical analysis, means were separated by ANOVA using the modified LSD procedure, with P=0.05.

Norway maple and green ash were the tree species used and both species yielded consistent results between the systems and formulations tested. Imicide 25 percent failed to increase imidicloprid residue levels as compared to the 10 percent formulation when using the Sidewinder and Arborjet systems. In three of four trials it actually resulted in a lower average value as compared to the 10 percent formulation, although these differences were not significant. The Pointer 10 percent formulation, used in four of the systems, consistently resulted in very low values that were not significantly different from the control trees, but Pointer 5 percent and the Imajet formulation gave results that were consistent with those of Imicide 10 percent.

The Quik-inject System requires large holes to be bored into a tree, and the residue levels were similar to Mauget in maple, but significantly less in ash. Both the wedgle and Sidwinder systems had significantly lower residue levels as compared to Mauget. The wedgle method also often resulted in bark splitting and separation. Both the VIPER and ALB injector methods resulted in similar residue levels to the Mauget. It is recommended that damage assessment comparisons be made between the injection systems, esp. the high pressure ones, for a more complete analysis of the injection systems. Based on field experience, the ALB injector was least intrusive and most consistent with the standard Mauget method in terms of residue levels and damage.

Invasion Potential of *Paulownia tomentosa* (Scrophulariaceae) into a Managed Forest Landscape

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Abstract

There are often two central questions in invasion biology: what makes some ecosystems more invasible than others and what characteristics of invasive species allow them to be able to invade new habitats? There have been many suggested characteristics of ecosystems that may make them more invasible, such as disturbance or patch size. Likewise, there have been many suggested traits of invasive plants that are thought to allow them to attain a foothold into new ecosystems, such as early age of reproduction and fast growth. I was interested in comparing the success of seeds and seedlings of the *Paulownia tomentosa* (princess tree) species across a managed forest landscape that included clear cuts, forest edges, and intact secondary forest.

The work was carried out at Waterloo Wildlife Experimental Station in Athens Co. in the unglaciated part of SE Ohio where several clearcuts are maintained. I used five replicate clear cuts to establish habitat transects into clearcuts, on forest edges, and within intact forest. In summer of 1997, *P. tomentosa* were planted into plots that had been cleared and uncleared as well as in 4 x 4 x 10 inch pots to see the effects of above- and below-ground competition. After the first season of planting, the experimental design was revised due to high rates of herbivory on experimental plants. From then on, plants were placed inside and outside of cages as well as in and outside of pots for the 1999 and 1998 growing seasons. At the end of the growing season, half of plants were harvested and half were left to overwinter. In the summer of 2000, all plants were harvested. Seed establishment was also monitored in field. Seed bags were prepared with 100 seeds in each and placed under the leaf litter layer or at 5 cm depth in January of 1998 in three replicate sites. Each June and August, seed bags were harvested and seeds that did not germinate were tested for viability using a standard tetrazolium test.

The invasion potential for established seedlings is greatest in clearcut sites, second in edge sites (with below-ground competition having an effect on plants in this habitat), and lowest in intact forest. Nonetheless, some plants were able to survive the course of the experiment. Seeds were found to be able to survive with high rates of viability after 3 years. Seeds did show dormancy, especially those collected in August. In a common garden experiment, seeds were not found to germinate through leaf litter or on sandy soils. Seed germination in field sites where litter had been removed was only observed in clearcut sites. This species shows growth typical of a shade intolerant species. Seeds require light to germinate and it can grow fastest in habitats with high light. Since seeds also require light to germinate and can remain viable in the seed bank, management of forests to preclude *P. tomentosa* should prevent large openings in the canopy as this will make an area susceptible to invasion.

Ethanol and (-)-α-pinene Attract Woodborers and Weevils in Northern Florida

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Abstract

Two trapping experiments with Lindgren funnel traps were conducted in the spring and summer of 2002: one in a stand of mature slash pine in the Osceola NF and the second in a stand of longleaf pine in Ocala NF in northern Florida. In each experiment, traps were grouped into 10 replicates of four treatments per replicate and the following treatments were randomly assigned to one of four traps within each replicate: blank, ethanol alone, (-)-α-pinene alone, and ethanol with (-)-α-pinene (each released at about 2-3 grams/day). Collection cups contained an aqueous solution of propylene glycol, formaldehyde and soap. Trap catches were collected at 2- to 3- week intervals, with the glycol solution or dichlorvos strip replaced on each occasion.

Ethanol increased attraction of *Acanthocinus nodosus* (Fabricus), *A. obsoletus* (Olivier), *Monochamus titillator* (Fabricus), *Xylotrechus sagittatus* (Germar) (Coleoptera: Cerambycidae), and *Hylobius pales* Herbst and *Pachylobius picivorus* (Germar) (Curculionidae) to funnel traps baited with (-)-α-pinene. *Buprestis lineata* Fabricus and *B. consolaris* Gory (Buprestidae) were attracted to (-)-α-pinene but unaffected by ethanol. Ethanol and (-)-α-pinene were not attractive to *Chalcophora virginiensis* (Drury) and *C. georgiana* (LeConte) (Buprestidae).

Mapping Susceptibility and Spread Associated with Beech Bark Disease

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Abstract

Also known as beech scale *Nectria* canker, beech bark disease is an insect-fungus complex composed of the European scale insect (*Cryptococcus fagisuga*) and the exotic canker fungus *Nectria coccinea* var. *faginata* or the native *Nectria galligena* that kills or injures American beech (*Fagus grandifolia*). The disease results when a *Nectria* fungus infects the bark through the feeding wounds caused by beech scale insects. Invasions by exotic insects and diseases are one of the most important threats to the stability and productivity of forest ecosystems around the world. One of the most important steps in the development of effective strategies for management of alien species is to evaluate the risk of future impacts from specific exotic organisms. The generic activity “risk assessment” is considered an important component to management of exotics both before and after their arrival in new habitats. Our research focuses on estimating the expected geographical extent of beech bark disease through 2025 and which areas within that extent will be the most at risk. We used USDA Forest Service Forest Inventory and Analysis (FIA) data to create an estimated surface of American beech basal area and historical survey data to model beech bark disease spread.

Mapping Susceptibility and Spread Associated with Gypsy Moth

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Abstract

The gypsy moth was originally introduced near Boston in 1868 or 1869, it has been slowly expanding its range mostly to the south and west. The gypsy moth is a polyphagous insect; North American populations feed on over 300 different shrub and tree species. In order to plan for the management of the gypsy moth over the next decade and beyond, there is a need to delimit the distribution of susceptible stands in areas that are currently uninfested. Invasions by exotic insects and diseases are one of the most important threats to the stability and productivity of forest ecosystems around the world. One of the most important steps in the development of effective strategies for management of alien species is to evaluate the risk of future impacts from specific exotic organisms. The generic activity "risk assessment" is considered an important component to management of exotics both before and after their arrival in new habitats. Our research focuses on estimating the expected geographical extent of gypsy moth through 2025 and which areas within that extent will be the most at risk. We used USDA Forest Service Forest Inventory and Analysis (FIA) data to create an estimated surface of basal area that is composed of species preferred by the gypsy moth and historical survey data to model gypsy moth spread.

Mapping Susceptibility and Spread Associated with Hemlock Woolly Adelgid

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Abstract

The hemlock woolly adelgid, *Adelges tsugae*, is native to Asia and was first introduced to North America in British Columbia in the 1920s and was later discovered in the Shenandoah Mountains of Virginia in the 1950s. It has gradually been expanding its range, largely to the North. In the eastern US, the adelgid's principal host is eastern hemlock, *Tsuga canadensis*. Thus, the hemlock wooly adelgid is likely to cause considerable damage in the future as it expands into areas with large quantities of hemlock. Invasions by exotic insects and diseases are one of the most important threats to the stability and productivity of forest ecosystems around the world. One of the most important steps in the development of effective strategies for management of alien species is to evaluate the risk of future impacts from specific exotic organisms. The generic activity "risk assessment" is considered an important component to management of exotics both before and after their arrival in new habitats. Our research focuses on estimating the expected geographical extent of hemlock woolly adelgid through 2025 and which areas within that extent will be the most at risk. We used USDA Forest Service Forest Inventory and Analysis (FIA) data to create an estimated surface of eastern hemlock basal area.

The EPPO Project on Quarantine Pests for Forestry

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Abstract

EPPO is an intergovernmental organization responsible for international cooperation in plant protection in the European and Mediterranean region. In the sense of the International Plant Protection Convention, it is the regional plant protection organization for Europe. Founded in 1951 with 15 member governments, it now has 44 member governments including 15 countries of the European Union and 29 non-EU countries.

The EPPO Secretariat proposed and the EPPO Council of 1999 adopted a new Project on Quarantine Pests for Forestry, which would systematically evaluate the phytosanitary risks for the EPPO region (mainly from pests occurring on the territory of the former USSR) and would take account of the special nature of forestry phytosanitary problems to develop procedures to reduce the risk of spread of pests. It was also decided by the Council to create a new EPPO Panel on Quarantine Pests for Forestry for the implementation of this Project.

Under the Project, the EPPO Secretariat collected data on the distribution of 653 species of main forest trees (196 coniferous & 457 deciduous) and 1342 species of forest pests (1142 insects & 200 pathogens) occurring on the territory of the former USSR. Information on most of them exists only or mainly in Russian. In 2000 – 2002 EPPO held six meetings of the Panel on Quarantine Pests for Forestry (in Finland, Russia, Croatia, Lithuania and France - twice). The Panel have been prioritizing insect pests and performing the Pest Risk Analysis (PRAs) (according to the EPPO standards) for the most important pests on the base of datasheets collected by the Secretariat. This work will be continued in 2003 when two more Panel meetings are planned (in Latvia and Italy).The main criteria being used for the prioritization are: major importance on the territory of the former USSR, damage to plants important within the EPPO region, absence from the non-Asian part of the EPPO region, availability of trade pathways.

Twenty-seven species of insect pests have been analysed for phytosanitary risk by 2003. Seven of them have been proposed by the Panel as quarantine pests for the inclusion into the EPPO lists: *Dendrolimus sibiricus* Tschetverikov, *Aeolesthes sarta* Solsky, *Xylotrechus altaicus* Gebler, *Scolytus morawitzi* Semenow, *Tetropium gracilicorne* Reitter, *Ips subelongatus* Motschulsky and *Ips hauseri* Reitter. Pest specific phytosanitary requirements (PSPRs) were elaborated for these pests. At the end of the Project, commodity standard for wood will be prepared. It is planned to publish all databases, data sheets, PRAs, PSPRs and other results obtained under the Project. The collaboration with EXFOR Project is also being developed.

Population Ecology of Gypsy Moth in Kyrgyzstan

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Abstract

While a large amount of information has been published in the western literature about gypsy moth (*Lymantria dispar* L.) populations in Europe and the far East, relatively little information exists about populations in Central Asia. Within this region, gypsy moth populations have been recorded in Kyrgyzstan, Uzbekistan, and Kazakhstan. The range in Kyrgyzstan is limited to a region in the south which stretches from the southern and southwestern spurs of the Tien-Shan mountains to the southern banks of the Caspian Sea. This population is separated from other Eurasian gypsy moth populations by deserts to the north, spurs of the Tien-Shan to the northeast and east, and the Caspian Sea to the west.

The composition of stands where the gypsy moth is known to exist vary considerably among different elevations. Ashimov (1989) defined three vegetation zones: pistachio from 800-1200 m; apple, hawthorn, cherry, and poplar from 1200-1500 m; and walnut from 1500-2000 m. There may be significant reproductive isolation among populations at different elevations as a result of variation in developmental time and among populations that are geographically separated by high-elevation spurs of the Tien-Shen mountains.

There are no records of gypsy moth outbreaks prior to the 1960s. Since the late 1970s, gypsy moth outbreaks have occurred in most of the fruit and walnut forests of southern Kyrgyzstan. Since the early 1980s, the annual outbreak area has ranged from 17,000 to 52,000 ha. Serious defoliation has most frequently been observed in pistachio, walnut, and apple forests. At elevations above 800-1000 m, outbreaks tend to be localized and sporadic through time. At lower elevations, outbreaks tend to be more uniformly distributed and have persisted for many years. None of these populations exhibit the cyclical nature which characterizes outbreaks in European populations. During an outbreak, populations may reach very high densities up to 200 egg masses per tree. An extended outbreak of >30 years may result in tree dieback and mortality. This damage may be critical since these forests are important for prevention of watershed erosion as well as being important sources of fruit and nuts.

Considerable phenotypic variation exists among gypsy moth populations located in different elevation zones (Kosminski 1929). Ashimov (1989) noted the dominance of the light phenotype at lower elevations and the dominance of the dark phenotype in higher elevations. Also, at low elevations, females have greater flight activity than at high elevations. However, female flight in all populations has a limited character and is primarily used for location of oviposition sites. These oviposition sites vary considerably with elevation and microclimate. In the lower pistachio zone (dry conditions), most egg masses occur on the shaded side of lower trunks. At higher elevations (wet conditions), most egg masses are located on middle and upper trunks up to 10m in height, and very rarely occur on lower trunks.

Analysis of nutritional indices showed that young larvae from Kyrgyzstan are characterized by very low efficiency of digested food conversion (ECD) and, accordingly, a low net growth efficiency (ECI) in comparison with populations form the Ural Mountains and North Caucases. This may explain the finding that Kyrgyz populations develop poorly on artificial diet (Ilinikh, pers. comm.). No differences in growth of larger instars were found among populations.

Khamdam-Zada (1972) described the "Ferganica race" from collections in Central Asia, but the characteristics that he used (egg mass weight, wing size, etc.) are typically not stable (e.g. vary with density) and therefore are not appropriate for differentiation among populations. The following characteristics of Central Asian gypsy moth populations may be more useful:

- Very characteristic larval coloration which is not found in Europe or elsewhere in Asia (e.g. pigmentation of the dorsal stripe)

- Total lack of gray coloration on wings of males

- Extreme darkening of larvae that develop at low temperatures

- Comparatively lower ECD in small instars and high mortality of small instars during feeding on artificial diet.

In addition, Kyrgyz populations are characterized by extensive covering on top of egg masses (this covering may reach 40 percent of the total egg mass in extreme cases). However, this characteristic might not be particular to this race, but instead related to very dry conditions during egg maturation. During late summer months all zones experience very low humidity.

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Design and Cost Analysis of a Detection Survey for the Emerald Ash Borer in Michigan

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Abstract

With the goal of detecting infestations of 20 or more ash trees with 95 percent confidence, an emerald ash borer survey in the detection survey zone in southeast Michigan will cost an estimated $1.4 million, with considerable uncertainty about the actual value. To achieve this goal, virtually the entire DSZ must be surveyed and approximately 15 percent of all ash trees must be inspected (360,000 out of the estimated 2.4 million ashes present in the DSZ). A large number of assumptions underlie the cost estimate. A key assumption is that recently or lightly infested individual trees can be identified as such with only 65 percent certainty (35 percent of the time an infested ash will be declared healthy upon inspection, using methods likely to be applied in an extensive survey under reasonable time and cost constraints). Alternatives to this and other assumptions about the sampling strategy were explored using an Excel-based model. Sensitivity analysis showed that parameters defining the woodland habitat in the DSZ dominate the cost and uncertainty about the cost of conducting the detection survey.

Symbiotic Microorganisms Associated with Hemlock Woolly Adelgid, *Adelges tsugae*

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Abstract

The hemlock woolly adelgid, *Adelges tsugae*, is a devastating non-native pest of eastern hemlock, *Tsuga canadensis*, and Carolina hemlock, *T. caroliniana*. A better understanding of the biology of hemlock woolly adelgid and its interaction with host plants is essential for development of effective pest management strategies. Symbiotic microorganisms are common in Aphidoidea (aphids, phylloxerans, adelgids) and have been shown to be necessary for normal growth and fecundity. We studied the ultrastructure of the symbiotic microorganisms associated with *A. tsugae*.

Adelges tsugae harbors bacterial organisms located in mycetocytes – large specialized cells distributed in groups in the posterior abdomen. Based on their ultrastructure, *A. tsugae* symbionts appear to be prokaryotic bacteria with four distinct morphological forms. There are no apparent differences in the types of symbionts present in the sistens, progrediens or sexupara morphs. Three forms of symbionts are present in embryos, nymphs and adults; the fourth form is found only in oocytes, eggs and developing embryos. Form "A" bacteria are exclusively intracellular, residing in mycetocytes. This form is not present in oocytes or eggs prior to formation of mycetocytes, but is found in all other *A. tsugae* stages, with the exception of the post-egg production adult, which also lacks mycetocytes. Form "B" symbionts occur both intra- and extracellularly. They are found in mycetocytes, separately and in combination with the "A" form. The "B" forms are released through ruptures in the mycetocyte plasma membrane and enter the hemocele where they appear to transform into morphological form "C". Form "C" symbionts are found extracellularly in the hemocele of *A. tsugae* nymphs and adults, and in oocytes and eggs. They do not appear in mycetocytes. This form penetrates oocytes, transmitting the symbionts to the next adelgid generation. As oocytes develop, fourth morphological form, "D", appears along with the "B" and "C" forms in a bacterial syncytium (a mass of protoplasm). The symbiont syncytium is incorporated into the developing embryo, mycetocytes then develop, the "D" form disappears and the "A" form appears in the new mycetocytes. Based only on ultrastructure, it is not possible to determine with certainty if the "A", "B", "C", and "D" forms are distinct primary and secondary endosymbionts or pleomorphic forms of a single primary microorganism.

Plasticity in the Feeding Preferences of Gypsy Moth Larvae (*Lymantria dispar*)

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Abstract

Gypsy moth larvae (*Lymantria dispar*) (L.) (Lepidoptera: Lymantriidae) are major forest pests in most of the United States and destroy millions of acres of trees annually. The larvae are highly polyphagous feeders and defoliate a variety of tree species, including forest, shade, fruit, and ornamentals. Lepidopteran larvae, such as gypsy moth larvae, depend largely on their sense of taste and smell to find food sources. Feeding behavior is controlled by neural input from mouthpart gustatory organs. These sensory organs are in continuous contact with plant sap during feeding and are capable of detecting different phytochemicals present in the plant. The gustatory sensory input is encoded as patterns of nerve impulses by receptor neurons, housed in these sensory organs, and sent to higher processing centers in the brain. These neural messages signal acceptance or rejection of food. Shields et al. (2001) established a feeding preference hierarchy of fifth instar gypsy moth larvae to seven overstory tree species. A subset of these tree species was strongly favored, whereas at least one tree species was highly unfavored. In a follow-up study, Shields and Rodgers (2002) tested a large number of phytochemicals, typically found in host and nonhost plant species of gypsy moth larvae, and found both phagostimulatory (increase feeding) and phagodeterrent (decrease feeding) compounds. In the present study, we addressed whether unfavored tree species could be rendered more preferred or palatable by the addition of phagostimulatory compounds. More specifically, we examined if selected phagostimulatory compounds were capable of decreasing or suppressing the deterrent effects of compounds found in an unfavored tree species. We found that certain phagostimulatory compounds rendered the unfavored tree species more palatable. Our results suggest that this insect exhibits distinct feeding plasticity and furthers our understanding about the importance of gustatory cues in larval-host plant interactions.

Isolation of a Strain of LdMNPV that Stably Produces Polyhedra in Cell Culture after Serial Passage

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Abstract

A screen was developed to identify viral strains of the *Lymantria dispar* multinucleocapsid nucleopolyhedrovirus (LdMNPV) that maintained stable polyhedra production during extended propagation in cell culture. Isolate 22b was identified in this screen and was found to exhibit stable polyhedra production through 14 serial passages in Ld652Y cells. In contrast, wild-type viral isolates formed few polyhedra (FP) mutants, which became the predominant virus present after only 4 to 7 serial passages. In addition, isolate 122b exhibited an apparent 10-fold increase in budded virus (BV) synthesis. A FP mutant of 122b was isolated and was found to produce the same amount of budded virus as 122b. This finding suggests that isolate 122b's stable polyhedra production is due to synthesis of the same amount of BV as produced by an FP mutant. To determine if the apparent increase in BV synthesis was real, the amounts of viral DNA and BV produced by 122b and wild-type virus under the same conditions were determined. Cells infected with 122b yielded about 10-fold more BV compared to cells infected with wild-type virus (determined by TCID50 analysis). However, there was no difference in the amount of BV DNA produced by 122b compared to wild-type virus. This result suggests that the apparent increase in BV synthesis is actually a consequence of increased viral infectivity. Marker rescue, coupled with serial passage of virus in cell culture, of a cosmid library of 122b with isolate 122 was used to identify the genomic region containing the gene(s) responsible for the increased infectivity of isolate 122b BV. One cosmid, containing the genomic region from approximately 30 to 66 kbp consistently yielded virus with the traits of isolate 122b. Subclones of this cosmid were generated and used in marker rescue studies to identify the gene responsible for the increased infectivity of isolate 122b BV. The results of these experiments indicate that a mutation in a DNA binding protein gene is responsible for the enhanced infectivity of isolate 122b budded virus.

Prospects for Inundative Release of Natural Enemies for Biological Control of *Anoplophora glabripennis*

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Introduction

Anoplophora glabripennis is native to China and Korea, where it is a serious pest of deciduous broadleaf tree species **[1]**, particularly poplar and willow, as well as elm and maple. It is widespread in China, found in parts of at least 25 provinces. ALB is thought to have been accidentally introduced into the U.S. in solid wood packing materials originating from China, with breeding populations discovered in New York City and Long Island (1996), Chicago (1998) **[2, 3],** and Jersey City, NJ (2002). By September 1, 2002, 5,888 and 1,545 trees had been found infested, cut and removed in New York and Chicago, respectively **[4, 5]**. For the lumber, maple syrup, tourist and other forest-related industries, costs in survey, detection and management costs, and lost revenues could mount into the billions of dollars **[3]**. Furthermore, a recent report projects that if ALB spreads to urban trees across North America, there could be a loss of 35 percent of total canopy cover (1.2 billion trees) and a compensatory value loss of $669 billion **[6]**.

Objectives

Eradication of ALB currently relies primarily upon: (1) detection of infested trees that are then cut and chipped, and (2) injection of trees with systemic insecticides that target adult beetles should they feed on trees and/or larva feeding within infested trees. However, detection of infested trees relies solely on visual surveys, which are labor-intensive and costly, and only ca. 30-60 percent effective. Furthermore, use of systemic insecticides is labor-intensive and costly, and thought to be primarily effective against adult beetles. Therefore, the objectives of this research are to develop and utilize biological control agents: (1) that possess good dispersal and host searching capability; (2) that are highly effective parasitoids; (3) that can be efficiently reared and released in large numbers; and (4) for which an operationally feasible distribution system and protocol can be developed for effective delivery within the APHIS eradication program. The biological control approach of choice for eradication, which is the focus herein, is inundative release of parasitoids. Inundative biological control is the release of large numbers of mass-produced biological control agents to reduce pest populations without necessarily achieving establishment.

Sources of Natural Enemies

The potential sources of natural enemies of ALB under consideration are as follows:

	Natural Enemies of ALB	Congeners of Non-Indigenous Natural Enemy Species	Natural Enemies of Related Cerambycids
Exotic Natural Enemy Species	Asia Europe		Asia Europe
Native Natural Enemy Species	North America	North America	North America

Prioritized selection of natural enemies attacking other cerambycid species is based upon: (1) the phylogenetic, ecological and behavioral relatedness of their cerambycid hosts to ALB, including North American congener species **[7]**; and (2) the ALB life stage attacked, with emphasis on parasitoids that attack eggs and early larvae instars. Project components are composed of at least five primary objectives, each with a series of systematic lines of research: (1) parasitoid efficacy evaluation (i.e. mobility/dispersal; host searching; parasitism rate); (2) nontarget evaluation (i.e. identify; bioassay; permit acquisition); (3) development of mass rearing technology (i.e. substitute hosts; nutritional ecology; artificial diets); (4) development of release technology and protocols (i.e. prerelease conditioning; delivery systems & protocols); and (5) implementation (i.e. mass rearing; inundative release; monitoring efficacy, spread & establishment).

China

Parasitoids have been identified that are known to attack longhorned beetles that share a common host tree with ALB, as well as those known to attack ALB and/or other *Anoplophora* species. Among the first group are several egg parasitoids: encyrtids *Oophagus batocerae* and *Zaommoencyrtus brachytarsus*, parasitoids of *Batocera horsfieldi*, and *Austroencyrtus ceresii*, a parasitoid of *Ceresium sinicum*; and the eulophid *Aprostocetus prolixus*, a parasitoid of *Apriona germari*. Also among the first group are larval parasitoids, including: the tachinid *Bullaea* sp., the bethylid *Scleroderma guani*, a parasitoid of *Saperda populnea*, *Semanotus bifasciatus* and *Semanotus sinoauster*; the braconids, *Ontsira palliates*, a parasitoid of *Semanotus bifasciatus* and *Semanotus sinoauster*, and *Zombrus bicolor* and *Zombrus sjoestedti*, larval parasitoids of cerambycid spp.; and the ichneumonids *Xylophrurus coreensis*, *Schreineria* sp. and *Megarhyssa* sp., larval parasitoids of cerambycid spp. Among the second group is the egg parasitoid *Aprostocetus fukutai* (Eulophidae), which parasitizes both *Anoplophora chinensis* and *A. germari* **[8, 9]**. However, no egg parasitoids have as yet been reported from ALB or *A. nobilis* **[10, 11]**. Also among this second group are several larval parasitoids, including the braconids *Ontsira* sp. parasitizing *A. chinensis* larvae, and *Ontsira anoplophorae* Kusigemati and Hashimoto., parasitizing *Anoplophora malasiaca* on citrus in Japan; as well as the Colydiidae beetle *Dastarcus longulus*, a larval-pupal parasitoid of ALB, *A. nobilis*, *B. horsfieldi, A. germari, Monochamus alternatus*, and *Trirachys orientalis* **[12]**.

To date, investigations by Yang, Smith et. al. have found no egg parasitoids of ALB. Therefore, efforts have focused in large part on two of the species mentioned above, *S. guani* and *D. longulus*. Primary objectives have been to evaluate their relative efficacy to parasitize ALB, and to develop mass rearing technology.

***Scleroderma guani*:** Results from studies of *S. guani*, to date, have shown that this species is an idiobiont ectoparasitoid, and females first paralyze their host by stinging, and then lay eggs on the host body. Larvae are gregarious while developing on their host. After hosts are consumed, mature wasp larvae spin cocoons and pupate. An average of 45 adult *S. guani* emerged from a single mature host larva of *Saperda populnea*. In nature, *S. guani* was found parasitizing 41.9 - 92.3 percent of *S. populnea* larvae in poplar stands in many areas. Parental wasps remain with their young until they have completed their development and emerged as adult wasps. Should their eggs or larvae become separated from the host, parental wasps have been observed to return them to the host. Most female wasps are apterous, and *S. guani* usually parasitizes longhorned beetle species whose larvae are small, ca. 15 mm in length. Therefore, *S. guani* would likely be used to specifically target ALB 1st to 3rd instar larvae.

***Sclerodermus* spp. (Hymenoptera: Bethylidae):** Two species, *Sclerodermus guani* and *S. sichuanensis,* have been used in large scale release programs for biological control of woodboring Coleoptera in the Far East. Releases of *S. guani* were made against the cerambycids *Saperda populnea* (64.5 percent control) **[13]**, *Semanotus bifasciatus* in fir forests (62-64 percent parasitism, with a reduction of infested trees from 39 percent down to ca. 2 percent) **[14]**, and *Monochamus alternatus* in pine forests for indirect control of pine wood nematode (*Bursaphelenchus xylophilus*) **[15]**. In the latter case, parasitism ranged 26-47 percent, averaging 35 percent, and control of withering caused by the nematode was reduced 68-87 percent. In addition, *S. guani* was released against the anobiid beetle *Ptilinus fuscus,* in poplar, but the degree of efficacy was not clearly stated in the abstract **[16]**. Releases of *S. sechuanensis* were made against *M. alternatus* and *S. bifasciatus* with rates of parasitism ranging 36-100 percent **[17]**. Zhou et al. **[18]** conducted studies on the biology of *S. sechuanensis* and stated that it could reproduce on a number of hosts such as *Semanotus sinoauster*, Hymenoptera and lepidopteran larvae. It was not clear from the abstract whether attacks on Hymenoptera and Lepidoptera occurred in nature, or were limited to laboratory trials. Attacks on surrogate hosts in the laboratory do not necessarily indicate that such attacks would occur in nature **[19]**, but if such a broad host range were exhibited under field conditions, the introduction of *S. sechuanensis* could not be entertained. Mass rearing of *S. guani* has been reported **[20 and references cited therein]**, and studies are currently continuing.

***Dastarcus longulus*:** Results from studies of *D. longulus*, to date, have shown that it is an ectoparasitoid, with females laying eggs in frass and sawdust in the host gallery or on the host gallery wall. First instar larvae possess thoracic legs and crawl in search of a host. Upon finding an acceptable host, the larvae lose their thoracic legs and attach to the body of its host for feeding. It feeds singly or gregariously on its host, and as many as 30 individuals of this parasitoid are capable of successfully completing their development on a single ALB larva or pupa, which usually kills the ALB within 10 days. In many areas, parasitization rates of ALB by *D. longulus* reach between 50-70 percent, and in locations where *D. longulus* is established in relatively high numbers, ALB is apparently under natural control.

Additional investigations, which are in progress, have focused on development of mass rearing technologies for both of these species. Given their respective optimal preferences for different sized larvae, inundative releases of these two species, in tandem, appears to offer a possible complementary approach to the existing strategies in the ALB eradication program. However, prior to releases, nontarget studies are planned and will be conducted at BIIR. Preliminary results of the initial studies have been published **[21, 22, 23]**. In addition, two manuscripts on *D. longulus* have been written and will soon be submitted for journal publication, and additional manuscripts are in preparation. It should also be mentioned that investigations of a braconid species, not previously described, have been initiated. Studies conducted under natural field conditions (Smith and Bancroft, unpublished), have thus far suggested that it may be an egg or early larval parasitoid of ALB.

Europe

Herard et. al. recently initiated investigations of potential natural enemies of ALB in Europe, with an initial emphasis on studies of *Saperda populnea* (L.) and *Saperda carcharias* (L.). These two species were selected because they share common traits with ALB: (1) both are Lamiinae; (2) both attack trembling aspens, poplars, and willows, among the preferred hosts of ALB in China; and (3) both attack healthy trees. While no egg parasitoids have been found in France to date, the eulophid *Euderus caudatus* has been reported as an egg parasitoid of *S. populnea* and *S. carcharias*. Two early larval parasitoids have been found thus far: a tachinid (not yet identified) from France (southern and eastern) and Finland, and the eulophid *Euderus albitarsis* from southern Finland, where it was found parasitizing 1st instar *S. populnea* larvae. Two parasitoids whose adults emerged from full-grown larvae of *S. populnea* were found in 2001: the tachinid *Billaea irrorata* and the ichneumonid *Dolichomitus populneus*, previously mentioned from *S. populnea* and *S. carcharias*. Although *B. irrorata* emerges fairly late during its host development, its ability to attack very early larval instars will be elucidated. Rate of parasitism by each species in the various sites has not as yet been determined.

In addition, the following predatory Diptera larvae were found in *S. populnea* galleries by dissection of branches: *Odinia xanthocera* (Odiniidae), *Lasiambia baliola* (Chloropidae), and *Thaumatomyia elongatula* (Chloropidae). While no braconids have been found to date, four species are known parasitoids of *S. populnea* and one species is known to parasitize *S. carcharias*. Among tachinids, two other species are known (one from *S. populnea* and one from *S. carcharias*). Among Ichneumonids, 22 other species are known from *S. populnea*, and 11 other species are known from *S. carcharias*. Consequently, it appears that the biocomplex of enemies of these two cerambycids in Europe constitutes a great reservoir of species that can be tested against *Anoplophora* spp.

In concert with identifying and selecting candidate natural enemies for evaluation against ALB, development of laboratory rearing techniques for the cerambycid species, specifically on live plant material, was initiated. Studies that were planned for 2002 included:

(1) Continue exploration and develop of an inventory of early stage parasitoids of *S. populnea* and *S. carcharias* across Europe. During summer 2002, 80 sites with low to high levels of infestation by *S. populnea* and *S. carcharias* were visited across France, Germany, Denmark, Sweden, and Finland. In northern Europe, *S. populnea* has a 2-year cycle. The populations of adult hosts, including egg-laying females, and of the solitary early-stage parasitoid *Euderus albitarsis* (Hym.: Eulophidae) had been abundant during summer 2001 in most of the visited sites. In contrast, during summer 2002, the populations of host and parasitoid adults were extremely low in most sites simultaneously, suggesting that this natural enemy is available in the field during odd years mainly, in this part of its native area. However, in Finland we identified a very few sites where the development cycles of the host and its parasitoid appeared to be asynchronous compared with what was observed in most other sites (host oviposition and attack by *E. albitarsis* would occur during even years). During winter 2001-2002, it was determined that *E. albitarsis* hibernates as pupae in the gallery of its host, as first or a second instar larva of *S. populnea*. Concerning *S. carcharias*, in Finland, the last week of June and the first week of July, 2002 was a period of intense activity of the adults (feeding on leaves, and ovipositing). This was also

the time of emergence of the gregarious egg parasitoid *Euderus caudatus* (Hym.: Eulophidea). *E. caudatus* was obtained from 17 out of the 34 sites where its host was collected. During winter 2001-2002, it had been determined that *E. caudatus* hibernates as full-grown larvae in the host eggs.

(2) Finalize *S. populnea* and *S. carcharias* rearing techniques using rooted cuttings. Rooted cuttings of *Populus deltoides*, *P. tremula*, *P. alba*, and *Salix* sp. were successfully grown in a greenhouse (initiated fall 2001) using a soil mixture and watering regime. However, infestation of the rooted cuttings by *S. populnea* did not equally affect the various host plants. For example, it was revealed that *P. alba* is the best host plant in terms of survival following pest attack. In addition, no problem of unexpected secondary pest was observed on this host plant. Rooted logs of *Salix* sp., 4 to 10 cm in diameter and 50 cm in length, were successfully cultured for the purpose of rearing *Lamia textor* (European Cerambycid, Lamiinae, Lamiini) (initiated March 2002), and *S. carcharias* (initiated July 2002). Survival rate of the rooted logs was affected by the number of oviposition scars and developing larvae. For example, if long survival of the logs is desired, using logs of the above mentioned size, a maximum number of two oviposition scars per log should be allowed. If the logs are maintained to allow the cerambycid larvae to only reach a medium size, deposition of no more than five cerambycid eggs per log should be allowed. In some instances, survival rate of logs was also affected by the occurrence of a secondary pest, a Homoptera encrusted in crevices of bark, which developed from eggs that were not visible when the logs were collected in the field. Careful washing of the infested logs was insufficient to solve this problem. Thus, it is suggested that logs be cut and rooted at least 6 months prior to exposure to cerambycids. Following collection in the field, the logs should be sprayed with an insecticide (with low residual activity) and then isolated in sleeve cages to totally eliminate any risk of inadvertent infestation by secondary pests.

(3) Implement ALB rearing techniques in 5-10 cm diameter rooted cuttings. The same type of logs of *Salix* sp. were successfully used to rear ALB and CLB (*Anoplophora chinensis*).

(4) Test *Saperda* spp. parasitoids on ALB, in quarantine at Montpellier, France. *Euderus albitarsis (Hym: Eulophidae)*, and *Dolichomitus populneus (Hym:* Ichneumonidae), two larval parasitoids of *S. populnea*, were tested on ALB. *D. populneus* was also tested on CLB and on *L. textor*, a European cerambycid we are now rearing. We think that *L. textor* may eventually be used as a surrogate for the production of parasitoids in the laboratory. The egg parasitoid *Euderus caudatus* was tested using rooted cuttings of *Salix* sp. infested with eggs of its original host, *S. carcharias*, rooted cuttings infested with eggs of *L. textor,* and rooted cuttings infested with eggs of ALB. All infested rooted cuttings that had been exposed to parasitoids were placed in a sleeve cage made of organdy until dissection. Infestation of rooted cuttings and rate of parasitization of the hosts will be studied during winter 2002 by collecting data during dissection of the plant material. Dissections will not be completed before the end of 2002. Thus, results of the tests are not yet available.

(5) Survey ALB and *Anoplophora chinensis* populations in sites where these two species were accidentally introduced in Europe, for possible occurrence of parasitism by native species. The ALB population that occurred in Braunau (Austria) until January 2002 was submitted to a program of eradication by the Austrian local authorities. Before the operation of eradication was made, branches of infested maple trees were given to us by our Austrian colleagues for dissection. Unhatched eggs of ALB and one L3 larva were placed on diet. No parasitoids emerged from these pest stages.

The CLB population that established at Parabiago (near Milan, Italy) was visited in December 2001 and February 2002. Infested trees were cut and the stumps dissected. Larvae of various stages were sampled and placed on artificial diet until adult eclosion. None of these larvae were found to be parasitized. Three unhatched eggs of CLB were separated during dissection of the stumps. One was old, empty, and showed an exit hole of a parasitoid. The two other eggs were fresh and unhatched. One of these two eggs was dissected and revealed the presence of larvae of a gregarious parasitoid. The second egg was maintained intact. The parasitoid larvae found in the first egg were subjected to DNA analysis by Marie-Claude Bon, molecular biologist at EBCL, Montpellier, France. This analysis showed that the parasitoid has a high probability of being a Eulophid belonging to the genus *Aprostocetus*. A comparison of the data available from existing gene banks allowed us to determine that the probability of this *Aprostocetus* to belong to the European fauna was much greater than the probability that it belonged to the Asian fauna. The second unhatched CLB egg was kept until mid July 2002 when eight adult chalcids emerged. The specimens were submitted to Gérard Delvare, chalcid taxonomist at CIRAD, Montpellier, France, who identified them as a new species of *Aprostocetus* (sub-genus *Aprostocetus*). Additional DNA analyses and comparisons with fresh material of other European *Aprostocetus* were planned. DNA analyses of Asian material and comparisons with our European material is also foreseen. Additional collections of CLB infested material are planned during winter 2002-2003 in Italy to find more parasitized eggs, and to try to determine the original host of this *Aprostocetus* species. The anticipated product(s) from these studies are parasitoids of the western Palearctic region cerambycids that show promise as efficacious biological control agents against early stages of ALB and which can be used in the Nearctic region without significant nontarget effects on North American ecosystems.

North America

A number of natural enemies of the Cerambycidae have been reported worldwide, including predators belonging to the Cucujidae, Ostomidae, Cleridae, Colydiidae, and Elateridae beetles; Asilidae, Xylophagidae, and Rhagionidae flies; Phymatidae and Reduviidae bugs; and predaceous thrips and carpenter ants, as well as parasitoids belonging to the Braconidae, Ichneumonidae, Bethylidae, Encyrtidae, Eulophidae, Gasteruptiidae, Pteromalidae, Eupelmidae, and Eurytomidae; and Tachinidae and Sarcophagidae flies **[24].** Natural enemy species that appear to be consistently associated with Cerambycidae are *Avetianella longoi* (egg parasitoid), and tachinids in the genus *Billaea*, and the braconid *Iphiaulax imposter*.

This third line of research is being pursued because host specificity is an important consideration in obtaining regulatory permission to make releases of nonindigenous natural enemies. Host specificity can be either phylogenetically or ecologically driven. Phylogenetic host specificity is associated with host-parasite groups that clearly have had a long history of co-adaptation. Examples include weevils with ichneumonids in the genus *Bathyplectes*, and aphids with parasitoids in the subfamily Aphidiinae. Ecological host specificity, on the other hand, is prevalent among natural enemies that attack hosts that live in concealed places, such as gallmakers, leafminers, and woodborers. With these kinds of herbivores, host specificity might be determined by such secondary considerations as the host plant, or size or shape of the gall; thus, ecologically similar but taxonomically unrelated host species may have similar or nearly identical parasite complexes. Thus, it might prove difficult to find imported natural enemies that will not attack a wide range of nontarget organisms.

A. Natural Enemies of ALB: Smith and Fuester recently initiated investigations of potential natural enemies of ALB in North America. To date, they have found a dipteran parasitoid associated with ALB-infested Norway maple trees from New York (1998), which has not yet been identified. Progress in this area has been slow due in part to the lack of access to, and/or short supply of ALB-infested logs originating from the U.S. infestations. In addition to searching for natural enemies associated with ALB-infested trees in New York and Chicago, efforts to identify and evaluate parasitoids of selected North American cerambycids are in the planning stages.

B. Congeners of NonIndigenous Natural Enemies: North American congeners of nonindigenous natural enemies found attacking *A. glabripennis* or other *Anoplophora* species in Asia or Europe is another approach that offers several advantages. Among potential congeners of *Sclerodermus* under consideration are *Sclerodermus carolinensis,* whose hosts include *Dicerca lepida* (Buprestidae: Buprestini) and *Urographis fasciatus* (Cerambycidae: Lamiinae); and *Scleroderma macrogaster,* whose hosts include *Megacyllene antennatus* (Cerambycidae: Clytini), *Scolytus rugulosus* (Scolytidae: Scolytini), and *Xyletinus peltatus* (Anobiidae: Xyletininae). While no North American *Dastarcus* species are reported, 85 species of Colydiidae are reported, with some parasitizing cerambycids [**25**]. Other common hosts include scolytids and platypodids. Colydiids are reported as predators, feeding on small wood-borers, parasitoids, and feeders of decaying plant matter. Other possible congeners of nonindigenous natural enemies of *Anoplophora* are under consideration, including *Ontsira anoplophorae*, a braconid parasitoid of *A. malasiaca.*

***C. Potential Native Cerambycid Sources*:** Because host plant recognition is frequently an important component in the sequence of events (host location → host acceptability → host suitability) that determine host utilization, natural enemies of cerambycids that attack trees preferred by *A. glabripennis* might prove to be promising candidates for inundative releases against this pest. Prime candidates would include the sugar maple borer, *Glycobius speciosus* (Say); poplar borer, *Saperda calcarata* Say; poplar-butt borer, *Xylotrechus obliteratus* LeC.; and cottonwood borer, *Plectrodera scalator*. Other common cerambycids that could yield natural enemies include banded ash borer, *Neoclytus caprea*; hickory borer, *Goes pulcher*; and locust borer, *Megacyllene robiniae*.

Summary: Inundative Release of Natural Enemies and Eradication

Although most of the applied research on parasites and predators in biological control has been focused on the suppression of pest populations, Knipling [**26**] has proposed using the parasite augmentation technique to eradicate pests from prescribed areas, especially in concert with autocidal techniques. At present, mass rearing of the ALB is not possible and autocidal techniques therefore seem problematic, so inundative releases might have to be a stand-alone strategy or combined with other techniques. The parasite complexes of forest insects usually contain parasitoid species that are well adapted to low host densities and others that predominate when outbreaks of the host occur **[27]**. Therefore, it might be necessary to use two or more species in an eradication program, including high density specialists in the beginning to knock down populations, and other species with the highest host-finding ability at the end of the program. Compared to most insects, ALB is a relatively low fecundity species, so it might be possible to find natural enemies with sufficient biotic potential and searching capacity to use inundative releases of natural enemies to eliminate localized ALB infestations.

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Traps and Lures for Detection of *Tetropium* spp. and Other Longhorn Beetles (Coleoptera: Cerambycidae)

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Abstract

The brown spruce longhorn beetle, *Tetropium fuscum* (Fabr.), (Coleoptera: Cerambycidae), is a quarantine pest recently found established near the port of Halifax, Nova Scotia. In its native Europe the BSLB mainly attacks weakened Norway spruce, *Picea abies* (L.) Karst. In Nova Scotia it is infesting apparently healthy red spruce, *P. rubens* (Sarg.), white spruce, *P. glauca* (Moench) Voss., and black spruce, *P. mariana* (Mill.) B.S.P. spp. as well as Norway spruce. In 2001, we analyzed cortical volatiles collected *in situ* from *T. fuscum*-infested red spruce to determine the relative concentrations of monoterpenes emitted. This information was used to create a synthetic "spruce blend" which was field tested in trapping trials in Halifax, NS, in 2001 and in Halifax and Europe in 2002. Spruce blend-baited traps captured significantly more *T. fuscum* than unbaited traps in Halifax in 2001 and 2002, but not in Poland. The addition of an ethanol lure to spruce blend-baited traps significantly increased capture of *T. fuscum* in both Halifax and Poland. In the Poland trials, the combined spruce blend + ethanol lure was also significantly attractive to *Tetropium castaneum* (L.), more common than *T. fuscum* in Europe but not known to be established in Canada or the US. The combination of spruce blend and ethanol was also attractive to *Spondylis buprestoides* (L.), a European cerambycid that usually infest fresh pine stumps. Ethanol or alpha-pinene, either alone or combined, were not attractive to either *Tetropium* species, but the combination of ethanol and alpha-pinene was significantly attractive to *Asemum striatum* (L.), a common cerambycid in windfelled and dying conifers. Spruce blend alone was significantly attractive to *Monochamus urussovi* (Fischer), a cerambycid which feeds as an adult on the bark and sapwood of spruce and fir shoots in north-eastern Europe and in north Asia Colossus-dry traps caught the most *T. fuscum* but mean catch did not differ significantly among the trap types tested. Volatiles were sampled from girdled and ungirdled red and Norway spruce in 2002 to determine the monoterpene profile emitted from stressed versus unstressed spruce. Girdled spruce trees emitted greater amounts of beta-pinene than ungirdled trees. The attraction of a synthetic lure simulating the blend of cortical volatiles emitted from stressed spruce trees will be compared with that for unstressed spruce in *Tetropium* trapping trials in 2003. Our results indicate that the addition of an ethanol lure synergizes attraction of the spruce blend to both *T. fuscum* and *T. castaneum*. The combined lure is being used in cross-vane traps as part of the survey effort for *T. fuscum* in Halifax in 2003.

Gypsy Moth Mating Disruption Research Update

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Abstract

Mating disruption is the primary treatment component of the National Slow-The-Spread (STS) of the Gypsy Moth program, a federally-funded, multi-state effort to reduce the rate of spread of gypsy moth populations into previously-uninfested areas. In 2002, mating disruptants were applied to over 550,000 acres under STS. As part of a research effort to improve the efficacy and cost-effectiveness of mating disruption treatments, field experiments were conducted by USDA Forest Service, ARS, and APHIS in collaboration with Virginia Tech and industry partners. The primary focus of the experiments was to determine the effects of reduced application rates and modified application patterns on levels of mating disruption. A dose-response test was conducted using a commercially-available and EPA-registered formulation, Disrupt II flakes (Hercon Environmental, Emigsville, PA), applied at doses ranging from 0 to 15 g a.i./acre. Laboratory-reared male gypsy moths were released twice per week and recaptured in standard milk carton pheromone traps. Reduction in trap catch was used as a measure of the effectiveness of the treatment. Trap catch was reduced to very low levels at the 6 and 15 g a.i./acre application rates, with no noticeable difference between the two rates. Below 6 g/acre, trap catch increased with decreasing application rate. The results of this experiment support the operational use of a 6 g a.i./acre application rate.

Another experiment was conducted to determine if uniform coverage of treated areas is necessary, or if it is possible to leave skips in coverage and still disrupt mating. Two 25 ha plots were treated with Disrupt II flakes applied in 30 m swaths alternated with 30 m skips. Pheromone was applied at an overall rate of 15 g a.i./acre. Two additional plots were monitored but left untreated. Three rows of standard milk carton pheromone traps (30 m between traps) were placed through each of the plots. Very few moths were captured in traps placed inside of the treated swaths (0.3/trap). While nearly twice as many moths were captured in traps placed in the skipped areas between the treated swaths (0.6/trap), moth capture was still extremely low. Traps that were placed up to 300 m beyond the perimeter of the treated plots captured an average of close to 10 moths, but this number was much lower than the average number captured in traps in the untreated plots (107/trap). Based on these results, it appears that it may be possible to alternate treated and skipped swaths with no measurable reduction in effectiveness. While the same amount of formulation would be used in either case, some savings in time and fuel would occur as spraying would only occur over half of the plot. Additional tests will be needed to determine if a skipped swath pattern could be used effectively at lower application rates.

Sudden Oak Death: Surveys and Monitoring in Forest Environments

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Abstract

Accelerated mortality of tanoak (*Lithocarpus densiflorus*), coast live oak (*Quercus agrifolia*), and California black oak (*Quercus kelloggii*) has been noted in central coastal California since 1995. This phenomenon is commonly known as "sudden oak death" (SOD). A newly identified pathogen, *Phytophthora ramorum*, has been confirmed to be the causal agent of this mortality.

A multi-scale approach, utilizing remote sensing, aerial and ground surveys, has been used to monitor SOD in California since 2001 to determine the incidence, severity and impact of the disease. Polygons of suspected SOD mortality are mapped by observers in aircraft at 1,000 to 2,000 feet above ground level. Ten million acres were surveyed in 2001 to find 60 polygons covering 44,800 acres. In 2002, 20 million acres were surveyed to map 453 polygons covering 150,000 acres. High priority polygons of mortality were visited on the ground to confirm presence of *P. ramorum*. The disease was confirmed in 10 counties in 2001 and in 12 counties in 2002.

Special aerial detection surveys for SOD were flown in southern Oregon in 2001. The disease was confirmed in nine mortality centers on approximately 40 acres near Brookings, OR. A 9-square-mile area was quarantined by the OR Department of Agriculture. Disease centers were delineated on the ground and eradication treatments (cutting and burning) were implemented. Aerial surveys in 2002 identified a few additional centers within the quarantine area. Ground monitoring plots have been established to determine success of eradication efforts.

The Forest Health Monitoring program has initiated a National SOD Detection Pilot Survey in cooperation with state and federal agencies to determine if SOD is present in areas outside the known infested areas in CA and OR. A preliminary risk map has been developed incorporating current knowledge of affected and potential hosts, favorable climatic conditions and likely pathways of introduction into new areas. High-risk areas include portions of CA, OR, and WA in the West and PA, MD, WV, VA, NC, SC, GA, TN, AL, and MS in the East. Ground sampling of high-risk areas will commence during the spring of 2003. Additional information is available at: http://www.na.fs.fed.us/spfo/fhm/index.htm.

The Regulation of Eruptive Pest Abundance by a Specialist Predator is Associated with Transitions in Spatial Structuring

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Abstract

We examined spatiotemporal abundance data in a transient system involving an outbreak of house flies and a specialist predatory beetle. Prior to beetle colonization, fly populations were highly spatially structured, but as predators immigrated and colonized they became increasingly clustered at local spatial scales, causing spatial decorrelation in the dynamics of their prey. Larval flies appeared to regain local clustering as beetle abundance approached a carrying capacity with the prey population. During exponential population growth, predators were generally strongly negatively cross-correlated with their prey at local spatial scales. Negative spatial cross-correlation could serve as a diagnostic for transient behavior in natural enemy-victim systems. We were able to simulate these spatially-extended interactions in a predator-prey coupled map lattice model, and used this model to investigate the effects of prey and predator dispersal on spatial structure and cross-correlation. This work shows in a uniquely detailed fashion how the transition from eruptive pest abundance to regulation by a specialist predator is associated with a transition in spatial structure.

Biochemical Analyses of the *Bacillus thuringiensis* Cry Toxin Binding Receptor in the Western Spruce Budworm, *Choristoneura occidentalis*

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Abstract

Formulations of the natural HD-1 strain of Btk are the most widely used biopesticide products for the control of insect pests in agriculture and forestry. While these products are considered to be effective and environmentally safe, there is a recognized need for increasing their specificity, thus minimizing their effect on nontarget insects, and for increasing their potency against less susceptible insects, such as older larvae.

Numerous new Bt toxins have recently been generated from genetic and proteomic technologies, and novel methods are needed to filter and identify their potential as pesticidal agents. Screening assays have assumed critical importance in the characterization of novel Bt strains. Bioassay with target insects is the conventional method for scoring strategies. However, this procedure is time-consuming and may not be practical for identifying effective toxins against new invasive insect pests where breeding techniques have not yet been established. The first steps in developing an effective and reliable *in vitro* screening assay for Bt toxins involve identifying and characterizing the toxin-binding molecules in the target insects, and understanding their role in the mechanism of action. The final task will be to develop an expression system that produces suitable amounts of biologically active material for generating probes to analyze the insecticidal potential of new isolates, and for designing improved toxins. Elucidation of the molecular basis for the insecticidal specificity of Bt is a key for the successful development of new, improved Bt-based biopesticides.

In this study, a novel Bt toxin receptor was identified in the western spruce budworm midgut. This toxin-binding molecule, BTR-100, displays an apparent size of approximately 100 kDa, is sensitive to degradation with proteases and appears to be glycosylated. It stains blue with Stains-all, indicating that it may be an anionic calcium-binding protein. Evaluation of its toxin-binding properties by ligand-blotting assay revealed that BTR-100 binds a number of toxins that are known to be toxic to the budworm. Based on homology of its N-terminal amino acid sequence to a yolk-degrading protease previously characterized in *Bombyx mori*, BTR-100 was tentatively identified as an elastase-like serine protease. This finding is consistent with the observation that BTR-100 stains blue with Stains-all, as is characteristic of serine proteases, which are known to have Ca^{2+} binding sites that interact with the calcium mimic dye. Moreover, the identification of BTR-100 as a protease implies that after binding the Bt toxin receptor proteolytically triggers the formation of an oligomeric pre-pore toxin structure leading to the irreversible insertion of the toxin into the brush border membrane of midgut epithelial cells that causes lysis of the cells and death of the insect.

Geographic Spread of Viburnum Leaf Beetle (*Pyrrhalta viburni*), a Recently Introduced Landscape Pest in the Northeast

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Abstract

Pyrrhalta viburni (Paykull), commonly known as viburnum leaf beetle, is a chrysomelid leaf beetle native to Eurasia that became established in Canada (Ottawa, Ontario and Hull, Quebec) in the late 1970s. It was first detected in Maine in 1994, and in central New York in 1996. By summer of 2002, *P. viburni* had been recorded from 33 counties in New York, and its subsequent spread throughout a larger portion of the U.S. can be anticipated. Distribution records are given and mapped for this *Viburnum*-feeding specialist in New York, Pennsylvania, Ohio, and Vermont. In addition to feeding on several species of cultivated viburnums, the beetle also thrives on the native *Viburnum dentatum* var. *lucidum* (arrowwood), a widely occurring understory shrub in northeastern North America. The dispersal of *P. viburni* in New York has largely followed the distribution of its host plants, which leads us to predict that future spread will proceed most quickly through habitats contiguous with the current distribution of the pest and containing denser stands of *V. dentatum* var. *lucidum* or other native and cultivated viburnums that are suitable hosts for *P. viburni*. Ultimately, we expect *P. viburni* in North America to occupy the range of suitable host plants (primarily the *V. dentatum* complex, *V. trilobum*, and *V. rafinesquianum*), with possible limitation of southward spread imposed by lack of sufficiently cold winter temperatures since the insect apparently is an obligatory diapauser.

Tracking Movements of *Anoplophora glabripennis* Adults: Application of Harmonic Radar

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Abstract

This study estimated the movement capacity of *Anoplophora glabripennis* (Motschulsky) adults to help make the current USDA, APHIS survey program as efficient, cost-effective, and reliable as possible. Harmonic radar provides a way to study movements by tracking individual insects. The harmonic detection system consists of two parts: a hand-held radio transceiver and a small "tag" attached to a beetle that reflects the transceiver signal at harmonic frequencies. We report on the use of harmonic radar to estimate the movements of individual beetles and explore the challenges of applying the technique to a large flying insect. We conducted the experiment about 80 km southeast of Beijing, China. It was carried out using a single straight row of 200 willow trees planted along a highway. Seven to 12 tagged beetles were released daily along the row of willows from 30 June to 5 July 2002. Fifty-five beetles were released in all (27♀: 28♂). Search and recapture was carried out daily from 1 July to 15 July. Nearby willows outside the study area were checked for tagged insects on two dates, but none was found.

The 43 beetles that were recaptured moved an average of almost 14 m, ranging from 0 m to 92.3 m, at a rate of almost 3 m per day. With almost half of the beetles not moving at all, the median path length was just 4 m. Movement by the two sexes differed significantly: males averaged over 6 times the displacement distance of females and moved at twice their average rate. For the most part, females did not move from the tree on which they were released, and those that moved did not go far (maximum of 32 m). On the other hand, although some males were sedentary, most moved considerable distances and were spread about evenly among distance ranges up to 100 m.

Our overall recapture rate was 78 percent, but the radar tags often broke or were rendered undetectable after several days in the field. Only 14 of the 55 tags were whole and detectable by the end. Our results suggest that the tags typically remained detectable for 3-5 days. Harmonic radar shows promise as a method for tracking individual *A. glabripennis* adults and estimating their movement rates over short time periods. However, because of the fragility of the tags currently available, longer studies will only be possible with improvements in the tags.

Behavior of Adult Asian Longhorned Beetles as it Relates to Detection and Control Efforts

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Abstract

Anoplophora glabripennis was discovered in the New York City and Chicago areas in 1996 and 1998, respectively. This pest infests a wide variety of hosts in both its native range of China and in North America, including poplar (*Populus* spp.) and maple (*Acer* spp.). Research on its behavior in relation to host trees was conducted in the field and in the laboratory.

In 2001, two studies were performed in Gang Chen Zi Commune, near Qintongxia, Ningxia A.R., China, to determine if (1) host types, or (2) population density, affect flight propensity. Significantly more beetles were retained on *Populus nigra var. thevestina*, a preferred host of *A. glabripennis* in China than on *P. alba* (a nonpreferred host) or on an artificial, model tree. Population density did not appear to play a role in retention of beetles on *Populus nigra var. thevestina*. Percentages of beetles remaining on maples were significantly higher than on poplars or model trees after 23 hours. Between hour 0 and hour 3, significantly more beetles left poplars and model trees than maples. We ended the study because the sugar maples had been stripped by heavy beetle feeding.

We also conducted a study to observe the flight orientation of adult *A. glabripennis* to host trees. Potted specimens of *A. platanoides*, *A. saccharum*, *P. nigra var. thevestina*, *P. alba* and a model tree were placed in a 7.5 m radius circle. Beetles were released from a central location, and their behavior was observed. Of all beetles released (n=1017), over 94% flew out of the circle without showing any signs of orienting to one of the host trees.

Currently, detection relies on visual identification of beetles and/or the damage they cause. Detection efforts are inefficient and labor-intensive. The only control methods in place are the removal of infested trees and prophylactic insecticide use to protect trees in infested areas. An effective trapping system could improve the sensitivity and efficiency of *A. glabripennis* survey programs. Although a useful long-range attractant is not currently available, observations of beetles crawling on trunks and large branches of host trees suggest that passive traps, or perhaps traps that incorporate short-range attractants, could effectively capture fairly high percentages of beetles that are already present on a tree. Our objective was to design alternative methods to assist in the control and detection efforts for this pest.

In previous tests in China and the U.S., several contact insecticides produced substantial mortality of adult *A. glabripennis*. Our objective was to develop a supplemental control method for use in *A. glabripennis* eradication programs. Contact insecticides could be applied to limited areas (spots or bands) that are traversed by beetles, and efficacy could be enhanced if beetles were drawn to and retained at sites of application. A set of five treatments developed with IPM Technologies, Inc., containing a green leaf volatile mixture, a feeding stimulant (maple syrup), or both in combination with a contact insecticide (permethrin), was tested against trees with nothing applied to them or trees with only the insecticide. A second set of five treatments (the IPM Tech matrix used above with permethrin, cyfluthrin-treated burlap bands, permethrin-treated burlap bands, Fipronil-treated burlap bands, plastic laminate strips impregnated with permethrin) was also tested against a set of control trees.

Mortality of beetles in trees with cyfluthrin-treated burlap bands was significantly higher than mortality on control trees or trees with the permethrin-treated burlap bands, but not significantly different from the other treatments. Mortality of beetles was also significantly higher in trees treated with the matrix containing pesticide and feeding stimulant than in untreated trees, but mortality for the other four treatments did not differ significantly from any of the treatments. More total beetles were killed by the treatments containing green leaf volatiles and the feeding stimulant separately than either the control trees or the treatment containing just the matrix.

A set of five on-tree trap designs were tested in a black poplar windbreak in Qintongxia, Ningxia A.R., China. The treatments were A) Plastic sleeve trap, B) Screen sleeve trap, C) Jar trap, D) IPM Tech Intercept Panel Trap, E) Combination funnel-sleeve trap. Capture of dead beetles in all of the designs was low. There were significantly more live beetles caught by the screen sleeve trap design, than in any other trap design. This may have been due to the increased amount of air flow through the trap dispersing the insecticide.

The following abstracts were not submitted for this publication.

Climate Change Disruption of Forest Pest Dynamics
Jesse Logan

Emerald Ash Borer: Discovery, Impact, and Eradication Plans
Deborah McCullough

Sudden Oak Death: Research Update
Garland Mason

The Role of Density-dependent Mortality in Weed Patch Spread
David Mortensen

The Population Biology of Alien Species Eradication
Sandy Liebhold

Rapid Detection of Exotic Lymantriidae and Scolytids Pilot Study: 2002 Update
Mary Ellen Dix

The Evaluation Process for New Natural Enemies for Release Against Invasive Species
Robert Flanders

Case History: Augmentative Weed Biological Control Agents
Raghavan Charudattan

A New Look at an Old Problem: Experimentally Assessing the Effects of Gypsy Moth Defoliation on Tree Phytochemistry and the Performance of Leaf-feeding Lepidoptera
Dylan Parry

Genes Responsive to Gypsy Moth Feeding
Susan Lawrence

An Ecological Model for Predicting the Establishment of Invasive Species
James Andreasen

Auto Confusion Technology for Controlling Lepidopteran Pests
Philip Howse and Karen Underwood

Success of *Entomophaga maimaiga* in Michigan and Potential Implications for the North Central Region
Nathan Siegert and Deborah G. Mccullough

Pathogenicity and Virulence of *Entomophaga maimaiga*: Comparison of North American and Japanese Isolates
Steve Thomas, Joseph Elkinton and Ann Hajek

ALB Program Update
Mike Stephan and Christine Markham

Five Years of Cooperative Research in China with Insecticides for the Asian Longhorned Beetle
Baode Wang

Current Status of Research on Alb Semiochemicals
Stephen Teale

Heat Treatment for Pathogens in Solid Wood Packing Materials
Eric Allen

Posters

Development of Alternative Methods for Managing Adult Asian Longhorned Beetle, *Anoplophora glabripennis*
J.A. Francese, D.R. Lance, B. Wang, V.C. Mastro, A.J. Sawyer, D. Czokajlo, Z. Xu, S.A. Teale and Y. Luo

Rapid Detection of Exotic Woodborers in West Coast Port Areas
K.J.R. Johnson, A.D. Mudge, J.R. Labonte and K. Puls

Chalcoprax and Pine Shoot Beetle Lures: How Specific are They?
K.J.R. Johnson, J.R. Labonte and A.D. Mudge

New Formulations for *Ceratitis* Fruit Fly Trapping and Management
G. Booysen, J.R. Mclaughlin, C.V. Sack, D. Czokajlo, P. Kirsch and S. Venter

Effective New Lure Maximizes *Anastrepha* Fruit Fly Captures in North and South America
D.C. Robacker, D. Czokajlo, J. Mclaughlin, P. Kirsch, K. Bederski, S. Bederski, C. Almeyda and J. Quispe

Floral Volatile Attractants: Development of Novel Lures for Management of Moth and Beetle Pests
L. I. Abu Ayyash, J.R. Mclaughlin, G. Booysen, S. Venter and P. Kirsch

Semiochemical-based Management of the Larger Pine Shoot Beetle, *Tomicus piniperda*
S.A. Teale, D. Czokajlo, B. Hrasovec, M. Pernek, A. Kolk, J. Hilszczanski and P. Kirsch

Intercept Panel Trap Modified for Monitoring Forest Cerambycidae
D. Czokajlo, J.R. Mclaughlin, S.A. Teale, J.C. Warren, R. Hoffman, B. Hrasovec , M. Pernek, J. Hilszcanski, A. Kolk, K.F. Raffa, B.H. Aukema, A. Mudge, R. Westcott, F. Noguera, J. Labonte and P. Kirsch

Potential for Attract and Kill to Control Gypsy Moth
F.X. Webster, C. Sack, J McLaughlin and P. Kirsch.

Emerald Ash Borer in Ontario
T. Scarr and G. Howse

Potential Applications of Exosect Auto-Confusion
K. Underwood, P. Howse and D. Loughlin

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