CONTENTS

PLENARY PRESENTATIONS

ABSTRACTS AND PAPERS OF PRESENTATIONS AND POSTERS

SPATIAL ANALYSIS OF THE CHICAGO

ASIAN LONGHORNED BEETLE INFESTATION

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ABSTRACT

The Asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky) (ALB), was first reported from Chicago, IL on July 9, 1998. Several adult beetles were discovered in a truck that had hauled firewood from the Ravenswood neighborhood of Chicago. Infested trees, including some that had apparently been dead for several years, were found near a warehouse of a company that had imported plumbing supplies, packed in wooden crates, from China. A visual survey revealed additional infested trees, and a quarantine was imposed on a 12-block area on July 17. By September, 130 infested trees had been removed and the quarantine had been expanded to 12.3 mi^2. In the spring of 1999, the ground-based survey was supplemented using bucket trucks and tree climbers, revealing many more infested trees. By the end of 1999, the quarantined area was 14 mi^2, and 1165 trees, predominately maples and elms, had been removed.

Infested trees have been found at 5 additional locales around Chicago: Addison, 20 mi. W of Ravenswood (54 trees); Summit, 15 mi. SW of Ravenswood (24 trees); the Kilbourn Park area of Chicago (3 trees); Loyal University in Chicago (1 tree); and a forest preserve near O'Hare airport, 10 mi. W of Ravenswood (4 trees).

The initial discovery and all outlying infestations were found, not as a result of survey activities, but by citizens who had noticed adult beetles. Because of limited resources, survey activities have generally been restricted to areas within one block (1/8 mi.) of known infestations. This limited detection program does not appear to have contained the infestation, which appears to have spread at least 2.5 mi. from the point of origin by natural dispersal of the insect. It is not known how long this has taken, but in some cases recently infested trees have been found nearly a mile from the nearest known earlier infestations. In addition, known human-assisted displacement has carried the beetle up to 10 mi. away. It is suspected that the Addison infestation, if not the one in Summit, had an origin independent of the one in Chicago.

Based in part on the Chicago data, several types of survey have been developed for the ALB. An *intensive core-area survey* would examine every host tree, by bucket truck or tree climber, within 0.5 mi. of any tree known to be infested. A *delimiting survey* from the ground would visually inspect all public trees and 4 private properties per city block, once every other year, in the area

extending 1.0 mi. beyond the boundary of the intensive core-area survey. A *targeted survey* would identify sources of, and then "trace-forward," host material that had been removed from quarantined areas. An *area-wide survey* would sample 2 host trees at each of 9 well-separated sites per mi^2 in an area extending 25 mi. from the center-of-origin of an existing infestation.

ASSESSING LOSS POTENTIAL IN FORESTS FROM EXOTIC SPECIES INTRODUCED IN SOLID WOOD PACKING

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ABSTRACT

Exotic species have many deleterious effects, one of them is that they often competitively displace or directly destroy native species. Indeed, exotic species are second only to habitat destruction in causing the disappearance of native species. Some 360 exotic insect species are established in forests in the United States. The effect of newly introduced pest species is a function of the characteristics of the pest organism, the characteristics of the host(s), the nature of the pest-host interaction, and the interactions of the pest-host complex with the biological and physical environment. The potential loss from exotic forest pests introduced in solid wood packing was assessed during our study using formal risk assessment procedures. We used an epidemiological approach for this risk assessment. We used specific case histories to exemplify the kind of impact expected from exotic invasive forest pests (note that they are not meant to represent the totality of damage expected from all exotic species, nor do they represent the only examples). In our approach, each pest was described in terms of its damage potential, time to build up a damaging population within a discrete area, rate of spread, hosts attacked and host susceptibility conditions, expected geographic range, and other details relevant to damage forecast. The distribution and density of hosts susceptible to each of the nine pest cases was obtained for each county in the continental United States plus Hawaii. Host growth minus natural mortality and harvest was assumed constant. Likely points of introduction and initial establishment were determined and used as the initial infestation foci. From these initial foci, each pest was analyzed separately in terms of its yearly spread. Hosts increasingly came under attack as the pest expanded its range. The buildup period required to reach damaging levels was simulated with a logistic function (a parameterized Weibull). The loss for the pest being considered was estimated yearly for a thirty year forecast. Losses were expressed in terms of timber volume and value. Data for our studies and model parameters were obtained from the literature and from heuristics from an expert panel. The pests chosen and the analysis conducted are not meant to be additive nor inclusive of all damage types under all possible circumstances. The cases are meant to illustrate some of the expected effects of the introduction of new insect pests into American forests through the solid wood packing pathway. In summary, data to establish the impact of a pest species and which make up the supporting information for damage estimates included: a) United States distribution of the resource at risk; b) density of the resource at risk; c) expanding "fronts" of the infestation over time (single vs. multiple entries, slow vs. fast moving bugs); d) pest-induced mortality and damage; and e) average expected forest growth. Damage estimates were obtained yearly by multiplying 'green' timber values by estimated yearly damage.

STUDIES ON MODE OF ACTION OF STILBENE OPTICAL BRIGHTENERS OR "I GET A KICK OUT OF YOU"

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ABSTRACT

Although the gypsy moth nuclear polyhedrosis virus (LdMNPV) has been used successfully to reduce gypsy moth populations, the virus acts slowly and larvae may continue to feed for some time after exposure. Greater larval mortality and faster kill might be achieved by the addition of chemicals to the virus preparation or by the use of more active virus isolates. Several years ago we discovered that optical brighteners (= fluorescent brighteners) could not only serve as radiation protectants but could act as virus enhancers. Initial tests demonstrated that LC_{50}s could be reduced by as much as 2000-fold in laboratory tests, and that LT_{50}s by the addition of selected stilbene brighteners. Subsequent research indicated that selected brighteners also could act as enhancers in other insect-virus systems. Recent research has centered on the mode of action of these chemicals. Stilbenes, such as DIDS and SITS have long been used in mammalian systems because of their biological activities. It has been demonstrated that they can act as anion transport inhibitors, cation transport inhibitors, and carbonic anhydrase inhibitors. Because of these biological activities, studies were initiated to determine whether other inhibitors of anion and cation transport, as well as carbonic anhydrase inhibition could act as enhancers for LdMNPV. Whereas organic calcium channel blockers reduced virus activity, several inorganic calcium channel blockers (cobalt, manganese, ruthenium, zinc) acted as enhancers. All potassium channel blockers reduced virus activity, whereas carbonic anhydrase inhibitors acted as enhancers. At present, different combinations of enhancing chemicals are being tested to determine if additive or synergistic effects could be obtained. These tests are necessary and instructive but they are not direct measures of brightener activity.

BIOECONOMICS OF MANAGING THE EXPANSION OF EXOTIC PEST SPECIES WITH BARRIER ZONES

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INTRODUCTION

In this paper I address two questions: what are economic benefits from slowing the spread of a pest species, and when to give up with eradication project and replace it by slowing the spread.

Three strategies can be used to manage exotic pest species: (1) *total-area management* is applied uniformly through the whole area of the species (e.g., eradication or biological control); (2) *scattered management* is applied to local areas where pest density is high (e.g., IPM); and (3) *barrier zone management* is applied mostly along population boundaries. Barrier zones can be used not just for stopping the spread of a pest species, but also for slowing the spread, or eradication.

Barrier zones were used against several insect species. In 1923 a barrier zone was established along the Hudson River to prevent the spread of the gypsy moth to the west (McFadden and McManus 1991). This zone was managed until 1941 when it finally became infested. It did not stop the advance of population front, but the rates of spread were reduced (Liebhold et al. 1992). Currently the USDA Forest Service is conducting the Slow-the-Spread (STS) project, which goal is to slow the spread of the gypsy moth to the west and south by early detection and eradication of small isolated colonies ahead of the moving population front (Leonard and Sharov 1995). In the Appalachian Mountains, where sufficient historical data was available, the rate of spread has been reduced from 21 km/yr to 9 km/yr (Sharov and Liebhold 1998b).

After the screwworm was successfully eradicated from the US in 1966, a barrier zone was set along the border of Mexico to prevent the reinvasion of this cattle parasite (Knipling 1978). Screwworm populations were managed using sterile insect release. Later, the eradication program was expanded to Mexico and Central American countries with a goal to move the barrier zone towards Panama.

Before africanized honey bees entered the US, there was an attempt to stop their spread in Mexico (Flakus 1993). In 1985 a Bee Regulated Zone was established by the USDA in the Tehuantepec region. However, this zone was soon invaded and the goals of the project were transformed into slowing the spread. It is believed that the project has postponed the invasion of africanized honey bees by 2 years.

The boll weevil was successfully eradicated in Virginia, both Carolinas, Georgia, Florida, Alabama, California, and Arizona (Smith 1998). However, further progression of eradication was more difficult than expected because of increase in insect resistance, decrease in the abundance of natural enemies, and other environmental and economic problems. Whether complete eradication of the boll weevil in the US is possible or not, it is important to keep the pest from spreading back into areas where it has been eradicated. Thus, barrier zones are maintained along the borders of the area where eradication was successful.

MODEL OF ECONOMIC BENEFITS FROM USING BARRIER ZONES

Let us consider economic benefits from managing the spread of invading species. The most simple case is a pest species spreading along the infinite habitat strip of uniform width. Without a barrier zone, the species spreads at its maximum rate of v_{max}. In a space-time diagram, damage occurs in the area below the line $x = tv_{max}$ (Fig. 1). If the rate of spread is reduced from v_{max} to v, then damage occurs in the area below the line $x = vt$. Thus, benefits from slowing the spread occur in the shaded area between lines $x = tv_{max}$ and $x = vt$ (Fig. 1). Benefits are discounted with time (i.e., immediate benefits are more valuable than postponed benefits). The present value of benefits from slowing the spread is equal to

$$B = \int_0^\infty tD(v - v_{max})e^{-\alpha t}dt = \frac{D(v - v_{max})}{\alpha^2} \qquad (1)$$

where D is damage per unit area per year, and α is the inflation rate per year.

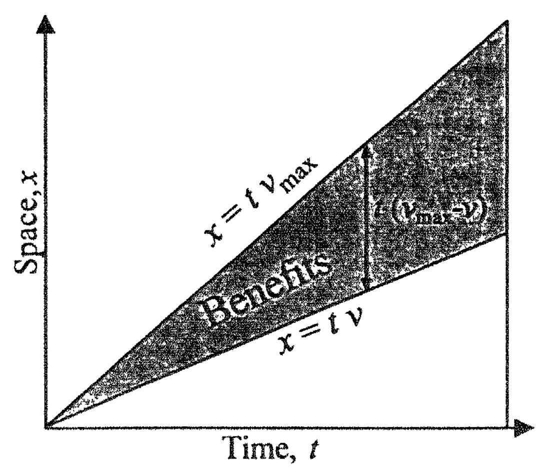

Figure 1. Space-time diagram of benefits from slowing the spread of a pest species.

The cost, $C(v)$, of slowing the spread per unit length of the barrier zone is a function of target rate of population spread, v (Fig. 2A). $C(v_{max}) = 0$, because no management is needed if the population spreads with its natural rate, v_{max}. The smaller is the target rate of spread, v, the higher is the cost of the program; $C(0)$ is the cost of stopping the spread.

The present value of net benefits, NB, is equal to benefits B minus inflation-corrected costs.

$$NB = B - \int_0^\infty C(v)\, e^{-\alpha t} dt = \frac{D(v - v_{max})}{\alpha^2} - \frac{C(v)}{\alpha} \qquad (2)$$

The program is optimal if it generates maximal net benefits, NB. The optimal target rate of population spread can be found by solving the equation $dNB/dv = 0$. The solution is

$$\frac{dC}{dv} = -\frac{D}{\alpha} \qquad (3)$$

The slope of the cost function should be equal to damages, D, divided by inflation rate, α. In Figure 2B, the line with a slope of $-D/\alpha$ touches the cost function at the point that corresponds to the optimal target rate of spread, v_1.

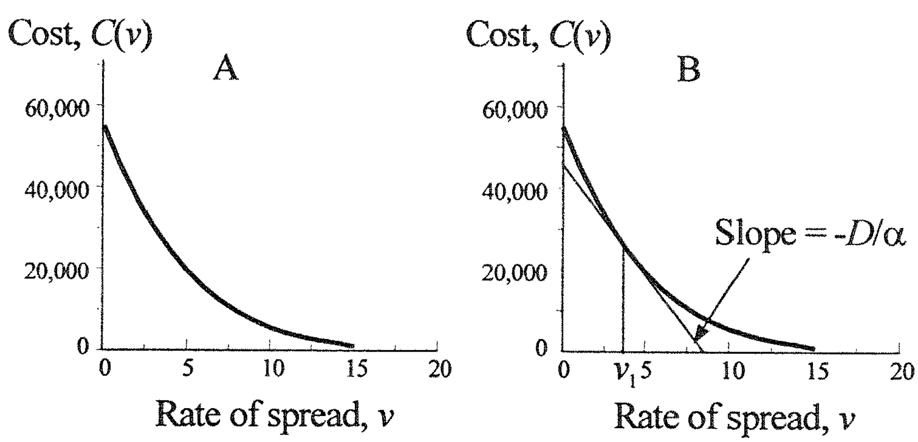

Figure 2. Cost, $C(v)$, of slowing the spread per unit length of the barrier zone as a function of target rate of population spread, v (A); determining the optimal target rate of spread, v_1 (B).

If damage, D, is high, then the slope, D/α, is steep; hence, the target rate of spread is low. If damage is low, then the slope, D/α, is gentle; hence, the target rate of spread is large, and little management is needed. In two cases equation (3) has no solution for positive rates of spread: if the damage is too low (Fig. 3A), or if the damage is too high (Fig. 3B). In the former case, the optimal strategy is to do nothing. In the latter case, a solution may exist for some negative rate of spread. A negative rate of spread means that the population front retreats due to barrier-zone management. Eventually it leads to eradication of the species. If damage is so high that there is no solution of equation (3) even for negative rates of spread, then eradication should be done in one step rather than with a barrier zone.

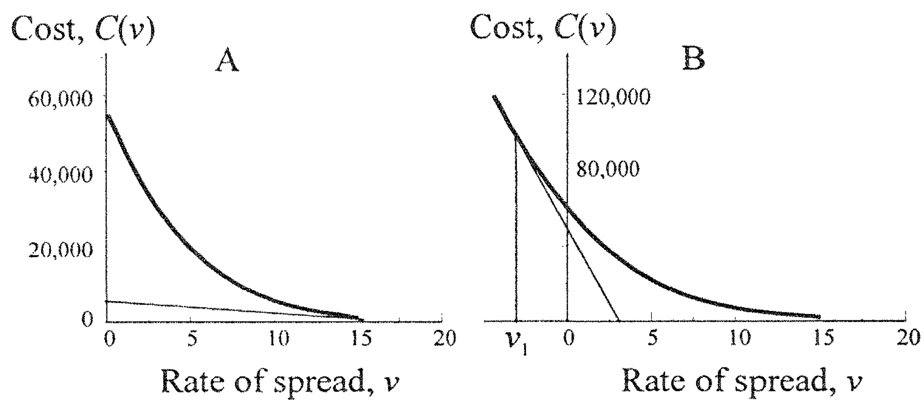

Figure 3. Two cases where equation (3) has no solution for positive rate of spread: (A) damage is too low and doing nothing is the best strategy; (B) damage is too high and eradication (negative rate of spread, v_1) is the best strategy.

The model described above is oversimplified because it assumes that a population spreads along an infinite habitat strip. Sharov and Liebhold (1998a) developed 2 more realistic models: (1) population spread in a rectangular area from one side to the opposite side, and (2) population spread in all directions from the center. In both cases, the optimal target rate of population spread is a function of time rather than a constant. Thus, a more sophisticated optimization method is needed. Sharov and Liebhold (1998a) used the Euler's equation of variational calculus for solving the problem. In short, net benefits (2) are maximized by changing the control function $v(t)$, which is the rate of spread at time t.

A typical solution of Euler's equation is shown in Figure 4. The horizontal axis is the location of the population front relative to the introduction point; the total length of the potential area is 1000 km. The vertical axis is the target rate of spread. The upper branch of the graph corresponds to slowing the spread because the rates of spread are positive, and the lower branch corresponds to eradication because rates of spread are negative. As the population front approaches the end of the potential area, slowing the spread is no longer needed. The optimal target rate of spread becomes equal 20 km/yr, which is the rate of unmanaged spread in this example.

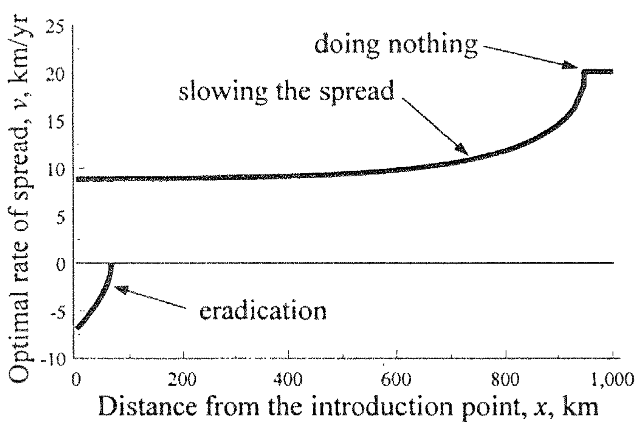

Figure 4. Optimal management of a barrier zone for a population that spreads in a rectangular area of 1000 km width from one side to the opposite side. Management strategy depends on the location, x, of the population front from the introduction point.

If the population has occupied most of its potential area, then the only solution is slowing the spread or doing nothing (upper branch in Fig. 4). But if the pest has just arrived and has not spread far enough, then both slowing the spread and eradication are possible solutions. These two strategies correspond to 2 local maxima of net benefits. Euler's equation does not tell us which of these solutions is the best. Thus we need to compare net benefits for each strategy.

Figure 5 shows net benefits from slowing the spread and eradication as a function of distance from the introduction point, x. Net benefits from eradication decrease rapidly with increasing distance; this means that eradication is most profitable when the population front has not spread far enough from the introduction point. Net benefits from slowing the spread change very little with increasing distance from the introduction point. The intersection of two lines in Figure 5 indicates the maximum size of an infestation that can be eradicated. If the population is larger, then slowing its further progression generates greater net benefits than eradication. Stopping the spread is never an optimal strategy (unless there are natural barriers) because it generates lower net benefits than either eradication or slowing the spread.

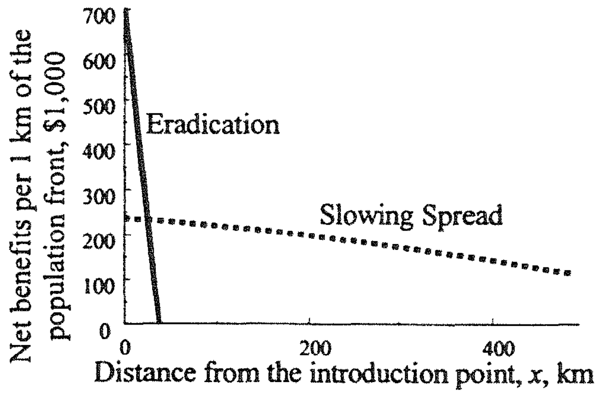

Figure 5. Net benefits from slowing the spread and eradication as a function of distance from the introduction point, x.

Sharov and Liebhold (1998a) applied this model to the spread of the gypsy moth in North America. The minimum distance from the end of potential range, at which it is beneficial to slow the spread, is 49-53 km. The optimum target rate of spread is 3-4 km/yr (except if the population front comes close to the end of potential area). The maximum radius of a population that can be eradicated is 195 km for the annual inflation rate of 4%, and 45 km for the inflation rate of 10%.

DISCUSSION

Any bioeconomic analysis is based on the assessment of costs and benefits. But when a new exotic species arrives, there is a lack of understanding of potential damage and possible management costs. If the pest species is potentially dangerous, eradication is the first logical option even if economic assessment is not available. As information about the species accumulates, a reasonable evaluation of costs and benefits of the project is needed.

Eradication costs are not limited to manufacturing and application of pesticides. They also include pest monitoring, public relations, potential lawsuits, risk to human health, and other indirect costs (Dahlsten and Garcia 1989). Cost/benefit estimations are never absolutely certain. We take best knowledge and evaluate potential strategies. As we learn more about the species, the model and the strategy are updated.

If eradication project has smaller net benefits than slowing the spread, then it should be transformed into a containment project. Termination of eradication projects is often politically charged; thus, the benefits of some projects may have been overestimated and costs underestimated in order to keep these projects going. But it is wrong to view the termination of an eradication project as a total failure. Even if eradication was not achieved, the project might have postponed the spread of the pest species by several years. Postponing or slowing the spread of a pest species generates economic benefits, as shown by the model. Transition from an eradication objective to containment is an adjustment in the pest control strategy that makes it more effective in a given situation.

ACKNOWLEDGMENTS

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EVALUATING THE SUCCESS OF SUPPRESSION OF ISOLATED GYPSY MOTH COLONIES USING PHEROMONE TRAPS

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ABSTRACT

The goal of the Slow-the-Spread (STS) project, initiated by the USDA Forest Service in 1993, is to slow the progression of gypsy moth populations in the U.S. by early detection and suppression of isolated colonies beyond the population front. Suppression of isolated colonies often results in eradication because mating success is limited in low-density populations. Our objective was to evaluate the effect of treatments in low-density isolated colonies. The traditional method of treatment evaluation based on egg mass sampling can not be used in low-density populations because egg masses are too scarce. Thus, we had to use moth counts in pheromone traps to evaluate treatment success. The success of an individual treatment was evaluated by a reduction in moth counts in the area treated adjusted to the natural change in moth counts in the control area around it. Moth counts were interpolated in each 500-m cell using kriging. Then these estimates were averaged in all cells within the area treated and in the neighboring 24 x 24 km area (control). The buffer area around treatment blocks (2 km wide) was not considered in the analysis. We propose to use the coefficient of treatment success

$$T = \frac{N_t \, n_{t-1}}{N_{t-1} \, n_t}$$

where N_t is the average moth counts in area treated in year t, n_t is the average moth counts in the control area in year t, and t is the year of treatment. Mating disruption treatments (Disrupt II, 30 g AI per ac) are evaluated in the following year after treatment. Thus, for evaluating mating disruption, N_t and n_t in this equation should be substituted with N_{t+1} and n_{t+1}, respectively. A treatment is considered successful if $T < 1/3$, partially successful if $1/3 < T < 2/3$, and unsuccessful if $T > 2/3$. Results of treatment evaluation are available at URL: www.ento.vt.edu/~sharov/stsdec. Out of 110 blocks in Virginia, West Virginia, and North Carolina treated in 1993-1998 with Bt or mating disruption, 89 were successful, 15 were partially successful, and 6 were not successful. The difference between the proportion of successful Bt treatments (77%, N=66) and successful mating disruption treatments (86%, N=44) is not statistically significant. This analysis shows that mating disruption is at least as effective as Bt treatments against low-density isolated colonies of the gypsy moth.

A PRELIMINARY DESCRIPTION OF ANTENNAL SENSORY RECEPTORS OF *ANOPLOPHORA GLABRIPENNIS*

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ABSTRACT

Anoplophora glabripennis, an exotic Asian longhorned beetle (ALB), was first detected in the United States infesting living trees in Brooklyn, NY, in 1996. Since that time, other infestations have been discovered in New York City and Long Island, and Chicago, IL. This wood-boring beetle, previously unknown in North America, could become a significant forest pest throughout the United States. There is little information on attractants for longhorned beetles or on the location of sensory receptors and how they might function. Here, we report our preliminary findings on potential sensory receptors on the antennae of ALB.

Freshly cut ALB-infested logs were transported from Chicago, IL and Queens, NY to the USDA Forest Service Quarantine Laboratory, Ansonia, CT, where adults emerged. Living male and female beetles were fixed in a 1:3 mixture of dimethoxypropane and absolute ethanol. Antennae were processed for scanning electron microscopy (SEM). The antenna of both sexes consists of a basal scape, pedicel, and flagellum. The latter is divided into 9 similar annuli joined to each other by membranes so that the flagellum as a whole is flexible. Preliminary observations with SEM revealed a variety of bristles and hairs on the scape, pedicel, and flagellum. On the basis of their location and surface structure, the long hairs near the junction of annuli likely function as trichoid sensilla, responding to annular movement. That the setae covering most of the surface of the flagellum might function as sensory receptors seems unlikely because they closely resemble the setae on the elytra and other parts of the body. Smaller spines are dispersed among the longer setae on all of the annuli. Whether these function as sensilla will be determined by histological and ultrastructural analysis of the underlying cells. However, most of these spines are covered by the larger, longer setae, so it is unlikely that they have an olfactory function. A number of cuticular structures that bear the surface characteristics of chemosensory sensilla (basiconic, styloconic and coeloconic pegs, and sensory pores or pits) are located at the apex of the most distal annulus of the antennae of both male and female ALB. Many of these structures closely resemble insect chemoreceptors that are known to have an olfactory function. However, few of these structures have been located and they are in an area of the antenna that apparently is used for surface contact. This leads us to speculate that these cuticular structures might function as contact or short-range chemoreceptors. Ultrastructural work is underway to determine whether antennal structures function as sensilla.

DEVELOPMENT OF IMPROVED STRAINS OF THE *LYMANTRIA DISPAR* NUCLEAR POLYHEDROSIS VIRUS

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ABSTRACT

To facilitate commercial production of the *Lymantria dispar* nuclear polyhedrosis virus (LdNPV) we have developed improved viral strains through genetic and genetic engineering approaches. As described below, LdNPV strains that produce wild type (WT) numbers of polyhedra with WT potency in cell culture, and with increased potency and killing speed have been developed.

During replication in cell culture the LdNPV exhibits a high rate of mutation in the 25K few polyhedra (FP) gene (Bischoff and Slavicek, 1996, *J. Gen. Virol.*, 77: 1913; Bischoff and Slavicek, 1997, *J. Virol.*, 71: 1097). Once 25K FP mutants form they become the predominate virus type after just a few serial passages (Slavicek *et.al.*, 1995, *Biol. Con.*, 5: 251). FP mutants have the traits of production of very few polyhedra, synthesis of polyhedra that contain few or no viral nucleocapsids, and production of approximately 10 fold more budded virus particles compared to WT virus (Slavicek *et.al.*, 1992, *J. Inverte. Path.*, 59: 142). In order to enable polyhedra production in cell culture bioreactors LdNPV strains needed to be developed that either have a lower frequency of FP mutant formation and/or that could outcompete FP mutants. To solve the FP mutant problem we have developed two improved viral strains through genetic selection techniques. Isolate A21-MPV exhibits a lower frequency of FP mutant formation compared to WT virus (Slavicek *et. al.*, 1996, *J. Inverte. Path.*, 67: 153), and isolate 122b is able to outcompete FP mutants during production in cell culture bioreactors. Both of these viral strains have been successfully produced in cell culture bioreactors. Patents have been obtained on LdNPV isolates A21-MPV and 122b from the U.S. Patent and Trademark Office.

Polyhedra produced in the Ld652Y cell line are approximately 20-40 fold less potent compared to polyhedra generated by the same viral line in gypsy moth larvae. Examination of viral occlusion revealed that polyhedra produced in the Ld652Y cell line contained approximately half the number of viral occlusions compared to polyhedra produced in larvae. However, a few polyhedra generated in the 652Y cell line contained a large number of viral nucleocapsids. This finding suggested that a viral variant existed within the viral population that was able to occlude WT levels of viral nucleocapsids. We developed a selection protocol to isolate viral variants (selected strains) that occlude WT levels of viral nucleocapsids. Through the selection method we have isolated selected strains that occlude high numbers of viral nucleocapsids in polyhedra

produced in the Ld652Y cell line. Polyhedra produced in the Ld652Y cell line by these viral strains exhibited the same potency as Gypchek polyhedra produced in gypsy moth larvae. In addition, polyhedra produced in gypsy moth larvae by the selected viral strains exhibited potencies approximately 3 fold higher than polyhedra produced by Gypchek in larvae. A patent has been obtained on the selection procedure developed to isolate selected strains from the U.S. Patent and Trademark Office.

The LdNPV requires approximately 10-14 days to kill its host. The insertion of foreign genes and deletion of viral genes from the viral genome have been successful in increasing the killing speed of the *Autographa californica* NPV. The deletion of the ecdysteroid UDP-glucosyl transferase gene from the AcNPV genome generated a virus that killed its host in approximately 25% less time compared to WT virus. The function of the viral EGT is to inactivate ecdysteroids through sugar conjugation. The inactivation of ecdysteroids results in an extension of the larval instar period, which results in the production of increased viral progeny. After identifying an EGT gene in the LdNPV we generated a virus lacking this gene in an effort to increase viral killing speed (Riegel et al., 1994, *J. Gen. Virol.*, 75: 829). The EGT minus LdNPV strain killed infected 5th instar larvae in about 35% less time compared to WT virus (Slavicek et al., 1999, *Biol. Cont.* 16: 91). In addition, larvae infected with EGT minus virus gained less weight compared to larvae infected with WT virus.

During analysis of the 25K FP gene we identified a gene in the LdNPV with homology to the enhancin genes present in granuloviruses. The enhancin proteins are able to degrade mucin and may have the function of degrading the peritrophic membrane within the larval midgut to facilitate viral passage through the membrane. We characterized the LdNPV enhancin gene homolog (E1) and found that it is required for full viral potency (Bischoff and Slavicek, 1997, *J. Virol.*, 71: 8133). Deletion of the E1 gene generated a virus with about half the potency of WT virus. We discovered a second enhancin gene in LdNPV after sequencing the viral genome (Kuzio et al., 1999, *Virol.* 253: 17), and found that it also is needed for full viral potency. Deletion of both enhancin genes from the LdNPV genome generated a virus that was over 1000 fold less potency than WT virus. This result indicates that the enhancin genes are necessary for viral potency. We are currently continuing the characterization of enhancin function and will try to manipulate the enhancin genes to increase viral potency.

MOLECULAR CHARACTERIZATION OF A SECOND ENHANCIN GENE HOMOLOG IN THE *LYMANTRIA DISPAR* NUCLEAR POLYHEDROSIS VIRUS

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ABSTRACT

Enhancins are a group of metalloproteases first found in the granuloviruses (GVs) that have the ability to enhance the potency of nuclear polyhedrosis viruses (NPVs). We have previously identified an enhancin gene (E1) in the *Lymantria dispar* NPV (Bischoff and Slavicek, 1997, *J. Virol.*, 71:8133). Recently a second enhancin gene homolog (E2) was identified during the sequencing of the LdNPV genome (Kuzio et al., 1999, Virol., 253:17). E2, located between 155.8 and 158.2 kbp on the viral genome, exhibits a 30% amino acid identity to the LdNPV enhancin 1 protein, and contains the characteristic metalloprotease HEXXH zinc binding domain. Northern analysis of viral RNAs indicate that the E2 gene is expressed at late times postinfection. When the E2 gene was expressed in a rabbit reticulocyte coupled transcription/translation system, a protein of the predicted 89 kDa was visualized. A recombinant virus containing a 2.0 kbp deletion in the E2 gene was constructed and confirmed by southern analysis. When tested in bioassay to determine the effect of the E2 protein on viral potency, a very slight drop in potency was consistently noted in infections of 2nd instar *L. dispar* larvae in comparison with wild type viruses.

PATTERNS OF TREE INJURY AND RESPONSE TO ICE STORM 1998

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ABSTRACT

Weather-related stem and branch breakage commonly occurs to trees during winter storms. An unusually severe and widespread storm in January 7-8, 1998 affected 17 million acres of forestland in northern New England and New York. Adjacent portions of eastern Canada were also greatly affected. Forest managers and the wood processing industry are concerned about damage to the northern hardwood resource resulting from tree mortality, decreased growth, and loss of wood quality due to ice storm injury.

To determine the relationship of storm injury to damage, a five-year study is underway to determine the relationships among crown loss, tree growth, and tree wound response. During the 1998 growing season, 484 injured trees were selected from the storm footprint in Maine, New Hampshire, and Vermont. Selected trees were tagged and categorized by species (sugar maple, red maple, yellow birch, paper birch, and white ash), size (large poles, 20-30 cm dbh and standards, 30-60 cm dbh) and crown loss (class A with less than one-half crown loss, class B with one-half to three-quarters crown loss, and class C with greater than three-quarters crown loss).

The survival or death of each tagged tree will be determined at the end of each growing season for 1999-2002. The number of years for closure of a drill wound (1-cm-diameter x 5 cm deep) inflicted in October 1998 will be used to assess relative growth rates and the closure wound response. Annual growing season (1999-2002) cambial electrical resistance measurements will be used to assess growth potential. The growth response index of individual trees (the periodic growth rate for years following the ice storm divided by the periodic growth rate prior to the ice storm) will be used to assess actual changes in radial growth. A subsample of the trees will be felled and dissected throughout the study period to assess the progress of wound-initiated discoloration and decay. Additional trees that were injured during previous storms during the last 10-20 years will also be felled and dissected for comparisons of internal patterns of discoloration decay. The tree dissections will be incorporated into field demonstrations for forest and wood resource professionals. Photographic records of standing and dissected trees will form the basis of a database to be used to develop teaching tools for tree injury and damage.

Preliminary conclusions after two years of this five-year study include:

- Branch architecture contributes to tree sensitivity to storm injury.
- The survival of intact primary branches near the point of crown breaks results in slower progress of wound-initiated discoloration.
- The greatest amount of wound-initiated discoloration due to the storm occurred in trees with basal scars from previous wounds.

MOVEMENT OF *ANOPLOPHORA GLABRIPENNIS* AND *ANOPLOPHORA NOBILIS*: STUDIES OF FLIGHT, ORIENTATION AND DISPERSAL POTENTIAL

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ABSTRACT

The Asian longhorned beetle (ALB), *Anoplophora glabripennis* Motsch., is native to China and Korea. *A. glabripennis* was first discovered in North America in New York in 1996, followed by its discovery in Chicago, Illinois in 1998. ALB is believed to have colonized North America as a stowaway in solid wooden packing materials (i.e. crating, palettes, dunnage) originating from China. Larvae of this species feed in the cambium and xylem of a large variety of hardwood tree species, including maple, first killing branches and eventually the entire tree.

USDA-APHIS-PPQ has mounted a campaign to eradicate this pest from North America by establishing domestic quarantines that prohibit local transportation of potentially infested wood, aggressively scouting for infested trees and eliminating them, and imposing a new and more stringent shipping rule that requires wooden packing materials from China be treated to kill wood borers (18 September 1998 Federal Register 63 FR 50100-50111, Docket No. 98-087-1). However, in spite of these efforts, which have resulted in the removal of over 3,900 trees in New York and over 1,200 trees in Chicago, ALB-infested trees were discovered during 1999 in three areas outside quarantine zones in New York (including ca. 1,000 trees) and Chicago (including ca. 315 trees) (USDA-Forest Service 1999).

Research directed at ALB includes efforts focused on the eradication of ALB, as well as on the management of ALB should eradication fail. In regard to eradication, where the aim is to eliminate all reproductively viable individuals from the infested areas, establishment of quarantine boundaries inside of which intensive search and destroy operations are conducted, is essential. Delineation of such boundaries are based in large part upon the dispersal potential of ALB. Furthermore, central to the development and implementation of management strategies for ALB, is an in-depth understanding of its population dispersal potential, as well as other key biological and behavioral characteristics. Such an understanding of the process of invasion is a cornerstone to the development of a proactive program for the prevention and early detection of

new introductions. Therefore, investigations of ALB (*A. glabripennis* and *A. nobilis*) movement were initiated in Gansu Province in north-central China during 1999. These investigations included studies of both the individual ALB flight and orientation behavior, as well as its population dispersal potential.

Individual Flight Behavior. The first year of a two-year study of the flight distance, direction, orientation and host selection behaviors of individual adult beetles of *A. glabripennis* and *A. nobilis* was conducted under natural field conditions in Gansu, China. In addition, evaluation of how this behavior is affected by key environmental parameters (i.e. wind direction and speed, temperature, cloud cover, angle and aspect of sun, time of day) and biotic factors were also determined. During these studies a total of 450 adult ALB were evaluated. To date, analysis of these data has shown that an individual ALB can fly an average distance of ca. 25- 46 m in a single flight, which ranged from 3 - 420 m. These data also indicated that flight propensity and flight distance are strongly influenced by the time of day. Most importantly however, this data suggest that the size (linear distance) of host-free space is a key factor governing dispersal distance. Furthermore, the data also indicate a strong directionality to flight, as well as a strong landing orientation to standing trees.

Population Dispersal. The first year of a multi-year study of the season-long population dispersal potential of *Anoplophora glabripennis* was conducted under natural field conditions in Gansu, China. The Mass-Mark Recapture (MMR) method was employed, in which over 16,000 adult ALB were marked and released. These included both newly emerged (0-24 hr old) ALB (obtained from caged infested logs), which were released daily, as well as free living field collected ALB (of unknown age), which were released weekly. ALB were recaptured weekly for a total of 14 weeks by sampling groups of trees at 50, 100, 150, 200, 250, 300, 400, 500, and 600 m from the release points in each of the primary compass directions (N, NE, E, SE, S, SW, W, NW). In addition, ALB were also randomly sampled around the outer periphery of the study area. During this 3.5 month study, dispersal distance, direction, and rate, as well as body size and egg load of recaptured ALB were determined. In addition, daily environmental data (temperature, wind direction and speed, rain fall), weekly ALB population density (n=769 trees; calculated based upon meters of linear tree canopy), and landscape heterogeneity (spatial aspects) were also determined. Field experimentation was completed in early October 1999. To date, analysis of the data has shown that the mean dispersal distance for male and female *A. glabripennis* and *A. nobilis* ranged from approximately 220 - 300 m. More notably, this study showed that ALB can disperse over 1,400 meters in a single season, carrying eggs, well over the previously reported distance of 100-200 meters. In addition, these studies showed a noticeable directional effect as well. Analysis of recapture data relative to ALB population density (temporal and spatial) and landscape heterogeneity are in progress. Molecular techniques are also being employed in an effort to predict the potential dispersal distance of ALB. To this end, ALB larvae (20 larvae) were collected from 5 trees beyond the outer recapture distances (740 - 1,350 m) from the center release site in each of the 8 primary compass directions. Molecular analysis are only now being initiated.

The second year of the individual flight behavior and population dispersal studies will be conducted in China during 2000. The implications and practical application of the new information developed in the individual flight and orientation behavioral studies will also be explored (i.e. trap development and host tree selection). In addition, data from these studies, together with investigations of ALB colonization behavior, will be utilized for the development of prediction models of ALB dispersal and establishment under different landscapes at risk to ALB invasion in the U.S.

APHIS GUIDELINES FOR THE LYMANTRIIDAE

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ABSTRACT

In 1992, APHIS began a new series of plant pest documents called Guidelines. These documents were designed to offer options for dealing with a particular class of pests, assuming that any one of the pests in that class became a matter of concern that could require some sort of regulatory action. The documents are worldwide in scope, that is, all the important and possible pests of that class of pests are dealt with. In several cases, guidelines have been prepared for a few significant pests of worldwide import. These options deal with general information about that class of pests, field identification/ specimen handling of that class of pests, survey options, regulatory options, and control procedures. Since that date, a number of Guidelines have been produced, including one on the family Lymantriidae. The Lymantriidae Guidelines contain information on 136 Lymantriids which have been identified as pests or potential pests. Among these are the familiar gypsy moth, the browntail moth, and the white-spotted tussock moth. Generally, information taken from the world literature is summarized for each species for which such information is known and which would be useful in any kind of control program, should one become necessary. Options taken from programs against known pests are summarized as well, and presented in a way which might be useful for programs against unknown or lesser known Lymantriids. Known life cycle history useful from a program standpoint are summarized. Steps for identification procedures are given. Survey options include a possible survey program, types of traps, lures (if known), and specialized surveys. Regulatory options include the kind of regulated articles that might need to be controlled, the types of establishments that may need to be regulated, the regulatory treatments needed to keep commerce flowing through the regulated area, and examples of regulatory activities which may need to be implemented. Control procedures are highly structured and offer a decision table to help decide what kind of action or program to undertake. Controls are balanced with a view to current concepts of the use of all bio-control options that are possible and away from the pure application of insecticides in the environment. These bio-control options against the Lymantriidae include biological insecticides, useful microorganisms, various natural insecticides, and plant extracts. Behavioral manipulations, classical biological controls, augmentation, conservation of natural enemies, enablement and autocidal control options are also covered. Other control options include habitat manipulation, host-plant resistance, and mechanical means of control. Sections dealing with a more in-depth discussion of regulatory, survey and control options are in Addenda and provide the tools needed to get a program underway within a minimal time frame. Finally, the known biology of a number of species is written, with an emphasis on those features useful when drawing up a program, especially features which can be safely extrapolated to a Lymantriid about which little or nothing is known.

STATUS OF SPRAY MODEL DEVELOPMENT

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ABSTRACT

Over the last 25 years, the USDA-Forest Service has developed modeling techniques to predict deposition of aerially sprayed material. This modeling effort was in response to the relatively inexact nature of aerial spraying at a time when environmental concerns were increasing and chemical application was increasingly expensive. These modeling efforts have markedly advanced the understanding of deposition from aerially released sprays and powders and have contributed to dramatic increases in the technical level of aerial spraying both through applicator practice and improved equipment. The original models were known as FSCBG and AGDISP.

Currently, there are two primary directions in which this modeling effort is moving. USDA-FS is a partner in a Cooperative Research and Development Agreement (CRADA) with USEPA. USEPA is successfully completing a model development effort which brings this type of modeling into the regulatory arena. This effort adopted AGDISP as the core deposition code (around which many modules have been added) and christened the new model AgDrift.

The other thrust of the effort is in the development of a GIS-based model so output will be displayed spatially overlain on maps. This model, dubbed SprayAdvisor, will serve as a platform for future development including development of a genetic algorithm for spray system optimization, a complex terrain deposition and drift model, real-time GIS-based drift estimation available to a pilot during application and other smaller efforts. Finally, pest mortality and dose response models will be tied to the deposition model to yield estimates of operational efficacy.

EFFICACY OF PESTICIDES ON THE

ASIAN LONGHORNED BEETLE *ANOPLOPHORA GLABRIPENNIS*

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ABSTRACT

One of our major cooperative projects since 1997 has been evaluating the efficacy of different insecticides in China against the Asian longhorned beetle, *Anoplophora glabripennis*. Following the field test conducted in 1998, more studies were done in 1999.

Five systemic insecticides including Disyston (AI: Disulfoton), Merit (AI: Imidacloprid), Metasystox-R (AI: Oxydemeton-methyl), Monitor (AI: Methamidophose), and Othene (AI: Acephate) were tested in field through soil injection, trunk injection and trunk implanting at two sites in Gansu province of China. Trees at the first site were primarily *Popular alba var pyramidalis* (height = 8.5 m, and DBH = 10.9 cm) that was once considered to be one of the least preferred species by the beetle. These were ornamental trees on roadside, and close to city residential area. Applications were made three times at this site: April, June and September for soil injection, and May, June, and July for trunk injection and implanting. Trees at the second site were mainly *P. nigra var thevestina* (height = 8.0 m, and DBH = 8.6 cm). These were windbreak trees planted in rows and surrounded by farmland. They are highly preferred and heavily attacked by the beetle. Applications were made two times at the second site: July and September for soil injection, trunk injection and trunk implanting. Efficacy of these insecticides were evaluated by checking the mortality of adult beetles during flight season, and by checking mortality of all stages of beetles through dissecting trees in late November.

The following 8 insecticides were tested in laboratory together with water as the control: Biflex 2 EC (bifenthrin), DeltaGard* 5C (deltamethrin), Astro 3.2 (permethrin), Orthene 75S (acephate), Dursban 4E (chlorpyrifos), Lindane 20%, FICAM (bendiocarb), and Regent (fipronil). Three dosages of each insecticide were tested. Newly collected willow (*Salix matsudana*) twigs were

dipped into insecticide solutions for 1 minute and then placed in cages together with a pair of beetles at 25-32°C. Fipronil and permethrin were also selected for testing their residual effects to the beetle. This was done by spraying insecticides onto tree twigs at different times of the year and then providing beetles with these treated twigs. Mortality of beetles was checked once every 24 hours for a week for both tests.

All data collected from the field tests are still in evaluation. However, based on our preliminary analyses, efficiency of different insecticides varied depending on the time of application and tree species as well as population level and stage of the beetle. Generally, imidacloprid seemed to cause higher mortality to the beetles than other insecticides tested, especially, when applied through trunk injection. Samples of different parts of treated trees have been collected for chemical analyses of the levels of insecticides in trees. Similar chemical analyses for treated trees in the US started in 1999, when imidacloprid and Bidrin (dicrotophos) were applied through soil injection, trunk injection and, implanting to sugar maple (*Acer saccharum*) and red maple (*Acer rubrum*) located in western Massachusetts. These data together with data that will be collected in 2000 by dissecting treated trees left from 1999 will provide us more information about the efficacy of these insecticides against the beetle.

Results of laboratory test showed that the 8 tested insecticides had very good immediate effects on adult beetle, i.e., an almost 100% mortality within 72 hours from each insecticide, though there were slight differences among different insecticides. However, fipronil and permethrin showed very poor residual effects against the beetle. Less than 25% mortality resulted when the two insecticides were applied to twigs 2 weeks before the treated twigs were provided to the beetle.

More field and laboratory tests of insecticides for controlling the beetle together with residual analyses of these insecticides will be conducted in China and the US in 2000.

FIELD TESTING GYPCHEK - *IS THERE MORE TO DO?*

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ABSTRACT

Gypchek (a gypsy moth nuclear polyhedrosis virus product) has been registered with the U. S. Environmental Protection Agency for use against the gypsy moth using either aerial or ground equipment. Environmental concerns over the effects of non-specific insecticides applied to forest ecosystems have stimulated interest in the use of Gypchek. When properly applied at the appropriate dosage against appropriate population structures under appropriate weather conditions, the product will usually provide adequate foliage protection; however, the product is expensive and is non-forgiving if applied under marginal conditions. Yes, there is more to do if Gypchek is to fulfill its potential. Specifically, overall efficacy should be improved, especially for the one-application treatment option. Secondly, cost reduction is needed for the virus, its formulation, and its application. While improvements in efficacy and cost must arise from laboratory research, such improvements must be field-validated. Thirdly, the "window of application" must be widened. Currently, Gypchek must be applied against first-second instar larvae to be effective, leaving program managers with little leeway in time to achieve a reasonable benefit.

Gypchek product improvement may arise from a number of sources including improved natural or engineered strains, improvements in formulations such as improved UV protection (= increased persistence of the viral agent) and improved stickers (= increased persistence of the deposit). Feeding stimulants may be added to formulations to overcome feeding repellency, which may be overlooked in laboratory studies. Additives such as enhancers can be added. However, our past research indicates that product improvements will lose an order of magnitude in increased efficacy when transferred from the laboratory to the field. Thus, product improvements that show promise in the lab require field validation.

The product must reach the target site to be effective. Increasing effective spray deposition by optimizing droplet size, number, and canopy penetration remains a target for additional field research. The effects of weather on program success should be addressed - current recommendations for spraying Gypchek are based more on experienced opinion than hard data.

Finally, the virus that is the active ingredient of Gypchek has the potential to spread in time and space. New strategies and tactics that take advantage of such potential spread should be conceived and field validated.

POTENTIATION BY A GRANULOSIS VIRUS OF GYPCHEK, THE GYPSY MOTH NUCLEAR POLYHEDROSIS PRODUCT: FIELD CONFIRMATION

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ABSTRACT

We used a bugs-in-bags approach to confirm a laboratory finding that the co-application of Helicoverpa armigera granulosis virus (HaGV) with Gypchek (LdMNPV) increased viral mortality at a given dose compared to that resulting from Gypchek applied alone. We applied Gypchek and the granulosis virus in various combinations against several gypsy moth instars under field conditions (with a Blankophor BBH + Gypchek treatment included as a comparison of virus enhancers), and determined the residual effects of the treatments over a 3-week period. The addition of HaGV at 1% to Gypchek resulted in a log increase in observed mortality, confirming the laboratory finding of such potentiation. The addition of Blankophor BBH at 1% resulted in a two-log increase in observed mortality. The addition of HaGV at a lower dose of 0.1% resulted in no consistent increase in recorded mortality, and 1% granulosis virus applied alone was inactive against gypsy moth. The residual activity of Gypchek was little enhanced by the addition of the granulosis virus at either dose.

OBSERVATIONS ON *ANOPLOPHORA GLABRIPENNIS* AND *ANOPLOPHORA MALASIACA* IN SOUTH KOREA

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ABSTRACT

We searched for populations of *Anoplophora glabripennis* (Motschulsky) for six weeks in South Korea during July and August 1999 and, after finding one, investigated the ecology of the beetle. We also found *Anoplophora malasiaca* (Thomson). Museum collection records in South Korea indicated the presence of endemic populations of *A. glabripennis* there. Because South Korea is different in climate, topography, and ecology from China, where work is currently underway by scientists from other USDA agencies, we felt that our investigations in Korea would complement and perhaps provide a contrast with those going on in China.

Anoplophora glabripennis was sought in urban and forest habitats within about 50 miles of Seoul and in forest habitats at Mt. Sorak National Park on the eastern coast of South Korea. The only population of *A. glabripennis* located was at Mt. Sorak National Park. Small numbers of *A. malasiaca* were found at several locations around Seoul and at Mt. Sorak.

The only tree species *A. glabripennis* was observed to attack in South Korea were silver maple, *Acer saccharinum,* and Chinese maple, *A. palmatum.* Silver maple is not native to Korea, and both *Acer* species attacked were planted as ornamentals. Although *Populus*, *Betula*, and *Salix* have been cited as hosts elsewhere in the world, extensive searches of those taxa in various habitats in South Korea did not turn up *A. glabripennis. Anoplophora malasiaca* apparently attacked sycamore, paper birch, and silver maple. None of those species is native to South Korea.

At the site at Mt. Sorak National Park containing *A. glabripennis,* all 44 ornamental silver maples were measured and assessed for beetle damage. Beetles generally attacked silver maples >10 cm DBH and on the main trunk as high as 2-4 m. Many larger trees sustained heavy damage, but were still alive. After it was determined that silver maple was a preferred host in Korea, areas in Seoul with major street tree plantings of that species were located and a brief survey was carried out. There were well over 1,000 silver maples planted along streets in northern sections of the city. However, no evidence of *A. glabripennis* was found in the survey.

After chewing an oviposition pit in the bark and placing an egg, the female covers the egg with a plug of frass. In the field, *A. glabripennis* was observed to oviposit on relatively flat surfaces on the trunk and main branches. However, females also oviposited in twigs as small as 1 cm in diameter in the laboratory when no larger material was available. In this case, the egg was simply inserted through a slit in the bark. First instars emerged from the eggs after about a week in the laboratory and began to feed.

Two ichneumonid wasp species were associated with silver maple trees damaged by *A. glabripennis*. The female of one parasitoid species was observed to antennate fresh egg niches of *A. glabripennis* and then probe them with the ovipositor. The species, which currently are being identified, are probably both in the genus *Lissonota*.

A major research objective was to investigate the dispersal of adult beetles. Harmonic radar was used to that end. The technique involved attaching a small radar-reflective antenna (Alberta Microelectronic Corporation, Edmonton, Alberta, Canada) to an individual beetle, releasing it, and then relocating it at time intervals using a portable radar device (RECCO AB, Lidingo, Sweden). Harmonic radar may prove to be a useful tool for tracking *A. glabripennis* in the field. However, a more durable radar-reflective tag than is currently available and a more dependable means of attaching the tag to the adult beetle are needed.

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INSECT NATURAL ENEMIES AND THEIR POTENTIAL FOR BIOCONTROL OF ASIAN LONGHORNED BEETLE

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ABSTRACT

Asian longhorned beetle (ALB) (*Anoplophora glabripennis*) is a serious pest in China. It can attack over 20 host tree species, specifically broadleaf species. For biocontrol purposes, we initiated investigations of its insect natural enemies.

Compared with other longhorned beetles, few natural enemies of ALB have thus far been identified. This may be one reason for the outbreaks of ALB over large areas. To date, we have not found any egg parasitoids. There are, however, larval parasitoids: *Dastarcus longulus* Sharp (Coleoptera: Colydiidae), *Scleroderma guani* Xiao et Wu (Hymenoptera: Bethylidae), *Bullaea* sp. (Diptera: Tachinidae), and *Megarhyssa* sp. (Hymenoptera: Ichneumonidae); and pupal parasitoids: *D. longulus, S. guani*, and *Aprostocetus* sp. (Hymenoptera: Eulophidae). *D. longulus* and *S. guani* are the most important among these natural enemies of ALB, as they parasitize both larvae and pupae.

D. longulus, in many areas, has been reported to have parasitization rates of 50-70%. Female *D. longulus* lay eggs in frass and sawdust in host gallery or on the host gallery wall. First instar larvae possess thoracic legs and crawl about 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 is an ectoparasite, feeding singly or gregariously on its host (1-27 individuals per host), but in all cases the host is killed. *D. longulus* is considered to have the highest potential for use in biological control of ALB.

S. guani usually parasitizes longhorned beetle species whose larvae are small, ca. 15 mm in length. It is an idiobiont ectoparasitoid. Female wasps first paralyze their host by stinging, which immobilizes the host, 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. 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. The degree days of *S. guani* is 448.89 for development from egg to adult. It can be mass reared for biocontrol. Therefore, *S. guani* has great potential for use in the biological control of ALB larvae, specifically 1^{st} to 3^{rd} instars.

IMPACTS OF *ANOPLOPHORA* SP. IN CHINA

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ABSTRACT

Main species and their distribution, causes and control methods of *Anoplophora* in China are briefly discussed. In China, main species of *Anoplophora* included *Anoplophora glabripennis*, *A. nobilis* and *A. chinesis*, which had brought about enormous damage to forest.

ALB and *A. nobilis* was emphasized in this paper because of their serious damage in China. Because most of "Three North" areas with abominable natural geological and climatic environment are not the native habitat of ALB, and plantation area of poplar is increasing continually, these are few local rapid growing tree species suitable to these areas. To the contrary, poplar inevitably becomes the preferred tree species in construction of protection forest for its adaptability, fast growing ability and acceptability by people. Since 1980s, most of the first-stage artificial forest mainly made up of poplar of the world-famous "Three North" shelter forest system has been almost devastated by A. *glabripennis* and *A. nobilis*. Now, there are reports that *A. glabripennis* and *A. nobilis* have been introduced into Western Huanghe Corridor, Qinghai, Jilin, and even Hami of Xingjiang and Heilongjiang.

To analyze the damage causes of *Anoplophora*, we can find answers from the inherent bio-characteristic of *Anoplophora* and the irrational cultivation, utilization and management of poplar trees. According to the studies of *Anoplophora* in China, the control measures can be summed up to 3 levels, which were respectively aimed at pest, individual tree, pest population and forest and even ecosystem. However, effective and simple methods are still in searching. Because of the limitation of the first 2 level methods, many efforts are still taken to search effective and simple control methods. Only the 3rd level measures were toward whole forest and their effects were sustainable. Thus they are the basic methods to control *Anoplophora*.

Great progresses had been attained after 20 years' research on management of *Anoplophora*. Biology, ecology, control measures and other behavior were systemic studied. According to the habit of adults, new type insecticides with high technology had been made up, such as imidacloprid, contacting-breaking microcapsule. Some volatile compounds from ash-leaf maple had been isolated and identified. After field test, some of them were proved to be attractive in certain degree to adult of *A. glabripennis*.

The concept of 1st generation, 2nd generation and strengthened 2nd generation shelter forest was put forward firstly according to the construction of tree species composition. Rational

arrangement of multiple tree species and its basic theories that included stability of ecosystem, relative resistance principle and risk dispersing mechanism were presented firstly. Its main aim was to change the situation that forest systems were composed of single tree species or variety that was susceptible to the beetle and to strengthen the resistance of tree species to *Anoplophora*. It was also pointed out that tree species in the forest included resistant trees, immune trees and luring trees that were aimed at *Anoplophora*.

It was pointed out that ecological reasons cause serious damage of poplar longhorned beetle in China, which included irrational selection of tree species and cultivation way. Therefore, a proposal are put forward that the relationships among host tree, longhorned beetle, natural enemy and living habitat should be considered thoroughly when we try to control *Anoplophora*. Then, we should strengthen the studies on *Anoplophora* as follow in order to find effective methods to control the beetles. It can be seen from Figure 1. Lastly, suggestions for further Sino-US cooperation on ALB was put forward, which included development of attractant, biological control, and chemical control so on.

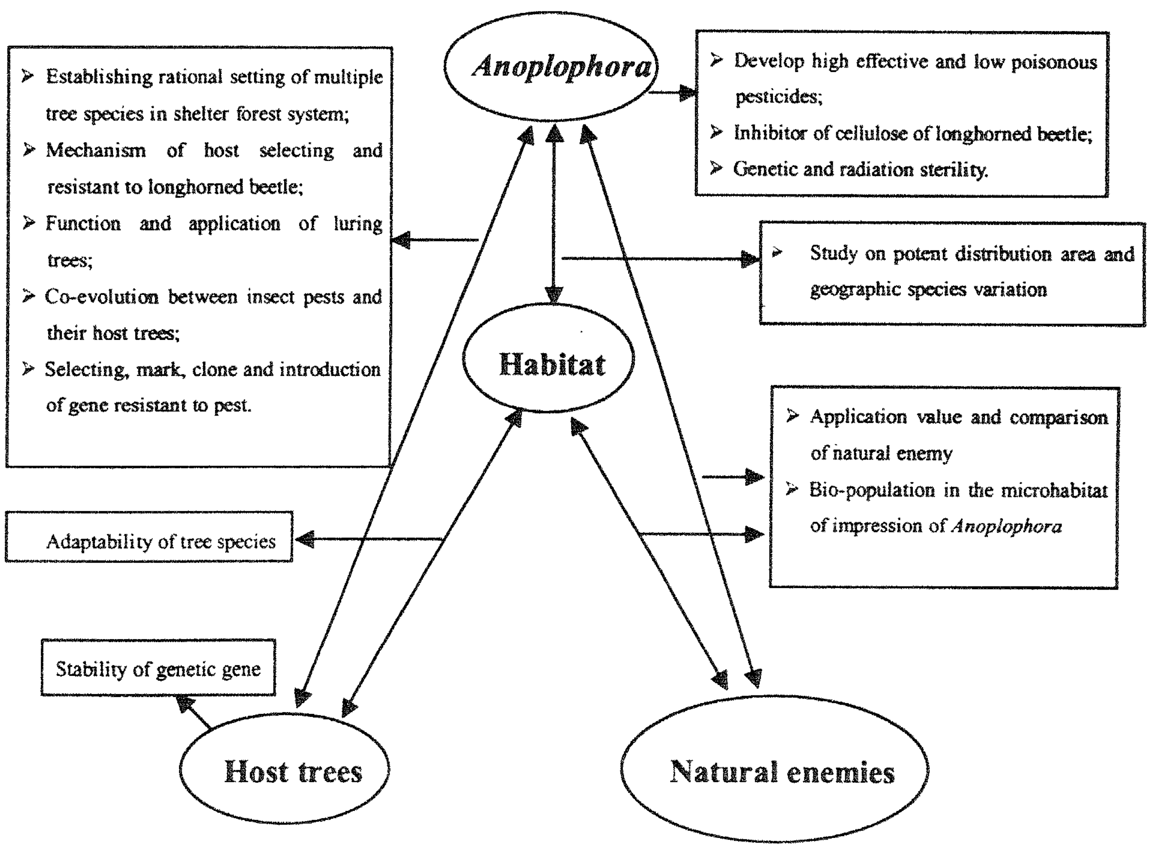

Figure 1. Frame of studies to control *Anoplophora*.

USDA Interagency Research Forum on Gypsy Moth and Other Invasive Species
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