FHP TECHNOLOGY DEVELOPMENT PROJECT PROPOSAL-- FY 2000

PROJECT STATUS: New, not previously funded.

PROJECT NUMBER: NA-2000-05

PROJECT TITLE: Development of Acoustic Technologies to Detect the Asian Longhorned Beetle

SUBJECT: Survey, Evaluation, and Monitoring; exotic insect; *Anoplophora glabripennis*

PROJECT OBJECTIVE: This project will identify unique acoustic signal descriptors associated with the presence of the Asian longhorned beetle (ALB) in live trees and in solid wood packing materials (SWPM). Ultimately, this will lead to the development of a field-portable ALB detection system.

BRIEF DESCRIPTION OF PROJECT: The Asian longhorned beetle, *Anoplophora glabripennis* (Coleoptera: Cerambycidae), is the most serious non-native (exotic) invasive forest insect to have entered the United States in recent years. ALB was first discovered in New York City in 1996, and then in Chicago in 1998. As of October 1999, more than 3000 ALB-infested trees were cut in New York City and more than 1000 in Chicago. ALB is native to China and Korea, where it is a major wood-boring pest of hardwood trees, especially aspen, elm, maple, and willow. Because of its wide host range and its ability to attack and eventually kill apparently healthy trees, ALB has the ability to destabilize forest ecosystems nationwide.

ALB likely entered the US inside infested SWPM (e.g., wood pallets, crating, and dunnage) that was associated with Chinese imports. Besides visual inspection, there is currently no other technology available to determine if live trees or SWPM are infested with ALB. However, even visual inspection can be difficult, especially when attempting to inspect tall trees, pallets that already support cargo, or shipping containers that are packed with goods. This research proposal will address these difficulties by developing acoustic technologies that will subsequently aid in the detection of ALB-infested trees and SWPM.

These studies will be accomplished through a series of laboratory and field experiments. Some tests will be conducted in quarantine facilities where ALB is being reared, while other tests will be conducted with infested trees in Illinois and New York. The analytical work will be completed by the Instrumentation and Controls Division of the Oak Ridge National Laboratory.

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PRINCIPAL INVESTIGATORS:
Robert Haack, Research Entomologist and Project Leader, NC-4501, East Lansing, MI
Therese Poland, Research Entomologist, NC-4501, East Lansing, MI

COOPERATORS:
Cyrus Smith, Oak Ridge National Laboratory, Oak Ridge, TN
Michael Buchanan, Oak Ridge National Laboratory, Oak Ridge, TN

JUSTIFICATION: Exotic forest insects pose a significant threat to forest ecosystems throughout the US (Haack and Byler 1993, Liebhold et al 1995, Niemela and Mattson 1996, Mattson 1998). There are currently more than 400 exotic forest insects established in the US (Mattson et al. 1994 and unpublished data), with ALB being among the most recent (Haack et al. 1996, 1997, Poland et al. 1998). Given the severe threat posed by ALB and its apparent limited US distribution, USDA APHIS initiated an eradication program that requires removal of all known infested trees. As of October 1999, more than 3000 ALB-infested trees in New York and 1000 in Chicago have been removed. In both New York and Chicago, more infested trees are found each month as inspectors look for ALB-associated oviposition pits, frass, and exit holes.

Solid wood packing materials are often infested with wood-boring insects like ALB and thereby can serve to transport insects from one location to another. In recent years, ALB has been regularly assoiciated with imports from China (Cavey 1998, Poland et al. 1998). For example, according to the USDA APHIS port inspection network

database, ALB was intercepted 29 times on imports from China during 1997 and 1998: 27 times in crating, 1 time in pallets, and 1 time in dunnage. During the period 1985 through 1998, USDA APHIS made 6447 interceptions of insects at US ports-of-entry on wood products, like crating, pallets, and dunnage (Haack and Cavey 1997, 1998, and unpublished data). All 6447 interceptions were made on the basis of strict visual inspection, given that no other methods were or are available.

This study addresses one of the high priority objectives of the Special Technology Development Program, i.e., to develop or improve detection, analysis, and management of exotic pests. The development of an effective ALB detection system will improve our ability to locate infested trees and SWPM. This new technology can be employed at currently infested sites in the US, at future sites of infestation in the US, at US ports-of-entry, and at US military bases, especially bases in Japan and Korea.

URGENCY: New technologies are desperately needed to allow more effective detection and monitoring of ALB-infested trees and SWPM. Currently, visual inspection is the only method available to detect the presence of ALB. At this time there are no known pheromones or host attractancts that can be used to trap and monitor ALB. Although eradication efforts have been underway in New York City since 1997 and in Chicago since early 1999, infested trees are still being found on a regular basis as of October 1999. In both New York and Chicago, several new infestations were discovered in 1999. ALB infestations likely exist in other US cities. At US ports-of-entry less than 5% of shipments containing SWPM are ever inspected. When products are shipped in containers the inspection rate is even lower. And when containers are inspected, typically it is only the outer cargo adjacent to the doors that is looked at, i.e., containers are almost never unloaded until they reach their final destination. Clearly there is a need for improved technologies for the detection of wood-boring insects in trees and SWPM. The aim of this proposal is to develop a more effective ALB-detection system that is based on the acoustic signals associated with ALB feeding within infested trees and SWPM.

LINK TO NATIONAL FHP TECHNOLOGY DEVELOPMENT PRIORITIES: This study addresses the 4th national priority objective which is to "develop or improve detection, analysis, and management of non-native invasive insects, pathogens, and plants, especially technologies or methods that contribute to our ability to prevent introductions or to detect and eradicate new introductions." This proposal specifically focuses on development of a detection device that will target ALB. If successful, the fully developed ALB detection system will (a) allow for better inspection of SWPM at ports-of-entry or subsequent destinations and thereby prevent introductions, and (b) allow for better detection of infested trees and thereby improve eradication efforts.

SCOPE OF APPLICATION: This project will provide technologies that will be immediately useful in the currently infested areas of Chicago and New York City. In addition, an ALB-detection system, when fully operational, would be a useful tool at all US ports-of-entry, and major shipping terminals within the US. Such a tool would also be of value for any city, state, or federal employee involved in plant health and regulatory issues. In addition, a device that can detect acoustic signals from wood-boring insects would have worldwide appeal.

RESEARCH BASIS: Acoustic signals are generated by wood-infesting insects as they feed and tunnel in wood. The specific acoustic signals created by a given wood-boring insect may be related to their size, the shape of their mouthparts, their feeding behavior, the size and configuration of their gallery, the specific species of tree infested, and the moisture content of the woody material that they infest (i.e., a live tree or lumber). In recent years, researchers have investigated the acoustic signals produced by stored-grain insects (Hagstrum and Flinn 1993, Mankin et al. 1997, Shade et al. 1990, Shuman et al. 1993), termites, (Matsuoka et al. 1996, Noguchi et al. 1991, Shade 1990), and one species of cerambycid beetle that infests dry lumber (Schmidt et al. 1995). Depending on the insect species, insect-associated sounds were recorded at both audible (0.5-20 kHz) and ultrasonic (40-150 kHz) frequencies. In one study (Sugimoto et al. 1988), it was noted that a parasitic insect located its insect host by the sounds that it made while feeding within the host plant. Given the above findings, it is possible that ALB larvae produce unique acoustic signals as they feed. Adult beetle most likely also produce sound as they chew their way out of a tree or as they chew twigs during maturation feeding or holes in the bark during oviposition. The ultimate objective of this work is to determine unique "Acoustic Signal Descriptors" that indicate the presence of ALB and to initiate development of a field-portable system using these descriptors that can detect ALB in live trees and SWPM.

METHODS:

Experimental ALB Populations: We will work with ALB populations that are currently housed at USDA quarantine laboratories and at field sites in Chicago and New York. Currently, there are ALB colonies at the USDA quarantine laboratories in Connecticut (USDA Forest Service), Delaware (USDA Agricultural Research Service), and Massachusetts (USDA APHIS). We will be able to work in any or all of these laboratories. In addition, there are plans to initiate other ALB colonies in the Great Lakes region, including a colony at the Canadian Forest Service quarantine lab in Sault Ste. Marie, Ontario. .

Other Wood-Infesting Insects: Besides ALB, there are many other insects that commonly infest live trees or are found in SWPM. Many of the exotic bark- and wood-infesting insects that are commonly intercepted at US ports-of-entry have close relattive that are native to the US. Therefore, in companion studies, to test the uniqueness of the ALB-associated acoustic signals, we will also analyze acoustic signals of at least six other native trunk-infesting insects. We will use at least two species of bark beetles (Scolytidae), two species of flat-headed woodborer (Buprestidae), and two species of round-headed woodborers (family Cerambycidae). Such insects are readily collected in Michigan and will represent a range of sizes and feeding strategies that will overlap or contrast with ALB.

Tree Species: We will emphasize the tree species that are most commonly attacked by ALB in the US, such as maple (*Acer*), ash (*Fraxinus*), and elm (*Ulmus*). In addition, for the work with solid wood packing materials, we will also test at least one species of pine (*Pinus*) because pine is one of the most commonly used species for crating and pallets worldwide. For the SWPM studies, we will use wood with at least two levels of moisture content to represent the range of wood moisture levels typically found in trade.

ALB-Associated Acoustical Signal Descriptors: We will first obtain data in the ultrasonic frequency range (20 kHz to 500 kHz) for actively feeding ALB larvae in trees and SWPM. Special accelerometers will be mounted on the infested trees and SWPM to determine attenuation length scales for the ultrasonic frequency range. It is possible that each tree species will have a somewhat unique frequency range given their particular xylem cell structure. In addition, the frequency range and attenuation factors may be altered by the moisture content of the SWPM. Using infested trees and SWPM, we will measure the amount of energy generated by a single feeding larva. We will analyze tree and wood samples with ALB larvae of known age (instar) and densities.

We will also obtain hi-fidelity data in the audio range (20 Hz to 20 kHz) for actively feeding ALB larvae in trees and SWPM. We anticipate that the frequency range and energy level will change as larvae grow, given that the size of the cavity holding each larva will alter the resonance frequency to some degree. At some point in the larval growth cycle, the signal frequency may drop from the ultrasonic range into the audio range, at which time microphones with parabolic reflectors could be used to measure sounds from trees and SWPM.

We will also record hi-fidelity data in the audio range (20 Hz to 20 kHz) of ALB adults as they chew their way out of the trees and as they chew twigs and oviposition pits. In addition, we will obtain ultrasonic and audio frequency range data for other common wood-boring beetles as described above. This information will be necessary to determine the uniqueness of the acoustic signal descriptors of ALB when compared with other wood-boring beetles.

Once the above recordings have been made, extensive analyses of the ultrasonic and acoustic data will be conducted to develop algorithms for identifying the presence of ALB. We will then design and test one or more prototype instruments that embody the ALB-identification algorithms and test it uder field conditions.

MEASURE OF SUCCESS: This project will be considered successful if (1) unique acoustic descriptors are identified that can be used to detect ALB, and (2) if a field prototype instrument is developed that can detect these sounds under field conditions. We also anticipate that we will identify acoustic descriptors that will be useful in identifying generalized wood-feeding insects.

COOPERATORS:

1. Principal investigators:

Robert Haack, Research Entomologist and Project Leader, NC-4501, East Lansing (10% time)
Therese Poland, Research Entomologist, NC-4501, East Lansing (30% time)

Toby Petrice, Biological Technician, NC-4501, East Lansing (30% time)
Matt Gennrich, Biological Technician, NC-4501, East Lansing (30% time)
Dennis Haugen, Entomologist, FHP, St. Paul

2. Currently identified cooperators:
Cyrus Smith, Instrumentation and Controls Division, Oak Ridge National Laboratory (10% time).
Michael Buchanan, Instrumentation and Controls Division, Oak Ridge National Laboratory (5% time)

Cyrus Smith and Michael Buchanan of the Oak Ridge National Laboratory (ORNL), Instrumentation & Controls Division have extensive knowledge and experience with: (a) field collection of acoustic data, (b) acoustic noise analysis methods, (c) pattern recognition and transient analysis techniques, (d) nonlinear system analysis using theory of chaos, (e) applied acoustic sensors and instrumentation, (f) system integration and development, and (g) designing and developing acoustic systems. The ORNL Instrumentation & Controls Division have specialized laboratories with unique capabilities in: (a) basic and applied sensor research, (b) computer data acquisition, signal processing, algorithm development and systems integration, (c) technical support for instrument hardware development, and (d) technical service support for development and fabrication of instrumentation.

We established an inter-agency agreement (NC-23-99-29; DOE 2287-P267-A1) with ORNL in late FY99, and transferred 50k to ORNL to support the work on recording and analyzing acoustic signals from ALB and other wood-boring insects.

PRODUCTS: This project will develop new knowledge about the acoustic signals produced by ALB larvae and adults and other wood-boring insects and it will evaluate the feasibility of producing an acoustic detection system for ALB. The ultimate goal is to produce a field-portable ALB detection system. However, the funding level requested in this proposal is to support the sound analyses, conduct a feasibility study, and design and test one or more prototype instruments.

PUBLICATIONS: A project report will be completed by the end of FY00 and again in FY01. Results from this study will be published in scientific journals. Patents will be applied for as appropriate.

TECHNOLOGY TRANSFER: The products of this project will be transferred to regulatory officials, forest entomologists, forest health specialists, and port inspectors through publications, presentations, electronic mail, newsletters, and postings on the Internet. If successful, we anticipate that a private electronics firm would be interested in marketing this product.

PROJECT DURATION: Two years - FY00-01.

LONG TERM BUDGET: We are requesting 50k in STDP funding in FY00 and 50k in FY01. We have 100k of ALB research funds already devoted to this project, of which 50k has already been moved to the Oak Ridge National Laboratory. In addition, we will direct at least 50k per year of in-kind Unit (NC-4501) funds to this project to cover some of the costs related to salaries of the NC-4501 scientists and technicians, vehicle charges, meeting costs, travel costs, supplies, and publication costs.

FY 2000 BUDGET REQUEST:

	Item	Requested FHP STDP funding ($)	NC-4501($)	ORNL ($)
Admin items:	Salary	29,500	45,000	20,000
	Overhead	10,500		750
	Travel	5,000	5,000	2,000
Procurement	Contracting		20,000	
	Equipment	2,000		1,000
	Supplies	3,000	5,000	
Total FY2000 Budget		50,000	75,000	25,000 =150,000

STDP PRODUCTION FUNCTION

PROJECT NUMBER: NA-00-xx

PROJECT COST: $100,000

PROJECT OBJECTIVE: To identify unique acoustic signal descriptors associated with the presence of the Asian longhorned beetle (ALB) in live trees and in solid wood packing materials (SWPM) and to develop a prototype ALB detection system.

ASSUMPTIONS & BACKGROUND DATA:

- According to USDA APHIS, surveys will be conducted in quarantine zones in Chicago and New York for 5 years after the last ALB is found. We make the optimistic assumption that the last ALB will be found in 2000, and then surveys will continue for 5 more years.

- Costs and benefits are thus projected for 6 years for the current survey efforts in Chicago and New York. Again, this is optimistic given that ALB will likely be found for more than one more year and ALB will likely be found in additional US cities.

- In both Chicago and New York, we assume that without the new technology each city will employ at least 8 tree climbers (working in 2-person crews), and 2 bucket trucks with 3-person crews.

- Specially-trained crews are required for tree-climbing and we assume they will be brought in from the outside and be given time and a half for hazard duty. We assume the average tree climber to be GS-7 and that they will work 8 hour days and that per diem will be $125 per day. Current GS-7 salary plus benefits is $16.50/hr and overtime/hazard pay is $23.25/hr.

- We assume that the bucket truck driver and bucket-operator are hired locally, but that the actual ALB inspector is brought in from the outside and is thus on per diem. We assume that all three employees are near a GS-7 with salaries of $16.50/hr.

- We are projecting that the ALB detection system could be used for about 7 months (about 150 work days) each year, i.e., when temperatures are warm enough to support larval feeding.

- We assume that a 2-person tree climbing crew can inspect 2 trees/hr; that a 3-person bucket truck crew can inspect 4 trees/hr, and that a single inspector with an ALB-detection system can inspect 8 trees/hr and be paid a GS-7 salary ($16.50/hr). Thus, 8 tree-climbing crews will inspect 128 trees/day or 19,200 trees in 150 days. Similarly, 4 bucket truck crews will inspect 128 trees/day or 19,200 trees in 150 days. Combined, the climbers and the bucket truck crews will survey 38,400 trees in 150 days. To survey the same number of trees (38,400) with the ALB detection system, only 4 inspectors would be needed (38,400 trees/150 days/64 trees per day per person = 4 persons).

- Bucket trucks rent for $200/day.

- The ALB detection system is assumed to cost $2500 per unit, which is a one time cost.

- Per diem is assumed to be charged for only 150 days, but of course outside workers would be on per diem during weekends. Airfare and other travel costs were not projected into the costs.

Calculations:

Expenditure and output values (EOV) without project:

Costs of Detection/Survey:
Climbers salaries: 16 climbers * 150 days/year * 8 hours/day * 23.25 $/hr * 6 years = **$ 446,400/year.**
Climbers per diem: 16 climbers * 125 $/day * 150 days/year = **$300,000/year**
Bucket trucks: 4 trucks * 200 $/day * 150 days/year = **$120,000/year**
Bucket truck crews salaries: 12 crew members * 150 days/year * 8 hours/day * $16.50/hr = **$ 237,600**
Bucket truck crews per diem: 4 crew members * 125 $/day * 150 days/year = **$ 75,000**

Total annual cost of detection surveys with climbers and bucket trucks: = **$1,179,000 in Year 0;**
For Years 1-5 =$ 5,248,696; Years 0-6 = **$6,427,696**

Expenditure and output values (EOV) with project:

Ground inspectors with ALB-detectors salary: 4 inspectors * 8 hours/day * $16.50/hr * 150 days = **$79,200/year**
Cost of acoustic devices (1 time cost): 4 * $2500 = **$10,000**

Total cost with ALB-detectors: Year 0 = $89,200; Years 1-5 = 79,200 per year or when discounted = $352,504; Years 0-6 = **$441,704**

Benefit (Change in EOV) attributable to project:
$ **$6,427,696 – $441,704** = **$5,985,992**

Benefit/Cost Ratio:
$ 5,985,992/ $ 294,231 = 20.34

Benefit attributable to STDP:
20.34 * $ 98,077 = $1,994,886

PNV of project:
$ 5,985,992 - $ 294,231 = $5,691,761

PNV of STDP
$1,994,886 - $ 98,077 = 1,896,809

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