FHP TECHNOLOGY DEVELOPMENT PROGRAM
FINAL REPORT AND PROJECT PROFILE

PROJECT NUMBER: NA-2000-05

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

PROJECT STATUS: Completed

EXPECTED PROJECT DURATION: Two years - FY00-01.

ACTUAL COMPLETION DATE OF THE PROJECT: September, 2001

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

STATUS OF SUBJECT SPECIES: non-native

PROJECT OBJECTIVE: The project objectives were to identify unique acoustic signal descriptors associated with the presence of the Asian longhorned beetle (ALB) larvae in live trees and in solid wood packing materials (SWPM). Ultimately, the goal of this project was to develop 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 September 2001, more than 5400 ALB-infested trees were cut in New York City and more than 1500 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 addresses these difficulties by developing acoustic technologies that will subsequently aid in the detection of ALB-infested trees and SWPM.

The goal of this project was to develop a field deployable, easily used, hand-held instrument that could detect the presence of ALB larvae at ports of entry and potential areas of infestation. The instrument would perform the analyses necessary to distinguish ALB feeding vibrations from those of other similar insects that could also be infesting trees and wood products.

In order to develop this instrument, the project was designed to acquire vibration data from feeding ALB larvae and other wood-boring larvae that could potentially infest trees and wood products. In addition, vibration data from ALB larvae at several different stages of development would also be collected. These data would then be analyzed to identify specific characteristics that would indicate the presence of ALB larvae irrespective of the presence of other insect larvae. Upon learning these characteristics, algorithms would be developed that would analyze incoming data to identify for these same characteristics and thereby identify the presence of ALB.

These algorithms would then be incorporated into a prototype instrument that would detect the presence of trunk-infesting larvae and further determine if the feeding larvae were ALB. This prototype instrument would be field tested to document its accuracy. This instrument could have several attachments that would allow collection of data from SWPM on the one hand or from potentially infested tress on the other.

Once the operation and accuracy of the prototype instrument is refined and field tested, the technology will be transferred to an industrial partner for commercialization and miniaturization.

CHANGES TO ORIGINAL PROJECT SCOPE OR OBJECTIVES: Originally we had proposed to conduct field tests in Chicago and in New York City. However, because of the eradication program, infested trees in both cities were often cut down and chipped within hours of when they were found by visual surveys. Since we have been conducting other research on ALB in the field in China, we decided to conduct several of the field tests on naturally infested trees and lumber in China rather than in the US.

ADDITIONS TO ORIGINAL PROJECT SCOPE OR OBJECTIVES: none

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PRINCIPAL INVESTIGATORS:
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Therese Poland, Research Entomologist, NC-4501, East Lansing
Toby Petrice, Biological Technician, NC-4501, East Lansing
Dennis Haugen, Entomologist, FHP, St. Paul

COOPERATORS:
Cyrus Smith, Instrumentation and Controls Division, Oak Ridge National Laboratory (ORNL)
Glenn Allgood, Instrumentation and Controls Division, Oak Ridge National Laboratory

COOPERATOR INVOLVEMENT:

Name	Role	Time Commitment
Cyrus M. Smith	Instrument Development	10%
Glenn O. Allgood	Data Analysis	5%

A. FUNDING

1) First fiscal year funded: FY-00
2) Funds obligated from beginning of project through final fiscal year:

	Item	STDP funding ($)	NC-4501($)	ORNL ($)	
FY 2000					
Admin items:	Salary	33,000	45,000	20,000	
	Overhead	3,000		750	
	Travel	5,000	5,000	2,000	
Procurement	Contracting		20,000		
	Equipment	6,000		1,000	
	Supplies	3,000	5,000		
Total FY2000 Budget		50,000	75,000	25,000	=150,000
FY 2001					
Admin items:	Salary	33,000	45,000	20,000	
	Overhead	3,000		750	
	Travel	5,000	5,000	2,000	
Procurement	Contracting		20,000		
	Equipment	6,000		1,000	
	Supplies	3,000	5,000		
Total FY2001 Budget		50,000	75,000	25,000	=150,000
TOTAL		100,000	150,000	50,000	= 300,000

B. PROPOSED OUTPUTS:

1) Products and due dates**:** 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. 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.
2) Were the proposed outputs delivered? Considerable new knowledge about the acoustical signals of ALB larvae

and other wood-boring insects has been gained. A prototype acoustic detection system has been developed for research use. Project reports were submitted at the end of FY00 and FY01. A journal publication will soon be prepared. An invention disclosure document was submitted within ORNL and a patent will be sought in FY02. Results of the research have been presented at five scientific meetings.

3) Were the outputs delivered on time? Yes.

C. TECHNOLOGY / METHOD USE

1) Were the proposed or actual outputs used? . The prototype acoustic detection system is being used to gather additional data which will be used to refine the system. A field portable ALB detection system is still under development by staff at ORNL.
2) If outputs were not used provide the reasons the project may not have provided a usable product.
   A field portable ALB detection system for operational use is still under development. A patent application will soon be filed. Final product development is planned for FY02

D. DISTRIBUTION OF OUTPUTS

1) University and/or Research Involvement
   a) Universities involved: none
      Research Unites involved: NC-4501
   b) Number of graduate theses written: none

2) Dissemination of Results
   a) Number of peer-reviewed journal articles accepted for publication: none. One or more scientific papers will be prepared.
   b) Number of reports written: 2
      STDP Progress Report
      STDP Final Report
   c) Number of Presentations made: 6
      (a) Joint Annual Meeting of the Entomological Society of America and Entomological Society of Canada in 2000, (b) USDA Interagency Research Forum on Gypsy Moth and Other Invasive Species conference in 2001, (c) North Central Forest Pest Workshops in 2000 and 2001, and (d) IUFRO conferences in France in 2001 and Scotland in 2001.

3) Technology Transfer Activities
   a) Number of sessions: no formal TT efforts

E. REFINEMENT OF T&M

1) Does the project investigate use with or use of other forest health management tools? No.
2) Do the results of the project improve on existing technologies? Yes
   Current technology relies on visual inspection. However, results from the current STDP project will allow for the development of acoustic technologies to detect infested trees and SWPM.
3) Did the project identify new research or technology needs? Yes
   Additional recording should be made of other bark- and wood-boring insects to further expand the current library of insect feeding sounds.
4) Did the project result in new technologies? Yes.
   A new prototype acoustic detection system has been developed which will be refined for operational use as a hand-held field-portable detector.
5) Product leveraging
   Was the project part of a development sequence? No.
   Does the project build on past research and/or STDP project results? No.

ACCOMPLISHMENTS:

In 2000, we collected vibration data from native cerambycid larvae (e.g., pine sawyer, red oak borer and locust borer) feeding in cut logs in the laboratory. In addition, vibration data were collected from different ALB larval instars at the USFS quarantine facility in Ansonia, Connecticut. Field work to collect vibration data of ALB larval

feeding in trees (elm, poplar and willow) in a natural setting was performed in China. Different tree species were infested with both ALB and other cerambycid species to determine the effect of tree species upon larval feeding vibrations.

The results demonstrated that larval feeding in wood produced detectable vibrations. The vibrations from ALB and other cerambycids were, as expected, somewhat similar. In addition, the type of woody tissue being consumed apparently influenced the vibrations. The tissue at the wood-bark interface, where young larvae feed, is soft and pliable and resulted in small amplitude vibrations. Older larvae feed deeper in the sapwood of the tree and their feeding produced larger amplitude vibrations. In areas of suspected new tree infestations, there may be a lower limit to the age at which larvae can be detected.

We also observed that the amplitude of larval feeding vibrations diminished with distance between the sensor and the larva and also with the type of coupling between the sensor and the infested wood (i.e., air or direct wood contact). In trees, vibrations appeared to move most strongly with the wood grain. Therefore, detection instruments may need to be intrusive (i.e., the sensor may need to be coupled to the wood). It was originally hoped that a detection system for airborne sound would be practical to construct (i.e., ALB in the tops of trees could be detected by a person on the ground with a parabolic microphone pointed toward the top of the trees). However, this may not prove to be practical.

Initial algorithms for detecting feeding larvae from the vibration data were developed. These algorithms were successful in detecting the presence of infestations in sample logs and in trees in natural settings in China. The algorithm is a real time filter that is optimized to respond to beetle feeding vibrations in manually selected representative data sets. Incoming data is passed through this algorithm (filter). The output of the algorithm is proportional to how closely the incoming data "matches" the manually selected representative data sets. (i.e., a close match yields a high amplitude output and no match yields no output).

The detection algorithms were incorporated into a data collection and analysis system and installed on a laptop computer. This system is fully portable and has been used to acquire and analyze data in the field in China. The analysis of the data is completed in real time and indications and confidence factors of infestations are delivered and displayed on the computer's screen in real time. All of the components utilized in this system are easily miniaturized and can be integrated into a much smaller package size.

In 2001, the data acquisition and analysis efforts were concentrated on improving the detection and identification capabilities of the system. The initial version of the hardware and software utilized only a single channel of information. However to adequately characterize the influences of distance between larva and sensor and differences in wood species, we needed to collect multiple channels of data. The hardware data acquisition system was expanded to incorporate the collection of three channels of data. This allowed for simultaneous observation of the "bite signature" from a single event at different distances between the larvae and sensor in the same piece of wood. This provided insight into how the characteristics of the "bite signature" changed as they passed through the wood. The detection and identification analysis algorithm must take these changes into account so that "bites" can be identified anywhere on a piece of wood where larvae may be present.

The analysis algorithms were modified to analyze the three channels of simultaneous data. In addition, better discrimination routines were incorporated into the analysis to increase the rejection of vibrations that were not ALB "bites" and to give indications of how good a match the detected "bites" were to the detection algorithm. Figure 1 illustrates a simultaneous time waveform from each of the three vibration sensors. The three sensors were spaced at various distances along an infested tree in Chicago. The ALB larva was located near vibration sensor #2. Vibration sensor #1 was located on the same branch of the tree within 2 m of sensor #2 and was close enough to also detect the "bite". Vibration sensor #3 was located on a different branch of the tree at least 3m away so the vibrations from the "bite" were not detected by the current analysis algorithms. Figure #2 illustrates one type of output, a false colored spectral image of the signals from each of the three vibrations sensors. The detection of the "bite" can be seen as increased red coloring over a range of frequencies (vertical scale) at the time location (horizontal scale) of the "bite". These indications are important in evaluating the effect of distance and wood type on the "bite signature."

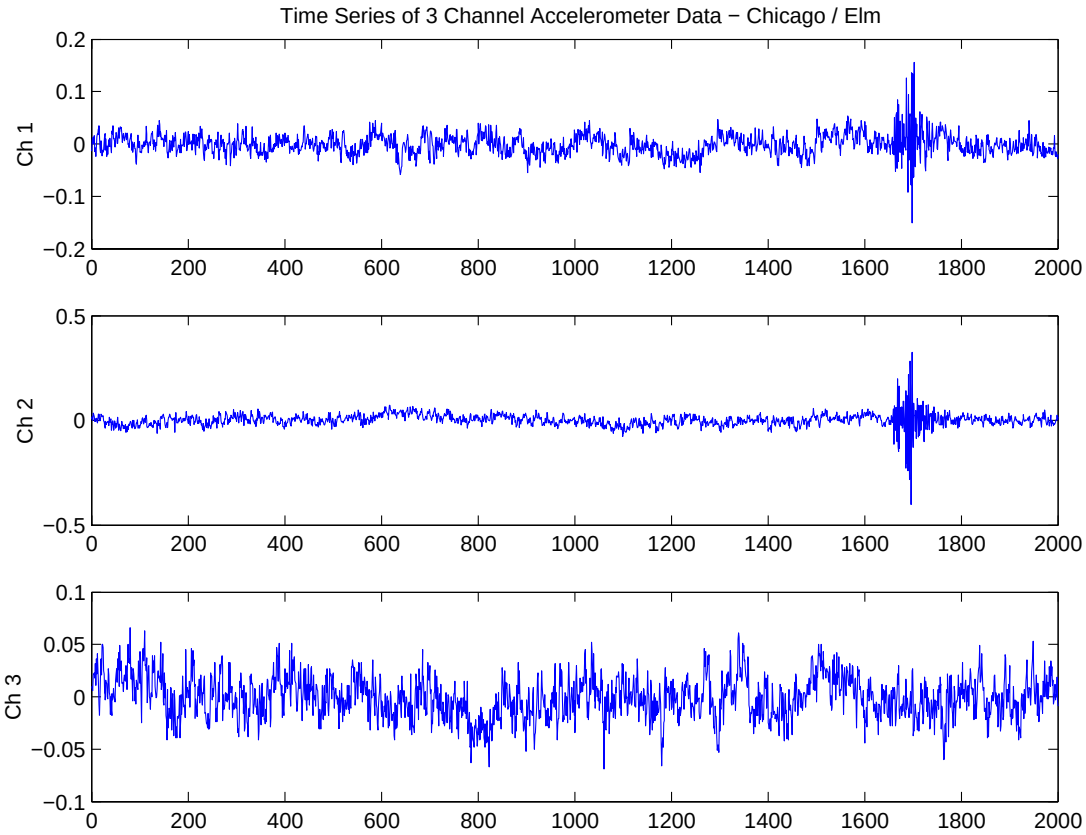

Figure 1. Simultaneously-collected time waveforms of a single ALB "bite" that was recorded at different distances between the vibration sensors and the larva.

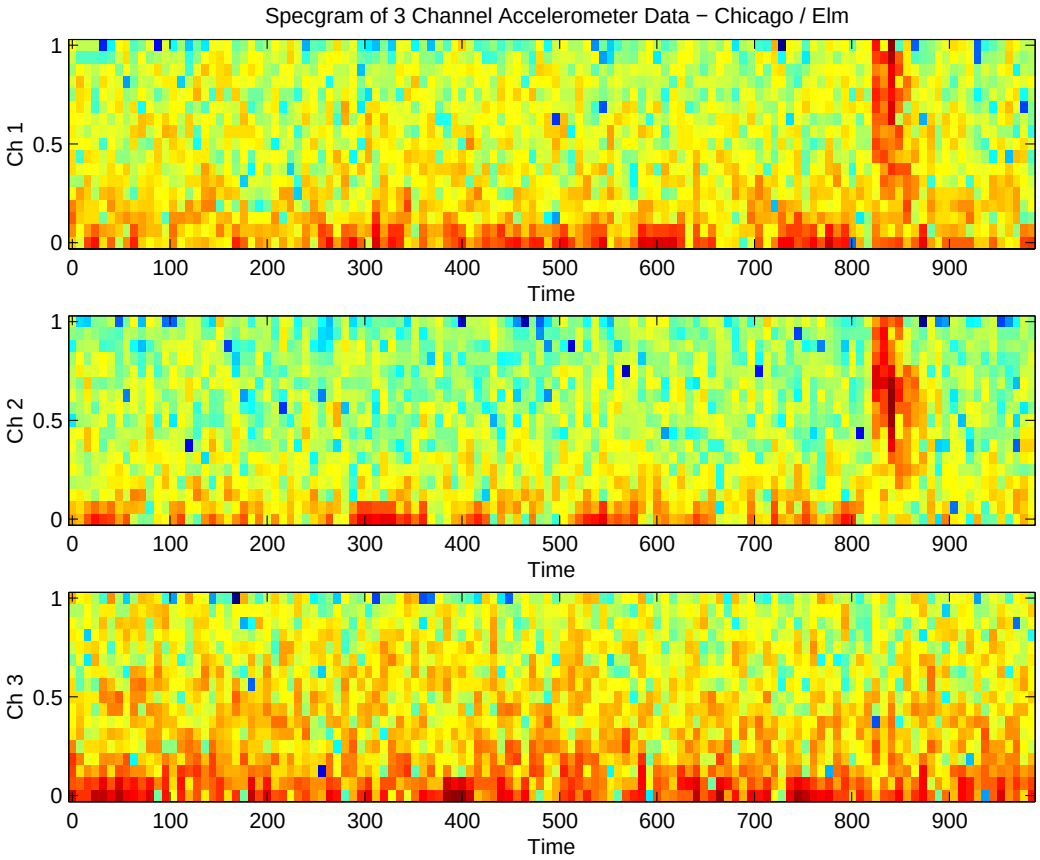

Figure 2. Spectrograms of the vibration signals from three simultaneously sampled vibration sensors of a single ALB "bite."

A Generation II system was assembled at ORNL that could be used in the field. The Generation II system incorporated the same data acquisition and analysis hardware and software on a "belt-worn" format computer. "Belt-worn" computers are much smaller, lighter, and more portable than laptop computers and are carried in a mesh "belt" worn around the user's waist. This Generation II system paves the way to produce an inexpensive, hand-held instrument for detection of the ALB.

A series of experiments utilizing ALB and non-ALB larvae to quantify the effects of distance between larva and sensor and type of wood is planned for October/November of 2001 and during spring 2002. These experiments should provide the necessary data to complete the characterization of the ALB detection and identification algorithms. The information from these experiments will be incorporated into the analysis algorithms of the original and Generation II systems. Both systems will be employed in field work and additional controlled experiments to verify and confirm the performance of the new algorithms.

Final research efforts during FY 2002 will be funded with NC-4501's internal funds.