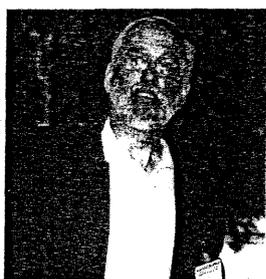


US Department of Agriculture, Forest Service, North Central Research Station, East Lansing, Michigan, USA

## Research on *Anoplophora glabripennis* in the United States

Forschungsarbeiten zu *Anoplophora glabripennis* in den Vereinigten Staaten von Amerika

Robert A. Haack



In the mid-1990s it was estimated that more than 400 exotic (non-native) forest insects had already become established in the United States (HAACK and BYLER, 1993; MATTSON et al., 1994; NIEMELA and MATTSON, 1996). This number has continued to grow with new exotics discovered annually in the United States (HAACK, 2002; HAACK and POLAND, 2001; HAACK et al., 2002). One recent arrival is the Asian cerambycid beetle *Anoplophora glabripennis* (Motschulsky). In North America, this beetle is commonly referred to as the "Asian longhorned beetle." *Anoplophora glabripennis* was first found in New York City in 1996 (CAVEY et al., 1998; HAACK et al., 1996, 1997; HAACK et al., 2000), then in Chicago, Illinois, in 1998 (POLAND et al., 1998), and most recently in Jersey City, New Jersey, in October 2002. Breeding populations of *A. glabripennis* were also recently discovered in Austria in 2001 (TOMICZEK et al., 2002).

In the United States, a federal quarantine was implemented by the United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA APHIS) in March 1997 to regulate the artificial movement of host material that could contain life stages of *A. glabripennis*. The quarantine regulates movement of recently cut tree branches and logs, firewood, and nursery trees. Beginning in 1997, USDA APHIS initiated an eradication program, which aims to detect, cut, and chip all infested trees in the United States. As of November 2002, 5923 infested trees have been cut in New York State and 1545 trees in Illinois. As of October 2002, about 100 infested trees have been located in New Jersey within an area that is 4 ha in size.

United States researchers have conducted dozens of studies on *A. glabripennis* since 1997. The main focus of these studies was to develop new knowledge and technologies that would be useful in the *A. glabripennis* eradication program. So far, only a small percent of these studies have been formally published in scientific journals; however, abstracts of most studies have been published in conference proceedings (ANONYMOUS, 2002; FOSBROKE and GOTTSCHALK, 1999, 2000, 2001, 2003; PARKER and ANDRUS, 2001) and on the internet (<http://www.uvm.edu/albeetle/research/index.html>). Dozens of federal and university researchers have been involved in studies that addressed *A. glabripennis* biology, taxonomy, rearing, survey, control, economic impact, regulatory issues, and public education. Studies have taken place in the China, South Korea, and the United States.

Studies on *A. glabripennis* biology have been conducted in both the United States and Asia. Given the objective to eradicate

*A. glabripennis* in the United States, most biological studies are conducted in quarantine laboratories in the United States or under field conditions in Asia, primarily China. These biological studies have focused on host range, within-tree attack pattern, dispersal, adult longevity, fecundity, larval development, and antennal receptors. Four formal papers have so far been published. KEENA (2002) and SMITH et al. (2002) reported that under laboratory conditions average *A. glabripennis* fecundity ranged from 51 to 193 eggs per female and average adult longevity ranged from 73 to 104 days. In another study, SMITH et al. (2001) noted that season-long dispersal by *A. glabripennis* adults was nearly 1.5 km under field conditions in China. In a study conducted in China, GAO et al. (2000) reported that *A. glabripennis* and *A. nobilis* were able to cross-breed successfully and therefore were likely a single species.

Two papers have been published on *A. glabripennis* morphology and taxonomy. First, CAVEY et al. (1998) described in detail *A. glabripennis* larvae and how they can be distinguished from *Monochamus* larvae as well as other commonly encountered North American cerambycid genera. Second, LINGAFELTER and HOEBEKE (2002) completed a revision of the genus *Anoplophora* in which they recognized 36 species of *Anoplophora*, as well as placed *A. nobilis* in synonymy with *A. glabripennis*. In a related paper, LINGAFELTER and HOEBEKE (2001) described variation in the elytral pattern of several *Anoplophora* species from Japan and Taiwan. Several studies involving DNA analysis are also being conducted to (a) compare Chinese and United States *A. glabripennis* populations, (b) develop DNA markers so that individual cerambycid larvae can be identified to species, and (c) explore phylogenetic relationships among *Anoplophora* species.

Many researchers have worked on rearing methods for *A. glabripennis* given that beetle colonies are being maintained in at least four quarantine laboratories in the United States (ANONYMOUS, 2002; FOSBROKE and GOTTSCHALK, 2001; PARKER and ANDRUS, 2002). In general, adults are fed twigs and allowed to oviposit on cut branch sections. The resulting eggs or larvae are later dissected from the branches and then reared on artificial diet. A cold period is generally needed prior to pupation. DUBOIS et al. (2002) published details on one of three artificial diets that are being used to rear *A. glabripennis* larvae. In addition, *A. glabripennis* oviposition on artificial substrates is being evaluated to obviate the need for cut branch sections.

As part of the survey effort, all potential host trees are visually inspected for signs and symptoms of *A. glabripennis* attack, such as oviposition pits, exit holes, frass, and sap exudation (HAACK et al., 1997, 2000). Acoustic detectors have been developed to supplement visual inspection. These devices perceive the feeding sounds of *A. glabripennis* larvae within distances of 6–7 meters (ANONYMOUS, 2002; FOSBROKE and GOTTSCHALK, 2001,

2003; PARKER and ANDRUS, 2002; POLAND et al., 2002). There has been little success in the development of attractive lures and traps for *A. glabripennis* adults. It now appears that *A. glabripennis* does not produce a long-distance pheromone, but rather orients visually to its host and then finds a mate using contact pheromones. Several cuticular hydrocarbons from adult females elicit mating behaviour in males (FOSBROKE and GOTTSCHALK, 2001, 2003; PARKER and ANDRUS, 2002). In addition, ZHANG et al. (2002) reported on two attractive compounds that are produced by *A. glabripennis* adult males. In studies that attempted to record the rate of spread of the actual infestations in Chicago, it appeared that 96% of *A. glabripennis* adults dispersed within 200 m, and 99% dispersed within 400 m of their larval host tree. These values have been used to set certain survey and quarantine boundaries (FOSBROKE and GOTTSCHALK, 2001, 2003; PARKER and ANDRUS, 2002).

Several systemic and topical insecticides were evaluated for control of *A. glabripennis* wood-feeding larvae and twig-feeding adults (ANONYMOUS, 2002; FOSBROKE and GOTTSCHALK, 2001, 2003; PARKER and ANDRUS, 2002; POLAND et al., 2002). This line of research was needed because APHIS wanted safe and effective insecticides to apply to all potential host trees growing in buffer zones around each infestation. Imidacloprid, which is relatively safe to mammals, was found to be effective against both *A. glabripennis* larvae and adults. Therefore, APHIS selected imidacloprid as the primary pesticide that would be used in the eradication program (FOSBROKE and GOTTSCHALK, 2003; PARKER and ANDRUS, 2002).

A variety of Chinese and North American predators, parasitoids, and entomopathogens have been evaluated for *A. glabripennis* control in case eradication is not successful (ANONYMOUS, 2002; FOSBROKE and GOTTSCHALK, 2001, 2003; PARKER and ANDRUS, 2002). One general review paper was written on *A. glabripennis* biological control agents (SMITH, 2000), and another paper described the effectiveness of nematodes in controlling *A. glabripennis* (SOLTER et al., 2001). Other researchers have evaluated various species of fungi (e.g., *Beauveria brongniatii*), microsporidia, *Bacillus thuringiensis* toxins to control *A. glabripennis*. Surveys for *A. glabripennis* natural enemies are being conducted in both China and the United States. The parasitoids *Dastarcus longulus* (Coleoptera: Colydiidae) and *Scleroderma guani* (Hymenoptera: Bethyilidae) are the two principal natural enemies of *A. glabripennis* in China (ANONYMOUS, 2002; FOSBROKE and GOTTSCHALK, 2001, 2003; SMITH, 2000).

As part of the eradication program, all infested trees were at first cut, chipped, and burned soon after discovery. However it was not known if burning was necessary. As a result, WANG et al. (2000) conducted a study that indicated that chipping alone was sufficient in killing nearly all within-tree life stages.

NOWAK et al. (2001) used field data from nine United States cities along with national tree cover data to estimate the potential effects of *A. glabripennis* on the nation's urban trees. Overall, the maximum potential national urban impact of *A. glabripennis* was estimated to be a loss of 1.2 billion trees (30.3% mortality of all urban trees) with a value of US \$ 669 billion. These authors are now completing a similar study that will estimate the potential economic impact on natural and planted forests in the United States.

Several studies addressed regulatory issues and exclusion (ANONYMOUS, 2002; FOSBROKE and GOTTSCHALK, 2001, 2003; PARKER and ANDRUS, 2002). Heat treatment studies of infested lumber indicated that all test larvae died when the core temperature of the wood reached 60 °C for 30 minutes. Fumigation with methyl bromide was effective in killing *A. glabripennis* larvae

between temperatures of 4–21 °C, but sulfuryl fluoride was not effective. Microwave treatment of 900 W killed larvae in 30 seconds in dry wood, and in 2–5 minutes in green lumber. Indicators that verify treatment are still being developed. Non-contact ultrasound and acoustic technologies have been evaluated for their ability to detect larvae in lumber. Another related project will determine which tree species are the most commonly used for solid wood packing material in various parts of China and what are the most commonly associated wood-infesting insects of each tree species.

Before the eradication programs began in Illinois and New York, several public meetings were held with local officials and residents to obtain local support (HAACK et al., 1997, 2000). Local residents and community leaders were assured that tree removal would be followed by a tree planting program, and that all costs would be paid by the government. A formal survey of homeowner attitudes towards the eradication program found that it is important to keep the public well informed, provide regular updates, and assure that all authorities involved in the eradication effort provide a clear and consistent message to the public (PARKER and ANDRUS, 2002).

In October 2002, a workshop was sponsored by USDA APHIS to identify high priority research projects that would be useful to the eradication program. Alternative survey methods were discussed, including the use of sentinel trees, development of branch or trunk traps to capture walking adults, and remote sensing technology to help identify potential host trees on properties where access is difficult such as rooftops and courtyards. With respect to trunk injection methods, improvements are needed to more quickly apply the insecticide and to assure better within-tree distribution. Similarly, environmentally acceptable, easy-to-apply methods are needed to deliver *A. glabripennis* pathogens to individual trees. Other discussion topics involved mass-rearing of *A. glabripennis* for research as well as for possible release of sterile adults, and mass-rearing of biocontrol agents.

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Contact address: Dr. Robert A. Haack, US Department of Agriculture, Forest Service, North Central Research Station, 1407 S. Harrison Road, East Lansing, Michigan 48823 USA, e-mail: rhaack@fs.fed.us