

# The United States Experience with the Exotic Cerambycid *Anoplophora glabripennis*: Detection, Quarantine, and Control

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## Introduction

It is estimated that there are at least 4500 exotic (non-indigenous) organisms currently established in the United States (US) (US Congress 1993) and possibly as many as 50,000 (Pimentel et al. 2000). Of the many exotic organisms now in the US, more than 400 are insects that feed on trees and shrubs (Haack and Byler 1993, Mattson et al. 1994, Niemela and Mattson 1996). Many of these exotic insects have severely impacted forest ecosystems throughout the US (Ciesla 1993, Liebhold et al. 1995, Morrell and Filip 1996, Wallner 1996, Mattson 1997).

Primarily as a result of world trade and travel, established populations of new exotic organisms are found in the US almost every year. During the past decade, for example, established populations of four major bark- and wood-feeding insects were discovered in North America. They include (1) the pine shoot beetle, *Tomicus piniperda* (Coleoptera: Scolytidae), which was first found in Ohio in 1992 and is now found in 11 US states and 2 Canadian provinces (Haack and Kucera 1993, Haack et al. 1997a); (2) an Asian longhorned beetle, *Anoplophora glabripennis* (Coleoptera: Cerambycidae), which was first found in New York in 1996 and now is also in Chicago, Illinois (Haack et al. 1997b, Poland et al. 1998); (3) the smaller Japanese cedar longhorned beetle, *Callidiellum rufipenne* (Coleoptera: Cerambycidae), which was first found in North Carolina in 1997 and now is known to occur in six northeastern US states (Haack 1998, USDA APHIS 1999); and (4) a spruce-feeding Eurasian longhorned beetle, *Tetropium fuscum* (Coleoptera: Cerambycidae), which was only recently reported from Halifax, Nova Scotia, Canada, in May 2000 (Halifax Regional Municipality 2000).

Of these new arrivals, the longhorned beetle *Anoplophora glabripennis* (Motschulsky) is probably the most significant threat to the hardwood forests of the US. This beetle is often referred to as the Asian longhorned beetle in US newspapers and other media outlets. This paper will summarize the discovery of *A. glabripennis* in the US, basic life history data for the beetle, survey and eradication efforts, and interception data at US ports-of-entry.

## **Native Range and US Discovery**

The native range of *A. glabripennis* definitely includes China and Korea (Peng and Liu 1992). In China, *A. glabripennis* is found across a latitudinal range from 21°N to 43°N Latitude (Yan 1985). Earlier references to *A. glabripennis* being native to Japan are likely in error (Nobuo Ohbayashi, Ehime University, Japan, personal communication).

*Anoplophora glabripennis* now occurs in two US states: New York and Illinois. Established populations of *A. glabripennis* were first discovered in New York in 1996 (Haack et al. 1996, 1997b, Haack and Mastro 1997, Cavey et al. 1998, Haack and Cavey 1998,) and then in Illinois in 1998 (Poland et al. 1998). In New York, *A. glabripennis* was first reported on 19 August 1996 when a resident of Brooklyn (which is part of New York City and is located on the western end of Long Island) notified city officials that all of the Norway maple (*Acer platanoides*) trees on his property had several large holes and that there were large beetles walking on these trees. Over the next few days, beetles were collected and identified by experts as *A. glabripennis*. This was the first report of *A. glabripennis* being established anywhere in the world outside of its native range. In September 1996, populations of *A. glabripennis* were discovered in the town of Amityville, which is also on Long Island, about 50 km east of Brooklyn. Since 1996, *A. glabripennis* has been found in a few additional areas of New York City (Manhattan Island and Queens) and other towns in central Long Island (Islip, Lindenhurst). The Brooklyn infestation is considered to be the original site of infestation and probably occurred sometime in the 1980s. The infestation in Queens could have resulted from an independent infestation or it could have resulted from natural or human-assisted spread from Brooklyn. The population in Amityville is thought to have resulted from the inadvertent movement of infested wood from Brooklyn. Similarly, the populations in Islip and Lindenhurst appear to have resulted from the inadvertent movement of infested wood from Amityville. Lastly, the origin of the population in Manhattan may have resulted from natural spread from Brooklyn or again from inadvertent movement of infested wood from either Brooklyn or Queens.

On 10 July 1998, a resident of the Ravenswood area of Chicago, Illinois, collected a few beetles that had emerged from branch sections that had been cut from a local tree. Finding these beetles to be very interesting in appearance, the resident used the Internet in hopes of obtaining information about their identity. By chance, the resident found an Internet web page that described *A. glabripennis* and the infestation in New York. The resident immediately informed local Chicago officials that he had collected beetles that may be *A. glabripennis*. The adult beetles were soon sent to experts and on 13 July 1998 they were positively identified as *A. glabripennis*. As a result of extensive newspaper, television, and radio coverage on the discovery of *A. glabripennis* in Chicago, two other smaller infestations were reported by local Chicago residents by August 1998. One infestation was found in a part of Chicago known as Addison and the other was found in an area called Summit. Each of these three infestations is thought to have originated independently from infested solid wood

packing materials that were associated with imports from Asia sometime in the early to mid-1990s. In 1999, at least 3 other small infestations were found in the Chicago area; however, each of these probably resulted from human-caused spread as a result of inadvertent movement of infested tree branches and trunk sections.

### Host Range and Life Cycle

In China, the primary host trees of *A. glabripennis* include species of maple (*Acer*), poplar (*Populus*), willow (*Salix*), and elm (*Ulmus*), while occasional host trees in China include chinaberry (*Melia*), mulberry (*Morus*), plum (*Prunus*), and pear (*Pyrus*) (Qin et al. 1985, Sun et al. 1990, Gao et al. 1993, He and Huang 1993). It is important to note that confusion still exists in the host range data for *A. glabripennis* in China due to possible errors in beetle identification in earlier scientific literature and taxonomic uncertainties among the 40-plus species of *Anoplophora* that are native to Asia. For example, in recent crossbreeding experiments in China, *A. glabripennis* and *Anoplophora nobilis* produced viable offspring and therefore now should be considered a single species (Gao et al. 2000). *Anoplophora glabripennis* has been especially destructive in the northern half of the China where tens of millions of hectares of land have been planted since 1978 to genera and species of *Populus*, *Salix*, *Robinia pseudoacacia*, *Ulmus*, *Paulownia*, and *Amorpha* as part of China's "Three-North Protective Forest System" (Li et al. 1999).

In Chicago and New York, *A. glabripennis* has attacked primarily species of maple, including boxelder (*Acer negundo*), Norway maple, sycamore maple (*Acer pseudoplatanus*), red maple (*Acer rubrum*), silver maple (*Acer saccharinum*), and sugar maple (*Acer saccharum*). In New York and Chicago, *A. glabripennis* has also completed development on one or more species of horsechestnut (*Aesculus hippocastanum*), birch (*Betula*), ash (*Fraxinus*), Rose-of-Sharon (*Hibiscus*), poplar, willow, and elm. Complete development of *A. glabripennis* on species of *Aesculus*, *Fraxinus*, and *Hibiscus* had never before been reported in the Chinese literature. More than 80% of the infested trees in Chicago and New York have been maple trees, indicating both the beetle's preference for maples but also reflecting the fact that maples had been the most popular type of tree planted along streets and in parks in these two infested US states.

In Chicago and New York, *A. glabripennis* adult females have been observed laying eggs on trees from June to mid-December, with peak adult activity occurring in July and August. Newly emerged adults first feed on the bark of twigs, or occasionally on leaves and petioles, and then mate on the trunks and branches. Adults can fly distances of more than 1000 meters in search of host trees. Although it is possible that adult females produce a pheromone (= sex attractant), no pheromones have yet been identified for this species (He and Huang 1993). When laying eggs, an adult female will chew through the bark to the cambium, and then turn and lay a single egg (5-7 mm long) in the cambial region under the bark. Adult beetles can live for several weeks, and females often lay 25 to 50 eggs in their lifetime.

Eggs usually hatch in one to two weeks depending on temperature. Larvae first feed in the cambial region of the tree and later enter the wood, both sapwood and heartwood, tunneling in an upward direction for 10 to 30 cm. Full-grown larvae often reach 50 mm in length (Cavey et al. 1998). The larval stage is the most common overwintering stage for *A. glabripennis*, but some eggs and pupae have been found during the winter months in the US. Typically, larvae transform to pupae, usually 30-33 mm long, in early summer and then later emerge as adults through circular exit holes that measure 6 to 18 mm in diameter but average about 12 mm. Adults commonly measure 20 to 35 mm long, they are shiny black in color with several white dots on their elytra, and have antennae that are banded in black and white (Haack et al. 1997b).

### **Attack Behavior and Damage**

*Anoplophora glabripennis* attacks healthy trees, stressed trees, and recently cut logs (Peng and Liu 1992, Gao et al. 1993, He and Huang 1993). Both small diameter and large diameter trees are attacked. For example, in New York, attacked trees varied from less than 10 cm to greater than 1.8 m in diameter (Haack et al. 1997b). Adults typically initiate egg laying in the upper trunk and along major branches where the bark tends to be smooth. Individual trees are attacked repeatedly over several years. Eventually the attacks extend from small branches that are only 2 to 4 cm in diameter to the base of the tree and along exposed roots.

Adult beetles may cause some twig mortality as a result of their maturation feeding; however, most damage is caused by the larvae as they tunnel through the wood. After several years of repeated attack, individual branches or entire trees can be killed. However, what happens more often is for heavily attacked branches and stems to break, especially during strong winds (Qin et al. 1985, Yan 1985, Gao et al. 1993, Haack and Mastro 1997). The quality of lumber, veneer, and wood fiber is also reduced as a result of the larval feeding tunnels.

### **Survey and Eradication Efforts**

In New York, surveys for *A. glabripennis*-infested trees began in September 1996. Surveys were conducted by city, state, and federal inspectors. At first, surveys consisted of visual inspections of all known potential host trees that were located along the streets or in parks within the infested area of Brooklyn. For all of Brooklyn, it is estimated that there are more than 500,000 trees that grow along streets and in parks and an additional 100,000 trees in private properties of which more than one-third are potential hosts of *A. glabripennis* (Kucera 1996). Inspections were done from the ground. When examining a tree, inspectors looked for characteristic signs of *A. glabripennis* infestation, such as exit holes, oviposition pits, bark staining near the oviposition pits, and frass that had been pushed out of the tree by the larvae through the original oviposition pits. Some frass sticks to the bark near the oviposition pits, while most of the frass falls and accumulates along the bark of the trunk, in branch crotches, and at the base of the tree. New York State imposed a quarantine on the infested areas of Amityville and Brooklyn in December

1996. The quarantine restricted the movement of all potential host material, including firewood, to areas outside the two quarantine zones. A similar federal quarantine was imposed by USDA APHIS (United States Department of Agriculture, Animal and Plant Health Inspection Service) in March 1997. As additional areas of infestation were discovered in New York, they were immediately placed under the quarantine.

USDA APHIS convened a group of experts in October 1996 to serve as a Science Advisory Panel that would provide advice as to what actions should be taken against *A. glabripennis*. The Science Advisory Panel concluded that an eradication program should be attempted because *A. glabripennis* was considered a high risk pest, the known New York infestations were relatively small in size, and there was no known practical way to kill all the larvae inside each infested tree, even with the use of systemic insecticides. The goal of the eradication program was to locate, cut, chip, and burn all infested trees. In addition, the eradication program stated that all potential host trees in each infested area would be inspected at least once per year and that the inspections would continue for at least five years after the last infested tree was found.

Before the eradication program could begin it was necessary to obtain the support of local officials, environmental groups, and private citizens that lived in the affected areas. Several public meetings were held with local officials and residents to discuss the biology of *A. glabripennis*, the damage it causes, and the rationale for the eradication program. In addition, local residents and community leaders had to be assured that tree removal would be followed by tree planting programs. After the eradication effort was approved, contracts had to be made with local tree removal companies. The contracts listed a specific payment schedule for each tree based on its diameter, and included payment for tree felling, stump-grinding, chipping, cleanup, and burning.

When *A. glabripennis* was confirmed to be in Chicago on 13 July 1998, local officials were able to benefit greatly from New York's previous two years of experience with *A. glabripennis*. On 15 July 1998, city, state and federal officials met in Chicago and developed an action plan, and on 16 July the Mayor of Chicago announced that the City of Chicago would implement an eradication program and that the costs of the program would be covered by the government. As in New York, local television, newspaper, and radio coverage in Chicago was excellent, and public support for the eradication program was strong. Both quarantines and tree surveys were initiated in each infested area by late July 1998. City, state, and federal employees assisted in the surveys. In addition, several other US states sent their plant inspectors to Chicago to assist in the surveys and thereby receive training in how to recognize signs of *A. glabripennis* infestation. The first round of visual inspections was completed during the summer and fall months of 1998, with tree removal beginning during February 1999. Early in 1999, inspectors in Chicago started to use bucket trucks and eventually tree climbers to improve inspection of the upper crowns of tall trees. In Chicago it was discovered that many lightly infested trees had been missed when the inspections were conducted only from

the ground. For example, in the same area of Chicago where 425 infested trees had been found by surveying from the ground, another 300 additional infested trees were found when bucket trucks and tree climbers were used.

### **Current Situation in the US**

As of the time of this writing (June 2000), the eradication programs have been in existence for nearly 4 years in New York and 2 years in Chicago. As of May 2000, 4693 infested trees have been cut in New York and 1357 trees in Chicago, for a total of 6050 trees. During the first year of the eradication program in New York, 1220 trees were discovered and cut. Similarly, 784 trees were cut in New York during the second year of the program, 954 in the third year, and 1735 in the fourth year. The major increase in the number of infested trees found during the fourth year of New York's eradication program reflects the discovery of three new infested sites during that year. In Chicago, 886 trees were discovered and cut in the first year of the eradication program and 471 trees in the second year. The decrease in the number of infested trees discovered during the second year in Chicago, may reflect the fact that Chicago inspectors started to use bucket trucks and tree climbers during the end of the first year of their eradication program. By contrast, surveys in New York have used only visual inspections from the ground during the first four years of their eradication program. Surveys will continue in the year 2000 and for the foreseeable future in both New York and Chicago. Because of the good success that tree climbers have had in locating infested trees in Chicago, New York will begin to use tree climbers in 2000. In Chicago during May 2000, a new program was conducted to help slow the spread of *A. glabripennis*. In this trial project, nearly 7000 healthy trees were injected with the systemic insecticide imidacloprid. The injected trees formed a protective barrier between infested and uninfested areas in Chicago. It is hoped that if *A. glabripennis* adults reach these insecticide-treated trees that either the adults will die while feeding on the twigs or else their larvae will die as they begin to feed in the sapwood. It is estimated that the total combined city, state, and federal expenditures on *A. glabripennis* survey, eradication, restoration, public education, and research from 1996 through 2000 will be nearly US\$ 35,000,000.

### **Restoration Activities**

In both New York and Chicago, large-scale tree planting efforts have been initiated in the infested areas. Generally, for each infested tree that is cut, another tree is planted at government expense. Trees used for replanting are currently thought not to be hosts of *A. glabripennis*. The most common tree genera and species used for replanting include serviceberry (*Amelanchier*), ironwood (*Carpinus betulus*), catalpa (*Catalpa bignonioides*), Turkish filbert (*Corylus colurna*), ginkgo (*Ginkgo biloba*), honeylocust (*Gleditsia triacanthos*), Kentucky coffeetree (*Gymnocladus dioica*), tuliptree (*Liriodendron tulipifera*), dawn redwood (*Metasequoia glyptostroboides*), London plane tree (*Platanus acerifolia*), sweetgum (*Liquidambar styraciflua*), oak (*Quercus*), Japanese lilac (*Syringa reticulata*), baldcypress (*Taxodium distichum*), and linden (*Tilia*).

## Public Education

A large number of educational efforts have been initiated in Illinois and New York, and also in many other US states. Brochures (e.g., USDA Forest Service 1997) describing how to identify *A. glabripennis* adults and characteristic signs of infestation in trees have been prepared for professional groups that work with trees such as arborists, urban foresters, landscapers, nursery managers, foresters, garden clubs, and extension specialists. Cavey et al. (1998) published a paper that describes morphological details of *A. glabripennis* larvae and highlights differences between larvae of *Anoplophora* and *Monochamus*. In addition, several Internet websites have been created to provide up-to-date information and color photos of *A. glabripennis*. The three most popular and most complete *A. glabripennis* websites are:

<http://willow.ncfes.umn.edu/asianbeetle/beetle.htm>

<http://www.ceris.purdue.edu/napis/pests/alb/>

<http://www.aphis.usda.gov/ppq/longhorn.html>

## Research Efforts

Several research programs have been initiated on *A. glabripennis* by federal and university researchers in the US. Most of these studies are being conducted in quarantine laboratories in the US where *A. glabripennis* can be handled and studied safely. These studies cover many aspects of the beetle's biology such as development, fecundity, host preference, flight behavior, rearing techniques, pheromones, insecticides, microbial control, and genetic relatedness of *A. glabripennis* populations in the US. A few studies are being conducted in the affected areas of Chicago and New York, such as determining the direction and rate of beetle spread, the within-tree attack pattern, and community reactions to the eradication efforts. Other studies are aimed at acoustic detection of larval feeding noises in trees and wood treatment techniques using fumigants, heat, and microwaves. Still other studies are being conducted in China in cooperation with the Chinese Academy of Forestry, Beijing Forestry University, and the Chinese Inspection and Quarantine Agency. The main areas of study in China deal with aspects of chemical control, adult dispersal, biological control, host range, rate of spread, and wood treatment technologies. In addition, research on *A. glabripennis* was initiated in Canada at a quarantine facility of the Canadian Forest Service in 2000. Canada is very concerned about *A. glabripennis* given that the two US *A. glabripennis* infestations are relatively close to Canada's borders with the US and the fact that *A. glabripennis* has been intercepted in Canada in recent years on wood articles from China. Initial studies in Canada will focus on cold-hardiness of *A. glabripennis*.

## Interception History

Even though *A. glabripennis* probably entered New York during the 1980s and Chicago during the early 1990s, no cerambycid had ever been intercepted at a US port-of-entry and identified as *A. glabripennis* until 1997. This situation probably reflects the fact that cerambycid larvae are difficult to identify, and that larvae in the genus *Anoplophora* closely resemble larvae in the genus *Monochamus* (Cavey et al. 1998).

During the years 1985 to 1998, there were more than 150 interceptions of *Monochamus* larvae at US ports-of-entry in solid wood packing materials from China (Cavey 1998, Poland et al. 1998). It is now thought that some of these 150 *Monochamus* interceptions were identified incorrectly, and that some of the larvae were probably *Anoplophora*. However, once *A. glabripennis* was discovered in the US in 1996, USDA APHIS placed much more effort on identification of intercepted cerambycid larvae, especially if the cerambycid larvae originated from Asia. As a result, during 1997 and 1998, there were 28 interceptions of *A. glabripennis* or *Anoplophora* sp. at US ports-of-entry in solid wood packing materials from China. Of these 28 interceptions, 10 were associated with crating, 1 with pallets, 1 with dunnage, and 16 with unspecified solid wood packing material. For the 28 *Anoplophora* interceptions, the associated products were barbells on 2 occasions, 5 occasions with iron products, 2 with machinery, 2 with metal products, 3 with miscellaneous cargo, 4 with slate, 2 with tiles, and 8 occasions where the product was not listed. In 1999, no *Anoplophora* were intercepted in the US on wood articles from China. This dramatic decrease in the number *A. glabripennis* interceptions is a result of both stricter US regulations that were imposed on solid wood packing material from China beginning in December 1998 (USDA APHIS 1998) and excellent compliance with the new regulations by Chinese exporters. For example, during September 1999, USDA APHIS inspected 8276 shipments from China and of these only 11 shipments (0.1%) were found to have solid wood packing material that was not in full compliance with the new regulations. Moreover, of the 11 shipments that were not in full compliance, only 1 was found to have a live insect (but not *A. glabripennis*), while the other 10 were not in compliance due to invalid documents such as improper treatment certificates or exporter statements.

Although it was mentioned above that no *A. glabripennis* had ever been intercepted at US ports-of-entry until 1997, there had been one earlier report of *A. glabripennis* being discovered in crating from China at a point of final destination in Loudenville, Ohio, in 1992 (Haack et al. 1996). Surveys for *A. glabripennis* in Loudenville, Ohio, were conducted in 1996 and 1997, but there was no evidence that *A. glabripennis* had become established.

### **World Trade Issues**

As a result of world trade, there is always the risk of unintentional introductions of exotic pests. For example, during the years 1985 through 1998, USDA APHIS intercepted insects on 6952 occasions on various wood articles at US ports-of-entry (Haack and Cavey 1997, and chapter in this proceedings). During the years 1985-1998, there has been a steady increase in the number of insect interceptions on wood articles from China at US ports, likely reflecting the growing volume of Chinese exports to the US (Haack et al. 1997b). For example, using US Bureau of the Census statistics, imports from China in 1985 represented 1.1% of all US imports for that year, and similarly, 3.1% in 1990, 6.1% in 1995, 6.5% in 1996, 7.2% in 1997, and 7.8% in 1998. Similarly, the number of insects intercepted on wood articles from China represented 1.2% of all insects

intercepted on wood in the US in 1985, 1.2% in 1990, 11.2% in 1995, 21.2% in 1996, 28.6% in 1997, and 43.5% in 1998. In 1999, however, the number of insects intercepted on wood articles from China, as a fraction of all US insect interceptions on wood, fell to 10.4%, again reflecting the stricter regulations imposed on China in December 1998 that required that all solid wood packing material used in association with exports to the US be certified as having been heat treated, fumigated or treated with preservatives prior to export (USDA APHIS 1998). The North American Plant Protection Organization (NAPPO) plans to adopt similar regulations on solid wood packing materials in the next few years and apply them worldwide. If all countries adopted such a policy there would be a dramatic reduction in the number of new introductions of bark-infesting and wood-boring insects as a result of world trade.

However, even if all solid wood packing materials were free of insects there would still be a risk of moving wood-boring insects through other means. For example, in 1999, both *Anoplophora chinensis* and *Anoplophora malasiaca* were found in bonsai trees imported to the US from China. For both *Anoplophora* species, adult beetles emerged from bonsai trees while in greenhouses in the US. However, no beetles are known to have escaped and possibly become established. These two *Anoplophora* species are primarily pests of fruit trees, especially citrus. Also in 1999, the cerambycids *Callidiellum rufipenne* and *Callidiellum villosulum* were found in semi-artificial Christmas trees that had been imported to the US from China (Jane Levy, USDA APHIS, Riverdale, Maryland, personal communication). During the manufacturing of these semi-artificial trees, the branches and foliage were made from plastic, but the trunks were actual trunk sections from trees of the genus *Cryptomeria*. These two species of *Callidiellum* attack primarily trees in the families Cupressaceae and Taxodiaceae (USDA APHIS 1999). In the above case, several thousand semi-artificial Christmas trees were imported into the state of Kansas, and from there distributed to retail stores in several other states throughout the US. Live *Callidiellum* adults were found emerging from several of these "trees" in stores in at least six US states (Georgia, Kansas, Minnesota, Nebraska, Oregon, and Wisconsin). USDA APHIS and state plant health regulators attempted to locate and fumigate all of these semi-artificial trees, but many of the trees had already been sold to the public. It is not known if any adult *Callidiellum* beetles reached the outdoors and established themselves, but inspections for these beetles will be conducted in each of the states that received the infested semi-artificial trees. In the US, artificial Christmas trees are classified as "holiday decoration products" and as such are seldom associated with plant material and therefore not generally inspected at US ports-of-entry. In summary, it is critical that all exporters and importers take great care in ensuring that all products that move in world trade are pest free.

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