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Managing Invasive Populations of Asian Longhorned Beetle and Citrus Longhorned Beetle: A Worldwide Perspective

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Key Words

Anoplophora chinensis, *Anoplophora glabripennis*, Cerambycidae, exotic, eradication

Abstract

The Asian longhorned beetle (ALB), *Anoplophora glabripennis* (Motschulsky), and citrus longhorned beetle (CLB), *Anoplophora chinensis* (Forster) (Coleoptera: Cerambycidae), are polyphagous xylophages native to Asia and are capable of killing healthy trees. ALB outbreaks began in China in the 1980s, following major reforestation programs that used ALB-susceptible tree species. No regional CLB outbreaks have been reported in Asia. ALB was first intercepted in international trade in 1992, mostly in wood packaging material; CLB was first intercepted in 1980, mostly in live plants. ALB is now established in North America, and both species are established in Europe. After each infestation was discovered, quarantines and eradication programs were initiated to protect high-risk tree genera such as *Acer*, *Aesculus*, *Betula*, *Populus*, *Salix*, and *Ulmus*. We discuss taxonomy, diagnostics, native range, bionomics, damage, host plants, pest status in their native range, invasion history and management, recent research, and international efforts to prevent new introductions.

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Exotic: species not native to a given area; similar terms include alien, nonnative, nonindigenous

ALB: Asian longhorned beetle

CLB: citrus longhorned beetle

INTRODUCTION

As international trade continues to expand, so does the number of pests that become established outside their native range (57). Dozens of bark- and wood-infesting insects are among the thousands of exotic insect species found worldwide (39, 72, 103). Two of the most destructive wood borers that invaded Europe and North America in recent years are Asian longhorned beetles (Coleoptera: Cerambycidae), commonly called the Asian longhorned beetle (ALB), *Anoplophora glabripennis* (Motschulsky), and the citrus longhorned beetle (CLB), *A. chinensis* (Forster) (16, 39, 49). This review focuses on ALB and CLB biology, pest status, invasion history, management efforts, and recent research. We conclude with a discussion of international efforts aimed at preventing new introductions.

TAXONOMY

ALB and CLB are members of the recently revised genus *Anoplophora* Hope that now consists of 36 species (80). In this revision, *Anoplophora nobilis* (Ganglbauer) was placed in synonymy with *A. glabripennis* (80). This synonymy has been supported by cross-mating studies (35), isoenzyme comparisons (116), and random amplified polymorphic DNA (RAPD) comparisons (6), but not by molecular comparisons of sequence-characterized-amplified-region (SCAR) primers (65). *A. malasiaca* (Thomson) was also placed in synonymy with *A. chinensis* (80). We found no journal articles that supported or refuted this synonymy, although the name *A. malasiaca* is still commonly used in Japan (32, 139, 140). In this review, we consider *A. nobilis* a synonym of *A. glabripennis*, and *A. malasiaca* a synonym of *A. chinensis*.

DESCRIPTION

The life stages of ALB and CLB are similar in appearance (**Figures 1–3**). Adults of both species are glossy black with 10–20 distinct irregular-shaped patches on the elytra, although in rare instances the number of patches ranges from 0 to over 60 (80). Patch color is usually white but can be shades of yellow to orange in the *nobilis* form of ALB and at times pale yellow in CLB (80). Body length usually ranges between 17 and 40 mm (79, 80). The major distinction between ALB and CLB adults is the presence of 20–40 small projections (tubercles) on the basal quarter of each elytron in CLB, but not in ALB (**Figure 1**). Antennae are composed of 11 segments, with a banding pattern in which the basal portion of each segment (antennomere) is pale blue or white and the distal portion is black (**Figure 1**). The ratio of antennal length to body length in ALB is about 2 for males and less than 1.5 for females (44).

Eggs are oblong, white, and 5–7 mm long (79, 80) (**Figure 3**). Larvae are legless, cream-colored, and 30–50 mm long when mature (16) (**Figure 2**). Larvae of both species have a pigmented pronotal shield that differs in shape and size between the two species (**Figure 3**). Pupae are whitish and 27–38 mm long (79, 80) (**Figure 2**).

NATIVE RANGE

All *Anoplophora* species are native to Asia; most species occur in the tropics and subtropics (80). The native range of ALB includes China and Korea (80). Museum records of ALB in Japan from 1860, 1911, and 1912 led some authors to conclude that ALB was native to Japan (16, 55). However, as of 2009, ALB is not considered native to Japan nor does it occur in Japan (80, 83). In fact, a recent introduction of ALB in Japan was eradicated (114). The native range of CLB includes primarily China, Korea, and Japan, with occasional records from Indonesia, Malaysia, Philippines, Taiwan, and Vietnam (80).

BIONOMICS

The life cycles of ALB and CLB are similar and well described (ALB: 39, 41, 47, 55, 62, 78, 80, 98, 110, 135, 146, 147; CLB: 1, 3, 4, 37, 79, 80, 126, 134). Both species generally take one year

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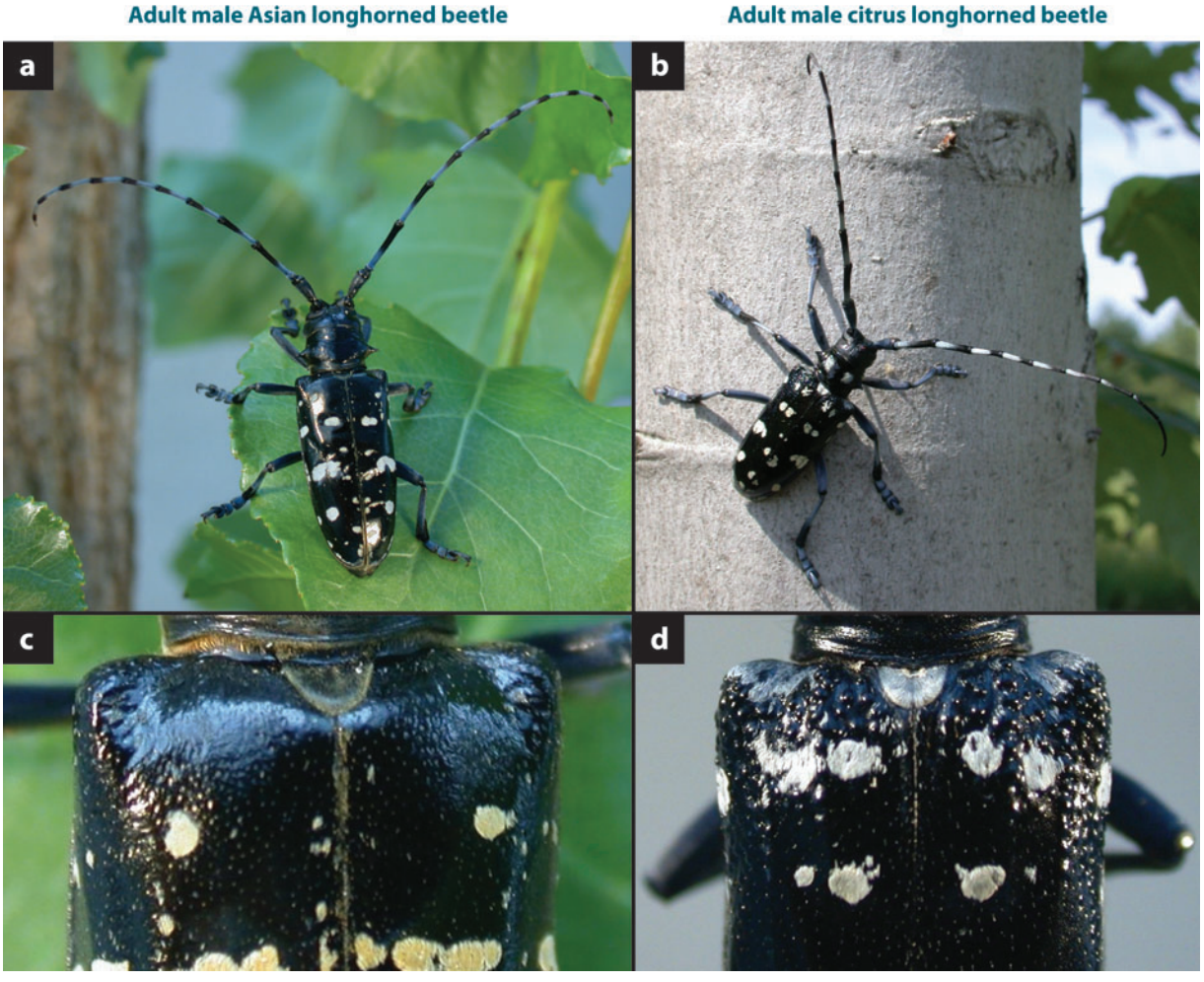

Figure 1

(*a*) Adult male Asian longhorned beetle (ALB). (*b*) Adult male citrus longhorned beetle (CLB). (*c*) Smooth surface of the basal portion of the elytra of ALB. (*d*) Grainy surface, due to small projections or tubercles, of the basal portion of the elytra of CLB. Photos by Franck Hérard.

to complete their life cycles, although two years is common. Apparently larvae need to reach a critical weight before overwintering to induce pupation the next summer (63).

Depending on local temperatures, adults have been observed from April to December, with peak activity usually during May to July. Adults of both species conduct maturation feeding for 10–15 days before initiating oviposition, usually feeding on twigs, petioles, and veins of leaves (**Figure 2**). Mate-finding is mediated by contact and short-range pheromones for ALB (47, 143, 144) and CLB (30, 31, 90, 125, 138, 139); no long-range pheromones have been reported. Adult longevity and fecundity are influenced by the larval host plant and temperature conditions (1, 46, 47, 62, 64, 78, 89, 110, 135). ALB typically initiates oviposition along the upper trunk and main branches (39), whereas CLB usually lays eggs along the lower trunk, root collar region, and on exposed roots (18, 86). ALB females usually chew a distinct funnel-shaped

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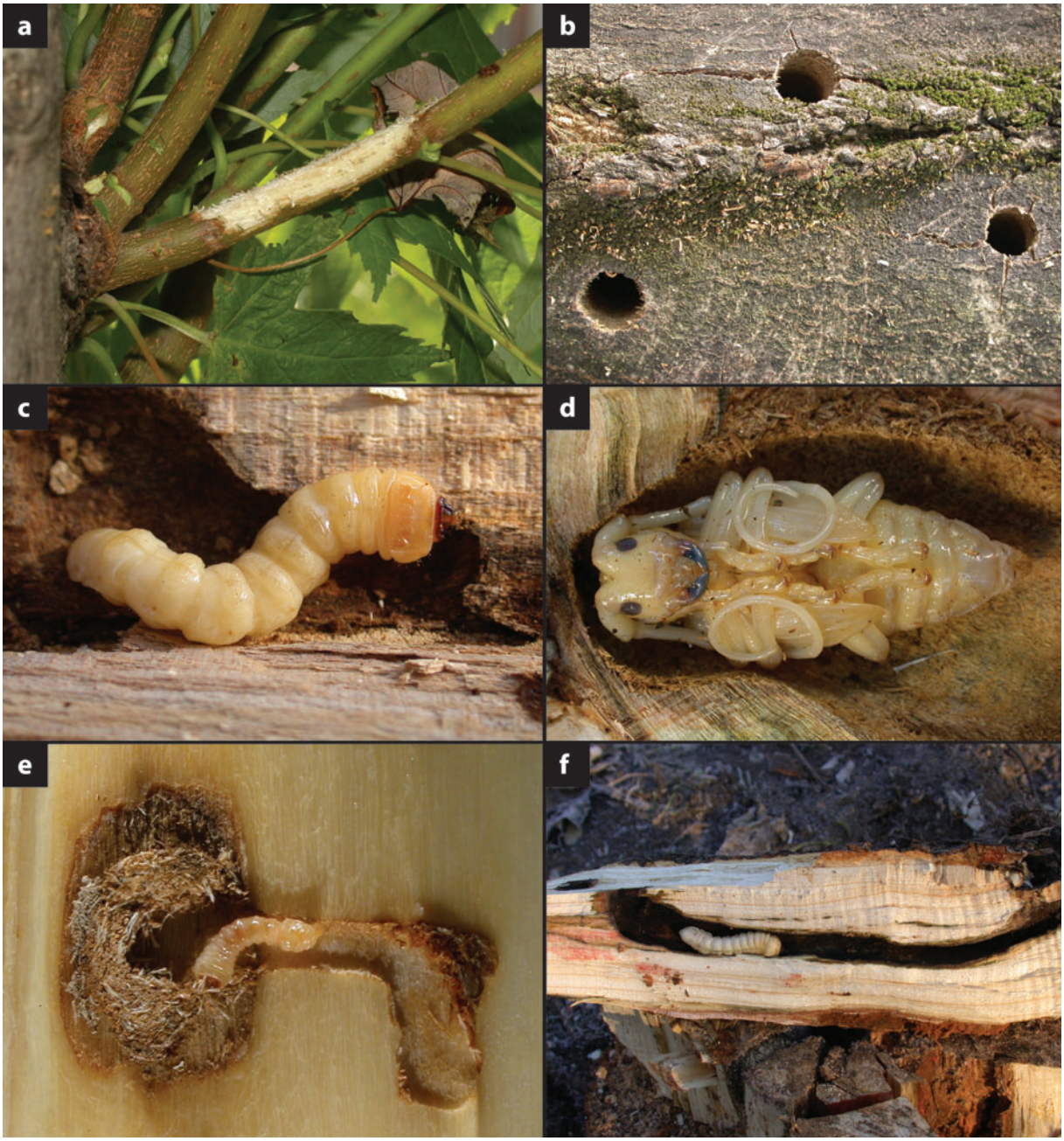

Figure 2

Features that Asian longhorned beetle (ALB) and citrus longhorned beetle (CLB) have in common. (*a*) Feeding damage by adults on twigs. (*b*) Circular exit holes. (*c*) General shape of a full-grown larva. (*d*) General shape of a pupa. (*e*) A young larva feeding in cambial region. (*f*) Larval gallery or tunnel in wood. Photos by Franck Hérard.

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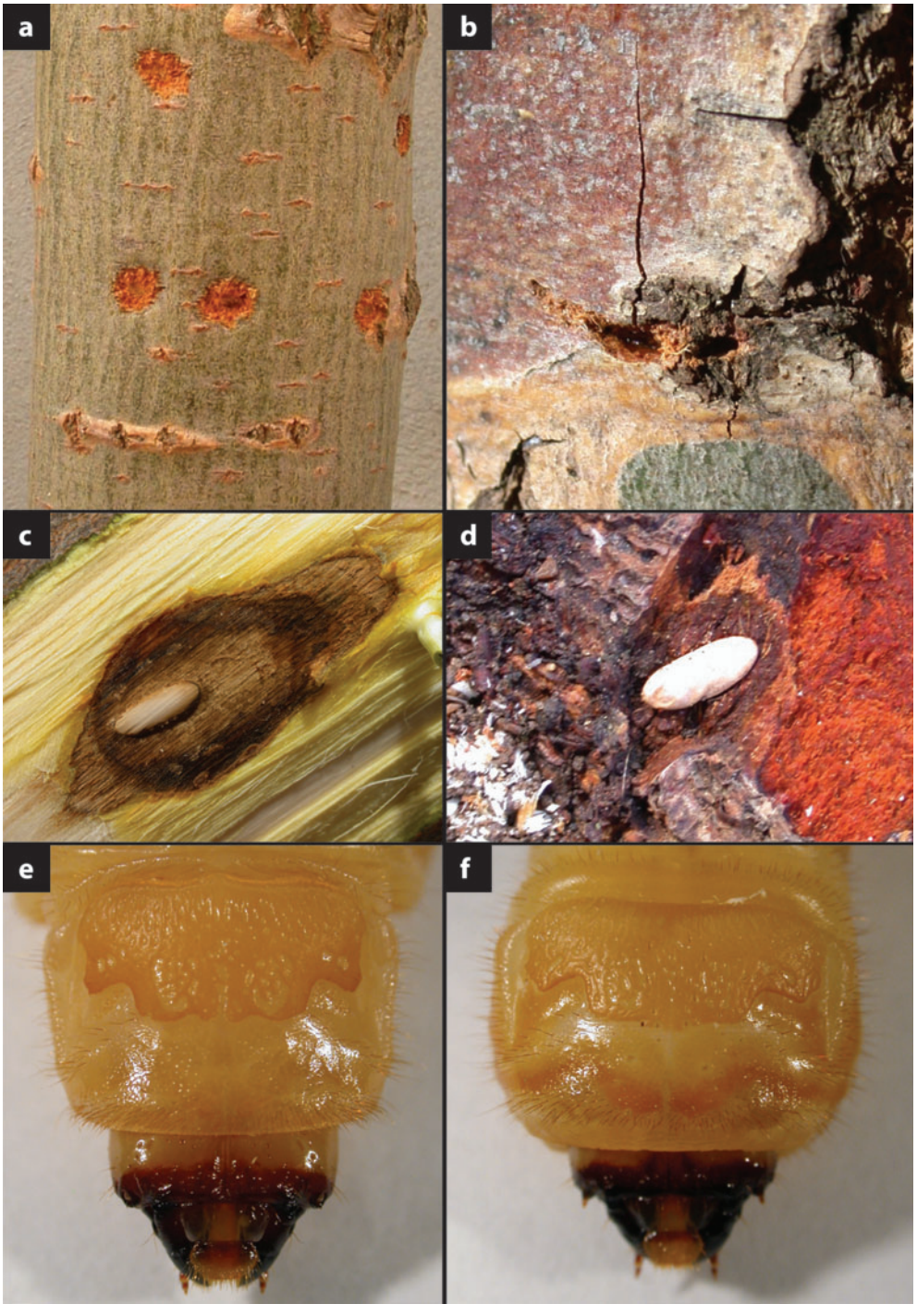

Figure 3

Features in which the Asian longhorned beetle (ALB) and the citrus longhorned beetle (CLB) differ. (*a*) Typical ALB oviposition pits. (*b*) Typical CLB T-shaped oviposition slit. (*c*) ALB egg laid beneath the bark in the cambial region. (*d*) CLB egg laid within the bark tissue. (*e*) Typical pronotal plate of an ALB larva. (*f*) Typical pronotal plate of a CLB larva. Photos by Franck Hérard.

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Oviposition pit and oviposition slit: locations on the bark surface where the adult female has chewed before oviposition

Cambial region: tissues between the bark and wood, usually including the inner bark, cambium, and outer sapwood

Polyphagous: feeding on several plants from more than one family

Complete development: when adults successfully emerge from eggs laid on a given host plant

Infested and suspect trees: an infested tree contains live individuals of the target pest; a suspect tree possesses only signs or symptoms of infestation

oviposition pit through the bark and inject a single egg beneath the bark (**Figure 3**). In CLB, females chew a slit in the bark and inject a single egg within the bark tissues (**Figure 3**) (18). The bark often splits when the ovipositor is inserted, resulting in T-shaped oviposition sites for CLB (**Figure 3**). These T-shaped oviposition slits are also made by ALB on occasion (118). Mark-release-recapture experiments revealed that adults of both species can disperse 1–3 km during their life span, although most remain near the tree where they emerged (ALB: 7, 104, 109, 111, 120, 133, 149; CLB: 3).

Eggs laid in summer usually hatch in 1–2 weeks. Larvae first create a feeding gallery in the cambial region and later an oval-shaped tunnel in the sapwood and heartwood (**Figure 2**); larvae expel frass from their tunnels near the original oviposition site. Most individuals overwinter as larvae. Pupation occurs at the end of the larval tunnel usually in late spring and early summer. Adults emerge through circular exit holes that typically measure 10–15 mm in diameter (**Figure 2**) but can range from 6 to 20 mm (80, 118, 135).

DAMAGE

Adult feeding on twigs and foliage is considered of minor importance except occasionally on fruit-bearing trees (37, 79). Most damage results from larval tunneling in the cambial region and wood (4, 18, 34, 41, 101, 135). After years of repeated attack, larval galleries disrupt the tree's vascular tissues and cause structural weakness, both of which can lead to tree death. Both species attack healthy and stressed trees (34, 55), varying in size from small bonsai and potted trees (especially CLB) to mature trees (18, 39, 41, 49, 121). Larval feeding also reduces wood quality (34, 142).

In its native range, ALB has killed millions of trees in China (15, 78, 97, 142, 148), whereas the greatest economic losses from CLB in Asia have occurred in fruit-tree plantations, especially citrus (37, 79). Outside their native range, both ALB and CLB have caused tree mortality (39, 41, 49) and are ranked as high-risk quarantine pests (82, 121). In addition to natural forests, 35% of U.S. urban trees are considered at risk of infestation by ALB (95).

HOST PLANTS

ALB and CLB are highly polyphagous; dozens of tree species from several families (at least 15 families for ALB and 36 for CLB) have been reported as hosts in Asia, Europe, and North America (49, 80, 105). However, complete development has not been confirmed on all tree species listed as hosts (112).

In its native range, ALB infests trees primarily in the genera *Acer* (Sapindaceae), *Populus* (Salicaceae), *Salix* (Salicaceae), and *Ulmus* (Ulmaceae) (39, 80, 128, 132). Several other genera have been reported as occasional hosts in Asia (13, 80, 112, 123, 128). In the United States, ALB has completed development on species of *Acer*, *Aesculus* (Sapindaceae), *Albizia* (Fabaceae), *Betula* (Betulaceae), *Cercidiphyllum* (Cercidiphyllaceae), *Fraxinus* (Oleaceae), *Platanus* (Platanaceae), *Populus*, *Salix*, *Sorbus* (Rosaceae), and *Ulmus* (40, 105). *Acer* was the most commonly infested tree genus in the United States, followed by *Ulmus* and *Salix* (**Table 1**). In Canada, complete development has been confirmed only on *Acer*, *Betula*, *Populus*, and *Salix*, although oviposition has occurred on other tree genera. *Acer* was the most commonly infested tree genus in Canada (118) (**Table 1**). In Europe, complete development has been recorded on *Acer*, *Aesculus*, *Alnus* (Betulaceae), *Betula*, *Carpinus* (Betulaceae), *Fagus* (Fagaceae), *Fraxinus*, *Platanus* (Platanaceae), *Populus*, *Prunus* (Rosaceae), *Salix*, and *Sorbus* (49, 51). The top five host genera infested in Europe, in decreasing order, are *Acer*, *Betula*, *Salix*, *Aesculus*, and *Populus* (49) (**Table 1**). Not all *Populus* species are equally susceptible to ALB attack. For example, in China, *Populus* species in sections *Aigeiros* and *Tacamahaca* are generally more susceptible to ALB than species in section *Leuce* (128, 142). Whether susceptibility differs greatly in other tree genera has not been reported.

In Asia, CLB has a much broader host range than ALB and may even include conifers

in the genera *Cryptomeria* (Cupressaceae) and *Pinus* (Pinaceae) (13, 80). In Europe, CLB has completed development on species of *Acer*, *Aesculus*, *Alnus*, *Betula*, *Carpinus*, *Citrus* (Rutaceae), *Cornus* (Cornaceae), *Corylus* (Betulaceae), *Cotoneaster* (Rosaceae), *Crataegus* (Rosaceae), *Fagus*, *Lagerstroemia* (Lythraceae), *Liquidambar* (Altingiaceae), *Malus* (Rosaceae), *Platanus*, *Populus*, *Prunus*, *Pyrus* (Rosaceae), *Quercus* (Fagaceae), *Rhododendron* (Ericaceae), *Rosa* (Rosaceae), *Salix*, *Sorbus*, and *Ulmus* (49). *Acer* was the most commonly infested tree genus in Europe, followed by *Betula* and *Corylus* (**Table 1**). In addition, CLB oviposition, but only partial larval development, has been recorded on species of *Acacia* (Fabaceae), *Cryptomeria*, *Viburnum* (Adoxaceae), *Ficus* (Moraceae), and *Eriobotrya* (Rosaceae) in Europe.

ASIAN LONGHORNED BEETLE OUTBREAKS IN CHINA

History

Regional outbreaks of ALB in China have been reported during the past few decades, but we found no reports for regional CLB outbreaks in Asia. The first ALB outbreaks occurred in eastern China in the 1980s (136). By the early 1990s, ALB infestations had been reported throughout most of China except for the far western provinces of Qinghai, Tibet, and Xinjiang and the far northeastern province of Heilongjiang (78). In the early 2000s, ALB was present in all provinces in mainland China, although only a limited number of counties were infested in some provinces (113, 127–129). By 2004, ALB distribution had expanded in China by about 2° northward, 2° eastward, and 15° westward compared with 20 years earlier (128).

In China, ALB has been a pest primarily of plantations, windbreaks, and urban trees (112). ALB outbreaks and range expansion in China were linked to widespread afforestation and reforestation programs that began in eastern China in the 1960s, using mostly native *Populus dakuanensis*, a species later found to be highly susceptible to ALB (74, 78). The largest of the tree-planting programs was the Three-North Shelterbelt Forest Program, initiated in the arid regions of northern China in 1978 with the goal of establishing forests on more than 35 million ha by 2050 (15, 74, 78, 115, 142). The main goal of the Three-North Program was to increase forest cover and thereby slow desertification and reduce soil erosion. A secondary goal was to increase lumber production. Initially, *Populus*, *Salix*, and *Ulmus* were the principal genera planted, including several exotic *Populus* species (142). Single clones were used in some plantings, and mixed species or clones were used in others. As of 2003, over 22 million ha had been planted in the Three-North Program (142). Widespread tree mortality has been reported in several provinces, especially where ALB-susceptible *Populus* species were planted (15, 141). For example, more than 80 million infested trees were cut in Ningxia and 11 million in Inner Mongolia (97). In the past decade, ALB outbreaks were most severe in the provinces of Heilongjiang, Jilin, Tibet, and Xinjiang (113, 127–129).

ALB outbreaks have not been reported in South Korea, where ALB is also native (132), perhaps because the natural forests of South Korea are dominated by conifers and *Quercus* (73), which are not preferred ALB hosts. South Korea began an ambitious reforestation program in 1959, planting about 3.8 million ha by 1992, including 781,000 ha of ALB-susceptible *Populus* species (73). Therefore, the potential exists for ALB outbreaks in South Korea.

Management

The Chinese State Forestry Administration initiated a major research and development program for ALB in 1985 (97). The principal research areas related to forest management were identifying host and nonhost tree species, designing mixed-species plantations, breeding for tree resistance, testing tree species such as *Acer negundo* as trap trees to protect high-value forest trees, lowering stand rotation age to reduce losses, and developing integrated pest

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Table 1 Summary data for the Asian longhorned beetle and citrus longhorned beetle infestations in North America and Europe through 2008[a]

	Year of discovery	Status in 2008	Maximum size of regulated area (km^2)[b]	No. infested trees cut[c]	No. high risk trees cut[d]	No. trees treated[e]	Eradication costs ($\times$ 1000)[f]	Top five infested tree genera in decreasing order[g]
ALB								
Europe								
Austria	2001	Ongoing	50 (1)	192	900[d]	0	€464	*Acer*, *Betula*, *Salix*, *Aesculus*, *Fagus*
France	2003	Ongoing	12 (2)	173	0	0	€55	*Acer*, *Betula*, *Salix*, *Aesculus*, *Carpinus*
Germany	2004	Ongoing	26 (2)	106	0	0	€65	*Acer*, *Salix*, *Betula*, *Aesculus*, *Populus*
Italy	2007	Ongoing	13 (1)	4	309[d]	0	NA	*Acer*, *Betula*
North America								
Canada	2003	Ongoing	152 (1)	662[c]	25,000[d]	0	CAN$23,500	*Acer*, *Salix*, *Populus*, *Betula*
United States								
Illinois	1998	Eradicated	93 (1)	1,551	220	286,227[e]	US$6,881	*Acer*, *Ulmus*, *Fraxinus*, *Salix*, *Aesculus*[g]
Massachusetts	2008	Ongoing	166 (1)	0[c]	0[d]	0	NA	NA (mostly *Acer*)
New Jersey	2002	Ongoing	65 (2)	730	21,251	480,574	US$6,392	*Acer*, *Ulmus*, *Salix*, *Betula*[g]
New York	1996	Ongoing	362 (1)	6,262	12,124	99,782[e]	US$54,114	*Acer*, *Salix*, *Ulmus*, *Aesculus*, *Betula*[g]
U.S. total	1996	Ongoing	593[b] (5)	8,543	33,595	866,583[e]	US$373,430[f]	*Acer*, *Ulmus*, *Salix*, *Aesculus*, *Fraxinus*[g]

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CLB								
Europe								
France	2003	Eradicated	NA (1)	2	0	0	NA	*Acer*
Italy	2000	Ongoing	NA (6)	5,189	0	Several[e]	€1,500	*Acer*, *Betula*, *Corylus*, *Carpinus*, *Alnus*
Netherlands	2007	Ongoing	7 (1)	7	2,000	0	€1,250	*Acer*, *Corylus*

[a]Summary data were supplied by federal agencies in each infested country.
[b]Area is in km^2. The number of distinct infestations or regulated areas is given in parentheses. The total for the United States varied from year to year as new infestations were found and others were eradicated. The area was largest in 2008 with regulated areas in Massachusetts, New Jersey, and New York. (NA, not available).
[c]From year of discovery through 2008. Tree removal total for Canada included both infested and suspect trees. Tree removal in Massachusetts began in January 2009, with 15,085 infested trees cut through August 2009.
[d]From year of discovery through 2008. For Austria, the number does not include all trees cut in a Braunau woodlot in 2007. For Italy, only trees in the genera *Acer*, *Betula*, *Populus*, and *Salix* were considered at high risk. For Canada, the number is an estimate. For Massachusetts, tree removal began in January 2009, with 10,250 high-risk trees cut through August 2009.
[e]From year of discovery through 2008. U.S. policy states that trees will be treated for a minimum of three consecutive years. Thus, the U.S. data represent the total number of annual treatments made, several of which were made to the same trees in consecutive years. For Italy, numerous trees were sprayed with foliar insecticides to kill citrus longhorned beetle (CLB) adults.
[f]From year of discovery through 2008. The values given for individual U.S. states represent only state expenditures. The value given for the U.S. total includes the state expenditures plus federal expenditures by three USDA agencies involved in Asian longhorned beetle (ALB) eradication, research, and restoration: Agricultural Research Service, Animal and Plant Health Inspection Service (APHIS), and Forest Service.
[g]U.S. data for Illinois were based on Reference 40. Data for New Jersey and New York were through 2005 and supplied by A. Sawyer, USDA APHIS.

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Interception: detection of a pest during inspection of imported products or their associated packaging materials, or incidentally near to where infested material is stored, but prior to establishment

Wood packaging material (WPM): wood used to support (pallets), protect (crating), or brace (dunnage) cargo

management strategies (54, 97, 142). Other major research themes were in the areas of chemical, physical, and biological control, as well as pheromone development and trapping techniques (54, 97).

China has used internal quarantines to limit human-assisted spread of ALB within China by regulating movement of logs, lumber, firewood, and seedlings. In 1984, when *A. nobilis* and *A. glabripennis* were considered distinct species (80), both were placed on quarantine lists in several Chinese provinces (58). *A. nobilis*, which had a more western distribution in China (13, 128), was placed on China's national internal quarantine list in 1996 to slow its westward passive spread. In 2005, *A. nobilis* was removed from the national list once both forms of ALB became established in all mainland provinces. As of 2009, ALB remained on various provincial quarantine lists, especially where it had a limited range. Some recent ALB outbreaks were reported in areas of China where putatively ALB-resistant *Populus* varieties were planted, and therefore the threat of future outbreaks continues (113).

INVASION OF NEW AREAS

Interceptions

We requested historical *Anoplophora* interception data from several countries in the Americas, Australasia, and Europe. Most countries had interception records available in electronic databases that dated from the 1980s and a few that dated from the 1950s. Overall, 219 distinct interceptions of ALB, CLB, or *Anoplophora* spp. were made in 18 countries from 1980 through 2008 (**Table 2**). Both ALB and CLB were intercepted in wood packaging material (WPM) associated with imports such as steel, ironware, tiles, and quarry products as well as in live woody plants such as bonsai and nursery stock. Where species-level identifications were made (75% of 219 interceptions), most *Anoplophora* interceptions on WPM were ALB (96%), whereas most *Anoplophora* interceptions on live plants (i.e., bonsai and plants for planting) were CLB (99%). For this reason, in the discussion below, we considered *Anoplophora* spp. interceptions from WPM as ALB, and those from live plants as CLB. For those interceptions for which the country of origin was known (71% of 219 interceptions), most interceptions on WPM originated from China (97%), whereas infested live plants originated from China (85%), Japan (13%), and South Korea (2%).

The first reported ALB interception was in 1992 in both Canada and the United States (41); CLB was intercepted first in 1980 in the Netherlands (**Table 2**). Interceptions were made at ports of entry during inspection of imports and postentry at locations such as warehouses and nurseries. Overall, 86 of 145 ALB interceptions (59%) were made at ports of entry, compared with only 7 of 74 CLB interceptions (9%). The location where most interceptions were made varied among world regions. For example, for ALB and CLB combined, 45% of the 11 interceptions made in Australasia were made at ports of entry, as were 5% of 116 interceptions in Europe and 89% of 92 interceptions in North America. Although port inspectors often target high-risk cargo, overall inspection rates are low worldwide. For example, less than 2% of U.S. imports are inspected (93). In general, trained inspectors make pest interceptions at ports, whereas interceptions made postentry can be made by inspectors, company employees, and the public.

The most interceptions reported worldwide in a single year were 44 for ALB in 1998 and 24 for CLB in 2008 (**Table 2**). It is likely that the onset of ALB interceptions in 1992 and the sudden increase through 1998 were related to the outbreaks of ALB in China, increased trade between China and most other countries worldwide, and more targeted inspection of WPM from China after discovery of ALB in the United States in 1996. For example, for the years 1985, 1992, and 1996, trade with China represented 1.1%, 4.8%, and 6.4% of total U.S. imports, respectively (41). Similarly, for the same three years, the percentages of U.S. insect interceptions on WPM that originated from

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Table 2 Historical data on the number of reported interceptions[a] of Asian longhorned beetle (A) and citrus longhorned beetle (C) from selected countries[b] from 1980 through 2008[c]

Year	Australasia				Europe										North America							
	AU		NZ		FR		DE		UK		NL		EU[d]		CA		MX		US		Total	
	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C
1980												0/1[c]										1
1986												0/4										4
1987												0/6										6
1988												0/9										9
1989												0/1										1
1991												0/1										1
1992															2/0				0/1		3	
1994									0/1												1	
1995			1/0												0/1						2	
1997									0/1						2/0	1/0			6/0		9	1
1998						0/2			0/9			0/1			10/1				24/0		44	3
1999			0/1						0/4						3/0					1/2	8	3
2000			0/1						0/5			0/1			3/0				2/0		11	1
2001			1/0			0/1	0/1								1/1				1/0	1/1	5	3
2002						0/1	0/1		0/1						1/1						4	1
2003				0/1			0/1					0/1	0/1		4/1				2/0		9	2
2004			0/1				0/1		0/3	0/1		0/1	0/3		1/0				4/0		13	2
2005	0/1						1/4		0/2	0/1					3/0			1/0	1/1		13	2
2006	1/0		1/0							1/5				0/2							2	8
2007	1/0						1/1	0/1						0/1					1/0		4	2
2008	0/1				0/1		1/1	0/4	0/1	0/2	0/3	2/15	0/2	0/1	2/0				5/0		17	24
Total	2/2	0/0	3/3	0/1	0/1	0/4	3/10	0/5	0/27	1/9	0/3	2/41	0/6	0/4	32/5	1/0	0/0	1/0	46/2	2/3	145	74

[a]A single interception consisted of all *Anoplophora* specimens recovered from an entire consignment where the products had the same origin, shipping history, and arrived together. When larvae were intercepted, identification was usually made only to the genus level. To condense the dataset, specimens identified as *Anoplophora* spp. from wood packaging material were designated Asian longhorned beetle (A), and those from live plants were designated citrus longhorned beetle (C). It was not always possible to distinguish between the absence of interceptions and absence of survey; thus numbers were only entered in cells where at least one interception was made. A blank cell indicates that no ALB or CLB was recorded that year from each particular country, or that for some countries, surveys were not conducted during all years, especially during the 1980s.

[b]Country codes: AU, Australia; CA, Canada; DE, Germany; EU, rest of Europe; FR, France; MX, Mexico; NL, Netherlands; NZ, New Zealand; UK, United Kingdom; US, United States.

[c]For each pair of numbers, the left value is the number of interceptions made at ports of entry and the right value is the number of interceptions made post entry, such as at warehouses and nurseries. Postentry interceptions were not recorded consistently in all countries.

[d]Data for rest of Europe: year, country (number of interceptions). For ALB: 2003, Sweden (1); 2004, Czech Republic (1), Luxembourg (1), and Poland (1); 2008, Belgium (1) and Denmark (1). For CLB: 2006, Belgium (1) and Switzerland (1); 2007, Croatia (1); 2008, Lithuania (1).

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Established population: when a pest species perpetuates itself in a given area after entry

USDA APHIS: U.S. Department of Agriculture, Animal and Plant Health Inspection Service

Eradication: use of phytosanitary measures to eliminate a pest from a given area

China represented 1.2%, 4.4%, and 21.2% of all U.S. interceptions on WPM (41). With millions of ALB-infested trees being cut in China during the past few decades, it is understandable that some infested trees were ultimately used to construct WPM. The reason for the sudden increase in worldwide interceptions of CLB in 2008 is less clear. Perhaps this upsurge in CLB interceptions simply reflected an increase in imported live plants from Asia, or perhaps CLB populations were increasing near nursery production areas in Asia. Overall, it is difficult to discern actual trends in the interception data given annual variation in trade volume, trading partners, international regulations, and country inspection rates. However, it is clear that both ALB and CLB continued to move in international trade in 2008 despite implementation of measures to reduce their occurrence, especially in WPM (**Table 2**).

Arrival and Management

The first discovery of an established population of ALB outside its native range was in North America in 1996 (16, 41), and that of CLB occurred in 2000 in Europe (49). All infestations discovered through 2008 were first reported by the public, indicating the importance of public involvement in early detection. The management response by USDA APHIS (United States Department of Agriculture, Animal and Plant Health Inspection Service) to the discovery of ALB in 1996 was to attempt eradication. APHIS designed and implemented an eradication plan that addressed organizational structure, survey procedures, regulatory activities, control, restoration, public outreach, and media relations (120). That plan has served as a template to other countries that have discovered established populations of ALB and CLB.

United States: 1996. Breeding populations of ALB have been found in four U.S. states as of August 2009: first in Brooklyn, New York, in 1996; then Chicago, Illinois, in 1998; Jersey City, New Jersey, in 2002; and Worcester, Massachusetts, in 2008 (39, 41, 98) (**Table 1**). The infestations in Illinois, Massachusetts, and New York likely originated from single introductions in each state, whereas two distinct introductions likely occurred in New Jersey (104, 112) (**Table 1**). The management goal is to eradicate all infestations (120). Upon discovery of each infestation, delimitation surveys were undertaken to locate all trees with signs (oviposition pits, frass, and exit holes) and symptoms (thin crowns and sap flow near the oviposition pit) of attack (41, 112). In the first infestation in New York, observers worked from the ground with binoculars. Bucket trucks (starting in 1998) and tree climbers (1999) were used for the first time in Illinois to improve detection and soon were used in other U.S. states (85, 98).

USDA APHIS conducted four types of surveys in ALB-infested areas (71, 85, 120). First, intensive surveys were conducted annually of all ALB host trees (105) within the core area (defined as the area within 800 m of an infested tree). Survey boundaries were extended each time a new infested tree was found. Second, a delimiting survey was conducted every two years of all host trees within a buffer zone that extended 1600 m beyond the boundary of the core area. The boundaries of each regulated area were agreed upon by APHIS and local officials but at a minimum included the core area and buffer zone (120). Third, surveys were conducted at high-risk sites that may have received ALB-infested woody material from the core area years before the infestation was discovered. Typically, 50–100 host trees were visually inspected annually at each suspect site. Fourth, an area-wide detection survey was conducted within a 40-km radius of each infestation, but beyond the regulated area, in which two host trees at nine sites per square mile were inspected once every three years. USDA APHIS updated its program guidelines and list of ALB host trees as new research findings became available (105, 120).

The eradication plan required that all trees with ALB oviposition pits or exit holes be cut, chipped, and often burned (71, 85, 124). Beginning in Chicago in 2000, apparently uninfested host trees were treated with systemic

insecticides that had imidacloprid as the active ingredient (85, 99, 100, 122). Insecticides were used in case some infested trees were missed during inspection. The systemic insecticides targeted both ALB larvae as well as adults during maturation feeding. Originally, trees within a 200-m radius of an infested tree were treated; the treatment radius was extended to 400 m in 2002 and 800 m in 2003. New York began insecticide treatments in 2001 (85, 120). Insecticide treatments of the same trees occurred for a minimum of three years and were coupled with intensive detection surveys.

Overall, 8543 ALB-infested trees and 33,595 high-risk host trees were cut in the United States from 1997 through 2008 (**Table 1**). State and federal expenditures from 1997 through 2008 were about US$373 million (18% state, 82% federal; **Table 1**). Estimates of federal costs through 2001 indicated that the two largest expense items were survey (65%) and control (19%) (85). As of August 2009, all ALB infestations in Illinois and the infestation in Jersey City have been declared eradicated. Current federal policy permits eradication to be declared when no evidence of ALB or its signs are found during four successive surveys of the core area and buffer zone (120).

Since discovering ALB in Worcester in August 2008, the regulated area has increased to 166 km^2 as of August 2009. Removal of infested trees began in January 2009 (**Table 1**). The ALB infestation in Worcester is different from other U.S. infestations in that Worcester is located in the midst of natural forests dominated by *Acer* species. In fact, ALB has infested at least one large forest preserve in Worcester.

As of August 2009, no established populations of CLB have been detected in the United States. However, in 2001, five CLB adults were thought to have emerged from *Acer* bonsai trees held outdoors at a nursery near Tukwila, Washington, and flown into the local environment (39, 130). This conclusion was reached because three live CLB adults were captured at the nursery and subsequent inspection revealed the presence of eight exit holes on the 369 bonsai that had been imported from South Korea. Given the threat posed by CLB, Washington State initiated an eradication program in 2002, although there was no evidence of CLB establishment. This program included destroying all 369 bonsai trees, cutting and chipping over 1000 host trees within 200 m of the nursery, treating 1500 host trees that were within 200–400 m of the nursery with systemic insecticides, and conducting annual surveys of host trees within 800 m of the nursery through 2006. The quarantine was lifted in January 2007 because no CLB or its signs were ever found beyond the nursery. The approximate cost of the five-year eradication program was US$2.2 million.

Europe: 2001. Populations of both ALB and CLB have become established in Europe (**Table 1**). As of April 2009, populations of ALB were found in Austria (at Braunau in 2001), France (Gien in 2003, Sainte-Anne-sur-Brivet in 2004, and Strasbourg in 2008), Germany (Neukirchen in 2004 and Bornheim in 2005), and Italy (Corbetta in 2007) (11, 12, 18, 49, 51, 53, 67, 68, 87, 108, 117). Breeding populations of CLB were found in Italy (Parabiago in 2000; Assago, Milan, and Montichiari in 2006; Gussago in 2007; Rome in 2008), France (Soyons in 2003), and the Netherlands (Het Westland in 2007) (19, 49, 86, 88, 121). According to the European Commission (23, 24) and national or local decrees, the management goal is to eradicate all ALB and CLB infestations. Each infested country developed an eradication program that incorporated three types of activities: regulatory, to limit pest movement and spread; survey, to detect and delineate the infestation; and mitigation, to remove the pest population.

A quarantine area was established around each infestation and consisted of the infested zone and a buffer zone (51, 86). ALB surveys were conducted by ground observers equipped with binoculars to detect known signs and symptoms of attack. Bucket trucks and tree climbers were used occasionally to improve pest detection (49). The signs and symptoms targeted for CLB surveys included accumulated

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CFIA: Canadian Food Inspection Agency

frass near the base of the trunk and along exposed roots, exit holes along the basal 50 cm of trunk and exposed roots, feeding injury by adults to twigs and suckers, and branch dieback. Trees with signs of ALB or CLB were promptly removed and burned.

The Plant Protection Services (PPS) of Austria, France, Germany, and Italy surveyed all ALB or CLB host trees within 1 km of an infested tree two times per year. In the Netherlands, however, surveys of all CLB host trees within 100 m of an infested tree were surveyed three times per year (121). Survey boundaries were adjusted each time a new infested tree was found (49, 68, 86, 107). Buffer zones extended 1–2 km beyond the infested zone. Within the buffer zone, host trees were selected at random and surveyed once a year. In addition to these activities, surveys were conducted at high-risk sites that may have received infested WPM or live plants from countries in Asia that were infested with ALB or CLB.

As of December 2008, 475 ALB- and 5198 CLB-infested trees had been removed in Europe (**Table 1**). In addition, many trees considered at risk of being infested by ALB or CLB were removed (**Table 1**). Italy was the only country to apply insecticides to potential host trees to control CLB adults (86). In Europe, ALB monitoring and control expenditures from 2001 through 2008 were about €550,000 and CLB survey and control costs were about €2.8 million (**Table 1**). As of April 2009, only the CLB infestation in Soyons, France, had been declared eradicated in Europe. Current European policy allows eradication to be declared after four consecutive years of not finding any infested trees (60, 61).

Canada: 2003. In September 2003, the Canadian Food Inspection Agency (CFIA) confirmed the discovery of ALB north of Toronto in an industrial park in Vaughan, Ontario (52). The CFIA soon approved an action plan similar to the U.S. plan to eradicate ALB. The ALB plan consisted of survey activities to detect and delimit infestations, control tools to remove the population, regulatory tools to limit its spread, a recovery program to reduce the impact on affected areas, and an outreach program to educate and inform the public. The plan was modified as new biological information became available.

Delimitation surveys initiated within days of the discovery resulted in establishing a regulated area of about 160 km^2. The regulated area, which in 2003 consisted of a core infestation and a few satellite infestations, was subdivided into three zones: infested areas, suspect areas, and buffer areas that surrounded the infested and suspect areas. The size of each zone was based on the presence of ALB or its signs and symptoms, the risk of infestation associated with its presence, and the known biology and dispersal ability of ALB (14).

The mitigation strategy consisted of removing all infested trees together with all trees belonging to genera considered at high risk of being infested by ALB and located within a 400-m radius of an infested tree. All trees were examined for signs and symptoms of ALB attack. In addition, the eradication plan required removal of suspect trees. In 2003, 10 genera were considered at high risk of being attacked by ALB in Canada, but by 2007 this list had been reduced to 4: *Acer*, *Betula*, *Populus*, and *Salix*. All infested, high-risk, and suspect trees were cut and chipped to less than 15 mm on a side, a size considered small enough to prevent survival of ALB immature stages (124) and used as compost. No pesticides were used.

Detection surveys within the regulated area were conducted by ground inspectors with binoculars and tree climbers looking for ALB signs and symptoms (118). Each zone was assigned an intensity of survey consistent with its proximity to an infested tree. Surveys in the infested zones (400 m of an infested tree) targeted exclusively genera considered at lower risk of attack because all high-risk trees had been removed: These surveys occurred for two years after the removal of the high-risk trees. In the first buffer zone (within 400–800 m from an infested tree), all high-risk trees were surveyed annually using tree climbers where necessary. Surveys in the second buffer zone

(800–2400 m) originally targeted high-risk genera but eventually focused only on *Acer*, considered the highest-risk genus. Surveys in the remainder of the regulated area were conducted every second year and targeted only *Acer*.

No new infested trees were found in 2008. Current CFIA policy requires five consecutive years of not finding any ALB-infested trees before a regulated area can be declared pest free. No CLB infestations have been found in Canada through August 2009.

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RESEARCH

Hundreds of studies have been conducted on ALB and CLB during the past few decades, and dozens are ongoing (38, 43, 54, 81, 97, 112, 142). We highlight recent research in the areas of prevention, detection, ecology, and management, but more details can be found in the abovementioned reviews.

Prevention

Several methods to sanitize wood were tested given that WPM is a common pathway by which ALB has been transported beyond its native range. Methyl bromide was effective in killing ALB under a variety of treatment schedules (9) as well as when tested in whole containers (8). Similarly, ethanedinitrile (102) and sulfuryl fluoride (10), two candidate fumigants to replace methyl bromide, were highly effective against ALB in wood. High mortality of ALB in wood has been achieved with microwave irradiation (27) and low-pressure vacuum treatment (17) in laboratory trials. In addition, methods were developed to detect larvae in wood using noncontact ultrasound (26) as well as in live plants using acoustic signatures of feeding larvae (84).

Detection

There has been great interest in identifying pheromones of ALB and CLB to facilitate their early detection. As of 2008, no long-range pheromone has been reported for either insect, although male-produced short-range pheromones and female-produced contact recognition pheromones have been identified (see Bionomics, above).

Several studies have investigated the role of plant volatiles in host finding and acceptance with the goal of finding compounds that could be used as lures in trapping programs (54). For example, research on the North American tree *Acer negundo* in China revealed that numerous volatile compounds produced strong antennal responses in ALB (76), ALB adults were attracted to *A. negundo* trees over distances greater than 200 m (131), ALB adults were preferentially attracted to drought-stressed *A. negundo* trees (59), and ALB was attracted preferentially to *A. negundo* over three other *Acer* species tested (145). In addition, field studies have shown that the Asian maple *Acer mono* is highly attractive to ALB males and females, which has led to testing of this species as a sentinel tree to detect ALB (112).

Ecology

There have been many general accounts on the biology and ecology of ALB and CLB (ALB: 47, 54, 55, 97, 118, 135; CLB: 37, 79). In addition, detailed studies have been conducted on adult longevity and fecundity (ALB: 62, 63, 110; CLB: 1), adult reproductive behavior (ALB: 75, 137, 146, 149; CLB: 1, 31, 32, 33, 126), adult dispersal and movement (ALB: 7, 104, 109, 111, 132, 133; CLB: 9, 66), life-table analyses (ALB: 51, 147; CLB: 2, 3), within-tree infestation patterns (ALB: 40, 51; CLB: 134), development (ALB: 46, 89, 136; CLB: 4, 79), gut bacteria and digestive enzymes (ALB: 36, 106), and rearing on artificial diets (ALB: 54, 63; CLB: 91).

Management

Research results have been used to develop and shape many aspects of the current ALB and CLB eradication programs. For example, the need to burn chips after infested trees were cut and chipped was eliminated because mortality was expected to be high from chipping alone

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(124). In Illinois, distances from 1000 trees with only ALB oviposition pits were measured to the nearest tree with ALB exit holes to estimate typical adult dispersal distances in an urban setting where host trees are plentiful. Overall, 95% of trees with only oviposition pits were within 200 m of a tree with exit holes, and 99% were within 400 m (104, 120). These results were used by USDA APHIS to select 800 m as the radius of the core survey and treatment zone and were further supported by ALB mark-release-recapture studies in China (7, 109, 111). The tree species chosen for inspection and treatment in individual countries were usually those recognized as hosts or preferred hosts (49, 105, 118, 120).

Various physical and cultural control methods were developed in Asia. For example, collecting adults by hand, hammering egg sites, and inserting wires into galleries to kill larvae are commonly performed against ALB in China (54, 97). Techniques to exclude ovipositing adults have also been evaluated, especially with CLB because oviposition occurs mainly along the lower trunk (5).

A wide variety of insecticides have been tested for borer control. In Asia, for example, the fumigant aluminum phosphide is placed directly in larval galleries, organophosphates are used as systemics, and pyrethroids are commonly used as trunk and foliar sprays (54, 97). Another promising pyrethroid is lambda-cyhalothrin, which can be applied as an encapsulated contact insecticide (112).

Several systemic neonicotinyl insecticides were tested for control of ALB (98, 99, 122), and, based in part on positive results from these studies and the relatively low mammalian toxicity of this class of insecticides, imidacloprid-based products were selected for use in the U.S. eradication programs for ALB (120) and CLB (130).

Two recent studies have evaluated potential nontarget impacts of imidacloprid-treated trees on aquatic and terrestrial decomposers. In a laboratory study, senescent foliage from trunk-injected trees had no effect on the survival of leaf-shredding insects or litter-dwelling earthworms, but it did lead to reduced decomposition probably because feeding rates were lowered (70). In a field study, when imidacloprid was applied to trees as a soil trench, adverse effects were found on litter-dwelling earthworms when concentrations in the litter reached 3 mg kg^{-1} (69).

In the area of biological control, several studies have been conducted on natural enemies of ALB and CLB, including fungi, bacteria, nematodes, parasitoids, and predators. Progress in the use of entomopathogenic fungi, especially virulent strains of *Beauveria* and *Metarhizium anisopliae*, was recently reviewed (43, 54, 97). Various field application techniques were evaluated, and the most promising was the use of fungus-impregnated fiber bands when wrapped around tree trunks and branches (43, 45). Adult beetles become contaminated with spores when walking over the fiber bands. Several strains of bacteria have been isolated from field-collected ALB larvae and pupae in China (97). However, in a recent laboratory study, no significant negative impact was found on ALB larvae and adults during screening of several *Bacillus thuringiensis* toxins (20). Entomopathogenic nematodes in the genera *Steinernema* and *Heterorhabditis* were tested against ALB and CLB (25, 97). Strains of *Steinernema carpocapsae* and *S. feltiae* were the most effective against both ALB and CLB in tests with insects on filter paper, in artificial diet, and in actual galleries.

Because woodpeckers (*Dendrocopos major* and *Picus canus*) are the major predators of ALB in China, studies were conducted on methods to encourage nesting (97). Insects in several families are known predators of Cerambycidae; however, we found no detailed reports on insect predators of ALB or CLB. The three principal parasitoids of ALB and CLB in Asia are *Dastarcus helophoroides* (= *D. longulus*) (Coleoptera: Bothrideridae) and *Scleroderma guani* and *S. sichuanensis* (Hymenoptera: Bethylidae) (56, 97). All three are ectoparasitoids. Eggs of *D. helophoroides* are deposited within the host gallery, and after hatching, parasitoid larvae seek out and paralyze their host, including larvae, pupae, and adults (77). An artificial

diet has been developed for *D. helophoroides* (96). Studies conducted in China with *S. guani* and *S. sichuanensis* gave promising results for control of ALB and CLB (22, 97).

In Europe, a new species of egg parasitoid of CLB was recovered from specimens collected in Italy in 2002 (48, 50) and is considered to be of Asian origin (21). This species, subsequently described and named *Aprostocetus anoplophorae* (Hymenoptera: Eulophidae) (21), appears highly specific to CLB in field surveys and laboratory tests (50). Additional surveys in Italy found eight native Hymenoptera using early-instar CLB larvae: *Scleroderm*us sp. (Bethylidae), *Spathius erythrocephalus* (Braconidae), *Calosota agrili* and *Eupelmus aloysii* (Eupelmidae), *Eurytoma melanoneura* and *E. morio* (Eurytomidae), and *Cleonymus brevis* and *Trigonoderus princeps* (Pteromalidae) (48). In experimental field tests in Italy using ALB larvae, seven of the above eight larval ectoparasitoids were recovered, with *S. erythrocephalus* and *T. princeps* being most frequent (48).

OUTLOOK

In the past few years, a few ALB infestations have been declared eradicated in the United States, and others appear on their way to become eradicated (**Table 1**); the same is true for CLB in France. The success of an eradication program depends on many factors (92). We believe that the success of the ALB and CLB eradication programs is related primarily to the following factors: (*a*) availability of sufficient funding, (*b*) clear lines of authority among the agencies involved in the eradication efforts, (*c*) susceptibility of the target organisms to control, (*d*) availability of measures to prevent reinvasion, and in most instances (*e*) detection of the pest relatively early after establishment.

To date, sufficient funds to support eradication efforts in each infested country have been forthcoming (**Table 1**). However, given the high expense and long-term nature of eradication programs, it may be difficult to maintain adequate funding, especially if infestations are discovered many years after establishment. Although several government agencies are involved in eradication efforts in each infested country, it appears that lines of authority are well-defined and legislation is in place to allow eradication activities to proceed with few legal challenges. Having clear lines of authority helps maintain strong public support for eradication efforts, especially from people living within regulated areas where trees are removed. Among the life-history traits of ALB and CLB that favor control are their one- to two-year life cycle, fairly low fecundity, propensity for limited dispersal, and tendency to reinfest the same tree for several years. However, the lack of long-range pheromones or other strong attractants remains an obstacle to achieving effective, low-cost surveys and prevents early detection over large areas. Strong local regulations help reduce human-assisted movement of infested host material, and adoption of new international trade standards should lower pest incidence in future imported products (see below). To date, most infestations were detected relatively soon after establishment. However, some infestations (e.g., ALB in Massachusetts) apparently were established for many years before discovery and thus control could prove challenging. Nevertheless, such situations will provide valuable insight into the probability of success and the costs and duration of an eradication program when compared with infestations that are detected early.

ISPM: International Standards for Phytosanitary Measures

PREVENTING NEW INTRODUCTIONS

ALB and CLB are transported among countries inside live plants and WPM. The world community recognized the threat of the WPM pathway and in 2002 adopted International Standards for Phytosanitary Measures No. 15 (ISPM 15), which set standards for heat treatment and fumigation of WPM used in international trade (28). It appears that the incidence of live insects in WPM has been lowered as a result of compliance with ISPM 15, but live insects are still occasionally found in WPM (42). It is not clear if the presence of live insects

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in WPM stamped with the ISPM 15 logo represents some type of treatment failure, insect tolerance of the treatment, infestation after treatment, or fraudulent use of the ISPM 15 mark (42). As of 2006, all countries listed in **Table 2** had implemented ISPM 15, and therefore all WPM that arrived with imports in those countries in the past few years should have been treated. Nevertheless, it is apparent from **Table 2** that live ALB were still intercepted in WPM after 2006. In 2009, ISPM 15 was revised to set maximum size limits for residual bark on WPM, which should further reduce the occurrence and number of live pests (28, 29, 42).

As of August 2009, there was no international standard similar to ISPM 15 that addressed international trade of live plants. However, a draft version of a standard on this topic is under development. At a regional level, the North American Plant Protection Organization (NAPPO) has approved Regional Standards for Phytosanitary Measures No. 24, which discusses various options to reduce pest incidence on imported plants for planting but does not set firm guidelines (94). Future international standards could establish guidelines for exporting countries that would address production practices (e.g., use of pest-free mother stock, isolation of introduced plant material, best management practices, and treatments) and quality control (e.g., standard operating procedures, record keeping, training, internal audits, and traceability) (119). Others have discussed requiring documentation indicating that imported plants had been grown in pest-free areas or were kept isolated from pests (121). Continued research into improving ISPM 15 standards and developing effective international standards for live plants should reduce future pest introductions.

SUMMARY POINTS

1. ALB (*A. glabripennis*) and CLB (*A. chinensis*) are two cerambycids that have become established beyond their native range of Asia. As of April 2009, breeding populations of ALB had been found in Austria, Canada, France, Germany, Italy, and the United States; CLB had been found in France, Italy, and the Netherlands.
2. The genus *Anoplophora* was revised in 2002, placing *A. nobilis* in synonymy with *A. glabripennis*, and *A. malasiaca* in synonymy with *A. chinensis*.
3. ALB and CLB infest primarily hardwood trees in several plant families. ALB and CLB tunnel into the cambial region and woody tissues of both stressed and apparently healthy trees and cause tree death after several successive years of attack.
4. ALB outbreaks have occurred in many parts of China during the past few decades, especially where ALB-susceptible tree species were used in major tree-planting programs.
5. ALB is intercepted mostly in WPM such as pallets and crating, whereas CLB is intercepted mostly in live woody plants such as bonsai and nursery stock.
6. Quarantines and eradication programs were initiated in each country where ALB and CLB became established. As of August 2009, eradication has been declared for the ALB infestations in Illinois and Jersey City and the CLB infestation in France.
7. A wide variety of studies have been conducted in Asia, Europe, and North America on nearly all aspects of the biology, ecology, and management of ALB and CLB.
8. International standards (ISPM 15) were approved in 2002 for heat treatment and fumigation of WPM to practically eliminate all pests. Bark tolerance limits for WPM were approved in 2009. International discussions have begun on best management practices for the live plant industry.

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FUTURE ISSUES

1. Tree species resistant to ALB and CLB should be identified or developed, and planting strategies should be designed to reduce outbreak potential.
2. Improved lures, including host volatiles and pheromones, and trapping technologies are needed for use in monitoring and detection programs. Novel control methods are needed that use attractants to lure adults to traps where they become contaminated with entomopathogens.
3. Improved methods ensuring pest-free WPM and live plants are needed in international trade.
4. In case eradication fails, agencies should plan additional management options such as biological control.
5. The list of host plants on which ALB and CLB have completed development in Asia needs clarification.
6. Spread models for ALB and CLB in urban, managed, and natural forests need to be refined.
7. Molecular studies that refine relationships among all *Anoplophora* species and that support or refute recent synonymies are needed.
8. Detailed maps showing the geographical range of ALB and CLB in Asia should be created.

DISCLOSURE STATEMENT

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