Potential Effect of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) on Urban Trees in the United States

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ABSTRACT *Anoplophora glabripennis* Motschulsky, a wood borer native to Asia, was recently found in New York City and Chicago. In an attempt to eradicate these beetle populations, thousands of infested city trees have been removed. Field data from nine U.S. cities and national tree cover data were used to estimate the potential effects of *A. glabripennis* on urban resources through time. For the cities analyzed, the potential tree resources at risk to *A. glabripennis* attack based on host preferences, ranges from 12 to 61% of the city tree population, with an estimated value of $72 million–$2.3 billion per city. The corresponding canopy cover loss that would occur if all preferred host trees were killed ranges from 13–68%. The estimated maximum potential national urban impact of *A. glabripennis* is a loss of 34.9% of total canopy cover, 30.3% tree mortality (1.2 billion trees) and value loss of $669 billion.

KEY WORDS *Anoplophora glabripennis*, urban forestry, urban forests

RECENT INFESTATIONS OF the longhorned beetle *Anoplophora glabripennis* Motschulsky have led to the removal of thousands of infested urban trees in an effort to eradicate this exotic insect in the United States. This pest, which attacks several species of healthy hardwood trees, was first detected in the Greenpoint section of Brooklyn, NY, in August 1996 (Haack et al. 1997). In July 1998, an *A. glabripennis* infestation was discovered in the Ravenswood area of Chicago (Poland et al. 1998). Although various life stages of the beetle have been detected in warehouses in at least 14 states in the late 1990s, no other established populations in live trees have yet been detected in the United States.

Larvae of *A. glabripennis* feed in >24 species of hardwood trees in the Orient and Palearctic (Yang et al. 1995). In its native China, it prefers *Salix* spp. and *Populus* spp. (Li and Wu 1993), whereas in the United States *Acer* spp. are most commonly attacked (Haack et al. 1997). Other hardwood species are also attacked and several new hosts have been documented in North America. This tendency to attack and use a wide variety of host tree species appears to be a characteristic of *A. glabripennis.*

Adults have been found as early as 8 July in Chicago (K. Kruse, personal communication) and 26 June in New York (J. Gittleman, personal communication). It is believed that some emergence occurs earlier in both locations. In China, adult beetle emergence begins in May in the southern Guangxi Provence, and in late June or early July farther north (Li and Wu 1993). In New York, adults typically emerged in July, August, and September, especially during the heat of the day (Kucera 1996).

Beetle dispersal is believed to be for relatively short distances, but adults can fly up to 1,000 m to locate new host material (Thier 1997). Released beetles moved an average of 106.3 m (Wen et al. 1998). Analysis of the spatial distribution of infested trees in Chicago indicates natural movement is short range (A. Sawyer, personal communication). Spread by human activity (e.g., shipping infested packing material, movement of infested firewood) can accelerate dispersal.

Anoplophora glabripennis bores into the main trunk, branches, and exposed tree roots of both young and old trees. It is one of the most serious pests on poplar (*Populus* spp.) in China (Li and Wu 1993, Luo and Li 1999). As trees are repeatedly attacked, infested trees are killed within several years of initial attack. As of 23 June 2000, >4,720 infested trees in New York were removed (USDA Forest Service 2000a), and >1,390 infested trees in Illinois were removed as of 17 July 2000 (USDA Forest Service 2000b), at a total cost for both areas of more than $25 million (M. Stefan, personal communication).

Because larvae bore deep into the wood, they are difficult to kill with biological or chemical pesticides. However, recent studies with systemic insecticides in China and the United States have identified imidacloprid, either injected into the soil or directly into the tree, as having the potential to control this beetle (V.C.M., unpublished data). Field trials are ongoing with this material and recently ≈9,000 uninfested trees were treated with imidacloprid in Chicago. Ef-

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fective methods of trapping, or control with pesticides, are not yet available.

Though quarantines and eradication programs have been established in Chicago and New York to prevent further spread of *A. glabripennis,* this insect has a high potential for introduction to other urban (or rural) areas through movement of infested wood materials, particularly pallets and crating imported from China. Additional pest introductions would lead to more urban tree losses. Urban trees infested by *A. glabripennis* pose the threat of personal injury, property damage, and liability that can result from tree breakage where beetles have weakened stems and branches. The objective of this analysis is to quantify the potential impact of this insect, in terms of tree mortality and monetary value, on urban trees in selected cities and across the United States.

Materials and Methods

Field data were used to determine the entire urban forest structure (e.g., tree species composition and number of trees on all land uses) of nine cities: Atlanta, GA; Baltimore, MD; Boston, MA; Chicago, IL (Nowak 1994); Jersey City, NJ; New York, NY; Oakland, CA (Nowak 1993a, 1993b); Philadelphia, PA; and Syracuse, NY. These cities were sampled based on methods developed by the USDA Forest Service for various urban forest research projects (e.g., Nowak 1993a, 1993b, 1994; Nowak et al. 1998, 2000; Nowak and Crane 2000). These data comprise the entire set of comprehensive U.S. urban forest structure and monetary value data available. City tree data (except for Oakland and Chicago) were collected between 1995 and 1999 and analyzed using the Urban Forest Effects (UFORE) model based on a stratified random sample of ≈200 plots (0.04 ha each) per city (Nowak and Crane 2000). Data collection included location, species, stem diameter at 1.37 m above the ground, tree and crown height, crown width, and canopy condition. *Anoplophora glabripennis* data analyses for these cities are in relation to live trees; data from Oakland and Chicago refer to the entire city population, and include 2.9% dead trees in Oakland and 5% dead trees in Chicago.

Data on urban forest structure were combined with *A. glabripennis* host preferences (Table 1) to quantify the potential number of trees, percent of total canopy cover (leaf area), and potential monetary loss associated with *A. glabripennis* infestation scenarios. Host preferences were divided into the following four classes: (1) Preferred: known host in China (He and Huang 1993, Li and Wu 1993, Li et al. 1999), or verified completion of life cycle (exit holes) on host in the United States (V.C.M., unpublished data). (2) Oviposition: genera that have been attacked (oviposition) in the field, but complete development in a tree has not been confirmed (V.C.M., unpublished data). (3) Conifer: conifer species (no known conifer hosts). (4) Unknown: hardwood genera with no host data.

Anoplophora glabripennis was estimated to spread at two rates: 300 m/yr and 3 km/yr. The slower spread rate is based on an estimate of the natural spread rate of beetles (Thier 1997), whereas the upper spread rate is dependent upon human-assisted transport of infested wood, such as firewood. The slower spread rate provides a conservative estimate of potential impacts over time for situations where effective programs to restrict movement of infested wood are implemented. The faster spread rate represents a worst case scenario where no quarantine restrictions or sanitation practices are adopted and people actively move infested materials. The spread rates were assumed to be averages for the described scenarios, and no modeling of beetle population fluctuations was attempted. However, given an expanding radius of infestation, beetle populations would need to increase exponentially over time to maintain the spread rates.

An infestation was assumed to start at the center of the city and spread outward until the entire city area was encompassed, and to spread at equal rates through all land uses, proportional to the city land use distribution and tree composition in the land use (e.g., if 50% of the city was residential land, then 50% of the infestation occurred on residential land each year). All trees within preferred host genera are assumed to be killed within 4 yr of infestation in natural areas (e.g., forests, vacant lands). On all other land uses, it was assumed that these trees would be removed within 2 yr of infestation due to increased maintenance and hazard liability for these land uses. No trees were

Table 1. Genera assignments in *A. glabripennis* preference classes

Genera	Preference class[a]	China[b]	Chicago[c]	New York[d]
Acer	Preferred	Host	Host	Host
Aesculus	Preferred		Host	Host
Albizzia	Preferred			Host
Alnus	Preferred	Host		
Betula	Preferred	Host	Host	Host
Elaeagnus	Preferred	Host		
Fraxinus	Preferred	Host	Host	Oviposition
Hibiscus	Preferred			Host
Malus	Preferred	Host	Oviposition	
Morus	Oviposition			Oviposition
Platanus	Preferred	Host		Oviposition
Populus	Preferred	Host		Oviposition
Prunus	Preferred		Host	
Pyrus	Preferred	Host	Host	
Quercus	Oviposition			Oviposition
Robinia	Preferred	Host	Host	
Salix	Preferred	Host	Host	Host
Sophora	Preferred	Host		
Tilia	Preferred	Host	Oviposition	
Ulmus	Preferred	Host	Host	Host

Host, known host; oviposition, genera has been attacked (oviposition) in the field, but complete development in the tree has not been confirmed.

[a] Preference class rating as defined in methods.

[b] Host preference data from China (He and Huang 1993, Li and Wu 1993, Li et al. 1999). Some hosts described in the literature may be misleading as a number of *Anoplophora* spp. in China have a similar appearance.

[c] *A. glabripennis* program records from Chicago (V.C.M., unpublished data).

[d] *A. glabripennis* program records from New York City (V.C.M., unpublished data).

assumed to be killed by *A. glabripennis* in other host preference classes.

The value of the trees in each susceptibility class was calculated based on compensatory value of trees as prescribed by the Council of Tree and Landscape Appraisers (1992). Compensatory value is used for monetary settlement for damage or death of plants through litigation, insurance claims of direct payment, and loss of property value for income tax deduction. It is based on the replacement cost of a similar tree, and is an estimate of the amount of money the tree owner should be compensated for tree loss. Other values can be ascribed to trees based on such factors as increases in local property values or environmental functions provided (e.g., air pollution reduction), but the compensatory valuation method is one of the most direct methods of establishing the value of compensation for tree loss.

Compensatory value is based on four tree and site characteristics: tree trunk area (cross-sectional area at 1.37 m above the ground), species, condition, and location. Tree trunk area and species are used to determine the basic value, which is then multiplied by condition and location ratings (0–1) to determine the final tree compensatory value.

For transplantable trees, average replacement cost and transplantable size were obtained from local International Society of Arboriculture publications (ACRT 1997) to determine the basic replacement price (\$ per cm^2 of cross-sectional area) for the tree. Basic replacement price was multiplied by tree trunk area and species factor (0–1) to determine the tree's basic value. Minimum basic value for a tree, before species adjustment, was set at \$150. Local species values (0–1) were obtained from International Society of Arboriculture publications (ACRT 1997). If no monetary or species data were available for the state, data from the closest state were used.

For trees larger than transplantable size:

$$\text{Basic Value} = \text{Replacement Cost} + (\text{Basic Price} \times [TA_A - TA_R] \times \text{Species Value}), \quad [1]$$

where replacement cost is the cost of a tree at the largest transplantable size, basic price is the local average cost per unit trunk area (\$ per cm^2), TA_A is trunk area of the tree being appraised, and TA_R is trunk area of the largest transplantable tree. Local average replacement cost, transplantable size, basic price and species values (0–1) were obtained from International Society of Arboriculture publications (ACRT 1997). If no data were available for the state, data from the closest state were used.

For trees larger than 76.2 cm in trunk diameter, trunk area was adjusted downward based on the premise that a large mature tree would not increase in value as rapidly as its trunk area would increase. The following adjusted trunk area formula was determined empirically based on the perceived increase in tree size, expected longevity, anticipated maintenance, and structural safety (Council of Tree and Landscape Appraisers 1992):

$$\text{Adjusted Trunk Area} = -0.335\,d^2 + 69.3\,d - 1087, \quad [2]$$

where d = trunk diameter in inches.

Basic value was multiplied by condition and location factors (0–1) to determine the tree's compensatory value. Condition factors were based on crown dieback: excellent (<1% dieback) = 1.0; good (1–10% dieback) = 0.95; fair (11–25% dieback) = 0.82; poor (26–50% dieback) = 0.62; critical (51–75% dieback) = 0.37; dying (76–99% dieback) = 0.13; dead (100% dieback) = 0.0.

Available data required using location factors based on land use type (International Society of Arboriculture 1988): golf course = 0.8; commercial/industrial = 0.75; cemetery = 0.75; institutional = 0.75; parks = 0.6; residential = 0.6; transportation = 0.5; forest = 0.5; agriculture = 0.4; vacant = 0.2; wetland = 0.1.

As an example of compensatory value calculations, if a 40.6-cm-diameter tree (1,295-cm^2 trunk area) has a species rating of 0.5, a condition rating of 0.82, a location rating of 0.4, a basic price of \$7/cm^2, and a replacement cost of \$1,300 for a 12.7-cm-diameter tree (127-cm^2 trunk area), then the compensatory value would equal:

$$[1{,}300 + (7 \times (1295–127) \times 0.5)] \times 0.82 \times 0.4 = \$1{,}767.$$

Data for individual trees in each city were used to determine the compensatory value of trees in each host class. To estimate the potential total loss in value of urban forests nationally due to *A. glabripennis,* total compensatory value of preferred host trees in each city was divided by total tree cover (m^2) to determine average compensatory value per unit tree cover (\$ per m^2). Extrapolation of city data to estimate national effects was done by region due to the regional divergence in *A. glabripennis* effects. Extrapolation to urban areas in the Northeast/North Central region (Connecticut, Delaware, Illinois, Indiana, Kentucky, Massachusetts, Maryland, Maine, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Virginia, Vermont, Wisconsin, West Virginia) was based on median data from Boston, Baltimore, Chicago, Jersey City, New York, Philadelphia, and Syracuse. Extrapolation to the rest of the United States was based on median data from Atlanta and Oakland. The standardized compensatory value (\$ per m^2) was multiplied by total urban tree cover in the region (Dwyer et al. 2000) to estimate the potential monetary impact of *A. glabripennis.* Tree cover estimates were based on 1991 advanced very high-resolution radiometer (AVHRR) data (Zhu 1994).

Results and Discussion

Tree resources at risk (i.e., preferred hosts) from *A. glabripennis* attack ranged from 61% of the trees in Chicago (2.5 million trees) to 12% in Oakland (192,000

Table 2. Estimated tree resources at risk for infestation by *A. glabripennis* in nine cities based on the total of all living preferred host species

City	Resources at risk for attack in preferred host class					City area, km^2	Years to total city infestation	
	% cover	No. trees	% trees	Total $	$/tree		@300 m/yr	@3 km/yr
Jersey City, NJ	68	57,600	44	72,160,000	1,254	38	12	2
Chicago, IL	64	2,509,200	61	1,159,250,000[a]	462[a]	588	46	5
Boston, MA	63	697,300	60	794,360,000	1,139	143	23	3
Syracuse, NY	61	385,900	47	260,210,000	674	65	16	2
New York, NY	54	2,246,100	47	2,251,420,000	1,002	800	54	6
Philadelphia, PA	53	1,098,200	56	772,670,000	704	342	35	4
Baltimore, MD	47	1,294,700	50	1,361,540,000	1,052	238	30	3
Atlanta, GA	19	1,777,900	20	391,280,000	220	341	35	4
Oakland, CA	13[b]	192,100	12	91,770,000[c]	478[c]	145	23	3

These estimates include: percentage of total city canopy cover (leaf area) in preferred host class (% cover); number of trees in preferred host class (No. trees); percentage of total live tree population in preferred host class (% trees); total compensatory value of preferred host trees (total $); and average compensatory value per preferred host tree ($/tree). Data are based on all living preferred host species, except Chicago and Oakland where all trees (living and dead) were analyzed.

[a] Estimate based on median dollar value per tree from Atlanta and Philadelphia as Chicago's tree diameter distribution was similar to the distributions of trees in these cities. These cities have similar values and are among the lowest values in the table.

[b] Percentage total tree cover.

[c] Based on original estimates for entire tree population (1.587 million trees, $385 million) (Nowak 1993) using a basic price of $4.18/cm^2$ that was adjusted upward based on a more recent basic price of $8.22/cm^2$ for California (ACRT 1997). Estimates of cost are based on total cost for entire population prorated by number of trees in class.

trees) (Table 2). If all preferred hosts were eventually killed, the corresponding percent canopy cover loss would range from 68% in Jersey City to 13% in Oakland. Total current value of tree resources at risk ranged from $2.3 billion in New York City to $72 million in Jersey City. Differences among cities in total number of trees that may potentially be attacked and killed by *A. glabripennis* and the value of those trees are related to size of city, percentage of land covered by trees (i.e., total number of trees in the city), and the proportion of the tree population that is in preferred host genera (Table 2).

The potential tree resources at risk for attack by *A. glabripennis* reveal patterns among cities that may be related to region of the country. In the Northeast/North Central (NE/NC) region, the percentage of trees that are preferred hosts and the corresponding percentage of the total canopy cover appear to be significantly greater than in cities found in the South (Atlanta) and West (Oakland). Median percentage of trees in the preferred host class (50.0%) and percentage of canopy cover that could potentially be lost (60.6%) for the NE/NC cities were greater than the median values for Atlanta and Oakland (16.0% of trees and 16.2% of canopy cover). Though the sample size is small, it is likely that regional differences in tree species composition will affect the overall potential magnitude of the *A. glabripennis* impact. Therefore, relatively high proportions of preferred host species in the NE/NC region will likely lead to greater impacts in this area. Other regions of the country (e.g., the Pacific Northwest) may also have relatively high proportions of preferred host species, but urban tree species compositions in these areas remain to be investigated. Due to the probability of forest types similar to the NE/NC region existing in areas outside of this region, the regional extrapolation procedure for the "rest of the United States" region is probably conservative.

Median compensatory value of tree resources at risk for *A. glabripennis* attack per m^2 of tree cover (NE/NC = $16.42; rest of the United States = $3.21) and median value per preferred host tree (NE/NC = $1,027; rest of the United States = $349) also vary by region. These differences are primarily due to varying amounts of preferred host species, and diameter and land use distributions of these species. Median basic price for the rest of the United States was actually higher than in NE/NC cities analyzed ($5.42/cm^2$ versus $3.49/cm^2$). Median species values used in the valuation formula appeared to be similar among regions (e.g., *Acer rubrum* = 0.8 in NE/NC and 0.815 in the rest of the United States).

Years until *A. glabripennis* infest the entire city at a 300 m/yr spread rate ranged from 12 yr in Jersey City to 54 yr in New York City (Table 2). Cumulative number of preferred host trees that would be infested after 5 yr at the 300 m/yr spread rate ranged from 9,400 in Oakland to 42,000 in Syracuse, and from 57,600 in Jersey City to 614,900 in Baltimore after 20 yr (Table 3). Corresponding current compensatory values of the infested trees would range from $4.5 million in Oakland to $40.4 million in Baltimore after 5 yr, and from $71.5 million in Oakland to $646.7 million in Baltimore after 20 yr (Table 4).

At a faster rate of spread (3 km/yr), city-wide infestation dropped to 2–6 yr for all cities, with the cumulative number of preferred hosts infested within 6 yr, ranging from 57,600 trees in Jersey City to 2.5 million trees in Chicago (Tables 2 and 3). Total current compensatory values of potentially infested trees ranges from $72 million in Jersey City to $2.3 billion in New York (Tables 4 and 5).

The lower spread rate of 300 m/yr may provide a reasonably good benchmark for *A. glabripennis* impacts over time for the cities analyzed, although spread rate can be reduced with implementation of eradication or control efforts and may be accelerated

Table 3. Estimated cumulative number of preferred host trees infested for selected years following establishment of *A. glabripennis* for nine U.S. cities at spread rates of 300 m/yr and 3 km/yr

City	Spread rate	Cumulative no. of trees (×1,000) infested					
		Year: 1	3	5	10	20	30
Atlanta, GA	300 m/yr	1.5	13.3	36.8	147.2	589.0	1,325.2
	3 km/yr	147.2	1,325.2	1,777.9			
Baltimore, MD	300 m/yr	1.5	13.8	38.4	153.7	614.9	1,294.7
	3 km/yr	153.7	1,294.7				
Boston, MA	300 m/yr	1.4	12.4	34.5	138.1	552.3	697.3
	3 km/yr	138.1	697.3				
Chicago, IL	300 m/yr	1.2	10.8	30.1	120.6	482.2	1,085.0
	3 km/yr	120.6	1,085.0	2,509.2			
Jersey City, NJ	300 m/yr	0.4	3.8	10.6	42.4	57.6	
	3 km/yr	42.4	57.6				
New York, NY	300 m/yr	0.8	7.2	19.9	79.5	317.8	715.1
	3 km/yr	79.5	715.1	1,986.3	2,246.1		
Oakland, CA	300 m/yr	0.4	3.4	9.4	37.4	149.7	192.1
	3 km/yr	37.4	192.1				
Philadelphia, PA	300 m/yr	0.9	8.2	22.7	90.9	363.7	818.3
	3 km/yr	90.9	818.3	1,098.2			
Syracuse, NY	300 m/yr	1.7	15.1	42.0	167.9	385.9	
	3 km/yr	167.9	385.9				

by human-assisted transport of infested wood. Actual spread following establishment likely will not follow an even pattern, with spot infestations occurring ahead of the main front due to human-assisted transport that eventually would coalesce with the primary beetle population. The faster rate of spread of 3 km/yr more likely represents a worst case scenario and would not be expected where eradication or control measures are implemented.

The tree compensatory values presented are dollar estimates for 1997. As compensatory value for trees generally increase over time, it is likely that these 1997 estimates will be less than future values. Costs associated with regulation, eradication, or control can increase total costs associated with the beetle in the short-term, but can reduce overall impact and costs by reducing beetle damage. If all trees in the oviposition host class actually are preferred hosts, an additional 1.9–19.7% of the tree population would be at risk for beetle infestation (Table 5). The potential impact of this beetle will likely increase through the probable discovery of new preferred host genera in the future.

The percentage of the total city tree population that would be killed (preferred hosts) at the lower spread rate of 300 m/yr (given a delay of 2–4 yr after initial attack) ranged from 0.1% in Atlanta to 4.0% in Jersey City after 5 yr, and from 5.2% in Atlanta to 47.2% in Syracuse after 20 yr (Table 6). Total potential mor-

Table 4. Estimated cumulative compensatory value of trees infested by *A. glabripennis* for selected years following establishment for nine U.S. cities at spread rates of 300 m/yr and 3 km/yr

City	Spread rate	Cumulative compensatory value (in million $) of infested trees					
		Year: 1	3	5	10	20	30
Atlanta, GA	300 m/yr	0.3	2.9	8.1	32.4	129.6	291.7
	3 km/yr	32.4	291.7	391.3			
Baltimore, MD	300 m/yr	1.6	14.6	40.4	161.7	646.7	1,361.5
	3 km/yr	161.7	1,361.5				
Boston, MA	300 m/yr	1.6	14.2	39.3	157.3	629.2	794.4
	3 km/yr	157.3	794.4				
Chicago, IL[a]	300 m/yr	0.6	5.0	13.9	55.7	222.8	501.3
	3 km/yr	55.7	501.3	1,159.2			
Jersey City, NJ	300 m/yr	0.5	4.8	13.3	53.2	72.2	
	3 km/yr	53.2	72.2				
New York, NY	300 m/yr	0.8	7.2	19.9	79.6	318.6	716.8
	3 km/yr	79.6	716.8	1,991.0	2,251.4		
Oakland, CA[b]	300 m/yr	0.2	1.6	4.5	17.9	71.5	91.8
	3 km/yr	17.9	91.8				
Philadelphia, PA	300 m/yr	0.6	5.8	16.0	64.0	255.9	575.7
	3 km/yr	64.0	575.7	772.7			
Syracuse, NY	300 m/yr	1.1	10.2	28.3	113.2	260.2	
	3 km/yr	113.2	260.2				

[a] Estimate based on median dollar value per infested tree from Atlanta and Philadelphia (Table 2) as Chicago's tree diameter distribution was similar to the distributions of trees in these cities.

[b] Based on original estimates for entire tree population (1.587 million trees, $385 million) (Nowak 1993) using a basic price of $4.18/cm^2 that was adjusted upward based on a more recent basic price of $8.22/cm^2 for California (ACRT 1997). Estimates of cost are based on total cost for entire population prorated by number of trees in class.

Table 5. *A. glabripennis* host preference class differences in nine cities based on number of live trees and associated compensatory value

City	No. of tree (×1,000)					Value (×$1,000,000)				
	PREF	OVI	CONF	UNK	Total	PREF	OVI	CONF	UNK	Total
Atlanta, GA	1,777.9	1,150.8	1,486.2	4,609.8	9,024.6	391.3	1,042.6	1,017.6	1,258.9	3,710.4
	19.7%	12.8%	16.5%	51.1%	100%	10.5%	28.1%	27.4%	33.9%	100%
Baltimore, MD	1,294.7	361.5	331.7	612.2	2,600.1	1,361.5	1,037.9	461.8	503.9	3,365.2
	49.8%	13.9%	12.8%	23.5%	100%	40.5%	30.8%	13.7%	15.0%	100%
Boston, MA	697.3	224.2	122.4	112.6	1,156.4	794.4	228.1	121.0	109.2	1,252.6
	60.3%	19.4%	10.6%	9.7%	100%	63.4%	18.2%	9.7%	8.7%	100%
Chicago, IL	2,509.2	299.2	376.4	943.3	4,128.1	1,159.2[a]	NA	NA	NA	NA
	60.8%	7.2%	9.1%	22.9%	100%					
Jersey City, NJ	57.6	8.1	33.2	32.9	131.8	72.2	10.3	7.5	10.9	100.9
	43.7%	6.1%	25.2%	25.0%	100%	71.5%	10.2%	7.5%	10.8%	100%
New York, NY	2,246.1	933.9	360.6	1,208.8	4,749.4	2,251.4	1,732.6	192.4	1,012.9	5,189.3
	47.3%	19.7%	7.6%	25.5%	100%	43.4%	33.4%	3.7%	19.5%	100%
Oakland, CA	192.1	201.6	282.6	911.3	1,587.7	91.8[b]	96.3[b]	135.0[b]	435.4[b]	758.5
	12.1%	12.7%	17.8%	57.4%	100%	12.1%	12.7%	17.8%	57.4%	100%
Philadelphia, PA	1,098.2	136.2	303.2	407.0	1,944.5	772.7	251.1	225.4	502.1	1,751.2
	56.5%	7.0%	15.6%	20.9%	100%	44.1%	14.3%	12.9%	28.7%	100%
Syracuse, NY	385.9	15.4	206.1	210.7	818.2	260.2	52.7	149.7	62.9	525.5
	47.2%	1.9%	25.2%	25.7%	100%	49.5%	10.0%	28.5%	12.0%	100%

PREF, preferred host class; OVI, oviposition host class; CONF, conifer host class, UNK, unknown host class; NA, not analyzed. Data are based on the number of live trees; except Chicago and Oakland where all trees (living and dead) were analyzed.

[a] Estimate based on median dollar value per infested tree from Atlanta and Philadelphia (Table 2) as Chicago's tree diameter distribution was similar to the distributions of trees in these cities.

[b] Based on original estimates for entire tree population (1.587 million trees; $385 million) (Nowak 1993) using a basic price of $4.18/cm^2 that was adjusted upward based on a more recent basic price of $8.22/cm^2 for California (ACRT 1997). Estimates of cost are based on total cost for entire population prorated by number of trees in class.

tality in cities ranges from 12% of the tree population in Oakland to 61% in Chicago (Tables 2 and 6).

Chicago and New York, two cities that have *A. glabripennis* infestations, are located in areas where beetle impact is potentially large. The number of infested trees removed in the Chicago area since 1998 (>1,390) roughly corresponds to the amount projected to be infested 1 yr following pest establishment, assuming a single point of introduction and a spread rate of 300 m/yr. For the New York City area, the number of infested trees removed since 1996 (≈4,720) corresponds to the number of trees expected to be infested ≈2 yr after pest introduction. Since populations in both cities are estimated to have been present for several years before initial detection, there likely is a short lag time necessary for population buildup before beetle spread becomes noticeable. This buildup would likely delay the actual progression of tree infestation and mortality by a few years compared with that projected in the calculations. In addition, mortality rates may be too high and it may take 8–10 yr to kill a host.

Other cities in the NE/NC region also have the potential for *A. glabripennis* to have a significant impact on the city's tree resources (e.g., Boston, Baltimore, Jersey City, Philadelphia, Syracuse), should the

Table 6. Projected cumulative percent tree mortality for selected years following establishment of *A. glabripennis* for nine U.S. cities at spread rates of 300 m/yr and 3 km/yr

City	Spread rate	Cumulative % tree mortality					
		Year: 1	3	5	10	20	30
Atlanta, GA	300 m/yr	0.0	0.0	0.1	1.0	5.2	12.7
	3 km/yr	0.0	2.7	12.0	19.7		
Baltimore, MD	300 m/yr	0.0	0.1	0.7	4.1	19.8	47.4
	3 km/yr	0.0	15.1	40.3	49.8		
Boston, MA	300 m/yr	0.0	0.4	1.6	8.8	41.0	60.3
	3 km/yr	0.0	36.1	57.2	60.3		
Chicago, IL	300 m/yr	0.0	0.1	0.4	2.1	9.9	23.6
	3 km/yr	0.0	8.4	36.8	60.8		
Jersey City, NJ	300 m/yr	0.0	0.9	4.0	23.1	43.7	
	3 km/yr	0.0	31.1	43.7			
New York, NY	300 m/yr	0.0	0.1	0.2	1.2	5.7	13.6
	3 km/yr	0.0	5.0	21.8	47.3		
Oakland, CA	300 m/yr	0.0	0.1	0.2	1.5	7.7	12.1
	3 km/yr	0.0	4.9	10.8	12.1		
Philadelphia, PA	300 m/yr	0.0	0.1	0.5	3.1	15.4	37.0
	3 km/yr	0.0	10.2	39.4	56.5		
Syracuse, NY	300 m/yr	0.0	0.6	2.7	14.9	47.2	
	3 km/yr	0.0	35.0	47.2			

pest become established in those locales. Cities in other areas of the United States may also be significantly affected by city-wide infestations (e.g., cities in the Pacific Northwest), but more data are needed to provide a more detailed analysis of variation across the country. Conservatively, a widespread infestation of *A. glabripennis* across the United States will likely kill at least 10% of the urban tree population (based on extrapolating data from the most conservative city estimate—Oakland).

The estimated potential national impact of *A. glabripennis* if every urban place in the coterminous United States becomes totally infested with this insect is a loss of 34.9% of the canopy cover, 30.3% of the trees (1.2 billion trees) and $669 billion dollars in compensatory value.

These estimates of *A. glabripennis* impact have a significant degree of uncertainty due to data limitations related to host preferences and associated tree mortality, rate of spread, limited data on urban forest structure and its regional variation, and compensatory valuation methods. As more data are gathered relative to host preferences, host responses, and urban forest structure across the United States, better estimates can be made to determine the potential impact of *A. glabripennis* and other insects and diseases on the urban forest resource of the United States.

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