Journal of Integrated Pest Management, (2021) 12(1): 10; 1–6
doi: 10.1093/jipm/pmab007
Brief Communication

ENTOMOLOGICAL SOCIETY OF AMERICA
SHARING INSECT SCIENCE GLOBALLY

OXFORD

First Recorded Asian Longhorned Beetle (Coleoptera: Cerambycidae) Infestation in the Southern United States

David R. Coyle,[1,4] R. Talbot Trotter, III,[2] Meredith S. Bean,[1] and Scott E. Pfister[3]

[1]Department of Forestry and Environmental Conservation, Clemson University, Clemson, SC 29634, USA, [2]USDA Forest Service, Northern Research Station, Hamden, CT 06514, USA, [3]USDA APHIS, PPQ, S&T, Otis Laboratory, Buzzards Bay, MA 02542, USA and [4]Corresponding author, e-mail: dcoyle@clemson.edu

Subject Editor: Nathan Walker

Received 2 January 2021; Editorial decision 5 February 2021

Abstract

The Asian longhorned beetle [*Anoplophora glabripennis* (Motschulsky), ALB] was found in Hollywood, SC, in May 2020. This infestation is at least 7-yr old and represents the southernmost infestation in North America. A federally regulated invasive forest and tree pest, ALB primarily attacks maples but is known to attack and reproduce in trees in at least 12 different genera. Damage observed in South Carolina is typical of that seen in other ALB infestations, including oviposition sites, splitting bark around larval feeding sites, and round holes made by emerging adults. Copious weeping from oviposition sites was commonly observed in the summer of 2020, and characteristic frass and wood shavings were commonly exuded from attacked trees. Federal and state regulatory officials established a 152 km^2 (58.6 mi^2) regulated area in October—which the state increased to 188.0 km^2 (72.6 mi^2) in January—and to date >4,000 trees (98% *Acer* spp.) infested with ALB have been identified. Several uncertainties regarding ALB's biology and ecology exist due to this area's subtropical climate, including impacts to the beetle's life cycle. Questions also surround potential biological control agents in this area and whether new host trees would be utilized. While the standard eradication strategy of tree removal and chipping is being performed, there are several forested wetlands and areas otherwise inaccessible to typical removal equipment where alternate eradication strategies may need to be developed and deployed. Because this ALB infestation is located within a novel environment, it provides an opportunity to research new strategies that will help improve future detection and eradication efforts.

Key words: *Acer*, *Anoplophora glabripennis*, invasive species, phenology, woodborer

In May 2020, a single adult Asian longhorned beetle (ALB), *Anoplophora glabripennis* (Motschulsky), was found on a resident's porch in Hollywood, SC (32.73° N, 80.24° W). ALB is an invasive polyphagous beetle native to China and the Korean Peninsula, which threatens the forests of North America and Europe (Cavey et al. 1998, Haack et al. 2010, Meng et al. 2015, Javal et al. 2019). State and federal regulatory officials initiated rapid surveys of this coastal community and discovered an established infestation, including adults and larvae (Fig. 1). South Carolina is the sixth and southernmost state in the U.S. which an established ALB population has been found (Fig. 2).

The story of ALB as a global invasive species begins in the mid-late 1900s on the edges of the Gobi Desert in China. With the desert expanding at a rate of 3,500 km^2/yr, the Chinese government launched the Three North Shelter Forest Program in 1978 (Wang et al. 2010). The goal of this program was to reforest and afforest a 4,400-km barrier or 'green wall' to both slow the expansion of the desert and provide wood resources for local populations. By 2018, the program had planted trees on 27 million ha and applied aerial seeding to >40 million ha (Cao et al. 2020). A large proportion of the trees used by the program were North American *Populus* species and hybrids which were selected for their rapid growth and tolerance for sandy soils. Unfortunately, many of these are also highly susceptible to infestation by ALB (Haack et al. 2010, Meng et al. 2015).

Feeding by ALB larvae leaves tunnels in the phloem and xylem of trees, greatly reducing the commercial value of the wood and structural integrity of the tree and branches (Fig. 3). Since low-quality wood is typically used for dunnage and to produce solid wood packing materials such as crates and pallets, an unintentional consequence of China's Three North Shelter Forest Program is that ALB-infested wood material has been integrated into international trade over the past several decades. In 1992, ALB was detected in warehouses and ports in North America (Haack et al. 2010) and by 1996 the first breeding population outside of Asia was found in Brooklyn, NY (Haack et al. 1996, Lingafelter and Hoebeke 2002). As of 2020, breeding populations are also established in several European countries (Javal et al. 2019).

Fig. 1. Asian longhorned beetle adults have a black body with white spots and can be up to 4-cm long, with black and white banding on the antennae which can be twice the length of the body for males and about 1.2 times the length of the body for females, which are usually larger than males (Lingafelter and Hoebeke 2002) (A). Signs of ALB include oviposition sites chewed into bark and round emergence holes made by adults when they exit the tree (B), oviposition sites often have a jagged edge created by the adult mandibles chewing the wood (C), 'weeping' from oviposition sites caused by larval feeding (D), and frass and/or wood shavings below ALB larval feeding sites (E). All trees pictured are red maple. Photos A, B, D, and E by D. Coyle (Clemson University), photo C by Donald Owen (California Department of Forestry and Fire Protection, Bugwood.org).

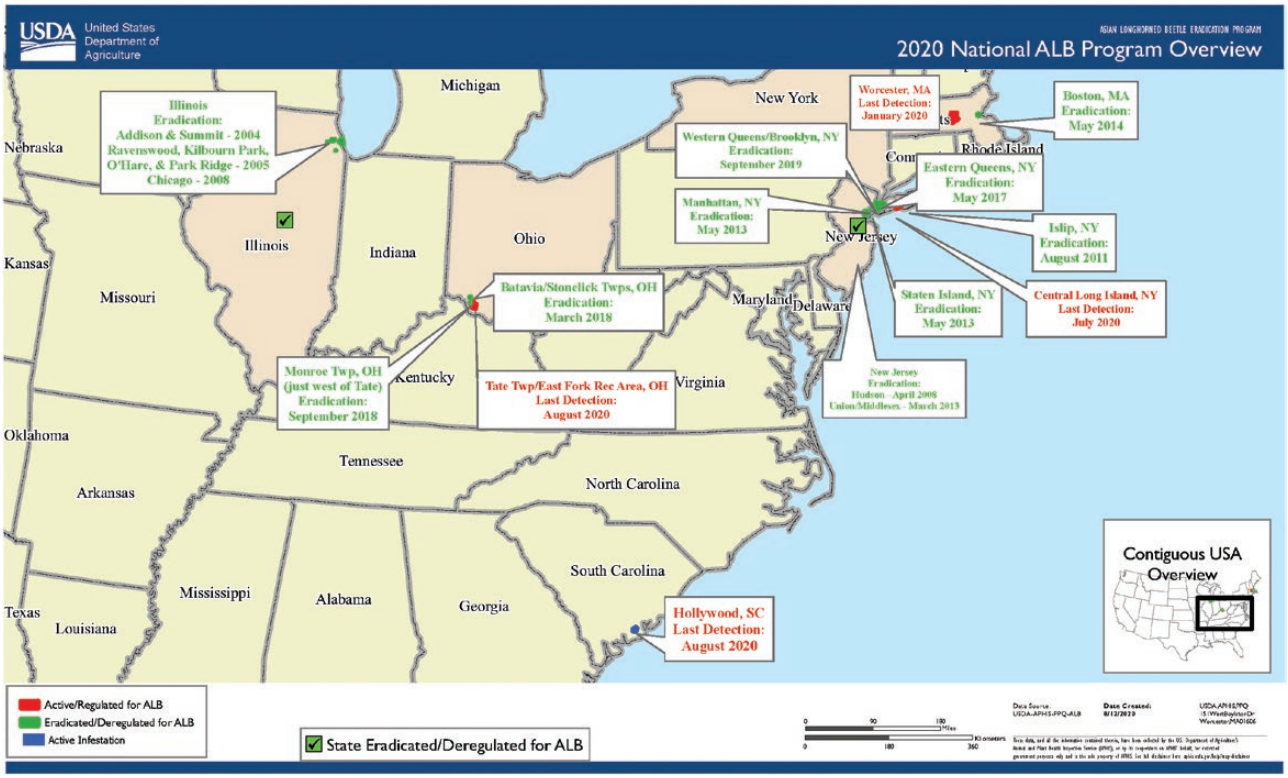

Fig. 2. Known infestations of Asian longhorned beetle in the United States. As of August 2020, four states have areas regulated for ALB with active infestations. This Program Progress Map is available at https://www.aphis.usda.gov/aphis/ourfocus/planthealth/plant-pest-and-disease-programs/pests-and-diseases/asian-longhorned-beetle/ct_alb_maps (accessed 20 December 2020).

ALB hosts include tree species in >12 genera including poplars, maples, elms, and willows (Lingafelter and Hoebeke 2002). Nowak et al. (2001) estimated the cost of damage to urban trees in the United States to be more than $1.2 billion, though it is worth noting this estimate is now two decades old and does not account for inflation or impacts on forested landscapes. Due to the ecological

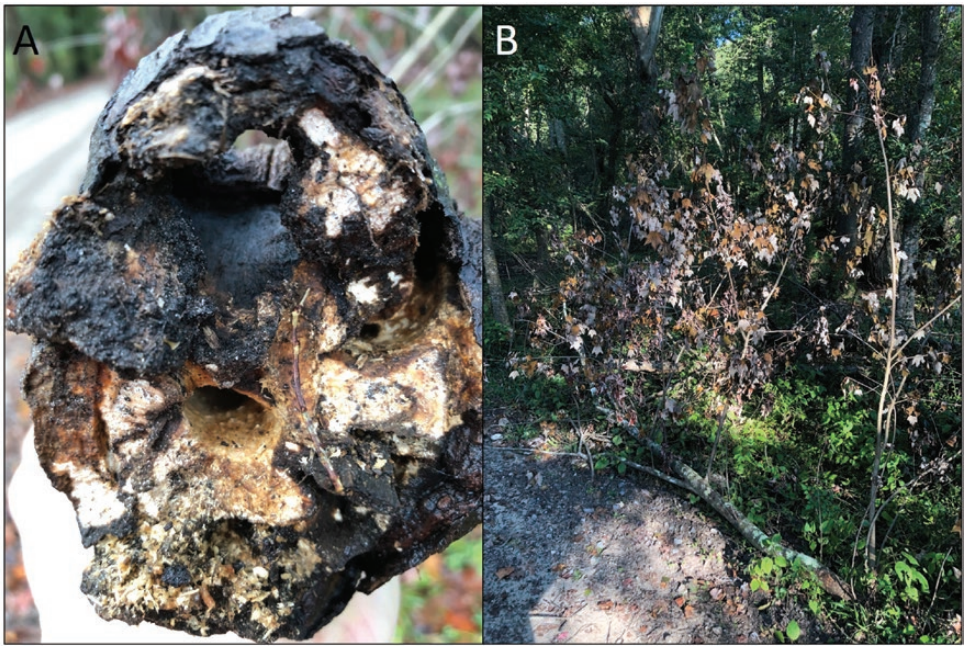

Fig. 3. Damage from Asian longhorned beetle larval feeding created large galleries in this 13 cm (5 in.) diameter red maple branch (A), which subsequently fell to the ground (B). The falling of large branches and tops of trees can be hazardous to people, especially in urban, residential, or frequently trafficked areas. Photos by D. Coyle (Clemson University).

and economic threat posed by ALB, the United States, Canada, and members of the European and Mediterranean Plant Protection Organization (EPPO, https://www.eppo.int/) have adopted policies of eradication when populations are found. International phytosanitary regulations (FAO 2018) have also helped slow the spread of invasive species by eliminating or intercepting introductions prior to establishment.

In the United States, breeding populations of ALB have been found in Illinois, Massachusetts, Ohio, New York, New Jersey, and now in South Carolina (Fig. 2). Efforts to eradicate infestations in New York City, New Jersey, Illinois, and parts of Massachusetts and parts of Ohio have been successful, and eradication programs continue in central Massachusetts, southern Ohio, and Long Island, NY. The most recent find in South Carolina raises new questions about ALB's biology and presents new challenges to its eradication.

ALB in South Carolina

The full extent of ALB infestation in South Carolina is not yet known, but as of January 2021, a 188.0-km^2 or 72.6-mi^2 regulated area has been established by the state of South Carolina (https://www.clemson.edu/public/alb), which is slightly larger than the original 151.8 km^2 (58.6 mi^2) regulated area (the federal quarantine area will soon mirror the state quarantine area). This is larger than regulated areas in Ohio (146.3 km^2 or 56.5 mi^2) and New York (137.3 km^2 or 53 mi^2) but smaller than the regulated area in Massachusetts (284.9 km^2 or 110 mi^2). Surveyors have found over 4,000 ALB-infested trees in several tree genera including *Salix*, *Ulmus*, *Platanus*, and *Populus*, with 98% of the infested trees being *Acer* – most of which were *A. rubrum* L. (Table 1).

Initial dendrochronology work indicates this infestation has been in South Carolina for at least 7 yr, and early genetics work indicates that this ALB population matches the ALB population in Ohio. While we will likely never know exactly how ALB arrived in South Carolina, these data suggest several plausible options. One possibility is the potential for the South Carolina infestation to be a secondary infestation from the Ohio infestation. The regulated area of South Carolina has a high volume of vacation traffic, of which a significant portion comes from the Midwest (College of Charleston 2020). The center of the primary area of infestation includes a railway and an RV park (where travelers may visit). The beetle may also have been directly imported from the same geographic origin in China as the Ohio population, as there are two major ports (Charleston, SC and Savannah, GA) within 145 km (90 mi) of the regulated area.

The Limits of Current Knowledge, and the Need for New Data

The discovery of ALB in South Carolina offers several research opportunities and new eradication challenges. Prior to this discovery, invasive populations of ALB have been found in several temperate and continental climates in Europe and North America. Those populations have been studied to better understand ALB biology, phenology, and population dynamics, and develop population and phenology models (Smith et al. 2001, 2004; Straw et al. 2015; Trotter and Keena 2016; Kappel et al. 2017) as well as reconstructions of population development and spread (Straw et al. 2016, Hull-Sanders et al. 2017, Trotter et al. 2018). These tools have supported eradication programs by providing information such as the amount of time beetles require to complete development as well as the seasonal timing associated with key life-stages, particularly emergence of adult beetles, which are capable of dispersing and expanding the infestation. Timing of tree removals or treatments using imidacloprid have been based on these findings.

While these tools and models have been successfully applied in temperate and continental climates (Trotter and Keena 2016, Kappel et al. 2017), the subtropical climate of coastal South Carolina is a novel environment for ALB in North America. Little is known about how beetle populations develop under conditions typical of this

climate and ecological environment, and some key questions have emerged.

One of the first unknowns is the length of time required for beetles to complete development from egg to adult. The analysis of populations in cooler climates has shown that development in the midwestern and northeastern United States can take from one to four years, and development in extremely cold locations such as Helsinki, Finland may require up to a decade (Trotter and Keena 2016). In each of these locations, the development of the beetle is partially limited by the length and intensity of the cold season, which slows development, but may also help synchronize populations. The subtropical climate of coastal South Carolina experiences mild winters in which beetle development may not slow. While most—but not all—ALB larvae needed a chilling period prior to pupation in a laboratory study (Keena and Moore 2010), ALB is known to exhibit plasticity in its life cycle, and Kappel et al. (2017) suggest a beetle may complete its life cycle in just over 7 mo in this area. Thus, it is difficult to determine whether all ALB will go through an overwintering diapause in subtropical areas such as the southeastern United States (Trotter and Keena 2016). If not, beetles may develop substantially faster creating the potential for shorter generation times and faster rates of population increase. Research into this dynamic is underway, and initial dendrochronology work indicates ALB has a life cycle of <1 yr in South Carolina.

A second unknown is the timing of adult emergence. Previous phenology models have provided estimates for when adults are likely to emerge. This information could benefit eradication programs by providing logistical flexibility with regards to tree removal and may

Table 1. Trees infested with Asian longhorned beetle in the South Carolina regulated area as of 5 January 2021

Family	Common name	Genus	Species	Count	Percent of total
Platanaceae	American sycamore	*Platanus*	*occidentalis* L.	1	0.02
Salicaceae	Willow sp.	*Salix*		14	0.35
	Black willow	*Salix*	*nigra* Marshall	29	0.72
	Weeping willow	*Salix*	*babylonica* L.	4	0.10
	Eastern cottonwood	*Populus*	*deltoides* W. Bartram ex. Marshall	5	0.12
Sapindaceae	Red maple	*Acer*	*rubrum* L.	3,947	97.6
	Silver maple	*Acer*	*saccharinum* L.	11	0.27
	Sugar maple	*Acer*	*saccharum* Marshall	6	0.15
Ulmaceae	American elm	*Ulmus*	*americana* L.	11	0.27
	Elm sp.	*Ulmus*		13	0.32

Infestations were confirmed by the presence of oviposition sites or adult exit holes by federal and state regulatory personnel either via ground surveys or by tree climbers.

Fig. 4. Asian longhorned beetle has infested host trees in swampy areas of South Carolina (infested host trees, primarily red maple in this photo, are denoted by arrows), and removing these trees using the traditional cut, remove, and chip method will be logistically difficult and could cause environmental damage. Photo by D. Coyle (Clemson University).

potentially guide regulatory personnel on effectively regulating host and infested material.

Logistical Challenges and New Research Questions

In previous eradication programs, managers have focused on using visual surveys to identify infested trees, which are then felled and destroyed (Rose 2014). Surveys are conducted from the ground using binoculars or spotting scopes, aerially using lifts or bucket-trucks, and within the canopies by tree climbers. Surveyors search the trunk and branches of trees for oviposition sites chewed into the bark by female beetles as well as the distinctive round exit holes chewed by emerging adults, which are ~2 cm in diameter (Fig. 1B). When infested trees are found they are felled and either chipped on site or moved to a central location for chipping.

The expansive wetlands and swamps of coastal South Carolina add new challenges to surveying and removals. Standing water, saturated soil, and certain local fauna (e.g., venomous snakes and, in some areas, alligators) can make it difficult for ground survey crews and tree climbers to access and move through stands, and these conditions can render it impossible to use lifts and bucket trucks (Fig. 4). When infested trees are found, felling trees in swampy conditions can add risk for felling crews, and the wet conditions can make it impossible to operate the equipment needed to remove or chip infested trees. Under these conditions, there is a need to identify alternative eradication strategies.

The ecological and economic impacts that ALB poses to the southeastern United States is largely unknown. While ALB's primary host, maples, are not as common in coastal ecosystems or forests in the southern United States as they are in other areas infested with ALB, *Acer* is commonly encountered in the highly diverse swamps and wetlands—many areas of which contain at-risk or threatened species (Noss et al. 2015). Similarly, while ALB hosts are not common in urban or managed areas in South Carolina, they are nonetheless present and there is a cost to removing them. Further, this area is threatened annually by hurricanes, and the associated high winds may exacerbate ALB damage via branch or stem breakage.

This new ALB infestation and novel environment also provides opportunities to expand our knowledge of factors that impact ALB population dynamics. For instance, answering how quickly an ALB infestation grows and spreads, both within a single tree and into neighboring trees. These questions can be answered using dendrochronology, provided an isolated but thriving ALB population can be located within the regulated area. Additionally, while biological control agents have been evaluated in ALB's native and invaded ranges (Duan et al. 2016, Liu et al. 2016), this infestation provides an opportunity to conduct comprehensive surveys for potential native vertebrate and invertebrate biological control agents.

Eradication efforts are underway for the South Carolina ALB infestation, though not without challenges. While unfortunate, discovery of ALB in South Carolina does provide opportunities to increase and improve our knowledge of this invasive pest. The goal is to use this information to improve our strategic approach and be better prepared should an ALB infestation be found elsewhere.

Acknowledgments

We thank P. Baldauf and R. Santos (USDA APHIS) and S. Long and H. Ritger (Clemson DPI) for earlier reviews which greatly improved this manuscript. Special thanks to E. Willey (USDA APHIS) for compiling the host information. Funding for MSB is provided by cooperative agreement number 20-JV-11242303-095 between Clemson University and the USDA Forest Service.

Conflict of Interest Statement

The authors declare no potential conflicts of interest.

References Cited

Cao, S., X. Sou, and C. Xia. 2020. Payoff from afforestation under the Three-North Shelter Forest Program. J. Cleaner Prod. 256:120461.

Cavey, J. F., E. R. Hoebeke, S. Passoa, and S. W. Lingafelter. 1998. A new exotic threat to North American hardwood forests: an Asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky) (Coleoptera: Cerambycidae). I. Larval description and diagnosis. Proc. Entomol. Soc. Wash. 100: 373–381.

College of Charleston. 2020. Estimation of Tourism's Economic Impacts in the Greater Charleston Area, 2019. Report by the Office of Tourism Analysis, School of Business, Charleston, SC, USA. 1 p.

Duan, J. J., E. Aparicio, D. Tatman, M. T. Smith, and D. G. Luster. 2016. Potential new associations of North American parasitoids with the invasive Asian longhorned beetle (Coleoptera: Cerambycidae) for biological control. J. Econ. Entomol. 109: 699–704.

FAO. 2018. ISPM 15: regulation of wood packaging material in international trade. produced by the secretariat of the international plant protection convention. Food and Agricultural Organization of the United Nations. https://assets.ippc.int/static/media/files/publication/en/2019/02/ISPM_15_2018_En_WoodPackaging_Post-CPM13_Rev_Annex1and2_Fixed_2019-02-01.pdf. Accessed 20 December 2020.

Haack, R. A., J. F. Cavey, E. R. Hoebeke, and K. Law. 1996. *Anoplophora glabripennis*: a new tree-infesting exotic cerambycid invades New York. Newsl. Mich. Entomol. Soc. 41: 1–3.

Haack, R. A., F. Hérard, J. Sun, and J. J. Turgeon. 2010. Managing invasive populations of Asian longhorned beetle and citrus longhorned beetle: a worldwide perspective. Annu. Rev. Entomol. 55: 521–546.

Hull-Sanders, H., E. Pepper, K. Davis, and R. T. Trotter, III. 2017. Description of an establishment event by the invasive Asian longhorned beetle (*Anoplophora glabripennis*) in a suburban landscape in the northeastern United States. PLoS One. 12: e0181655.

Javal, M., A. Roques, J. Haran, F. Hérard, M. Keena, and G. Roux. 2019. Complex invasion history of the Asian long-horned beetle: fifteen years after first detection in Europe. J. Pest. Sci. 92: 173–187.

Kappel, A. P., R. T. Trotter, M. A. Keena, J. Rogan, and C. A. Williams. 2017. Mapping of the Asian longhorned beetle's time to maturity and risk to invasion at contiguous United States extent. Biol. Invasions 19: 1999–2013.

Keena, M. A., and P. M. Moore. 2010. Effects of temperature on *Anoplophora glabripennis* (Coleoptera: Cerambycidae) larvae and pupae. Environ. Entomol. 39: 1323–1335.

Lingafelter, S. W. and E. R. Hoebeke. 2002. Revision of *Anoplophora* (Coleoptera: Cerambycidae). Entomol. Soc. Wash., Washington, DC. 236 pp., 41 color plates.

Liu, H., L. S. Bauer, T. Zhao, R. Gao, and T. M. Poland. 2016. Seasonal abundance and development of the Asian longhorned beetle and natural enemy prevalence in different forest types in China. Biol. Control 103:154–164.

Meng, P. S., K. Hoover, and M. A. Keena. 2015. Asian longhorned beetle (Coleoptera: Cerambycidae), an introduced pest of maple and other hardwood trees in North America and Europe. J. Integr. Pest Manage. 6(1): 4. doi:10.1093/jipm/pmv003.

Noss, R. F., W. J. Platt, B. A. Sorrie, A. S. Weekley, D. B. Means, J. Costanza, and R. K. Peet. 2015. How global biodiversity hotspots may go unrecognized: lessons from the North American Coastal Plain. Divers. Distrib. 21: 236–244.

Nowak, D. J., J. E. Pasek, R. A. Sequeira, D. E. Crane, and V. C. Mastro. 2001. Potential effect of Anoplophora glabripennis (Coleoptera: Cerambycidae) on urban trees in the United States. J. Econ. Entomol. 94: 116–122.

Rose, R. 2014. Asian longhorned beetle response guidelines. USDA APHIS. Available from https://www.aphis.usda.gov/plant_health/plant_pest_info/

asian_lhb/downloads/response-guidelines.pdf. Accessed 20 December 2020.

Smith, M. T., J. Bancroft, G. Li, R. Gao, and S. Teale. 2001. Dispersal of *Anoplophora glabripennis* (Cerambycidae). Environ. Entomol. 30: 1036–1040.

Smith, M. T., P. C. Tobin, J. Bancroft, G. Li, and R. Gao. 2004. Dispersal and spatiotemporal dynamics of Asian longhorned beetle (Coleoptera: Cerambycidae) in China. Environ. Entomol. 33: 435–442.

Straw, N. A., C. Tilbury, N. J. Fielding, D. Williams, and T. Cull. 2015. Timing and duration of the life cycle of Asian longhorned beetle *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in southern England. Agric. For. Entomol. 17:400–411.

Straw, N. A., N. J. Fielding, C. Tilbury, D. T. Williams, and T. Cull. 2016. History and development of an isolated outbreak of Asian longhorned beetle *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in southern England. Agric. For. Entomol. 18: 280–293.

Trotter, R. T., III, and M. A. Keena. 2016. A variable-instar climate-driven individual beetle-based phenology model for the invasive Asian longhorned beetle (Coleoptera: Cerambycidae). Environ. Entomol. 45: 1360–1370.

Trotter, R. T. III, E. Pepper, K. Davis, and R. Vazquez. 2018. Anisotropic dispersal by the Asian longhorned beetle (*Anoplophora glabripennis*): quantifying spatial risk and eradication effort with limited biological data. Biol. Invasions 21: 1179–1195.

Wang, X. M., C. X. Zhang, E. Hasi, and Z. B. Dong. 2010. Has the three norths forest shelterbelt program solved the desertification and dust storm problems in arid and semiarid China? J. Arid Environ. 74: 13–22.