NATIVE NATURAL ENEMIES OF NATIVE WOODBORERS: POTENTIAL AS BIOLOGICAL CONTROL AGENTS FOR THE ASIAN LONGHORNED BEETLE

Michael T. Smith[1], Roger W. Fuester[1], Joseph M. Tropp[1], Ellen M. Aparicio[2], Daria Tatman[2], and Jeff A. Wildonger[2]

[1]USDA Agricultural Research Service, Beneficial Insect Introduction Research Unit
501 South Chapel St., Newark, DE 19713

[2]Department of Entomology and Wildlife Ecology, University of Delaware
Townsend Hall, Newark, DE 19711

ABSTRACT

The Asian longhorned beetle (ALB) (*Anoplophora glabripennis*) is among high-risk invasive species that have invaded the U.S. from China. ALB has attacked 25 deciduous tree species in 13 genera in North America, most notably 7 maple (*Acer*) species. Methods developed for control of *A. glabripennis* include the removal of infested trees and the use of systemic and contact insecticides. However, alternative environmentally compatible biological control methods are desired. Of particular interest are biological control agents that possess high host searching ability, particularly under low pest population levels and within species rich landscapes. Focus is also on egg and early larval instar life stages of *A. glabripennis*.

Two broad approaches are recognized for developing biological control of invasive species. The first approach is based upon natural enemies native to the countries of origin, and the second approach is based upon natural enemies native to the countries of introduction. Based upon the **first approach**, parasitoids identified from *A. glabripennis* or related *Anoplophora* species in China (Chen and He 2006) include:

1. ***Sclerodermus guani*** (Bethylidae)–Reported as a larval ectoparasitoid of *Monochamus alternatus*, *Saperda populnea*, and *Semantus sinoauster*. *S. guani* is reported to control *M. alternatus*, *S. populnea*, *S. sinoauster*, and *A. chinensis* in China, and has been evaluated against *A. glabripennis* and *A. chinensis* in China.

2. ***Dastarcus helophoroides*** (**Colydiidae**–Reported as a larval/pupal ectoparasitoid of 12 cerambycid species, including *A. glabripennis*, *A. chinensis*, *A. nobilis*, *Apriona germani*, *A. swainsoni*, *Botcera horsfieldi*, *Chrysobothris succudanea*, *Melanophila decastigma*, *M. alternatus*, *Trirachys orientalis*, *Xustrocera globosa*, and *Xylocopa appendiculata* (Qin and Gao 1988). However, it is not clear which of these are indigenous hosts of *D. helophoroides* and which are associated only as a result of evaluations or introductions.

3. ***Ontsira palliates*** (**Braconidae**)–Reported as a larval ectoparasitoid of *A. chinensis*, *Callidium villosulum*, *S. sinoauster*, *Metipocregyes rondoni*, *M. alternatus*, *S. populnea*, and *Xustrocera globosa*. However, it is not clear which of these are indigenous hosts of *O. palliates* and which are associated only as a result of evaluations or introductions. *O. palliates* parasitism is limited to host larvae feeding within the inner bark, implying that early larval instars may be preferred.

4. ***Zombrus* bicolor**–Reported as a solitary larval parasitoid of many cerambycid and bostrychid wood borers, including *A. chinensis*, *Batocera horsfieldi*, *Ceresium sinicum*, *Chlorophorus annularis*, *C. diadema*, *Desisa subfasciata*, Dere sp., *Nadezhdella cantori*, *Olenecampus octopusitulatus*, *S. populnea*, *Semanotus bifasciatus*, *S. sinoauster*, *Trichoferus campestris*, and *Xylotrechus pyryhoderus* (Cerambycidae), and *Bostrychopsis parallel* and *Calophagus pekinensis* (Bostrychidae).

5. ***Scleroderma sichuanensis*** (**Bethylidae**)–Reported as a larval ectoparasitoid of *Semanotus sinoauster*. Reported to control *A. chinensis*, *Clytus validus*, *M. alternatus*, *S. sinoauster*, and *S. bifasciatus* in China.

6. ***Aprostocetus fukutai*** (**Eulophidae**)–Reported as an egg parasitoid of *A. chinensis* and *Apriona germarii* (Liao et al. 1987, Wang and Zhao 1988).

7. ***Ontsira anoplophorae* sp. nov.** (**Braconidae**–Reported as a gregarious larval ectoparasitoid of *A. malasiaca* on citrus (Yan and Qin 1992, Zhou 1992).

8. ***Ontsira sp.*** (**Braconidae**)–Reported as a larval parasitoid of *A. chinensis* (Yan and Qin 1992, Zhou 1992).

However, detailed investigations of natural enemies native to China for biological control of *A. glabripennis* have focused in large part on *S. guani* Xiao Wu (Hymenoptera: Bethylidae) and *D. helophoroides* (Fairmaire) (Coleoptera: Colydiidae). Both species are ectoparasitoids of a wide range of cerambycid species that attack either deciduous or coniferous tree species. Investigations and use of these and other potential natural enemies of *A. glabripennis* have largely been limited to highly disturbed landscapes, including windrows bordering agricultural fields, rural roads in agricultural areas, monoculture plantations, and street trees in urban landscapes, where *A. glabripennis* is more commonly undergoing cyclical outbreaks. These landscapes are typically restricted to one or a few tree species, including *Populus* (poplar), *Salix* (willow), *Acer* (maple), or *Ulmus* (elm), and occasionally *Eleagnus angustifolia* (Russian-olive). The host searching efficiency of *S. guani* and *D. longulus* is unknown. Furthermore, their efficacy under *A. glabripennis* outbreak conditions within landscapes of limited tree species diversity offers limited insight into their expected efficiency in the U.S., Canada, and Europe, where *A. glabripennis* population levels are low within species rich landscapes. Therefore, before *S. guani* and *D. longulus* can be considered for release outside their country of origin, non-target studies are needed. Such non-target studies in the U.S. are awaiting receipt of import permits for these species. Additional investigations of native natural enemies of *A. glabripennis* within the countries of origin are currently focused on non-disturbed natural landscapes where it has long been found attacking native tree species under only low pest population levels.

Based upon the **second approach**, investigations of natural enemies native to the countries of introduction were initiated in North America at the USDA Agricultural Research Service Beneficial Insects Introduction Research Lab (BIIRU) in 2001 (Smith et al. 2003, 2004). Subsequently, collaborative studies between BIIRU, University of Illinois, and University of Vermont were initiated in 2003 and 2005, respectively. These studies focus in large part on species rich landscapes under low cerambycid population pressure. These studies have the following three objectives:

1. To identify and determine the relative abundance and seasonal occurrence of native cerambycids and associated natural enemy fauna infesting tree species in the Lake States, Mid-Atlantic States, and Vermont. Studies have largely focused on known *A. glabripennis* hosts (e.g., *Acer* species) and species at risk, but have also included tree species reported to harbor cerambycids.

2. To determine the effects of stress on the relative abundance and seasonal occurrence of native cerambycids and natural enemy fauna. Stress was induced at three levels: half-girdled trees (girdled 180° around the circumference), fully girdled trees (girdled 360°around the circumference), and felling.

3. To evaluate the efficacy of the native natural enemy fauna to parasitize *A. glabripennis* within infested bolts in quarantine at BIIRU.

Results reported here focus on BIIRU investigations conducted in forest stands of red maple (*Acer rubrum*), pignut hickory (*Carya glabra*), mockernut hickory (*Carya tomentosa*), and Virginia pine (*Pinus virginiana*) within the Blackbird State Forest in central Delaware. During the first year of this multiyear study, trees were stressed from July 6, 2005, to August 3, 2005. Stressed trees were inspected on a regular basis from August 2005 to December 2006 for signs of colonization (frass, oviposition scars, sap ooze, inner bark sampling). Note that our primary goal, to induce colonization by native cerambycids whose natural seasonal phenology most resembles *A. glabripennis*, aimed to obtain the associated natural enemies that might in turn parasitize *A. glabripennis* egg and early larval life stages. Therefore, at the first sign of colonization, sample bolts (52 cm) were cut from infested trees, returned to BIIRU, and caged within sono-tubes held in an outdoor insectary. Emergence from each bolt was recorded daily for all insects until November 2006. Except for potential parasitoids, all insects were preserved for identification. Potential parasitoids were bioassayed by caging an individual female wasp, normally together with a single conspecific, on *A. glabripennis* infested *A. rubrum* bolts containing egg and larval (cambium and xylem) life stages. Bioassay cages were checked daily for parental mortality and emergence of parasitoid F_1 offspring. All bioassay bolts were subsequently dissected and all *A. glabripennis* and parasitoid life stages collected and recorded.

Cerambycidae

To date, approximately 66% of the pine trees that underwent colonization were among those that had been stressed by felling, with the remaining 33% equally divided among those that had been stressed by the two girdling methods. In contrast, nearly 100% of the maple and hickory trees that underwent colonization were among those that had been stressed by felling. Although identifications are thus far tentative, results indicate that *Neoclytus mucronatus* and *Xylotrechus colonus*, *Neoclytus mucronatus* and *Neoclytus a. acuminitas*, and *Monochamus* sp. were the most abundant cerambycid species found in *C. glabra* and *C. tomentosa*, *A. rubrum*, and *P. virginiana*, respectively (Table 1). Analysis of the relative seasonal abundance of all wood borers and bark beetles has not been completed. However, *Monochamus sp.* (from pine), *Neoclytus a. acuminitas* (from maple), and *Neoclytus mucronatus* (from hickory) each showed a well-defined emergence pattern in early, mid, and late season, respectively.

Parasitoids

Results also show the relative abundance of parasitoids belonging to the Braconidae, Ichneumonidae, and Chacidoidea emerging from *C. glabra* and *C. tomentosa*, *A. rubrum*, and *P. virginiana* (Table 2). While many of the cerambycids, braconids, ichneumonids, and Chalcidoidea have been identified to genus, they are awaiting species confirmation. Analysis of the relative seasonal abundance of hymenopterous parasitoids has not been completed. Coupling detailed analysis of associated cerambycid and bark beetle species within infested bolts and with published literature will establish parasitoid-host associations.

Bioassays

To date, most parasitoid species emerging from the 2005 field collected bolts were represented among those caged with *A. glabripennis* infested *A. rubrum* bolts in quarantine. However, among the represented hymenopterous families, the total number of individual parasitoids bioassayed was only 161, 61, and 28 individual parentals originally emerging from hickory, maple, and pine, respectively. Analysis of parental survival (duration), parasitization rate, F_1 density, and developmental rate has not yet been completed. However, at least two braconid species, including *Atanycolus* sp., and one ichneumonid species were observed displaying parasitization behavior on *A. glabripennis* infested bolts. Among these, only braconid species were found to successfully parasitize and complete development of F_1's. Furthermore, the successful braconids were largely among those whose natal host plant was *A. rubrum*. Subjectively, these results may indicate natal host plant conditioning among the braconids bioassayed. Reciprocal studies will test this hypothesis in an effort to obtain empirical (objective) data. While these results are from the first year of a multiyear study and should be considered as preliminary, these findings are significant in that they provide the first concrete evidence of a native natural enemy successfully parasitizing *A. glabripennis* and completing development outside the countries of origin.

Closing Remarks

While results to date are based upon sampling artificial stress-induced colonized trees, sampling will be expanded in 2007 to include trees undergoing naturally induced colonization. Furthermore, while results to date are based upon sampling of only the overwintering generation of woodborers and associated natural enemies, sampling will be expanded in 2007 to include the within season generations of woodborers and associated natural enemies. Finally, bioassay methods will be improved in 2007 in an effort to provide more naturally occurring conditions, e.g., environmental conditions.

Table 1. Cerambycid species colonizing (2005) and emerging from (2006) *Carya glabra* and *C. tomentosa*, *Acer rubrum*, and *Pinus virginiana*. Blackbird State Forest, Delaware. [Tentative Identification]

Tree Species	Family/Species	Total # Insects	Density (#/infested bolt)
Carya glabra & Carya tomentosa	Cerambycidae	5,982	20.3
	Neoclytus mucronatus	1,759	7.4
	Neoclytus a. acuminitas	5	1.3
	Neoclytus spp.	6	1.2
	Saperda dentatus	345	3.3
	Xylotrechus colonus	870	4.7
	Cerambycidae spp.	2,988	13.1
Acer rubrum	Cerambycidae	137	3.8
	Acanthocinus sp.	1	1.0
	Aegomorphus modestus	1	1.0
	Astylopsis macula	3	1.5
	Curius dentatus	2	1.0
	Neoclytus mucronatus	20	6.7
	Neoclytus a. acuminitas	63	3.9
	Cerambycidae spp.	46	2.2
Pinus virginiana	Cerambycidae	720	5.1
	Astylopsis collari	2	2.0
	Astylopsis macula	1	1.0
	Monochamus sp.	138	1.7
	Neoclytus mucronatus	5	2.5
	Neoclytus a. acuminitas	1	1.0
	Neoclytus spp.	1	1.0
	Xylotrechus colonus	3	1.5
	Cerambycidae spp.	569	5.0

Table 2. Hymenoptera parasitoid species colonizing (2005) and emerging from (2006) *Carya glabra* and *C. tomentosa*, *Acer rubrum*, and *Pinus virginiana*. Blackbird State Forest, Delaware. [Tentative Identification]

Tree Species	Family/Species	Total # Insects	Density (#/infested bolt)
Carya glabra & Carya tomentosa	Braconidae	1042	4.1
	Ichneumonidae	569	2.7
	Chalcidoidea	22	1.4
Acer rubrum	Braconidae	115	3.0
	Ichneumonidae	41	1.9
	Chalcidoidea	10	3.3
Pinus virginiana	Braconidae	92	4.4
	Ichneumonidae	11	1.8
	Chalcidoidea	28	4.7

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