POTENTIAL FOR BIOLOGICAL CONTROL OF THE EMERALD ASH BORER

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Abstract

The Emerald ash borer (EAB), *Agrilus planipennis*, is an invasive buprestid from Asia threatening North America's ash trees (*Fraxinus* spp.). Eradication of EAB in Michigan, although desirable, appears increasingly unlikely as managers discover a wide distribution of EAB throughout Michigan's Lower Peninsula and northern Ohio and Indiana. According to the National Management Plan for Invasive Species (National Invasive Species Council 2001), "When invasive species appear to be permanently established, the most effective action may be to prevent their spread or lessen their impacts through control measures. For certain invasive species, adequate control methods are not available or populations are too widespread for eradication to be feasible." We concur that integrated pest management methods, including the "release of selective biological control agents," are needed for control and management of EAB. Current containment efforts are critical to save our valuable ash resources while scientists develop rearing methods, perform safety testing, and conduct releases.

The results of studies conducted in Michigan since 2002, demonstrate that a variety of parasitoids attack EAB, including some that typically attack native *Agrilus* spp. (Bauer et al. 2005). Parasitism rates, however, are low (<1%) and clearly inadequate to suppress EAB populations below a density threshold for the survival of ash trees in Michigan. Entomopathogenic fungi resulted in ca. 2% mortality of EAB life stages under the bark. Predaceous beetles and woodpeckers also attack EAB in Michigan.

Emerald ash borer is reported from China, Mongolia, Japan, Korea, Russia, and Taiwan (Haack et al. 2002). During the past 2 years, scientists searched for EAB in each location except Taiwan. Although the type specimen of *A. planipennis* is from Mongolia, recent evidence suggests it was actually collected from Inner Mongolia in China (P. Schaefer). There appear to be few if any *Fraxinus* in Mongolia, thus, the prospects of collecting EAB natural enemies in that country are not promising. In Japan, *A. planipennis* subsp. ulmi is reported from the four main islands, with a host range of ash, elm (*Ulmus*), walnut (*Juglans*), and wingnut (*Pterocarya*) (Haack et al. 2002). Apparently EAB is rare and locally distributed in Japan, although a private collector secured a single EAB from ash after considerable effort (P. Schaefer). In South Korea, no EAB were found despite a month of searching that included applying sticky bands to girdled ash trees at nine locations; purple sticky traps; sweep netting for adults; and visual surveys for evidence of EAB-infested trees (D. Williams). In the Russian Far East, no *Agrilus* species were recovered from ash trees girdled at three sites in 2004 (V. Mastro).

We had considerably more success finding EAB in China. Working with cooperators from the Chinese Academy of Forestry (Dr. Yang Zhong-qi and Professor Gao Ruitong), surveys were conducted that successfully located populations of EAB in Heilongjiang, Jilin, Lianoning, and Hebei Provinces, as well as in Beijing and Tianjin City. EAB is typically at low density in China and is considered only a periodic pest of ash. Populations are probably maintained at low density by a combination of factors including host plant resistance and natural enemies.

Since 2002, several parasitoids of EAB were discovered in China. A new species of *Spathius* sp. (Hymenoptera: Braconidae) was found parasitizing EAB larvae in Jilin Province (H. Liu) and Tianjin City (Xu 2003). This gregarious ectoparasitoid paralyzes EAB larvae and deposits from 1 to 20 eggs per larva. The emergence of *Spathius* adults in the spring coincides with the

Table 1.—The characteristics of EAB parasitoids, and how they relate to the likelihood of successful biological control.

Characteristic	Probability for Biocontrol Success Higher	Spathius	Tetrastichus
Predator vs. Parasitoid	Parasitoid	Yes	Yes
# Generations per year	> 1 compared to host	Yes	Yes
Polyphagy	Monophagous	Unknown	Unknown
Sex Ratio	More Females	Yes (3:1)	Yes (2.5:1)
Oviposition Location	Oviposition on host	Yes	Yes
Internal Feeder?	Internal Feeder	No	Yes

presence of third and fourth-instar EAB larvae, which are the preferred host stages. This species also has four generations per year in Tianjin, and up to 90% parasitism was found in some ash stands (Yang et al. 2005). *Spathius* can be reared in the laboratory and host range studies in a quarantine facility in the U.S. are underway (J. Gould). A new species of *Tetrastichus* sp. (Hymenoptera: Eulophidae), a gregarious endoparasitoid, was found attacking EAB larvae in Heilongjiang, Jilin, and Liaoning Provinces; up to 50% EAB parasitism was found at one site in Jilin Province (Liu et al. 2003). This species has four generations per year (Yang Z.). Efforts to develop rearing methods for this *Tetrastichis* sp. are ongoing in a quarantine facility in the U.S. (L. Bauer and H. Liu). An undetermined species of *Sclerodermus* sp. (Hymenopetera: Bethylidae) attacks EAB pre-pupae (Yang Z. and R. Reardon), but parasitism levels are low. Female parasitoids enter overwintering chambers of EAB pre-pupae, remove frass, and deposit 15-20 eggs; ca. 70% of females are wingless, with limited dispersal capabilities. Members of this genus have also been known to sting humans, making this species unlikely to be approved for release. Egg parasitism has generally been low in China, but an egg parasitoid was discovered attacking EAB eggs in Jilin province: a new species of *Oobius* sp. (Hymenoptera: Encyrtidae) (Zhang et al. in press). This species reproduces parthenogenically and is currently being reared on EAB eggs in a quarantine facility in the U.S.; host range testing is planned (L. Bauer, H. Liu, R. Gao, and T. Zhao).

Predicting the potential for successful biological control of EAB cannot be done by investigating biocontrol success against other Buprestids. It is not that the projects were unsuccessful; it has simply not, to our knowledge, been attempted. We instead looked at how host-feeding niche and characteristics of the parasitoids might impact the probability of success. As the host-feeding niche becomes more concealed, e.g. from external feeders to leaf rollers/webbers to case-bearers, the average number of parasitoid species per host species increases from approximately six to twelve (Hawkins 1994). As the host becomes further concealed, however, the average number of parasitoid species drops to slightly over two in root feeders. Borers were found to support an average of four parasitoids species per host. A quick survey of *Agrilus* species in the United States (Solomon 1995) and Eurasia (Herting and Simmonds 1973) revealed an average of 3.6 and 4.0 parasitoids per host, respectively. There were certainly some *Agrilus* that supported more than four parasitoid species, however, this suggests that few additional EAB parasitoids will be discovered in China.

It is probable that one or more of the EAB natural enemies found recently in China will be useful biocontrol agents in North America. Kimberling (2004) reviewed characteristics of successful biological control agents and found that the most important traits are that the species is 1) a parasitoid, 2) multivoltine, and 3) monophagous. The qualities of *Spathius* and *Tetrastichus*

fit the profile of a successful natural enemy (Table 1). Although we do not yet know if these parasitoids are monophagous, both have more than one generation per year, oviposit on the host, and have a sex-ratio skewed towards females. *Tetrastichus* is an internal feeder, while *Spathius* is not.

We anticipate the favorable characteristics of the parasitoid species, coupled with some preliminary evidence that North American ash species can withstand some level of EAB attack, will result in a successful reduction in the population levels and damage inflicted by the EAB.

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