CAN EMERALD ASH BORER, *AGRILUS PLANIPENNIS* (COLEOPTERA: BUPRESTIDAE), EMERGE FROM LOGS TWO SUMMERS AFTER INFESTED TREES ARE CUT?

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ABSTRACT

Emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is a serious invasive pest of ash trees (*Fraxinus* spp.) in North America. Much of EAB's range expansion has been attributed to human-assisted movement of infested items such as ash logs and firewood. It is unclear the amount of time that logs cut from live EAB-infested ash trees should be restricted from movement until they are no longer capable of producing viable EAB adults. In March and April 2004, we cut log sections from EAB-infested green ash (*F. pennsylvanica* Marsh) trees in Ann Arbor, Washtenaw County, Michigan. Log sections (mean length = 24.8 cm; diam. = 11.6 cm) were stood upright on one cut end and stored beneath a hardwood forest canopy. Adult EAB were allowed to freely emerge from log sections during summer 2004. When logs were dissected in November 2004 to January 2005, approximately one half of the total EAB life stages that were present in the logs were dead, while the other half either emerged as adults in summer 2004 or were live prepupae. Also, adults emerged from a subset of these log sections when reared in the laboratory in January to February 2005. These data suggest that EAB adults can emerge from logs for two successive emergence periods after infested ash trees have been cut.

Emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is a serious invasive pest of ash trees (*Fraxinus* spp.) and, as of May 2008, it was established in the US states of Illinois, Indiana, Maryland, Michigan, Ohio, Pennsylvania, and West Virginia; and the Canadian province of Ontario (Haack 2006; http://www.emeraldashborer.info). EAB is native to Asia and was first discovered in North America in the Detroit metropolitan area of Michigan in 2002 (Yu 1992, Haack et al. 2002, Poland and McCullough 2006). Most of the range expansion of EAB has been attributed to inadvertent human-assisted movement of infested ash nursery stock, logs, and firewood. A federal quarantine was imposed to limit human-assisted dispersal of EAB by regulating movement of these articles (Federal Register 2003).

EAB larvae develop through four instars as they feed in the phloem of ash trees. When fourth instar larvae have completed feeding, they excavate pupation chambers in the outer sapwood or bark of ash trees (Cappaert et al. 2005, Wei et al. 2007). In southern Michigan, most EAB larvae overwinter as prepupae in their pupation chambers after they have developed from eggs laid in early summer of that same year. However, some EAB larvae do not complete larval development the same year they eclosed from eggs and overwinter as larvae in the phloem of ash trees (Cappaert et al. 2005). Some of these larvae complete feeding the following spring and emerge as adults later that same summer. However, a percentage of these larvae do not complete feeding and become prepupae until late summer or fall and overwinter a second time before emerging as adults. Thus, logs cut in mid-summer may have both newly initiated and fully developed larvae.

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EAB prefer to oviposit on live ash trees, but they will occasionally oviposit on freshly cut ash logs (Anulewicz et al. 2008). However, larvae that develop from eggs laid on cut logs rarely complete their development (Anulewicz et al. 2008; T.M. Poland and D.G. McCullough, pers. comm.). Therefore, it is unclear the length of time logs and firewood cut from EAB infested trees should be restricted from movement to assure the absence of live EAB life stages. We present information here from a recent study (Petrice and Haack 2006b) where data were generated suggesting that EAB adults can emerge from log sections two successive emergence-periods after infested trees are cut.

In April 2004, before adult EAB emerged, we cut 136 logs from green ash, *F. pennsylvanica* Marsh, trees that contained live EAB life stages in Ann Arbor, Washtenaw County, MI. Logs were cut approximately 50-cm long and averaged 12 cm in diameter. In May and June 2004, prior to EAB adult emergence, each log was cut into two equal sections, with one section treated with an insecticide and one section untreated to serve as a control (see Petrice and Haack 2006b for more details). Log sections averaged (mean ± SE) 24.8 ± 0.3 cm long and 11.6 ± 0.2 cm in diam. All exit holes present on log sections from previous years (2003 and earlier) were marked with white caulk. Data presented here represent only the control log sections. Log sections were stood upright on one cut end and placed under a hardwood-forest canopy during June to October 2004 and EAB adults were allowed to freely emerge during this period. During November 2004 to January 2005, 126 log sections were brought back to the laboratory and dissected. We recorded the number of EAB adults that had emerged from the sample log sections during summer 2004 based on the presence of new exit holes at the time of dissection. We also recorded the number of dead EAB adults, pupae, prepupae (larvae that have completed feeding and excavated pupation chambers in the bark or wood), and larvae present in log sections; and the number of live EAB prepupae in each log section. Live prepupae, which were apparently undamaged during dissection, were reared in petri dishes at 24ºC. Their final stage of development at death (e.g., prepupae, pupae) or whether they successfully developed to adults was recorded. On 4 January 2005, the 10 remaining log sections that had been cut in April 2004 were brought into the laboratory and placed in cardboard tubes to monitor for adult emergence.

Log dissections revealed that 30.9 ± 2.2 % of the total EAB in log sections had emerged as adults during summer 2004, 22.4 ± 1.9% were live prepupae, 17.0 ± 1.6% died as larvae, 9.6 ± 0.9 % died as prepupae, 0.1 ± 0.1 % died as pupae , and 20.1 ± 1.8% died as callow adults. Furthermore, 18% of the 151 live prepupae that were dissected from log sections in November 2004-January 2005 and reared in petri dishes developed to adults, while 17% died as pupae and 65% died as prepupae. A total of 8 adults emerged in February 2005 from 5 of the 10 log sections that were cut in April 2004 and reared in the laboratory during January-February 2005 (Table 1).

The logs for this study were only moderately infested with EAB and, therefore, competition for food among larvae was low. This likely enhanced EAB survival as compared to logs that would have been heavily infested. We suspect adults that emerged in summer 2004 were fourth instars or prepupae at the time logs were cut in April 2004. While adults that emerged in the laboratory in 2005 were likely younger instars in April 2004. These earlier-instar larvae would have had to continue developing during summer 2004, with adult emergence occurring in late summer 2004 or early summer 2005. Development may have been protracted because of log moisture loss and cooler temperatures that resulted from the log sections being stored in the shade. Alternatively, given that some EAB larvae may require a two-year life cycle (Cappaert et al. 2005; Wei et al. 2007), it is equally likely that live prepupae we found in log sections in November 2004-January 2005 and adults that emerged in February 2005 may have needed two seasons to complete development regardless of when logs were cut from infested trees. We assume all EAB individuals that emerged in

Table 1. Length and diameter of ash log sections that were cut from EAB-infested trees in Washtenaw County, MI in April 2004, and number of EAB adults that emerged from each log section during summer 2004 while log sections were stored outdoors and during February 2005 after log sections were brought indoors in January 2005.

Tree cutting date	Log dimensions (cm)		Number of adults that emerged	
	Length	Diameter	2004	2005
3 April 2004	22.0	13.2	3	0
3 April 2004	23.2	15.7	16	0
3 April 2004	20.8	17.4	3	0
29 April 2004	29.5	10.7	1	1
29 April 2004	23.7	12.5	6	0
29 April 2004	27.5	7.3	2	2
29 April 04	24.5	9.8	0	2
29 April 2004	28.0	11.8	3	1
29 April 2004	29.1	10.9	0	2
29 April 2004	31.4	14.3	2	0
Overall	25.8	11.4	36	8

2004 and 2005 had resulted from eggs laid in 2003 or possibly one year earlier. Although highly unlikely, it could be argued that the EAB adults that emerged in 2005 resulted from eggs laid on the log sections during summer 2004 because the log sections were exposed to natural attack. As mentioned above, EAB oviposition has been recorded on cut logs but is evidently rare (Anulewicz et al. 2008; T.M. Poland and D.G. McCullough, pers. comm.).

Surprisingly, even though the log sections were cut to very short lengths (25 cm) within 1-2 months after they were initially cut from trees in March and April, they still contained live EAB prepupae in November 2004-January 2005 that were able to develop into adults in the laboratory. Petrice and Haack (2006a) found that when firewood logs cut from EAB-infested trees remained uncovered outdoors in either the sun or shade, EAB survival was reduced the following summer compared to logs stored under tarps. This difference was likely a result of logs desiccating more when they were exposed to ambient conditions. Therefore it would be assumed that desiccation would have greatly reduced survival of EAB in the short, small-diameter log sections used in the current study. If log sections in the present study would have remained outdoors an additional 4-5 months until the 2005 summer emergence, it is likely that further desiccation would have lowered EAB survival even more. Nevertheless, our data show that EAB adults can be reared from short, small-diameter logs during two successive emergence periods after logs are cut from infested trees. Based on these results, ash logs and firewood potentially infested with EAB should be held at least two summers after trees are cut to allow EAB adults time to emerge prior to any log movement if the objective is to prevent human-assisted movement of EAB. Nevertheless, current EAB quarantine regulations prohibit movement of all hardwood firewood and ash logs to areas outside of EAB quarantine zones unless they have been treated with an approved method (Federal Register 2003).

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