
Predicting the Ability To Produce Emerald Ash Borer: A Comparison of Riparian and Upland Ash Forests in Southern Lower Michigan

Susan J. Crocker^{1,2}, Deborah G. McCullough³, and Nathan W. Siegert⁴

Abstract.—Concern for the future of ash trees in the United States has risen since the 2002 discovery of emerald ash borer (EAB) (*Agrilus planipennis* Fairmaire) in southeastern Michigan. The ability of ash forests in the Southern Lower Peninsula of Michigan to produce EAB was compared by physiographic class and stand size. Results showed that EAB production potential was significantly higher in riparian forests and in large- and medium-diameter ash stands. The potential to support dense populations of EAB suggests that riparian forests may have higher ash mortality and a greater ability to influence the rate of EAB spread.

Introduction

Four years after being identified in the United States, emerald ash borer (EAB) (*Agrilus planipennis* Fairmaire, Coleoptera: Buprestidae) has killed an estimated 15 million ash trees in southeastern Michigan (Cappaert *et al.* 2005). Discovered near Detroit, MI, in June 2002, EAB is an Asian native that is believed to have entered the country in solid-wood packing material in the early nineties (Cappaert *et al.* 2005). EAB is a wood boring beetle that feeds in the inner bark of ash trees. It attacks native species of ash (*Fraxinus* spp.), including white (*F. americana*), black (*F. nigra*), and green ash (*F. pennsylvanica*) and many planted cultivars (Cappaert *et al.* 2005). Primary insect damage is caused as larvae feed and produce galleries within the phloem and outer sapwood. Tree mortality

occurs within 1 to 3 years of initial attack (Haack *et al.* 2002, McCullough and Katovich 2004).

The known United States distribution of EAB is centered in southeastern Michigan. Outlier infestations have also been detected throughout the Lower Peninsula of Michigan, northwestern Ohio, northern Indiana, northeastern Illinois, and southwestern Ontario, Canada (Cappaert *et al.* 2005, Illinois Department of Agriculture 2006). In addition, transportation of infested firewood and infested nursery stock has introduced EAB to Maryland and the Upper Peninsula of Michigan (Maryland Department of Agriculture 2006, Michigan Department of Agriculture 2005).

Ash species are found on a variety of sites, from moist, well-drained uplands to partially inundated swamps and floodplains (Barnes and Wagner 2004). Because of its tolerance to flooding, ash is a dominant species in riparian forests and makes up a substantial portion of the overstory canopy. Riparian forests have a strong interaction with surface waters and are vulnerable to disturbance. Changes that occur in riparian forests have significant impacts on forest structure and composition, water quality, and stream and terrestrial habitat (Tepley *et al.* 2004). Because ash is a principal component of riparian forests, EAB presents a major threat to this vast network of resources.

In this study, the potential abilities of ash forests in different physiographic regions were compared to stand-size classes to produce adult EAB. Specifically, this study was designed to test the hypothesis that riparian ash forests have a greater potential to produce EAB compared to upland ash forests. The motivating factor was to assess the potential impact of EAB establishment in riparian forests and to evaluate the role of riparian ash in EAB dispersal.

¹ Forester, U.S. Department of Agriculture, Forest Service, Northern Research Station, 1992 Folwell Avenue, St. Paul, MN 55108. E-mail: scrocker@fs.fed.us.

² Graduate Student, State University of New York, College of Environmental Science and Forestry, 1 Forestry Drive, Syracuse, NY 13210.

³ Professor, Departments of Entomology and Forestry, Michigan State University, 243 Natural Science Building, East Lansing, MI 48824.

⁴ Postdoctoral Research Associate, Department of Entomology, Michigan State University, 243 Natural Science Building, East Lansing, MI 48824.

Methods

This study was conducted in the Southern Lower Peninsula (SLP) of Michigan (fig. 1). To estimate phloem area and determine EAB production potential for riparian and upland forests in the SLP, plot- and tree-level data were selected from the U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis (FIA) database. Plots were selected from the most current inventory and were measured between 2000 and 2004. Under the national FIA plot design, all trees greater than 12.5 cm in diameter at breast height⁵ (d.b.h.) are measured on four 7.32 m radius subplots and saplings with d.b.h. between 2.5 and 12.5 cm are measured on four 2.07 m radius microplots. Seedlings (d.b.h. is less than 2.5 cm) are counted but detailed, individual measurements are not recorded (Miles *et al.* 2001).

Figure 1.—Study area, Southern Lower Peninsula, Michigan.



Sixty plots with an ash forest type were randomly selected to analyze EAB production potential. The sample was selected so that one half of the plots had a riparian physiographic class (n = 30) and the other half of the plots had an upland physiographic class (n = 30). An equal number of plots (n = 10) from riparian and upland physiographic classes represented one of three stand-size classes: large-diameter, medium-diameter, or small-diameter.

For each plot, the diameter of each live ash tree greater than 4 cm d.b.h. was used to calculate phloem area (y) using the following second order polynomial equation that was developed to fit the relationship between phloem area (surface area) and d.b.h. ($r^2 = 0.9501$) (McCullough and Siegert, 2007):

$$y = 0.0216x^2 - 0.0922x \quad (1)$$

where y = phloem area and x = d.b.h. (cm). The phloem area of each ash tree (n = 216 on riparian plots and n = 136 on upland plots) was multiplied by the mean estimate of the potential number of adult EAB that can be produced per m² of phloem, defined as EAB production potential (McCullough and Siegert, 2007) (table 1). EAB production potential is an average, calculated for 5 different diameter classes, of the total number of observed EAB adults found per m² of phloem and is based on results from 148 ash trees. The production potential for each ash was summed with all other ash trees on the same plot to yield the total EAB production potential per plot.

To test the difference in total EAB production potential per plot by physiographic class and stand-size, a two-way analysis of variance was performed using SAS software (SAS Institute, Inc. 2004).

Table 1.—Mean emerald ash borer production potential per m² of phloem area by diameter class (McCullough and Siegert, 2007).

Diameter class (cm)	Mean (number of adult insects)
2.3–13	68.8 (5.86)
14–25	108.3 (10.08)
26–42	106.2 (10.15)
43–60	105.2 (11.18)
> 60	94.7 (8.28)

Note: Standard error in parentheses.

⁵ Diameter at breast height is measured at 1.3 m (USDA Forest Service 2001).

Results

Riparian and upland ash forests differ in their potential to produce EAB. Riparian ash forests had a significantly higher total EAB production potential than upland ash forests ($\alpha = 0.05$, $P < 0.01$). Stand-size class was also found to impact production potential. Total EAB production potential was significantly higher in the medium- and large-diameter classes than in the small-diameter stand-size class ($\alpha = 0.05$; $P < 0.01$ for the medium-diameter class, $P = 0.01$ for the large-diameter class). The medium- and large-diameter stand-size classes were not significantly different ($\alpha = 0.05$, $P = 0.74$). The interaction effect between physiographic class and stand-size class was not significant ($\alpha = 0.05$, $F = 0.25$, $df = 2$, $P = 0.78$).

Discussion

Riparian ash forests were found to have a significantly greater potential to produce adult EAB than upland ash forests. The difference in estimates of EAB production potential is due to a difference in ash density. A higher degree of species diversity (i.e., non-ash hardwoods) in upland forests is likely to contribute to the lower total production potential found among upland ash forests. In general, riparian forests contain more ash than upland forests and have more phloem area. Greater phloem area increases the potential area available to support the development of EAB. Higher total production potential in riparian forests indicates that EAB has a greater reproductive ability in riparian forests. Damage within riparian forests may be more significant, since populations of EAB may build more rapidly and spread more quickly. As such, the rate at which EAB can spread may be greater in riparian forests.

In addition to physiographic class, total EAB production potential was also found to be influenced by stand-size class. Medium- and large-diameter stands, where the majority of stocking is in trees larger than 12.5 cm, have more available phloem area. As a result, these stands can produce more EAB compared to small-diameter stands. EAB presents a significant risk to medium- and large-diameter stands, as these stands are areas of potentially high EAB density.

Eradication and containment are primary responses to EAB. Current control strategies include the removal of all ash within a 0.5 mile radius of an infested tree, voluntary reduction of ash in un-infested areas, and the application of insecticides (Poland and McCullough 2006). Results suggest that such efforts to mitigate the spread of EAB should be focused in riparian forests and in medium- to large-diameter stands where the potential to support high densities of EAB is the greatest. Knowledge of potential epicenters of EAB activity will allow managers to (1) reduce the rate of EAB spread, (2) lessen damage caused by EAB infestations, and (3) effectively allocate limited resources and management efforts.

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