

An Assessment of the Relationship Between Emerald Ash Borer Presence and Landscape Pattern

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ABSTRACT: Six years after its 2002 detection near Detroit, MI, the emerald ash borer (EAB) (*Agrilus planipennis* Fairmaire) has spread hundreds of miles across the Upper Midwest and Mid-Atlantic regions of the United States. Human-assisted transportation of infested ash materials is the primary mechanism of EAB dispersal over long distances. Natural spread occurs locally and is influenced by factors, such as host availability, meteorological conditions, and landscape configuration. This study looks at the effects of ash density and landscape pattern on current EAB distribution. Forest Inventory and Analysis (FIA) data were used to calculate plot-level landscape metrics (total edge length, edge density, and forest proportion) in Ohio, Indiana, Illinois, and Wisconsin. Initial results indicate that while EAB is primarily found in areas with a low proportion of forest land, it is also found in areas with a relatively high concentration of ash. Counties containing EAB infestations were also found to have high relative edge densities.

Keywords: Emerald ash borer, landscape metrics, forest inventory.

Introduction

The emerald ash borer (EAB) (*Agrilus planipennis* Fairmaire, Coleoptera: Buprestidae) is a wood-boring beetle that is believed to have been introduced to the United States from Asia during the early 1990s (McCullough and Katovich 2004, Siegert et al. 2008). Undetected until 2002, EAB was initially found near Detroit, MI, and in adjacent Windsor, Ontario, Canada. Since that time, EAB has killed tens of millions of ash trees (*Fraxinus* spp.) across the Upper Midwest and along the East Coast, causing it to become one of the leading threats to the nation's forest resource (de Groot et al. 2008). EAB is currently (as of October 2008) found in 10 U.S. states (Michigan, Ohio, Indiana, Maryland, Illinois, Pennsylvania, West Virginia, Virginia, Missouri, and Wisconsin) and two Canadian provinces (Ontario and Québec) (USDA APHIS 2008).

Natural spread of EAB has been facilitated by human transportation of infested ash materials, such as movement of firewood and nursery stock. This form of artificial spread has been the source of many localized, outlier infestations (Cappaert et al. 2005). Once an outlier infestation has been established, the gradual, natural spread of EAB becomes paramount. Natural dispersal is influenced by many factors, including host availability, meteorological conditions, insect flight ability, and the configuration of the landscape (Cappaert et al. 2005). Additional research on natural spread from outlier infestations is

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needed to help identify specific conditions which influence the direction and rate of natural dispersal of EAB. This information will enhance detection methods and aid in making management decisions.

Alterations in landscape pattern affect the quantity and suitability of the habitat that is available to organisms. Human activities, such as urban sprawl, land-use conversion, and commercial and residential development are the leading cause of landscape change. The most important outcome of changing landscape pattern is that it often leads to increases in forest fragmentation, i.e., the break up of large, contiguous forest parcels into small, isolated patches (Forman 1995).

The purpose of this study is to investigate the effects of ash density and landscape pattern on current EAB distribution. Results will provide insight on specific landscape conditions that may influence dispersal, or increase habitat suitability and thereby increase the risk of EAB invasion.

Methods

Study Area

Data from Ohio, Indiana, Illinois, and Wisconsin were examined in this study. EAB has been positively identified in each of the four states within the study area; however, infestations have not been found in every county. The study area was chosen to reflect the variation in the length of time that a known EAB infestation has been present within a state. Ohio (2003) and Indiana (2004) represented long infestation periods, while Illinois (2006) and Wisconsin (2008) represented short infestation periods. Michigan was not included in the study as the Lower Peninsula is considered generally infested.

Mapping Current EAB Distribution

Using quarantine and available EAB-positive location data (Ohio Dept. of Ag. 2008, Indiana Dept. of Nat. Res. 2008, Illinois Dept. of Ag. 2008, Wisconsin Dept. of Nat. Res. 2008), a map of the current distribution of EAB (i.e., EAB presence/absence) and state quarantine boundaries was constructed using ArcMap 9.2 (Fig. 1).

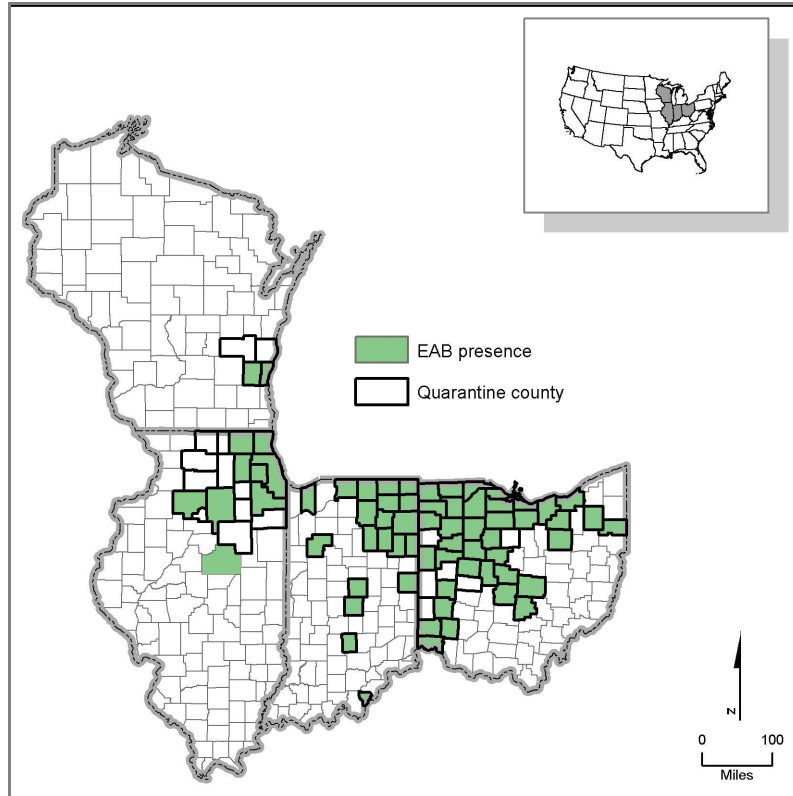


Figure 1: EAB presence and state quarantine boundaries in Ohio, Indiana, Illinois, and Wisconsin

Estimating Ash Density

Basal area was used as a measurement of ash density. Estimates of ash basal area (as a percentage of total live tree species basal area) were calculated using FIA plot data for all counties in the study area.

Landscape Metrics

Forest fragmentation that occurs as the result of natural disturbance events has a greater impact on the landscape than fragmentation that results from human activities, such as urban development. Human-caused fragmentation occurs more often, is less random, and has long-lasting effects that occur over a larger area (Haynes 2003). The process of fragmentation greatly alters the shape and pattern of continuous forest, leaving behind a collection of patches that vary in size and shape and that contain an increased amount of edge habitat. This increase in edge habitat has many negative effects on the remaining vegetation, including increased susceptibility to pest outbreaks. Therefore, it is important that the resulting landscape pattern be quantified for management and monitoring

purposes. Landscape pattern can be quantified using landscape metrics, i.e., “measurements designed to quantify and capture aspects of landscape pattern and include such measures as fragmentation indices” (Griffith et al. 2000). FIA plot data were used to calculate several landscape metrics in order to describe the landscape pattern within the study area. Calculated metrics included forest proportion, total edge length, and edge density. Total edge length was required to calculate edge density; however, measurements of total edge length are not reported.

Forest Proportion: Forest proportion represents the percentage of forest land area relative to the total land area, including noncensus water. These estimates were obtained by applying two algorithms that expanded plot condition level data (i.e., accessible forest, nonforest, and noncensus water) from the FIA database to county-level estimates for each state. The first algorithm was used to calculate area (acres) of accessible forest land, while the second was used to calculate the total area of all land and noncensus water. Forest land area was then divided by total land area to find the proportion (%) of forest land in each county.

Total Edge Length: The requirement to map different condition classes on FIA subplots allows the boundary, or edge length, between the conditions to be obtained. However, for this study, edge length was only obtained between forest and nonforest condition classes. Edge length may be measured as a straight line or as two lines that meet at a corner. When two different conditions are encountered on a subplot and the edge is a straight line, the right and left azimuths are recorded from subplot center, where the differing conditions intersect the subplot circumference. Given that the radius of the subplot is fixed at 24 feet, edge length has a maximum length of 48 feet. If the edge between the two conditions is not a straight line and contains a corner, a corner azimuth and a corner distance (from subplot center) are also recorded. When this occurs, the total edge length may be longer than 48 feet. Using azimuth, radius, and/or corner distance information, the total edge length for both types of edges was calculated using the law of cosines:

$$a^2 = b^2 + c^2 - 2bc * \cos A$$

where a is the edge length, and b and c are the length of the radii, or when a corner is present, the length of the segments from the corner to the subplot circumference. Angle A represents the corner angle, opposite the straight-line edge, at subplot center. If a corner was present, two angles were recorded and the law of cosines was used to find two edge lengths, which were then summed to find the total edge length. After edge lengths were obtained for each subplot, they were summed to find the plot-level edge length total (only if there was more than one subplot containing a forest/non-forest edge), which was then multiplied by the plot expansion factor. Finally, these expanded plot estimates were summed to find the total edge length for each county and state (as a whole) in the study area.

Edge Density: To make edge length estimates comparable across different levels of forestation, total edge length was converted to edge density equivalent to miles of edge per square mile of forest land. This was calculated by converting forest land area estimates from the FIA database from acres to square miles. The total edge length, in miles, was then divided by the forest land area, in square miles, to obtain edge density in miles per square mile. Similar to total edge length, edge density was calculated at the county and state level. Measures of relative edge density were then calculated for each county as the ratio of its estimate to the state-level estimate; this was done to determine how levels of edge density in each county compared to edge density in the state overall.

Results

Forest Proportion and Ash Basal Area

As of October 2008, EAB has been positively identified in 67 counties, or 18 percent of the study area (Fig. 1). EAB was predominantly found in counties where the land area was less than 25 percent forested (Fig. 2). While EAB-positive counties generally had a low percentage of forest, many of these counties also had a significant ash component (Fig. 2, Fig. 3). In these counties, the percentage of ash basal area ranged from zero to 60 percent of the total basal area of all live tree species (or the total live-tree basal area) (Fig. 3). On average, ash made up 13 percent of total live-tree basal area in counties containing EAB.

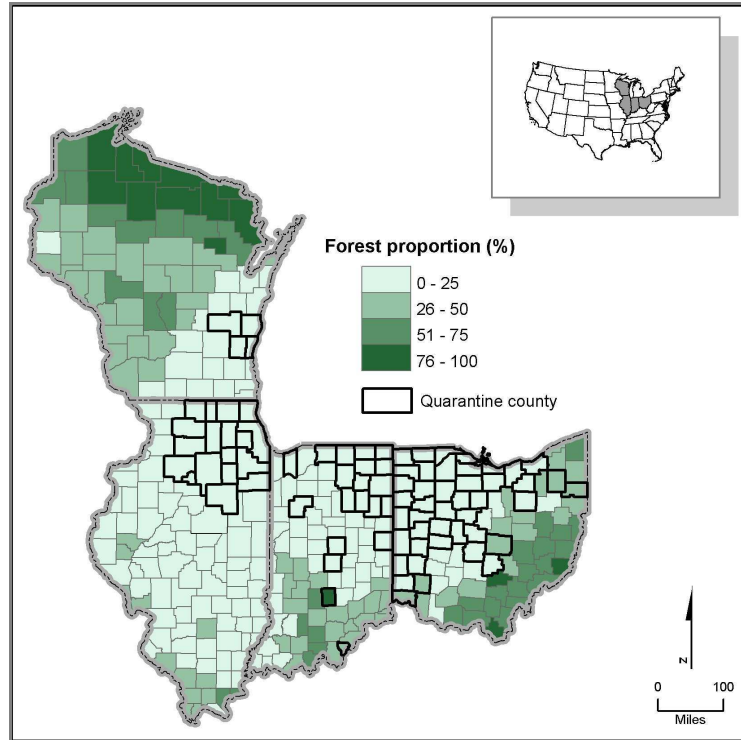


Figure 2: Forest proportion by county in Ohio, Indiana, Illinois, and Wisconsin

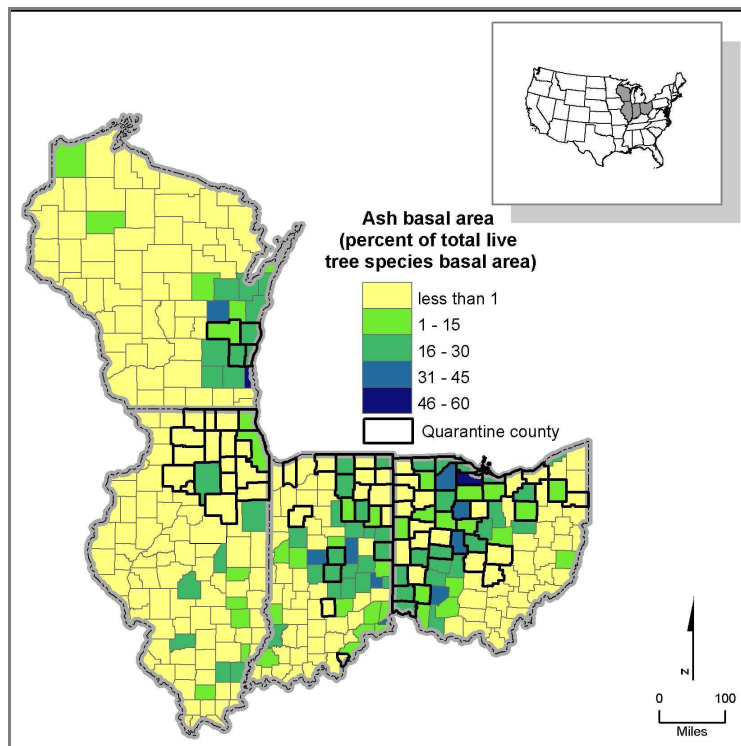


Figure 3: Ash basal area, as a percentage of total live tree species basal area, by county in Ohio, Indiana, Illinois, and Wisconsin

Edge Density

Counties with high proportions of forest land (Fig. 2) generally had low relative edge densities (Fig. 4). Not surprisingly, edge density was higher in counties containing EAB than in counties where EAB was absent (Fig. 5). Sixty-nine percent of EAB-positive counties had relative edge densities of 1.1 or greater. Conversely, 43 percent of counties where EAB has not been found had relative edge densities of 1.0 or less.

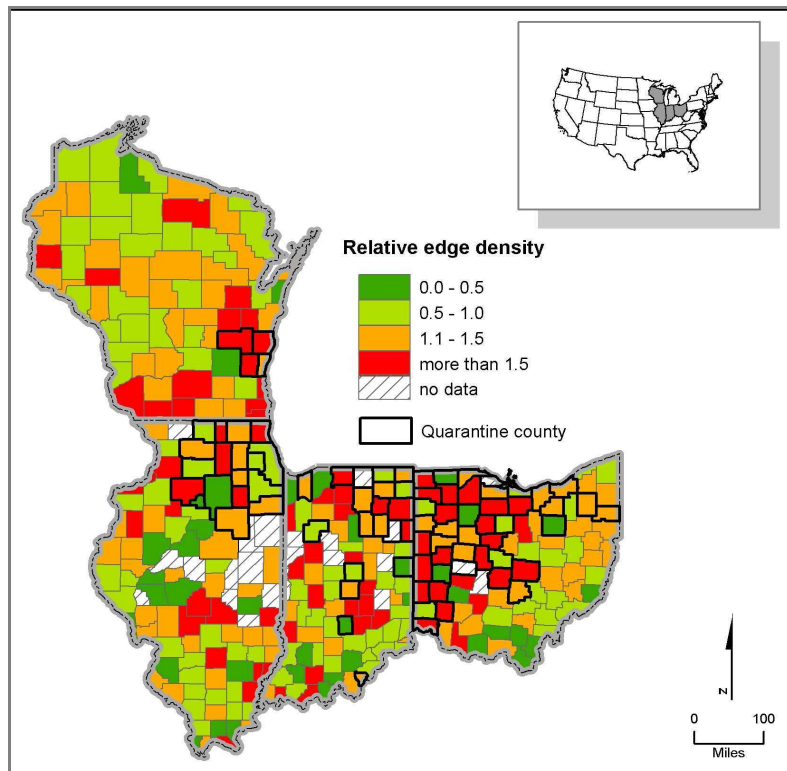


Figure 4: Relative edge density by county in Ohio, Indiana, Illinois, and Wisconsin (counties that did not contain accessible forest land and/or a forest/nonforest edge appear as 'no data')

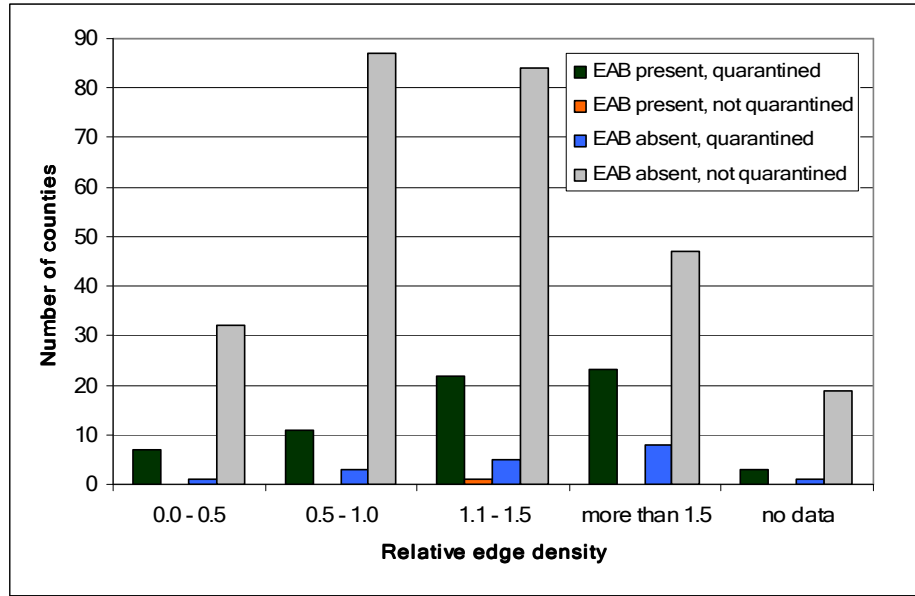


Figure 5: Relative edge density inside and outside of quarantine boundaries in Ohio, Indiana, Illinois, and Wisconsin

Discussion

In this study, we explored the relationship between EAB distribution, relative host abundance, and landscape pattern. We calculated county-level landscape metrics and compared them based on EAB presence or absence. Presence of EAB within a county was generally associated with low forest proportion, a high percentage of ash basal area, and high relative edge density. This is indicative of available habitats that consist of smaller parcels of fragmented forest that contain large amounts of ash.

Because EAB is found predominantly in areas with a relatively high percentage of ash, there is greater potential for damage and mortality of ash trees. A higher density of ash and therefore, more available phloem area increases EAB reproductive capacity. As a result of these factors, insect populations are more capable of rapid build up; therefore, smaller parcels of habitat may be quickly exhausted and spread of EAB may occur at a higher rate.

Initial results indicate a relationship between EAB presence and landscape pattern. Future work will involve the use of additional metrics, such as those derived from land cover imagery, to further characterize the landscape. These metrics will include road density, mean patch size, inter-patch distance, and connectivity. Furthermore, surrounding land uses will be examined in relation to EAB-positive locations and host abundance as a means of investigating the potential effects of changing landscape pattern on EAB dispersal.

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