CHAPTER 8

Ash Tree Decline and Mortality in Ohio and the Allegheny National Forest in Pennsylvania

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INTRODUCTION

The emerald ash borer (*Agrilus planipennis*) (EAB) is a wood-boring beetle from Asia that has killed billions of ash (*Fraxinus* spp.) trees in North America since its accidental introduction to southeastern Michigan in the mid-1990s. The EAB spread rapidly and has become one of the most costly/destructive pests in North America (Aukema and others 2011). It affects multiple ash species, driving several to be listed as endangered (Jerome and others 2017). Previous studies have shown substantial EAB-caused mortality of larger size classes of ash in forests (Flower and others 2013, Morin and others 2017); however, in some sites, ashes have survived as lingering survivor trees (Koch and others 2015), small seedlings (Klooster and others 2014), or trees from root sprouts (Kashian 2016).

The impacts of invasive pests on host trees vary by species and vary across the landscape based on geophysical characteristics and forest stand conditions (Flower and Gonzalez-Meler 2015). Earlier research has indicated differences in mortality from EAB among ash species (Anulewicz and others 2007, Rebek and others 2008, Tanis and McCullough 2012), which may be due to tree resistance to EAB, the preference of EAB adults, or both (Koch and others 2015). For example, adult EABs have been shown to prefer other native ash species over blue ash (*F. quadrangulata*) (Pureswaran and Poland 2009, Tanis and McCullough 2012). Understanding patterns of ash decline and mortality helps forest managers plan for and manage EAB impacts and also provides context for identification of lingering ash trees to test for EAB resistance.

METHODS

We studied the EAB impacts on ash in two very different landscape contexts in Ohio and Pennsylvania. The Ohio sites are typically smaller forested areas, including Federal and State lands, local parks, and privately owned land, completely surrounded by agricultural areas or suburban housing and retail. In contrast, the Pennsylvania sites are in the Allegheny National Forest (ANF), a heavily forested landscape with considerable geographic relief surrounded by and interspersed with forested State and private lands.

In Ohio, we set up three monitoring plots in each of 60 sites during 2005–2008 prior to ash mortality to include a range of ash densities, stand ages, and species: white ash (*F. americana*), green ash (*F. pennsylvanica*), pumpkin ash (*F. profunda*), black ash (*F. nigra*), and blue ash. Each of these five ash species has different habitat affinities, ranging from upland forests for white ash, to riparian areas for green ash, to limestone areas with high calcium soils for blue ash, to wet forests for black, pumpkin, and green ash. We used bark and twig morphology to identify blue ash, bark and sessile leaflets to identify black ash, and seed shape and calyx length to identify white, green, and pumpkin ash. We collected voucher specimens of ash seeds, leaves, and twigs and preserved them at the U.S. Department of Agriculture, Forest Service, Northern Research Station lab in Delaware, OH. In sites that contained a mix of white and green ash and hybrids, or green and pumpkin ash, it was difficult to distinguish among these tree species and so they were pooled.

In Ohio, we measured ash trees ≥10 cm diameter at breast height (d.b.h.) in three to five 11.3-m-radius circular plots per site and measured ash saplings and seedlings in smaller nested plots (see Knight and others 2014 for detailed methods). We tracked >3,000 individual trees and recorded ash canopy health condition on a 1–5 scale where 1 is healthy, 5 is dead, and 2, 3, and 4 are stages of decline. We also recorded EAB symptoms, d.b.h., mortality, and tree fall. Tree fall was defined as the main trunk of the tree on the ground, due to the lower trunk snapping or uprooting. We visited plots yearly 2005–2014 and again in 2019; we visited sites with remaining live trees in 2020 and 2021. From 2008–2021, in nine sites in central Ohio and five sites in northwestern Ohio, we measured EAB populations. We hung four purple prism traps coated with tanglefoot and baited with manuka oil lures in ash trees throughout the season when EAB adults are active (450–550 growing degree days [GDD] to late August) and counted EAB adults caught on the traps.

In northwestern Pennsylvania, we set up 190 monitoring plots in 2010 prior to ash mortality at the ANF. In contrast to the Ohio sites, the ANF is marked by considerable topography, creating upper slope areas where soil base cations may be depleted due to leaching and lower slope areas with richer soils. These soil differences have led to declines in ash health in upper slope areas prior to EAB impact (Royo and Knight 2012). We selected ash sites by superimposing a 700-ha grid throughout the ANF land base and used existing stand composition data to identify blocks containing ash and to select paired upper and lower slope plots. All ash trees in monitoring plots at the ANF are white ash, and very few ash saplings and seedlings existed in any of our sites. We used basal area factor (BAF) 10 prism plots to record ash canopy health condition, d.b.h., and mortality of ash trees in 2010, 2015, and 2018–2021.

RESULTS

Figures 8.1 and 8.2 depict the progression of ash mortality across the landscapes of Ohio and the ANF, respectively. In most sites, ash trees (≥10 cm d.b.h.) were relatively healthy at the beginning of the monitoring period and then progressed to substantial mortality. At the ANF, white ash had experienced 77-percent mortality by 2021. Mortality patterns differed markedly by species in Ohio (table 8.1), with blue ash exhibiting better survival rates than other species. In sites containing both white ash and blue ash, the white ash was attacked and killed first. Then, the blue ash began to decline, with some trees succumbing to EAB, but with >70 percent of the trees surviving. In contrast, < 5 percent of the white and green ash trees ≥10 cm d.b.h. originally present in all plots were still alive by 2019. In most sites, black ash had 100-percent mortality; however, at a few sites where nearby ash trees had been treated with systemic insecticide, black ash and pumpkin ash had greater survival. Ash trees fell rapidly after mortality, with 20 percent of the trees falling within 2 years and >80 percent falling within 8 years (fig. 8.3).

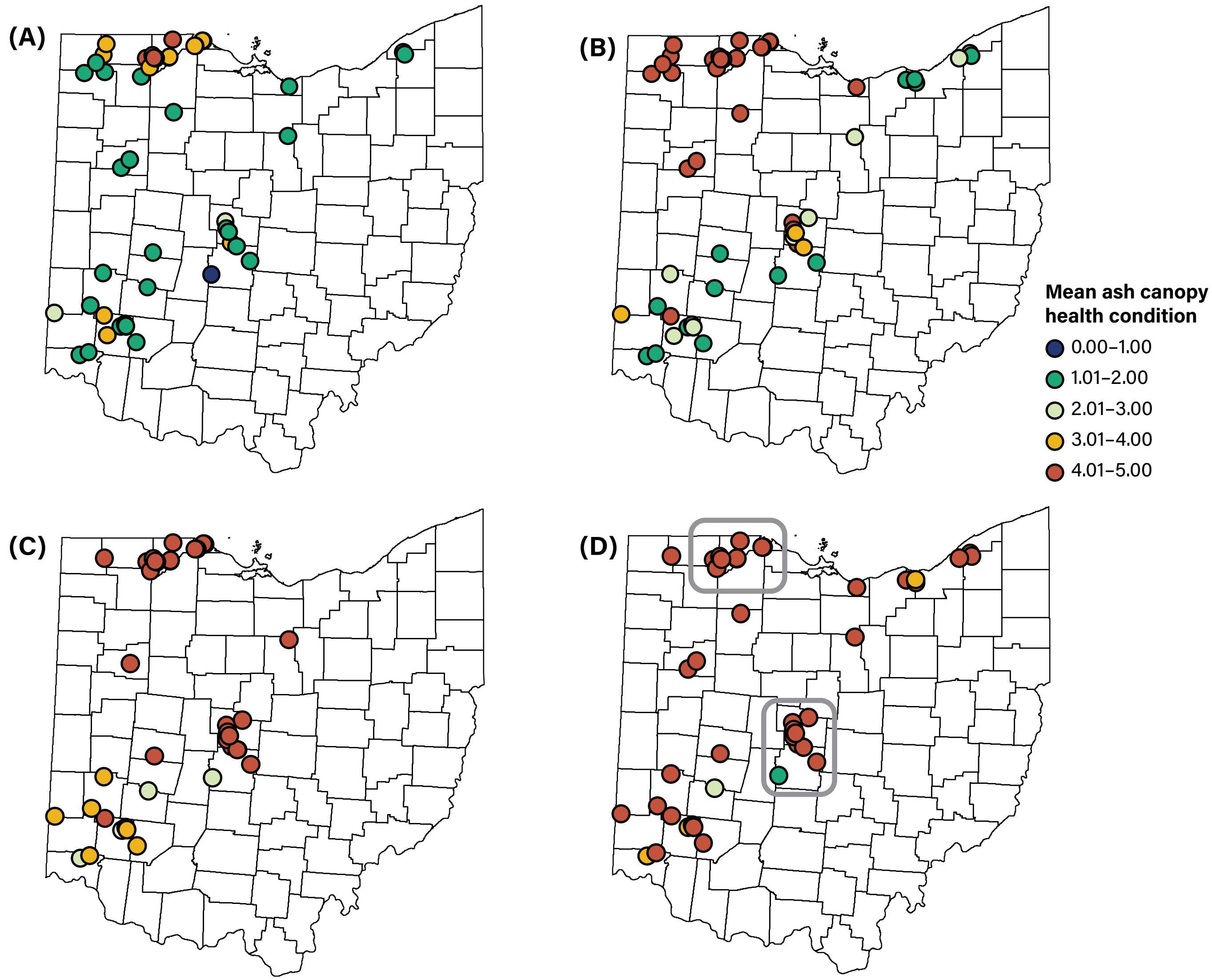

Figure 8.1—Ash canopy health condition of trees ≥10 cm diameter at breast height in Ohio in (A) 2008, (B) 2011, (C) 2014, and (D) 2019. Ash canopy health condition is a 1–5 rating, where 1 is a healthy canopy, 5 is a completely dead canopy, and 2, 3, and 4 are stages of decline. Sites in northwestern Ohio and central Ohio where emerald ash borer traps were used yearly are circled in panel D.

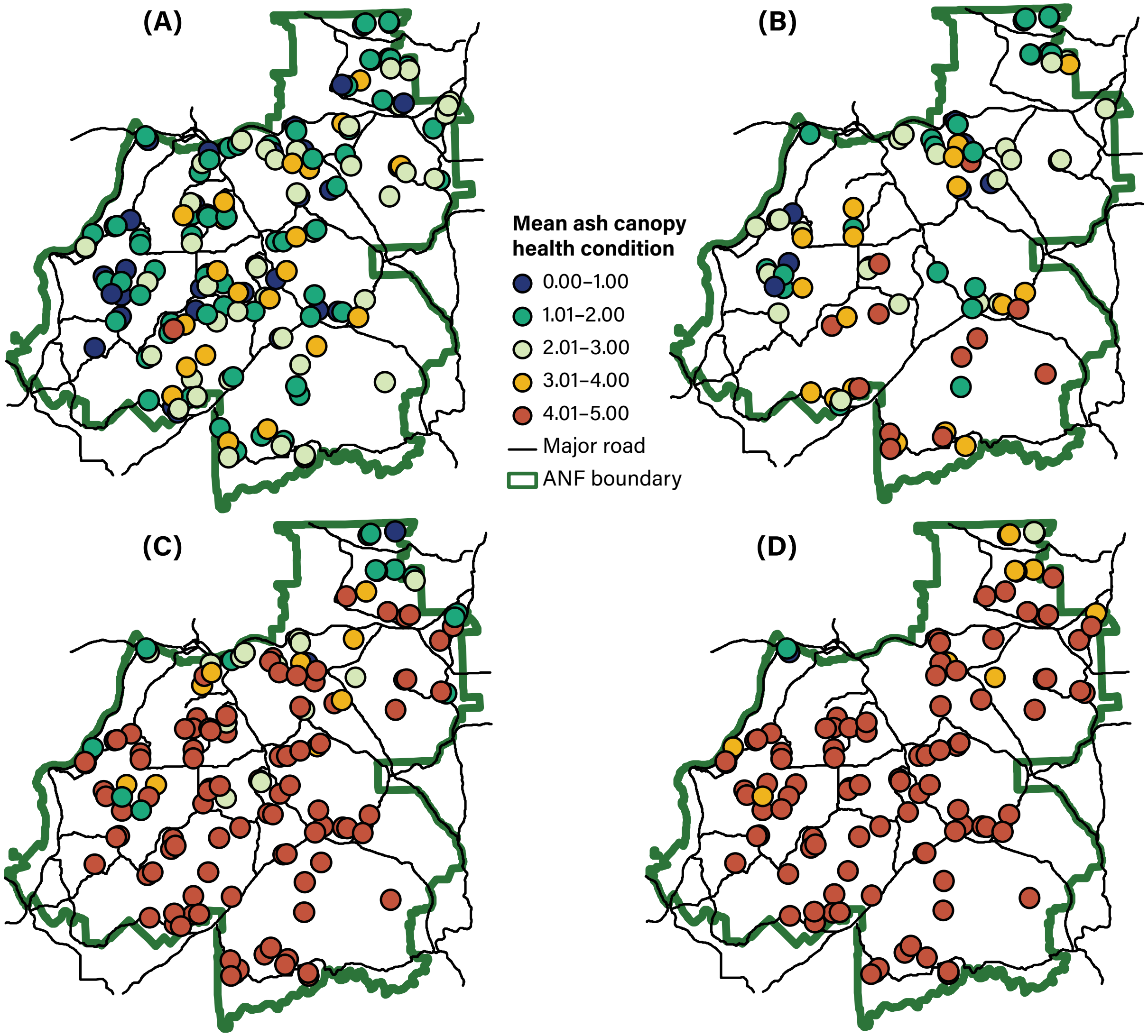

Figure 8.2—Ash canopy health condition from prism plots on the Allegheny National Forest (ANF) in (A) 2010, (B) 2015, (C) 2018, and (D) 2021.

Table 8.1—Differences in mortality and canopy health condition for ash trees ≥10 cm d.b.h. recorded in the Ohio monitoring plots, 2006–2019

Species	Number of trees	Mean initial d.b.h.	Mean canopy health rating, 2019[a]	Dead, 2019
		cm		*percent*
White ash (*Fraxinus americana*)	529	24.1	5.0	98.6
Black ash (*F. nigra*)	80	20.5	4.7	91.8
Green ash (*F. pennsylvanica*)	391	25.9	4.9	95.8
Pumpkin ash (*F. profunda*)	50	27.0	4.2	66.7
Blue ash (*F. quadrangulata*)	60	28.1	2.9	28.3
Green ash/white ash[b]	308	21.3	5.0	99.1
Green ash/pumpkin ash[b]	444	24.2	4.9	97.2

[a] Canopy health is rated on a 1–5 scale where 1 is healthy and 5 is dead.
b Species were lumped in sites with evidence of a mix of white and green ash and hybrids, or green and pumpkin ash.

Figure 8.3—Percentage of fallen dead trees from 1,100 ash trees ≥10 cm diameter at breast height that died during 2006–2014 in Ohio.

In Ohio, the abundance of ash saplings (1.0–9.9 cm d.b.h.) was quite variable and did not show consistent changes in abundance from pre-EAB to post-EAB impact (table 8.2). The sapling size class is highly dynamic due to mortality and recruitment, with some of the larger saplings killed by EAB, other saplings dying from other causes, and recruitment occurring especially in areas where abundant ash seedlings grew rapidly as canopy gaps opened. In many Ohio sites, ash seedlings are abundant (data not shown). However, newly germinated seedlings are not present or very rare.

The EAB traps in Ohio showed similar patterns in each monitored site. Trap catch numbers increased slowly at first and then rapidly in an exponential pattern, with peak catches typically coinciding with 50-percent mortality of the ash trees at a site, then a rapid crash in EAB populations as the remaining ash trees died (fig. 8.4). However, EAB populations persisted at low levels and showed a small resurgence more recently in northwestern Ohio (fig. 8.5).

Table 8.2—Presence of live mature ash (≥10 cm d.b.h.) and presence and abundance of ash saplings (1.0–9.9 cm d.b.h.) in Ohio monitoring plots prior to emerald ash borer (EAB) impact (2006–2008) and after EAB impact (2019)

	pre-EAB				post-EAB	
Species	Number of plots with mature trees	Number of plots with saplings	Mean number of saplings per plot	Standard deviation saplings per plot	Mean number of saplings per plot	Standard deviation saplings per plot
White ash (*Fraxinus americana*)	68	15	1.2	3.9	0.2	0.6
Black ash (*F. nigra*)	26	12	4.5	10.5	4.0	7.4
Green ash (*F. pennsylvanica*)	35	12	5.9	18.4	3.2	9.6
Pumpkin ash (*F. profunda*)	9	0	0.0	0.0	2.0	2.3
Blue ash (*F. quadrangulata*)	22	12	8.7	20.8	4.1	8.4
Green ash/white ash[a]	36	11	3.7	9.9	1.7	4.6
Green ash/pumpkin ash[a]	39	12	0.9	1.8	1.9	4.2

[a] Species were lumped in sites with evidence of a mix of white and green ash and hybrids, or green and pumpkin ash.

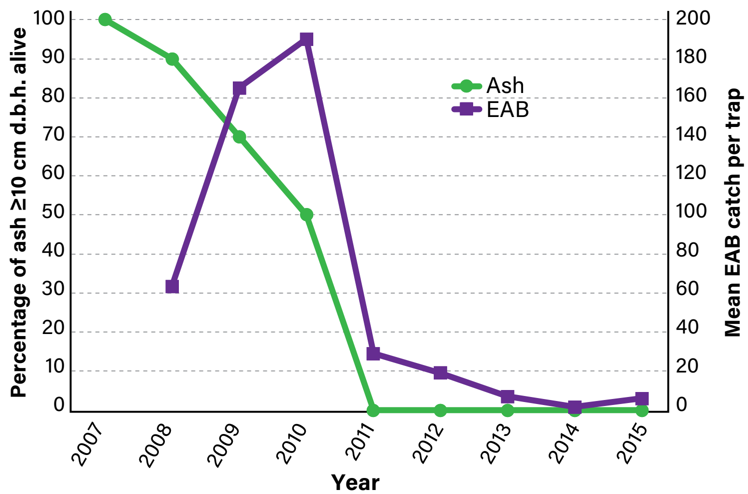

Figure 8.4—Emerald ash borer (EAB) trap catches and the percentage of live ash trees ≥10 cm diameter at breast height (d.b.h.) at a site in central Ohio showing the typical pattern of ash and EAB population dynamics.

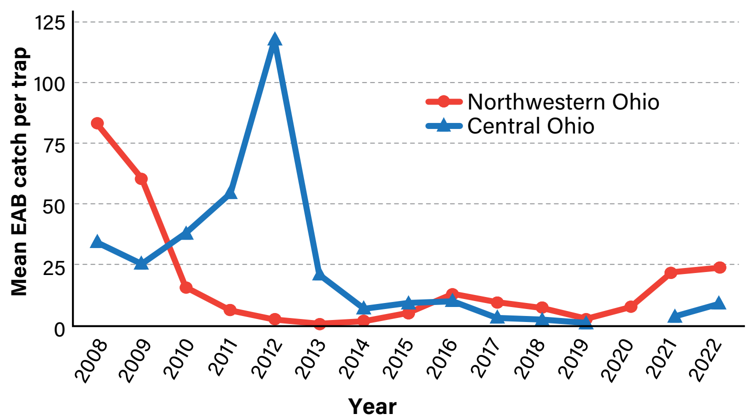

Figure 8.5—Emerald ash borer trap catches in northwestern and central Ohio monitoring sites. Note: Due to the COVID-19 pandemic, data were not collected from central Ohio sites in 2020.

CONCLUSIONS

Our data show nearly complete mortality of most species of ash ≥10 cm d.b.h. in two very different landscapes in Ohio and Pennsylvania. Tracking of individual trees on a yearly basis during a rapid mortality event allowed us to accurately quantify the effect of EAB. Because many trees die and fall in <4 years, estimates of mortality from one-time or longer interval surveys that only include standing trees likely underestimate mortality from EAB.

The survival of larger ash trees during the initial wave of EAB infestation may result from multiple mechanisms, including adult EAB feeding and landing preference, tree resistance (i.e., the tree's ability to kill the EAB larvae) (Koch and others 2015), and tree tolerance (i.e., the tree's ability to survive and grow while infested). The small percentage of large ash trees that have survived EAB infestation in Ohio and at the ANF are of considerable interest because they may be useful for breeding programs for resistance to EAB.

Consistent with research in Michigan showing blue ash to have generally higher survival than other ash species (Tanis and McCullough 2012), the survival of blue ash in the Ohio sites was much better than other species. This may be due to adult EAB having reduced preference for blue ash, as shown in feeding and landing studies (Pureswaran and Poland 2009). Long-term monitoring of blue ash sites will determine whether this higher survival rate will persist.

While the larger trees exhibit very high mortality rates, smaller ash saplings likely have less mortality caused by EAB, and seedlings <0.5 cm d.b.h. are not infested by EAB. We recorded abundant regeneration at some of the Ohio monitoring sites. The future dynamics of EAB populations and the surviving ash populations will determine the future of ash in Ohio. At the ANF, there is almost no ash regeneration at our monitoring sites, and white ash has simply disappeared from the landscape in only a decade.

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