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Fraxinus nigra (black ash) dieback in Minnesota: Regional variation and potential contributing factors

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ABSTRACT

Extensive tree dieback is a recurrent issue in many regions. Crown dieback of *Fraxinus nigra* Marsh. (black ash; brown ash) in the northeastern and north central United States is an example. *F. nigra* is a widely distributed hardwood that is often the dominant species in wetland forests from Manitoba to Newfoundland and West Virginia to Indiana. Widespread crown dieback of *F. nigra* has been noted in many regions, but there are few quantitative assessments of dieback extent or relationship to potential causes. Most *F. nigra* dieback episodes are not associated with specific disease or pest agents. Drought, excessive soil moisture, cohort senescense, and road influences, have all been suggested as potential contributing factors. Our objectives were to (1) quantify variable dieback across northern Minnesota, a region described as having extensive dieback, (2) determine the relationship between dieback and site moisture, (3) relate dieback to tree age/size distributions, and (4) assess whether dieback was related to road proximity. Given the increasing threat of *Agrilus planipennis* (emerald ash borer) in the region, it is important to know the current health status of *F. nigra* populations before widespread infestation occurs. Many stands in our study exhibited high incidences of crown dieback. However, the incidence of dieback was variable across the region. Spatial variability in dieback was associated with site wetland characteristics; more dieback occurred on jurisdictional wetlands and on sites with a higher wetness index and a deeper depth to a perching layer. Dieback was also positively correlated with mean stand diameter, and tree diameters were generally correlated with age, suggesting that stands with larger and older individuals experienced more dieback. Cohort senescence is a possible explanation for this trend. Finally, dieback occurred with higher frequency nearer to roads. The road influence could be related to hydrological alterations or perhaps toxicity from road deicing salt. The fact that dieback is more severe close to roads may contribute to a general perception that black ash dieback is more severe throughout the region than our study suggests. Collectively, our results indicate that the healthiest *F. nigra* stands in our study region are likely to be younger and located on relatively drier sites and farther from roads, compared to stands with significant crown dieback.

1. Introduction

Extensive tree dieback is a recurrent issue in many regions. Sometimes the cause is directly attributable to a specific agent, e.g., beech bark disease (Ehrlich, 1934). In other cases, synchronized tree demographic changes, sometimes in concert with climatic stress, are responsible for dieback and mortality (Mueller-Dombois, 1987). Sometimes the initiating agent or process behind dieback is not so easily identified. Extensive dieback of *Fraxinus nigra* Marsh. (black ash; brown ash) in the northeastern and north central United States is an example of the latter.

F. nigra is a native North American hardwood tree species that often grows in wetland forests between Manitoba, Newfoundland, West Virginia and Indiana (Wright and Rauscher, 1990), although it can occur in non-wetland settings on poorly drained soil (Wright and Rauscher, 1990). *Fraxinus* seed and twigs are valuable food for wildlife (Anderson and Nelson, 2003). The ring-porous wood is utilized for Native American basket making and as pulpwood and in the manufacture of furniture, paneling and other specialty products (Wright and Rauscher, 1990).

Crown dieback of *F. nigra* has been observed throughout its range (Croxton, 1966; Trial and Devine, 1994; Livingston et al., 1995; USDA Forest Service, 2004). Symptoms include thinning crowns, epicormic branching, twig and branch dieback, and occasionally small, discolored leaves (Trial and Devine, 1996). Widespread dieback was noted throughout the state of Maine by

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1993 (Trial and Devine, 1994), although some improvement in individual tree conditions was noted two years later (Trial and Devine, 1996). In Minnesota, dieback of *F. nigra* has occurred periodically over the last several decades, with nearly 9000 ha affected in 2009 (MN DNR, 2010).

Dieback of *F. nigra* has an unknown disease etiology. The species is susceptible to ash yellows caused by *Candiatus* Phytoplasma *fraxini* (French et al., 1989) that can result in crown dieback (Griffiths et al., 1999). *F. nigra* is also susceptible to leaf anthracnose caused by *Gloeosporium aridum*, cankers caused by *Nectria galligena*, oystershell scale caused by *Lepidosaphes ulmi*, trunk rot caused by *Stereum murrayi*, butt rot caused by *Armillarea mellea*, and spongy white rot caused by *Polysporus hispidus* (reviewed in Wright and Rauscher, 1990). However, most *F. nigra* dieback episodes do not seem to be associated with specific disease or pest agents. In such cases, tree demographics could be a factor if whole populations are senescing due to old age in synchrony across the landscape.

Researchers working in Maine presented preliminary evidence that the onset of widespread dieback of *F. nigra* was correlated with severe May drought (Livingston et al., 1995; Livingston and White, 1997) and stronger evidence that it was correlated with wetter sites (Trial and Devine, 1994). Others have noted dieback of *Fraxinus americana* (white ash) with drought (Tobiessen and Buchsbaum, 1976), although not necessarily on hydric sites (Woodcock et al., 1993). In contrast, Percival et al. (2006) consider *F. nigra* resilient to the effects of short-term droughts.

In Minnesota and elsewhere, the severity of *F. nigra* dieback varies across the landscape. In previous work, using USDA Forest Service Forest Health Monitoring and Forest Inventory and Analysis data, we found that clusters of dieback were associated with roads, perhaps due to altered site hydrology or adverse effects of road salt. We also found that proportionate mortality was greater on hydric sites than on mesic sites (Ward et al., 2009). To date, a finer scale extensive study of landscape variation in dieback, with an aim of relating dieback variation to potential causes, has not been conducted in Minnesota or other regions.

Our objectives in this study were to quantify variation in dieback (and recent mortality) of *F. nigra* across northeastern Minnesota and to relate dieback to potential contributing factors. During initial site selection for this study we were unable to associate dieback with any known insect or pathogen (M. Ostry, unpublished data). Consequently, we looked at other potential factors they may contribute to dieback. Specifically, we asked the following questions. How variable is dieback across the region? Is dieback related to wetland status and site moisture? Is dieback related to tree age/size distributions in a stand? Is dieback related to road proximity? Given the increasing threat of *Agrilus planipennis* (emerald ash borer) in the region, it is important to know the current health status of *F. nigra* populations before widespread infestation occurs.

2. Methods

2.1. Study sites

This study was conducted in five counties in northeastern Minnesota. A total of 54 *F. nigra* stands were selected for study (Fig. 1)

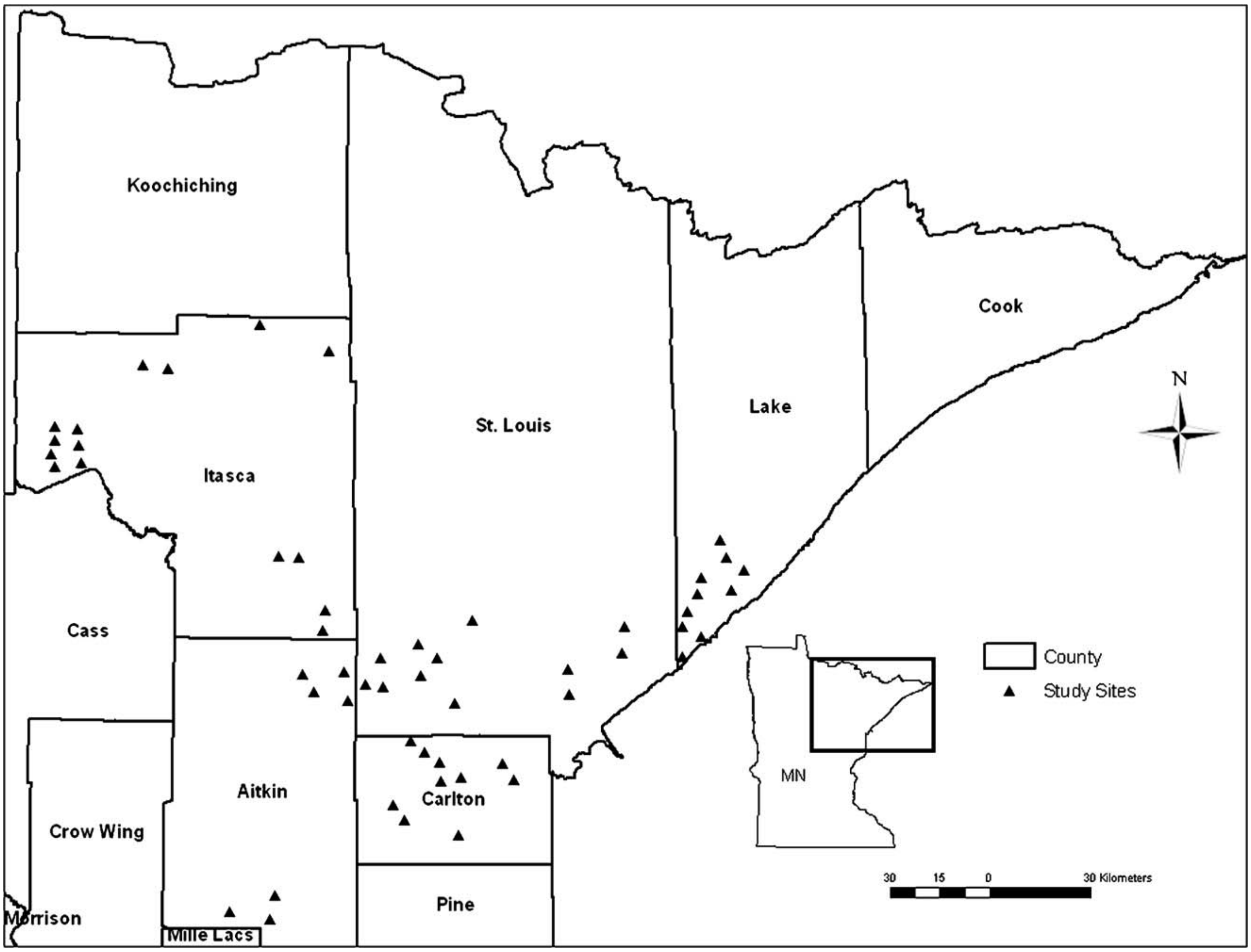

Fig. 1. Locations of study sites in northern Minnesota, USA.

Table 1
Density of trees (dbh $\geq$ 10 cm; stems per ha $\pm$1 standard deviation) by major species and NWI wetland system in black ash stands.

System	*Fraxinus nigra*	*Abies balsamifer*	*Thuja occidentalis*	*Fraxinus pennsylvanica*	*Ulmus americana*	*Populus balsamifera*	*Acer rubrun*	*Populus tremuloides*	*Acer saccharum*	Other species[a]	Total
Wetland (n = 38)	646 ± 211	47 ± 85	35 ± 124	15 ± 38	14 ± 31	12 ± 25	4 ± 14	3 ± 12	0.4 ± 3	31 ± 47	808 ± 262
Upland (n = 16)	564 ± 157	7 ± 14	13 ± 8	25 ± 41	4 ± 33	8 ± 25	5 ± 9	22 ± 39	21 ± 74	13 ± 15	681 ± 179

[a] Included: *Quercus rubra*, *Q. macrocarpa*, *Tilia americana*, *Acer spicatum*, *Betula papyrifera*, *Alnus incana*, *Picea glauca*.

Table 2
Density of saplings (2.5 $\leq$ dbh < 10 cm; stems per ha $\pm$1 standard deviation) by major species and NWI wetland system in black ash stands.

System	*Alnus incana*	*Fraxinus nigra*	*Abies balsamifer*	*Acer spicatum*	*Ulmus americana*	*Populus balsamifera*	*Salix*	*Acer rubrun*	*Populus tremuloides*	*Acer saccharum*	Other species[a]	Total
Wetland (n = 38)	754 ± 877	605 ± 537	150 ± 233	105 ± 289	56 ± 88	46 ± 176	18 ± 34	12 ± 34	11 ± 42	3 ± 14	114 ± 145	874 ± 1136
Upland (n = 16)	350 ± 684	512 ± 430	42 ± 89	13 ± 26	46 ± 64	1 ± 4	44 ± 122	38 ± 88	54 ± 88	41 ± 98	50 ± 40	1191 ± 837

[a] Included *Quercus macrocarpa*, *Tilia americana*, *Betula papyrifera*, *Picea glauca*, *Thuja occidentalis*, *Prunus virginiana*, *Fraxinus pennsylvanica*, *Betula alleghaniensis*.

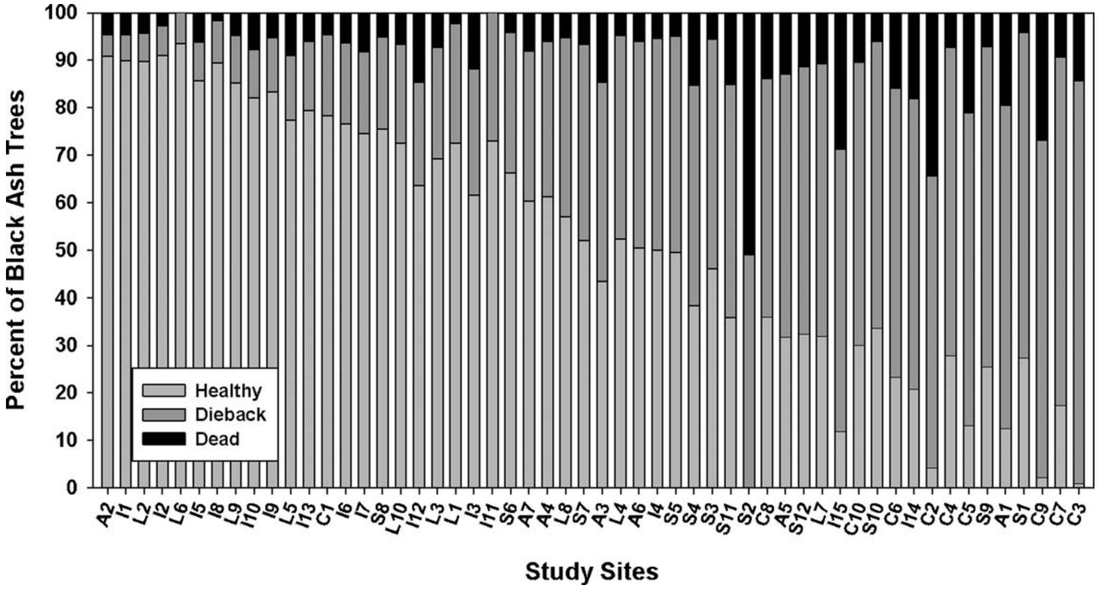

Fig. 2. Percentages of black ash that were healthy, experiencing dieback, or dead in 54 stands, ranked from low to high based on the percentage of trees experiencing dieback. First letter of each study site indicates the county: A, Aitkin; C, Carlton; I, Itasca; L, Lake; and S, St. Louis.

without prior knowledge of their health or wetland status. The criteria for stand selection included: (1) large enough to establish a minimum of three 0.02 ha circular plots spaced linearly 45 m apart (center to center) on a transect running perpendicular to a road; (2) no evidence of recent cutting in the stand; and (3) no large artificial openings, ditches, roads, or trails through the stand. Each study site was located on a National Wetlands Inventory (NWI) map, from which wetland type was determined (i.e., palustrine wetland or upland).

2.2. *Field methods*

During the growing seasons (mid-June to mid-August) of 2006 and 2007, three to five 0.02 ha circular plots (depending on stand size) were established in each site along a transect, which began near the boundary of the stand adjacent to the nearest access road. The transect location along the perpendicular boundary of the stand was determined arbitrarily. The center of the initial plot on the transect was placed approximately 45 m from the road center, so that the plot was within the stand proper and did not encompass ditching along the road. Subsequent plot centers were spaced 45 m apart. Plot centers were geo-referenced using a GPS.

On each plot the following tree and stand-level data were recorded. We assessed wetness with a qualitative index that used the following classes: 1 – dry, 2 – moderately wet (scattered standing water, saturated soil) or 3 – wet (standing water). Field observations indicated that the qualitative index was generally reflective of moisture differences even though sites were visited during two different years, at different times during the growing season, and at varying lengths of time after rainfall events. Additionally, at four locations in each plot, we determined depth of the (potentially) saturated soil down to a restrictive layer using a steel push rod. The rod was manually pushed into the soil until it could not be driven further with reasonable effort or we reached the end of all segments of the rod (3 m). The penetrated soil layer essentially acts like a sponge with an increasing depth equating to a thicker sponge. Sites with a thicker soil layer likely hold more water during saturated conditions, perhaps for longer periods of time (R. Kolka, personal communication).

The diameters at 1.4 m height (dbh) of all live overstory trees (dbh ≥ 10 cm) and subcanopy/sapling trees (2.5 cm ≤ dbh < 10 cm) were recorded. The health condition of each *F. nigra* was recorded as healthy, experiencing dieback, or dead. If a live tree had >15% of crown volume currently dead (excluding epicormic branches) it was considered to be experiencing dieback, otherwise it was considered healthy. Finally, in each plot, we selected four *F. nigra* to determine ring counts on increment cores. We cored two trees between 5 and 10 cm dbh and two trees >10 cm dbh. If present, one healthy and one tree with dieback were cored in each of the two size classes. Cores were air-dried, mounted on wooden holders, sanded, and their rings counted to get an age approximation. We did not build a cross-dated chronology for this study as we were only interested in general age-diameter relationships.

2.3. *Data analysis*

After confirming normality of data distributions and homogeneity of variances, parametric *t*-tests were used to compare several variables between NWI defined uplands and wetlands, including percentages of healthy, dieback, and dead *F. nigra* trees and depth to a restrictive layer. Differences in species densities and wetness index were compared using a Mann–Whitney Rank Sum Test due to non-normal data distributions. An alpha of 0.05 was considered significant for these tests.

Mean stand diameters of *F. nigra* were related to percentages of healthy, dieing back, and dead *F. nigra* trees in a stand using Spearman rank correlations, with $p = 0.05$ considered a significant relationship. Moreover, individual tree diameters were related to tree age with a Spearman correlation.

Percentages of healthy, dieback, and dead *F. nigra* trees, mean *F. nigra* diameter, depth to a restrictive layer, and wetness index were compared as a function of distance from the road using parametric or non-parametric repeated measure analysis of variance. Only the first three plots were used in these analyses, since not all of the 54 stands had fourth and fifth plots along transects. Percentage data were square-root arcsine transformed prior to analysis. Normality and variance–covariance structure were assessed for each data set. Percent of dieback and dead *F. nigra*, as well as mean plot diameters, met distributional and variance–covariance assumptions, so parametric repeated measure analysis was performed, followed by Holm-Sidak pair-wise comparisons. Percent of healthy *F. nigra*, depth to a restrictive layer, and wetness index were non-normal

Table 3
Stand-level summary health statistics for black ash trees, $n = 54$ stands.

Characteristic	Mean	Standard deviation	Median	Minimum	Maximum
Healthy (%)	53	28	52	0	94
Dieback (%)	37	23	41	5	85
Dead (%)	10	9	7	0	51

even after transformations. For these, we used a Friedman repeated measure analysis of variance on ranks, followed by Tukey comparisons of all pair of means. An alpha of 0.05 was considered significant.

3. Results

3.1. Forest composition

The overstory (dbh ≥ 10 cm) of the 54 stands was strongly dominated by *F. nigra*, which comprised around 80% of total density in both NWI classified uplands and wetlands (Table 1). Density of other species was generally very low, but did vary somewhat between uplands and wetlands. *Abies balsamea* (balsam fir) had significantly higher densities in wetlands than on upland sites ($p = 0.04$), while *Populus tremuloides* (trembling aspen) and *Acer saccharum* (sugar maple) had higher densities on upland sites than in wetlands ($p = 0.001$ and 0.05, respectively) (Table 1).

The subcanopy/sapling layer (2.5 ≤ dbh < 10 cm) was *F. nigra* dominated, with the species comprising 32% and 43% of total density in NWI wetland and upland sites, respectively (Table 2). Density of additional species in the sapling layer was generally low, but did vary somewhat between NWI systems. Uplands had significantly higher densities of *P. tremuloides* ($p < 0.001$) and *Acer saccharum* ($p = 0.03$) (Table 2).

3.2. Variation in F. nigra dieback

The 54 *F. nigra* stands reflected a continuum in dieback, from a low of 5% (of *F. nigra* trees in the stand) to a high of 85% (Fig. 2). On average (±1 standard deviation) 37 (23)% of *F. nigra* in a stand had dieback, 53 (28)% were healthy, and 10 (9)% were dead (Table 3). Five of the 54 stands had very few or no apparently healthy trees at the time of sampling, while all but two stands contained standing dead *F. nigra* trees (Fig. 2).

3.3. Wetland status, site hydrology, and dieback

The percentages of *F. nigra* in a stand that were healthy, had dieback, or were dead differed between uplands versus wetlands. Uplands had a significantly higher percentage of healthy trees ($p = 0.03$) and a significantly lower percentage of trees with dieback compared with wetlands ($p = 0.05$) (Fig. 3). The percentage of dead *F. nigra* was marginally significantly higher in wetlands than on uplands ($p = 0.06$).

Our site-level measures of wetland characteristics, specifically mean depth to a restrictive layer and wetness index, substantiated that NWI classified uplands and wetlands differed in local hydrology. Mean (±standard error) depth to a restrictive layer was significantly greater in wetlands (1.01 ± 0.07 m) compared with uplands (0.64 ± 0.06 m; $p = 0.005$), while wetness index also was marginally significantly ($p = 0.06$) higher in wetlands (1.08 ± 0.16) compared with uplands (0.57 ± 0.17).

The percentages, in a stand, of healthy *F. nigra* and those with dieback were significantly correlated to both depth to a restrictive layer and wetness index (Fig. 4). The percentage of healthy *F. nigra* decreased with increasing depth to a restrictive layer ($r = -0.51$, $p < 0.0001$) and increasing wetness index ($r = -0.31$, $p = 0.02$), while the percentage of *F. nigra* with dieback increased with these measures ($r = 0.49$, $p < 0.0001$ and $r = 0.33$, $p = 0.01$, respectively). The percentage of dead *F. nigra* increased significantly with depth to a restrictive layer ($r = 0.36$, $p = 0.008$) and perhaps with wetness index ($r = 0.24$, $p = 0.08$) (Fig. 4).

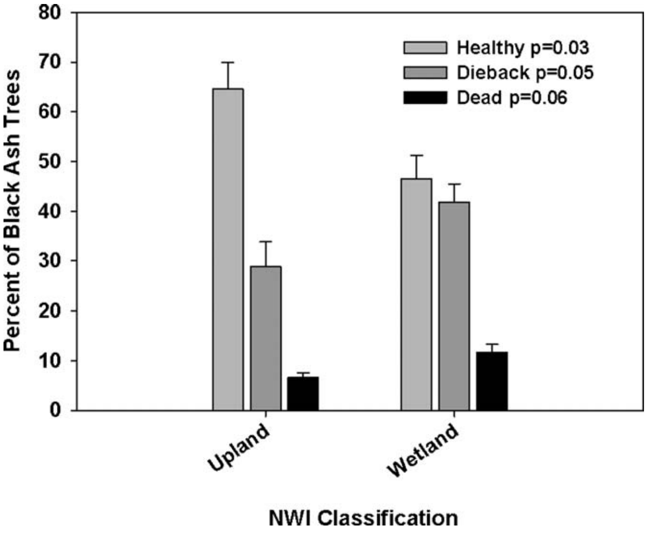

Fig. 3. Percentages of black ash that were healthy, experiencing dieback, or dead within palustrine wetlands ($n = 38$) and uplands ($n = 16$). Values are means ± standard error.

3.4. Stand size/age structure and dieback

Mean diameter of trees (based on trees > 2.5 cm dbh) ranged from about 6.5 cm to 23 cm among stands. Mean diameters were significantly correlated with the percentage of *F. nigra* that were healthy ($r = -0.31$, $p = 0.024$), experiencing dieback ($r = 0.27$, $p = 0.05$), and dead ($r = 0.33$, $p = 0.015$) (Fig. 5). Specifically, the percentages of healthy trees declined with increasing stand diameter, while the percentage of trees with dieback, as well as dead trees, increased with these measures (Fig. 5). In general, *F. nigra* tree age increased linearly with tree diameter ($r = 0.53$, $p < 0.001$; data not shown), suggesting that the percentage of healthy *F. nigra* trees was lower and the percentage of *F. nigra* with dieback and dead were higher in older (larger mean diameter) stands.

3.5. Road proximity and dieback

The percentages of healthy *F. nigra* and those experiencing dieback varied among plots that were arrayed at increasing distances from the nearest road (Fig. 6). The percentage of healthy trees increased with distance, while the percentage of trees with dieback decreased with distance (Fig. 6). Plots 2 and 3 had significantly greater percentages of healthy trees than plot 1 ($p < 0.05$), while plots 2 and 3 themselves did not differ significantly ($p > 0.05$). The percentage of trees with dieback was significantly lower on plot 3 than plot 1 ($p = 0.001$), while plots 1 and 2 and 2 and 3 did not differ significantly from each other ($p > 0.05$). The percentage of dead *F. nigra* did not differ significantly with distance ($p = 0.21$). None of the potential contributing factors we examined differed significantly along the plot distance gradient (data not shown), including mean tree diameter/age ($p = 0.79$), depth to a restrictive layer ($p = 0.94$), or wetness index ($p = 0.64$).

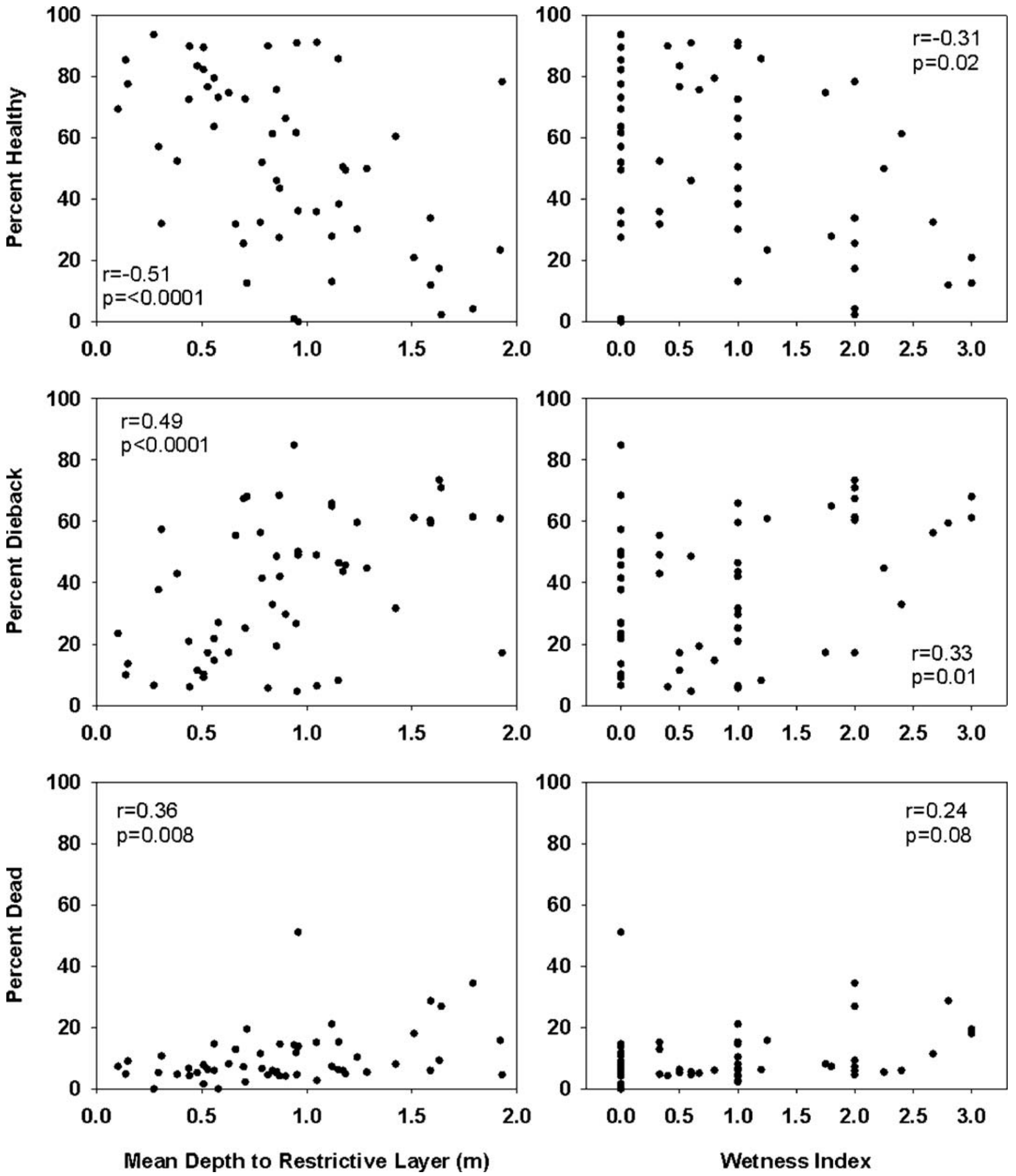

Fig. 4. Percentages of black ash that were healthy, experiencing dieback, or dead as a function of depth to a restrictive layer and wetness index.

4. Discussion

We documented a high incidence of crown dieback within *F. nigra* stands in northeastern Minnesota, although the incidence of dieback was highly variable across the region. While trees with crown dieback may eventually die, we did not collect data in a way that could verify this. In fact, branch abscission is a physiological mechanism *F. nigra* uses to recover from stress (Kozlowski, 1991; Pallardy, 2008). As such, trees with dieback now potentially could recover in time. This is also suggested by the presence of several years of epicormic branch growth on many of the trees (unpublished data).

High variation in amount of crown dieback among study sites suggests that the underlying cause is not uniformly important across the region. Similar to previous studies of *F. nigra* dieback (Livingston and White, 1997; Trial and Devine, 1994, 1996), no obvious insect or disease organism were associated with dieback. In *F. nigra* stands that were not part of our study, we observed initial attacks from an unidentified ambrosia beetle in girdled and healthy trees and a flatheaded wood boring beetle, *Chrysobothris sexsignata* (Say), has been found periodically in other Minnesota *F. nigra* stands (Mark Abrahamson, Minnesota Department of Agriculture, personal communication). However, in both cases, there was no obvious association of it with dieback symptoms.

Within our study area, we also documented variation in stand structural conditions and site variables and some of these factors were correlated with dieback of *F. nigra*. Notably, at the stand scale, the percentage of trees with dieback was significantly higher on sites classified as wetlands by the National Wetland Inventory, compared with upland sites. All sites, upland and wetland, were strongly *F. nigra* dominated in the tree and sapling layers and it is not uncommon for *F. nigra* to occur across a range of soil conditions, including sites that are jurisdictionally uplands (Erdmann et al., 1987; Tardif and Bergeron, 1997). Our data on local hydrologic conditions, specifically depth to a restrictive layer and wetness index, support a distinction between sites classified at wetlands and those classified as uplands. Wetland sites had a significantly greater depth to a restrictive layer and a higher mean wetness index compared to upland sites. In turn, these two variables were significantly negatively correlated with percentage of healthy trees and positively

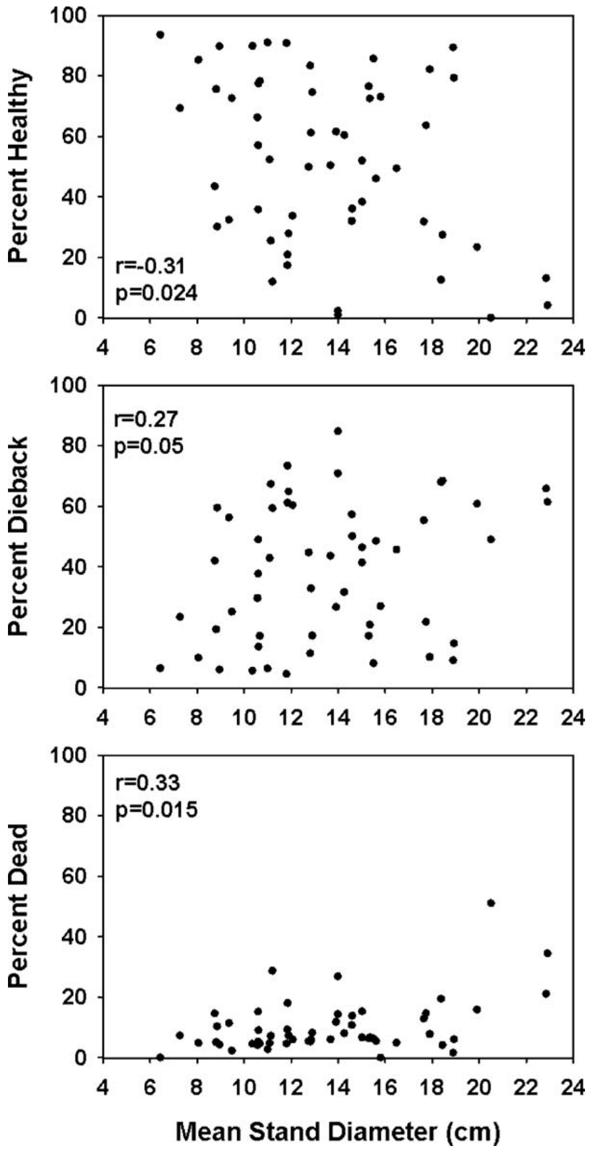

Fig. 5. Percentages of black ash that were healthy, experiencing dieback, or dead as a function of mean stand diameter (of black ash).

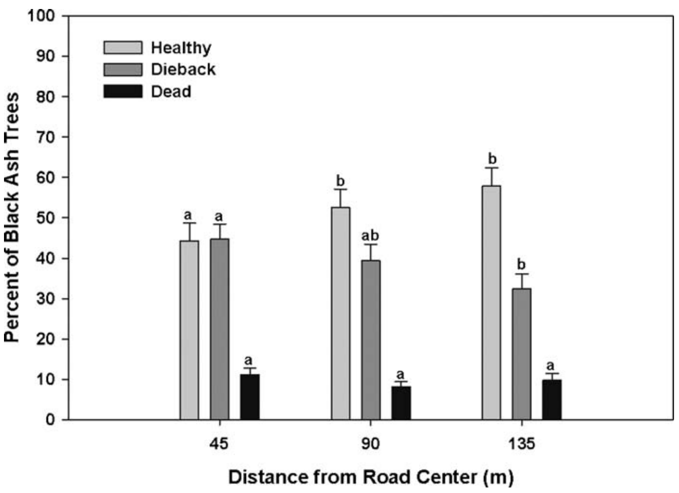

Fig. 6. Percentages of black ash that were healthy, experiencing dieback, or dead as a function of plot distance from a road. Values are means ± standard error ($n = 54$). Bars with the same letter within a health class are not significantly different ($p > 0.05$) based on a Tukey comparison of means.

correlated with percentage of trees with crown dieback, and in the case of depth to a restrictive layer, positively correlated with the percentage of dead *F. nigra*.

One possible explanation for this relationship is that dieback is more pronounced on sites with a greater frequency and/or duration of flooding, as others have suggested (Trial and Devine, 1994). Excessive flooding would lead to anoxia and root death, and branch abscission would maintain a constant ratio between living belowground and above-ground biomass.

An alternative explanation is that dieback begins on wetter sites during a drought. Livingston and White (1997) suggest this as a cause of *F. nigra* dieback in Maine. Specifically during spring drought, shallow rooted trees on wetland sites experience moisture stress, inhibiting the filling of vessels before leaf expansion; however they provide no strong evidence for this explanation. While we document higher dieback on wetter sites, it may be that these sites were wetter (at the time we measured them) because of declining productivity, reduced transpiration, and possibly increased mortality of *F. nigra* trees associated with a past drought, as suggested by Livingston and White (1997).

We cannot distinguish between these contrasting theories. To do so, we would need to know the vertical rooting profile of *F. nigra*, soil-drying patterns during drought years, and rates of root mortality over time in response to low moisture levels. Moreover, several episodes of dieback in *F. nigra* have occurred at least since the early 1990s in northern Minnesota. Thus, we could not accurately determine when dieback began on our sites and relate this occurrence to climate. However, from our study, the relationship to overall site moisture characterization is clear; dieback and perhaps mortality were greater on sites that typically are wet in the spring and into the growing season.

We also found a moderate, but significant positive relationship between percentage of *F. nigra* with crown dieback and mean stand diameter. This suggests that crown dieback occurs more frequently on larger trees, such that stands with a higher proportion of larger trees also have a higher frequency of dieback. Our estimates of age from annual ring counts were approximate since we did not crossdate cores and develop chronologies to identify locally absent rings. Having determinate growth, *F. nigra* does not produce false rings. Still, we did find that tree diameter was generally correlated with increasing ring count. As such, we hypothesize that crown dieback occurred more frequently on older back ash and in stands composed of a greater proportion of older individuals. Such a relationship suggests cohort senescence as a potential contributing factor to dieback and presumably eventual mortality. Synchronous, stand-level dieback has been proposed as a natural process related to forest dynamics, specifically the synchronized aging and decline in health of trees in a stand (Mueller-Dombois, 1987, 1992). Accurate lifespan estimates for *F. nigra* are lacking, however several sources suggest the species is short lived (80–130 years), relative to associated tree species (Ritchie, 1996; Barnes and Wagner, 2004). Estimated age on 45% percent of the trees we cored was 80 years or greater, while 67% had annual ring counts of 70 years or greater. These data suggest that aging populations and cohort senescence may have been contributing factor in the dieback we observed.

Finally, we found that the incidence of dieback decreased significantly as distance from a road increased. Our site moisture measures, including depth to a restrictive layer and wetness index, did not differ among plots along this gradient, nor did mean diameter of *F. nigra*. In earlier work using USDA Forest Service Forest Inventory and Analysis data, we found that *F. nigra* dieback polygons were significantly closer to city, county, and state roads than were randomly selected *F. nigra* polygons (Ward et al., 2009). Altered hydrology nearer to roads, not detectable by our site measures, may be a factor in this relationship. Also, toxicity to road salt may contribute to dieback. Road salt toxicity in trees is a well documented phenomenon (e.g., Lacasse and Rich, 1964; Westing, 1969; Menlove, 1973; Piatt and Krause, 1974), although species differ in their sensitivity. Studies on maple have found that toxicity symptoms decrease with distance from salted roads (Lacasse and Rich, 1964). *F. nigra* is rated as moderately tolerant of soil salt and salt spray by some sources (Ritchie, 1996), but having no tolerance for even moderate increases in salinity by other sources (USDA NRCS Plants Database). If the latter is the case, salt toxicity cannot be ruled out as a contributing factor in dieback.

Collectively, our results indicate that the healthiest *F. nigra* stands in our study region are likely to be younger and located on relatively drier sites and farther from roads, compared to stands with significant crown dieback. The fact that dieback increases closer to roads may contribute to a general perception that dieback in *F. nigra* is more severe throughout the region than our study suggests. We estimate that only 10% of *F. nigra* trees are dead, and the fate of the 38% of *F. nigra* trees with dieback is uncertain. If the latter trees are dying, the current density of saplings, that are generally healthy, may be inadequate to maintain current densities of overstory *F. nigra*, especially given future mortality that these saplings are likely to experience. However, if trees with dieback are recovering, the resource seems secure for the time being, barring any new disturbance agents.

The arrival of emerald ash borer (*A. planipennis*) in North America has stimulated a new appreciation for the ecological, sociological, and economic significance of ash species, including *F. nigra*. If this insect becomes established in northeastern Minnesota, it will be difficult initially to distinguish the effects of the insect from the dieback phenomenon we have studied. Symptoms of emerald ash borer infestation include formation of epicormic branches and branch dieback. Estimates of the potential impact of emerald ash borer on *F. nigra* in our study region must reflect the current condition of the resource and the projected condition of the resource if this insect were not to establish. Longer-term studies of the fate of trees with dieback are needed to support these projections.

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