CHAPTER 10.

Investigation of Rapid White Oak *(Quercus alba)* Mortality within the Ozark Plateau and Adjacent Forest-Prairie Transition Ecoregion

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INTRODUCTION

Between 2011 and 2014, foresters and landowners in Missouri reported abnormally high levels of white oak (*Quercus alba*) mortality, with large numbers of white oak trees dying abruptly after leaf-out or during late summer. Entire tree crowns rapidly wilted and dead leaves remained attached to branches. Foresters reported that mortality occurred mostly on lower slopes and in the bottoms of upland drainages. This new syndrome was named rapid white oak mortality (RWOM). Reports of RWOM peaked in 2012, but reports of new mortality are still being received. A number of regional events, including a late spring freeze in 2007, record amounts of precipitation in 2008 and 2009, a jumping oak gall outbreak in 2010, and a severe drought in 2012 may have played a role in the mortality event. The Iowa Department of Natural Resources also received reports of white oak mortality between 2011 and 2014. A one-year study was conducted during 2014 to describe the geographic distribution and the characteristics of RWOM. The first study objective was to develop a database that documented the occurrence of white oak mortality within Arkansas, Missouri, and Iowa and associated site characteristics. The second study objective was to characterize insect pests and fungal pathogens associated with declining white oak at two Ozark study locations in Missouri, with particular emphasis on *Phytophthora cinnamomi*. As part of objective two, the physical distribution of mortality within stands was documented along with associated site characteristics.

METHODS

Geographic Distribution (Objective 1)

A one-page survey with 24 questions was created and distributed to foresters in Arkansas, Iowa, and Missouri. Foresters walked a 0.2-ha area within an affected site and reported location, site characteristics, and types of trees dead or dying. A separate survey with 12 questions was created and distributed to landowners. Landowners reported on location of dying oaks; if the dead and dying trees were in the white or red oak groups; and general information about site, including topography, slope position, and relative size of the affected area. Foresters and landowners filled out forms between June and October 2014.

Characterization of Two Study Sites (Objective 2)

Sunklands Conservation Area (SCA) in the southern Missouri Ozarks and Harmon Springs campground in the northern half of the Mark Twain National Forest (MTNF) were selected to characterize insects and pathogens associated with white oak mortality. White oak species made up 33 and 45 percent of the oak-hickory forest at SCA, and MTNF, respectively. Ephemeral streams were present at both locations.

ArcMap® 10.1 was used to randomly generate geographic coordinates for potential plots. Forty-one plots were established within a three-stand area in SCA, and 39 plots were established in a three-stand area in MTNF. Sampling was only performed in sections of stands without signs of active management. Crown vigor of white oak trees was estimated on a scale of 1 to 6 and averaged for each plot (McConnell and Balci 2014). Site characteristics, including elevation, aspect, slope steepness, and slope position were recorded. The percentage of rock content was measured for high and low vigor plots. General information about soils was downloaded from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service Web soil survey. The numbers of live and dead tree stems with a diameter breast height (d.b.h.) of 5 cm or greater were counted for each white oak species, the red oak group, and all other genera. Crown positions of all dead stems and their estimated d.b.h. were noted.

Characterization of Insect and Fungal Pathogens (Objective 2)

Soils were sampled around three living white oak trees in each high and low vigor plot. Four soil samples were taken at the base of each white oak tree and were combined. Each soil sample was flooded and baited with *Quercus robur* leaves (McConnell and Balci 2014). After 48, 96, and 144 hours, infected leaf tissues were embedded in PARPNH medium. Resulting oomycete colonies were purified and grouped into morphotypes. Representative isolates of each morphotype were identified by DNA sequencing of the internal transcribed spacer (ITS) region, the mitochondrial cox2 locus, or both.

To sample for Armillaria fungi, the root collar of one severely declining or dead *Q. alba* tree in each high and low vigor plot was inspected for signs of Armillaria infection. Pieces of symptomatic tree tissues were embedded in water agar with streptomycin, and resulting colonies later transferred to lactic acid-amended malt agar. Morphological characteristics were used to identify colonies as Armillaria. DNA sequencing of the ITS region and restriction fragment length polymorphisms (RFLPs) were used to differentiate among three species known to occur in Missouri, *Armillaria mellea*, *A. tabescens*, and *A. gallica* (Baucom 2005, Harrington and Wingfield 1995).

All declining white oak trees in high and low vigor plots were examined for signs of Hypoxylon canker, including stroma occurring on branches or the main stem.

To collect insects associated with declining white oak trees, 2 main stem logs (30 cm length) and 4 branch logs were removed from each of 13 white oak trees at SCA that had a crown vigor rating of 4 or 5. Logs were also removed from five trees at MTNF with vigor ratings of 4 or 5 or that were recently dead. Most branch material from MTNF was dried out at the time of felling, so logs were removed from the stem at approximately 2, 5, and 7 m from the ground. Each main stem log was placed individually in emergence buckets. Branch logs from the same tree were placed together in one emergence bucket. Cerambycid, scolytid, and buprestid insects were collected over a 9-month period.

RESULTS

Reported Distribution (Objective 1)

White oak mortality was reported at 63 locations in Missouri and 2 locations in Iowa. The majority of forester reports were from the southeast and adjacent quadrants of Missouri (fig. 10.1). Mortality was also reported twice in southeastern Iowa and once in southwestern and northeastern Missouri. More than three-quarters of foresters reported white oak mortality on lower slopes and a quarter reported mortality on upper slopes. White oak mortality occurred on slopes with inclines between 0 and 60 percent; however, most reported mortality occurred on inclines of 20 percent or less. Mortality was reported similarly on slopes of all aspect.

Landowner surveys were received, including six, seven, and eight from Arkansas, Iowa, and Missouri, respectively. All Arkansas landowners reported trees in the white oak group dead or dying on upper slopes, and a third of landowners reported mortality on lower slopes as well. Almost half of Iowa landowners reported trees in the white oak group dead or dying on upper slopes, and nearly half of landowners reported mortality on lower slopes. Half of Missouri landowners (fig. 10.1) reported trees in the white oak group dead or dying on upper slopes and half reported mortality on lower slopes.

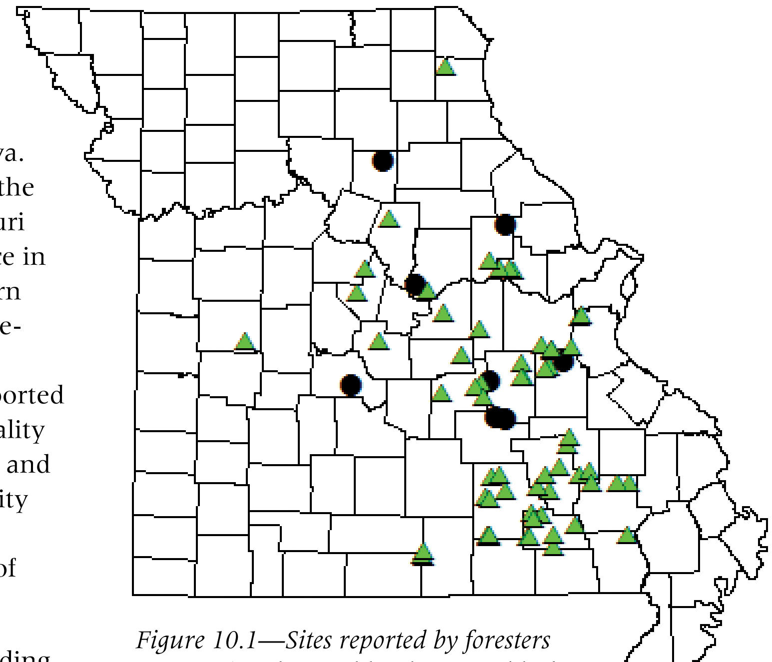

Figure 10.1—Sites reported by foresters (green triangles) and landowners (black circles) with rapid white oak mortality between 2011 and 2014.

Characterization of Study Sites (Objective 2)

Plots were established at the bottom of the hill and on the hillsides at MTNF and SCA. Nine plots were classified as high and 17 plots classified as low vigor at MTNF, whereas 17 plots were classified as high and 17 plots classified as low vigor at SCA. Low vigor plots were disproportionately associated with lower slope positions and the drainage bottom at both sites (fig. 10.2). Accordingly, high vigor plots tended to be at higher elevations at MTNF (316 ± 3 versus 309 ± 3 m) and SCA (309 ± 6 versus 264 ± 2 m) and on steeper slopes than low vigor plots at MTNF (21 ± 1.6 versus 10 ± 1.5 percent) and SCA (31 ± 1 versus 15 ± 3 percent). No aspect appeared to be associated with low vigor plots. Soils in low vigor plots were mostly gravelly silt loams or were occasionally loams or sandy loams. Soils ranged from well drained to somewhat excessively well drained.

Overall white oak mortality was 22 percent and 21 percent within the study areas at MTNF and SCA, respectively. Mortality was greatest in drainages at the bottom of the slope where more than half of all white oaks were dead (table 10.1). At both sites, mortality on lower slopes and in drainages mostly occurred among dominant, co-dominant, and suppressed crown classes while on upper slopes, mortality mostly occurred within the suppressed crown class (table 10.2). All crown classes were affected, with most of the mortality in each crown class occurring on the lower slope and in the drainage at both sites.

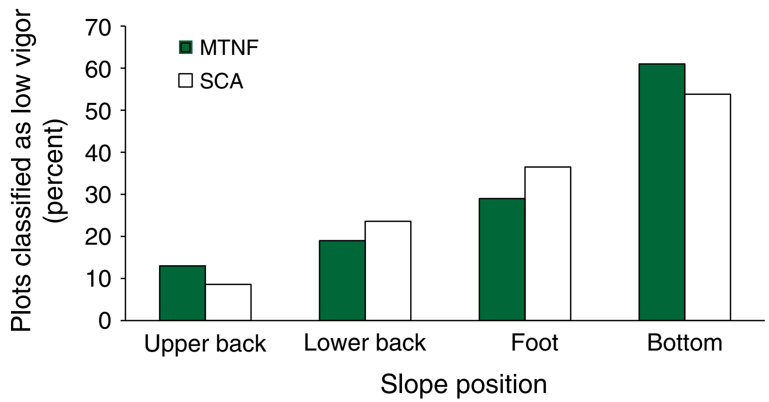

Figure 10.2—Percentages of plots rated as low vigor at each slope position for two locations in the Missouri Ozarks during 2014. MTNF = Mark Twain National Forest; SCA = Sunklands Conservation Area.

Eight oomycete species were detected in soils taken from the bases of white oak trees. *Phytophthora cinnamomi*, *Phytopythium vexans*, *Pythium* sp. I-845, and *Pythium* sp. UZ12 were detected at both MTNF and SCA. *Phytophthora cactorum*, *Phytophthora pini*, and *Phytophthora* sp. 1 were detected only at SCA, whereas *Phytophthora europaea* and *Pythium sensicosum* were detected only at MTNF.

Table 10.1—Percentage of mortality of white oak trees at different slope positions for two locations in the Missouri Ozarks during 2014

Slope position	MTNF		SCA	
	No. live and dead	Mortality	No. live and dead	Mortality
	stems / ha	*%*	*stems / ha*	*%*
Bottom	141	61	108	54
Lower half	558	24	425	30
Upper half	448	10	301	10

MTNF = Mark Twain National Forest; SCA = Sunklands Conservation Area.

Table 10.2—Relative contribution of each crown class to mortality at each slope position at Harmon Springs within Mark Twain National Forest (MTNF) and Sunklands Conservation Area (SCA) during 2014

Location and slope position	Number of dead *Q. alba*	*Q. alba* trees in each crown class		
		Dominant / codominant	Intermediate	Suppressed
	stems/ha	---------------------*percent*-----------------		
MTNF				
Bottom	86	38	20	42
Lower half	133	21	19	62
Upper half	34	14	9	76
SCA				
Bottom	58	36	14	50
Lower half	128	24	24	52
Upper half	31	7	7	86

Phytophthora cinnamomi was the most frequently detected oomycete, with detections in 12 plots at MTNF and in 7 plots at SCA. *P. cinnamomi* was detected more frequently on lower slopes and in drainages than on upper slopes and the summit at MTNF. *P. cinnamomi* was detected more frequently on upper slopes than on lower slopes at SCA.

Armillaria was isolated from roots of dead or severely declining white oak trees in 12 MTNF and 16 SCA plots. *Armillaria mellea*, *Armillaria gallica*, and *Armillaria tabescens* were isolated from high and low vigor plots at both locations. *A. gallica* was isolated more frequently from low vigor plots than *A. mellea*. *A. tabescens* was isolated infrequently.

Stroma of Hypoxylon canker occurred only on dead trees in plots at MTNF and SCA.

Three species of cerambycids and three species of scolytids were emerged from white oak logs. The scolytid *Xyleborinus gracilis* was the only insect species emerged from logs taken from MTNF and SCA. Other scolytids, *Monarthrum fasciatum* and *Monarthrum mali*, as well as cerambycid species, *Graphiusurus fasciatus*, *Neoclytus mucronatus*, and *Xylotrechus colonus*, were unique to logs taken from MTNF.

DISCUSSION

White oak mortality was largely associated with lower slope positions and bottoms of slopes in this survey of Ozark Plateau forests. This distribution of mortality was especially obvious for trees in the dominant and co-dominant crown class. As expected, *Armillaria mellea* and a *Biscogniauxia* sp. were commonly associated with declining and dead white oaks. *Phytophthora cinnamomi* was also frequently associated with declining white oaks, as was reported in a previous survey of declining red and white oaks within Missouri (Schwingle and others 2007). However, additional species of *Phytophthora*, including *P. cactorum* and *P. pini,* were also associated with declining trees in this survey. In many natural and agricultural ecosystems, *Phytophthora* causes root diseases in areas of high soil moisture that favor production and release of infective zoospores. Consequently, the occurrence of *Phytophthora* species in bottomland and lower slope locations was not surprising. Less frequent detection of *Phytophthora* around trees at higher slope positions may be associated with the occurrence of intermittent soil saturation and water flow patterns and bears further investigation.

The boring beetle, *Xyleborinus gracilis,* was commonly recovered from declining and recently dead white oak trees in this survey. This finding was unexpected. *Xyleborinus gracilis* is native to the Southeastern United States, but it was not detected in Missouri until 2008 and is infrequently collected in aerial trap surveys (Reed and Muzika 2010). Ambrosia beetles native to the Eastern United States mostly attack severely stressed, moribund, or dead trees and their associated fungi are not pathogenic. Nonetheless, the timing of *X. gracilis* beetle attack in relation to host condition and the types of fungi associated with these beetles should be explored.

The widespread occurrence of white oak mortality on bottomland and lower sites contrasts sharply with the decline of red oak species that occurs predominantly on ridge tops and upper slopes. That decline is attributed to the combined effects of advanced tree age, high stem density, and drought, conditions not commonly noted in the present white oak survey (Fan and others 2012). The opportunistic pathogens, *Armillaria* spp. and *Biscogniauxia* spp., reported in the white oak survey are also commonly associated with red oak decline

(Bruhn and others 2000, Stephen and others 2001). However, the frequent detection of *Phytophthora* species was unique to white oak.

CONCLUSION

Further analyses are needed to understand the interactions among weather events and site and biotic factors that determine the distribution of white oak mortality and the likelihood of occurrence on specific sites. Such data could be incorporated into risk models for locations within the Ozark Plateau and Forest Prairie–Transition area to improve management outcomes.

CONTACT INFORMATION

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LITERATURE CITED

Baucom, D. 2005. *Armillaria* species in the Missouri Ozark Forests. Columbia, MO: University of Missouri–Columbia. 79 p. M.S. thesis.

Bruhn, J.N.; Wetteroff, J.J., Jr.; Mihail, J.D. [and others]. 2000. Distribution of *Armillaria* species in upland Ozark Mountain forests with respect to site, overstory species composition, and oak decline. European Journal of Forest Pathology. 30: 43–60.

Fan, Z.; Fan, X.; Crosby, M.K. [and others]. 2012. Spatio-temporal trends of oak decline and mortality under periodic regional drought in the Ozark highlands of Arkansas and Missouri. Forests. 3: 614–631.

Harrington, T.C.; Wingfield, B.D. 1995. A PCR-based identification method for species of *Armillaria*. Mycologia. 87: 280–288.

McConnell, M.E.; Balci, Y. 2014. *Phytophthora cinnamomi* as a contributor to white oak decline in mid-Atlantic United States forests. Plant Disease. 98: 319–327.

Reed, S.E.; Muzika, R.M. 2010. The influence of forest stand and site characteristics on the composition of exotic dominated ambrosia beetle communities (Coleoptera: Curculionidae: Scolytinae). Environmental Entomology. 39: 1482–1491.

Schwingle, B.W.; Juzwik, J.; Eggers, J.; Moltzan, B. 2007. *Phytophthora* species in soils associated with declining and non-declining oak in Missouri forests. Plant Disease. 91: 633.

Stephen, F.M.; Salisbury, V.B.; Oliveria, F.L. 2001. Red oak borer, *Enaphalodes rufulus* (Coleoptera: Cerambycidae), in the Ozark Mountains of Arkansas, U.S.A.: an unexpected and remarkable forest disturbance. Integrated Pest Management Reviews. 6: 247–252.