A TALE OF TWO OUTBREAKS: ARE OAK POPULATIONS BECOMING MORE VULNERABLE TO INSECT OUTBREAKS AND CLIMATE STRESS IN CENTRAL MASSACHUSETTS, USA?

Audrey Barker Plotkin, Brian Keeven, and Jaclyn Hatala Matthes

PURPOSE AND SCOPE

Oaks (*Quercus*) have dominated biomass growth for more than half a century in southern New England (Eisen and Barker Plotkin 2015). However, spongy moth (*Lymantria dispar*) outbreaks and climate stress threaten oak dominance. Additionally, maturing oak forests may become more vulnerable to disturbance as they age, and the impact of losing a few large trees results in larger biomass losses (a metric of oak decline) than a disturbance in a younger stand comprising many small trees. We compared mortality rates following the two most recent major spongy moth outbreaks in central Massachusetts: an outbreak that peaked in 1980–1981, and a recent outbreak from 2016 through 2018. We hypothesized that the more recent outbreak caused larger losses of biomass because it affected an older forest composed of fewer, larger trees.

There is also increasing evidence that oaks are impacted by hydrological stress from climate change. Although oaks tend to be more deeply rooted than co-occurring species, their stomata tend to be less sensitive to periods of low soil moisture and dry atmospheric conditions, which might help to explain why oaks experience larger growth reductions and higher rates of mortality during intense drought than neighboring species (Novick et al. 2022). Climate stress, together with spongy moth impacts and changes with forest age, might create compound stress that influence the growth and mortality of oaks.

METHODS AND APPROACH

We analyzed data from a permanent plot network in the Quabbin Reservoir Watershed Forest in which individual trees in 283 plots were measured once per decade from 1970 through 2020. Averaged across all censuses, the oaks together comprised 27 percent of the total live trees. More than half of the oaks were northern red oak (*Q. rubra*). We used the *Forest Health Atlas* (Kosiba et al. 2018) to document the timing and spatial pattern of spongy moth defoliation during the two outbreaks. We estimated mortality risk for individual trees among the five census intervals using a generalized linear mixed modeling regression approach, with census interval, tree size (diameter), species group (oak, all others), and oak abundance as predictor variables.

Audrey Barker Plotkin, Harvard Forest, Harvard University, Petersham, MA 01366, USA

Brian Keevan, Massachusetts Department of Conservation and Recreation, Division of Water Supply Protection, West Boylston, MA 01583, USA

Jaclyn Hatala Matthes, Harvard University, Petersham, MA 01366, USA

We put the data from the permanent plots into context with 25-year trajectories of climate data and dendrometer band measurements from 130 oak trees at the nearby Harvard Forest Long-Term Ecological Research Site. Dendrometer bands were installed in 1998 on trees in 34 plots, and new recruits that exceeded the 10 cm minimum diameter threshold were added to the survey each year. All dendrometer bands were measured at least four times annually to track interannual tree growth.

FINDINGS AND IMPLICATIONS

We found that spongy moth outbreaks were a major cause of oak mortality. The percentage of oaks that died during outbreak intervals (1980–1990; 2010–2020) was more than triple that of nonoutbreak intervals (fig. 1). In general, smaller trees (<30 cm diameter at breast height) were more likely to die, but the largest diameter trees (>60 cm) also had an elevated risk of mortality. Mortality risk was significantly higher during the 2010s outbreak than during the 1980s outbreak.

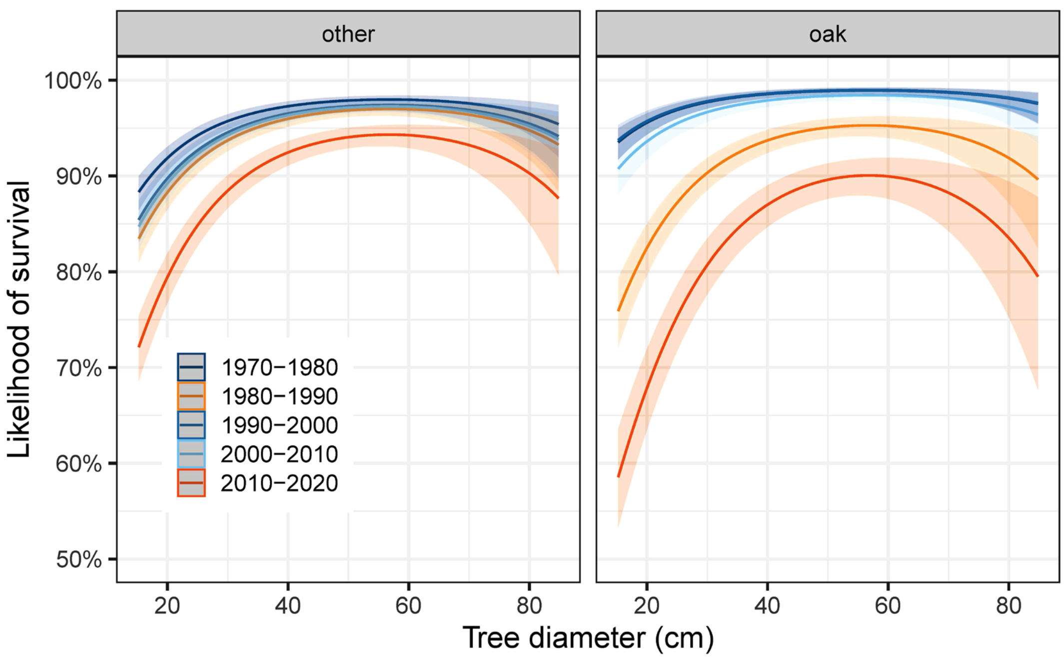

Figure 1—Modeled tree mortality risk for (right) oaks and (left) all other species. Mortality risk varied by census interval, species group, and tree size (diameter at the beginning of the interval). The lines show the predicted survival probability (shading shows 95-percent confidence intervals) for trees at the end of each census interval. Outbreak intervals are shown in orange tones; nonoutbreak intervals are shown in blue tones.

As expected, we found greater loss of oak biomass during the 2010s outbreak than during the 1980s outbreak, partially because the average tree that died between 2010 and 2020 was larger and contained much more biomass than the average tree that died between 1980 and 1990. However, the changing size structure of the maturing forest does not adequately explain why the individual-tree mortality risk was higher in the 2010s than in the 1980s. Other stressors likely contributed, highlighting the increased risk of oak mortality in an era of accelerating global change. Oak growth rates from dendrometer band measurements sustained a decadal decline after a series of droughts in 2010, 2016, and 2020.

LITERATURE CITED

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