Fire Suppression and Mesophication of Oak Landscapes

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This Presentation is the Result of Many Conversations with My Co-Authors

Mesophication of Oak Landscapes: Evidence, Knowledge Gaps, and Future Research

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Open-canopy woodlands

Pre-settlement, Oaks Dominated the Eastern U.S.

Photo from Bromley 1935, *Ecol Monog*

Hanberry and Nowacki 2016, *Qua Sci Rev*
Today, Oak Landscapes Still Dominate

Oak volume change (1980-2005)

Fei et al., 2011, FEM

Closed-canopy forests

http://www2.ca.uky.edu/forestry/maehrbearky.php
Shade-Loving, Fire-Sensitive Species Are Replacing Oaks

Alexander, et al., *BioScience* 2021
Why Does This Shift Matter?

Management and Conservation Article

Forestry Matters: Decline of Oaks Will Impact Wildlife in Hardwood Forests

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J. Wild Mgmt 2005

http://wkms.org/post/bourbons-effort-sustain-white-oak-necessary-future
Can Mesophication Explain Why This Shift Is Happening?

The Demise of Fire and “Mesophication” of Forests in the Eastern United States

Fire importance

- Fire suppression; canopy closure; increased shade
- Dramatic increase of shade-tolerant, mesophytic trees
- Decreased flammability due to mesophytic litter and cool, humid microclimate

Mesophication

Nowacki and Abrams 2008, BioScience
Important to Note:
• Mesophication is more than compositional shifts (that's just Phase 1)
• It's a positive feedback cycle where mesophytes perpetuate conditions that foster their continued proliferation over that of pyrophytic species (Phases 2-4)
Phase 1: Fire exclusion, mesophyte spread, and declining oak dominance

Fire and the Development of Oak Forests

In eastern North America, oak distribution reflects a variety of ecological paths and disturbance conditions

Marc D. Abrams

Oak (Quercus) represents one of the most dominant species groups in the eastern deciduous forest of North America (Table 1). In certain eastern regions, oak dominance reflects the importance of this genus in presentment forests (Abrams and Downs 1990, Spurr 1991, Whitney and Davis 1986). Yet, fire and human activity have affected the past and present ecology of oak forests. Factors will likely continue to affect forests in the future.

Paleoecology of eastern oak forests

During the last 18,000 years, dramatic shifts in species assemblages occurred in eastern North America.

Fire-Oak Hypothesis

1. Periodic fire
2. Maintained oak dominance
3. Warmer, sunnier, drier, higher fuel understory
4. Higher flammability


Alexander, et al., BioScience 2021
Paleorecord & Oak Adaptations to Fire

Ballard et al., 2017, Palynology
Fire Scar Analyses

McEwan et al. 2007, *J of Veg Sci*
Tree Establishment Dates

- REMA 2: Lots of oak establishment
- REMA 3: Lots of maple establishment
- Zaleski 2: Major fire
- Zaleski 3: Major fire
- Tar Hollow 2: Major fire
- Tar Hollow 3: Major fire

Hutchinson et al. 2008, *FEM*
“On one subject, all are in accord and that is the observation that the original forest was, in most places, extremely open and parklike, due to the universal factor of fire, fostered by the original inhabitants to facilitate travel and hunting.” – Bromley, 1935, *Ecol Monogr*

To quote from Thomas Morton³ (1632), “the Salvages are accustomed to set fire of the country in all places where they come; and to burn it, twize a yeare, vixe, at the Spring, and at the fall of the leafe. The reason that moves them to do so, is because it would be otherwise so overgrown with under-weedes⁴ that it would be all a copice wood, and the people could not be able in any wise to passe through the country out of a beaten path. . . . The burning of the grasse destroyes the underwoods, and so scorchethe the elder trees, that it shrinks them, and hinders their growth very much: So that hee that will look to finde large trees, and good tymbre, must not depend upon the help of a woodden prospect to find them on the upland ground; but must seeke for them . . . in the lower grounds where the grounds are wett when the country is fired . . . For when the fire is once kindled, it dilates and spreads itself against as with the winde; burning continually night and day, until a shower of raine falls to quench it. And this custome of firing the country is the means to make it passable, and by that meanes the trees growe here and there as in our parks: and makes the country very beautifull, and commodius.”
Lots of Other Things That Could Have Contributed to Mesophication

- Wet, humid climate with reduced droughts over last century
  - (McEwan et al. 2011; Pederson et al. 2013, 2015; Kutta and Hubbart 2018)
- Altered herbivore pressure
  - Increased deer browse (Thomas-Van Gundy et al. 2014, McWilliams et al. 2018, Kelly 2019)
  - Loss of herbivory from wood bison and eastern elk (Hanberry 2019; Hanberry et al. 2020, Mueller et al. 2020)
- Loss of passenger pigeons and canopy disturbances/fuel inputs (Ellsworth and McComb 2003)
- Loss of highly flammable American chestnut (Kane et al. 2018)
- Increased nitrogen deposition that favors mesophytes (Thomas et al. 2010)
Successfully Managing for Upland Oaks TODAY...

- Depends on current-day limitations to fire, which may hinge on vegetation-fire feedback loops that act to promote or suppress fire (i.e., phases 2-4 of the mesophication hypothesis)
Fire Exclusion Clearly Important For Oak Regeneration BUT...

- Lots of other things going on
- Not as easy as simply returning fire to the landscape

Table 5.—Distribution of prescribed fire projects conducted in mature oak forests by the number of burns and the effect on oak regeneration process. Note the trend of increasingly positive effects on oak as the number of fires increase from one to more than two.

<table>
<thead>
<tr>
<th>Effect on Oak</th>
<th>Single (1)</th>
<th>Dual (2)</th>
<th>Multiple (&gt;2)</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Positive</td>
<td>0</td>
<td>6</td>
<td>5</td>
<td>11</td>
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<tr>
<td>Ambiguous</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Negative</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11</strong></td>
<td><strong>12</strong></td>
<td><strong>8</strong></td>
<td><strong>31</strong></td>
</tr>
</tbody>
</table>
Phase 2: Mesophytes Create Shady, Cool, Humid Understories with High Fuel Moisture and Low Fuel Loads
Mesophytes Have Denser Crowns That Decrease Understory Light

Oaks: shallow, narrow crown

Mesophytes: wide, spreading crown

Babl, et al, 2020, *FEM*

Error bars ± SE; different letters denote significant differences (p < 0.05)

Siegert, Alexander, et al., Unpubl Data
This Decrease in Light Reduces Fuel Temperature
Increased Shade Decreases Fuel Temperature

Kreye, et al, 2018, CJFR
Mesophytes Often Have Thinner, Smoother Bark That Generates More Stemflow

Babl, et al, 2020, *FEM*
Error bars ± SE; different letters denote significant differences (p < 0.05)

MS = Siegert, Unpubl Data
KY = Alexander and Arthur, 2010, *CJFR*
More Stemflow Can Increase Soil Moisture Near Mesophytes

Drier

Wetter

B

2.5
0.0
-5.0
-7.5

VWC (%)

Mockernut Hickory
Red Maple
Southern Red Oak
White Oak

Overstory

A

A

B

C

Drotar, Siegert, Alexander, Varner, In Prep
Mesophyte Leaf Litter Often Decomposes Faster Than Oak Litter

A switch from oak to maple dominance could decrease fuel loads by 400 kg/ha/yr

Babl, Alexander, Nation, et al, *In Prep*
Fuel Loads Decline with Increased Mesophyte Contribution to Stand Basal Area

Dickinson, et al. 2016, *PLOS One*
Mesophyte Leaf Litter is Moister and Dries Slower Than Oak Litter

Litter soaked in water for 24 hours
Drained and placed in elevated pans to dry
Dried for 48 hours and weighed periodically

McDaniel, et al., 2021, FEM
Differential Moisture Responses Linked to Differences in Leaf Morphology

Alexander, et al., BioScience 2021
A Shaded Understory Beneath Mesophytes Also Reduces Fuels by Altering Ground-Layer Vegetation

Closed-Canopy Stand with Oak Overstory and Mesophytic Understory and Leaf Litter Fuel Bed

More Open-Canopied Stand with Oak Overstory, Scant Midstory and Herbaceous Fuel Bed

Vander Yacht, et al. 2017, FEM
Phase 3: Shadier, cooler, wetter environment, leaf litter fuels, and lower fuel loads beneath mesophytes reduces flammability
Increasing Mesophyte Litter to Fuelbed Decreases Flammability

Modeled Fireline Intensity

- Maple (C)
- Mixed (B)
- Oak (A)

Intensity (ranked)

Dickinson, et al., 2016

Laboratory Combustion Experiments

- Tall flames
- High consumption
- Prolonged smoldering

- Short flames
- Low consumption
- Abbreviated smoldering

Kreye, et al, 2018, FEM
Field Burns Confirm These Trends

Fuel beds constructed of oak or mesophytic litter

Ignited and measured flammability metrics

Oak fuel beds burned easily

Winged elm fuel beds often failed to ignite

McDaniel, et al., 2021 FEM
Field Burns Confirm These Trends

During
- Faster spread
- Higher temperature
- Taller flames
- Greater area burned

After

Decreasing Flammability?

Slower spread
- Lower temperature
- Shorter flames
- Smaller area burned
Field Burning Southern Red Oak Litter
Field Burning Sweetgum Litter
Phase 4: Shadier, cooler, moister, and reduced flammability beneath mesophytes promote mesophytes and hinder oaks

Canham, et al., 1994 CJFR

<table>
<thead>
<tr>
<th>Canopy species</th>
<th>FAGR</th>
<th>TSCA</th>
<th>ACSA</th>
<th>BELU</th>
<th>PRSE</th>
<th>PIST</th>
<th>ACRU</th>
<th>FRAM</th>
<th>QURU</th>
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<td>0.9</td>
<td>3.0</td>
<td>2.9</td>
<td>6.9</td>
<td>6.1</td>
<td>4.1</td>
<td>6.9</td>
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<td></td>
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<tr>
<td>FAGR</td>
<td>2.6</td>
<td>2.5</td>
<td>2.2</td>
<td>2.2</td>
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<tr>
<td>TSCA</td>
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<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
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<td>&lt;0.1</td>
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<td>&lt;0.1</td>
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<tr>
<td>ACSA</td>
<td>11.8</td>
<td>4.8</td>
<td>0.6</td>
<td>0.6</td>
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<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
<td>0.2</td>
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<tr>
<td>BELU</td>
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<td>11.2</td>
<td>2.3</td>
<td>2.4</td>
<td>1.0</td>
<td>1.1</td>
<td>1.7</td>
<td>1.0</td>
<td>1.0</td>
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<tr>
<td>PRSE</td>
<td>25.0</td>
<td>8.5</td>
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<td>0.1</td>
<td>&lt;0.1</td>
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<td>&lt;0.1</td>
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<td>PIST</td>
<td>30.0</td>
<td>22.3</td>
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<td>0.8</td>
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<tr>
<td>ACRU</td>
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<td>FRAM</td>
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<td>QURU</td>
<td>76.8</td>
<td>57.3</td>
<td>6.6</td>
<td>7.5</td>
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<td>2.1</td>
<td>0.1</td>
<td>0.1</td>
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</table>

Note: Mortality rates were computed for saplings 2 cm DBH at the beginning of the 5-year period, using functional relationships between light and growth (Fevziel et al. 1995) and relationships between growth and mortality given in R.K. Kobe et al. (see footnote 4). Because of the extremely large confidence intervals on our estimates of light extinction by yellow birch and white pine (Table 4), we have used the observed GLI data from fisheye photographs (Fig. 2) for estimates of GLI in monospecific stands of those two species. Species are listed in order of decreasing shade tolerance (see Tables 1 and 2).
Tree Traits Can Reinforce or Suppress Fire Leading to Self-Perpetuating Conditions

a) Fire-promoting
- Shallower, more open crown
- Thicker, rougher bark
- Drier, fluffier, more recalcitrant leaf litter
- Warmer, drier understory
- More herbaceous fuels
- Higher fuel load

b) Fire-suppressing
- Deeper, denser crown
- Thinner, smoother bark
- Moister, denser, more decomposable leaf litter
- Cooler, wetter understory
- Fewer herbaceous fuels
- Lower fuel load

Oak tree

Mesophyte tree

Zone of influence
Key Knowledge Gaps Remain

Current Knowledge

GAP

Target Knowledge

Our Understanding of Causes and Consequences of Shifting Oak Landscapes
Can self-perpetuating processes propagate to the stand and landscape scale?

- **Fire-promoting**
  - Shallower, more open crown
  - Higher throughfall
  - Thicker, rougher bark
  - Less stemflow
  - Drier, fluffier, more recalcitrant leaf litter
  - Warmer, drier understory
  - More herbaceous fuels
  - Higher fuel load

- **Fire-suppressing**
  - Deeper, denser crown
  - Lower throughfall
  - Thinner, smoother bark
  - More stemflow
  - Moister, denser, more decomposable leaf litter
  - Cooler, wetter understory
  - Fewer herbaceous fuels
  - Lower fuel load

- **Oak savanna or woodland**
- **Mesophytic forest**

**Decreasing Flammability?**
Can these processes overcome broadscale phenomena like climate change and its interaction with fire potential?

Vose and Elliott 2016, *Fire Ecology*

Iverson et al. 2008, *FEM*
How Important Are Species-Level Differences?

Varner, et al., 2016 Fire Ecology

Kane, et al., 2021 FEM
How Do We Apply Small-Scale Results to *In Situ* Wildland Fires?


Kane et al. 2016
Mesophication is more than compositional shifts; it’s a positive feedback cycle where tree traits act to reinforce or suppress fire.

Shifting the mesophytic state back to open-canopied savannas and woodlands by reintroducing fire alone, the primary disturbance thought to induce this shift, is often not enough.

Is this because there’s been insufficient time for fire restoration efforts to work, because fire exclusion interacts with other factors to limit oak regeneration, or because feedback loops between mesophytes and their understory reduce flammability and promote their own persistence, decreasing the effectiveness of fire?

Many knowledge gaps that we need to explore.
Questions