Repeated Prescribed Fires Favor Oak Regeneration in Canopy Gaps

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Collaborators

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Field crew, circa 1995
Oak regeneration across the landscape

- **Intrinsic accumulation**
  - Low moisture/nutrient availability
  - Upper slopes, S-aspect
  - Site index <60

- **Recalcitrant accumulation**
  - High moisture/nutrient availability
  - Middle-lower slopes, N-aspect
  - Site index >70

The Oak Regeneration Problem, Ohio

Ohio, FIA 2006
Widmann et al. 2009
## Southern Ohio Forests, ca. 1800

<table>
<thead>
<tr>
<th>Survey name</th>
<th>Scientific.name</th>
<th>Witness trees</th>
<th>Diameter (in)</th>
<th>Distance (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White oak</td>
<td><em>Quercus alba</em></td>
<td>1878 (33%)</td>
<td>18 (3 – 60)</td>
<td>22</td>
</tr>
<tr>
<td>Hickory</td>
<td><em>Carya spp.</em></td>
<td>779 (14%)</td>
<td>12 (1 – 36)</td>
<td>23</td>
</tr>
<tr>
<td>Black oak</td>
<td><em>Quercus velutina + coccinea</em></td>
<td>658 (12%)</td>
<td>18 (2 - 96)</td>
<td>25</td>
</tr>
<tr>
<td>Beech</td>
<td><em>Fagus grandifolia</em></td>
<td>572 (10%)</td>
<td>12 (3 - 50)</td>
<td>20</td>
</tr>
<tr>
<td>Sugartree</td>
<td><em>Acer saccharum</em></td>
<td>254 (4%)</td>
<td>12 (3 – 32)</td>
<td>20</td>
</tr>
<tr>
<td>Gum</td>
<td><em>Nyssa sylvatica</em></td>
<td>197 (3%)</td>
<td>10 (3 – 30)</td>
<td>17</td>
</tr>
<tr>
<td>Maple</td>
<td><em>Acer rubrum</em></td>
<td>193 (3%)</td>
<td>12 (4 – 24)</td>
<td>19</td>
</tr>
<tr>
<td>Poplar</td>
<td><em>Liriodendron tulipifera</em></td>
<td>158 (3%)</td>
<td>14 (5 – 48)</td>
<td>18</td>
</tr>
<tr>
<td>Dogwood</td>
<td><em>Cornus florida</em></td>
<td>149 (3%)</td>
<td>5 (2 – 12)</td>
<td>15</td>
</tr>
<tr>
<td>Elm</td>
<td><em>Ulmus spp.</em></td>
<td>111 (2%)</td>
<td>12 (3 – 48)</td>
<td>20</td>
</tr>
<tr>
<td>Chestnut</td>
<td><em>Castanea dentata</em></td>
<td>106 (2%)</td>
<td>18 (3 – 60)</td>
<td>29</td>
</tr>
<tr>
<td>Chestnut oak</td>
<td><em>Quercus prinus</em></td>
<td>89 (2%)</td>
<td>14 (3 – 36)</td>
<td>21</td>
</tr>
</tbody>
</table>

Witness trees, five counties ($n = 5696$)
Ecosystem Management Study, 1995
Oak (and hickory) fire adaptations

- Trees
  - Thick bark
  - Wound compartmentalization

- Seedlings
  - Root-centered growth
  - Location of dormant buds
  - Re-sprouting capacity
Hypotheses: Forest Structure and Tree Regeneration

Repeated low-intensity fires will:

1. Reduce the density of midstory and understory trees, which are predominately non-oaks

2. Increase the competitive status of oak regeneration due to their sprouting capacity and increased light to the forest floor
Study Site: Vinton Furnace State Experimental Forest (VFSEF)
Study site: VFSEF
Fire History, Vinton Furnace Exp. Forest

Oaks

Maples
Fire History, Vinton Furnace Exp. Forest

Forest Composition

- **Overstory**
  - White oak, *Quercus alba*
  - Chestnut oak, *Quercus montana*
  - Black oak, *Quercus velutina*
  - Hickories, *Carya* spp.
  - Scarlet oak, *Quercus coccinea*
  - Yellow poplar, *Liriodendron tulipifera*

- **Understory**
  - Red maple, *Acer rubrum*
  - Sugar maple, *Acer saccharum*
  - Blackgum, *Nyssa sylvatica*
  - Beech, *Fagus grandifolia*
  - Sourwood, *Oxydendrum arboreum*
Study Design

Vegetation Plots

Watch Rock Site
Arch Rock Site
Unburned
Burned 5X

2 m² quadrats
37.5 m² belts
312.5 m² Sapling subplot

Prescribed fires

<table>
<thead>
<tr>
<th>Stand</th>
<th>yr1</th>
<th>yr2</th>
<th>yr3</th>
<th>yr4</th>
<th>yr9</th>
<th>yr10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arch Rock 5X</td>
<td>4/19</td>
<td>4/2</td>
<td>4/6</td>
<td>3/26</td>
<td>4/17</td>
<td></td>
</tr>
<tr>
<td>Arch Rock 3X</td>
<td>4/18</td>
<td></td>
<td></td>
<td></td>
<td>3/26</td>
<td>4/15</td>
</tr>
</tbody>
</table>
This was another study......
Year 0, pre-burn

Year 4, after 4 burns

Year 13, after 5 burns
Year 0, pre-burn

Year 4, after 4 burns

Year 13, after 5 burns
Overstory trees >10” DBH

![Graph showing the number of trees per acre over different years for unburned and burned areas. The graph indicates a decrease in tree density over time, with a 4% decrease by year 7 and a 10% decrease by year 13.]
Midstory trees 4-10” DBH

Year
0 4 7 13
Trees per acre
40
60
80
100
Unburned
Burned

Midstory trees 4-10” DBH
Saplings 1-4” DBH

![Graph showing saplings per acre over years, comparing unburned and burned areas. The graph indicates a significant decrease in saplings in the burned area from year 0 to year 13, while the unburned area shows a slight increase from year 0 to year 13.](image-url)
# Midstory mortality, year 13

## Trees 4 – 10” DBH

<table>
<thead>
<tr>
<th>Species</th>
<th>“Fire” mortality.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red maple</td>
<td>43% (49 - 6)</td>
</tr>
<tr>
<td>White oak</td>
<td>21% (67 - 46)</td>
</tr>
<tr>
<td>Hickory</td>
<td>17% (26 - 9)</td>
</tr>
<tr>
<td>Yellow poplar</td>
<td>7% (23 - 16)</td>
</tr>
<tr>
<td>Blackgum</td>
<td>6% (9 - 3)</td>
</tr>
<tr>
<td>Chestnut oak</td>
<td>2% (15 – 13)</td>
</tr>
</tbody>
</table>
Canopy Openness

![Graph showing canopy openness over years for unburned and burned conditions.](image)

- **Unburned**: Starting at 4.8% in year 0, it increases to 9.3% by year 13.
- **Burned**: Starts at 3.4% and increases to 5.0% by year 13.

The graph displays a clear upward trend for both conditions over the years.
Small saplings (4.5’ tall to 1” DBH)
Dry sites

Dry plots, unburned (n = 10)

Dry plots, burned (n = 14)

Year 13, 5 burns
Small saplings (4.5’ tall to 1” DBH)

Mesic plots, unburned (n = 8)

Mesic plots, burned (n = 13)

Year 13, 5 burns
Oak-hickory advance regeneration, Year 13, Stems 1’ tall to 1” DBH

Stems per acre, year 13

Oak+hickory weighted frequency, year 0

0 20 40 60 80

Unburned
Burned

$\mathbf{r^2 = 0.60}$

$\mathbf{r^2 = 0.68}$

Oak+hickory weighted frequency, year 0

Stems per acre, year 13
Advance regeneration, Year 13
Stems 1’ tall to 1” DBH

Oak + hickory
- Unburned
- Burned

Stems per acre
- 0
- 500
- 1000
- 1500
- 2000

Sassafras
- Unburned
- Burned

Shade-tolerant species

Graphs showing the number of stems per acre for Oak + hickory, Sassafras, and Shade-tolerant species under unburned and burned conditions.
Sassafras albidum
Conclusions, Permanent Plots, Year 13

• Fire effects on stand structure:
  – Understory > Midstory > Overstory

• Fire changed the species composition of the small saplings on dry plots:
  – Shade-tolerant
  – Oak-hickory +
  – Sassafras +

• Oak-hickory advance regeneration (>1’ tall) was more abundant on burned sites
  – Highly variable across landscape
  – Dependent on the ABUNDANCE and SIZE of oak-hickory seedlings present initially
Years 8-10: White oak decline
Formation of canopy gaps
3 years since gap formed (year 11)

2 years after the last of five fires
Tree regeneration in burned and unburned canopy gaps, year 13

24 gaps in unburned units
28 gaps in burn units

Burned 5X:
96,97,98,99,04

Burned 3X:
96,99,05
<table>
<thead>
<tr>
<th>Attribute</th>
<th>Average Unburned gaps (n = 24)</th>
<th>Average Burned gaps (n = 28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead canopy trees</td>
<td>3.8 trees</td>
<td>4.1 trees</td>
</tr>
<tr>
<td>Area</td>
<td>0.05 acres</td>
<td>0.06 acres</td>
</tr>
<tr>
<td>Saplings/poles</td>
<td>331 per acre</td>
<td>37 per acre</td>
</tr>
<tr>
<td>% Full Sunlight</td>
<td>8%</td>
<td>18%</td>
</tr>
</tbody>
</table>
Saplings and poles, 1 to 8” DBH, year 13

Unburned Gaps (n=24)

- Oak-hickory
- Other species
- Shade-tolerant

Burned Gaps (n=28)
Large advance regeneration (>2’ tall), year 13

Unburned Gaps (n = 24)

- Oak-hickory
- Sassafras
- Other
- Shade-tolerant

Stems per acre

Oak-hickory, mean: 468 per acre

Burned Gaps (n = 28)

Oak-hickory mean: 2798 per acre
Large oak-hickory advance regeneration (>2’ tall) in burned gaps

$r^2 = 0.31, p = 0.002$

$r^2 = 0.34, p = 0.001$
Species composition of oak advance regeneration (>30 cm tall) in burned gaps

- White oak (*Quercus alba*) 67%
- Black oak (*Q. velutina*) 17%
- Chestnut oak (*Q. montana*) 7%
- Scarlet oak (*Q. coccinea*) 6%
- Northern red oak (*Q. rubra*) 4%
Oak seedling shading study

- White, chestnut, and red oak
- 25%, 18%, and 6% of full sunlight
- 2 years of growth and physiology measurements

Oak seedling shading study

Seedling $A_{max}$: Leaf area

Area-based seedling photosynthesis (µmol · seedling s$^{-1}$)

Shade treatment (% of full sun)

- Chestnut oak
- Northern red oak
- White oak

Rebbeck et al. 2012
Seedling mass at 2-years

Rebbeck et al. 2011
Root:shoot at 2-years

Rebbeck et al. 2011
When topkilled by fire...

• Red maple and yellow-poplar
  – 60% of seedling mass is destroyed

• Chestnut oak and northern red oak
  – 40% of seedling mass is destroyed

• White oak
  – 25% of seedling mass is destroyed
Conclusions, Gap Study, Year 13

• Unburned gaps: Filled by shade-tolerant saplings and poles
• Burned gaps: Saplings and poles were largely eliminated
• Oak-hickory regeneration was dominant in gaps within burned stands
• White oak (Q. alba) regeneration may benefit most from repeated low-intensity burns – the “slow approach”
Publications from this work..


Key papers on fire effects in oak forests


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  - David Hosack
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Year 13, after 5 fires