Stand dynamics 11 years after retention harvest in Rocky Mountain lodgepole pine

Justin S. Crotteau and Christopher R. Keyes

University of Montana
Applied Forest Management Program
The take-home message

Retention harvesting is a viable tool to create structural heterogeneity in lodgepole pine stands. Heterogeneity is good. But heterogeneity is costly.
**Outline**

- **Background**
  - Retention harvesting
  - Tenderfoot Creek Experimental Forest

- **Three lenses into stand dynamics**
  - Stand structural changes
  - Growth
  - Mortality
Retention harvesting

• Defined

*a silvicultural cutting used to create structural diversity and maintain biological legacies in stands*

Gustafsson et al. 2012, *Bioscience*

Retention harvesting

• Where it is commonly used
• Current state of knowledge
Tenderfoot Creek E.F.

- Where
- Forest type
- Fire history
The Tenderfoot Project

• Goals
• Experimental design
• Implementation
• Measurement
Stand dynamics after retention harvest

Outline

- **Background**
  - Retention harvesting
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- **Three lenses into stand dynamics**
  - Stand structural changes
  - Growth
  - Mortality
Stand structural changes

1. Overstory
   1. Stand density metrics
   2. Diameter distributions
   3. Species composition

2. Regeneration
   1. Composition and Density
Stand structural changes

1.1. Overstory stand density metrics

![Graphs showing stem density, basal area, relative density, quadratic mean diameter over time for different treatments.](image)

Mean and 1 standard error of mean
Stand structural changes

1.1. Overstory stand density metrics

Mean and 1 standard error of mean
Stand structural changes

1.1. Overstory stand density metrics

Standard deviation and 1 standard error of standard deviation
Stand structural changes

1.2. Overstory diameter distributions

![Graphs showing stand dynamics after retention harvest](image_url)
Stand structural changes

1.2. Overstory diameter distributions
Stand structural changes

1.2. Overstory diameter distributions

Control
- 0% of plots had no trees

Aggregated: Unburned
- 60% of plots had no trees

Dispersed: Unburned
- 38% of plots had no trees

Aggregated: Burned
- 37% of plots had no trees

Dispersed: Burned
- 34% of plots had no trees
Stand structural changes

1.2. Overstory diameter distributions
Stand structural changes

1.3. Overstory species composition
Stand structural changes

2.1. Regeneration composition and density
Stand structural changes

2.1. Regeneration composition and density
Stand structural changes

2.1. Regeneration composition and density
Outline

• Background
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• Three lenses into stand dynamics
  • Stand structural changes
  • Growth
  • Mortality
Growth

1. Overstory tree growth
Growth

1. Overstory tree growth

<table>
<thead>
<tr>
<th>Test</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control vs Treated</td>
<td>0.173</td>
</tr>
<tr>
<td>Aggregated vs Dispersed</td>
<td>0.002</td>
</tr>
<tr>
<td>Burned vs Unburned</td>
<td>0.095</td>
</tr>
<tr>
<td>Period1 vs Period2</td>
<td>0.050</td>
</tr>
<tr>
<td>Interaction: Cut + Burn</td>
<td>0.180</td>
</tr>
<tr>
<td>Interaction: Period + Cut</td>
<td>0.968</td>
</tr>
<tr>
<td>Interaction: Period + Burn</td>
<td>0.032</td>
</tr>
</tbody>
</table>

- D 100% greater
- U 42% greater
- P2 41% greater
- P2 U 92% greater than P2 B, but 15% less in P1
Growth
2. Seedling height growth
Growth

2. Seedling height growth

<table>
<thead>
<tr>
<th>Test</th>
<th>P-value</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Aggregated vs Dispersed</td>
<td>0.243</td>
<td>Aggregated vs Dispersed</td>
<td>0.089</td>
</tr>
<tr>
<td>Burned vs Unburned</td>
<td>0.149</td>
<td>Burned vs Unburned</td>
<td>0.493</td>
</tr>
<tr>
<td>Interaction: Cut + Burn</td>
<td>0.254</td>
<td>Interaction: Cut + Burn</td>
<td>0.457</td>
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</table>

Agg 15% faster
Outline

• Background
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  • Tenderfoot Creek Experimental Forest

• Three lenses into stand dynamics
  • Stand structural changes
  • Growth
  • Mortality
## Mortality

### 1. Effects of burning

<table>
<thead>
<tr>
<th>Retention Pattern</th>
<th>RxFire</th>
<th>Initial TPA</th>
<th>Initial QMD</th>
<th>Annual mortality rate, P1</th>
<th>Annual mortality rate, P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Unburned</td>
<td>361.6</td>
<td>9.4</td>
<td>3.3 %</td>
<td>1.8 %</td>
</tr>
<tr>
<td>Aggregated</td>
<td>Unburned</td>
<td>181.3</td>
<td>9.7</td>
<td>1.0 %</td>
<td>4.3 %</td>
</tr>
<tr>
<td>Dispersed</td>
<td>Unburned</td>
<td>110.6</td>
<td>10.7</td>
<td>2.6 %</td>
<td>4.0 %</td>
</tr>
<tr>
<td>Aggregated</td>
<td>Burned</td>
<td>266.0</td>
<td>9.3</td>
<td><strong>1.9 %</strong></td>
<td><strong>6.1 %</strong></td>
</tr>
<tr>
<td>Dispersed</td>
<td>Burned</td>
<td>117.8</td>
<td>10.4</td>
<td><strong>6.8 %</strong></td>
<td><strong>13.5 %</strong></td>
</tr>
</tbody>
</table>

1. Effects of burning
Mortality

2. Agents

- Bark beetles

<table>
<thead>
<tr>
<th>Retention Pattern</th>
<th>Unsuccessful attacks</th>
<th>Successful attacks</th>
<th>TOTAL TREES</th>
</tr>
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<tbody>
<tr>
<td>Control</td>
<td>11</td>
<td>52</td>
<td>2761</td>
</tr>
<tr>
<td>Aggregated</td>
<td>7</td>
<td>20</td>
<td>1570</td>
</tr>
<tr>
<td>Dispersed</td>
<td>0</td>
<td>3</td>
<td>626</td>
</tr>
<tr>
<td>TOTAL</td>
<td>18</td>
<td>75</td>
<td>4957</td>
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Mountain pine beetle
Mortality

2. Agents

- Bark beetles

### Retention Pattern

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<td>75</td>
<td>4957</td>
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### Ips spp.

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Rx Fire</th>
<th>Infested dead</th>
<th>TOTAL TREES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Unburned</td>
<td>62</td>
<td>2761 2.2%</td>
</tr>
<tr>
<td>Aggregated</td>
<td>Unburned</td>
<td>22</td>
<td>497 4.4%</td>
</tr>
<tr>
<td>Dispersed</td>
<td>Unburned</td>
<td>44</td>
<td>338 13.0%</td>
</tr>
<tr>
<td>Aggregated</td>
<td>Burned</td>
<td>320</td>
<td>1073 29.8%</td>
</tr>
<tr>
<td>Dispersed</td>
<td>Burned</td>
<td>125</td>
<td>288 43.4%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>--</td>
<td>573</td>
<td>4957</td>
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# Mortality

## 2. Agents

- Bark beetles

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<td>573</td>
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<table>
<thead>
<tr>
<th>Retention Pattern</th>
<th>Rx Fire</th>
<th>Initial QMD</th>
<th>QMD of beetle-evidence dead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Unburned</td>
<td>9.4</td>
<td>9.2</td>
</tr>
<tr>
<td>Aggregated</td>
<td>Unburned</td>
<td>9.7</td>
<td>11.1</td>
</tr>
<tr>
<td>Dispersed</td>
<td>Unburned</td>
<td>10.7</td>
<td>9.5</td>
</tr>
<tr>
<td>Aggregated</td>
<td>Burned</td>
<td>9.3</td>
<td>9.0</td>
</tr>
<tr>
<td>Dispersed</td>
<td>Burned</td>
<td>10.4</td>
<td>8.0</td>
</tr>
</tbody>
</table>
Mortality

2. Agents

- Wind
- Sunscald

<table>
<thead>
<tr>
<th>Retention Pattern</th>
<th>RxFire</th>
<th>Initial Ht:DBH of dead trees no beetle evidence</th>
<th>Initial Ht:DBH of trees still living in 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Unburned</td>
<td>72.5</td>
<td>72.0</td>
</tr>
<tr>
<td>Aggregated</td>
<td>Unburned</td>
<td><strong>97.9</strong></td>
<td><strong>82.1</strong></td>
</tr>
<tr>
<td>Dispersed</td>
<td>Unburned</td>
<td>83.7</td>
<td>72.2</td>
</tr>
<tr>
<td>Aggregated</td>
<td>Burned</td>
<td>79.4</td>
<td>79.9</td>
</tr>
<tr>
<td>Dispersed</td>
<td>Burned</td>
<td>79.1</td>
<td>80.9</td>
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Recap:
• More variability and greater overstory densities in Agg
• Better overstory growth as time passes, best in Disp and without burning
• Burning really hurt survival; MPB wasn’t a big factor
• Plenty of PICO regen, though more ABLA than hoping for
• Agg is slightly better enviro for PICO regen growth
The take-home message

Retention harvesting is a viable tool to create structural heterogeneity in lodgepole pine stands. Heterogeneity is good. But heterogeneity is costly.

Why is it worth it?

- Partial economic returns
- Aesthetics (maintains overstory)
- Habitat diversity
- Plant biodiversity
- Watershed outflow
- Improved resilience to fire
- Improved resistance to beetles
Acknowledgements

• USDA FS RMRS:
  • Ward McCaughey
  • Helen Smith
  • Sharon Hood
  • Elaine Sutherland
  • David Wright
  • Joel Egan

• UM CFC:
  • Tom Perry
  • Dave Affleck
Stand structural changes

2.1. Regeneration densities over time

Should this figure have SE shading like the overstory figure does? Odds are it will look messy...
Mortality

- Probability of mortality by treatment and period

Period 1
Agg trees survives better than control

Period 2
Only Disp:U survival as good as control

Both P1 and P2 models have low pseudo-R2 values. No interaction. No DBH effect. Use consistent treatment colors. Should these figs even be in here? Did not account for nesting.