Regeneration following fire in the Blue Mountains

Will Downing, James Johnston, Meg Krawchuk, Joseph Rausch
A quick note on images...
A quick note on images...
A road map: Where we are headed together this morning
A road map: Where we are headed together this morning?

1. Post-fire regeneration following high-severity fire in dry mixed-conifer forests
A road map: Where we are headed together this morning?

1. Post-fire regeneration following high-severity fire in dry mixed-conifer forests

2. Post-fire Alaska yellow-cedar mortality and regeneration in the Cedar Grove Botanical Area
Pre-settlement dry mixed-conifer forests in the Blue Mountains
Frequent historical fire
Significant changes in forest structure and the periodicity of fire
Contemporary fire effects raising concerns about forest resilience
High-severity burned areas may be at risk of converting to non-forest, alternative stable states.
Can high-severity burned areas regenerate forest?
Can high-severity burned areas regenerate forest?

1. Quantify conifer seedling regeneration following stand-replacement fire in Oregon’s Blue Mountains.
Can high-severity burned areas regenerate forest?

1. Quantify conifer seedling regeneration following stand-replacement fire in Oregon’s Blue Mountains. Are forests regenerating?
Can high-severity burned areas regenerate forest?

1. Quantify conifer seedling regeneration following stand-replacement fire in Oregon’s Blue Mountains. Are forests regenerating?

2. Identify the drivers of post-fire conifer seedling regeneration.
Can high-severity burned areas regenerate forest?

1. Quantify conifer seedling regeneration following stand-replacement fire in Oregon’s Blue Mountains. Are forests regenerating?

2. Identify the drivers of post-fire conifer seedling regeneration. What is the influence of surviving seed source pattern on conifer regeneration in stand-replacement patches?
Study design

# of seedlings

5.64 m
Study design

# of seedlings, overtopped Y/N

5.64 m
Study design
# of seedlings, overtopped Y/N, shrub cover
Study design

# of seedlings, overtopped Y/N, shrub cover, distance to seed source
Results: No evidence of large-scale regeneration failure
Results: No evidence of large-scale regeneration failure
Results: No evidence of large-scale regeneration failure

83% of plots contained conifer seedlings
Results: No evidence of large-scale regeneration failure

Most widespread species were ponderosa pine, Douglas-fir, and grand fir
Results: No evidence of large-scale regeneration failure

Most abundant species was grand fir
Variability in post-fire seedling densities
Variability in post-fire seedling densities

Dense regeneration:
Variability in post-fire seedling densities

Sparse, or absent regeneration:
Variability in post-fire seedling densities

Median seedling density across all plots was 1100 seedlings ha⁻¹
Results: Widespread post-fire regeneration
What are the key drivers of post-fire seedling density?
What are the key drivers of post-fire seedling density?
What are the key drivers of post-fire seedling density?

ponderosa pine       Douglas-fir       grand fir
What are the key drivers of post-fire seedling density?

- ponderosa pine
- Douglas-fir
- grand fir
- all species
Post-fire regeneration as a function of seed sources

Distance to seed source
Post-fire regeneration as a function of seed sources

Abundance of seed source
Seed source abundance

1 meter aerial imagery

[Image: Map showing seed source abundance with a scale in kilometers]
Seed source abundance

1 meter aerial imagery

1 meter maps of surviving seed source
Seed source abundance
Post-fire regeneration as a function of seed sources and site characteristics

- Distance to seed source
- Abundance of seed source
Post-fire regeneration as a function of seed sources and site characteristics

- Distance to seed source
- Abundance of seed source
- Elevation
Post-fire regeneration as a function of seed sources and site characteristics

- Distance to seed source
- Abundance of seed source
- Elevation
- Climatic moisture deficit
Post-fire regeneration as a function of seed sources and site characteristics

- Distance to seed source
- Abundance of seed source
- Elevation
- Climatic moisture deficit
- Pre-fire basal area
Post-fire regeneration as a function of seed sources and site characteristics

- Distance to seed source
- Abundance of seed source
- Elevation
- Climatic moisture deficit
- Pre-fire basal area
- Heat load
Post-fire regeneration as a function of seed sources and site characteristics

- Distance to seed source
- Abundance of seed source
- Elevation
- Climatic moisture deficit
- Pre-fire basal area
- Heat load
- Shrub cover
Post-fire regeneration as a function of seed sources and site characteristics

- Distance to seed source
- Abundance of seed source
- Elevation
- Climatic moisture deficit
- Pre-fire basal area
- Heat load
- Shrub cover
- Fire severity (dNBR)
Post-fire regeneration as a function of seed sources and site characteristics

- Distance to seed source
- Landscape fire refugia density
- Elevation
- Climatic moisture deficit
- Pre-fire basal area
- Heat load
- Shrub cover
- Fire severity (dNBR)
Post-fire regeneration as a function of seed sources and site characteristics

- Distance to seed source
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- Elevation
- Climatic moisture deficit
- Pre-fire basal area
- Heat load
- Shrub cover
- Fire severity (dNBR)
Distance to and abundance of seed source are key drivers of post-fire seedling abundance.
Distance to and abundance of seed source are key drivers of post-fire seedling abundance.
**Distance to** and abundance of seed source are key drivers of post-fire seedling abundance.

Decreasing distance to seed source from 300 meters...
Distance to and abundance of seed source are key drivers of post-fire seedling abundance

...to 50 meters increases predicted seedling density by 3-fold.
Distance to and **abundance of seed source** are key drivers of post-fire seedling abundance.
Increasing seed source abundance from 100…
Distance to and **abundance of seed source** are key drivers of post-fire seedling abundance. … to 500, triples predicted seedling density.
A shrub dominated post-fire landscape
A shrub dominated post-fire landscape
No evidence of a competitive relationship between shrubs and regenerating conifers
No evidence of a competitive relationship between shrubs and regenerating conifers
No evidence of a competitive relationship between shrubs and regenerating conifers
Can high-severity burned areas regenerate forest?

Key Points
Can high-severity burned areas regenerate forest?

Key Points

1. Forest is regenerating in high-severity burned patches of dry mixed-conifer forest in the Blue Mountains, providing evidence of resilience to contemporary fire effects.
Can high-severity burned areas regenerate forest?

**Key Points**

1. Forest is regenerating in high-severity burned patches of dry mixed-conifer forest in the Blue Mountains, providing evidence of resilience to contemporary fire effects.

2. The critical drivers of post-fire seedling abundance are distance to, and abundance of, surviving seed sources.
Can high-severity burned areas regenerate forest?

Key Points

1. Forest is regenerating in high-severity burned patches of dry mixed-conifer forest in the Blue Mountains, providing evidence of resilience to contemporary fire effects.

2. The critical drivers of post-fire seedling abundance are distance to, and abundance of, surviving seed sources.

3. Shrubs are abundant in the post-fire environment, but do not appear to constrain forest recovery.
Shifting gears...
Shifting gears…

Post-fire Alaska yellow-cedar mortality and regeneration in the Malheur NF’s Cedar Grove Botanical Area
Alaska yellow-cedar (*Callitropsis nootkatensis*): An introduction
Alaska yellow-cedar (*Callitropsis nootkatensis*): An introduction

Culturally important
Alaska yellow-cedar (*Callitropsis nootkatensis*): An introduction

Commercially valuable
Alaska yellow-cedar’s distribution is cool and wet
Alaska yellow-cedar is declining across much of its range due to warming temperatures

Buma et al. 2017
A cedar island in a dry mixed-conifer sea
A cedar island in a dry mixed-conifer sea

Cedar grove
A cedar island in a dry mixed-conifer sea
A cedar island in a dry mixed-conifer sea
A history of frequent fire followed by fire exclusion
In 2006, after over a century of fire exclusion, the grove burned
Despite low mortality in other species,
Despite low mortality in other species, initial assessments suggested that fire-induced cedar mortality was high.
Study objectives

1. What percentage of Alaska yellow cedar has died since fire in 2006?
Study objectives

1. What percentage of Alaska yellow cedar has died since fire in 2006?

2. Is cedar regenerating following fire?
Study design
Study design

12 transects along the length of the grove
Study design

12 transects along the length of the grove
Results

Mortality
Results

Moderate cedar mortality in 2006…
A year later, over 90% were dead
Results
Surviving cedar are distributed across the grove
## Results

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<tbody>
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<td>yellow-cedar</td>
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<tr>
<td>grand fir</td>
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<tr>
<td>Douglas-fir</td>
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<tr>
<td>western larch</td>
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<td>ponderosa pine</td>
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## Results

Cedar is regenerating

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<tbody>
<tr>
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<td>125</td>
<td></td>
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<td></td>
<td>(0 – 35250)</td>
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<tr>
<td>grand fir</td>
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<td>Douglas-fir</td>
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Cedar is regenerating vigorously!

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<td>2750</td>
<td>7375</td>
<td>8125</td>
<td>+10%</td>
</tr>
<tr>
<td></td>
<td>(0 – 35250)</td>
<td>(0 – 41000)</td>
<td>(0 – 10100)</td>
<td>(0 – 69250)</td>
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<tr>
<td>grand fir</td>
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<tr>
<td>Douglas-fir</td>
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Results
## Results

**Other species regenerating at background levels**

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<td></td>
</tr>
<tr>
<td>Douglas-fir</td>
<td>--</td>
<td>--</td>
<td>1250</td>
<td>1625</td>
<td>+30%</td>
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<td></td>
<td>(0 – 16000)</td>
<td>(0 – 13250)</td>
<td></td>
</tr>
<tr>
<td>western larch</td>
<td>--</td>
<td>--</td>
<td>0</td>
<td>250</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0 – 1750)</td>
<td>(0 – 3500)</td>
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<tr>
<td>ponderosa pine</td>
<td>--</td>
<td>--</td>
<td>0</td>
<td>0</td>
<td>0%</td>
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<td></td>
<td></td>
<td>(0 – 1750)</td>
<td>(0 – 2000)</td>
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## Results

Cedar is regenerating, but not as vigorously as grand fir.

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<td>7375 (0 – 10100)</td>
<td>8125 (0 – 69250)</td>
<td>+10%</td>
</tr>
<tr>
<td>grand fir</td>
<td>--</td>
<td>--</td>
<td>2750 (0 – 20250)</td>
<td>17750 (0 – 205500)</td>
<td>+545%</td>
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<tr>
<td>Douglas-fir</td>
<td>--</td>
<td>--</td>
<td>1250 (0 – 16000)</td>
<td>1625 (0 – 13250)</td>
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<td>western larch</td>
<td>--</td>
<td>--</td>
<td>0</td>
<td>250 (0 – 3500)</td>
<td>NA</td>
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<td>ponderosa pine</td>
<td>--</td>
<td>--</td>
<td>0</td>
<td>0 (0 – 2000)</td>
<td>0%</td>
</tr>
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Results

Cedar is regenerating, but not as vigorously as grand fir
Key Points

1. Contemporary (2006) low-intensity fire resulted in substantial (>90%) cedar mortality, and future fire could result in the local extirpation of the species.
Key Points

1. Contemporary low-intensity fire resulted in substantial (>90%) cedar mortality, and future fire could result in the local extirpation of the species.

2. Cedar is regenerating in the grove, but species with more surviving seed sources, like grand fir, may eventually outcompete reestablishing cedar seedlings.
Management implications
Management implications

1. Consider frequent (~every 15 yrs) prescribed fire treatments to limit the likelihood of future, severe fire in the grove.
Management implications

1. Consider frequent (~every 15 yrs) prescribed fire treatments to limit the likelihood of future, severe fire in the grove.

2. Consider mechanical removal of grand fir to reduce competition with yellow-cedar.
Take-home points
Take-home points

1. Dry forests can regenerate following stand-replacement fire in the Blues, provided there is adequate seed source
Take-home points

1. Dry forests can regenerate following stand-replacement fire in the Blues, provided there is adequate seed source.

2. Despite high fire-induced mortality, yellow-cedar is regenerating, but the population might need our help to persist.
Acknowledgements

Krawchuk LCSRG Lab
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Sandra Haire

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Carol Miller
Jonathan Coop
Geneva Chong
Thanks!
Any questions?

Will Downing, James Johnston, Meg Krawchuk, Joseph Rausch
Seed source abundance

Low density (~50)

300 meters

- Focal cell
- Forest cell
- High-severity cell
Seed source abundance

High density (~600)
Seed source abundance can vary when distance to seed source is held constant
Seed source abundance can vary when distance to seed source is held constant
Seed source abundance can vary when distance to seed source is held constant.
Seed source abundance can vary when distance to seed source is held constant
Distance to and abundance of seed source are key drivers of post-fire seedling abundance.
Distance to and abundance of seed source are key drivers of post-fire seedling abundance.
Distance to and **abundance of seed source** are key drivers of post-fire seedling abundance.
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Distance to and **abundance of seed source** are key drivers of post-fire seedling abundance.
Estimated PIPO establishment dates
Estimated PIPO establishment dates

Hash Rock

Seedling count


Overtopped
N
Y
Estimated PIPO establishment dates

Regeneration takes time!

Hash Rock

Seeding count

0 5 10 15


Overtopped
N
Y

Hash Rock

747

Seeding count

0 5 10 15


Roberts Creek

Burnt Cabin

Seeding count

0 5 10 15

Fire refugia: A brief introduction

Unburned or low-severity burned patches of surviving forest within fire perimeters that did not experience stand-replacing fire effects
Fire refugia landscape pattern

1 meter aerial imagery
Fire refugia landscape pattern

1 meter aerial imagery

1 meter maps of fire refugia
Landscape fire refugia density
Landscape fire refugia density (FRD)

\[
FRD = \sum_{i=1}^{n} \frac{1}{(d + 1)}
\]
Landscape fire refugia density

Low refugia density (~50)

- Focal cell
- Refugium cell
- Non-refugium cell

300 meters
Landscape fire refugia density

High refugia density (~600)

300 meters

- Focal cell
- Refugium cell
- Non-refugium cell
Landscape fire refugia density

1 meter aerial imagery

1 meter maps of fire refugia

1 meter maps of fire refugia density
We did not find evidence that moisture deficit was a key limiting factor of post-fire regeneration.
We did not find evidence that moisture deficit was a key limiting factor of post-fire regeneration.
Both geographically and climatically disjunct

Species distribution data courtesy of Brian Buma
Results

Surface fire history
Results

Surface fire history

Alaska yellow cedar survives -
Results

Surface fire history

Alaska yellow cedar survives - and records - fire!
The cedar grove burned periodically for hundreds of years.
Results
Surface fire history

Cedar grove burned 2.5x less frequently than the surrounding landscape

MFRI = 36 years

MFRI = 14 years
Results
Surface fire history
Widespread fire years

1827

1846
Results

Surface fire history

Localized fire years

1656 1756
1680
1751
1871
1. Contemporary low-intensity fire resulted in substantial (>90%) cedar mortality, and future fire could result in the local extirpation of the species.

2. Cedar is regenerating in the grove, but species with more surviving seed sources, like grand fir, may eventually outcompete reestablishing cedar seedlings.

3. Fire disturbed the cedar grove periodically prior to European settlement. However, fire return intervals appear to have been substantially longer inside the grove.
Weird scars...
Results

Fire-climate relationships

Fire years historically associated with hotter and drier conditions
Results

Fire-climate relationships

Fire years historically associated with hotter and drier conditions

cedar + pine
Results

*Fire-climate relationships*

Fire years historically associated with hotter and drier conditions

```
  Mean departure
-1.0  -0.5   0.0   0.5   1.0
-6    -4     -2    0     2

Year since fire
```

pine
Results

*Fire-climate relationships*

Fire years historically associated with hotter and drier conditions