Interactions Between Fire and Plant Invasions Under a Warming Climate in the Sierra Nevada Bioregion

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Presentation Outline

- Conceptual framework for climate x fire x invasive plant interactions
- Variation among multiple invaders and over time
- Collective implications of a warming climate
- Ways to potentially get ahead of the curve
Temperatures and precipitation affect growing conditions (e.g. soil moisture levels), which in turn affect vegetation characteristics.

Fuels affect ignition rates and fire behavior and fire regimes.

Lightning affects ignition distributions.

Wind, temp, RH, and precipitation (i.e. fire weather) affect fire spread rates.

Fire behavior and fire regimes affect vegetation distributions.
A Fire Triangle For The Modern Era?

- climate
- non-native plants
- fire regimes
Invasive Plant / Fire Regime Cycle

- Nonnative Plants
- Native Plants

Fire Regime

Fuels

Brooks et al. 2004
The Invasive Plant / Fire Regime Cycle is Influence by Many Interacting Factors

- Climate
- Vegetation (native and non-native)
- Fire regimes
- Climate x vegetation
- Climate x fire regimes
- Vegetation x fire regimes
- Climate x vegetation x fire regimes
Climate

Data from thermometers (red) and from tree rings, corals, ice cores and historical records (blue).
Climate

Nitrogen deposition?
Vegetation Zones

- Alpine
- Subalpine
- Upper Montane
- Lower Montane
- Foothill
Patterns of Plant Invasions

- Statewide estimate ≈ 1050
  - ≈ 16%
- Sierra Nevada estimate
  - No comprehensive inventory
  - ≈ 250 - 300 species (≈ 24% - 29%)
- Most are herbaceous species (= fine fuels)
- Most concentrated in lower elevations (grasslands, oak woodlands) and areas of anthropogenic use

Sources:
Rejmanek and Randall (1994)
Randall et al. (1998)
Gerlach et al. 2001
Keeley et al. 2003
Klinger et al. 2006
Invasion Process

Four general phases

- Colonization
- Establishment
- Spread
- Equilibrium

Transformer species = species that significantly alter ecosystem structure/processes
<table>
<thead>
<tr>
<th>Vegtype</th>
<th>Seasonality</th>
<th>FRI</th>
<th>Area</th>
<th>Complexity</th>
<th>Intensity</th>
<th>Severity</th>
<th>Type</th>
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<td>Moderate</td>
<td>Low</td>
<td>Multiple</td>
</tr>
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<td>Dry</td>
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<td>Moderate</td>
<td>Multiple</td>
<td>Multiple</td>
<td>Multiple</td>
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</tr>
<tr>
<td>Jeffrey Pine</td>
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<td>Moderate</td>
<td>Small</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Surface</td>
</tr>
<tr>
<td>Lodge Pine</td>
<td>Dry</td>
<td>Long</td>
<td>Small</td>
<td>Low</td>
<td>Multiple</td>
<td>Multiple</td>
<td>Multiple</td>
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<td>Small</td>
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<td>High</td>
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<td>Surface</td>
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<td>Small</td>
<td>Low</td>
<td>Low</td>
<td>Multiple</td>
<td>Surface</td>
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</table>
Climate x Vegetation

Predictions of vegetation shifts with a warming climate

Shrublands and woodlands moving upslope replacing forests

Forests moving above current treeline

Grasses Valley Grassland

Foothill Woodland

Lower Montane Forest

Upper Montane Forest

Subalpine Forest

Alpine Meadow

Great Basin Woodland

Grasses

Live oak

Foothill pine

Chaparral

Blue oak

Giant sequoia

White fir

Sugar pine

Incense-cedar

Ponderosa pine

Whitebark pine

Mountain hemlock

Jeffrey pine

Lodgepole pine

Western white pine

Red fir

Predictions of vegetation shifts with a warming climate.
Climate x Vegetation

- Alpine
- Subalpine
- Upper Montane
- Lower Montane
- Foothill
Climate x Invasive Plants: the Contemporary Version

Four general phases

- Colonization
- Establishment
- Spread
- Equilibrium

Climate

Distribution and/or Abundance

Time
Climate x Invasive Plants: the Warmer Version

Four general phases

- Colonization
- Establishment
- Spread
- Equilibrium

Distribution and/or Abundance vs. Time

Climate

• Longer growing season and milder conditions at higher elevations could:
  - Open niches
  - Increase the species pool
  - Increase chances of establishment of transformer species
Invasion x Elevation Relationship

- Climate has acted as a filter to invasions
- Decreased diversity and abundance of invasive plants with increased elevation
- Climate change could “lower the mountaintop” and improve conditions for invasions at higher elevations

\[ Y = \exp(3.191 + 0.666 \times \text{elevation} - 0.034 \times \text{elevation}^2) \]

\[ r = 0.972 \]

- Mooney et al. 1986
- Schwartz et al. 1996
- Keeley et al. 2003
- D’Antonio et al. 2004
- Klinger et al. 2006
Climate x Fire Regimes

- Temperature
- Precipitation
- RH
- Wind
- Lightning

Warming climate =
- Upslope shift in vegetation
- Drier fuels
- Longer fire season

...increased probability of ignition?
Climate x Vegetation x Fire

- Climate
- Topography
- Fire Regime
- Fuels
- Native Plants

variable factors

the one stable factor
Currently, environmental gradients have more influence than fire on presence of non-natives

Klinger et al. 2006

... but this may change as a warming climate reduces environmental limitations, especially at lower elevations
Post-fire succession itself can also suppress non-natives (Klinger et al. 2006)

...but this pattern can be affected by initial burn severity, with higher severity associated with longer dominance of non-natives postfire (Keeley et al. 2003)
Insights From The 2005 Mojave Fires

- Three species comprise >90% total herbaceous biomass
- Individualistic species responses
- Overlapping but shifting abundance peaks along environmental gradients
- Individual and cumulative effects along gradients
Relationship of Non-natives with Precipitation

- *Erodium cicutarium* peaks at drier end of precipitation gradient
- *Bromus rubens* peaks at intermediate part of precipitation gradient
- *Bromus tectorum* has monotonic increase along precipitation gradient

Transformer species exploiting a broad range of precipitation

**Distribution with rainfall In the Mojave Desert**

<table>
<thead>
<tr>
<th>Precipitation (Residuals)</th>
<th>Density</th>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
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<tr>
<td>10</td>
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<td>40</td>
<td>40</td>
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<tr>
<td>50</td>
<td>50</td>
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</table>
Relative Dominance Varies Over Time Postfire

Shifting patterns of dominance among postfire years is driven by rainfall in the Mojave Desert.
Non-natives May Themselves Alter Succession

Strong negative relationship between native diversity and density of non-natives

Strong negative relationship between native woody seedling density and density of non-natives
Effects of Repeated Spring Fires in the Sierra Nevada

% of biomass

Native forbs
Non-native forbs
Non-native grasses

redrawn from Parsons and Stohlgren 1989
Effects of Repeated Fall Fires in the Sierra Nevada

% of biomass

Native forbs
Non-native forbs
Non-native grasses

fall fire fall fire fall fire

redrawn from Parsons and Stohlgren 1989
## Relative Biomass of Herbaceous Species

<table>
<thead>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><em>Erodium botrys</em></td>
<td>0</td>
<td>16</td>
<td>0</td>
<td><em>Centauria melitensis</em></td>
<td>0</td>
<td>46</td>
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<tr>
<td><em>Trifolium microcephalum</em></td>
<td>1</td>
<td>11</td>
<td>0.1</td>
<td><em>Lotus subpinnatus</em></td>
<td>0</td>
<td>11</td>
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<td><em>Siline gallica</em></td>
<td>0</td>
<td>8</td>
<td>0.1</td>
<td><em>Siline gallica</em></td>
<td>0</td>
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<tr>
<td><em>Lotus subpinnatus</em></td>
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<td>7</td>
<td>0</td>
<td><em>Hypochoeris glabra</em></td>
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<tr>
<td><em>Festuca megalura</em></td>
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<td>0</td>
<td><em>Orthocarpus attenuatus</em></td>
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<td><em>Centauria melitensis</em></td>
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<tr>
<td><em>Avena fatua</em></td>
<td>77</td>
<td>12</td>
<td>39</td>
<td><em>Avena fatua</em></td>
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<td><em>Bromus diandrus</em></td>
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<td>1</td>
<td>12</td>
<td><em>Bromus diandrus</em></td>
<td>11</td>
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* Native species (all others are non-native species)

* redrawn from Parsons and Stohlgren 1989
## Relative Biomass of Herbaceous Species

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<td>4</td>
<td>0</td>
<td>0</td>
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<td>0</td>
</tr>
</tbody>
</table>

*Native species (all others are non-native species)

**Table Notes:**
- **spring burn increasers:**
  - *Erodium botrys* increased from 0 to 16 due to year.
  - *Trifolium microcephalum* increased from 1 to 11 due to year.
  - *Siline gallica* increased from 0 to 8 due to year.
  - *Lotus subpinnatus* increased from 0 to 7 due to year.
  - *Festuca megalura* increased from 0.1 to 6 due to year.

- **fall burn increasers:**
  - *Siline gallica* increased from 0 to 8 due to year.
  - *Hypochoeris glabra* increased from 0 to 5 due to year.
  - *Orthocarpus attenuatus* increased from 0 to 4 due to year.

**Additional Observations:**
- **A. fatua** decreased by 49% due to year.
- **Bromus diandrus** decreased by 84% due to burning.
- **A. fatua** decreased by 57% due to year.
- **Bromus diandrus** decreased by 94% due to burning.

Redrawn from Parsons and Stohlgren 1989.
General Patterns In Western Ecosystems

- Fire size has increased in Mojave and Great Basin shrublands
  - Linked to climate and invasive species
- Fire size and severity has increased in western forests
  - Linked to climate and historical factors, *not* invasive species (so far)
- Increase severity, coupled with decreased environmental impediments to invasion, may increase the effects of non-natives on forest fire regimes
Which Species May Emerge at the New Transformer Species?

- *Bromus tectorum*?
- *Bromus madritensis rubens*?
- *Cirsium vulgare*?
- *Arundo donax*?
- *Genista monspessulana*?
- *Cytisus scoparius*?
- *Tamarix spp*?
- *Ailanthus altissima*?
- *Pinus pinea*?
Where are New Species Coming From?

• We look most frequently for invaders from the west of the Sierra Nevada

• Species associated with agricultural and urban areas

• Forest cover can impede upward spread of species on the western slope, but this impediment may be moving upslope
But Many of the Barbarians are at the Eastern Gates

…and a few are already in the castle

- Mojave and Great Basin species
- Forest cover which impedes upward spread on the west slope is relatively low on the east slope
- Elevation gradient is also very steep on the east side, and upslope dispersal distances are much shorter than on the west side
What Does this all Mean for Land Management in the Sierra Nevada?

• Past experiences may be increasingly insufficient to predict future effects of land management actions (e.g. Rx fire, weed control, native spp. revegetation)

• Thus, well-intended management action may trigger unexpected and potentially undesirable outcomes?

• Example: The bighorn burns project (east side)

• Question: Will an unintended outcome of burning winter range for sheep be increased abundance of cheatgrass as the climate warms?
Getting Ahead of the Curve

Integration of prioritization and prediction

• What species will likely become invasive?
• What sites will likely be heavily invaded?

Brooks and Klinger in press

Underwood et al. 2004
Summary

Expect increase in colonizing species from both the west and east.

Expect upward elevational spread of non-native species.

Fire frequency will likely increase in upper elevations.

Combination of prioritization and species distribution models may provide some management options.