Changing forest conditions behind the redwood curtain?

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Redwood Field Station, 1655 Heindon Road, Arcata, CA 95521.
A dead-tree census by the U.S. Forest Service found that 22 million trees have died during California's four-year drought, and tens of millions more are expected to follow.
Annual Average Precipitation and Temperature for California

Precipitation & Minimum Temperature
Annual State Average

Historic 5 Year Averages
- Precipitation
- Minimum Temperature

Precipitation (mm)

Minimum Temperature (deg. C)

Year


6.0 6.5 7.0 7.5 8.0 8.5

Courtesy Jim Thorne UCD
The two components of drought are water supply and demand.

A leaky bucket analogy:
The two components of drought are water supply and demand.

A leaky bucket analogy:

Average supply (precip.)

Average demand (evap.)

Soil water

Credit: N. Stephenson
The two components of drought are water **supply** and **demand**.

A leaky bucket analogy:
The two components of drought are water supply and demand. A leaky bucket analogy:

- **Average conditions**: Average supply (precip.) to soil water, average demand (evap.)
- **“Normal” drought**: Reduced supply (precip.) to soil water, average demand (evap.)
- **Hotter drought**: Reduced supply (precip.) to soil water, enhanced demand (evap.)

Credit: N. Stephenson
If all we had was a rain gauge, we’d think the current drought was comparable to the 1924 drought.

Credit: N. Stephenson

But temperature-induced increases in evaporative demand have pushed the drought to historical extremes ... through 2014 only

Credit: N. Stephenson

Hydrologic changes in the West

More precipitation falling as rain vs. snow

Snowpack has been decreasing

Spring streamflow has been arriving earlier


Mote et al. 2005

Stewart et al. 2004, Clim. Change
What does this mean for our forests?
• Tree mortality and forest die-back
• Changing fire regimes

What does this mean for redwood forests?
• Climate change along the North Coast
• Forest responses?

What, if anything, can be done?
• Adaptation for resistance and resilience
Why tree mortality?

Tree populations are highly sensitive to changes in mortality rate.
A growing body of evidence suggests that environment (particularly climate) affects forest demographic rates.

Large-scale die-off

Background mortality
Southern Sierra Nevada die-back event of 2016

USFS Region 5 Aerial Detection Survey
Areas with mortality: 4.3 million acres
Estimated number of trees killed: 62 million (102 million since 2010)

Approximately 10.6 million ha of forest containing up to 888 million large trees experienced measurable loss in canopy water content...
Increasing incidence of forest die-back as an emerging global phenomenon

Locations of substantial drought- and heat-induced tree mortality around the globe since 1970 (Allen et al. 2015 *Ecosphere*)
A growing body of evidence suggests that environment (particularly climate) affects forest demographic rates.

**Large-scale die-off**

**Background mortality**

1. subtle, slow, neglected
2. ... but important!
Tree mortality rates are increasing in the western US

- 76 plots in undisturbed old forests
- observed from ~1981 to ~2004
- 87% of plots increasing mort. rate $P < 0.0001$
- mort. rate $\sim 18$ yr DOUBLING period
- temporal trend, $P < 0.0001$

Symbol size = magnitude of change
Red = increasing mortality
Blue = decreasing mortality

van Mantgem et al. 2009, Science
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Changing climate = changing fire regime
Changing climate = changing fire regime

High severity fire is increasing in low elevation forests in the Sierra Nevada of California

Mallek et al. 2013 *Ecosphere*
Miller et al. 2009, *Ecosystems*
(but see Miller et al. 2012, *Ecol. Appl.*)
Interactions of stressors

--- Have to sneeze

--- Have to pee

Disaster

from Martin 2012, *This is a Book*
Climatic stress increases forest fire severity across the western United States

- Data from NPS and USFS
- 18 sites
- >250 plots
- >7000 trees
- dominated by *P. ponderosa* and *A. concolor*

(also *Pseudotsuga menziesii*, *Calocedrus decurrens* and *P. lambertiana*)

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What does the future hold?
Temperature trends at RNSP

Wang et al., in prep
What does the future hold? Precipitation trends at RNSP

Wang et al., in prep
 Changing coastal fog?

33% reduction in (*high altitude*) fog frequency since the early 20th century

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Redwood growth increasing?

- Redwood radial growth increased with decreasing summer cloudiness (i.e., airport fog).
- Significant ($P<0.01$) at three locations in northern California.
The Klamath Inventory and Monitoring Network
The KLMN forest plots

Climatic velocity: modeled changes in actual evapotranspiration (AET) and climatic water deficit (CWD)

A2 scenario (higher emissions)

B2 scenario (lower emissions)

ENERGY RELEASE COMPONENT (ERC) CHART
FUEL MODEL G SHORT NEEDLE (HEAVY DEAD)

MEAN ANNUAL MAX MONTHLY TEMPERATURE (°F)

NORTH COAST PSA

OBSERVED HISTORICAL 1972-2006

HADLEY A2 MID CENTURY 2007-2041

HADLEY A2 LATE CENTURY 2042-2076

Courtesy of J. LENIHAN
MID-CENTURY  LATE-CENTURY

2007-2041 HADLEY A2

MEAN MAX DAILY ERC-G

RAWS MEAN MAX ERC = 59

2042-2076 HADLEY A2

MEAN MAX DAILY ERC-G

RAWS MEAN MAX ERC = 67

Courtesy of J. LENIHAN
NORTHERN COASTAL CALIFORNIA: ON THE BRINK OF A PHASE CHANGE IN FIRE BEHAVIOR?

Courtesy of J. LENIHAN
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Past forest conditions no longer *automatically* provide us with management targets!

AND

The future is highly uncertain

Dettinger 2005
Current NPS natural resources policy:
-- When possible, restore and maintain naturally-functioning ecosystems.
-- When this is not possible, “maintain the closest approximation of the natural condition.”
What, if anything, can be done?

**Adaptation strategies**

**Resistance**: ability to remain essentially unchanged following disturbance

**Resilience**: ability to recover quickly from disturbance
Adaptation: Can forest management increase resistance/resilience to drought?

Millar and Stephenson, 2015 Science
Can prescribed fire increase forest resistance to drought?

- Long-term forest plot data
- Surveys in 2014

- Ponderosa pine – mixed conifer forests (mostly *A. concolor*)
- 28 plots (28 burned, 13 unburned)
- $\geq$ 6 years post-fire
- >5000 trees

van Mantgem *et al.* in review.
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Findings


What is the impact of continued drought in 2015?

Can we explicitly identify the mechanisms of tree mortality??

i.e., roles of competition, pathogens, insects?

Other species, other regions???

www.werc.usgs.gov/DroughtForestFire

van Mantgem et al. in review.
Adaptation: Can forest management increase resistance/resilience to drought?
Prescribed fire as a thinning tool in coastal redwood forests -- Lower Airstrip Expansion site
Barriers to implementation
Prescribed fire funding, air quality, burning windows, site accessibility

Prescribed fire may not be sufficiently severe  *(Higgins IJWF 2015)*

Hotter droughts may produce stresses that exceed potential management responses

www.werc.usgs.gov/DroughtForestFire
Thanks!

Countless field crews, and data managers…
Laura Lalemand & Jon Hollis

National Park Service, USGS, Joint Fire
Sciences Program