Land management explains major trends in forest structure and composition over the last millennium in California’s Klamath Mountains

Clarke A. Knight · October 22, 2022
Klamath-Siskiyou bioregion, Six Rivers Nat’l Forest
Fire regimes in the north: High frequency, Low severity

Fire regimes in the south: Low frequency, High severity

https://www.fs.fed.us/database/feis/fire_regimes/CA_montane_mixed_conifer/all.html
Traditional Ecological Knowledge and millennia of forest stewardship

Indigenous influence on the landscape:
- Cultural burning practices
- Land stewardship
- Ongoing practices to this day

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California forests – vast, valuable, threatened
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Fires in California in August 2020

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• Began after the Forest Reserve system was established in 1905
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• Public communication – Smokey the Bear in 1944
Pre-suppression forests

Open, park-like conditions
Pre-suppression forest

Open, park-like conditions

Low severity fire

The Nature Conservancy: https://www.nature.org/
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Healthy forest

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Consequences of fire suppression

Overstocked

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High severity fire

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Consequences of fire suppression

Overstocked
High severity fire
High mortality

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The State uses forests to store carbon and combat climate change

Motivation: obtain and evaluate long-term datasets about forest biomass and fire to improve the evidence base for management decisions
Reconstruct forest density and fire history from
- Pollen from lake sediments
- Charcoal from lake sediments
- Fire scars from tree stumps
- Traditional Ecological Knowledge from Karuk-Yurok Tribes
- Reconstructed biomass record
Paleoecology basics

- Pollen analysis
- Fire history via charcoal and fire scars
- Philosophy about Native engagement
Pollen – “time machine” for understanding the ecology of the past

Photo: Ami Images
Obtaining lake sediment cores

PC: Summer Praetorius, David Wahl
Split cores are used to obtain:
-- pollen
-- charcoal
-- macro fossils

Sediments must be dated to create an age model (e.g., $^{14}\text{C}$, $^{210}\text{Pb}$)
A. Fish Lake
(-123.68, 41.26)
Elevation: 541 m

B. Lake Ogaromtoc
(-123.54, 41.49)
Elevation: 600 m

Legend
- Lake sites
- Forest roads
- Streams
- Fire scar sites
The pollen record

Pine pollen

Douglas-fir pollen

Tanoak pollen
3000-year high in shade tolerant taxa – fire suppression?

With data from *Crawford et al. 2015*
Charcoal

- Incompletely combusted organic matter
- Found in lake sediment cores
- Sedimentary charcoal record provides insight into past fire events

Whitlock & Larsen 2001
Qualitative interpretation using charcoal accumulation rates (# cm$^{-2}$ yr$^{-1}$)

Fish Lake

- **CHAR**

- **z-scores**

- **cal. yr. BP**

- **Medieval Climate Warming**
- **Little Ice Age**

- **increase**
- **decrease**
Insights from visual inspection: increasing charcoal accumulation during the Little Ice Age
Climatic expectations

Climatically-driven vegetation change

- Hot/dry
- More fire
- Forest opening

shade intolerant taxa

Icons from the Noun Project
Climatic expectations

Climatically-driven vegetation change

Hot/dry -> More fire

Cool/wet -> Less fire

Forest opening: shade intolerant taxa

Forest closure: shade tolerant taxa

Icons from the Noun Project
We detect anthropogenic impact

Human-caused vegetation change

Cool/wet  More fire  Forest opening

Little Ice Age (600-100 years BP, or 1300s-1850 AD)

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Significant positive correlation between charcoal accumulation and vegetation openness during a climatically cooler period of the Little Ice Age – this goes against climatic expectations!
What are fire scars?

- Fires burning at low intensity injure the bark cells of a tree
- These fires wounded trees but did not kill them
- Fire wounds can be dated
- Thus, past fire events can be determined
Fire scar record shows frequent fire between 1700 – 1900 AD

Median fire return intervals

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<thead>
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<th>Location</th>
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- 80-90% of scars in the latewood or dormant wood
- Scars under-estimate past fire because not all fires cause scars
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- Lightning fire = June/July
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Paleoecology and Native stewardship

- My view: talk to and learn from the people who have lived in the area for millennia! They are implicated in the research…
- Understand the role they had in influencing past ecosystems
- What was their stewardship like?
- What is the relationship between human ignitions and natural processes? How does that affect the detectability of Native actions in the paleorecord?
- Interpretations matter: scientific soundness, and implications for contemporary management

Practicing Pikyav (“fix it”)

• Karuk tribal policy for collaborative research
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• Enriches research design and data interpretation

https://sipnuuk.karuk.us/about
What is the extent to which climate and/or human activity have influenced major trends in reconstructed forest biomass over the past 3000 years?
Indigenous stewardship

- Native stewardship since terminal Pleistocene
- Sophisticated application of fire technology on the landscape by Karuk and Yurok
- Ongoing management activities and prescribed fire
Native history suggests substantial contribution to the fire regime

Historically:
• Both lake sites were gathering places for acorns/mushrooms
• Lower fuel levels and open forest were critical to crop cultivation (Lake 2007, Tushingham and Bettinger 2013)
• Supported a population of about 2-3,000 people before Euro-American colonization (Chartkoff and Chartkoff 1975)

Contemporary:
• Tribal members have long recognized that their traditional lands are currently over-enriched in biomass
• The Karuk compare the current forest conditions to an “ecological-cultural desert” (Sowerwine et al. 2019)
• “We never had this much fuel on the ground,” Karuk elder said (Lake 2007)
Evolution of Indigenous burning in the Klamath

- Over 70 uses of fire on the landscape (Kimmerer and Lake 2001)
- Pyrodiversity supported a mosaic of vegetation
- Cultural use of fire developed, evolved, diversified over time
- Tuluwat Pattern (1500 BP onwards)
  - More intense land usage
  - Migration into Northwest and population growth
  - More burning
Lake Ogaromtoc: Three millennia of Indigenous stewardship

Predicted aboveground live biomass (Mg/ha) vs cal yr BP
Predicted aboveground live biomass (Mg/ha)

Median tree biomass until colonization was 104 Mg/ha (SE 33.5)
Lake Ogaromtoc: Two centuries of contemporary stewardship

Predicted aboveground live biomass (Mg/ha)

Modeled age AD

1950
1850
1750
1650
2000

Fire suppression begins
Creation of National Forest (timber harvest begins)
Gold Rush Invasion
Timber harvests restricted

0
100
200
300
Predicted aboveground live biomass (Mg/ha)

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Modeled age AD

Biomass calculated from the public land surveys was 100 Mg/ha SE 7.1
Main findings

Karuk-Yurok ethnographic data about these watersheds and the fire scar histories are suggestive that Indigenous stewardship contributed substantially to the fire regime.

Biomass record strongly suggests frequent fire limited biomass relative to the potential productivity of the sites.

Consistent biomass predictions across multiple, independent lines of evidence.
Main findings

- Karuk-Yurok ethnographic data about these watersheds and the fire scar histories are suggestive that Indigenous stewardship contributed substantially to the fire regime.
- Biomass record strongly suggests frequent fire limited biomass relative to the potential productivity of the sites.
- Consistent biomass predictions across multiple, independent lines of evidence.

Thus,

- Integrating paleo and ethnographic records can be a powerful way of understanding the ecology of the past.
- Contemporary forest biomass is unprecedented.
- Indigenous forest and fire management was critical to maintaining forest conditions before colonization.
Returning to historical conditions via restoration of cultural practices

- Larger scale intervention needed to achieve historical fidelity
- Temper expectations about carbon storage
- Engagement with Tribes
- Restore Native burning practices
Thank you for listening!
Linking pollen to tree biomass

Modern pollen influx (grains cm\(^{-2}\) yr\(^{-1}\))

Modern tree biomass (Mg ha\(^{-1}\))

Linear relationship

PC: Diana Carriker

Key point: Count pollen and use ancient pollen influx values to calculate ancient biomass

Knight et al. 2021, 2022
Biomass from 7 lakes

Sediment cores

Pollen counts
Top of core = modern data

Bottom of core = ancient data
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Pollen influx (grains/cm² yr) is linearly related to distance-weighted biomass

Bottom of core = ancient data

Pollen grains from today

Forest biomass of today
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Pollen grains from today

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Skinner et al. 2006

PC: Rebecca M. Quiñones
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Dynamic correlation coefficient

-0.48
-0.57
-0.58
0.47
0.47
0.53
0.60
0.47
0.51
0.67

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