Assessment of Tree Mortality & Short-Term Impacts to Forest Structure & Composition in the Central & Southern Sierra Nevada

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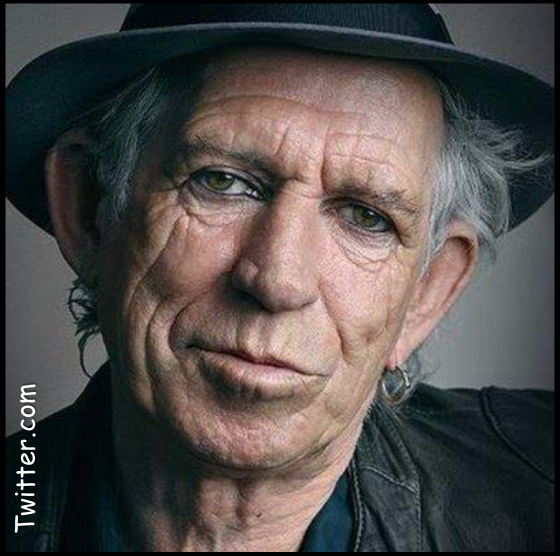
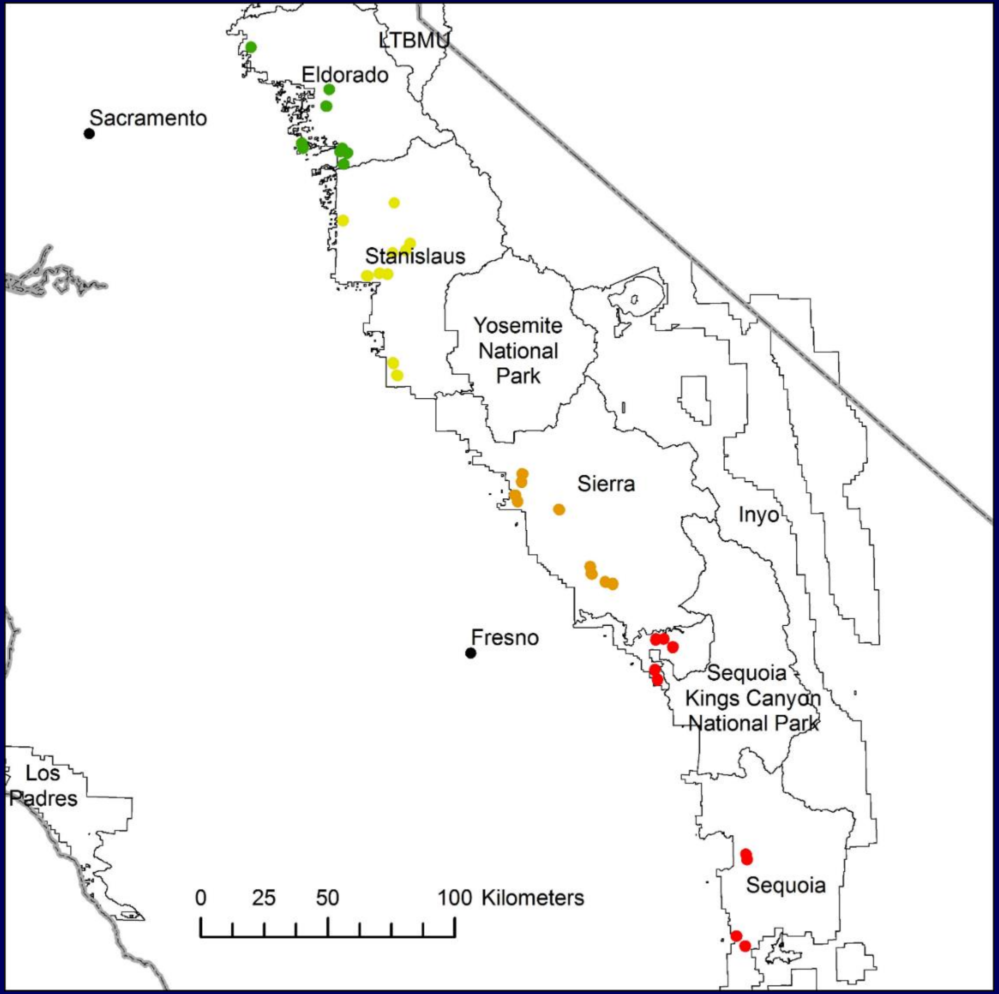
Tree mortality = OLD news, still a BIG deal!!!




...and changes are already occurring
rapidly in these forests in many locations

Network of 180 11.3-m fixed radius plots, stratified by elevation, in forests containing ≥35% ponderosa pine (by basal area) with ≥10% tree mortality in 2014; Sequoia, Sierra, Stanislaus and Eldorado National Forests.



Robust assessment of broad geographical area of:

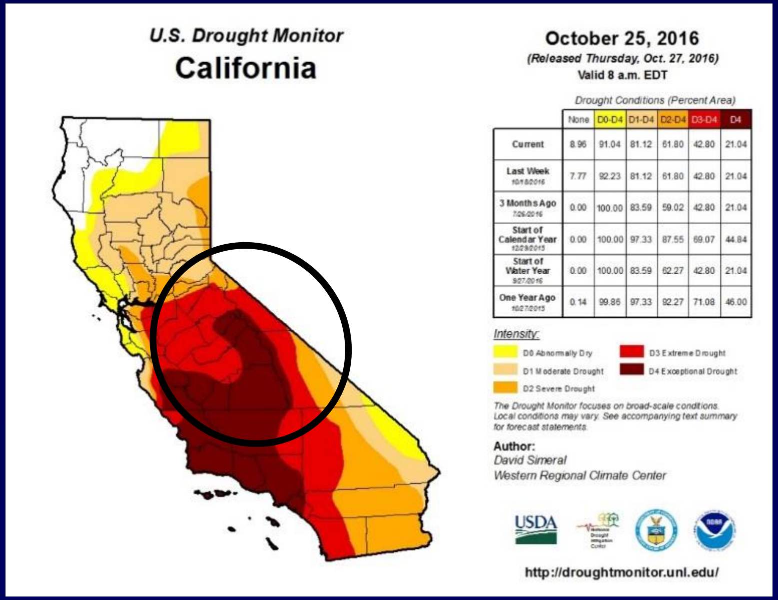
Causes, extent, severity & impact – what has happened already

Establishing baseline data – as to capture what's currently on the landscape and to capture change over time

Variables assessed

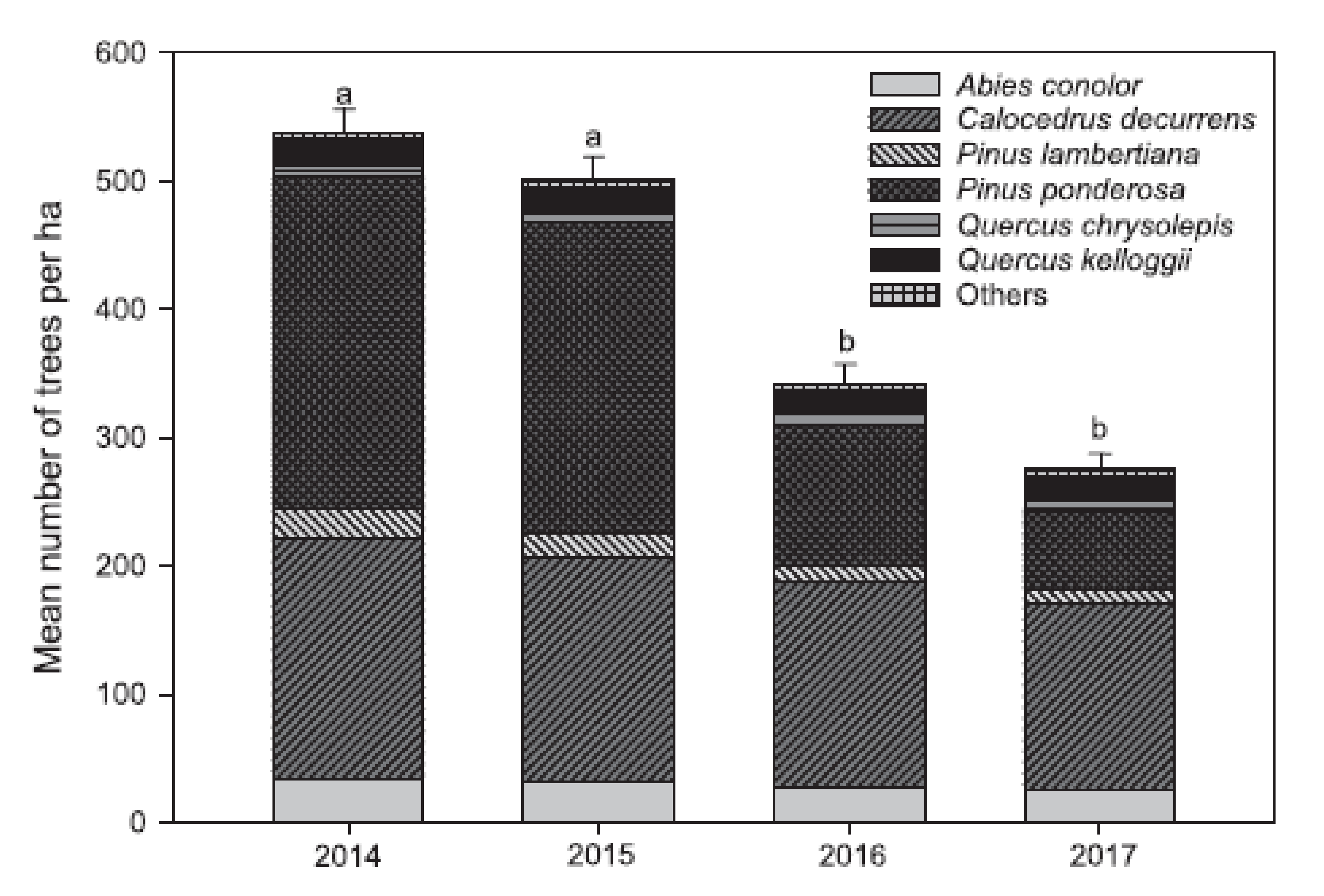
- Tree mortality rates and causes
- Resulting changes in stand structure and composition
- Regeneration/recruitment
- Understory vegetation and invasive weeds (baseline)
- Early look at snag fall rates and demography
- Forest pollinator community
- Surface and canopy fuels
- Collaborating with Mike Koontz (UCD) on using drones to assess structure and attributes of 40-ha areas around each of our sites

California's recent drought



- The state of California ended five years of consecutive drought in 2017.
- Water Year 2015 (ended 30 September 2015) was the hottest and driest on record. 2014 was the third driest and second warmest.
- Cause—a persistent ridge of high pressure over the northern Pacific that blocked winter storms from reaching California.
- Data from tree ring reconstructions suggest this was the most significant drought event in a 1,200-year chronology.

Major forest change!



48.9% of all trees died between 2014 and 2017

Consequences?

Significant modification of stand structure and composition, which may impact…timber and fiber production, fuel conditions, water quality and quantity, fish and wildlife populations, recreation, invasive species abundance, grazing capacity, real estate values, pollinator abundance, biodiversity, carbon storage, endangered species and cultural resources.

C. Fettig, USDA Forest Service

Mortality by National Forest/latitude

- Tree mortality ranged from 46.1 ± 3.3% on the Eldorado National Forest (NF) to 58.7 ± 3.7% on the Sierra NF, but differences between NFs were not statistically significant.

- Most mortality on the Eldorado NF (northern-most) occurred in 2016, while most mortality on the Sierra & Sequoia NFs (most southerly) occurred in 2015. Stanislaus NF mortality occurred in both 2015 & 2016

- Lag between first years of drought & severe tree mortality

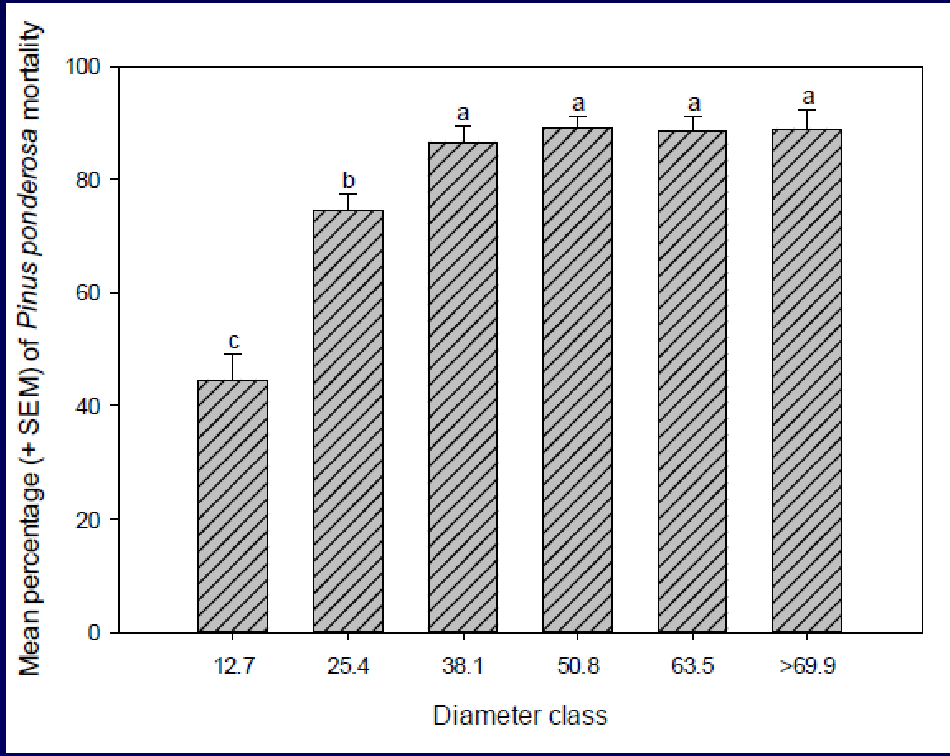
Mortality by elevation band

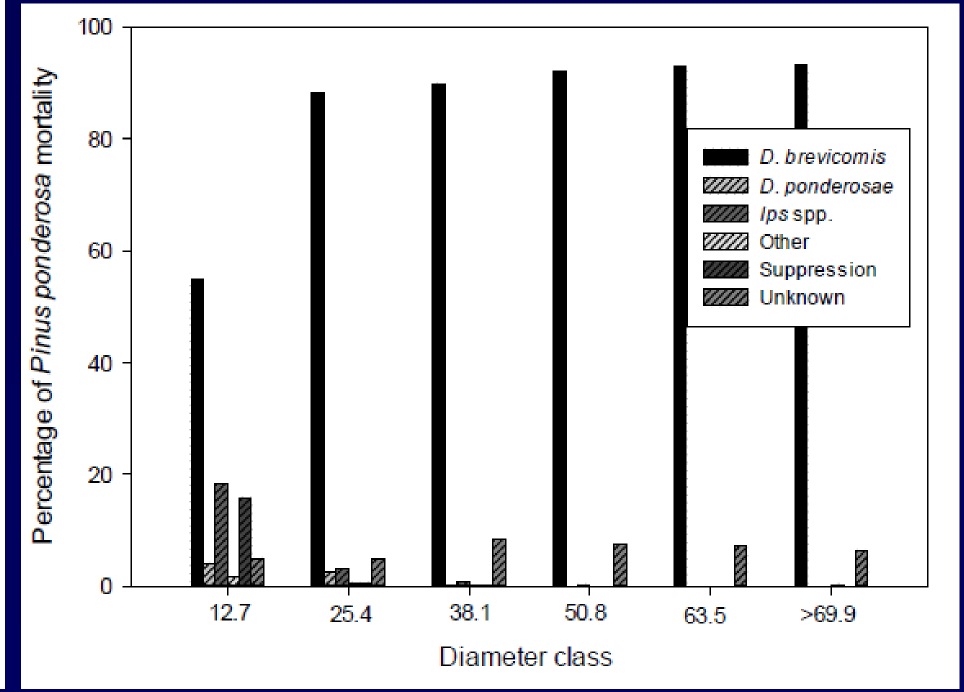
low: 60.4% ± 3.0%
mid: 54.4% ± 2.5%
high:46.1% ± 2.9%

*Difference between low & high are statistically significant, other differences between bands are not statistically significant.

(low = 914–1219, mid = 1219–1524 and high = 1524–1829m on the Eldorado, Stanislaus, Sierra; low = 1219–1524, mid = 1524–1829, and high= 1829–2134m on the Sequoia-tree species of interest occur higher in elev. due to lower latitude)

Ponderosa pine during the mortality event



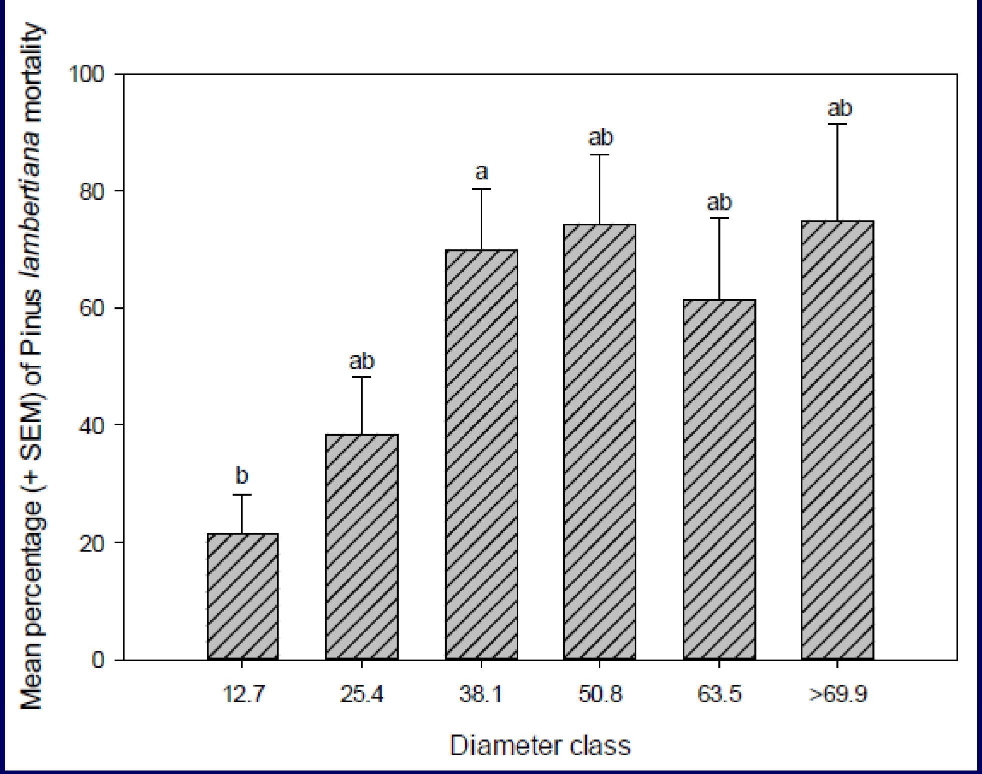


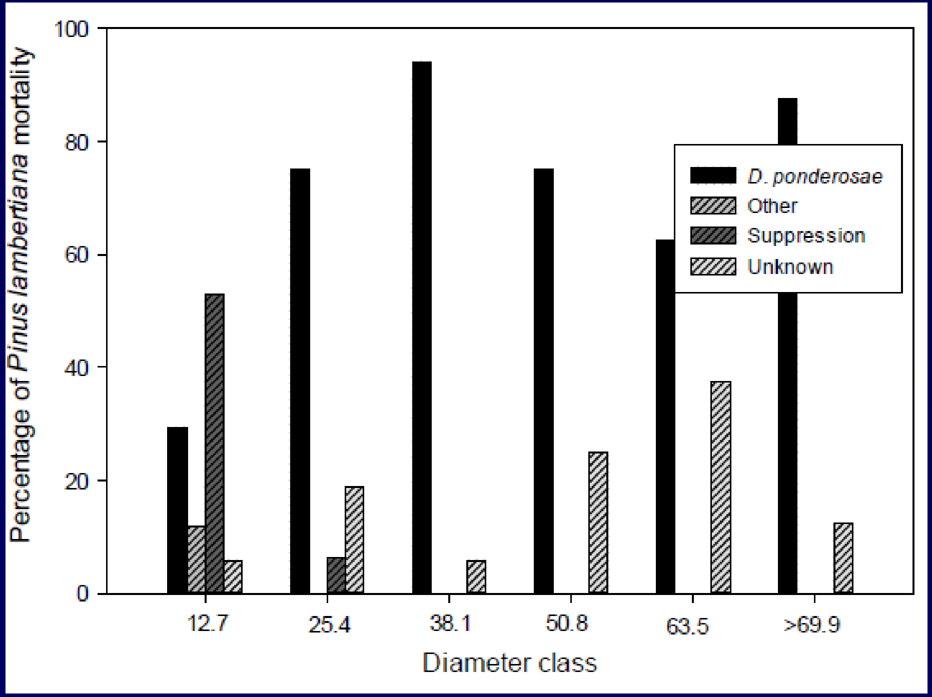
89.6% mortality & 39.4% of plots lost all *P. Ponderosa*

(*Dendroctonus brevicomis* = western pine beetle)

In (visual) Summary: ~90% of ponderosa trees like these are dead

Sugar pine during the mortality event

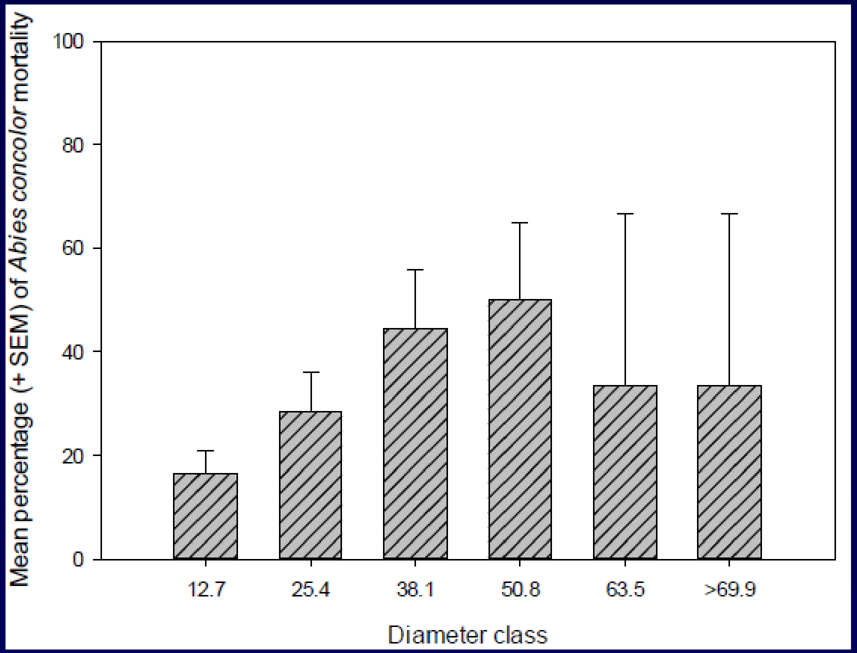


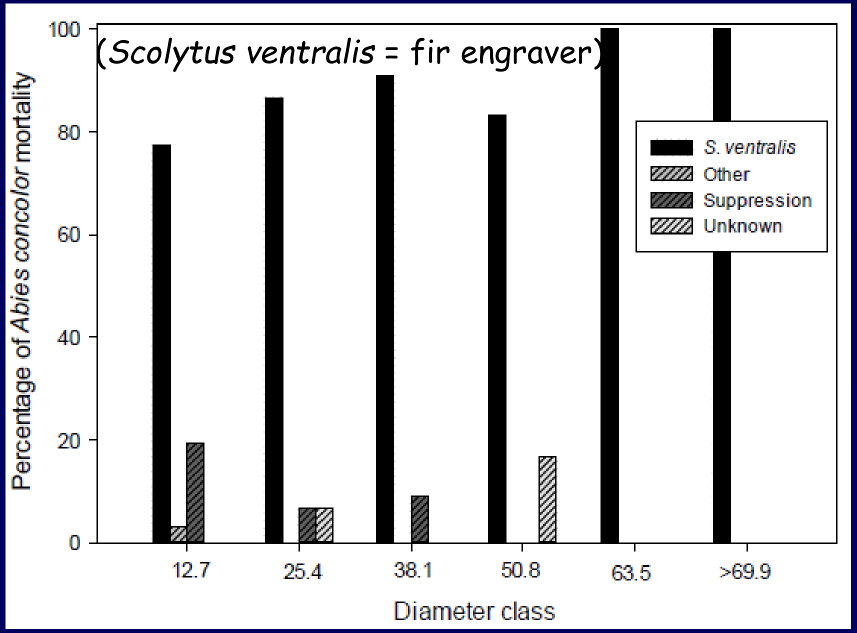


48.1% mortality

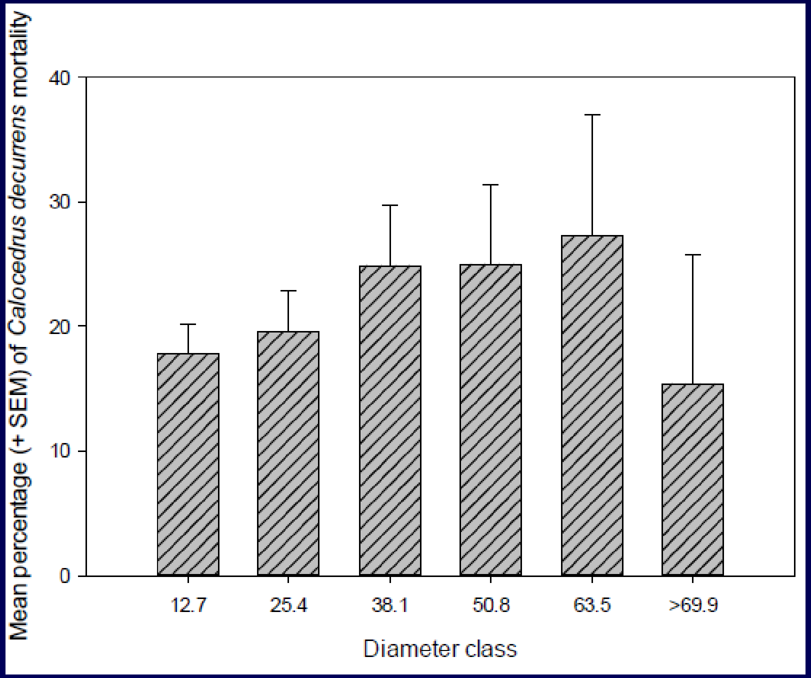
(*Dendroctonus ponderosae* = mountain pine beetle)

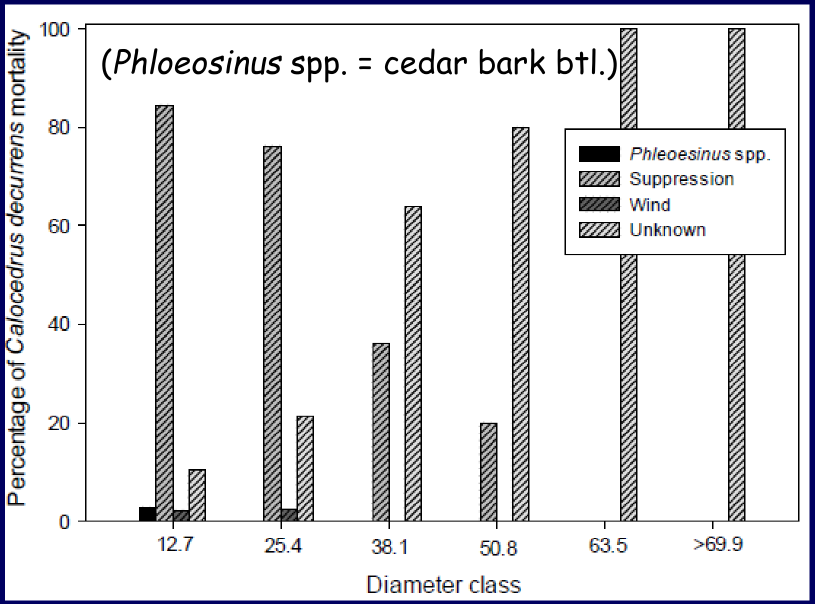
white fir





incense cedar





Tree mortality and stand density

Number of trees died positively correlated with density

However, SDI didn't explain variation well, suggesting that local resource competition is less important during severe drought

SDI = Stand density index, a measure of the stocking of a stand of trees based on the number of trees per unit area and diameter at breast height (DBH) of the tree of average basal area, also known as the quadratic mean diameter.

…tree mortality and stand density

Historic mixed-conifer stands in early 20th century shown by Collins et al. (2011) to contain 25-79 trees per hectare, Stafford & Stevens (2017), 159 trees per hectare.

We found pre-mortality event conditions to be heavily departed from these historic conditions (e.g., mean numbers of live trees ranged from **520.0** ± 38.8 per ha on the Sequoia NF to **556.8** ± 46.8 per ha on the Sierra NF)

Oliver (1995) described the optimal stocking level in even-aged NorCal Ponderosa to be 11m ^{2}. In our study, only one plot had ≤11m ^{2} per ha of basal area in 2014.

Typically this increase in density is attributed to suppression of wildfires in the modern era.

Bark beetles, stand density & mortality

Oliver (1995) reported maximum SDI (365) for even-aged P. ponderosa stands in northern California was regulated by bark beetles. A SDI value of 230 defined a threshold for a zone of imminent bark beetle-caused tree mortality within which endemic populations killed a few trees, but net stand growth was positive.

Only 27 plots in our study had SDI values ≤230 and only half (91 plots) had SDI values ≤365 in 2014. Based on these thresholds, the majority of our plots would have been classified as "susceptible" to mortality by bark beetles, and those that were not existed as small islands in a larger landscape mostly classified as "susceptible", which likely increased their susceptibility due to contagion (Miller and Keen, 1960).

The combination of the 2014 SDI we found and the severe drought California experienced makes the mortality experienced not surprising and almost "expected".

So what's out on the landscape?

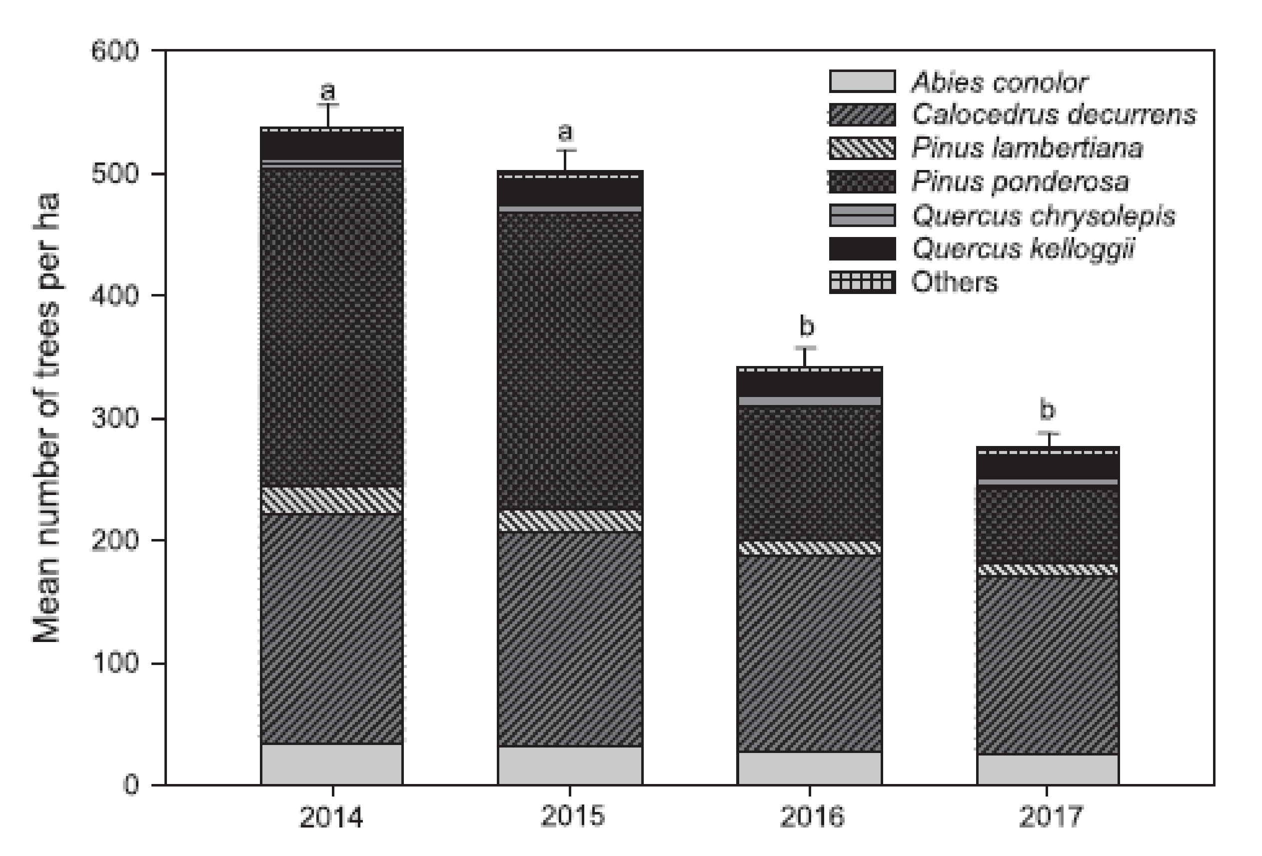
Sticking with bark beetles & stand density

In 2017, 84 plots had ≤11m²/ha of basal area, and 175 plots had SDI values ≤365. Based on these data, most plots would now be classified as of "low susceptibility" to bark beetles.

Now SDIs are better, but wrong composition and structure.

Loss of large trees, in particular *Pinus* spp.

Trees that died are not the ones that wildfire would have killed/removed.



What might be coming next (recruitment)?

Mean plot seedling (height ≤ 0.3 m) and sapling (height > 0.3 and DBH <6.35 cm) abundance.

Species	Seedlings/ha	Proportion of total (mean) seedlings	Saplings/ha	Proportion of total (mean) saplings
A. concolor	222.8 (± 73.9)	13.8	300.8 (± 103.5)	15.8
A. menziesii	0	0	2.7 (± 2.7)	<0.1
C. decurrens	568.7 (± 102.1)	35.1	754.6 (± 176.7)	40.0
C. nuttallii	4.1 (± 2.4)	<0.1	1.4 (± 1.4)	<0.1
N. densiflorus	0	0	5.5 (± 3.9)	<0.1
P. lambertiana	117.6 (± 32.5)	7.3	67.0 (± 15.7)	3.5
P. ponderosa	192.8 (± 41.7)	11.9	244.7 (± 57.9)	12.9
P. pisa	0	0	5.5 (± 5.5)	<0.1
P. menziesii	34.2 (± 16.5)	0.2	17.8 (± 11.1)	0.1
Q. chrysolepsis	164.2 (± 49.4)	10.1	236.5 (± 45.0)	12.4
Q. kelloggii	315.8 (± 68.3)	19.5	218.7 (± 40.6)	11.5
Q. wislizeni	0	0	5.5 (± 5.5)	<0.1
Total	1620.0 (± 194.8)		1902.9 (± 251.7)	

Only one (small, suppressed) oak died


THERE ARE SHRUBS !!!

Shrubs

Plots across the study averaged 34.8% ± 2.5 shrub cover.

Mountain misery or bearclover (*Chamaebatia foliolosa*) is THE dominant understory plant in these forests averaging 26.7% ± 2.4 cover. While dense, it is a short shrub perhaps less limiting to recruitment?

Greenleaf/whiteleaf manzanita (combined) surprisingly averaged only 2.8% cover.

However there are a few locations where type conversion to shrublands—dominated by tall/dense manzanita—does appear to be a possibility if there is not management intervention.

Forest type change to oaks likely in some locations—and perhaps more likely than to shrublands—without management intervention.

With the increased light availability, we have noticed a trend of increased poison oak abundance ☹

Invasive plants (Cal-IPC listing)

Cheatgrass (*Bromus tectorum*-above), was the most common (17 plots).

No brooms (yet)

No other invasives were overly abundant (yet) but we did encounter ripgut brome (*Bromus diandrus*), bull thistle (*Cirsium vulgare*), Johnsongrass (*Sorghum halepense*), yellow star-thistle (*Centaura solstitalis*), mullein (*Verbascum thapsus*), and Himalayan blackberry (Rubus armeniacus) in our plot network.


Early look at snag fall rates
Ch-ch-ch-ch-changes!!!

Snag demography

- Mean (± SEM) fall rate of 10.5 ± 1.2% (per plot, all species & size classes, 2014-2018)
- Examining by species and/or size class doesn't affect fall rates substantially (most, 10.5-13%).
- For context—as 10.5% may not appear high—we compared these data with others from a similar study we have in forests heavily impacted by the mid-2000s mountain pine beetle epidemic in the Rocky Mountains (sub-analyzing all plots in Wyoming). In Wyoming, zero (0) snags fell the first 4 years of the outbreak.
- Of the snags that have fallen so far in our study, 62% fell 3 years postmortem, 21% fell 2 years postmortem, and 11% fell 4 years postmortem.
- When snags fall they often knock over other snags (think bowling pins), crush/kill live trees (leading to yet more mortality), and crush regeneration.

The future…

- This event highlights increased mortality risks for trees during severe droughts, particularly under warmer temperatures attributed to climate change.

- In the future, it is likely that more frequent extreme weather events will increase the frequency and magnitude of severe ecological disturbances in many forests, driving rapid and often persistent changes in forest structure, composition and function across large landscapes.

- In the absence of management intervention we expect to see some type conversions, particularly in the lower elevations of the southern Sierra where mortality of dominant and co-dominant trees was most severe.

…the future

- Might stakeholders be alright with some low-elevation forests being managed as oak forests (granted oaks have their own insect/disease issues, e.g., GSOB)?
- Lower recommended stand stocking values should likely be adopted in CA (e.g., Egan et al. 2019, maybe?).
- Management should target increasing structural and compositional spatial heterogeneity.
- Statewide, the amount of forest treated with both prescribed fire and thinning needs to greatly increase.
- The Ferguson fire burned in areas of tree mortality in 2018 but was largely a non-WUI fire. With the amount of dead trees/fuels in close proximity to WUI the likelihood of catastrophic fires in the upcoming years seems high.
- We aim to continue following these forests to monitor change (funding dependent)

Questions

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Fettig, C. J., Mortenson, L. A., Bulaon, B. M., & Foulk, P. B. (2019). Tree mortality following drought in the central and southern Sierra Nevada, California, US. *Forest Ecology and Management*, *432*, 164-178.