California's Current Epidemic of Tree Mortality: Causes, Consequences and The Future

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Its getting warmer and its getting warmer faster….

Since 2000, 15 of the 16 warmest years on record have occurred.

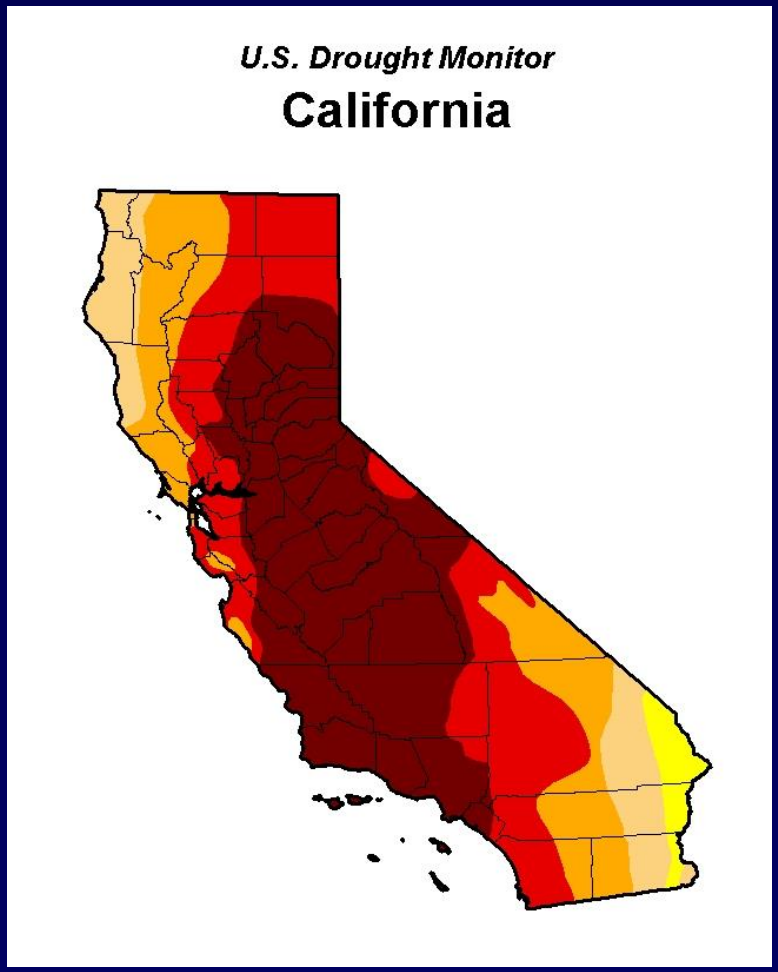
Table 3.1 The observed differences in annual global temperature anomaly for 2010 and its rank relative to the entire historical record since 1880 for the three primary datasets used to determine global average temperatures

	2010 Global anomaly relative to the 1961–1990 annual mean	Rank of 2010 to all years since 1880
HadCRUT3	0.50 °C	Second warmest after 1998
NASA-GISS	0.56 °C	Tied warmest with 2005
NOAA-NCDC	0.52 °C	Tied warmest with 2005

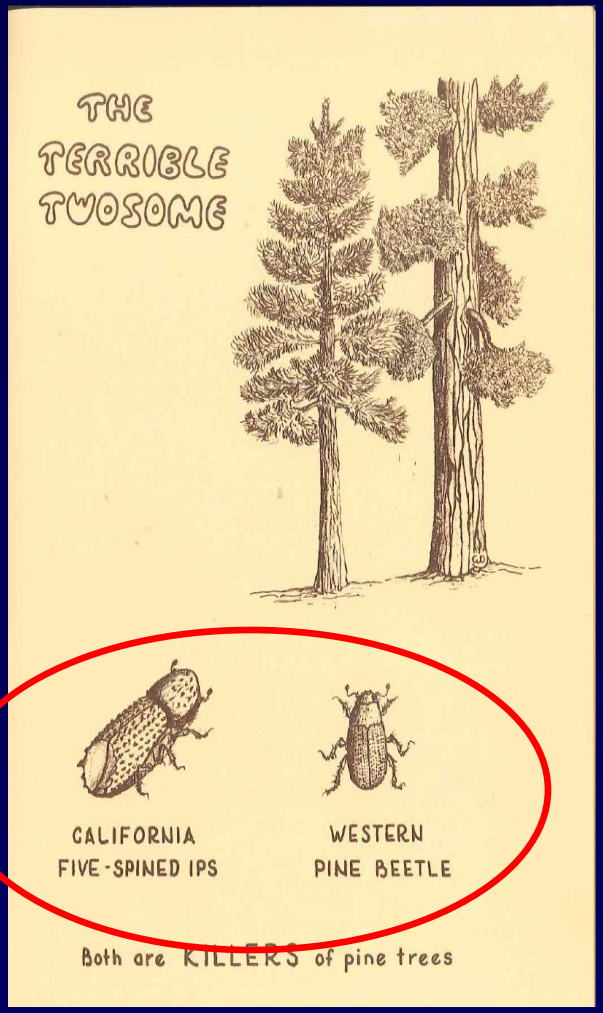
From Sanchez-Lugo A, Kennedy JJ, Berrisford P (2011) Surface temperatures. In "State of the Climate 2010," *Bull Amer Meteor Soc* 92:6:S36-S37, with permission

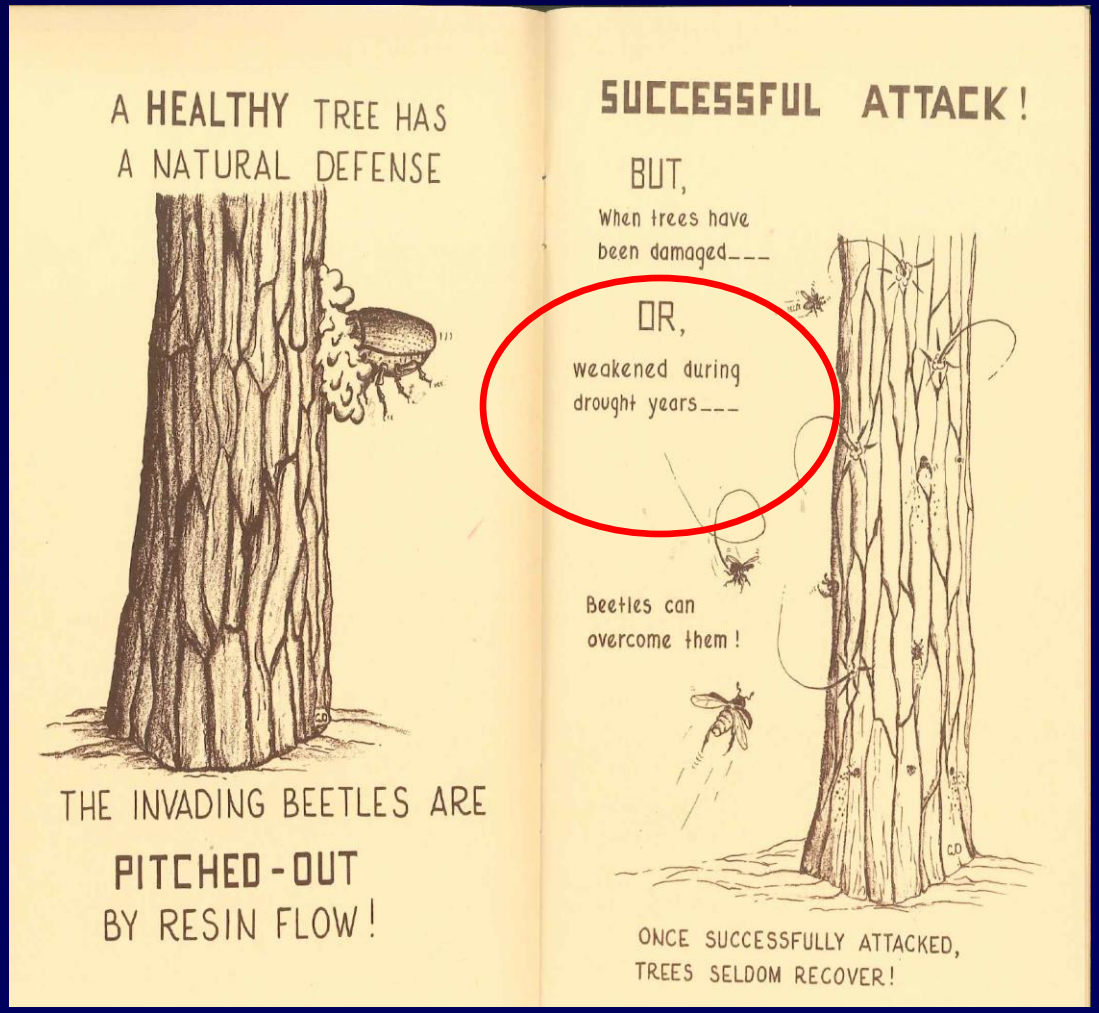
Levinson and Fettig 2014 in *Climate Change and Global Public Health*

Cause (inciting factor) - hot and dry…



- California is currently in its fourth year of severe drought. Water Year 2015 (ended 30 September 2015) was the hottest and driest on record.
- 2014 was the third driest and second hottest.
- In 2015, we estimated >22 million trees had died in the state due to the drought, elevated temperatures, and associated bark beetle outbreaks.

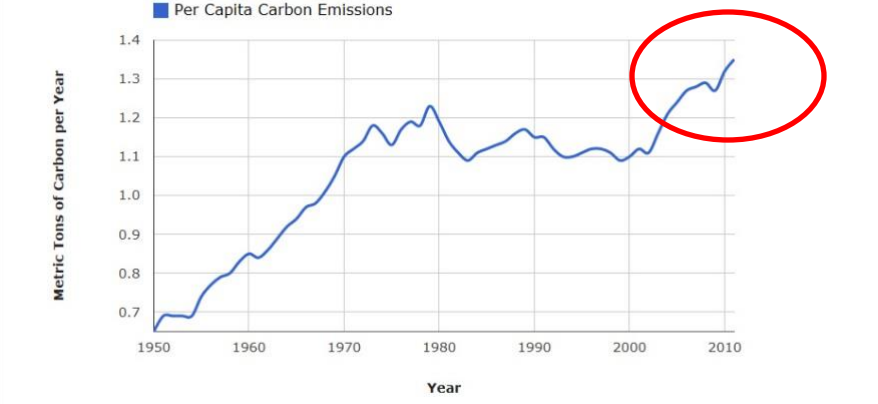




"The Tale of the Terrible Twosome" (DeMars, 1961)

- Most of the warming has been attributed to the radiative effects of CO_2, but other greenhouse gases such as methane, nitrous oxide and halocarbons are also important.

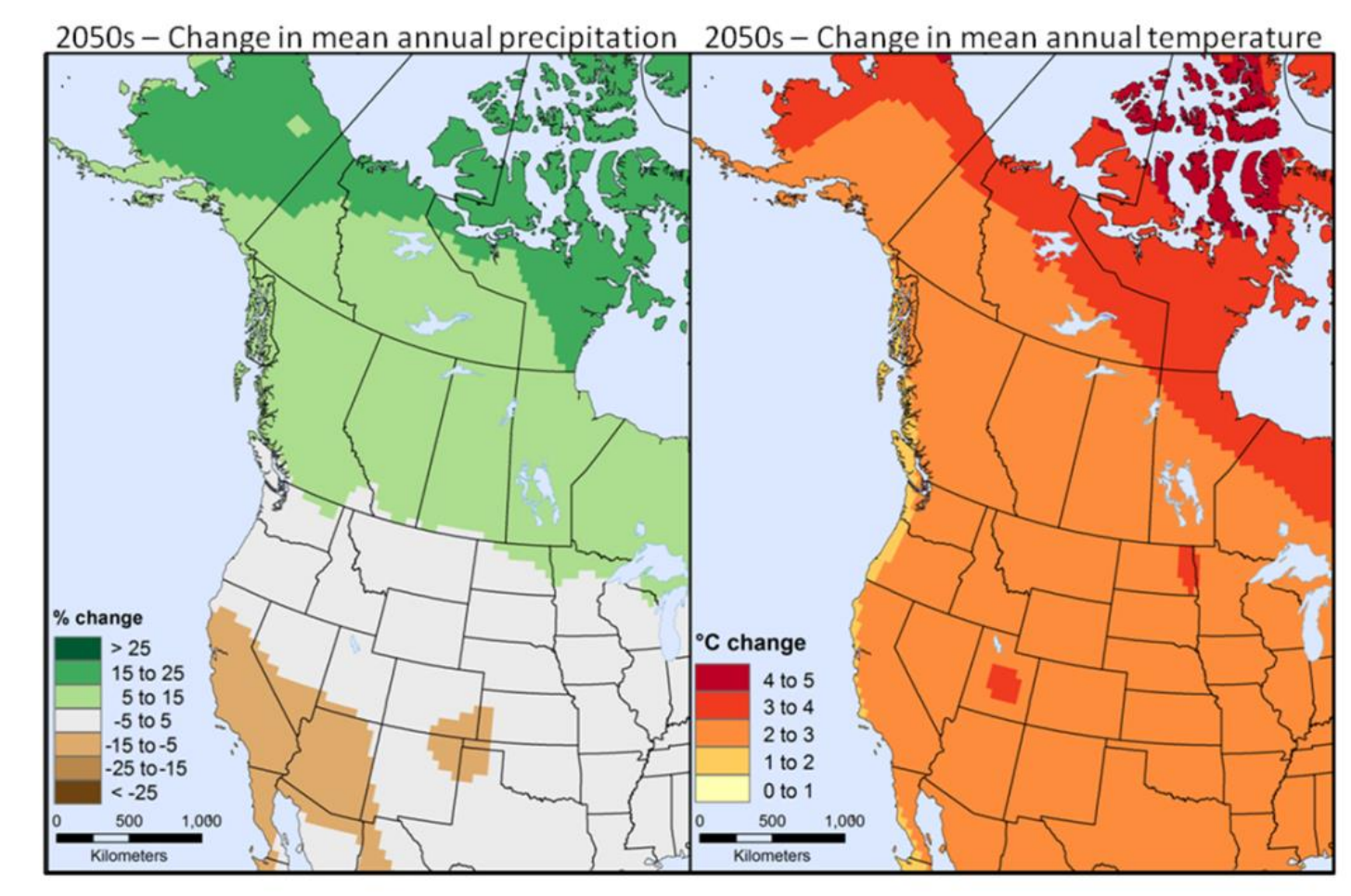
- Prior to the Industrial Revolution, atmospheric CO_2 was stable at ~270 ppm. Today, ~402 ppm (December 2015), and by the middle of this century is expected to reach 550 ppm and to surpass 700 ppm by the end of the century (IPCC 2007).



Source: Boden, T.A., G. Marland, and R. J. Andres. 2015. Global, Regional, and National Fossil-Fuel CO_2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi: 10.3334/CDIAC/00001_V2015

ww.esrl.noaa.gov

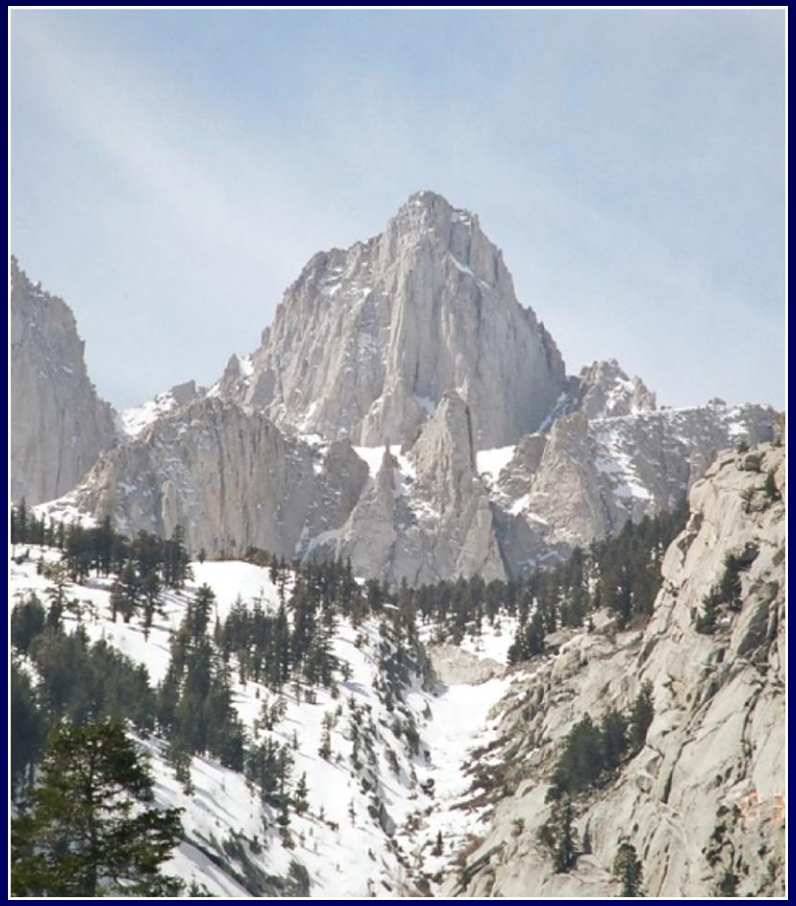
Since 1751, 374 billion metric tons of carbon have been released from the consumption of fossil fuels and cement (second most consumed substance on earth) production. Half since 1980s.



Fettig et al. 2013. Journal of Forestry 111:214-228.

Median change in mean annual precipitation (left) and air temperature (right) compared to the climatic normal period (1961-90) based on projection by 13 global climate models.

Climate signal has important direct and indirect effects on forests…



mountain-forecast.com

- Climate is one of the primary factors regulating the geographic distributions of forest trees (upper treeline = 6.4 °C, mean warm season).
- Species are adapted to a range of climatic conditions, which is often referred to as their "climatic niche".

Impacts

- For long-lived tree species, climate change will likely result in a mismatch between the climate to which trees are currently adapted and the climate that trees will experience in the future.

- Individuals or populations exposed to climate conditions outside their climatic niches may be maladapted (*P. radiata*), resulting in compromised productivity.

- Efforts to model the climatic niche of forest tree species and associate forest ecosystems, and to project their shifts under future climates, have proliferated.

There will be winners and losers…

The fate of any tree, species or population will depend on genetic variation, phenotypic variation, fecundity and dispersal mechanisms, and their resilience and resistance to a multitude of disturbances.

Two primary forest disturbances exacerbated by climate change…

C. Fettig, USDA Forest Service

Cone Fire, Blacks Mountain Experimental Forest, California.

B. Bulaon, USDA Forest Service

Western pine beetle outbreak, central Sierra Nevada, California.

C. Fettig, USDA Forest Service

Wildfires

- Frequency of large fires and the annual area burned have increased in recent decades (Westerling et al. 2006).
- Changes in fire severity are less clear.
  - Miller et al. (2009): mixed-conifer, Sierra Nevada and Southern Cascades; increase
  - Miller et al. (2012): conifer, mixed conifer and hardwood, NW CA; no change
- Suppression costs (16% of USFS budget in 1995, 52% in 2015).

Bark beetles

- 550 species in North America.
- Relatively few are economically important.
- Regulate certain aspects of primary production, nutrient cycling, ecological succession, and the size, distribution and abundance of forest trees.

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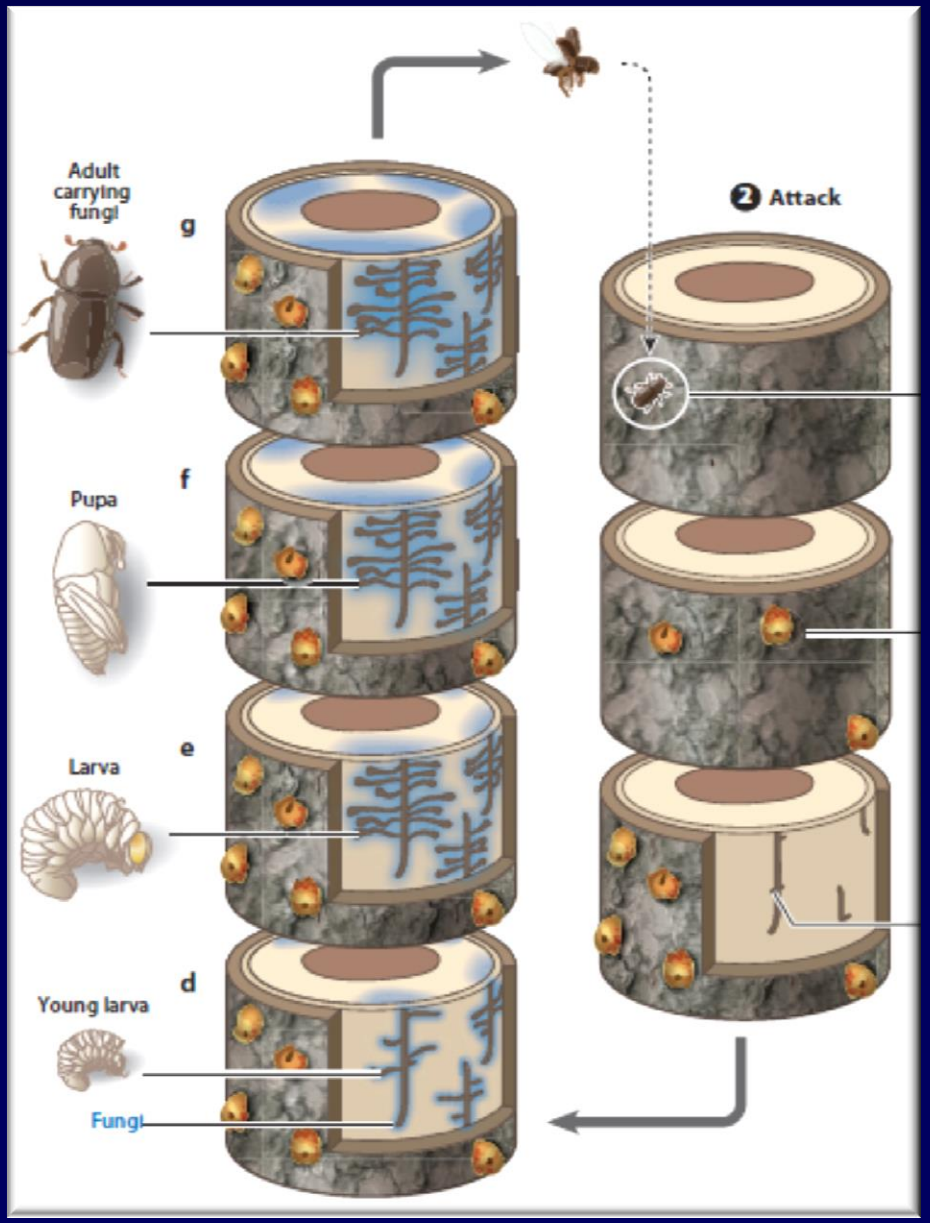
Robber fly (top) predating on red turpentine beetle attracted to residual trees following harvesting in California.



Six and Wingfield 2011. Ann. Rev. Entomol. 56:255-272.

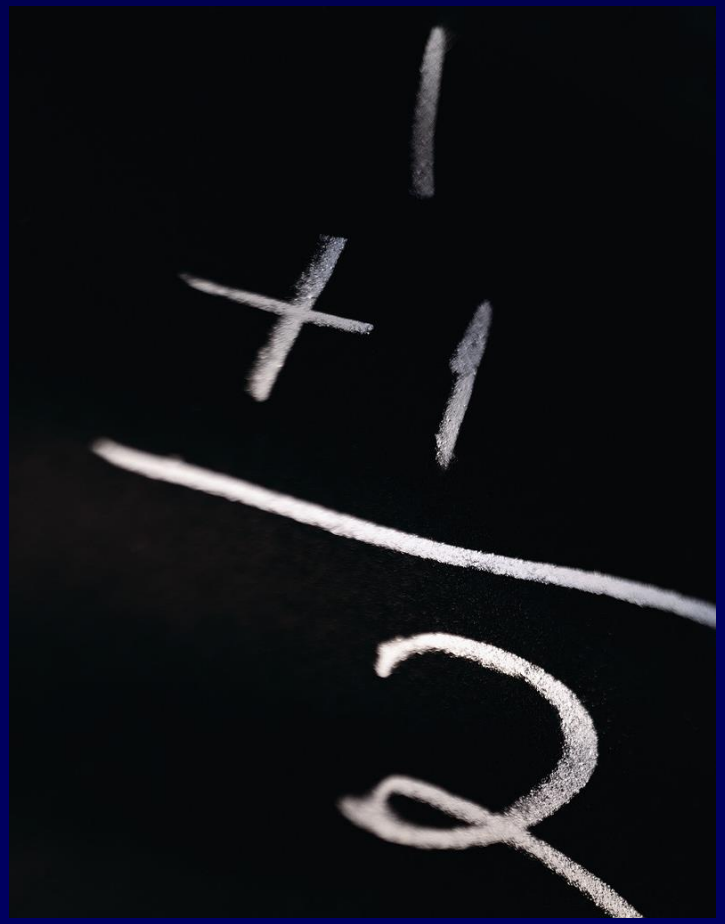
- Several species carry symbiotic fungi (e.g., *Ophiostoma montium*) that are inoculated into the tree upon colonization by the beetle.
- Following mating, adults lay eggs in the phloem. Larvae excavate feeding tunnels in this tissue and/or the outer bark.
- Tree death occurs by girdling of the phloem.

C. Fettig, USDA Forest Service

The extent of tree mortality resulting from bark beetles may be limited to small spatial scales (e.g., individual trees or small groups of trees at endemic or transient population levels) or may affect entire landscapes during outbreaks (i.e., occasionally with the same effect as high severity wildfire).

In brief….

- Favorable vegetative conditions
- Favorable climatic conditions



ClipArt

Site 1 - 3679′ elevation, central Sierra Nevada

March 2014

200 TPA
180.7 ft^2 BAA
65% PIPO
30% CADE
5% QUCH

March 2016

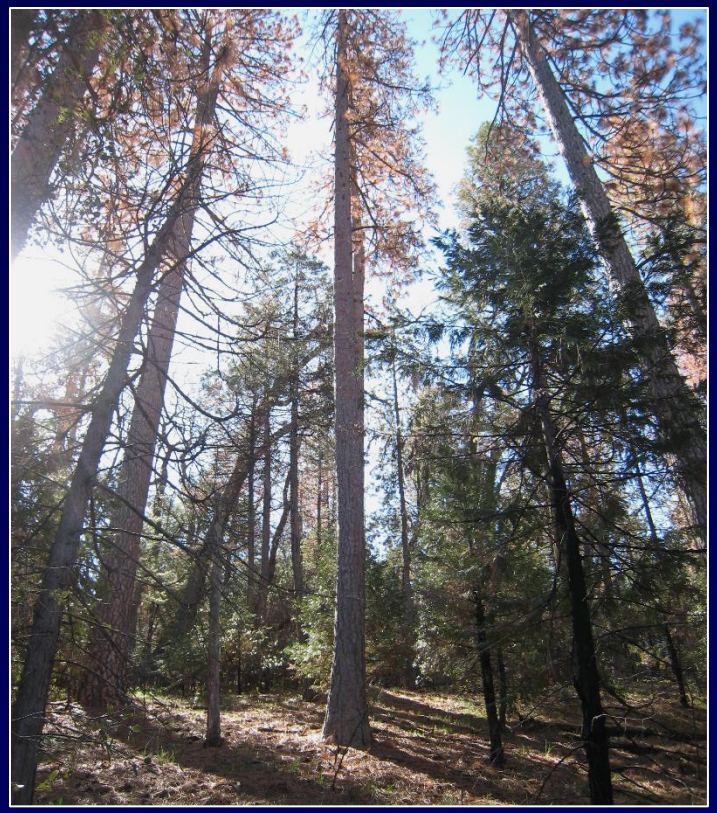
60 TPA
13.0 ft^2 BAA
83% CADE
17% QUCH

In a period of two years, 70% of trees and 93% of basal area were killed. A forest once dominated by medium-diameter (14.5 in. mean dbh) PIPO is now dominated by small-diameter (6.4 in. mean dbh) CADE. All PIPO were colonized by western pine beetle, most in 2015.

Site 2 - 3800' elevation, central Sierra Nevada

March 2014

360 TPA
500.1 ft^2 BAA
50% PIPO
39% CADE
11% QUCH



March 2016

230 TPA
73.1 ft^2 BAA
74% CADE
17% QUCH
9% PIPO*

In a period of two years, 36% of trees and 85% of basal area were killed. A forest once dominated by large-diameter (23.6 in. mean dbh) PIPO is now dominated by small-diameter (6.0 in. mean dbh) CADE. All PIPO were colonized by western pine beetle in 2015, but two trees have yet to exhibit crown fade.*

How resilient are our forests to bark beetle infestations?

- Depends of your definition…changes in functional state are rare, although they do occur.
- Engineering - capacity of a system to return to its more-or-less pre-disturbance state.

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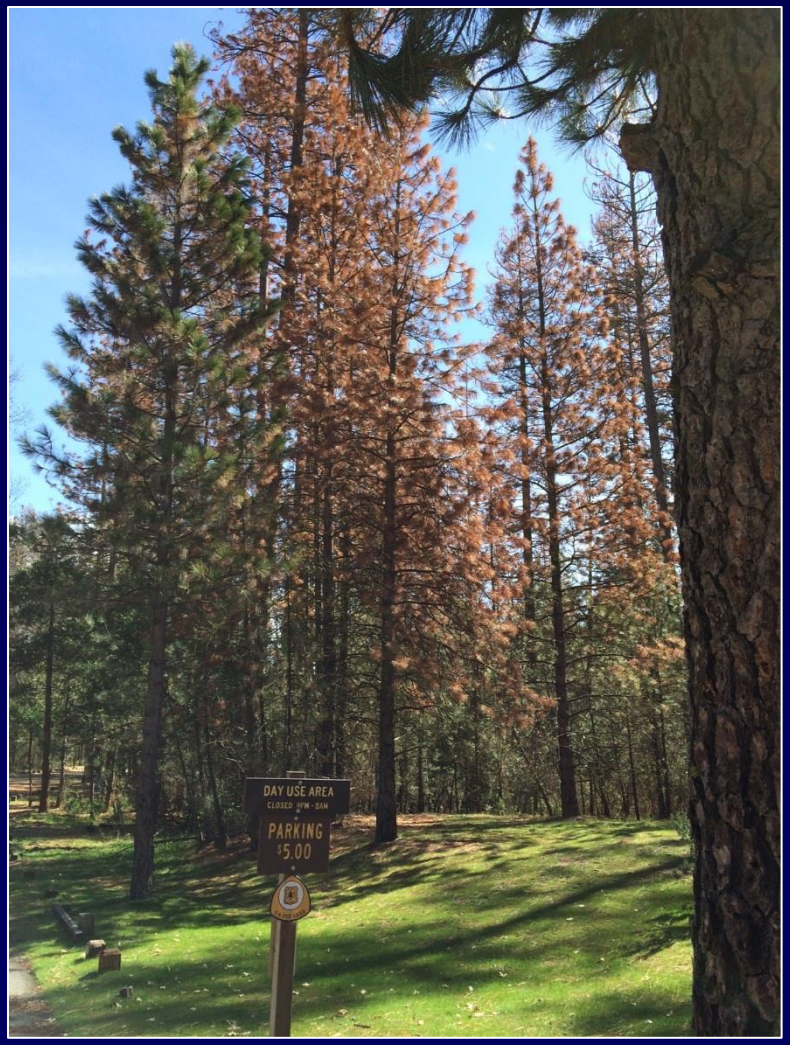
Consequences?

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, grazing capacity, real estate values, biodiversity, carbon storage, endangered species and cultural resources.



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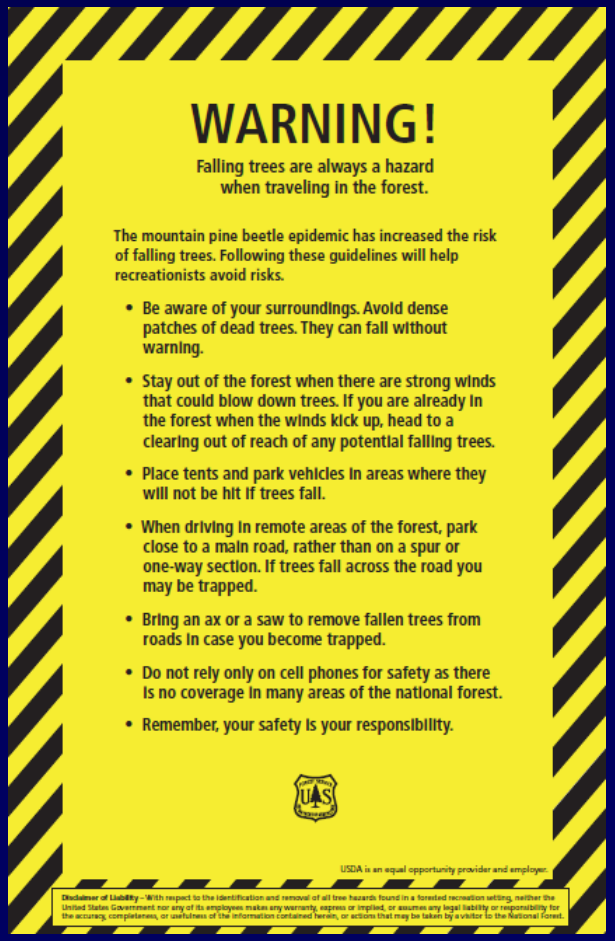
Human health and safety (Near- and long-term challenges)



WARNING!

Falling trees are always a hazard when traveling in the forest.

The mountain pine beetle epidemic has increased the risk of falling trees. Following these guidelines will help recreationists avoid risks.

- Be aware of your surroundings. Avoid dense patches of dead trees. They can fall without warning.
- Stay out of the forest when there are strong winds that could blow down trees. If you are already in the forest when the winds kick up, head to a clearing out of reach of any potential falling trees.
- Place tents and park vehicles in areas where they will not be hit if trees fall.
- When driving in remote areas of the forest, park close to a main road, rather than on a spur or one-way section. If trees fall across the road you may be trapped.
- Bring an ax or a saw to remove fallen trees from roads in case you become trapped.
- Do not rely only on cell phones for safety as there is no coverage in many areas of the national forest.
- Remember, your safety is your responsibility.

USDA is an equal opportunity provider and employer.

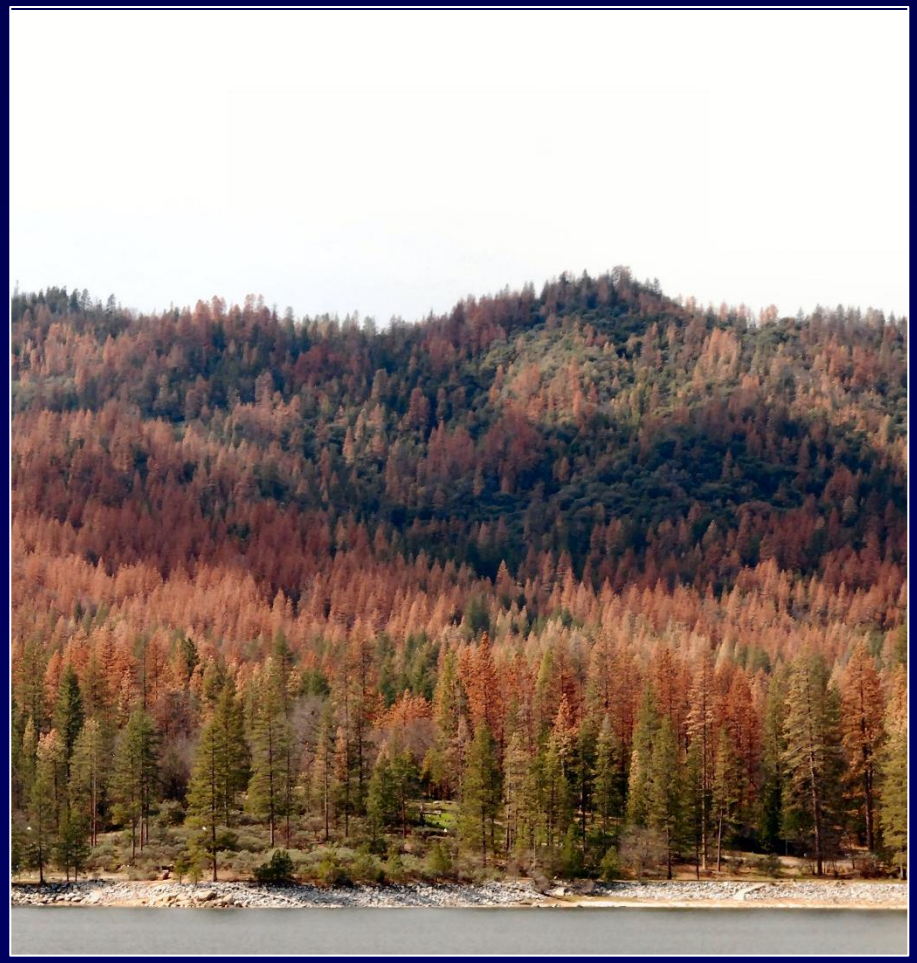
Disclaimer of Liability - With respect to the identification and removal of all tree hazards found in a forested recreation setting, neither the United States Government nor any of its employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of the information contained herein, or actions that may be taken by a visitor to the National Forest.

USFS

1. Hazard trees.
2. Fire risk.
3. Transportation and accessibility.
4. Power line maintenance.
5. Water supply.
6. Air quality.

Fire management (Near-term)

- Firefighter safety is dependent on recognition of anticipated fire behavior.
- Firefighters should expect increases in torching and crowning, and an increased likelihood of spotting.



M. MacKenzie, USDA Forest Service

Fire management (Long-term)

S. McKelvey, USDA Forest Service

- Firefighters should expect increased difficulties in fireline construction, and establishment of access and egress routes and safety zones.


Untreated lodgepole pine
Treated lodgepole pine

All is not lost…we are part of the solution

C. Fettig, USDA Forest Service

Mill, California, 2004.

"In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre, or energy from the forest, would generate the largest sustained mitigation benefit" (IPCC 2007, p. 543).

U.S. forests offset about 15% of annual carbon emissions

C. Fettig, USDA Forest Service

Fuel-reduction and forest-restoration treatments, California, 2014.

California Environmental Protection Agency
Air Resources Board

First California carbon offsets approved under Forestry Protocol

California forestry project generates 1.2 million credits for cap-and-trade program; provides habitat, watershed benefits

SACRAMENTO - Staff of the Air Resources Board (ARB) announced today it has approved the first California forest carbon credits issued under the cap-and-trade offset protocols.

The Willits Woods project developed by Coastal Ridges, LLC was issued 1.2 million Air Resources Board-approved carbon offset credits. Coastal Ridges, LLC is located in Willits, California and the Willits Woods project covers approximately 19,000 acres in Mendocino County.

"This action recognizes the important role forests play in fighting climate change," said ARB Chairman Mary D. Nichols. "Forests managed under the protocol not only furnish additional compliance options for covered businesses, they also provide habitat for wildlife and a wide range of improved watershed benefits for California."

Carbon offsets accepted by the ARB come from sectors not covered by the cap-and-trade program, and must be additional -- that is, above and beyond the carbon that would have been stored in the forest if it had been managed on a 'business-as-usual' basis.

The carbon credits approved today are from what are known as "early-action" projects and recognize voluntary projects developed under earlier versions of the offset protocols before the current protocols were adopted as part of the cap-and-trade Program.

As with all carbon offsets projects, this forestry project had to first be verified by an ARB-accredited verifier.

Keeping forests as forests through active management to increase resistance and resilience to a multitude of disturbances exacerbated by climate change.

C. Fettig, USDA Forest Service

"…healthy forests have a vital role to play in combating climate change (Levinson and Fettig 2014)."

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