Climate change, forests and fire in the Sierra Nevada, California: implications for current and future resource management

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Outline

I. Climate change past, present, and future

II. Changing patterns in wildfire occurrence, area, and severity

III. Climate change, fire and interactions with other factors: ecological implications for terrestrial ecosystems

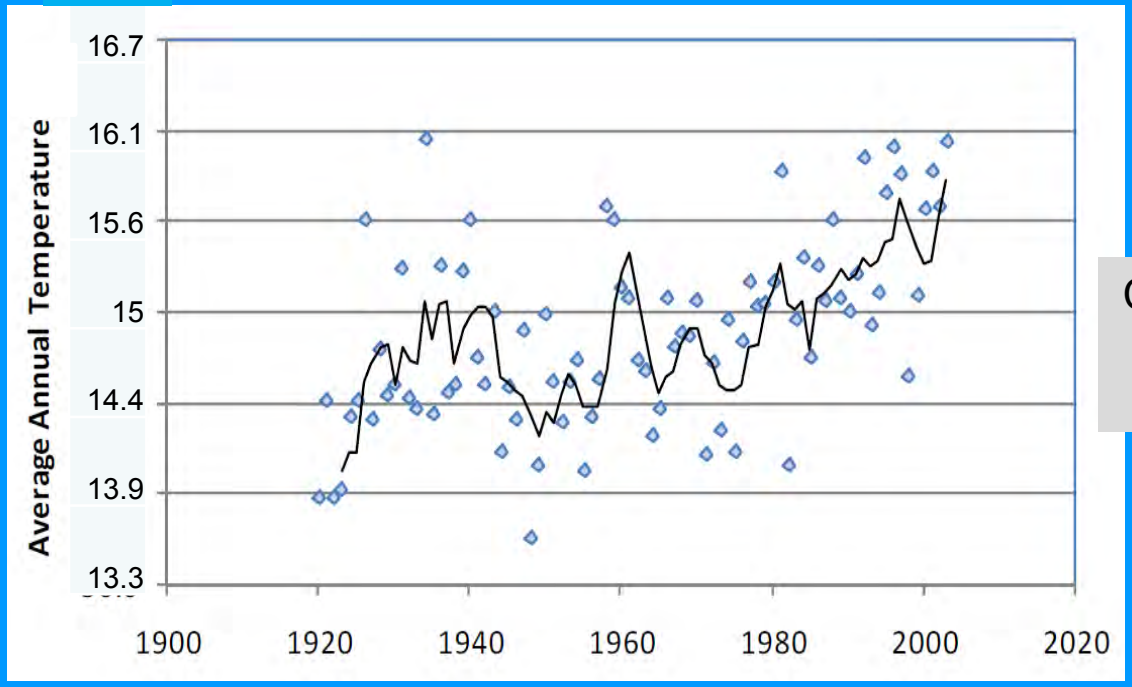
- Biological:
  - Vegetation
  - Plant diversity
  - Wildlife habitat
- Physical:
  - Water
  - Carbon, soil, air

← Not a central focus of my presentation

IV. Concluding thoughts

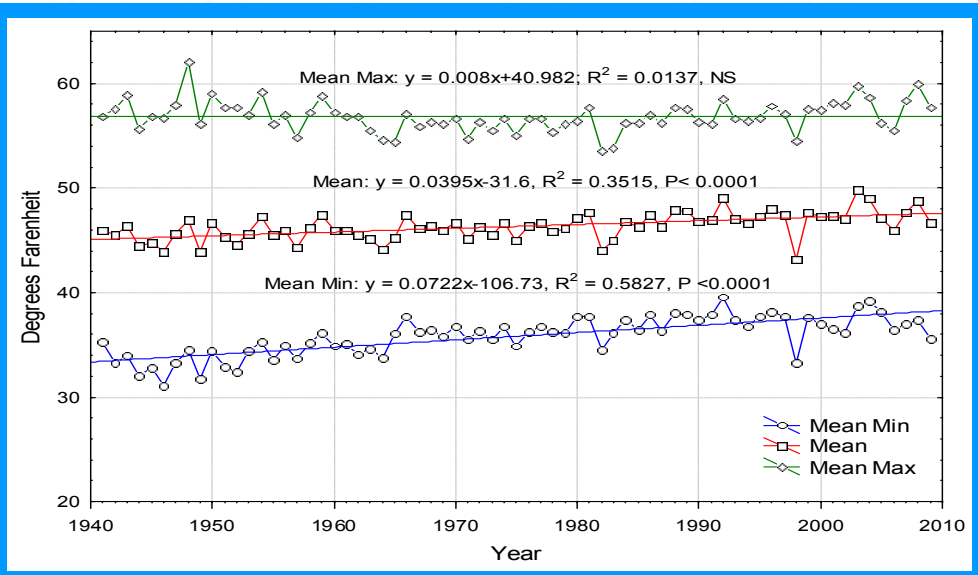
CLIMATE

Temperatures are climbing in California



California: mean annual temps, 1920-2005

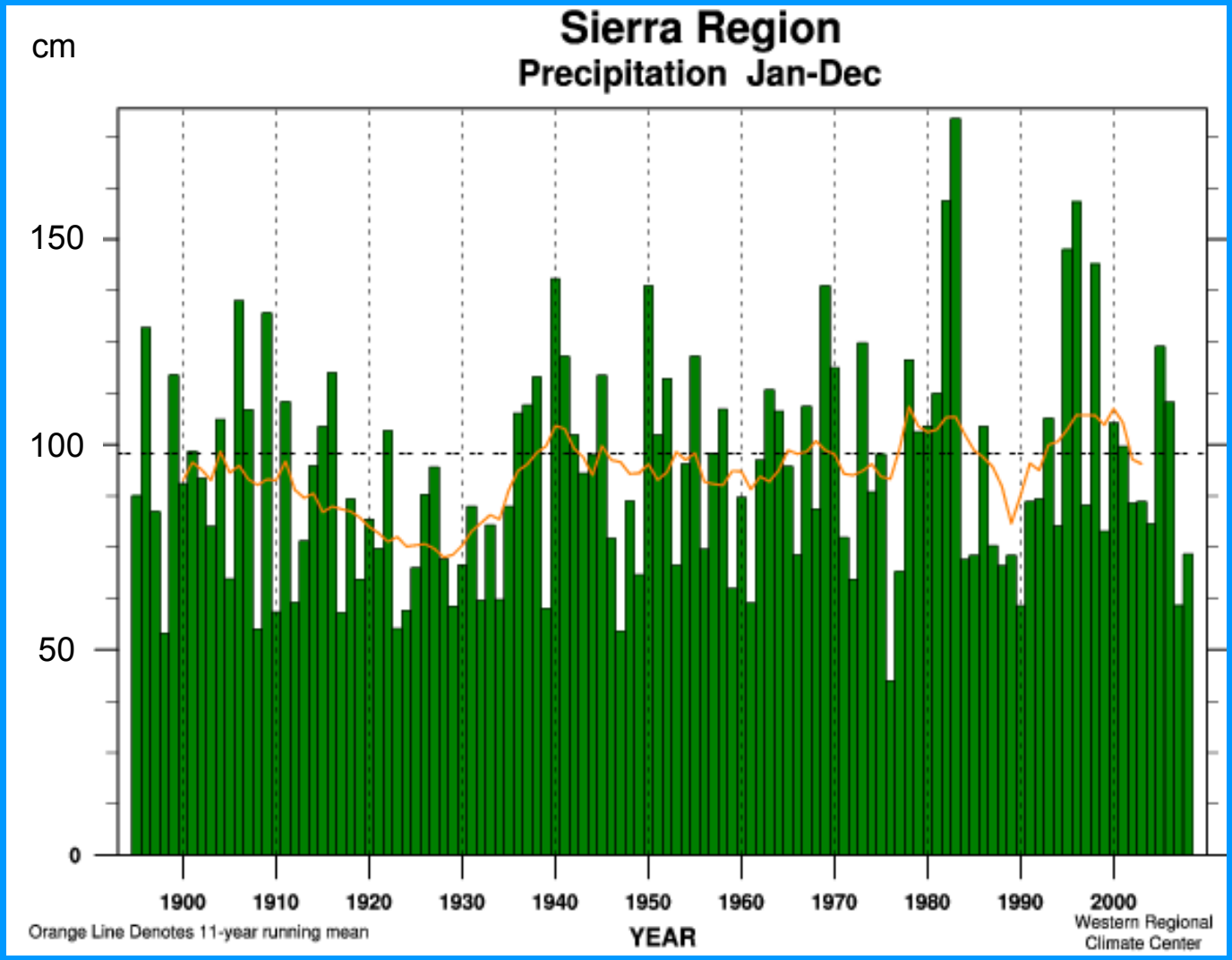
Moser et al. 2009



Pattern is driven by nighttime lows. E.g. Grants Grove (Sequoia-Kings Canyon NP)

CLIMATE

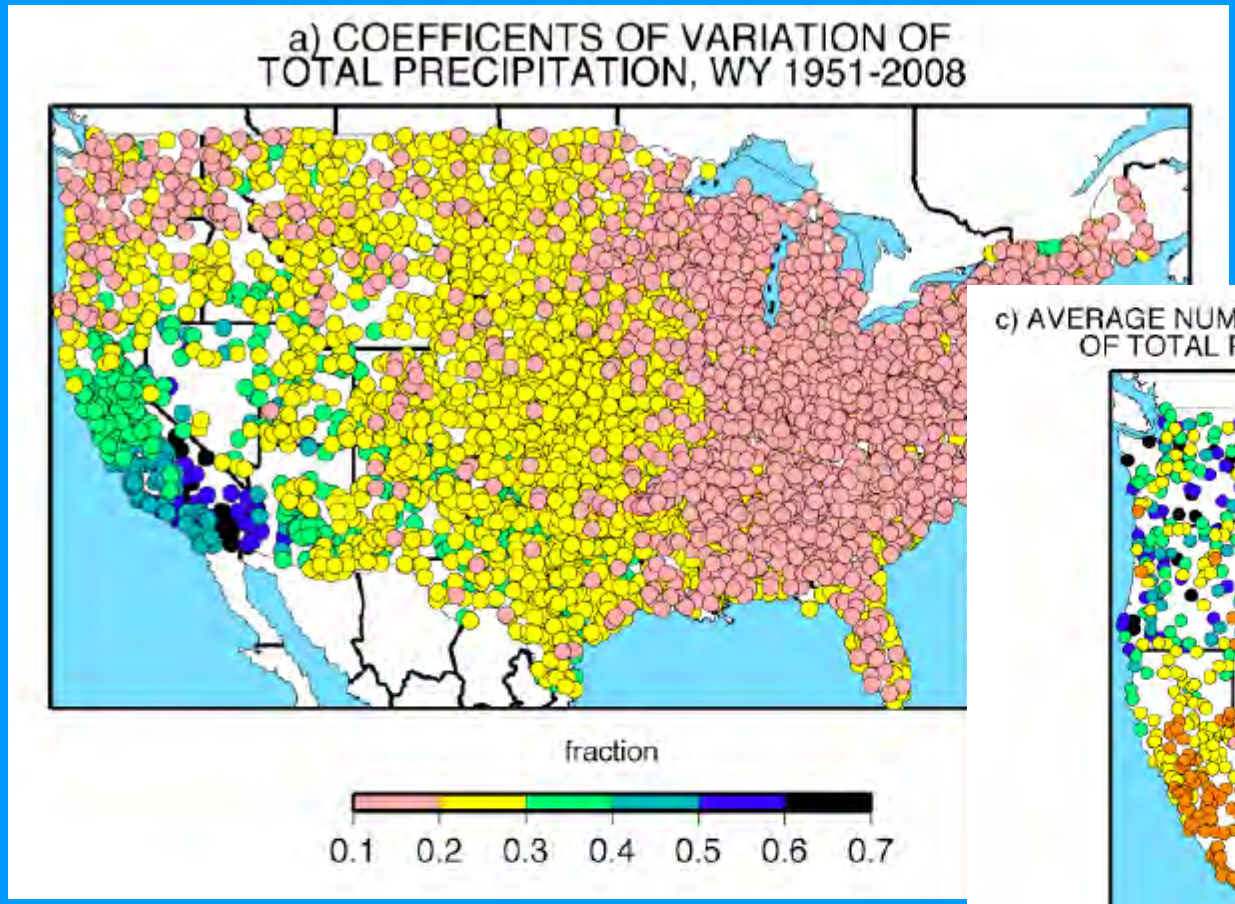
*Average annual precipitation is ~steady or rising**

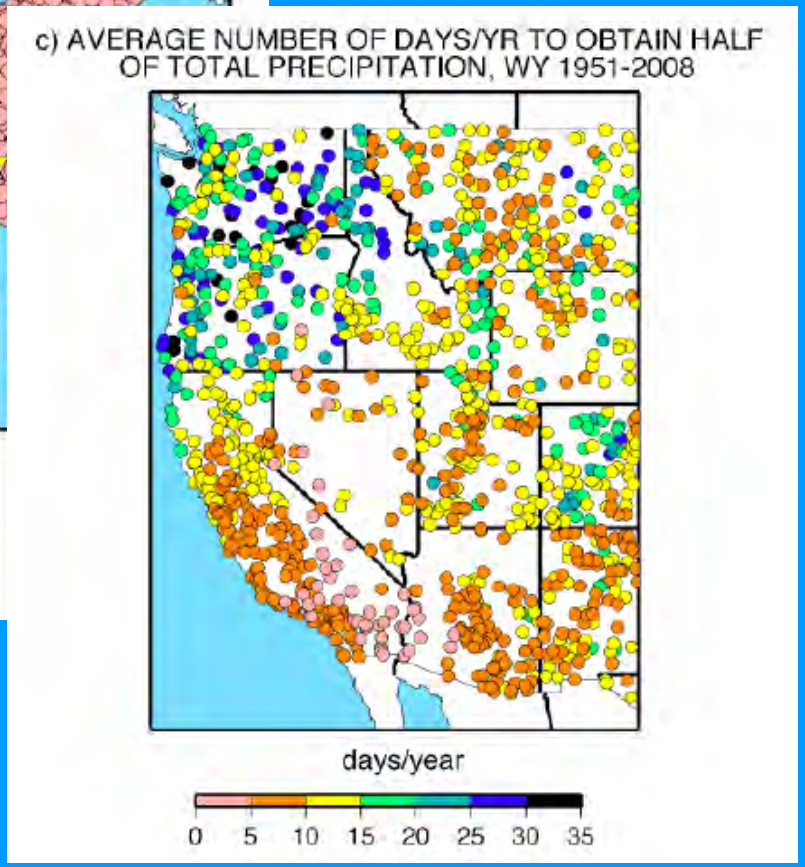


WRCC 2009

* Data do not include recent drought. 100+ year record shows modest increase in mean annual ppt in most N. California climate regions

California's Mediterranean climate is characterized by extreme variability in precipitation

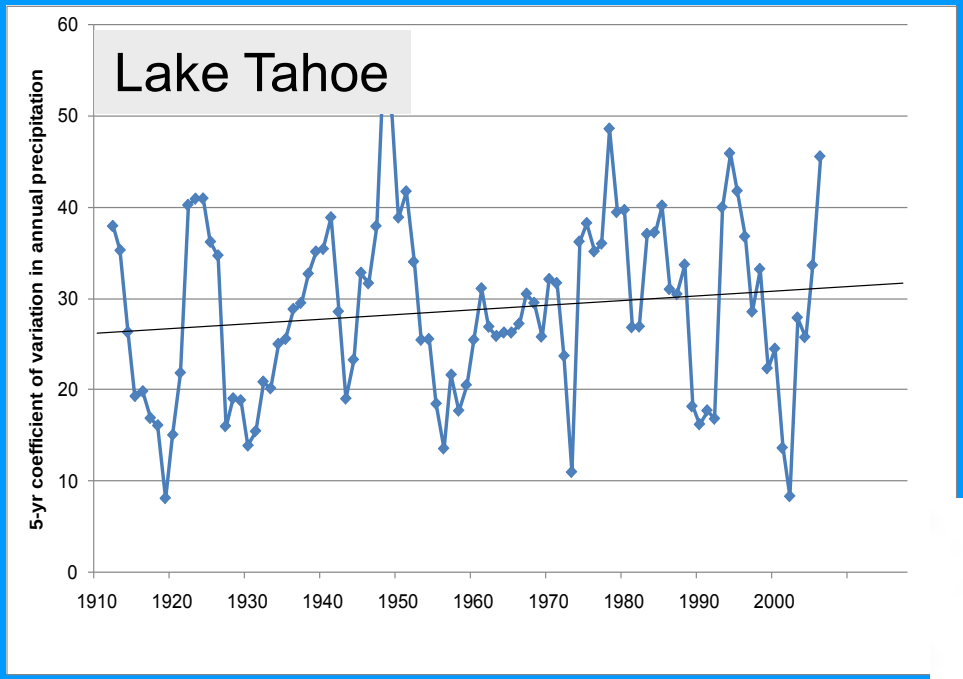




Species must be able to tolerate long summer drought, and high unpredictability in precip

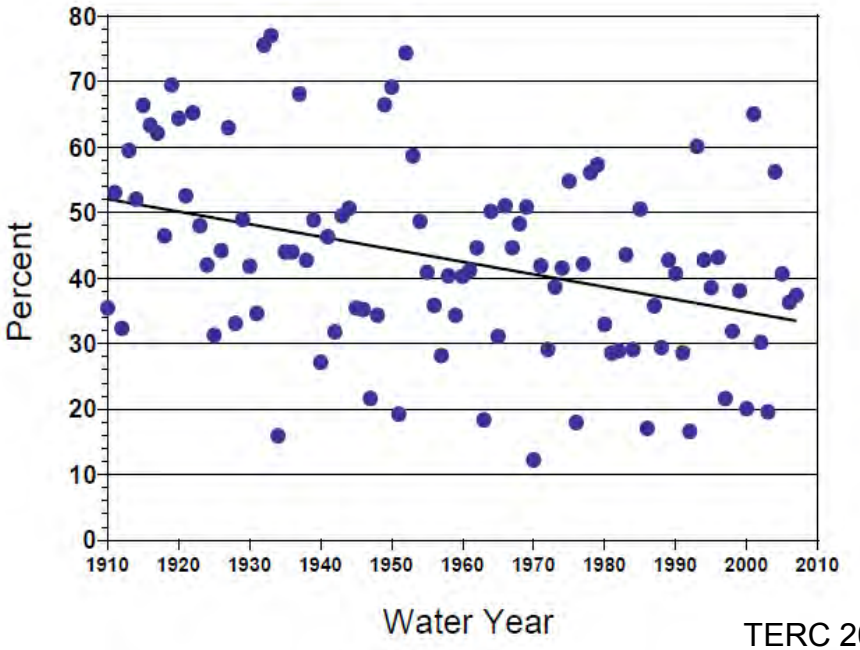
Dettinger et al. 2011

Interannual variability in precip. is up, and snow:rain proportion is down*



WRCC 2009

5-yr running coefficients of variation in mean annual precipitation

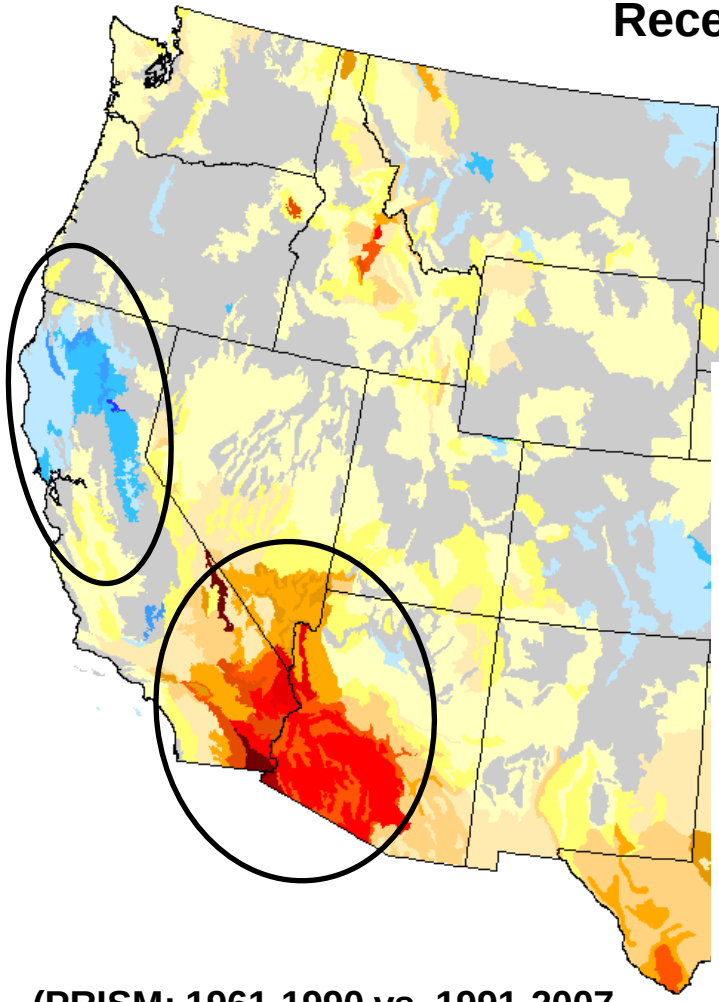


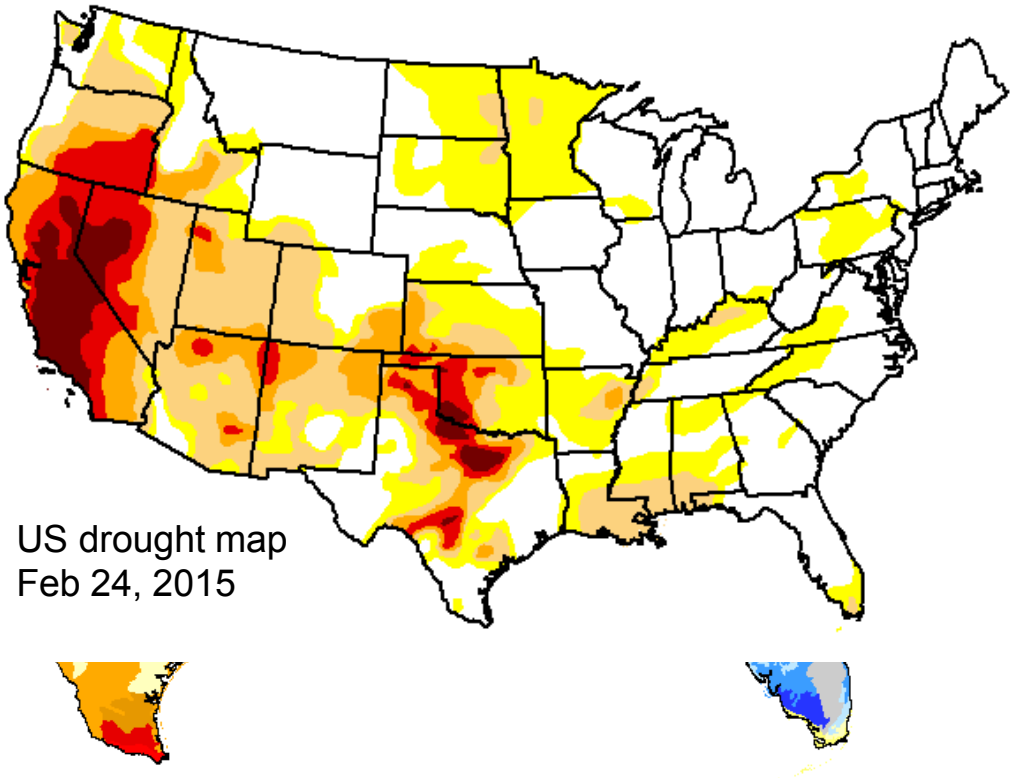
TERC 2009

Tahoe City: snow as a fraction of total precipitation

* but not at all stations

Recent shifts in climatic moisture balance





US drought map
Feb 24, 2015

(PRISM: 1961-1990 vs. 1991-2007 Precipitation minus PET)

Change_GS_P-PET

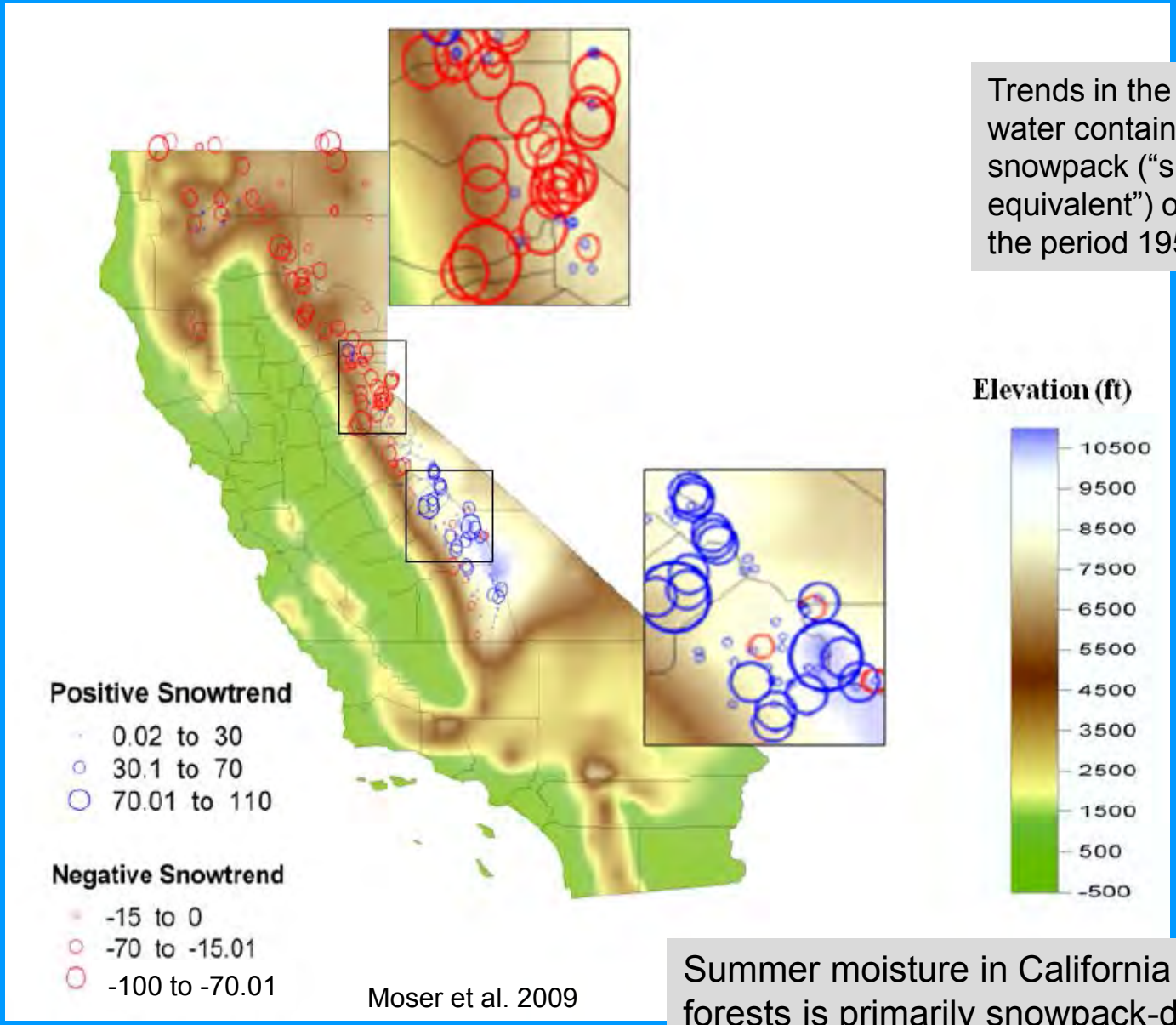
Subsections											
GS_CG_PPET	-5.4 - -5.0	-4.9 - -4.5	-4.4 - -4.0	-3.9 - -3.5	-3.4 - -3.0	-2.9 - -2.5	-2.4 - -2.0	-1.9 - -1.5	-1.4 - -1.0	-0.9 - -0.5	-0.4 - 0.0	0.1 - 0.5
-6.4 - -6.0	-5.9 - -5.5										

0.6 - 1.0	1.1 - 1.5	1.6 - 2.0	2.1 - 2.5	2.6 - 3.0	3.1 - 3.5	3.6 - 4.0

Graphic courtesy of D. Cleland, N. Research Station, USFS

Winter snowpack is down across most of California

CLIMATE



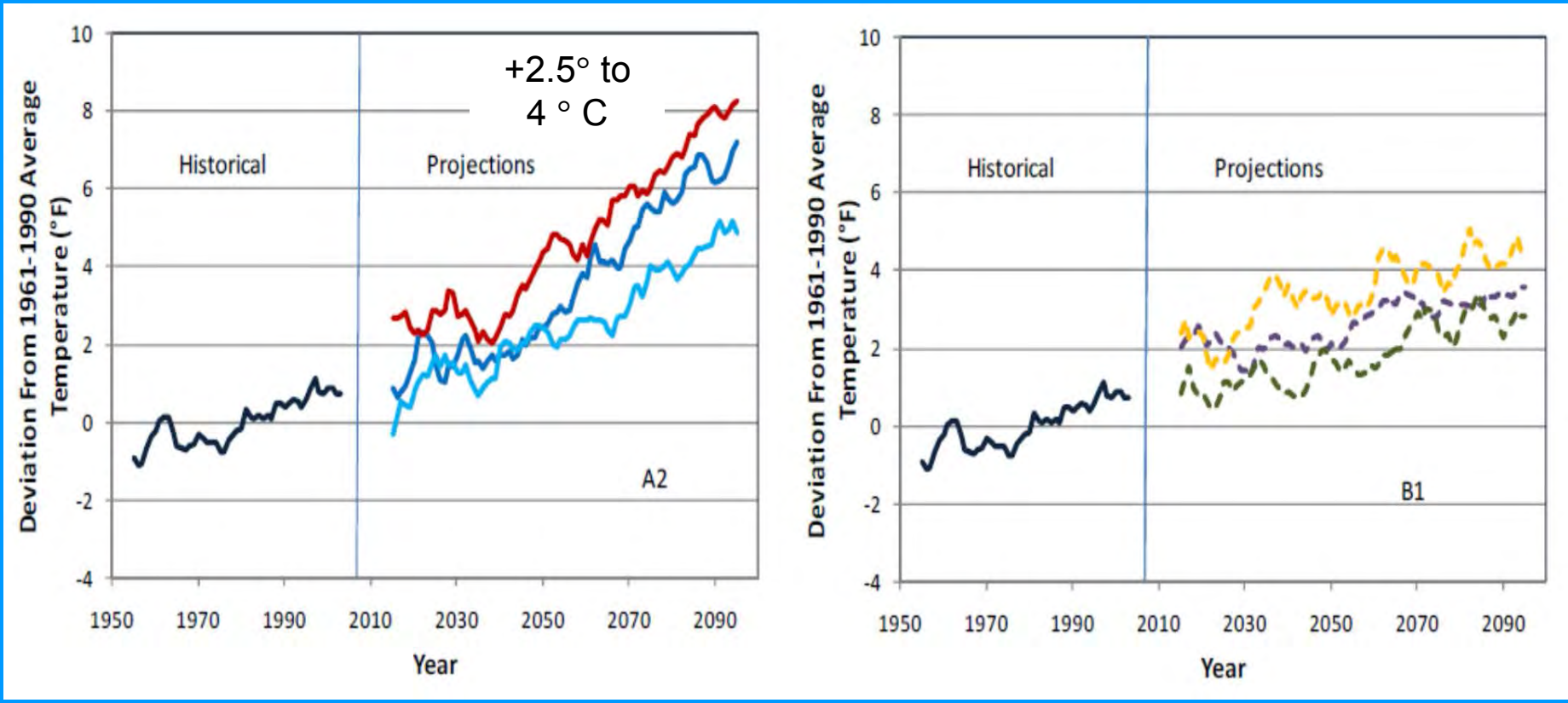
Moser et al. 2009

Trends in the amount of water contained in the snowpack ("snow water equivalent") on April 1, for the period 1950-1997.

Summer moisture in California montane forests is primarily snowpack-derived

Future climate: models project more of the same

California mean annual temperature

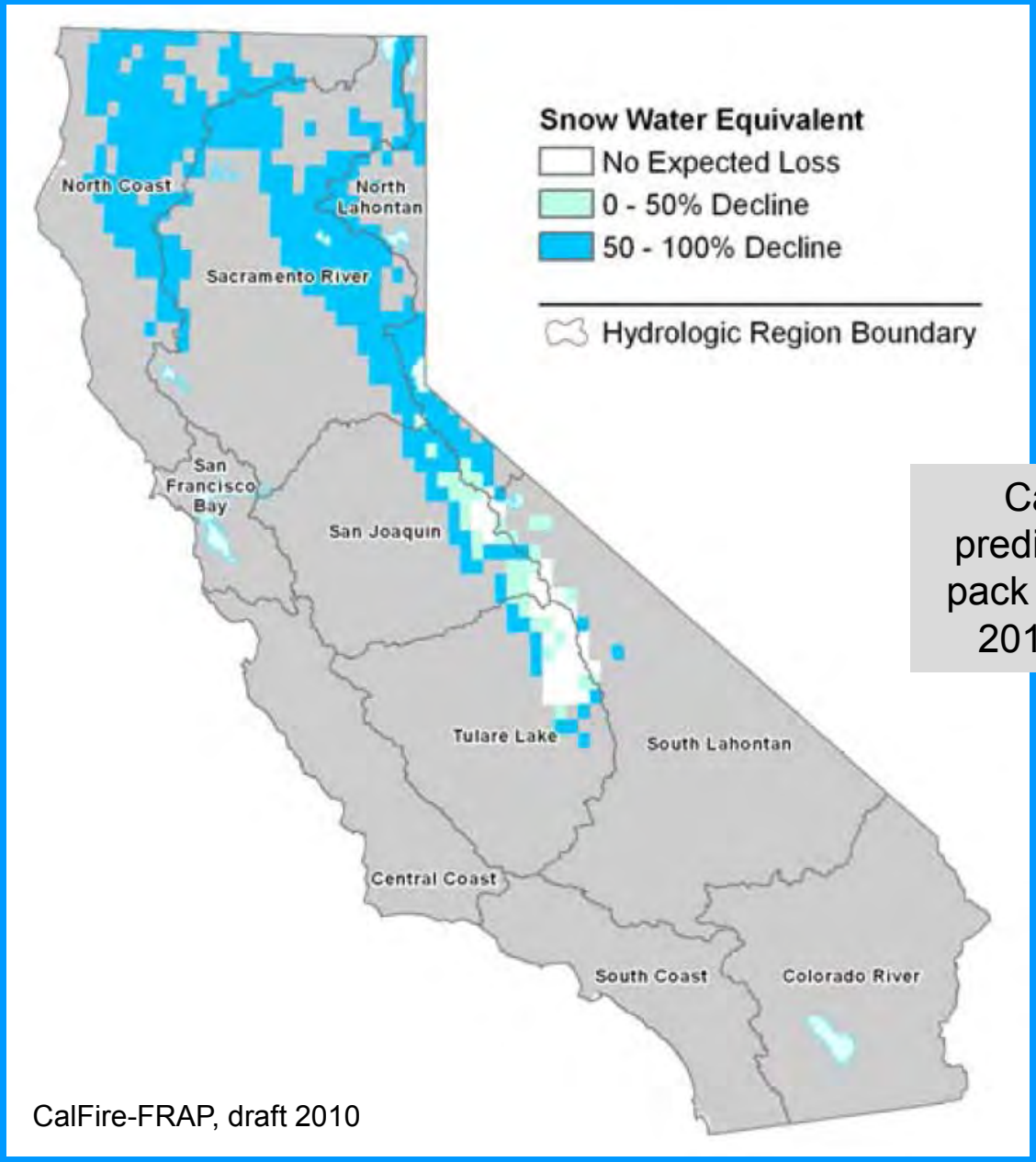


Moser et al. 2009

Historic and projected annual mean temperature for California, from three GCMs using the A2 and B1 IPCC emissions scenarios

CLIMATE

Future climate: snowpack



California: predicted snow-pack trends from 2010 to 2100

CalFire-FRAP, draft 2010

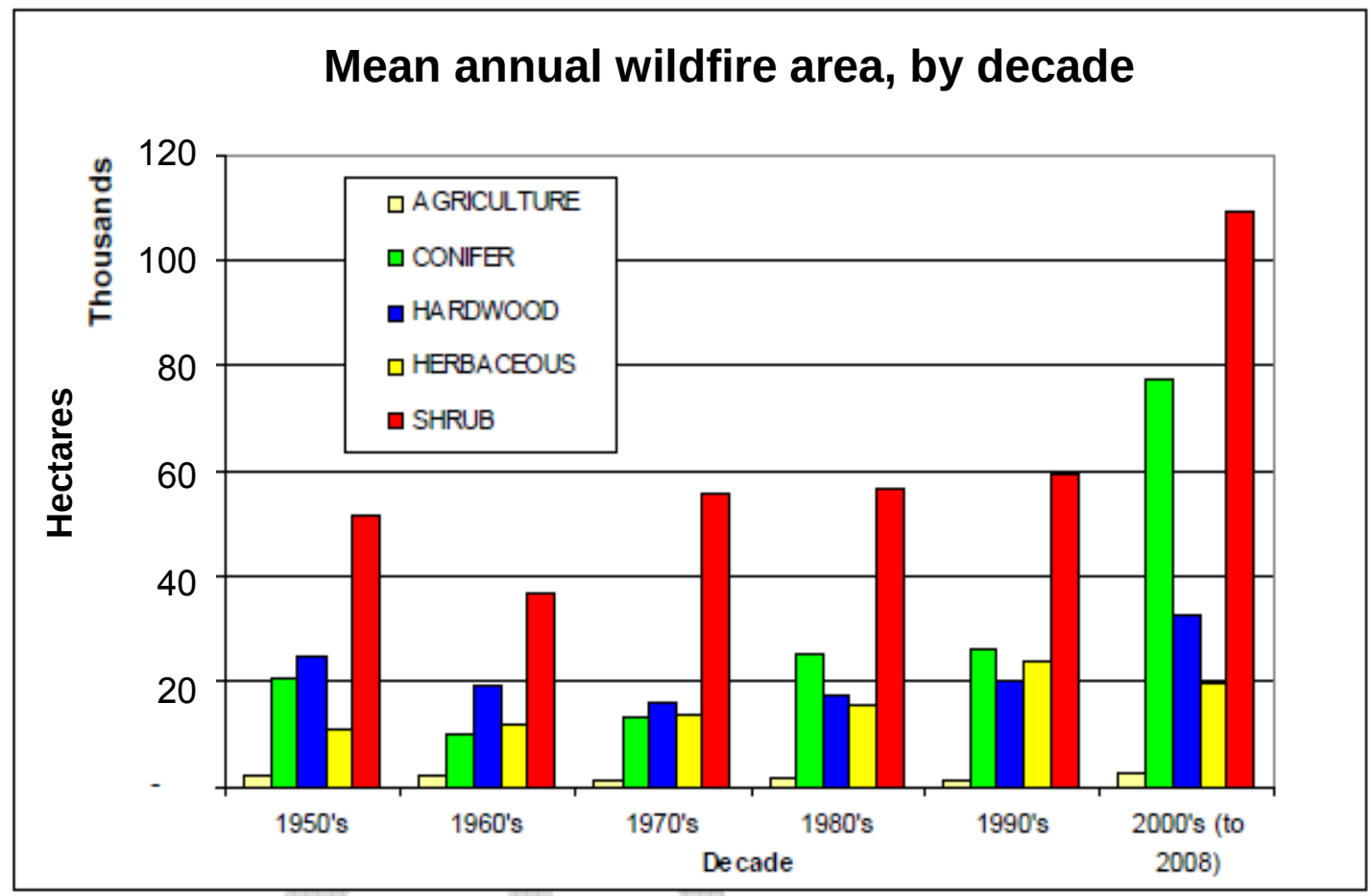
Climate summary

CLIMATE

1. It's getting warmer, especially at night
2. Mean annual precipitation appears to be holding steady (or rising) in the north, dropping in the south
3. Interannual variability in precipitation is increasing in many places (higher highs, lower lows). Current drought is lowest low in >1000 yrs
4. Snow:rain ratio and snowpack are decreasing
5. Combination of these factors is resulting in drier summers

Area burned by wildfire is increasing across California in many ecosystems

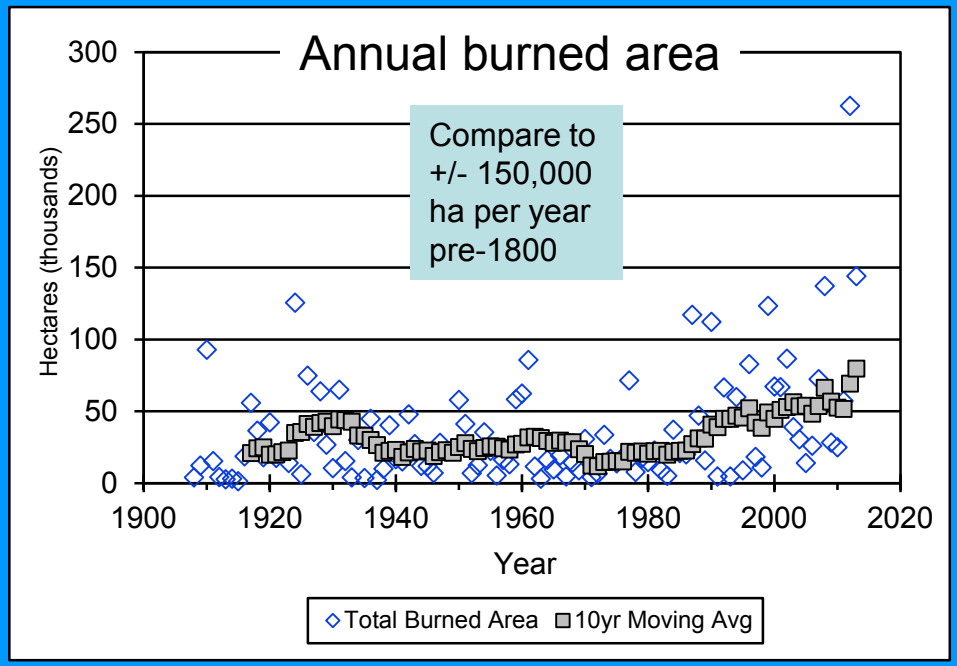
FIRE

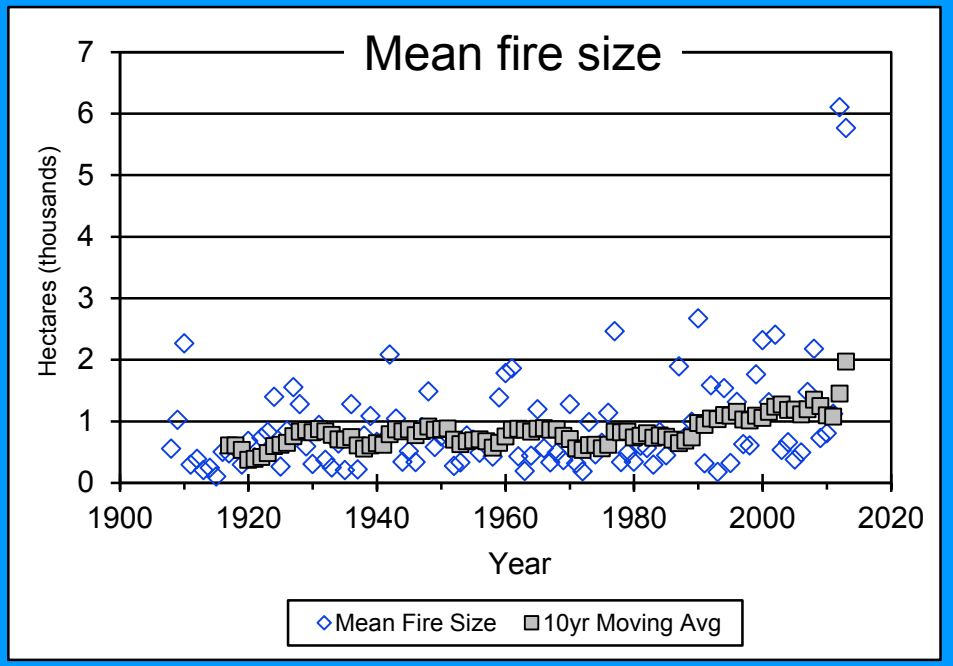


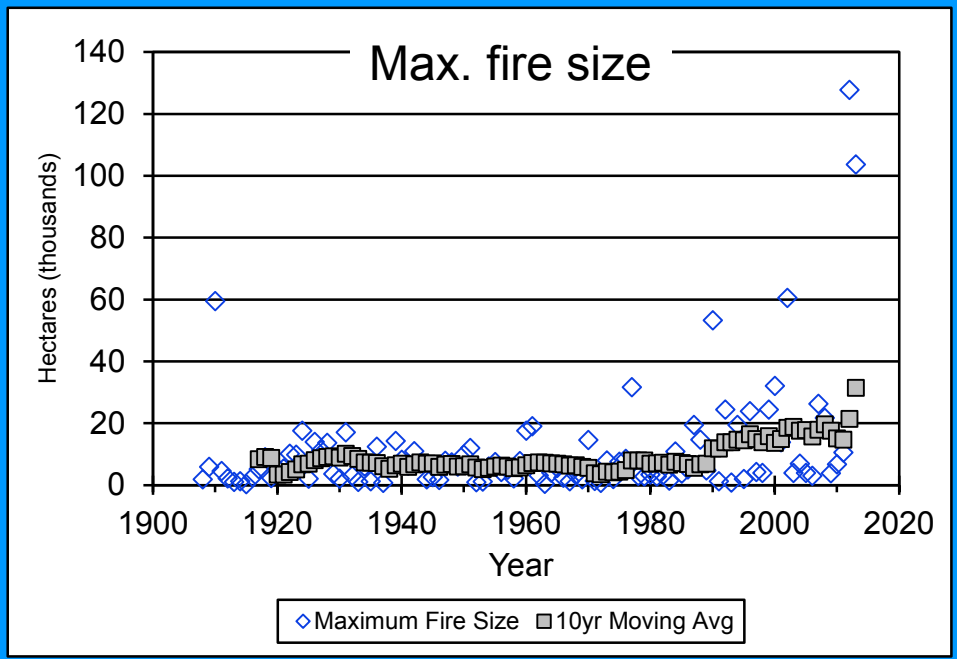
California: annual acres burned by decade and lifeform 1950's-2000's

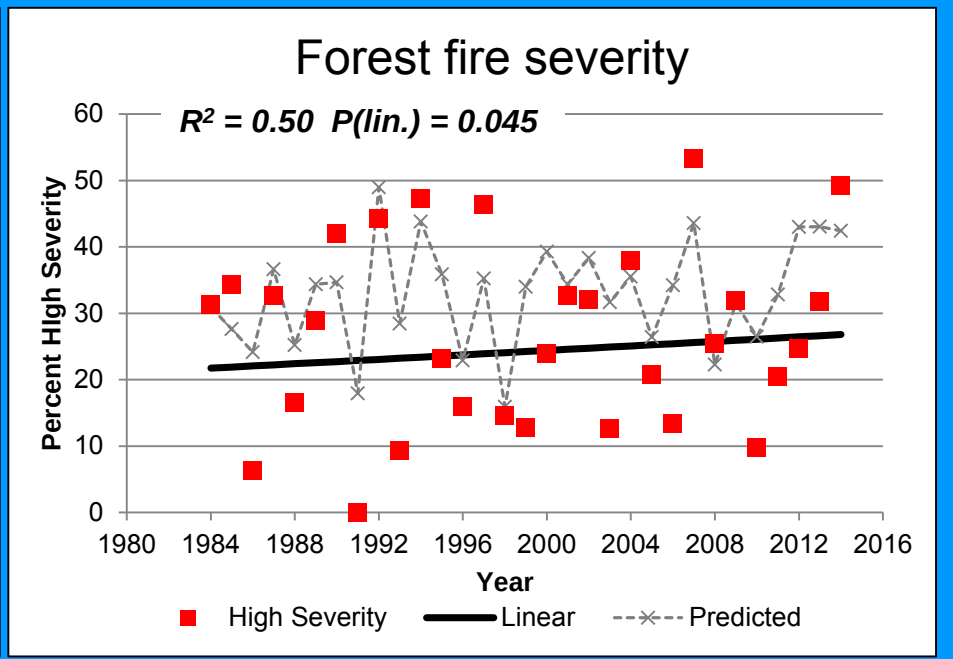
CalFire-FRAP, draft 2010

Sierra Nevada trends in fire area and severity to 2013

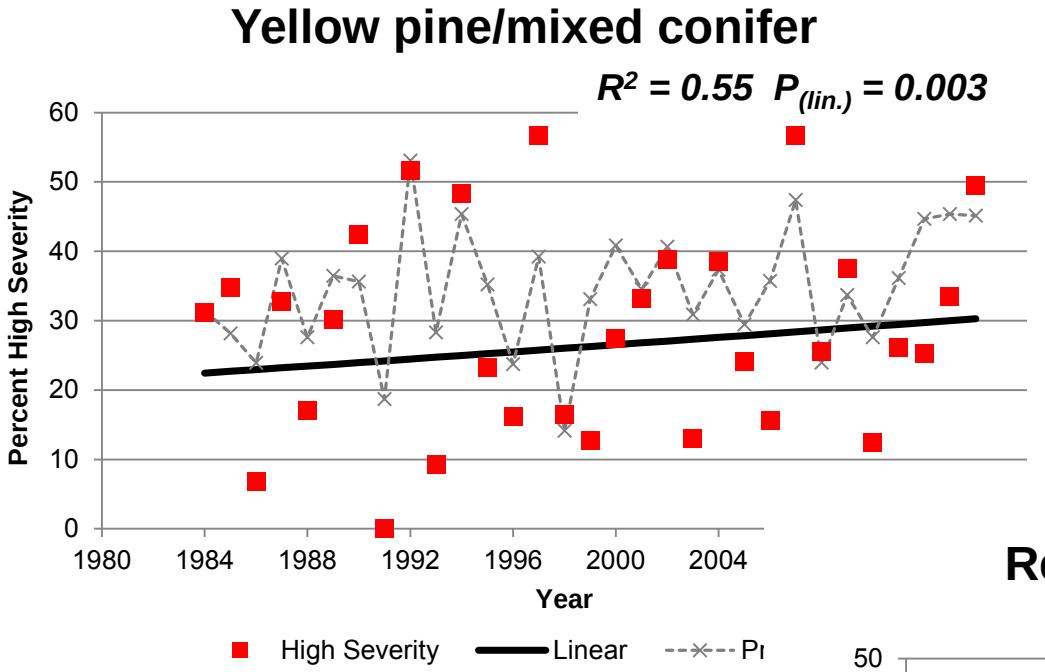




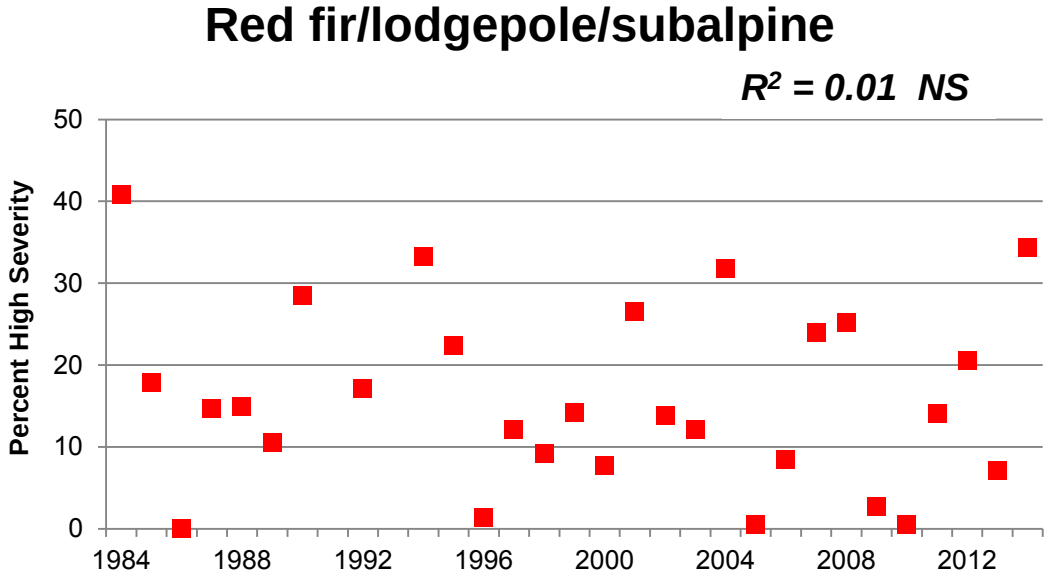




Fire severity: increasing in lower elevation forests, not in higher elevation forests



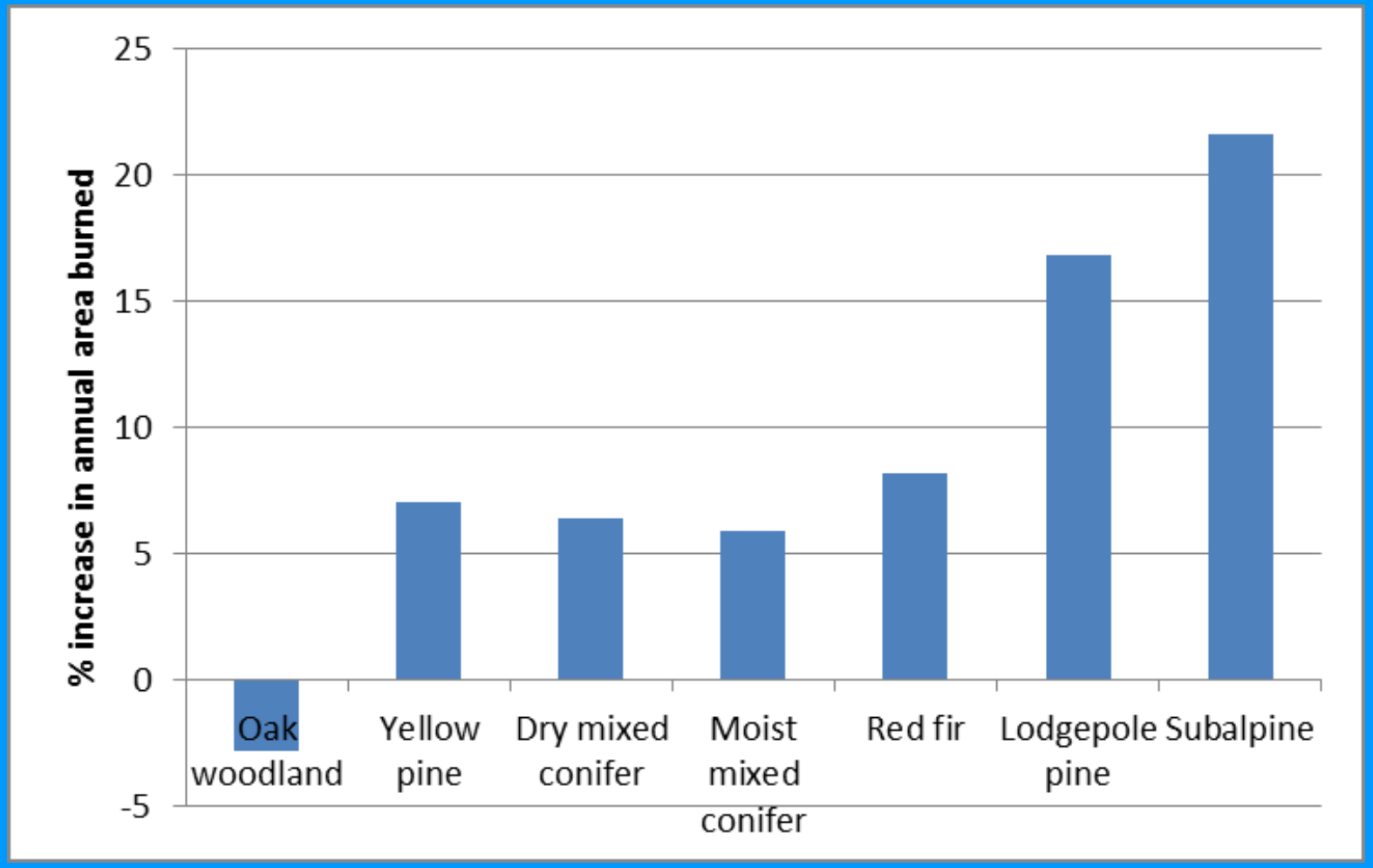
On Forest Service lands: Fire severity is increasing in low elevation forests (yellow pine, mixed conifer) but not in high elevation forests



Percent of annual area burned where tree mortality is ≥95%

Miller et al. 2009, Miller & Safford 2012, Mallek et al. 2013

Worrisome trend: overall burned area is (proportionally) increasing more rapidly in high elevation forests



Overall increase in median annual area burned, 1984-2009

Mallek et al. 2013

Future fire trends: All models project increases in fire activity in the Sierra Nevada

WILDLIFE

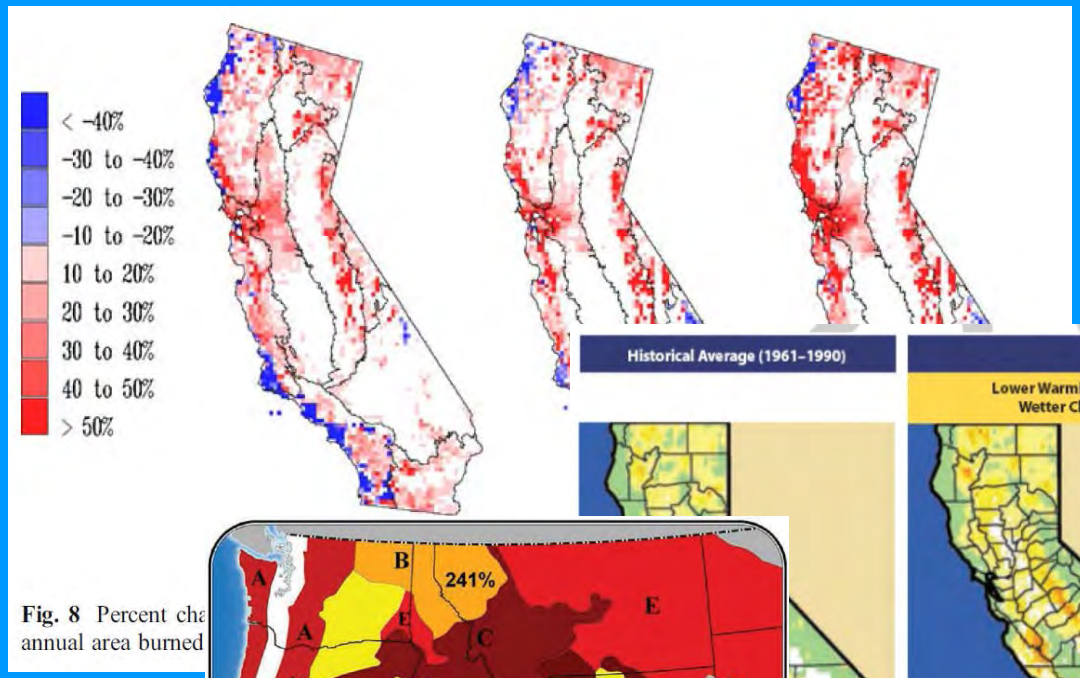
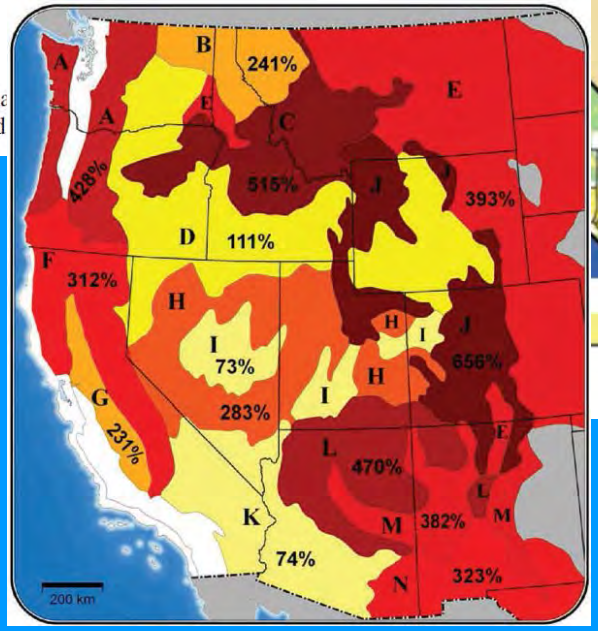
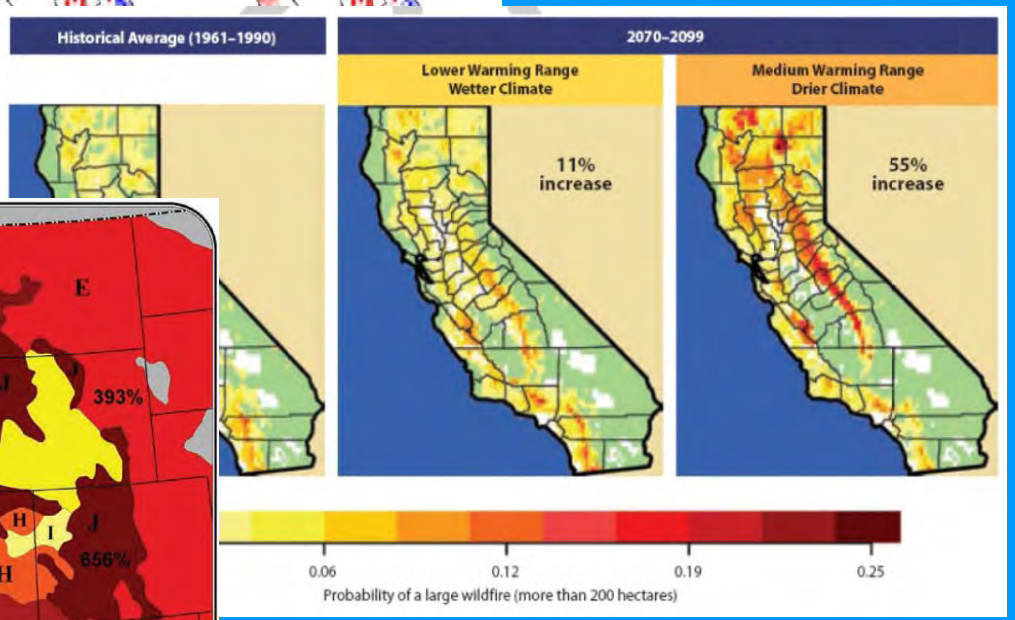


Fig. 8 Percent cha
annual area burned



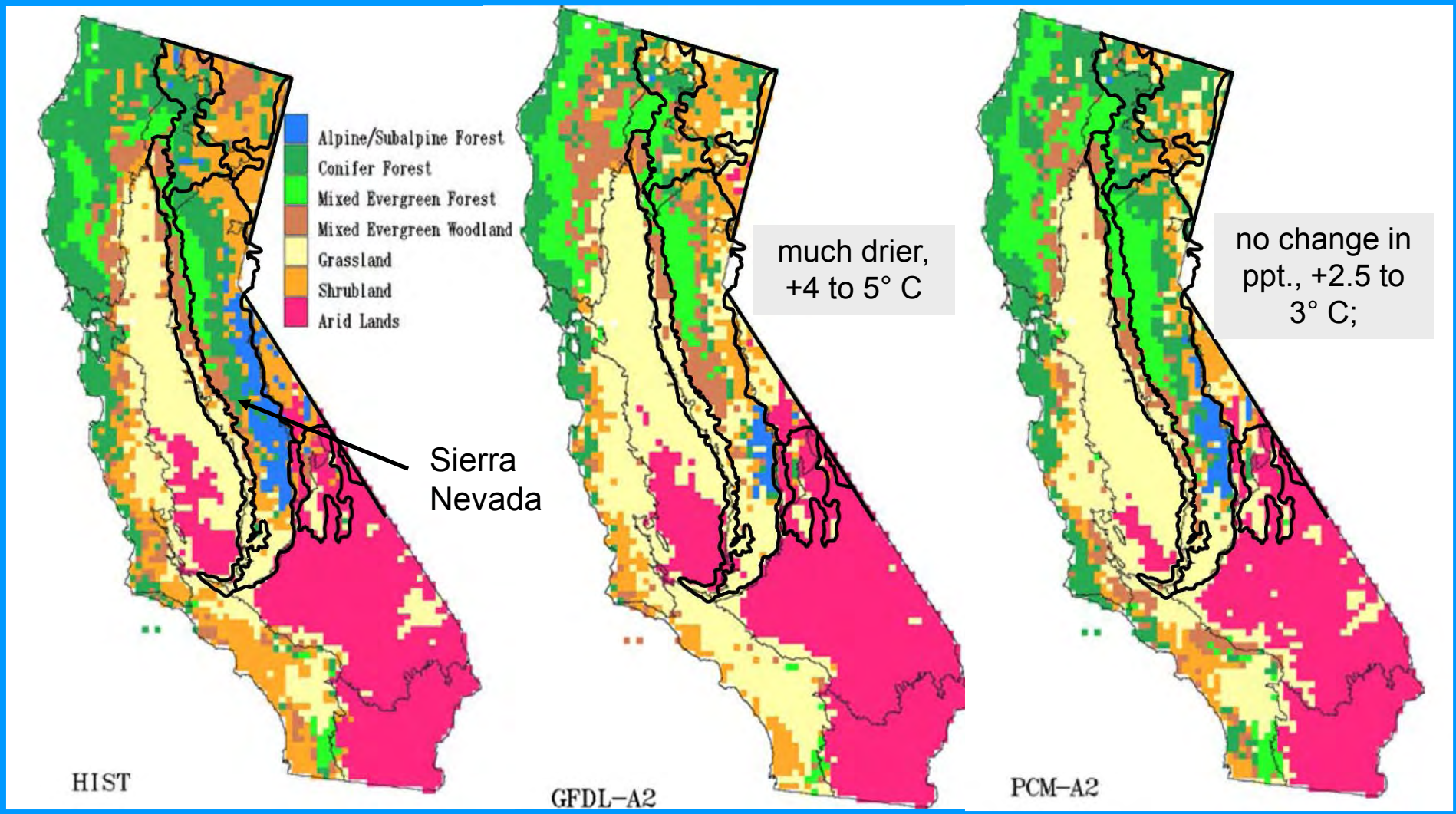


Fire summary

FIRE

1. Wildfires in California forests are becoming more frequent and larger
2. Annual burned area is increasing across most vegetation types
3. Fire severity is increasing in semi-arid forestlands (“fuel-limited” types), but not changing (yet) in wetter and/or higher elevation forests or in southern California chaparral (“climate-limited” types)
4. Future projections are for more frequent, larger, and more intense wildfires

Ecological implications of future fire regimes I. Vegetation

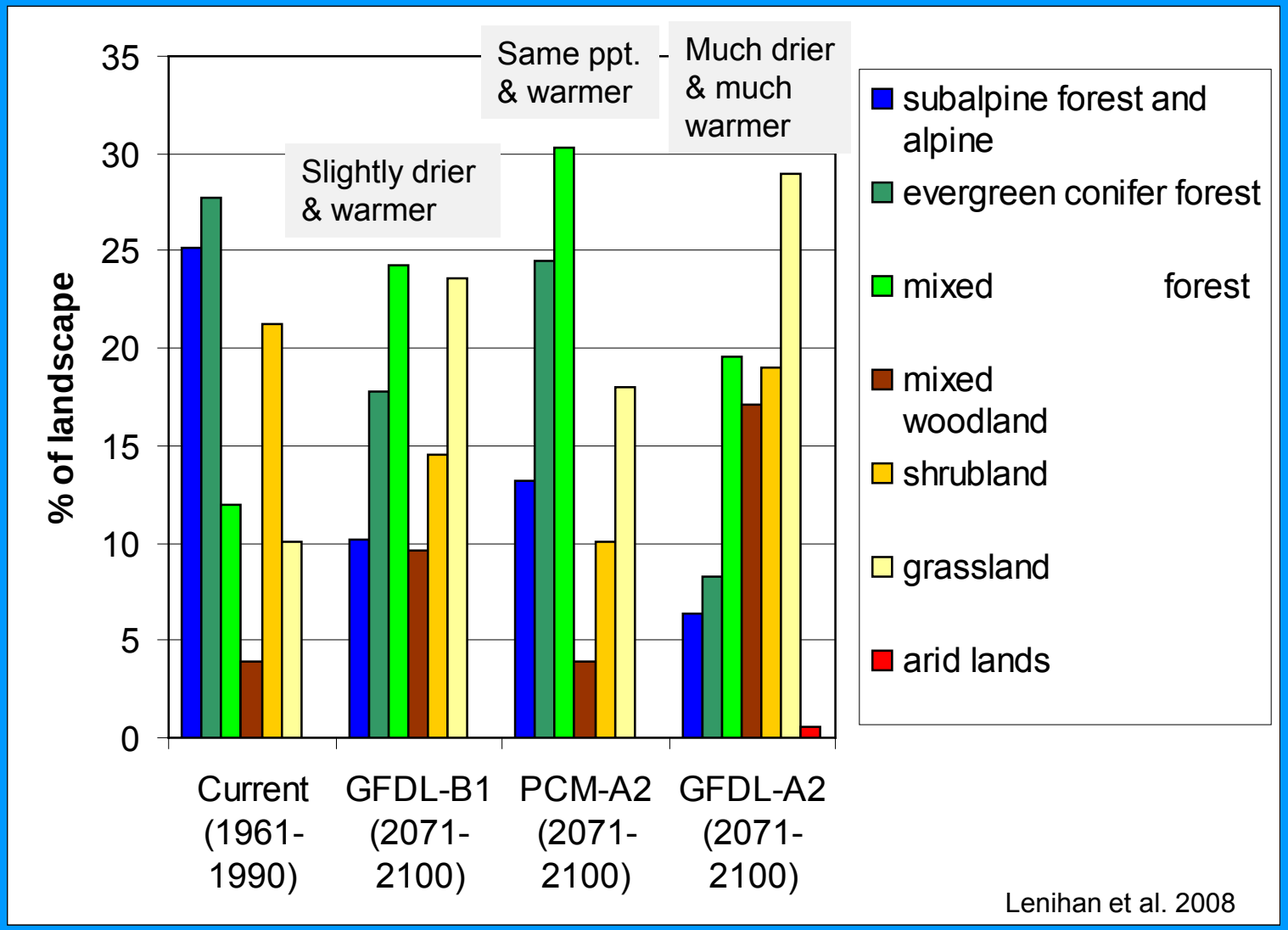


Lenihan et al. 2008

Interactions between climate change and fire are projected to have major effects on California vegetation

VEGETATION

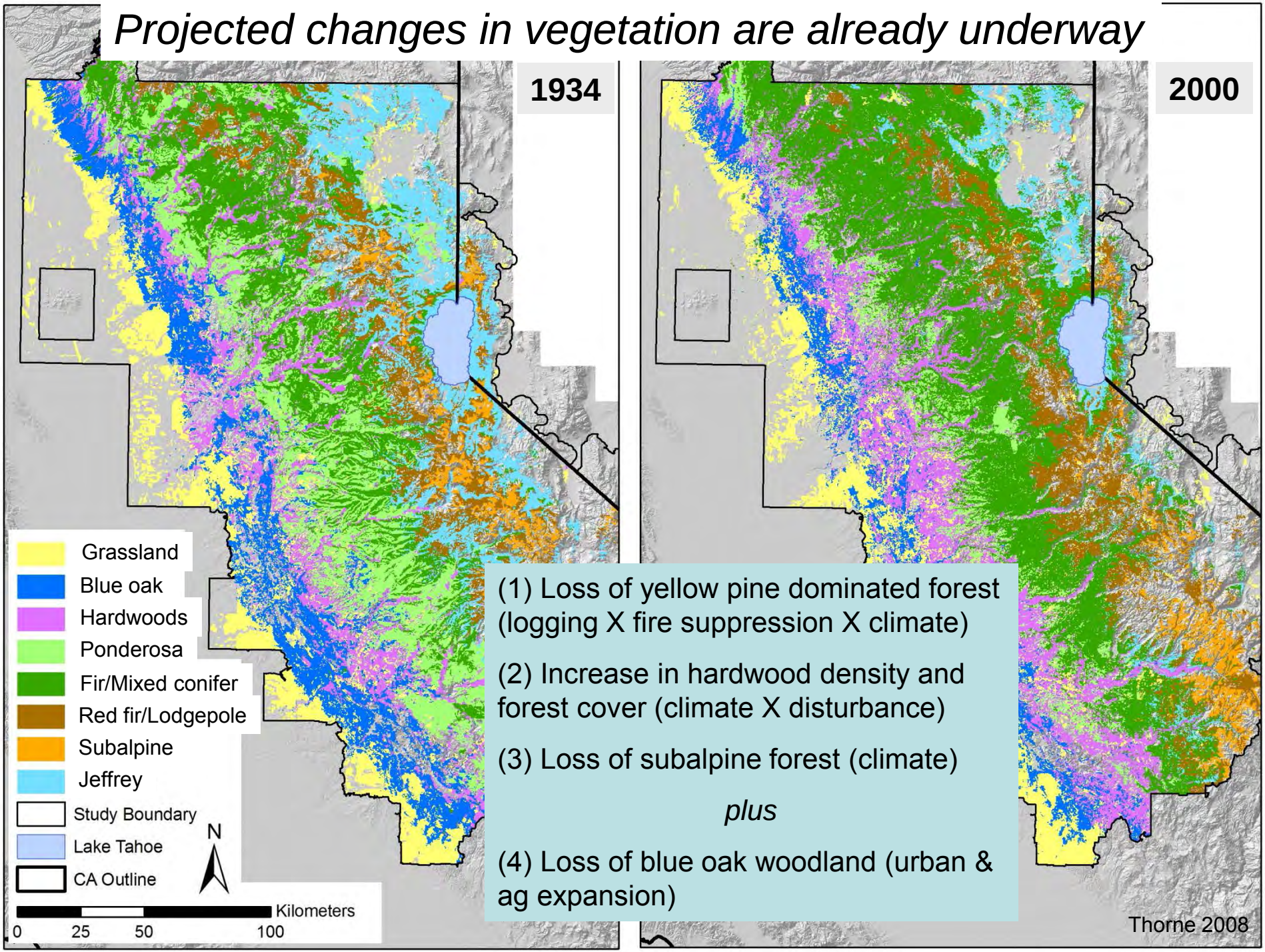
Sierra Nevada Ecoregion



Lenihan et al. 2008

Increase in hardwood types, loss in conifer forest; increase in grassland; major loss of subalpine forest

Projected changes in vegetation are already underway



Interactions among fire, insects, disease, drought, pollution, and other stressors are provoking vegetation changes across California

Forestland to shrubland and grassland

Jeffrey pine killed by fire near San Diego, 6 yrs post-fire with no regeneration: fire X temperature X drought X pine beetles

Loss of piñon pine near Topaz Lake, western Great Basin: invasive species X fire X pine beetles

Sierra Nevada forest mortality due to insects and disease rose over 300% between 2013 and 2014

Forestland to shrubland

Repeated wildfire reducing forest to shrubland: fire X temperature X drought

Shrubland to grassland

Frequent anthropogenic fire reducing coastal sage scrub to grassland: fire X exotic species X drought

Fire suppression: in much of the Sierra Nevada, lack of fire is just as serious an ecosystem disturbance as uncharacteristically severe fire

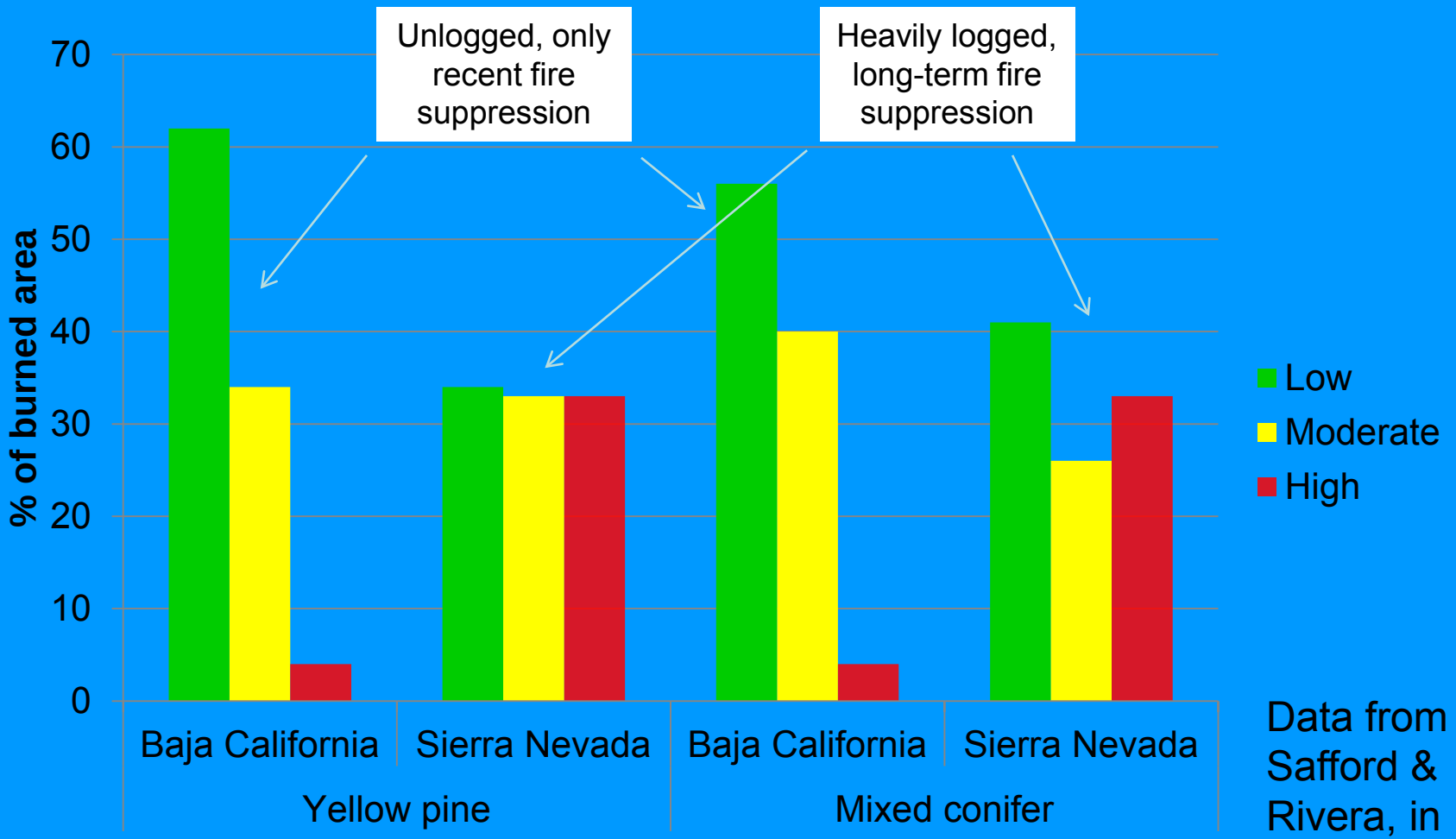
Pine forest to fir forest

Loss of large pine dominance in many montane forests: lack of fire X water stress

Meadow to forestland

Meadows being invaded by conifers: lack of fire X decreasing snowpack X grazing

Fire severity comparison, Baja California reference conditions vs Sierra Nevada, 1984-2010



Data from Safford & Rivera, in prep.

Sierra Nevada data from Miller et al. 2009, Miller and Safford 2012; YP = average of eastside pine and ponder

Vegetation summary

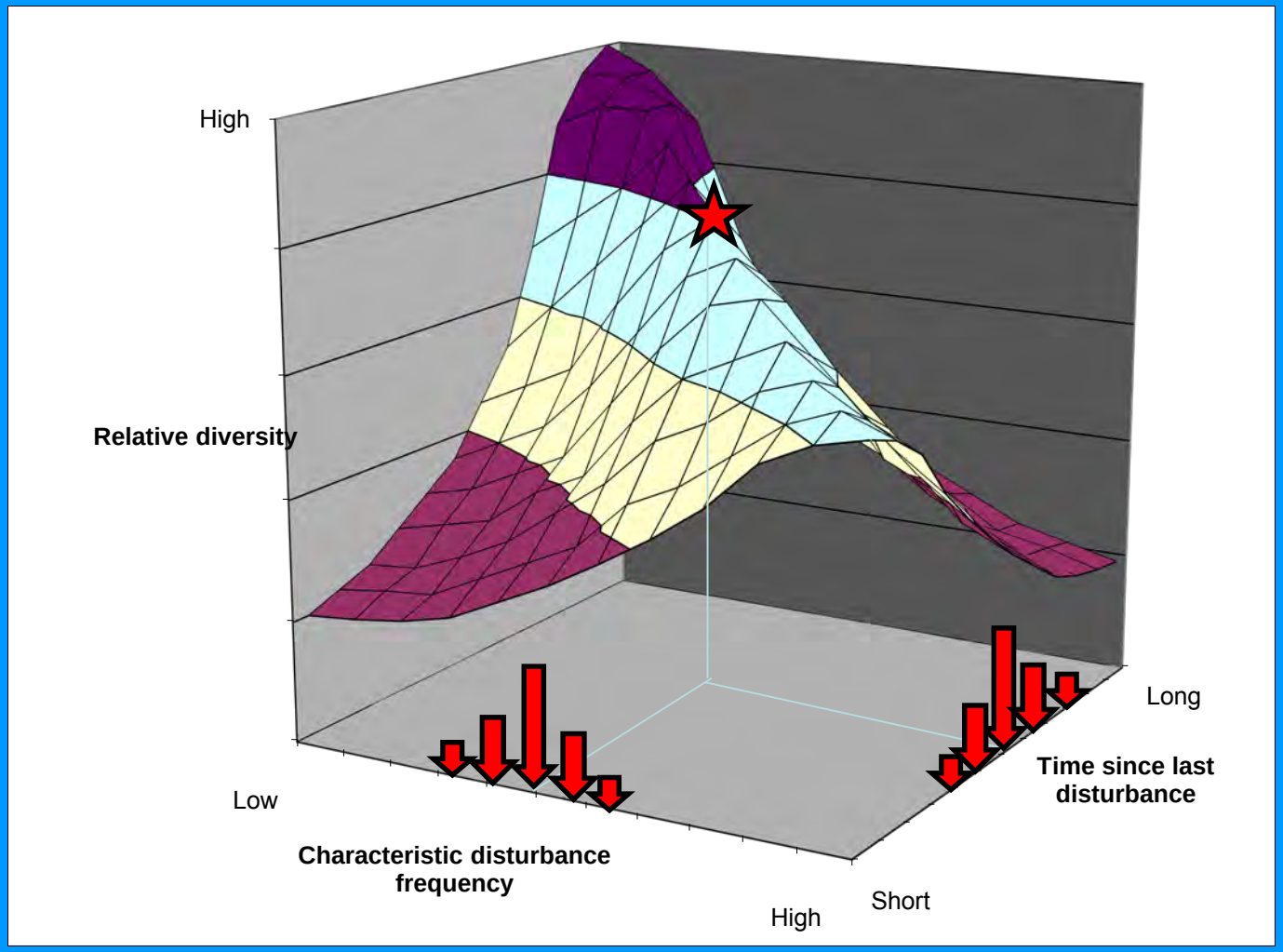
VEGETATION

1. Fire will interact with climate and other factors to provoke major changes in vegetation; projected changes are already occurring
2. As high severity area and patch size increase, and as summer droughts deepen, regeneration of some conifer species will become progressively more difficult
3. Given sufficient precip., hardwood species will replace many lower elevation conifer forests after disturbance
4. Many areas of persistent shrubland that succeeded to conifers under fire suppression may return to shrubs
5. Major expansion of grassland is projected for much of California due to frequent fires in forests and shrublands
6. Densification of subalpine forests and expansion of subalpine trees into previously “permanent” snowfields may increase continuity of subalpine fuels

Ecological implications of future fire regimes II. Biodiversity

BIODIVERSITY

Species adapt to fill niches created by an ecosystem's "characteristic" disturbance regime.



Denslow 1985, Milchunas et al. 1988, Huston 1994

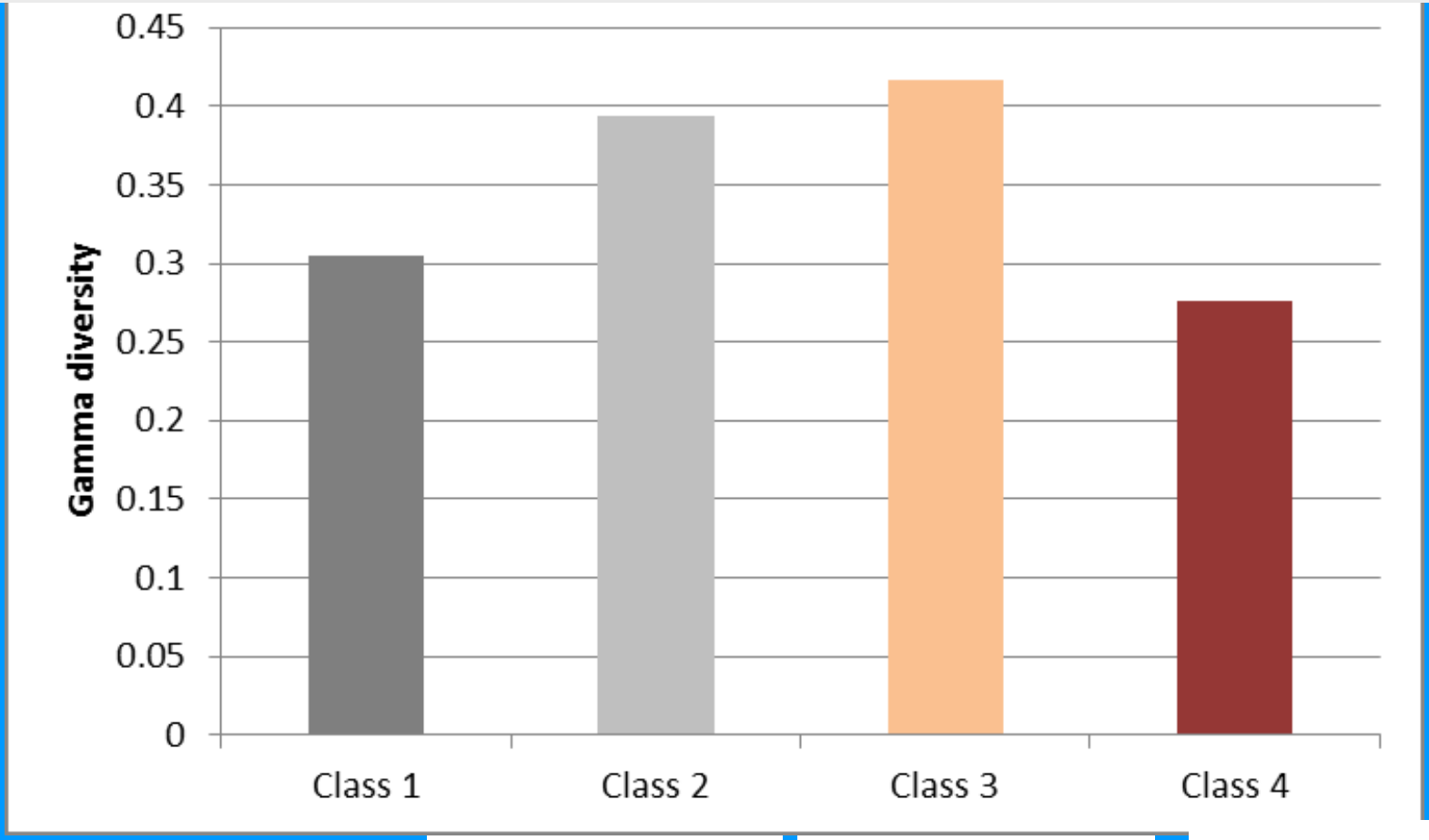
California yellow pine & mixed conifer forests are adapted to frequent fires of predominantly low to moderate severity

Most species are best adapted to this fire regime

100 yrs of fire suppression

Overall species numbers on the landscape ("gamma diversity") are highest in the areas of low and moderate severity disturbance

Data from 12 fires, mixed conifer forest, Sierra Nevada + S. California



Stevens, Safford, & Latimer, in review

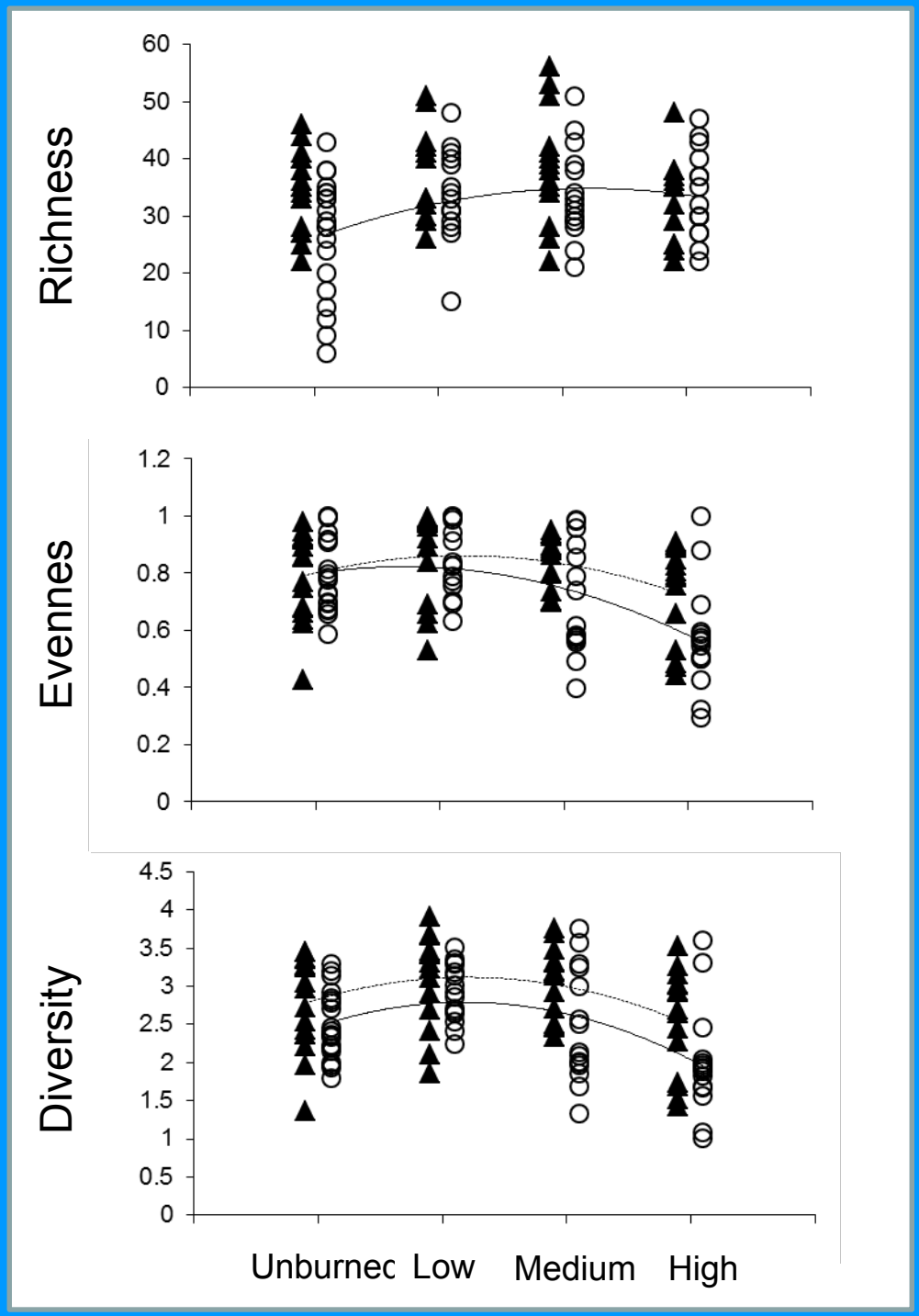
No disturbance

"Light-moderate" disturbance

"Light-moderate" disturbance + fire

No treatment + wildfire ≈ high severity

Postfire plant diversity: Rich Fire 2008, Plumas National Forest



130 800-m^2 plots, sampled in 2013

DeSiervo, Jules, and Safford, in press

Biodiversity summary

BIODIVERSITY

1. For a given ecosystem, species diversity should be highest under some "characteristic" regime of disturbance, due to evolutionary responses to disturbance selection. In YPMC forests, highest plant diversity is in low-moderate severity burns
2. Continued and exacerbated departure from historically "characteristic" disturbance regimes (i.e., the lack of low-moderate severity fire and the surplus of high severity fire) will have negative consequences for native biodiversity
3. The occurrence of uncharacteristically *infrequent* and *severe* fire in yellow pine and mixed conifer forests is the most important land management issue in the Sierra Nevada; it will require major economic and political investment, and the reinvigoration of fire as a major ecosystem process

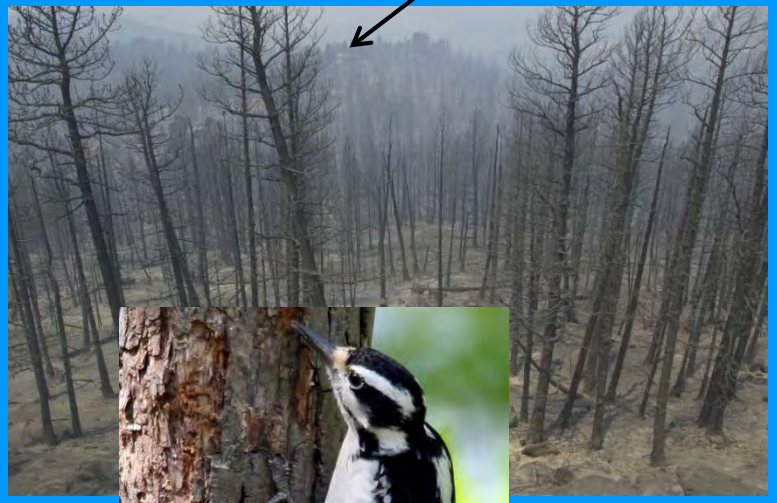
Ecological implications of future fire regimes III. Wildlife habitat

WILDLIFE

Two stories:

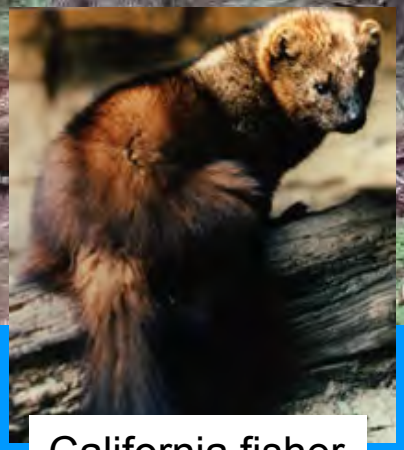
Old forest obligates

Postfire specialists



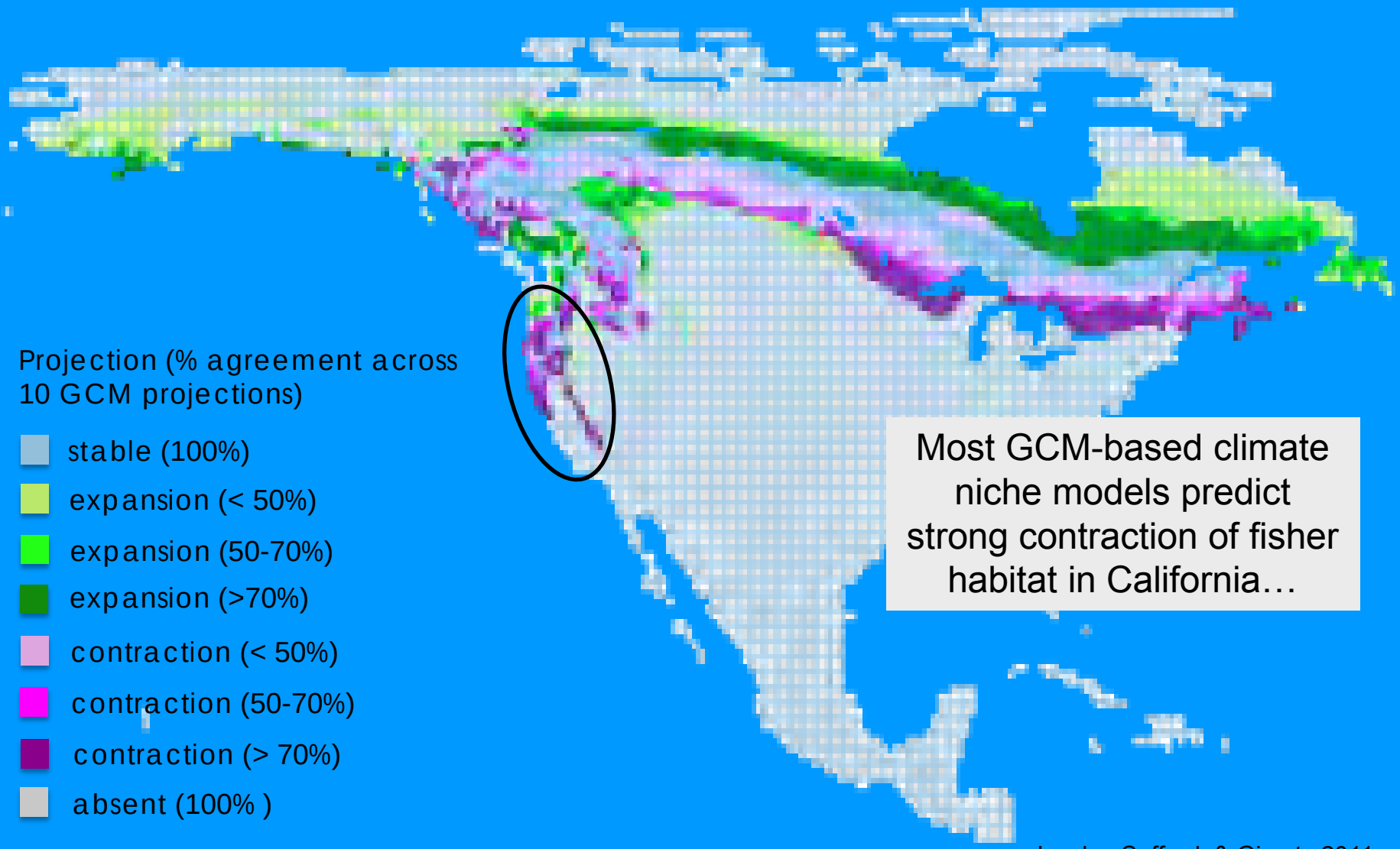
Woodpecker species

Spotted owl



California fisher

Old forest obligates: projected outcomes of climate change for Fisher (Martes pennanti)



Most GCM-based climate niche models predict strong contraction of fisher habitat in California…

Lawlor, Safford, & Girvetz 2011

WILDLIFE

…but these projections ignore the effects of future fire regimes, which will exacerbate the problem

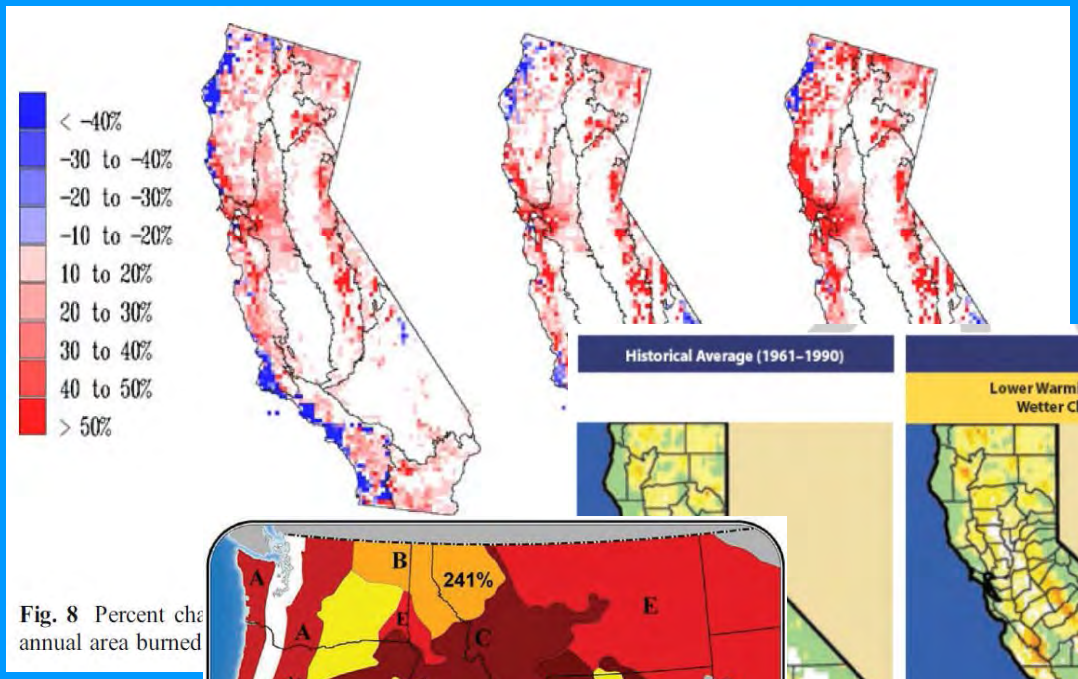


Fig. 8 Percent cha
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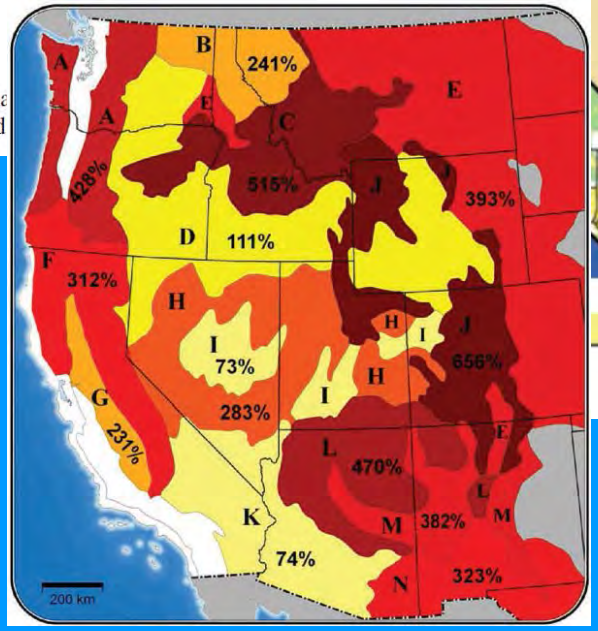
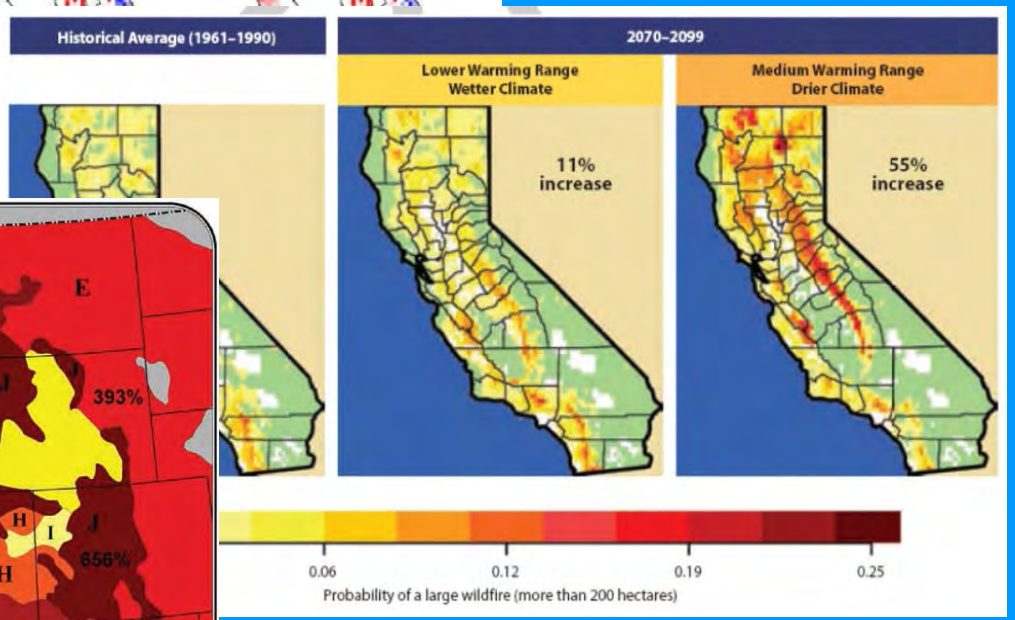
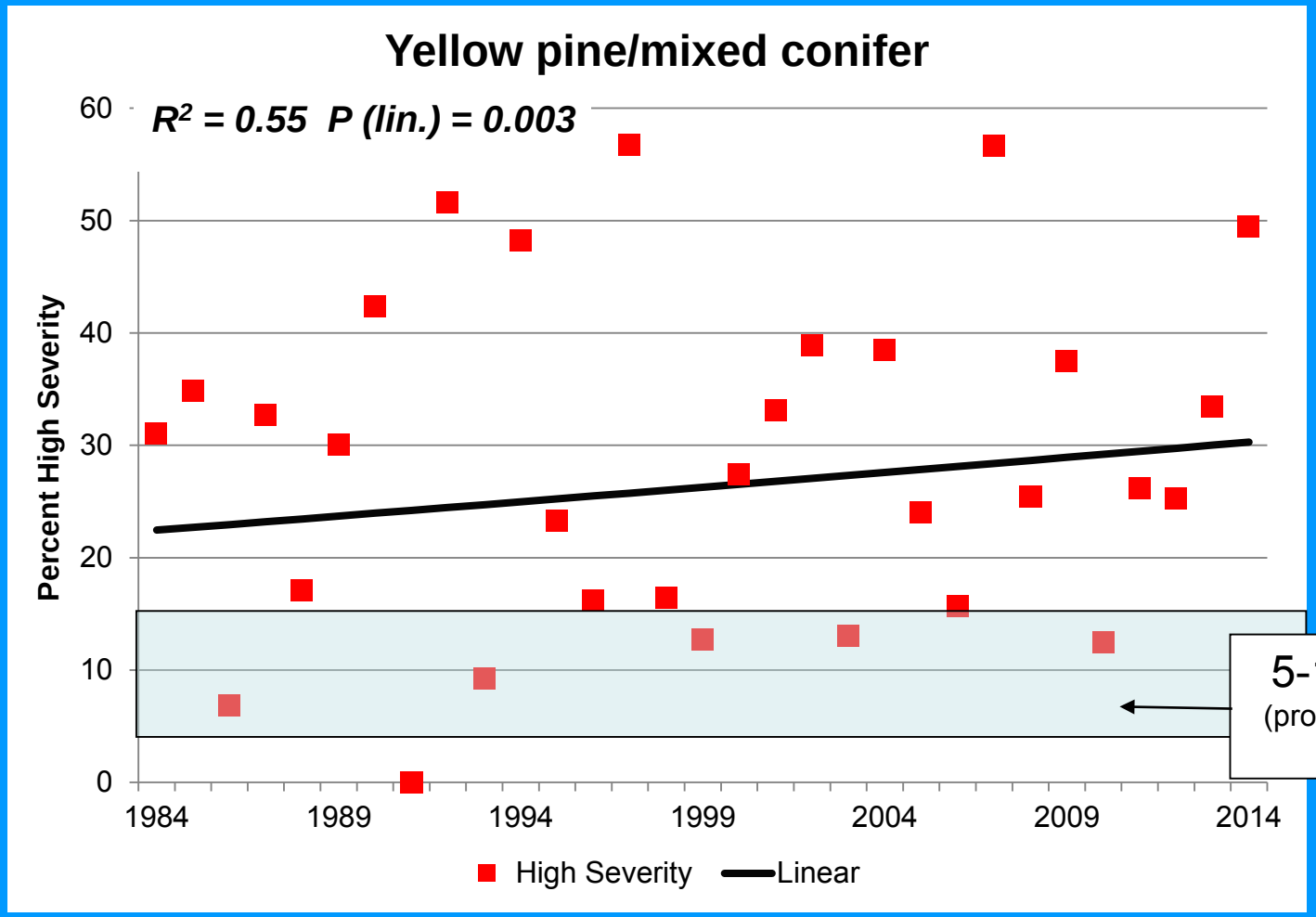




Predicted increases in fire intensity/severity are well-underway in the Sierra Nevada

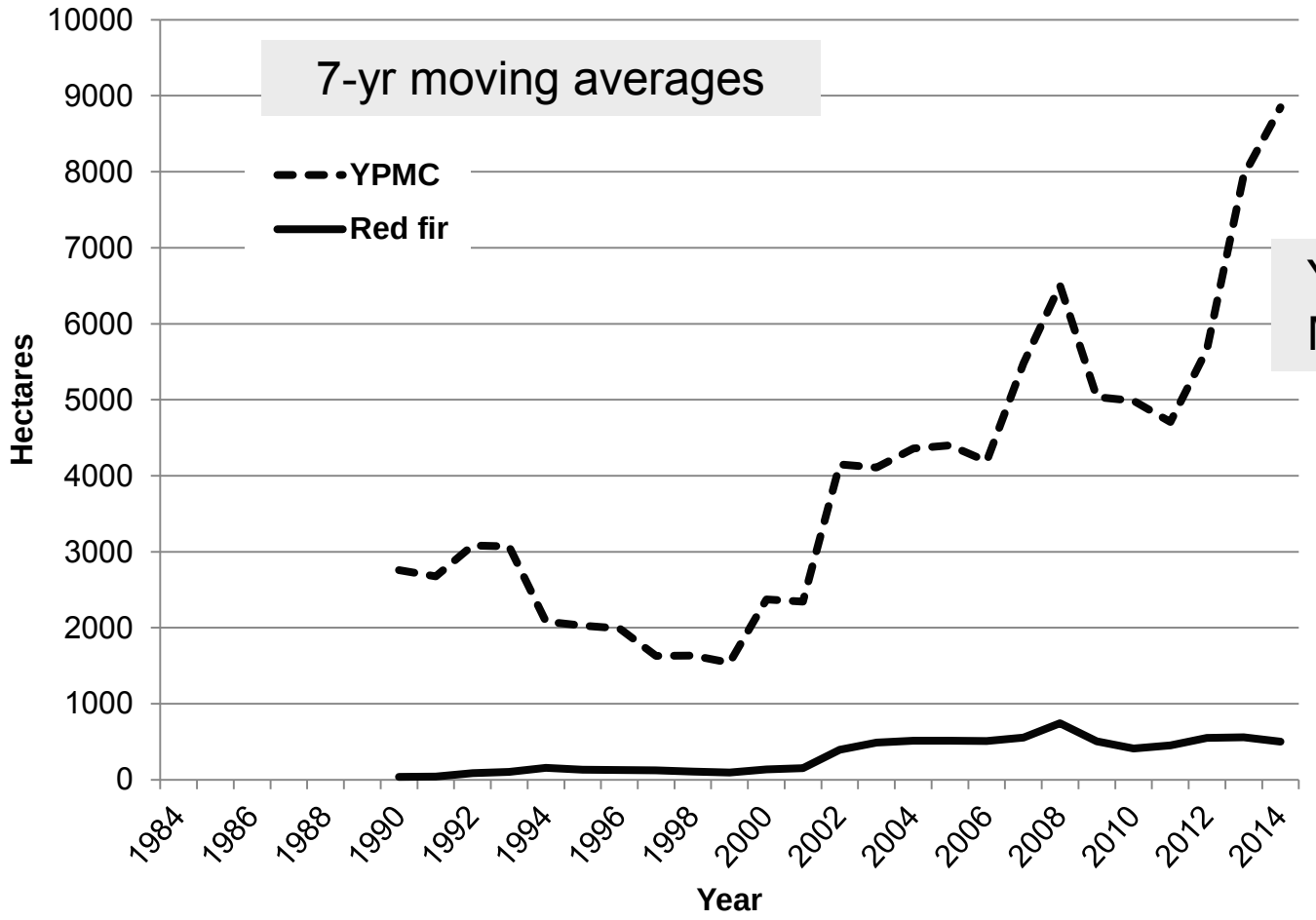
WILDLIFE



Data courtesy of Jay Miller, USFS

WILDLIFE

The mean annual area of stand-replacing fire is increasing = more habitat for snag-dependent species, less habitat for old-growth species



Data courtesy of Jay Milller, USFS

Wildlife summary

WILDLIFE

1. Current trends in fire regimes pose a growing challenge to species that require dense, old forest habitat during some part of their life cycle
2. Other direct and indirect effects of climate warming will increase stress on these species
3. At the level of the Sierra Nevada as a whole, current production of snag habitat through high severity fire is near levels characteristic of the pre-Euroamerican settlement period, and trends in high severity habitat creation are strongly upward
4. If current climate and fire trends continue, habitat for old forest obligate species will retract, and habitat for postfire specialists will expand

Concluding thoughts

1. Climate warming, fire management, and a variety of ecological disturbances are interacting to create “threshold conditions” in many ecosystems in the Sierra Nevada
2. Current Federal and State resource mgt priorities include focus on “ecological restoration”, ecosystem services, and climate change adaptation and mitigation
3. Mgt. focus on “restoration” requires some critical thinking: past reference conditions may not be an appropriate end target for future ecosystems, but they are a useful waypoint. Principal focus should be on restoration of ecological processes and maintenance of ecosystem services

Concluding thoughts

4. Insect outbreaks and disease are causing major ecosystem change in the western US; thus far the Sierra Nevada has only been moderately affected, but recent drought is greatly increasing mortality
5. Unless we reverse climate warming, dramatic changes in California mountain ecosystems are inevitable (and are already occurring). Reasoned management can change outcomes in some cases, and help “soften the landing” in others
6. Habitat for old forest obligate species will be very difficult to maintain under likely future climate and fire regimes. There is currently little consensus on what to do

Concluding thoughts

7. Past emphasis on all-out fire suppression is waning, but use of wildland fire for ecological benefit is still the exception rather than the rule. Use of purely mechanical means to reduce forest fuels and increase forest resilience to warming is an important component, but it will not solve the problem on its own

8. We should adopt a more experimental, learning-focused approach to managing for global change and its effects. Humans learn experientially and mostly through unexpected outcomes. We don't know exactly what is going to happen but waiting around for it could be disastrous

Concluding thoughts

9. Response to all of these issues will require unprecedented integration of science, management, and public participation, but environmental problems rarely attract public interest or investment until they become catastrophes…

Thank you