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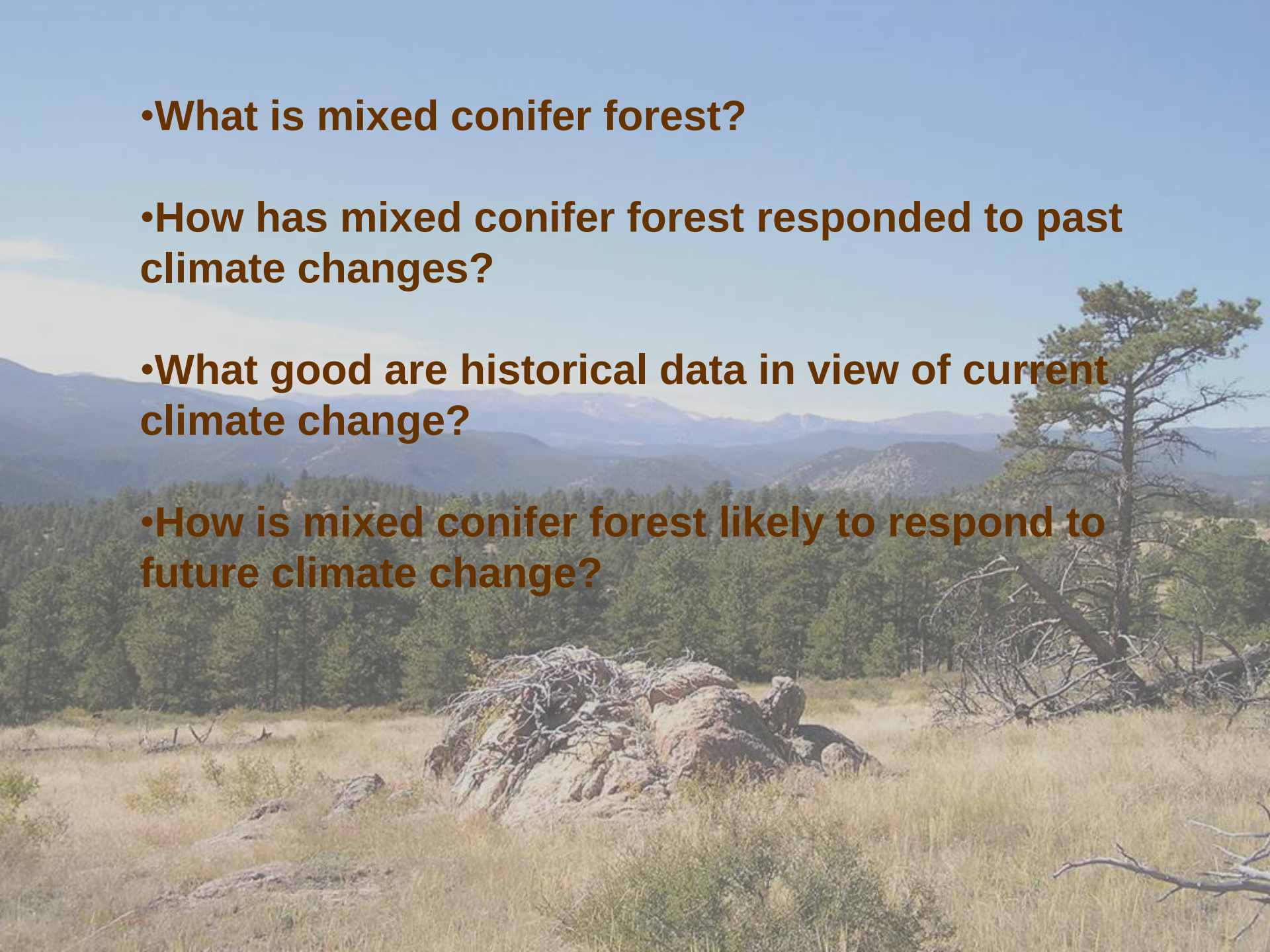
- Silence your cell phone and other devices
- Mute the dial-in phone except to ask questions
- Use the “raise hand” feature on your computer to ask questions

United States Department of Agriculture – Forest Service
Rocky Mountain Research Station

Mixed conifer forests, disturbances and climate change: lessons from the last 1000 years in the Colorado Front Range

Laurie S. Huckaby

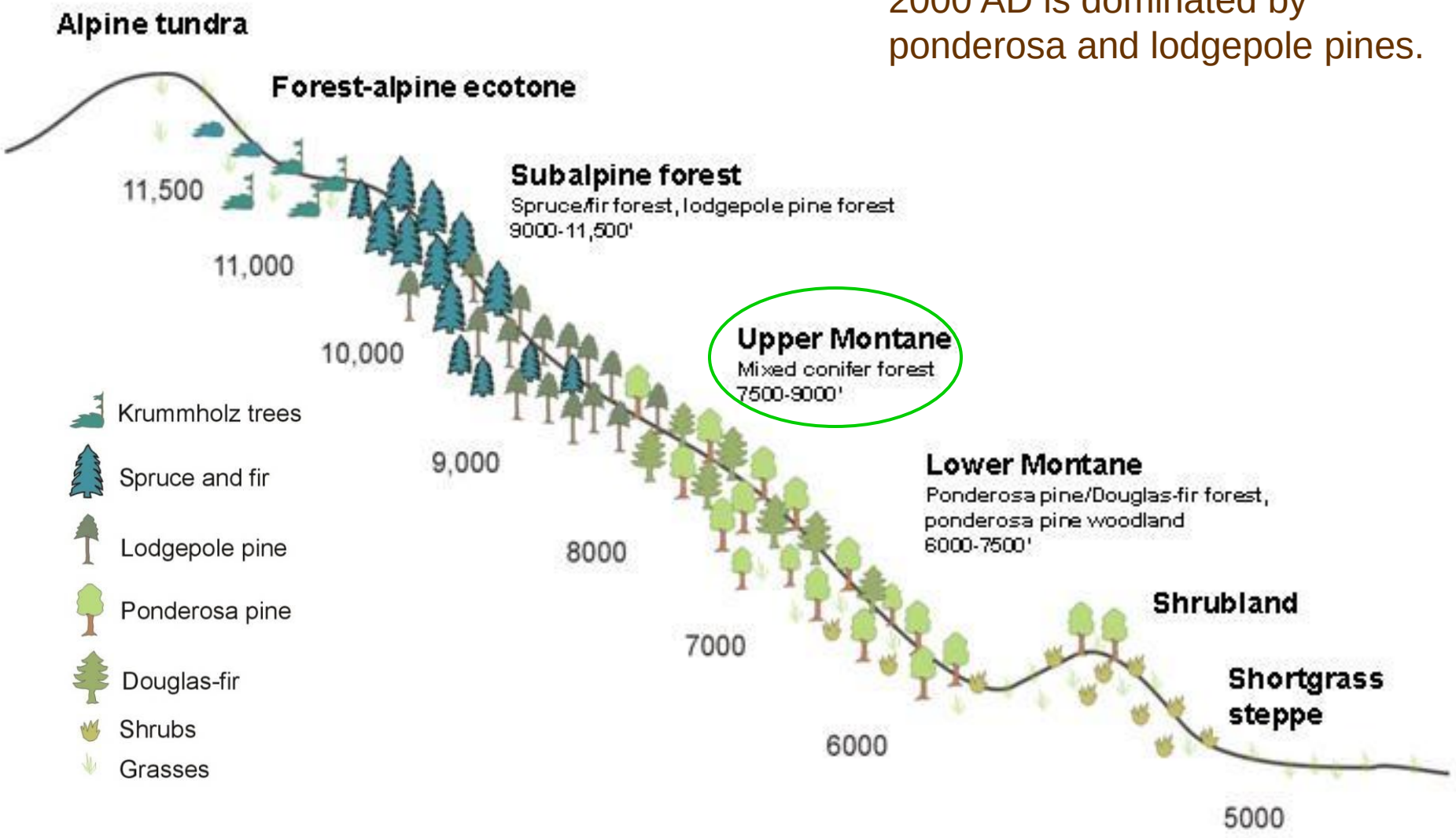


- What is mixed conifer forest?
- How has mixed conifer forest responded to past climate changes?
- What good are historical data in view of current climate change?
- How is mixed conifer forest likely to respond to future climate change?

Mixed conifer landscapes occur at mid-elevations in most western mountain ranges. They are characterized by complex mosaics of vegetation created by topography, climate and disturbances at varying scales in space and time.

Mixed severity fire regimes include both surface and stand-replacing components, sometimes within the same event. We detected them using a combination of fire scars and groupings of tree ages (live and dead). Some cohorts appeared to be linked to fire dates (usually in lodgepole pine); some were not (usually in ponderosa pine).

Front Range mixed conifer 2000 AD is dominated by ponderosa and lodgepole pines.

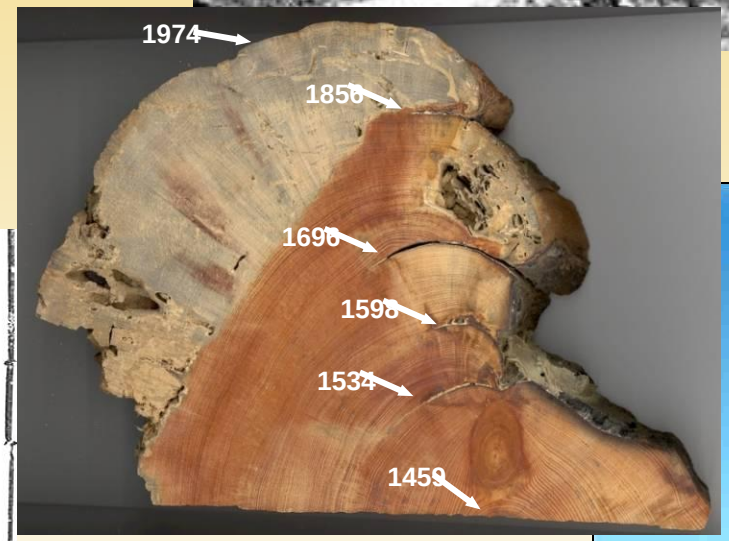


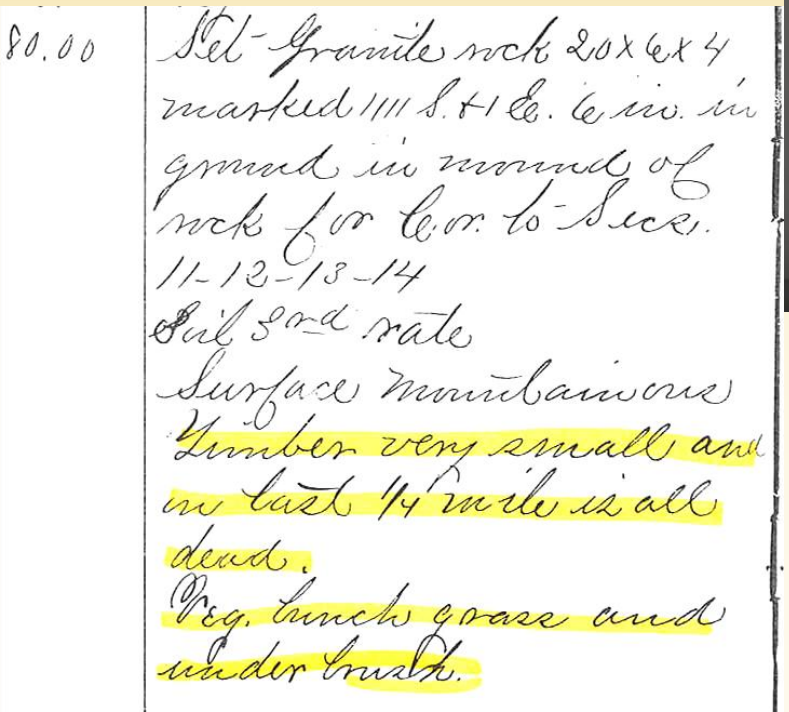
Elevational gradient of ecosystems in the Colorado Front Range in the 20th century. Approximate elevations in feet. Mixed conifer forest includes ponderosa pine, lodgepole pine, limber pine, Douglas-fir, aspen and small amounts of juniper, spruce and fir.

Historical Ecology

1. How did things get to be the way they are?
2. What processes interacted?
3. What was the role of climate and disturbance?
4. How did human land use change things?
5. How are changes in climate and land use likely to affect future fire and forests?

How can we manage forests to meet human needs and to be resilient in the face of disturbance and climate change?





Tools for reconstructing past landscapes:

1. Historical records
2. Historical photos
3. **Fire scars**
4. **Age structure**
5. Archaeology

A

MI

Original Study Objectives:

- To discover the spatial and temporal scales of historical disturbances, especially fire.

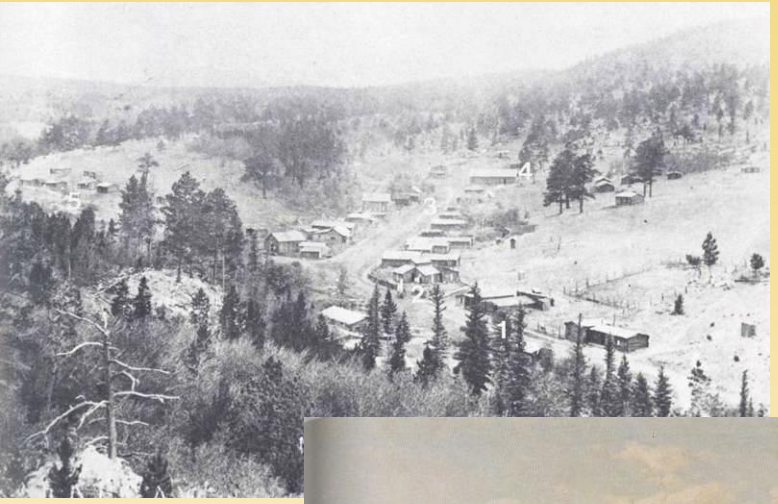
- To determine the stand and landscape structures of mixed conifer forests and the degree to which they are driven by disturbance history.

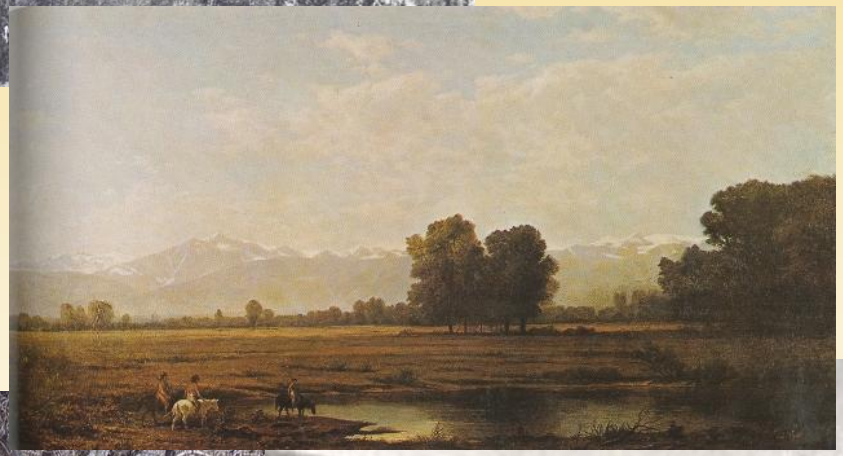
- To determine whether they are within their natural range of variability after a century of intensive human land use and to advise management on potential restoration activities.

What we found: a glimpse into the Medieval Warm Period, the effects of past climate changes on middle elevations, and the role of mixed conifer forests as a buffer for species and community response to climate change, with implications for the future.

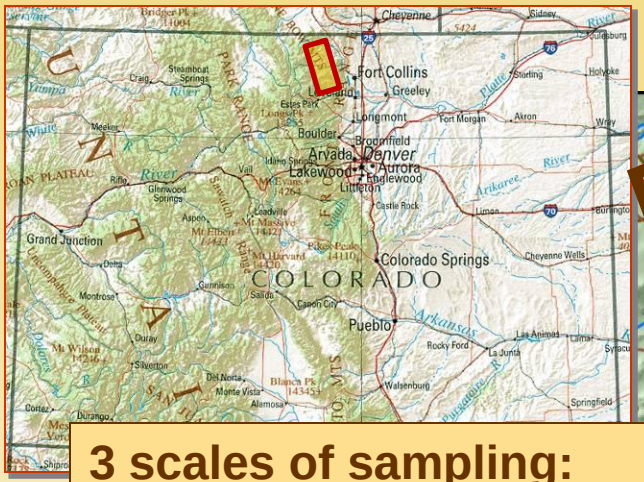
Land use history in Larimer county

Native Americans lived in the study area for at least 9000 years. Localized logging and widespread grazing occurred during the settlement era from 1860 onward, intensifying after 1879. Little mineral wealth was discovered and no railroad was built. Most of the study area was remote ranch land until around 1920. Logging, grazing, and recreation accompanied fire suppression during the 20th century.





Mixed conifer study area, Larimer County, Colorado

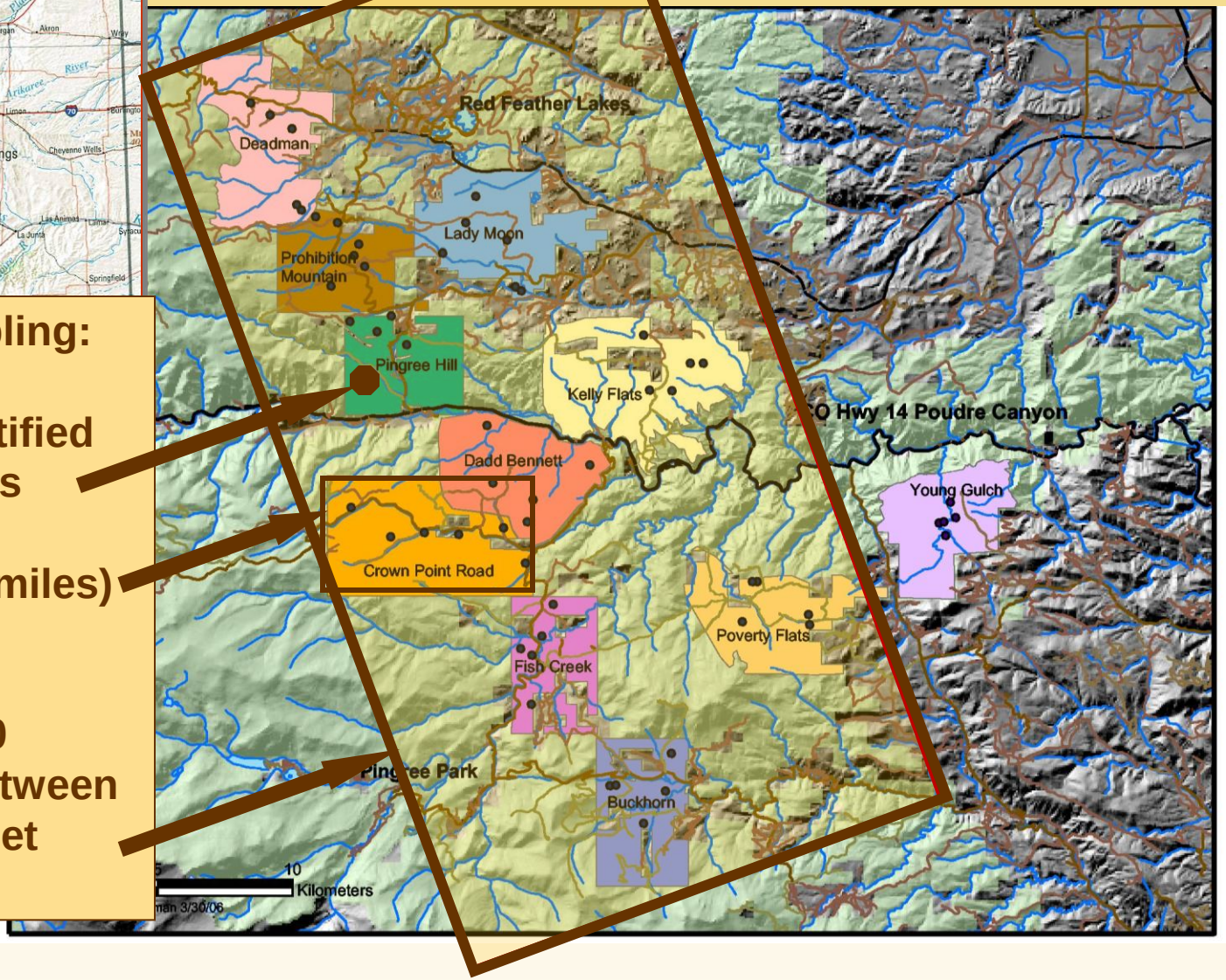


3 scales of sampling:

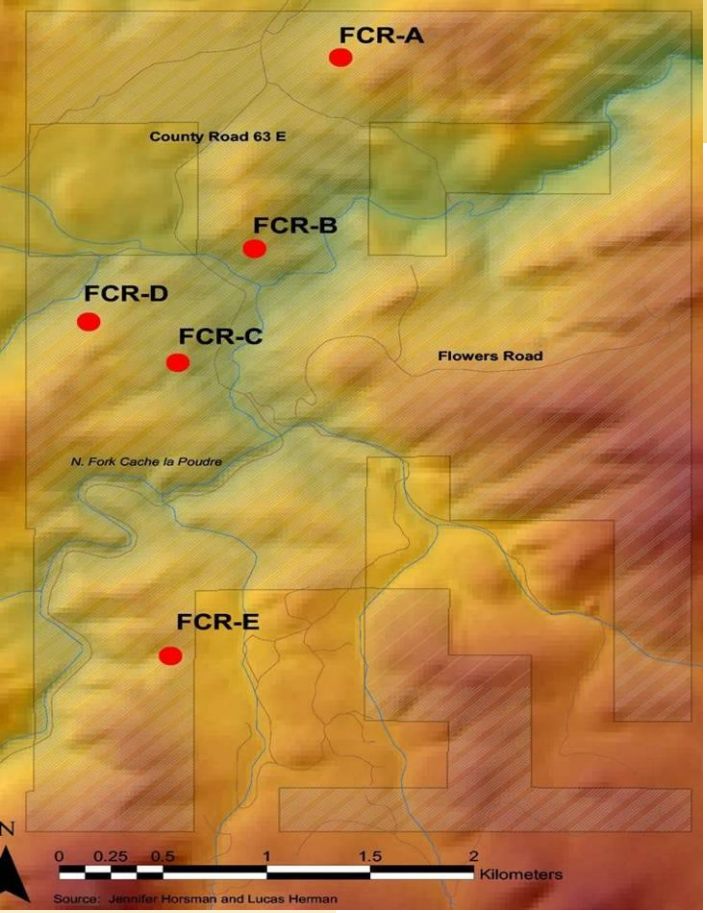
Plot (0.2 ha) stratified random—58 plots

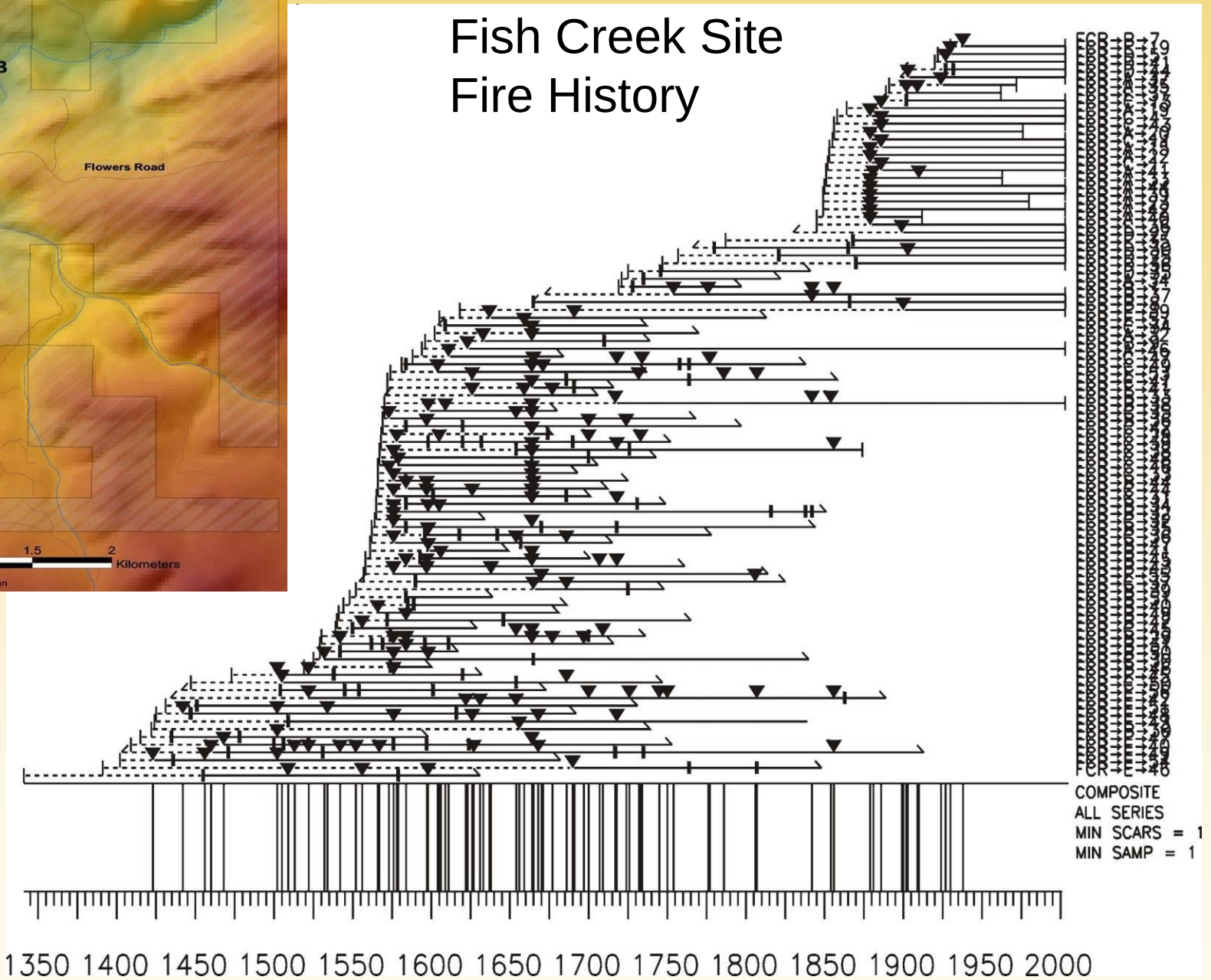
Site (4-7 square miles) 11 sites

Study Area (~300 square miles) between 7500 and 9000 feet elevation



Results: spatial variability in stand structure and fire history



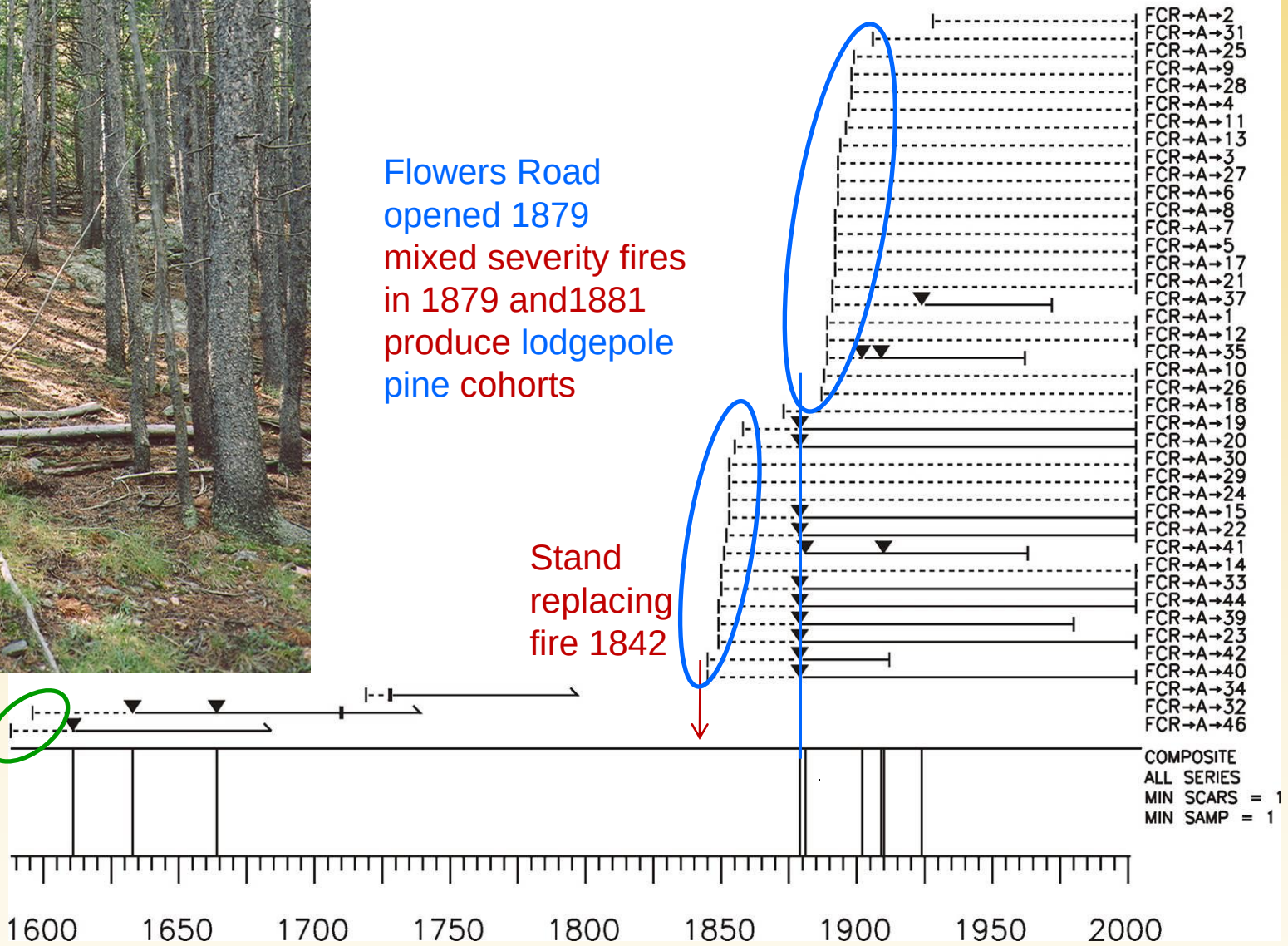


Fish Creek Plot A
Lodgepole pine mix
Fire History and Age Structure

Flowers Road
opened 1879
mixed severity fires
in 1879 and1881
produce lodgepole
pine cohorts

Stand
replacing
fire 1842

Sparse
ponderosa
pine



Fish Creek Plot B
Ponderosa pine
Fire History and Age Structure

Surface fires, episode of ponderosa pine establishment mid-1500s

Ponderosa pine establishment early 20th century

18th century gap in fire

Sparse ponderosa pine

FCR→B→4
FCR→B→23
FCR→B→14
FCR→B→3
FCR→B→7
FCR→B→7
FCR→B→24
FCR→B→5
FCR→B→18
FCR→B→10
FCR→B→21
FCR→B→22
FCR→B→11
FCR→B→15
FCR→B→26
FCR→B→13
FCR→B→17
FCR→B→19
FCR→B→16
FCR→B→12
FCR→B→6
FCR→B→1
FCR→B→37
FCR→B→8
FCR→B→20
FCR→B→9
FCR→B→38
FCR→B→33
FCR→B→36
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FCR→B→47
FCR→B→45
FCR→B→41
FCR→B→43
FCR→B→39
FCR→B→2
FCR→B→51
FCR→B→40
FCR→B→49
FCR→B→42
FCR→B→31
FCR→B→29
FCR→B→50
FCR→B→46
FCR→B→30

COMPOSITE
ALL SERIES
MIN SCARS = 1
MIN SAMP = 1

1450 1500 1550 1600 1650 1700 1750 1800 1850 1900 1950 2000

Fish Creek Plot C
Ponderosa pine
Fire History and Age Structure

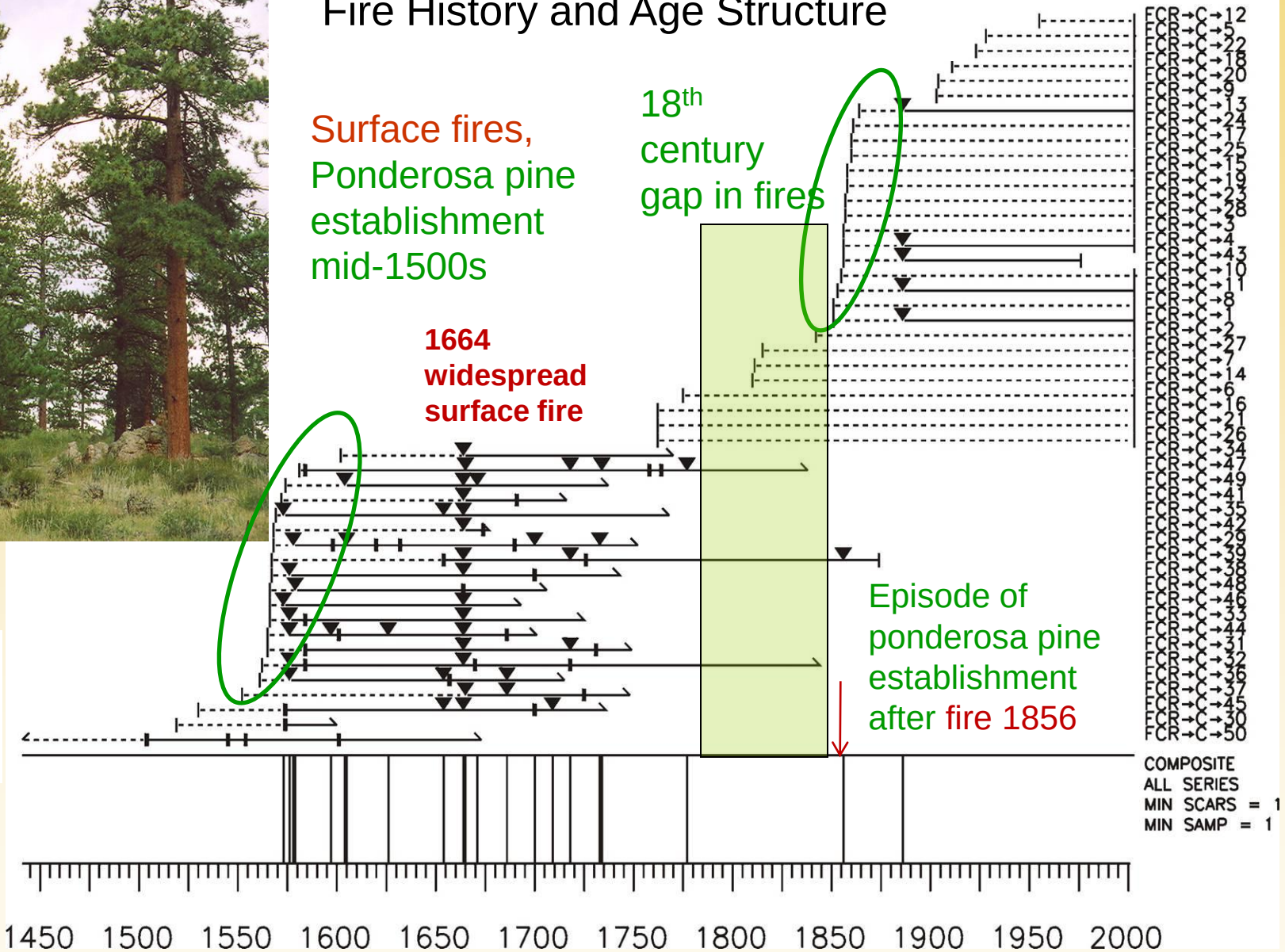
Surface fires, Ponderosa pine establishment mid-1500s

18th century gap in fires

1664 widespread surface fire

Episode of ponderosa pine establishment after fire 1856

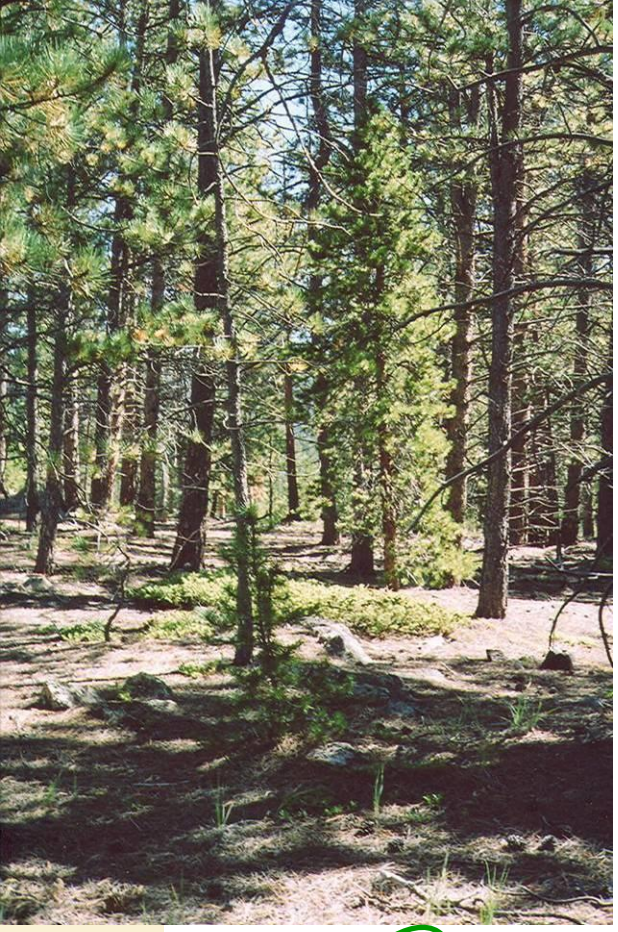
Sparse Ponderosa Pine



Fish Creek Plot D Douglas-fir mix Fire History and Age Structure

Mixed severity fire 1903, cohort of Douglas-fir and lodgepole pine

Douglas-fir stand, infrequent fire



Fish Creek Plot E Ponderosa pine mix Fire History and Age Structure

Stand-replacing fire 1856 or 1879; Flowers Road and mine 1879; dense ponderosa pine mixed cohort after fire

Ponderosa pine establishment late 1300s

Frequent surface fire and continuous age structure for 400 years

Sparse ponderosa pine

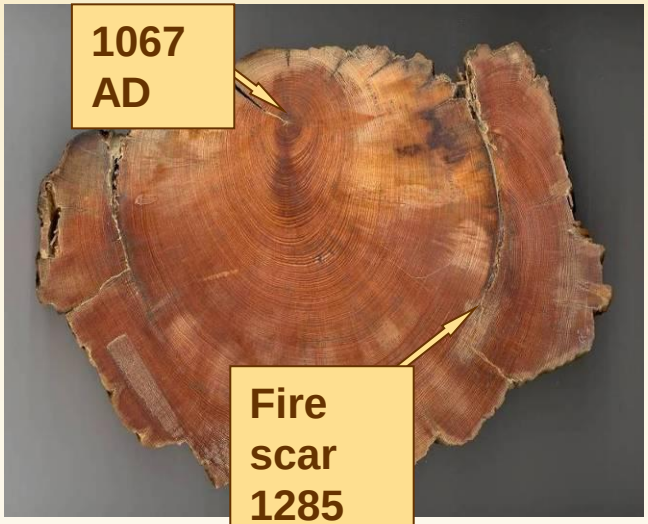
Results: the very long chronology

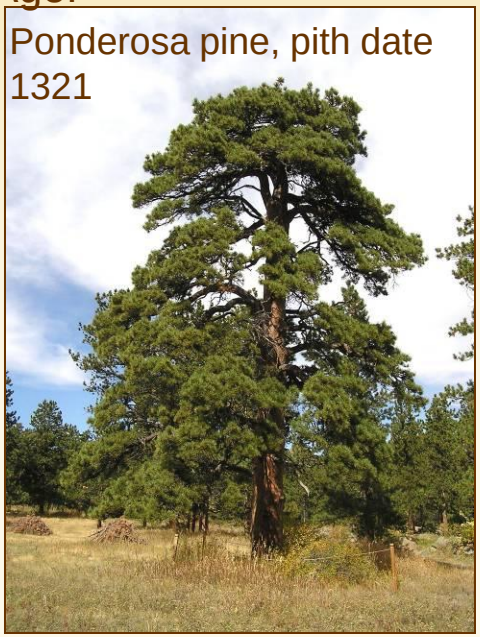
One of the longest chronologies in ponderosa pine:

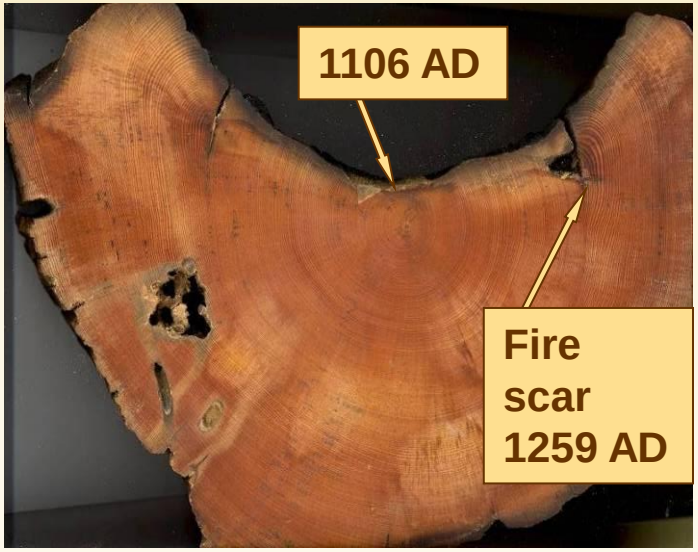
- 2571 pith dates
- 1038 fire-scarred samples from 58 sites
- 113 fire-scarred samples pre-date 1400.
- The earliest pith date: 1020 AD
- The earliest fire date: 1107 AD

Climatically driven episodes of tree establishment occurred in the early 1300s, the mid-1500s, the late 1700s and the early 20th century. Some of the early 1300s trees are still alive.

The Medieval Warm Period (800 AD to early 1300s) was warmer and drier than the 20th century and may be a better reference condition for future climate than the mid 19th century settlement period near the end of the Little Ice Age.




Ponderosa pine, pith date 1321



Question break

Results: Fire Regimes and Fire History

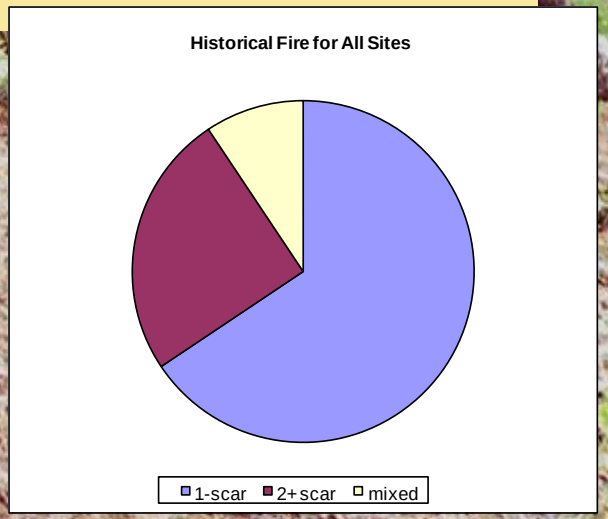
- Mixed severity fire regime: lots of surface fire, periodic mixed and stand-replacing fire with severe drought
- Fire behavior changed with changing climate over 1000 years

Mean Fire Interval (MFI) for all fires before 1400 AD= 6 years
MFI for all fires after 1400 AD=11 years

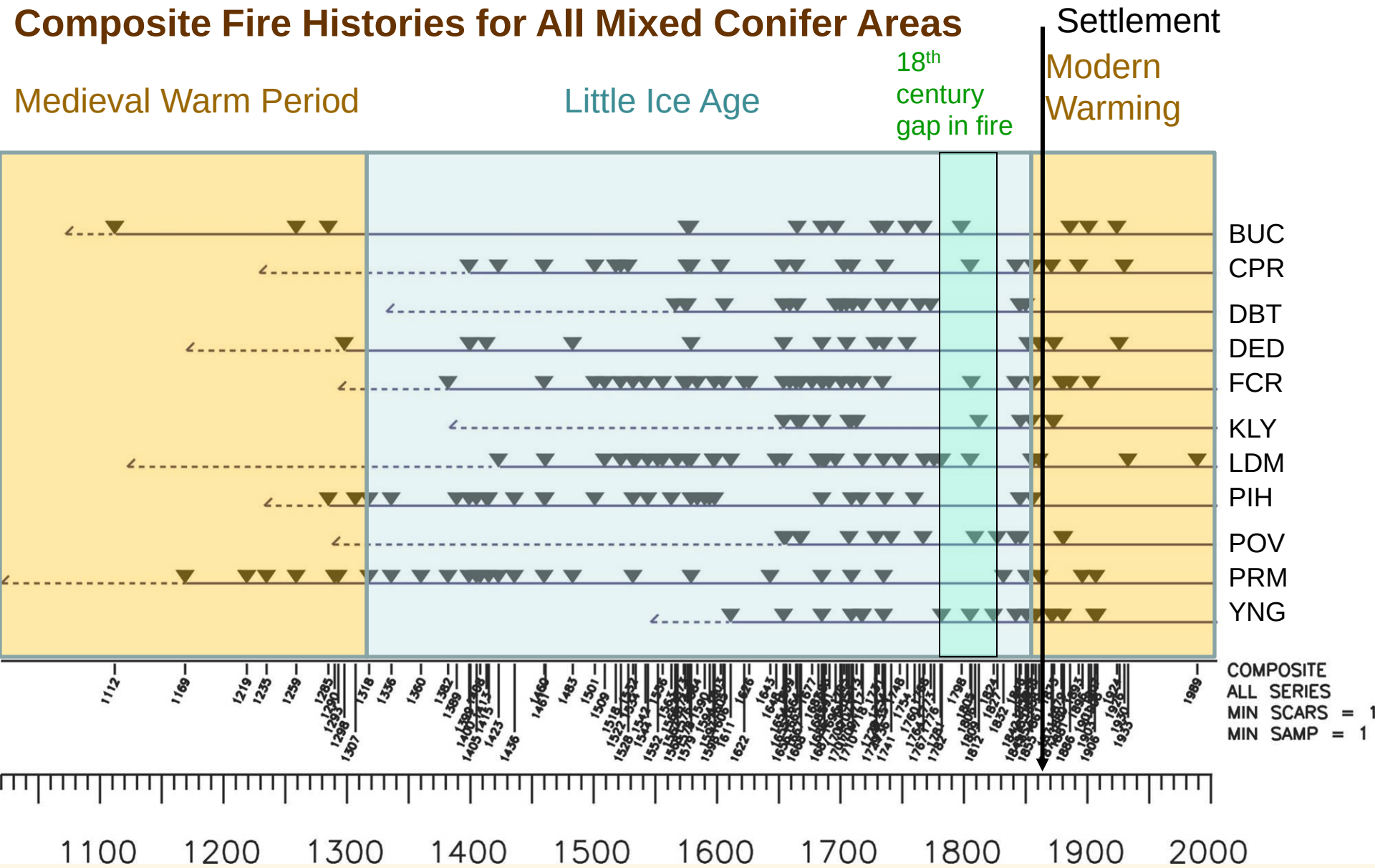
The first discernable stand-replacing fire that produced a post-fire cohort was in 1362 AD after the transition from Medieval Warm Period to Little Ice Age climate had begun.

Poudre Canyon acted as a fire barrier; different dates N and S of canyon
Most fires ceased around 1900 AD
Some sites burned through the 1930s

Most of the fires (about 65%) recorded in the study area over the last 900 years were localized, recorded by a single scar. More widespread fires recorded by 2 or more scars were about 28% of all fires. Mixed severity fires which produced cohorts of trees comprised about 15% of all fires.

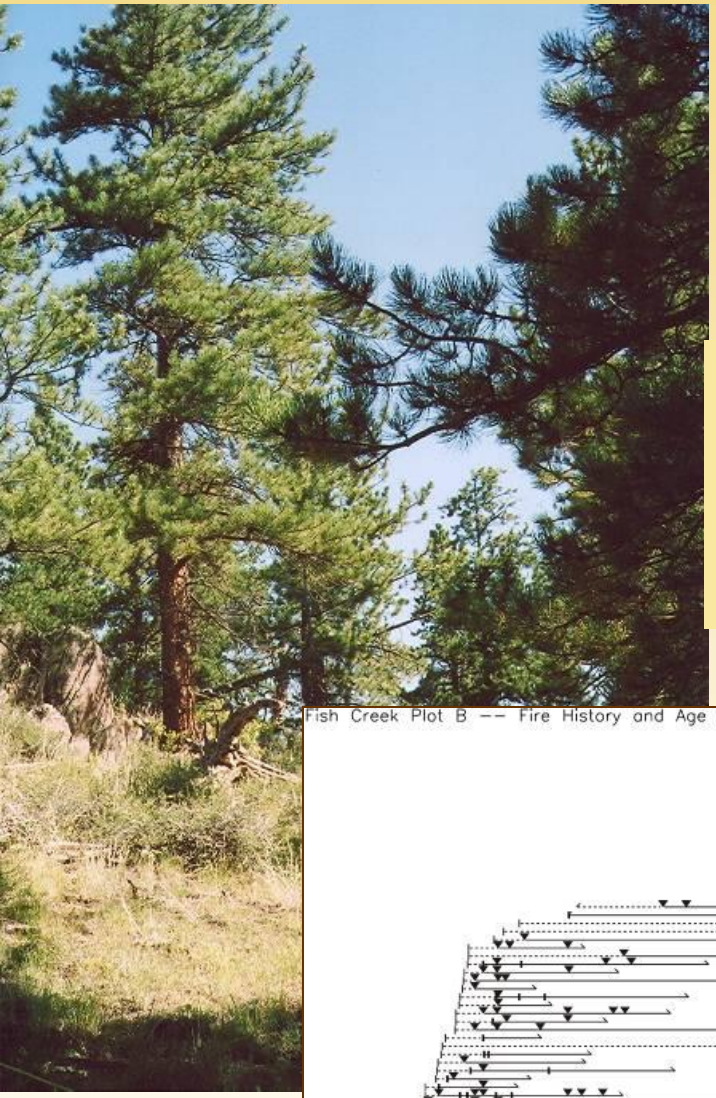


Composite Fire Histories for All Mixed Conifer Areas



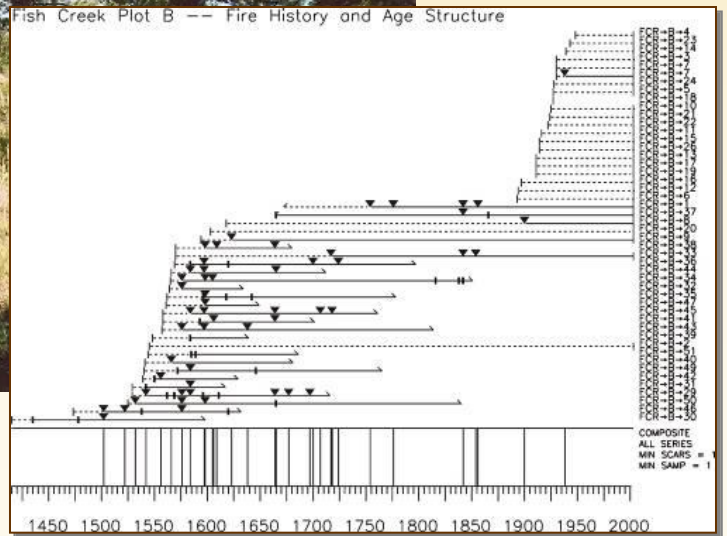
Mean fire intervals did not tell the whole story…

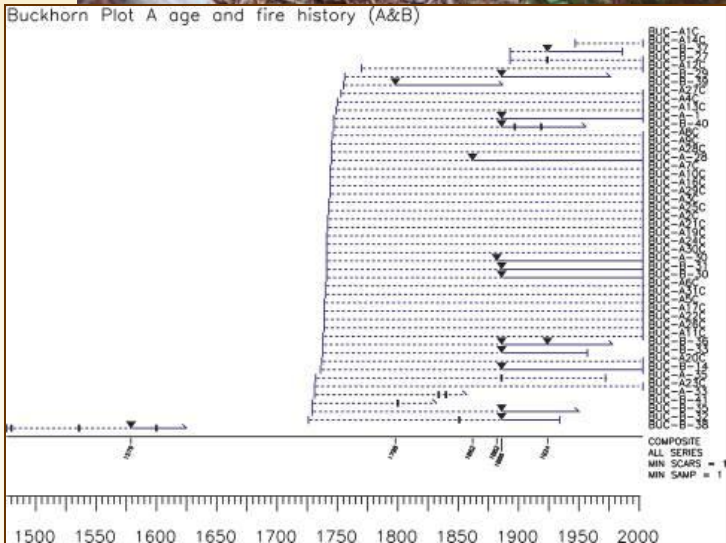
Mean fire intervals		
Species dominance	**MFI all**	**n=**
PICO mix	**39.0**	11
PICO	**60.5**	8
PIFL mix	22.2	1
PIPO mix	**28.0**	19
PIPO	**21.4**	11
POTR mix	27.1	2
PSME mix	26.9	6



Not in space…

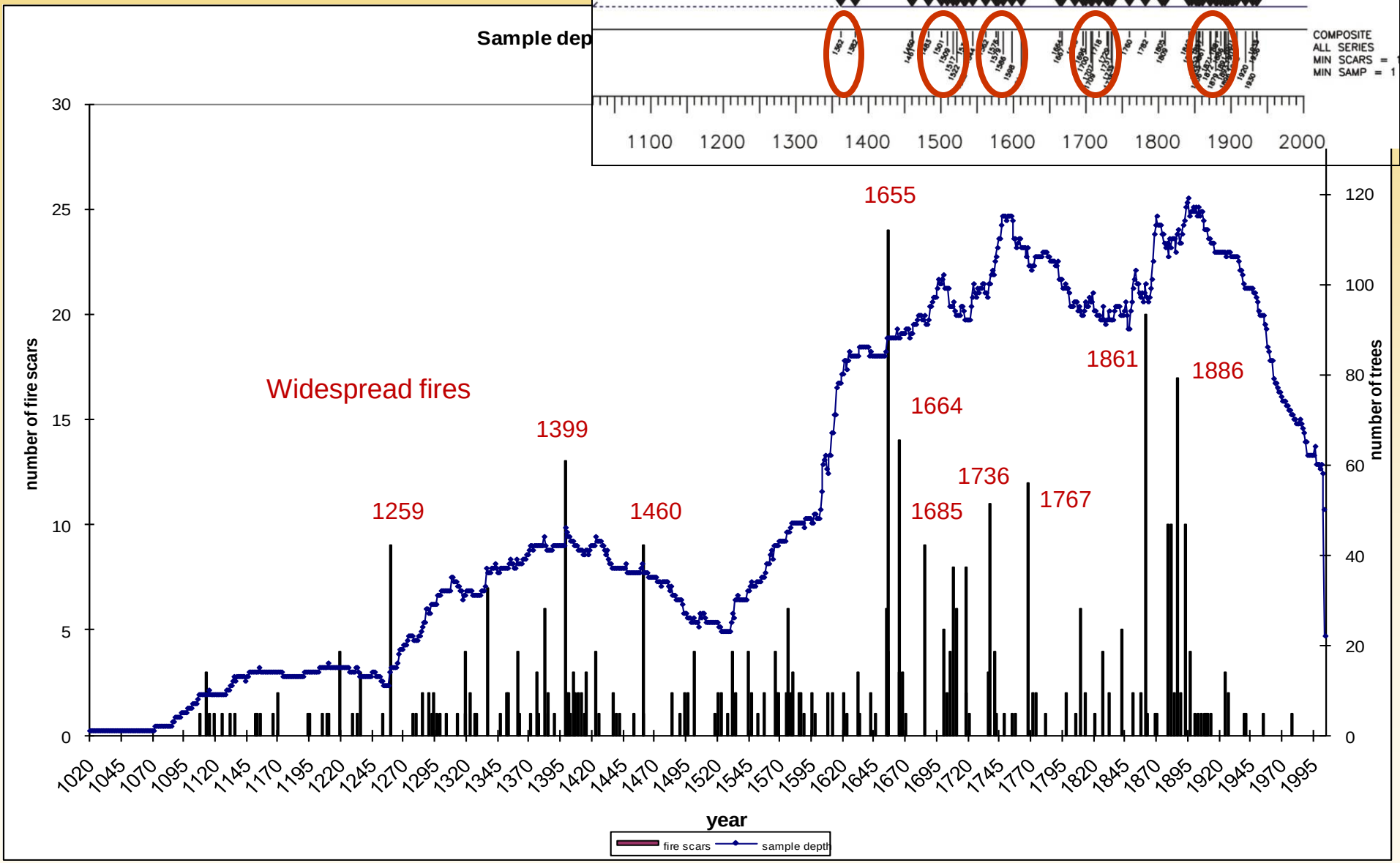
Stands of different species composition and ages had different fire regimes





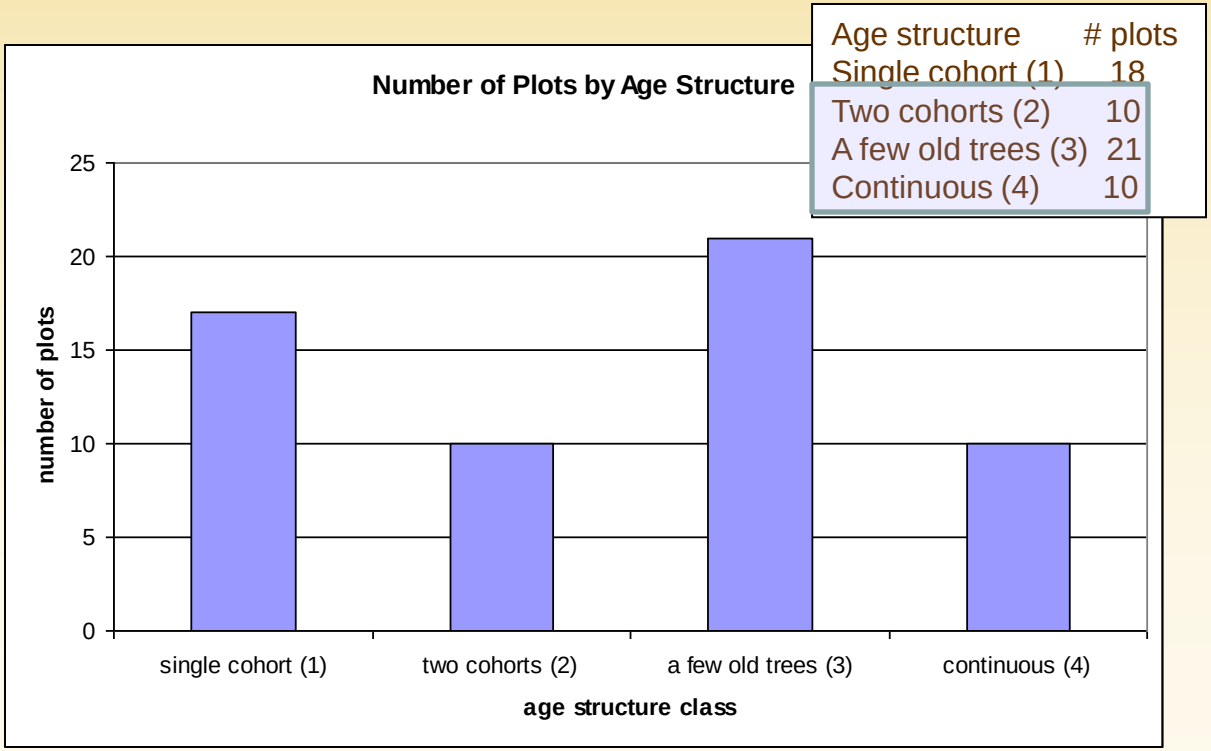
Nor in time…

Widespread and mixed severity fires occurred only during very dry periods



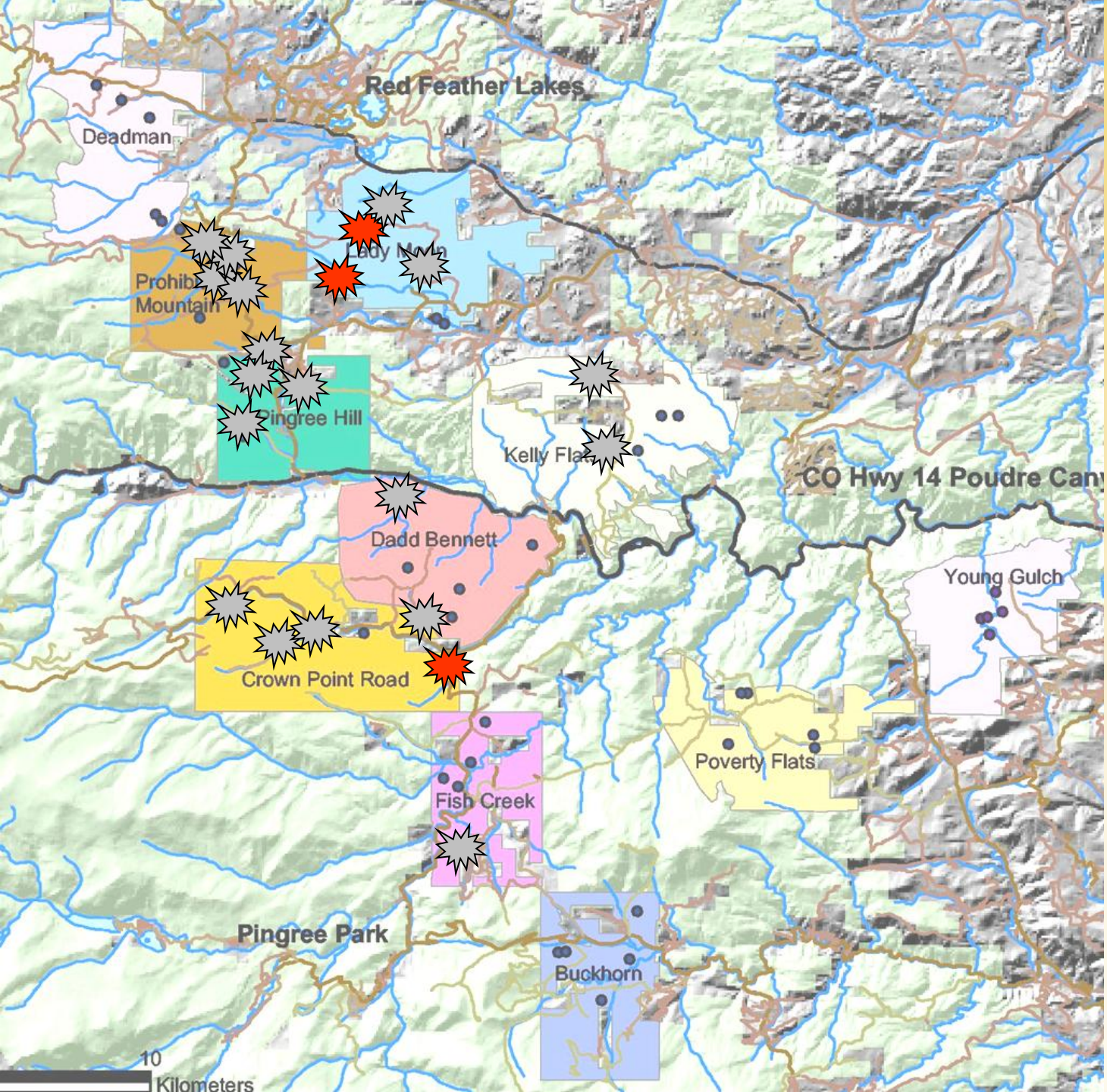
Evidence of Mixed severity fire

The most common age structure in all plots was a single younger cohort with a few remnant older trees (3), suggesting mixed severity fires that created openings but did not kill all the trees.



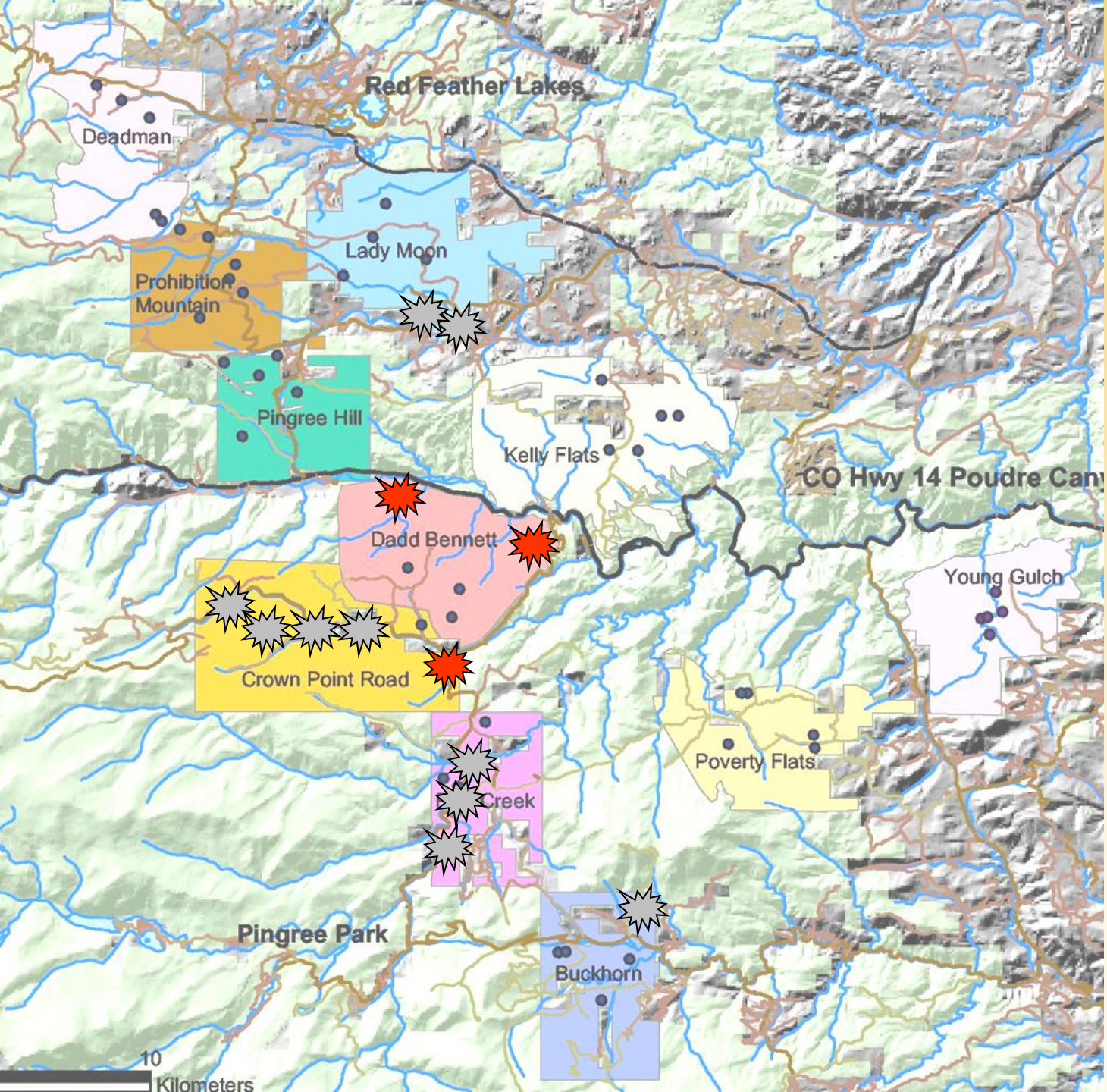
Age structure	# plots
Single cohort (1)	18
Two cohorts (2)	10
A few old trees (3)	21
Continuous (4)	10

Many plots where mixed severity fire occurred in the 19th century had evidence of post-fire dominance by aspen. Sometimes the aspen was dead; sometimes it persisted as isolated or small individuals. Aspen was clearly seral in these plots.



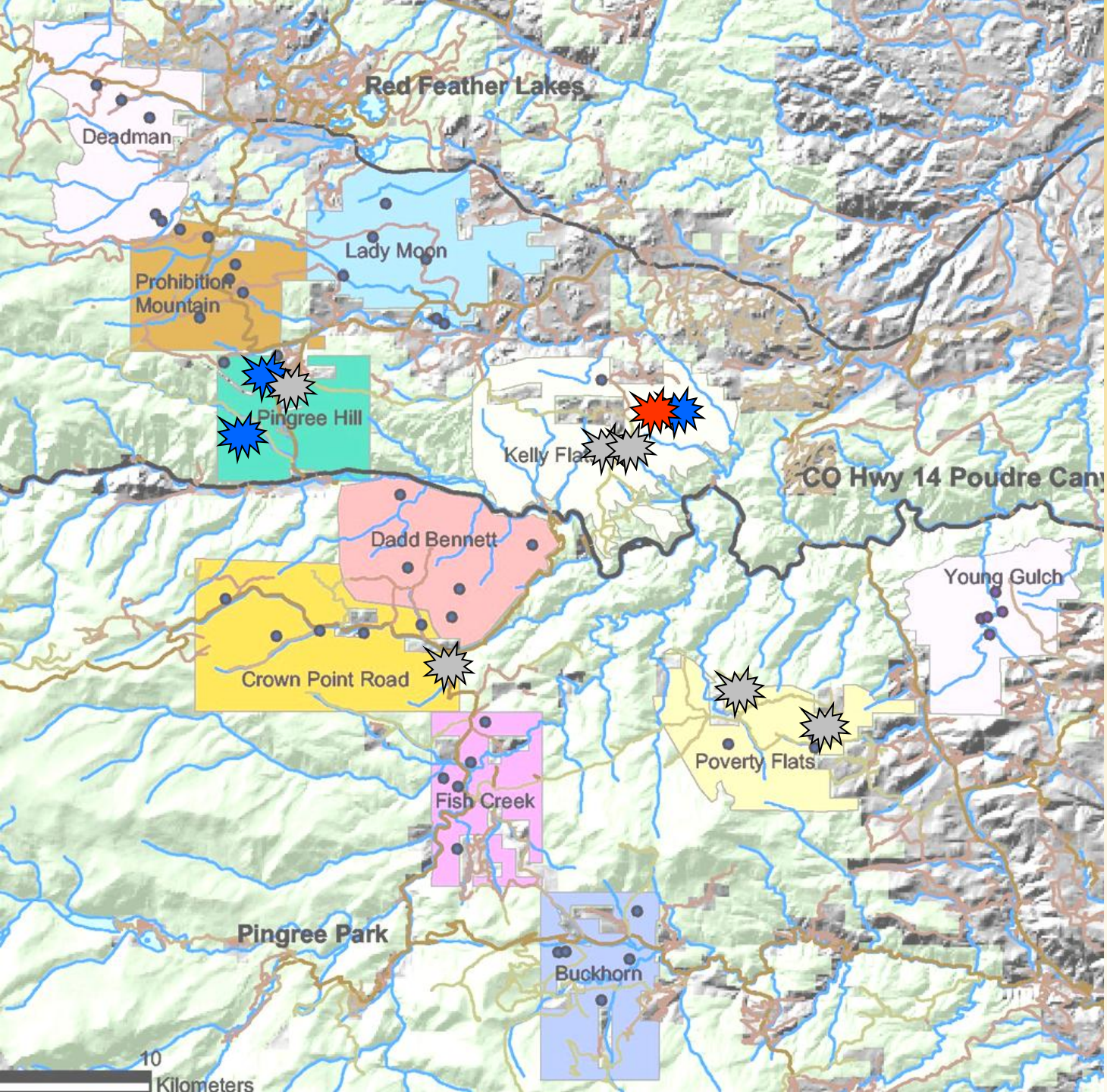
Fall 1460 fire

- Stand-replacing
- Mixed effects
- Surface fire



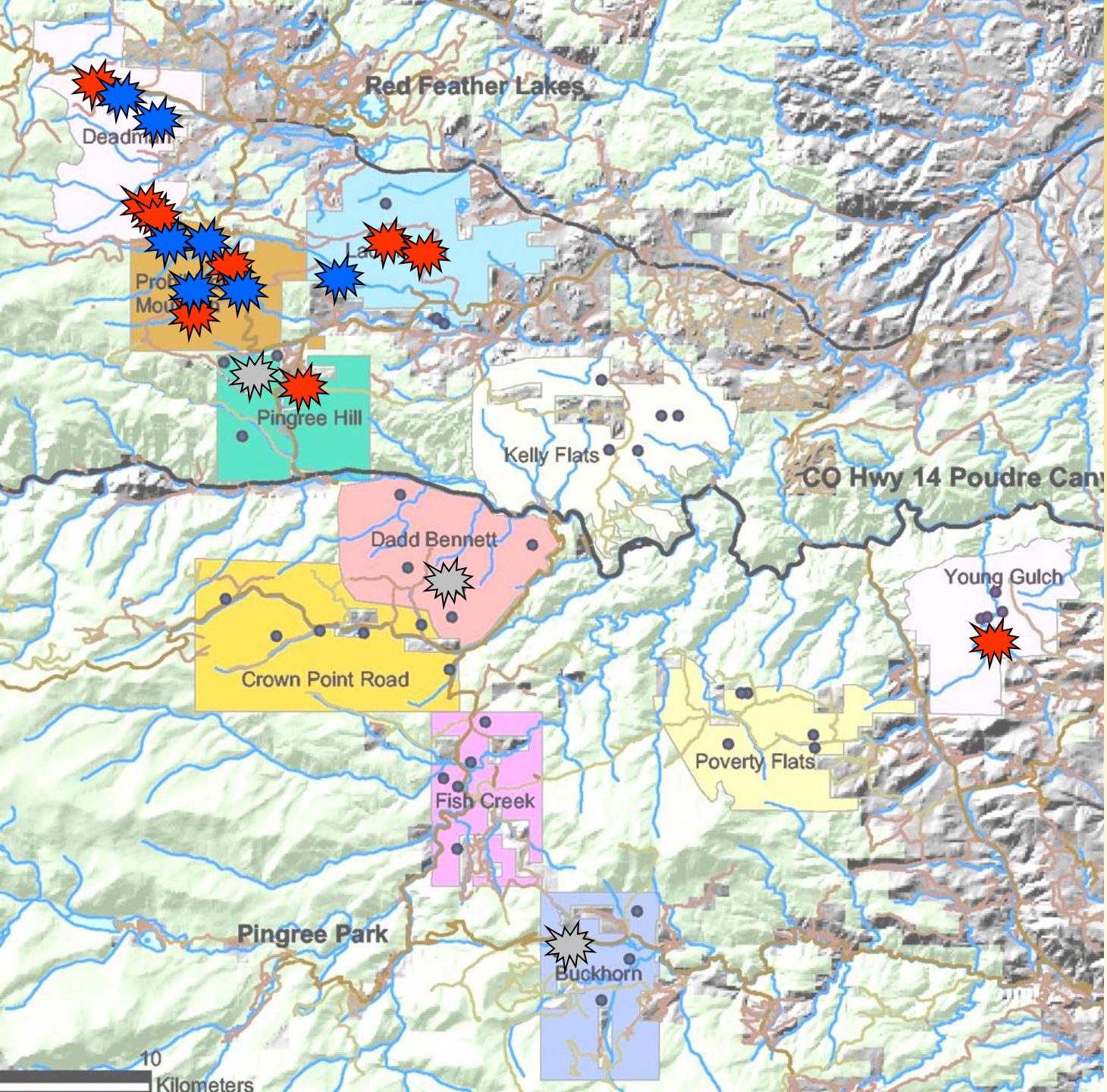
1576 fire

- Stand-replacing
- Mixed effects
- Surface fire



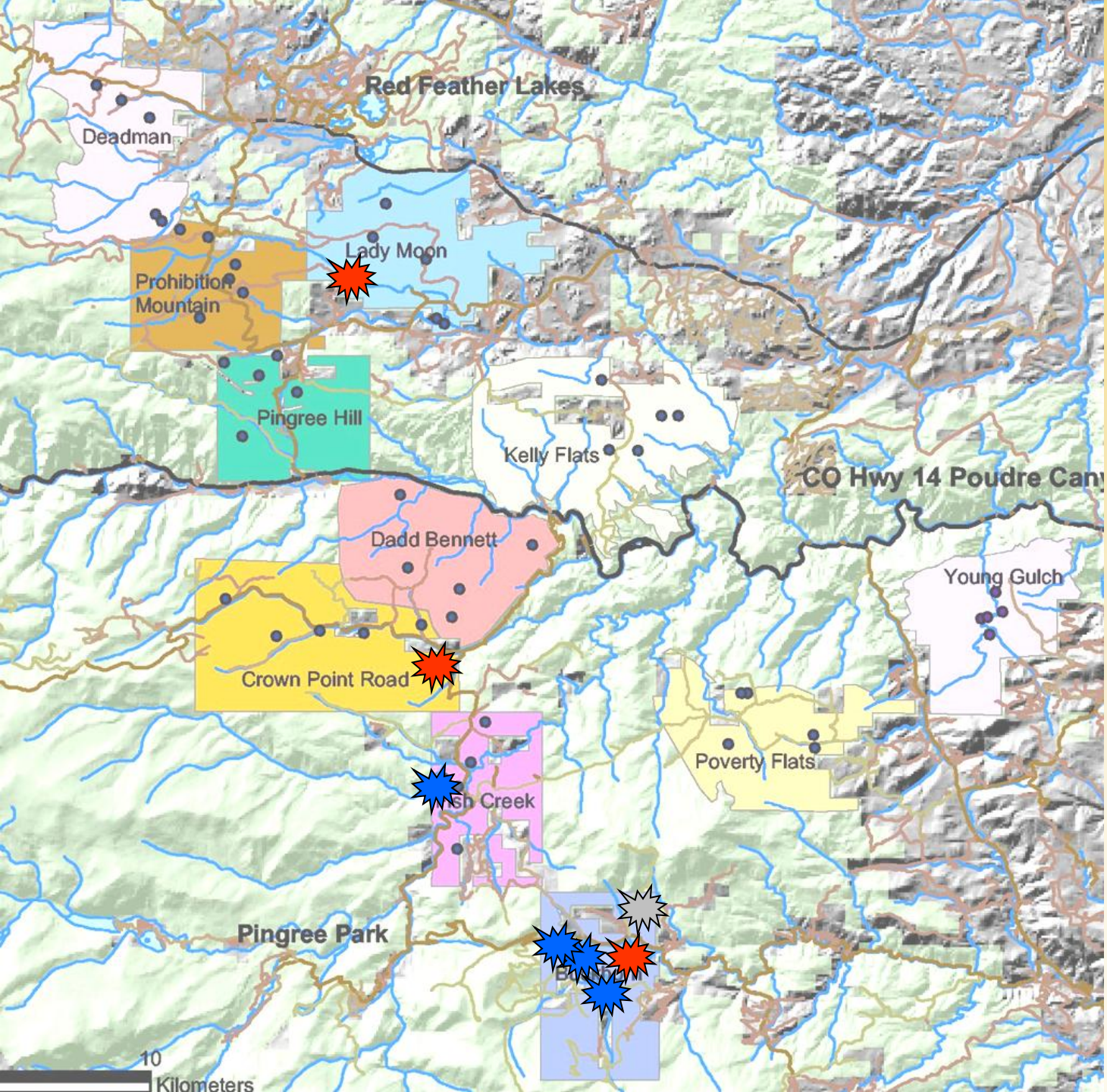
1846 fire

- Stand-replacing
- Mixed effects
- Surface fire



Fall 1861 fire

- Stand-replacing
- Mixed effects
- Surface fire



1886 fire

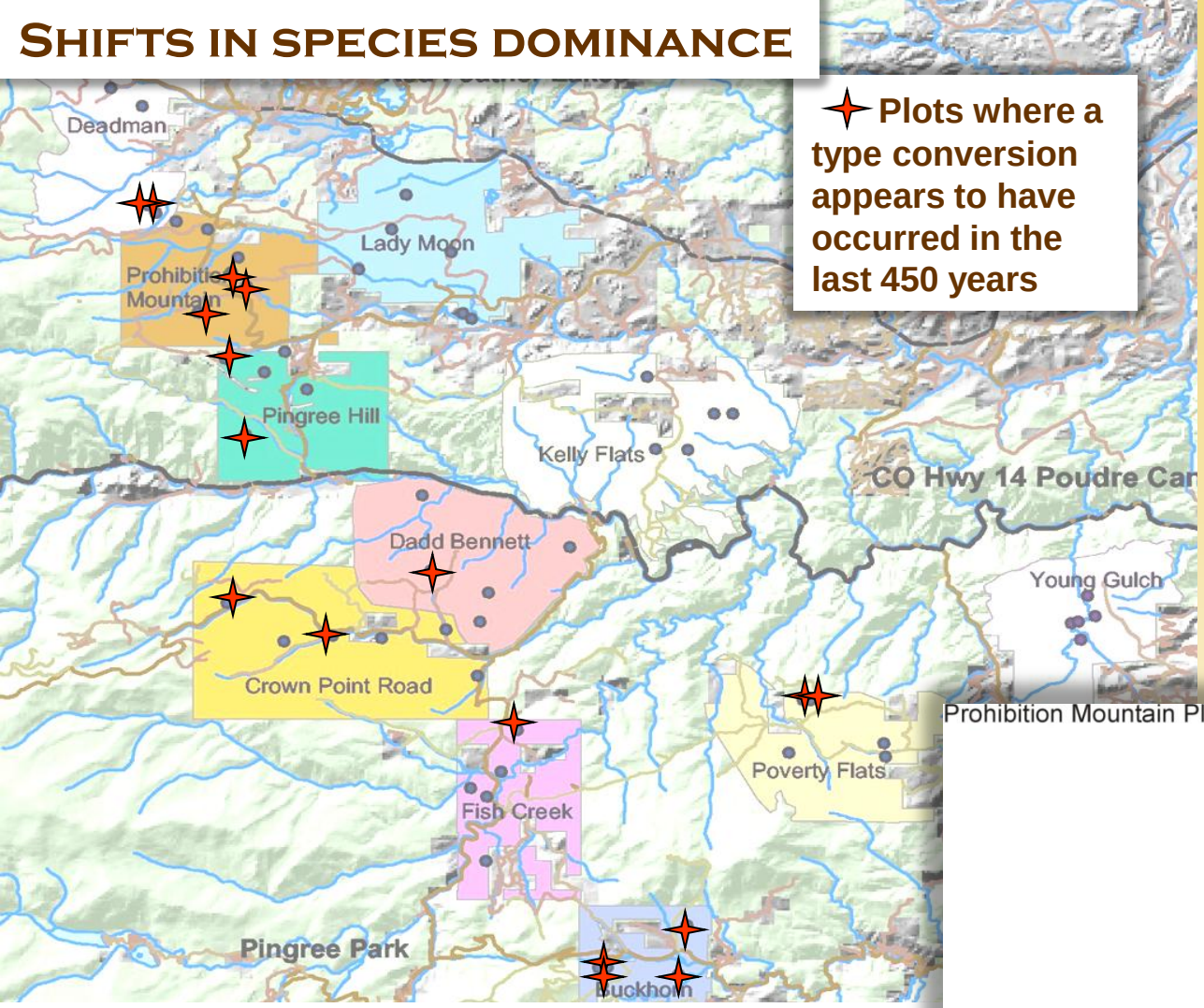
- Stand-replacing
- Mixed effects
- Surface fire

Results: Type conversions and forest expansion during the Little Ice Age

- **Shift from ponderosa to lodgepole pine in the upper elevations (8000-9000 ft)**
  evidence: old ponderosa logs under lodgepole pine forest
- **Shifts follow mixed or stand replacing fires during Little Ice Age**
  shifts were abrupt—old stand destroyed
- **First mixed severity fire 1362 AD at the end of Medieval Warm Period**

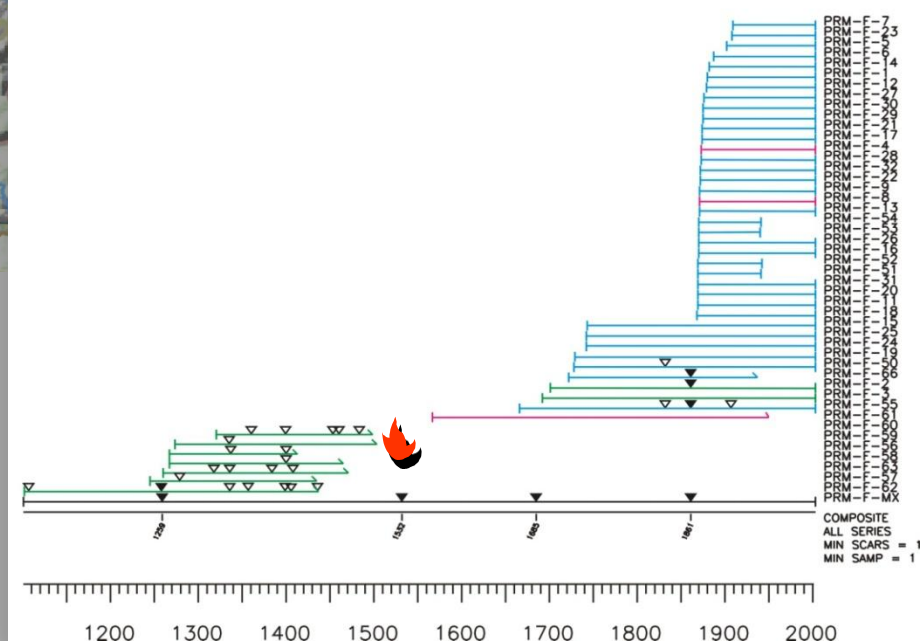
- **Lags between climate change and vegetation type shifts**
  mature trees can endure climate change—seedlings are sensitive
  fuels had to build up for a stand-replacing event
  regeneration was the species suited to the new climate
  regenerating species seed sources had to be nearby—historical mosaic complex
- **Migration of ponderosa pine to lower elevations during Little Ice Age**
  lower treeline in 1300AD around 8000 ft.
  pulses of ponderosa pine establishment early 1300s, mid 1500s, late 1700s, early 1800s

Shifts in species dominance

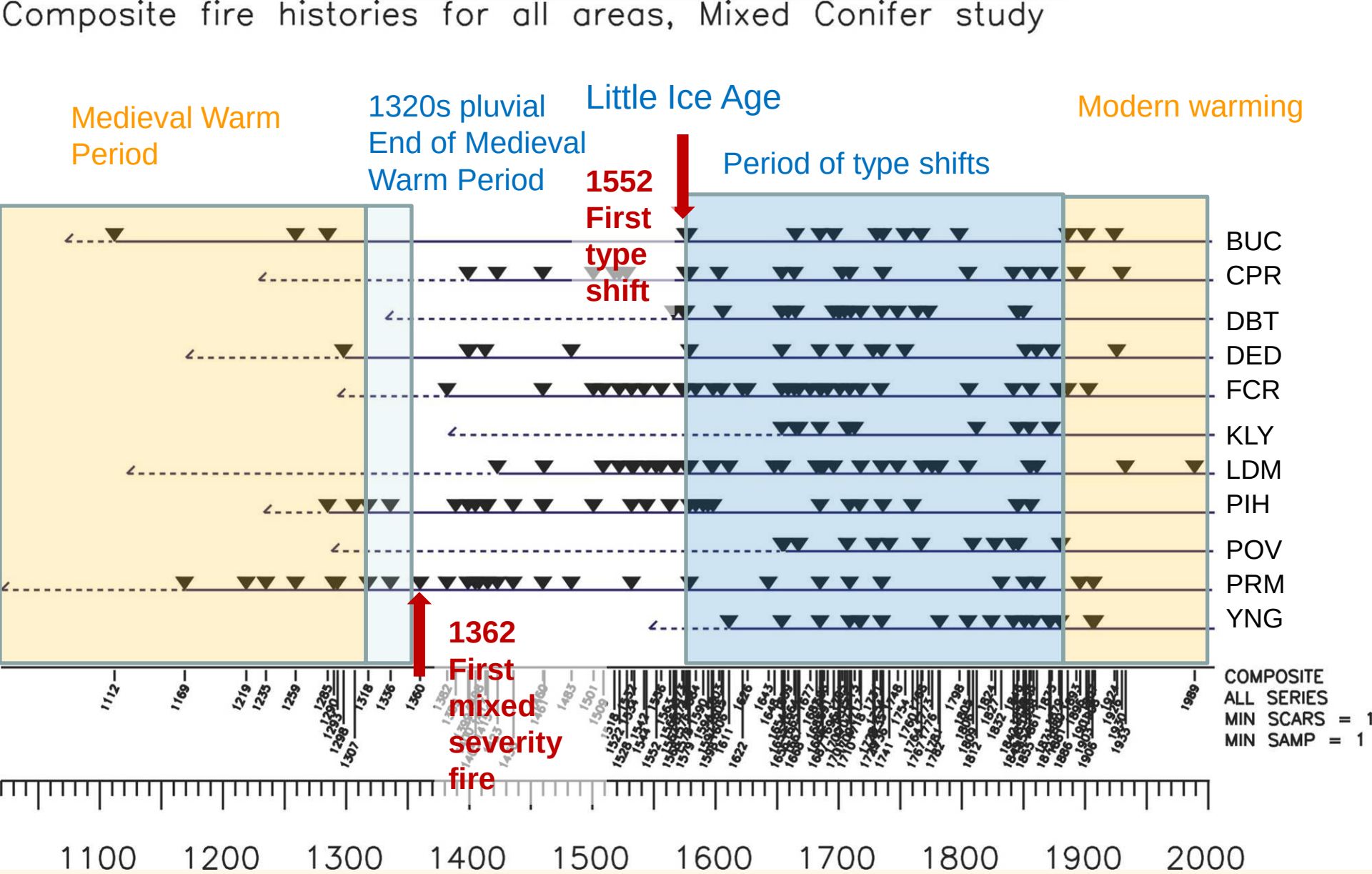


Plots where a type conversion appears to have occurred in the last 450 years

Prohibition Mountain Plot F Type Shift -- Fire history and age structure



The18 plots are currently dominated by lodgepole pine; all are above 8000 feet elevation. All plots were ponderosa pine - dominated stands that experienced at least one stand-replacing disturbance between 1552-1886.

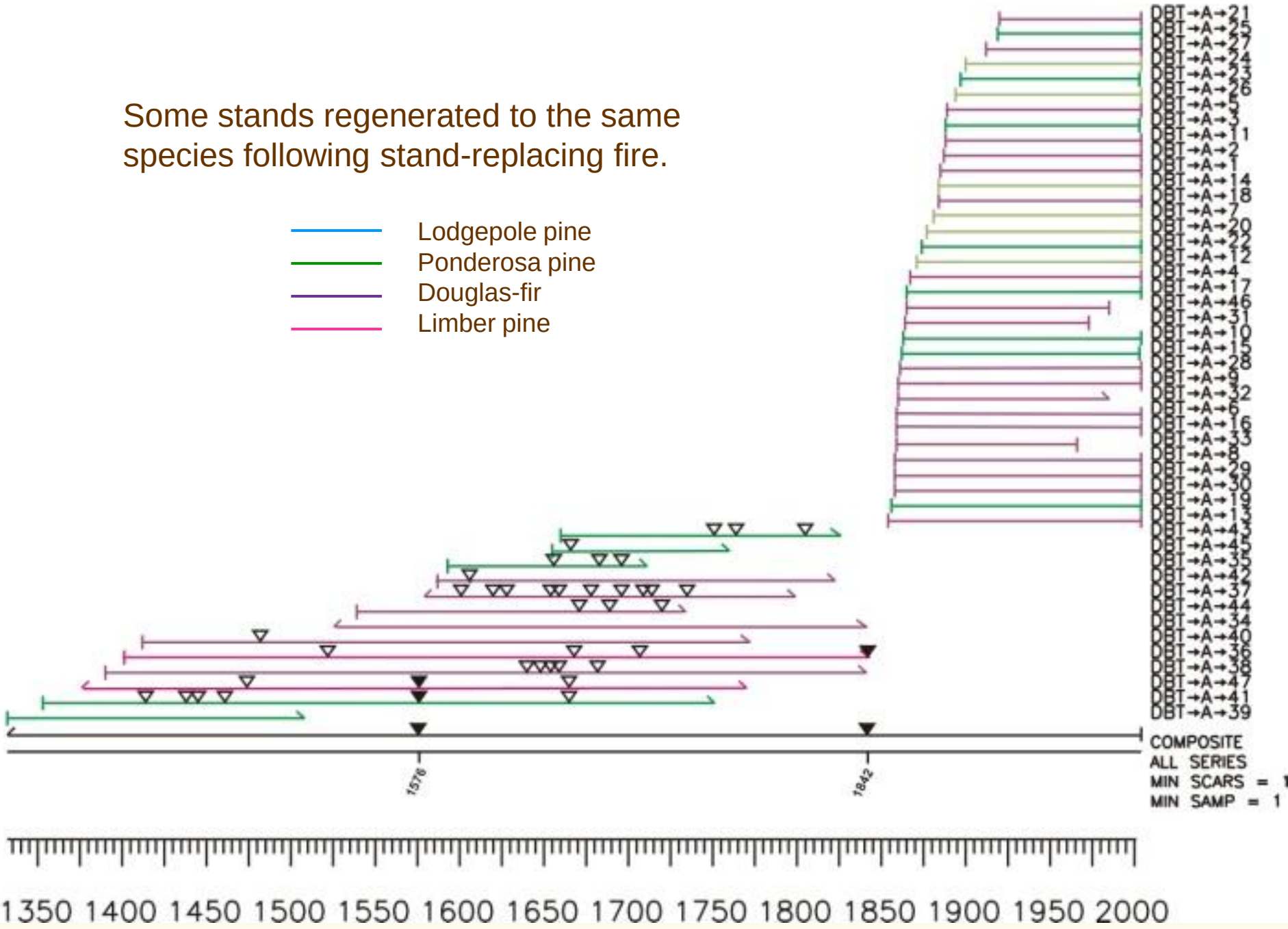


Climate change began in the early 1300s but type shifts were not recorded until mixed severity or stand-replacing disturbances occurred 200+ years later. Changes in fuels and severe droughts precipitated mixed severity fires. Regenerating species were those better suited to the new, cooler climate.

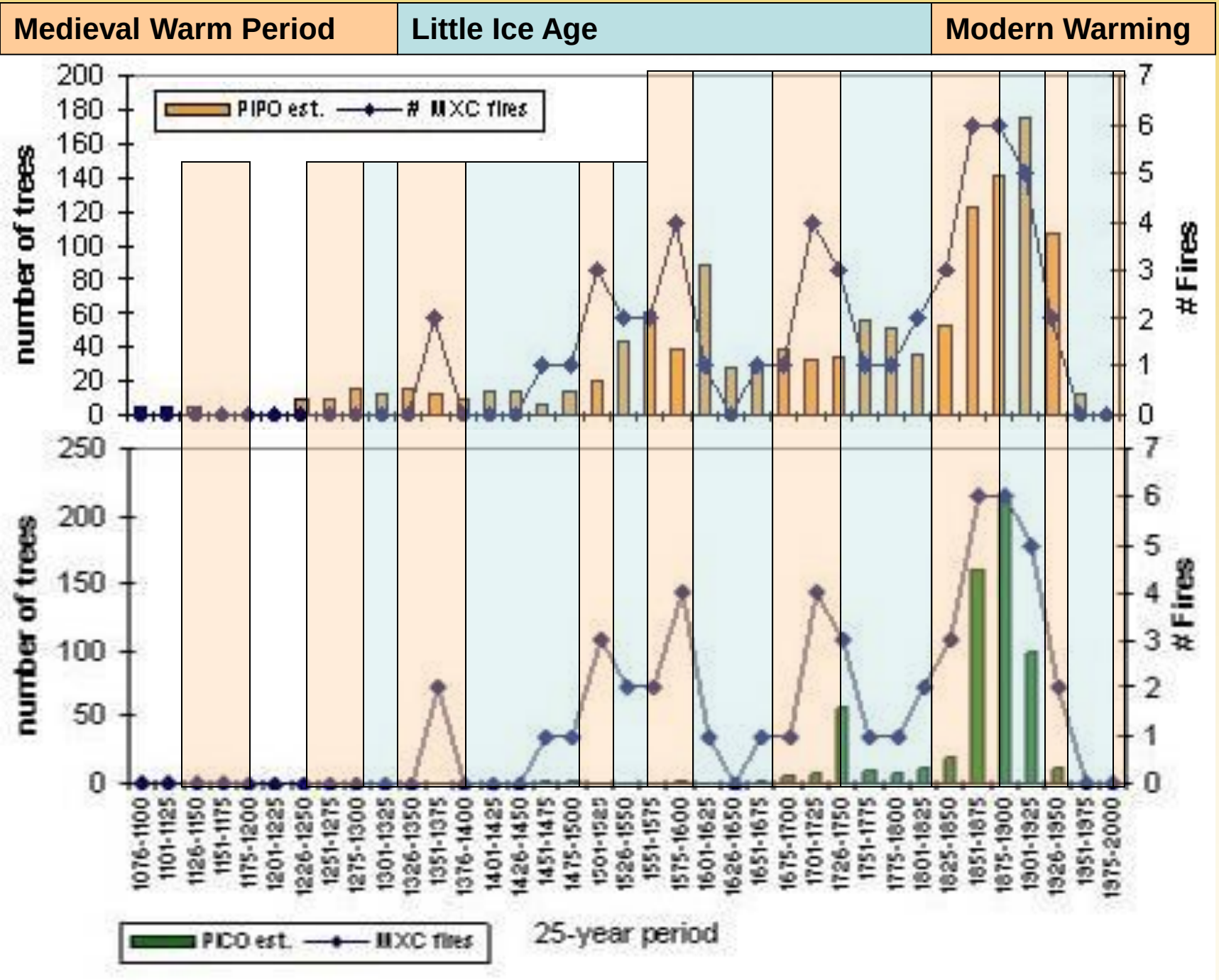
Dadd-Bennett Plot A No Type Shift -- Fire History and Age Structure

Some stands regenerated to the same species following stand-replacing fire.

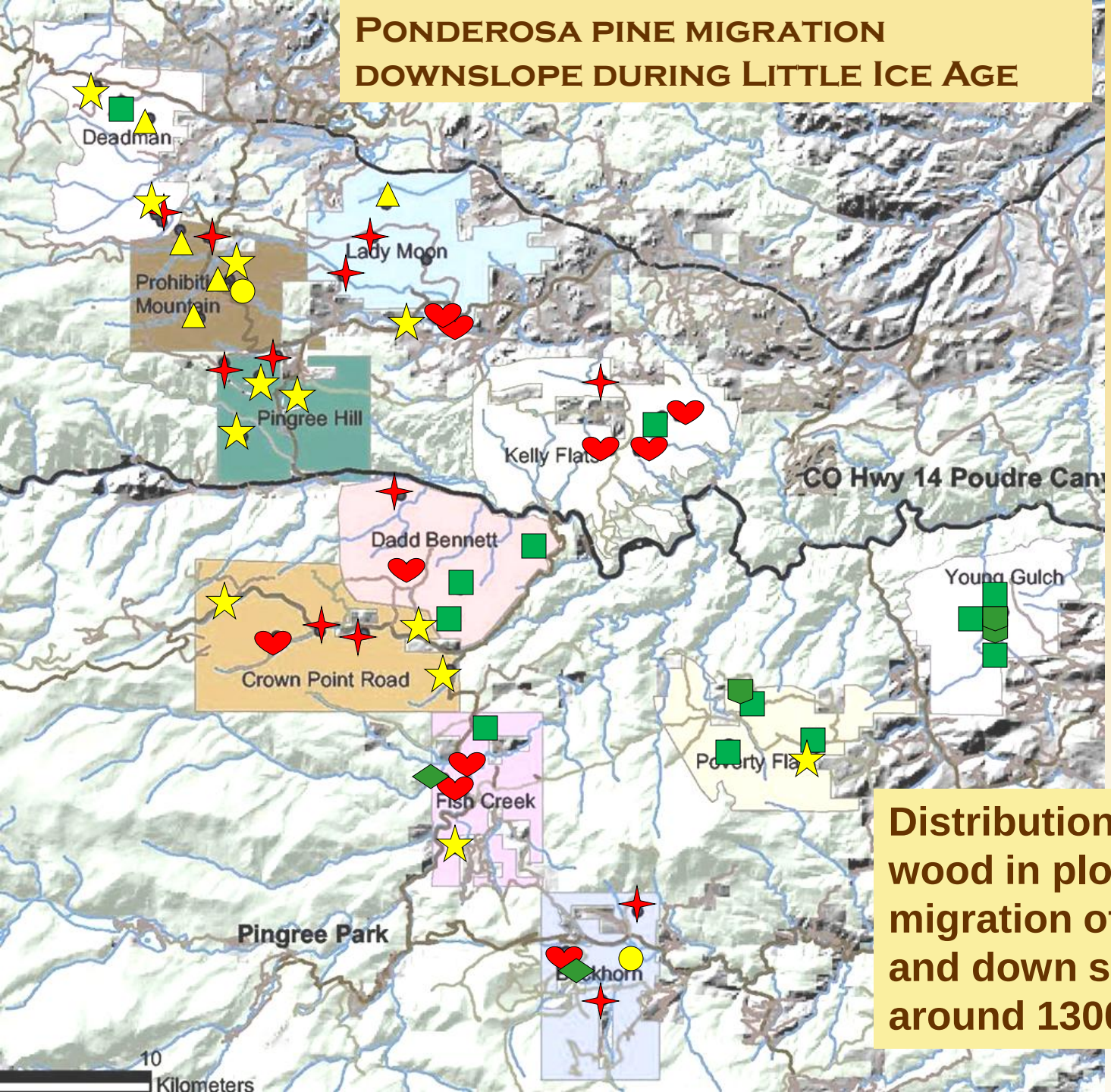
- Lodgepole pine
- Ponderosa pine
- Douglas-fir
- Limber pine



Establishment of Ponderosa and Lodgepole Pines and Occurrence of Mixed Severity Fire



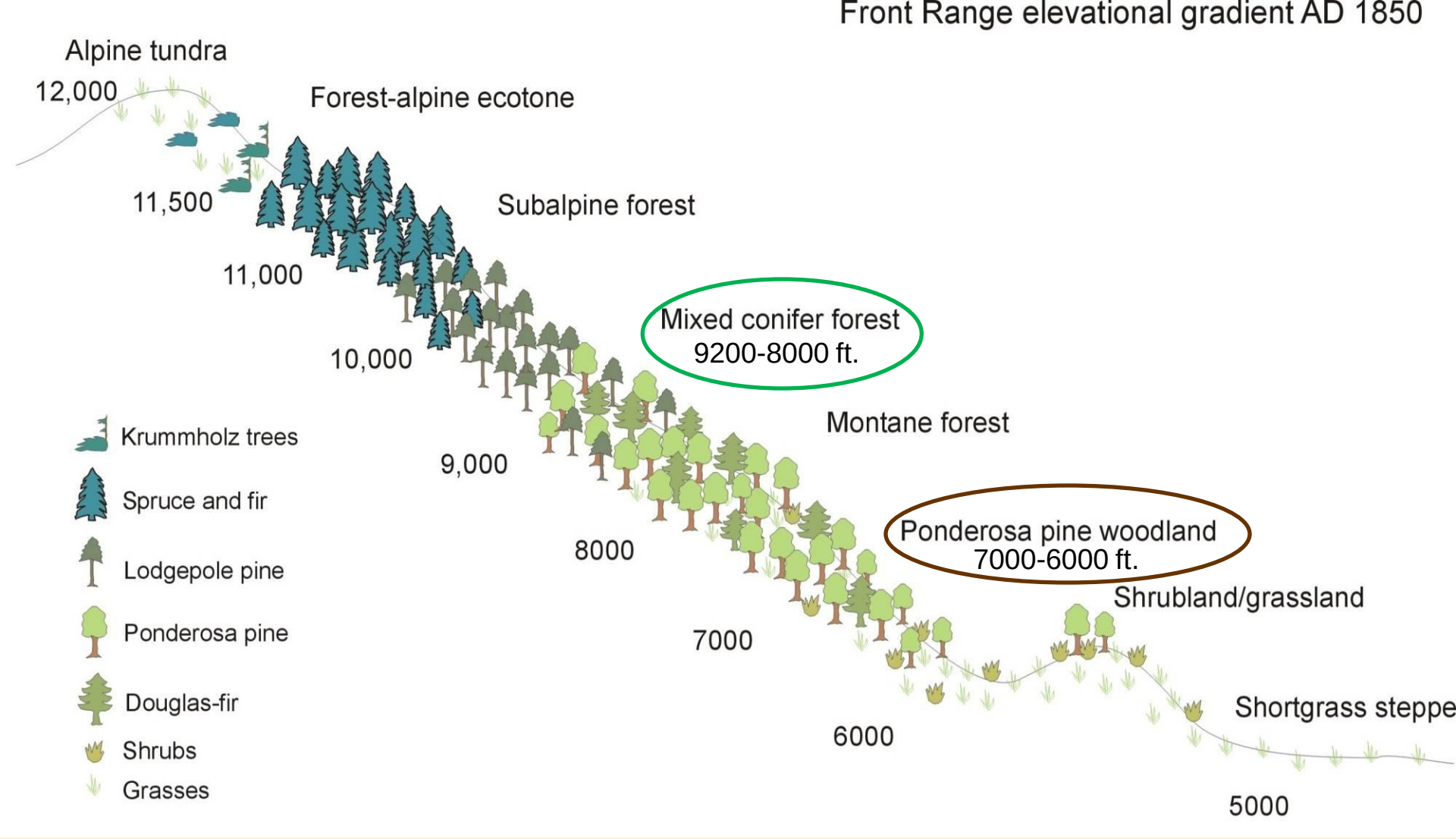
Ponderosa pine migration downslope during Little Ice Age



Establishment dates for oldest trees in plots

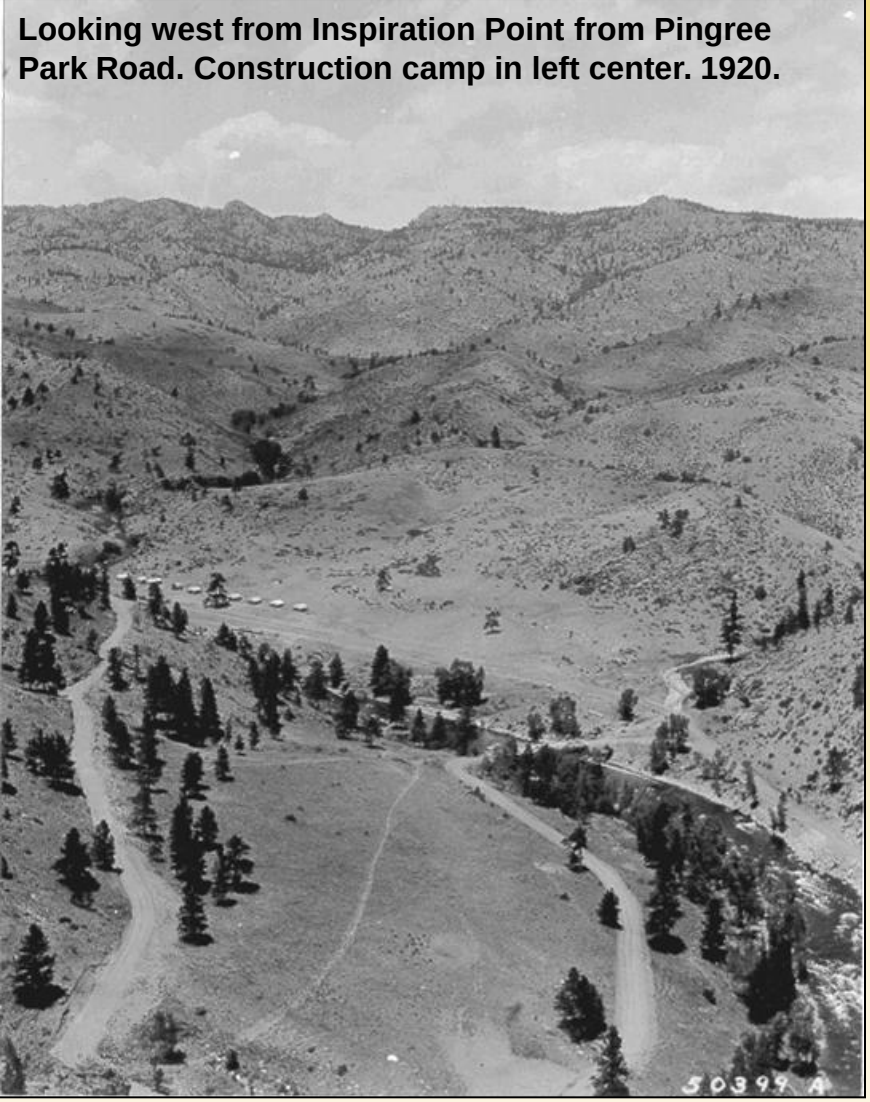
- 1000-1099
- 1100-1199
- 1200-1299
- 1300-1399
- 1400-1499
- 1500-1599
- 1600-1699
- 1700-1799

Distribution of the oldest wood in plots suggests a migration of trees eastward and down slope starting around 1300 AD.

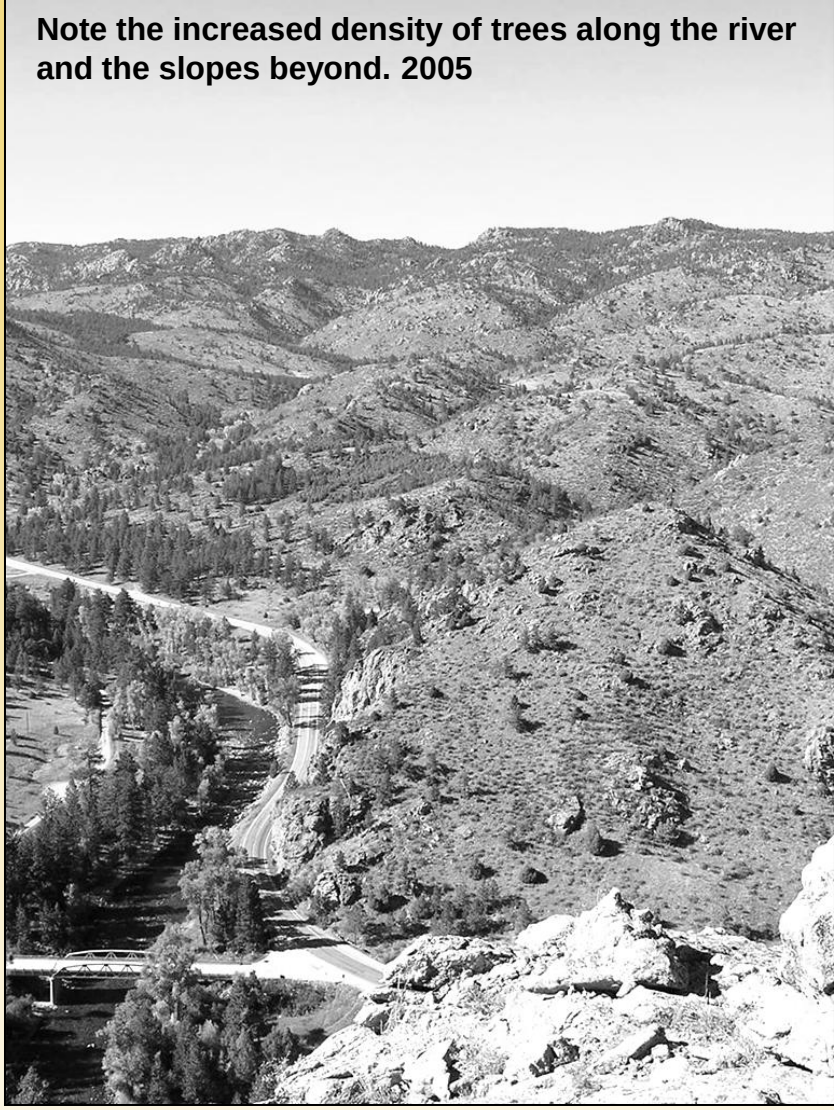


Our data suggest that the elevational gradient of vegetation has moved up and down with changes in climate over the last 900 years. Lower forest line may have been around 8000 ft. elevation during the Medieval Warm Period. Trees gradually spread eastward and downslope during three establishment episodes over the next 400 years. Lodgepole pine shifted its range downslope during the same period.

Looking west from Inspiration Point from Pingree Park Road. Construction camp in left center. 1920.



Note the increased density of trees along the river and the slopes beyond. 2005



20th century changes in forest density and composition have been more evident below 7500 feet elevation than above, due in part to fire suppression and in part to favorable climate as the Little Ice Age migration continued.

Question break

Climate change: the past predicts the future

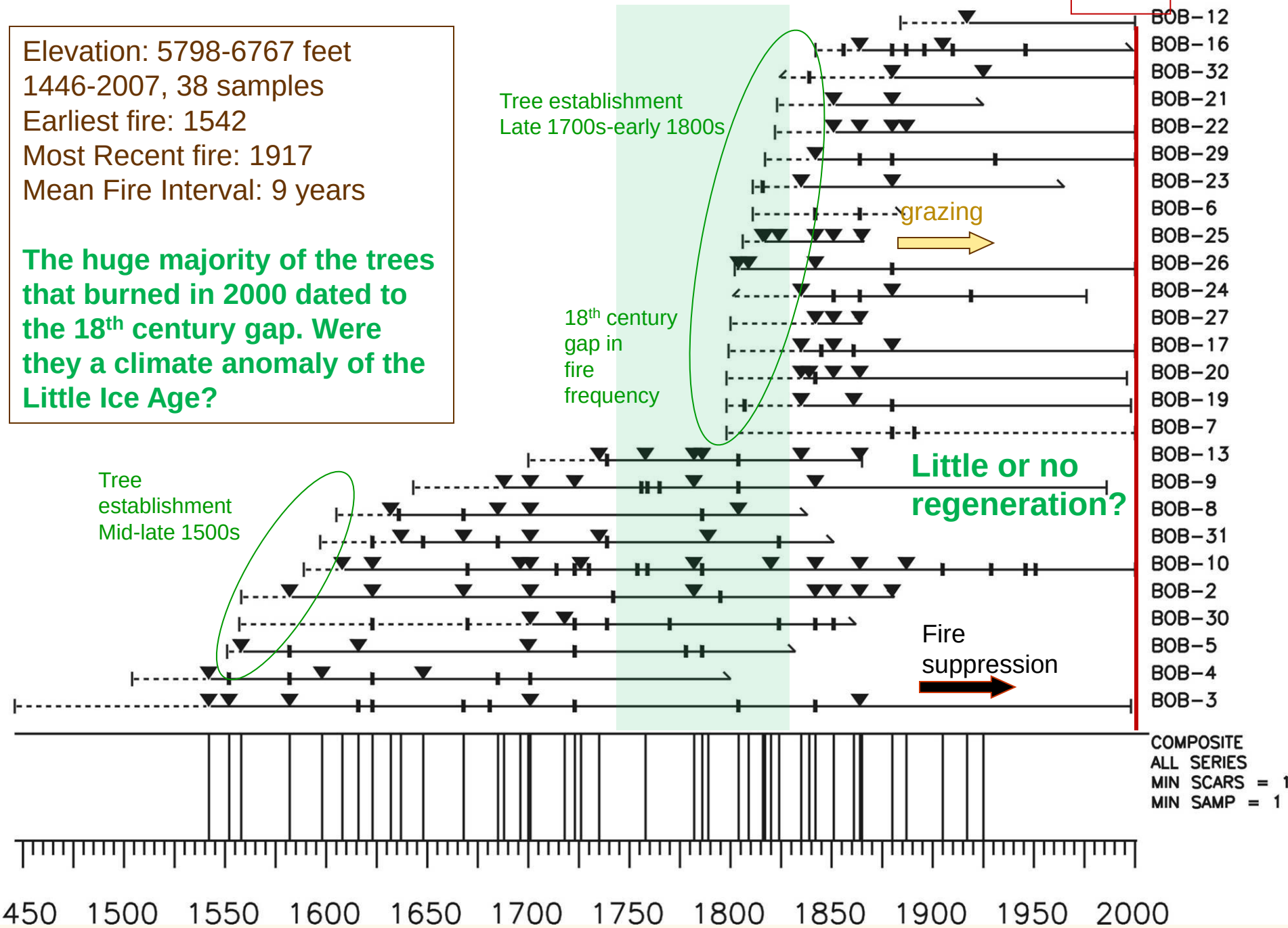
Bobcat Gulch fire, May 2000 10,600 acres burned

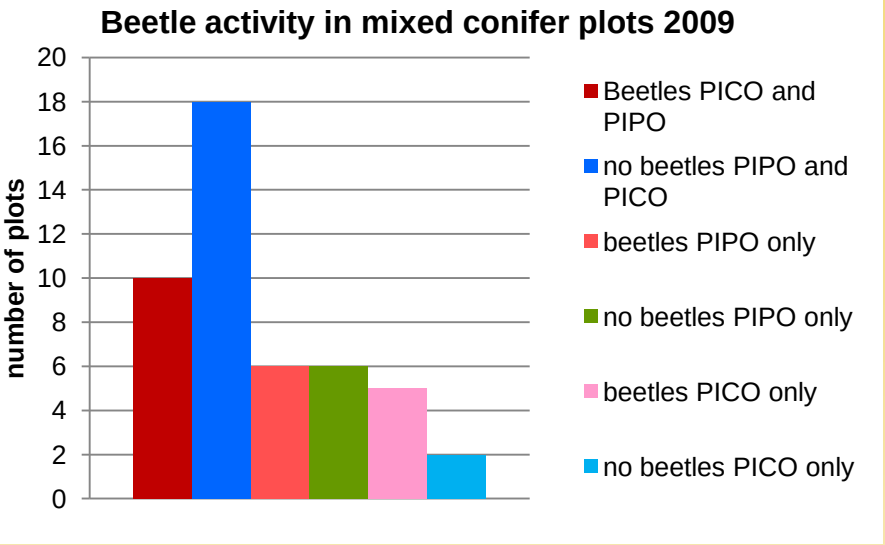
Bobcat Ridge Fire History

2000

Elevation: 5798-6767 feet
1446-2007, 38 samples
Earliest fire: 1542
Most Recent fire: 1917
Mean Fire Interval: 9 years

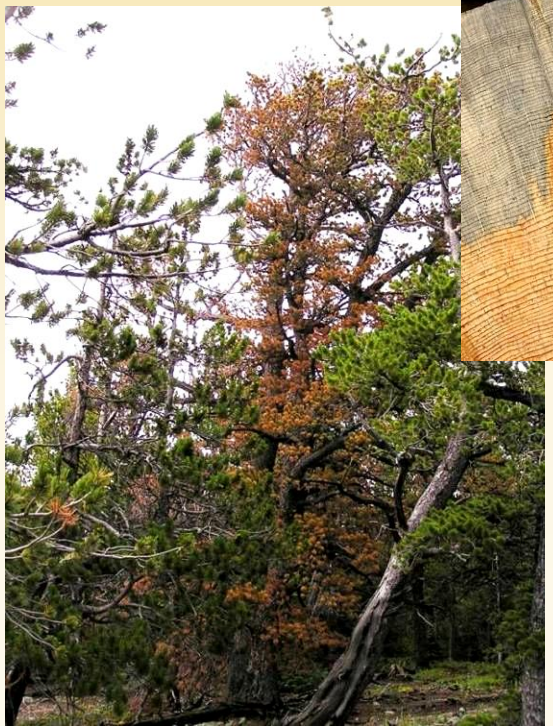
The huge majority of the trees that burned in 2000 dated to the 18th century gap. Were they a climate anomaly of the Little Ice Age?



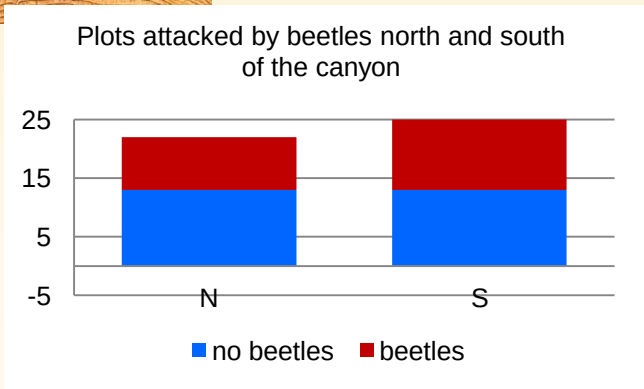


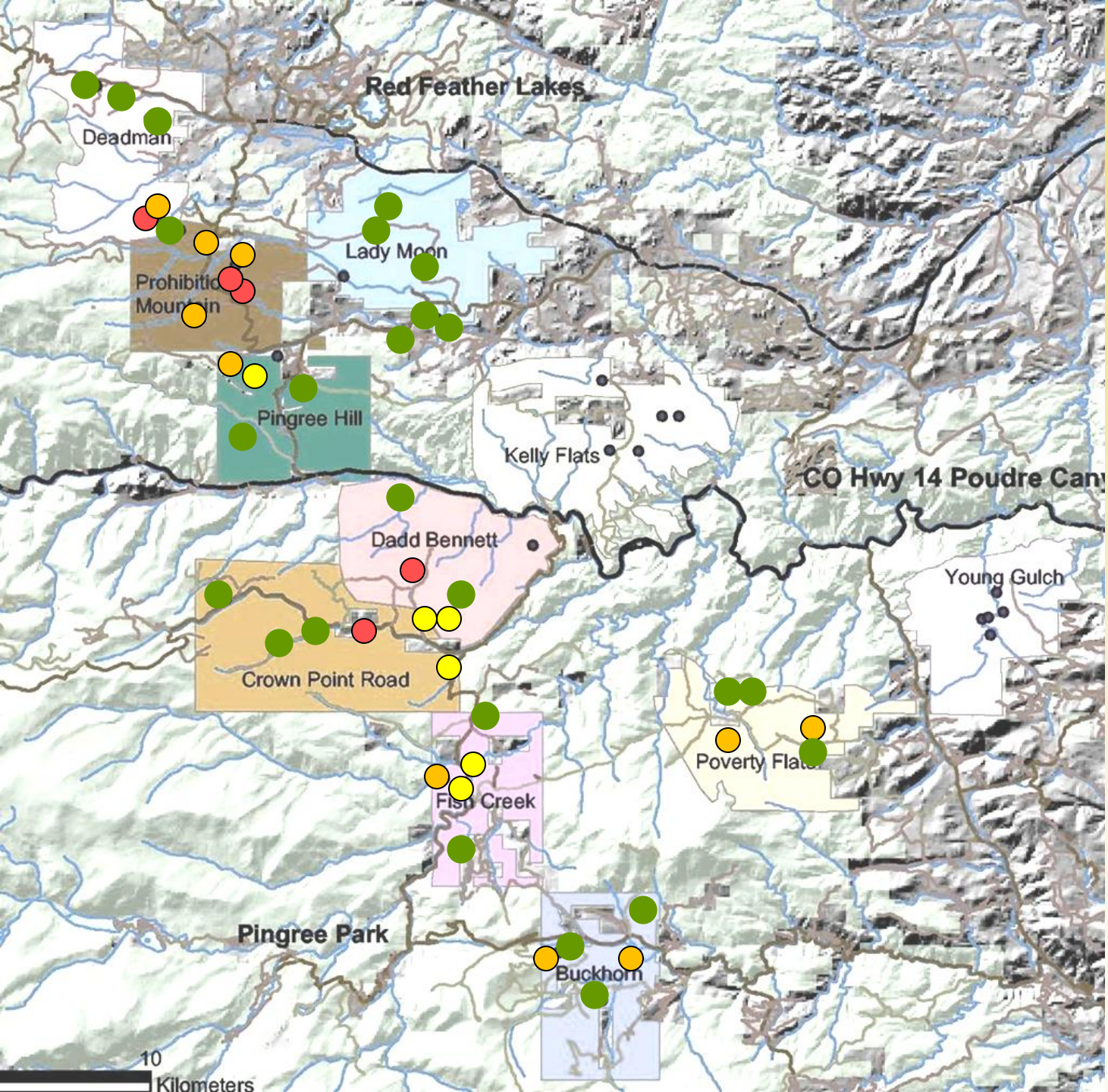
As of 2009, 21 mixed conifer plots had evidence of mountain pine beetle attacks on ponderosa pine, lodgepole pine and limber pine.

Infested stands are generally older, mixed and above 8000 ft elevation.



Blue stain fungus causes wood to rot more quickly.





Mixed conifer plots and mountain pine beetles 2009

- PIPO attacked
- PICO attacked
- PIPO and PICO attacked
- No beetles
- Not visited 2009

Will this mixed-severity disturbance and climate change cause another type shift?

A glimpse into the future?

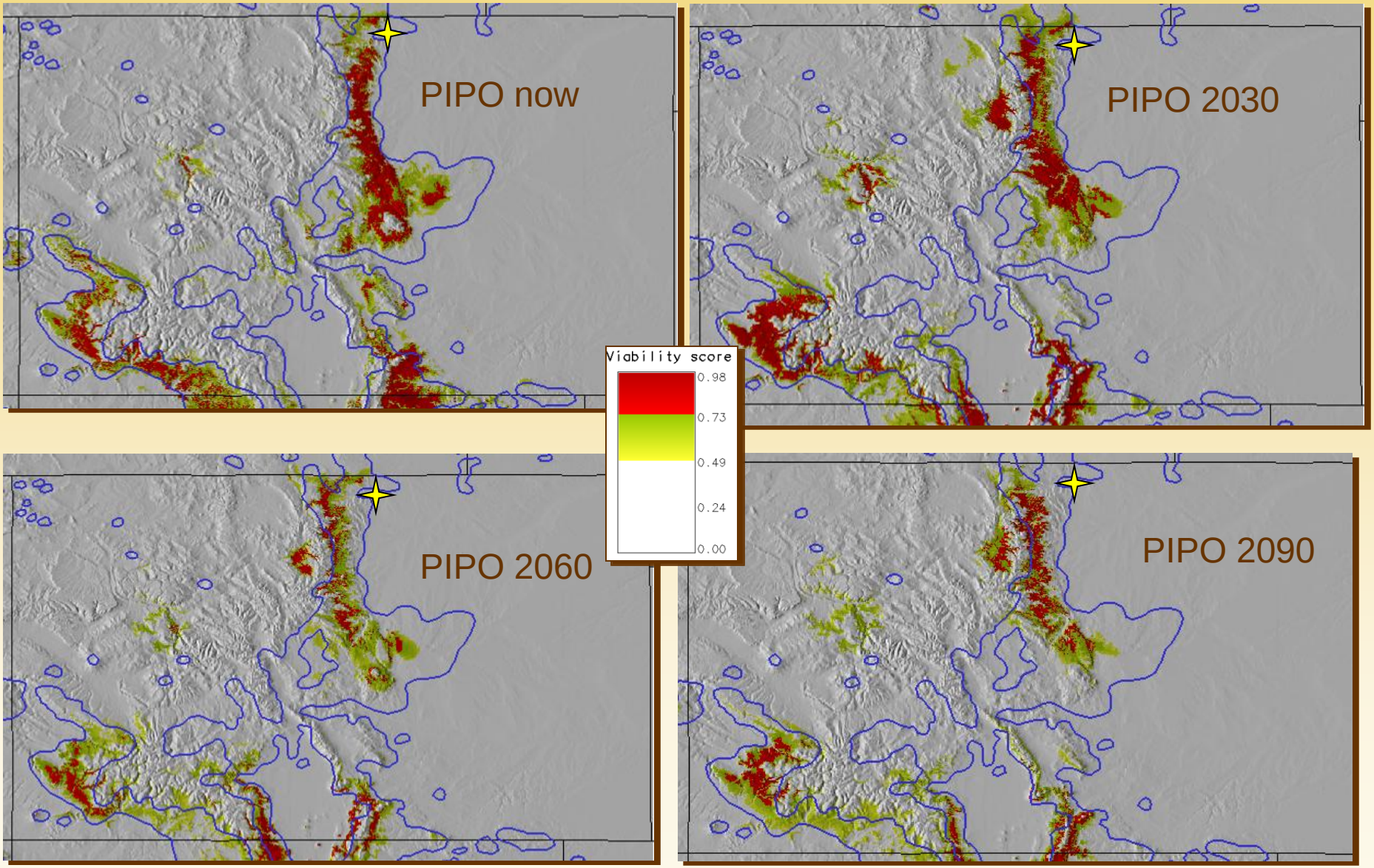
Modeling vegetation migration based on several different climate models predicts changes in species and community ranges similar to what we saw during previous climate transitions—but more with extreme changes and at a much faster rate.

Scientists at the US Forest Service Rocky Mountain Research Station Moscow Forestry Sciences Laboratory have developed plant-climate relationships for the present and predicted future species ranges based on information from three different General Circulation Models.

Rehfelt, G.E., N.L. Crookston, M.V. Warwell, and J.S. Evans. 2006. Empirical analyses of plant-climate relationships for the western United States. International Journal of Plant Science 167(6):1123-1150.

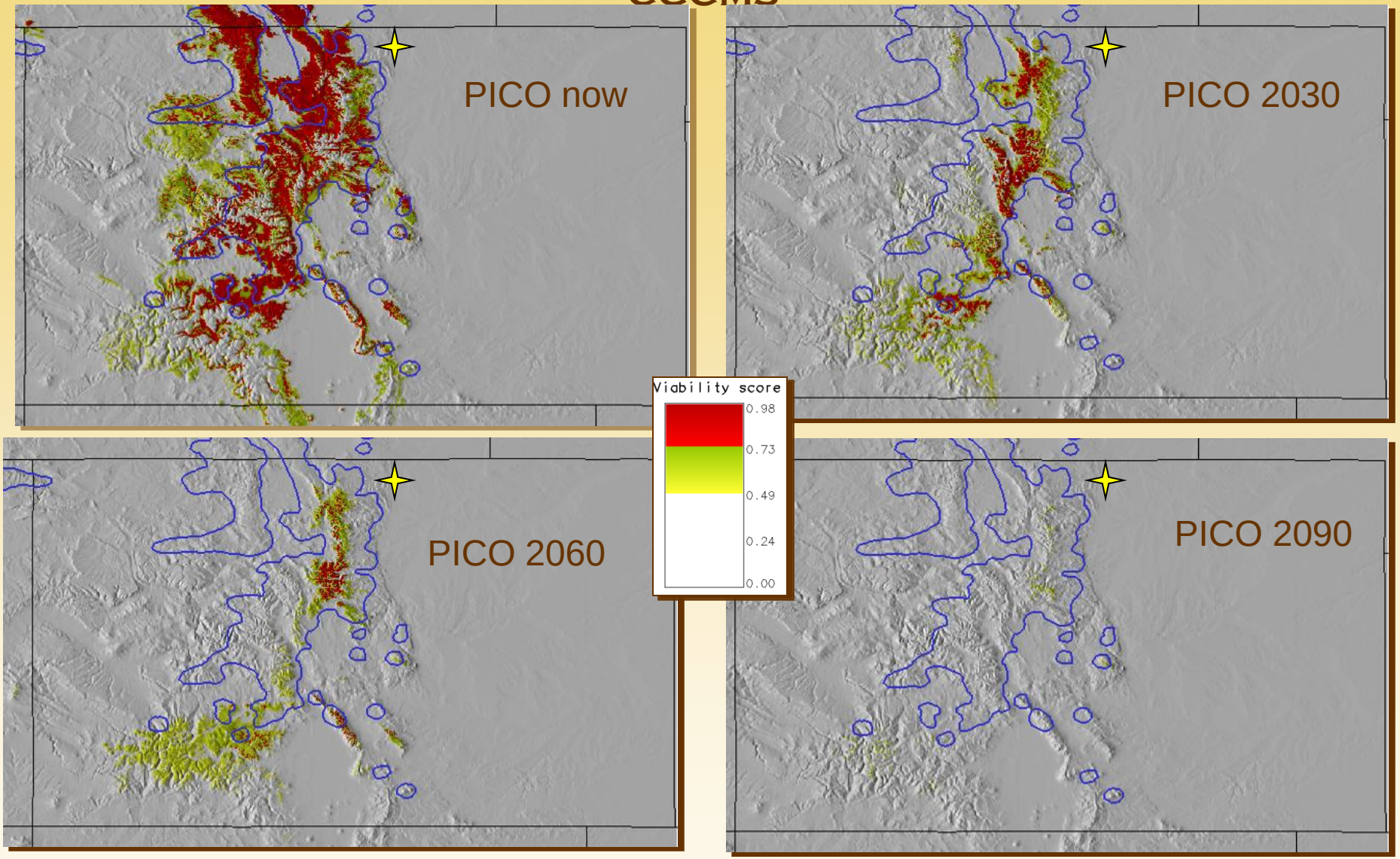
http://forest.moscowfsl.wsu.edu/climate/

Ponderosa pine migration in Colorado based on climate model CGCM3



Ponderosa pine approaches the Continental Divide in 80 years! Existing live remnant stands at 10,000 ft. may make this a possibility.

Lodgepole pine migration in Colorado based on climate model CGCM3



The elimination of lodgepole pine from the Front Range by 2090 seems like an extreme scenario given lags in vegetation migration in the past.

During periods of climate change, the mixed conifer zone is like the "crumple zone" of a car

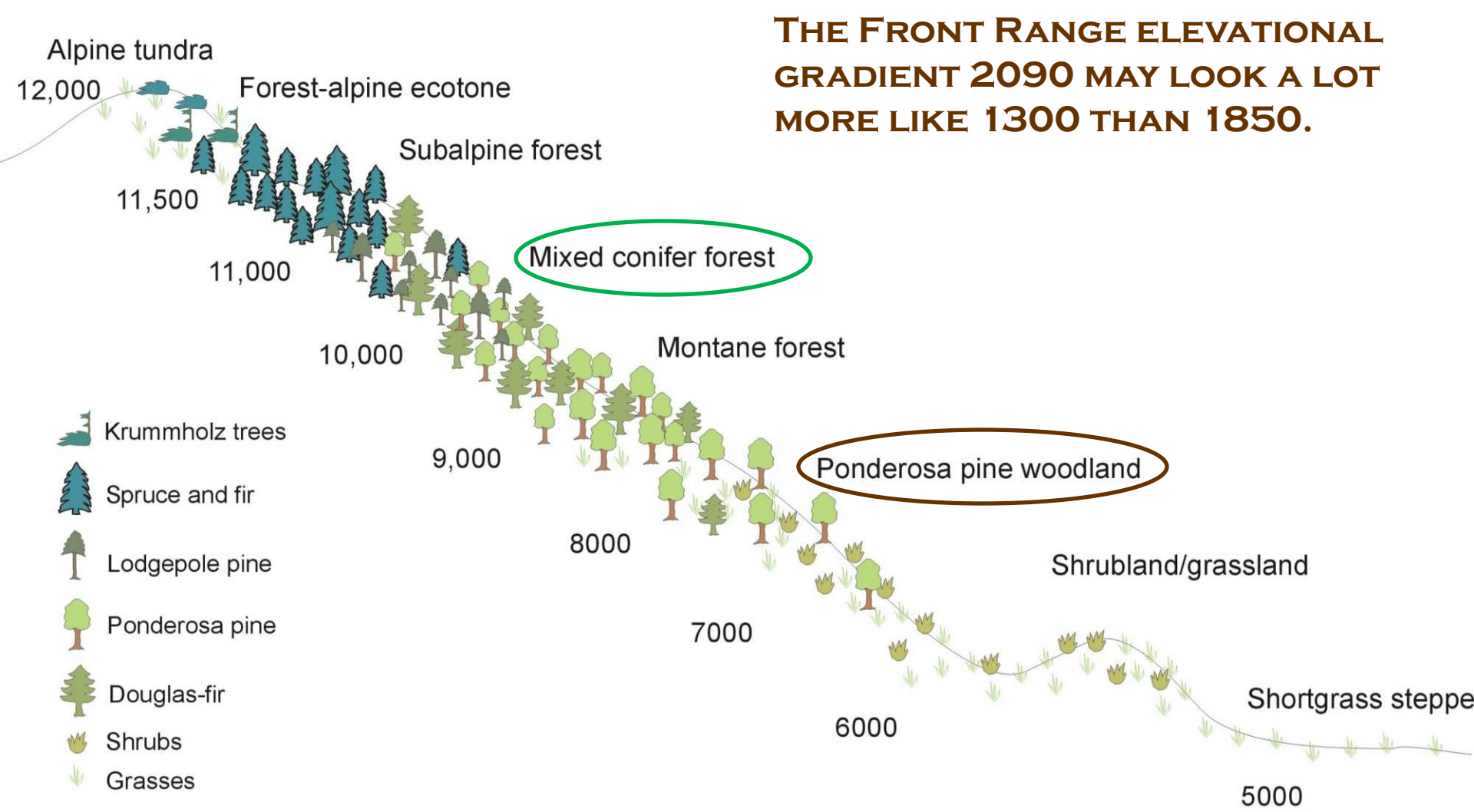
The Wall-the top of the mountains!

Fire and insects, climate change effects on ponderosa pine/Douglas-fir forest

Fire and insects, climate change effects on subalpine forest/alpine

The montane zone is predicted to change less during future climate change than ecosystems above and below it. The complex mosaic of vegetation will make mixed conifer resliient as it has been in the past.

The Front Range elevational gradient 2090 may look a lot more like 1300 than 1850.



Climate change and large disturbances like fire and insect outbreaks will eliminate existing communities, legacies of the Little Ice Age. What regenerates will be suited to the present climate. Disturbance regimes will likely follow vegetation—until a no analog future occurs.

Recommendations for managers based on this Study:

- **Change has already begun.**
  Large mixed severity and stand-replacing disturbances are altering the landscape. Species which regenerate will be suited to the current climate, not to the Little Ice Age.

- **A lag between climate change and landscape structure change is likely.**
  Trees are long-lived. Mature trees can endure less than optimum conditions. More than one stand-replacing disturbance may occur before species composition changes completely.

- **Use data from lower elevations to predict regeneration.**
  Communities and associated disturbance regimes are predicted to migrate northward and to higher elevations as climate change progresses. Future climate and landscapes may be more like the Medieval Warm Period than the Little Ice Age.

- **Maintain the landscape mosaic! Complexity is the key to mixed conifer resilience in the face of changing climate.**
  Mixed conifer is the “crumple zone” for climate change effects on communities both above and below it in elevation. The spatial and temporal complexity of mixed conifer provides refuges and seed sources for species as they migrate or adapt to new climates and disturbance regimes.

In defense of historical ecology:

"Reference conditions are not simply a historical snapshot…they must be viewed over much longer timescales. The fire-related adaptations of pine forests are associated with fire's role as a selective force going far back in evolutionary time…"

"Forests that currently occupy the middle range of elevation may be expected to face severe stress from climate change in the coming decades."

"Adaptation of reference information to future climates is logical: historical characteristics from lower, southerly, and drier sites may be increasingly relevant to higher, northerly, and currently wetter sites."

High elevation ponderosa pines

From: Fulé, P.Z. 2008. Does it make sense to restore wildland fire in changing climate? Restoration Ecology 16 (4) 526-531.

Acknowledgements

This study and any wisdom it may impart is due to the help and support of:

The Front Range Fuels Treatment Partnership and USFS Rocky Mountain Research Station for funding and support

Lucas Herman, Jennifer Horsman, Cinnamon Levi, Chris Welker, and John Popp for help in the field and laboratory

Merrill Kaufmann, Brian Kent, Paula Fornwalt and Jose Negron, RMRS

Peter Brown, Rocky Mountain Tree-Ring Research, Inc.
Rick Bachand, City of Fort Collins
US Forest Service, Canyon Lakes District
The City of Fort Collins
Larimer County

The trees and magnificent mountains of our backyard and all the people and creatures ancient and modern who have lived here.

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