The dark side of the forest: Belowground ecosystem response to fire

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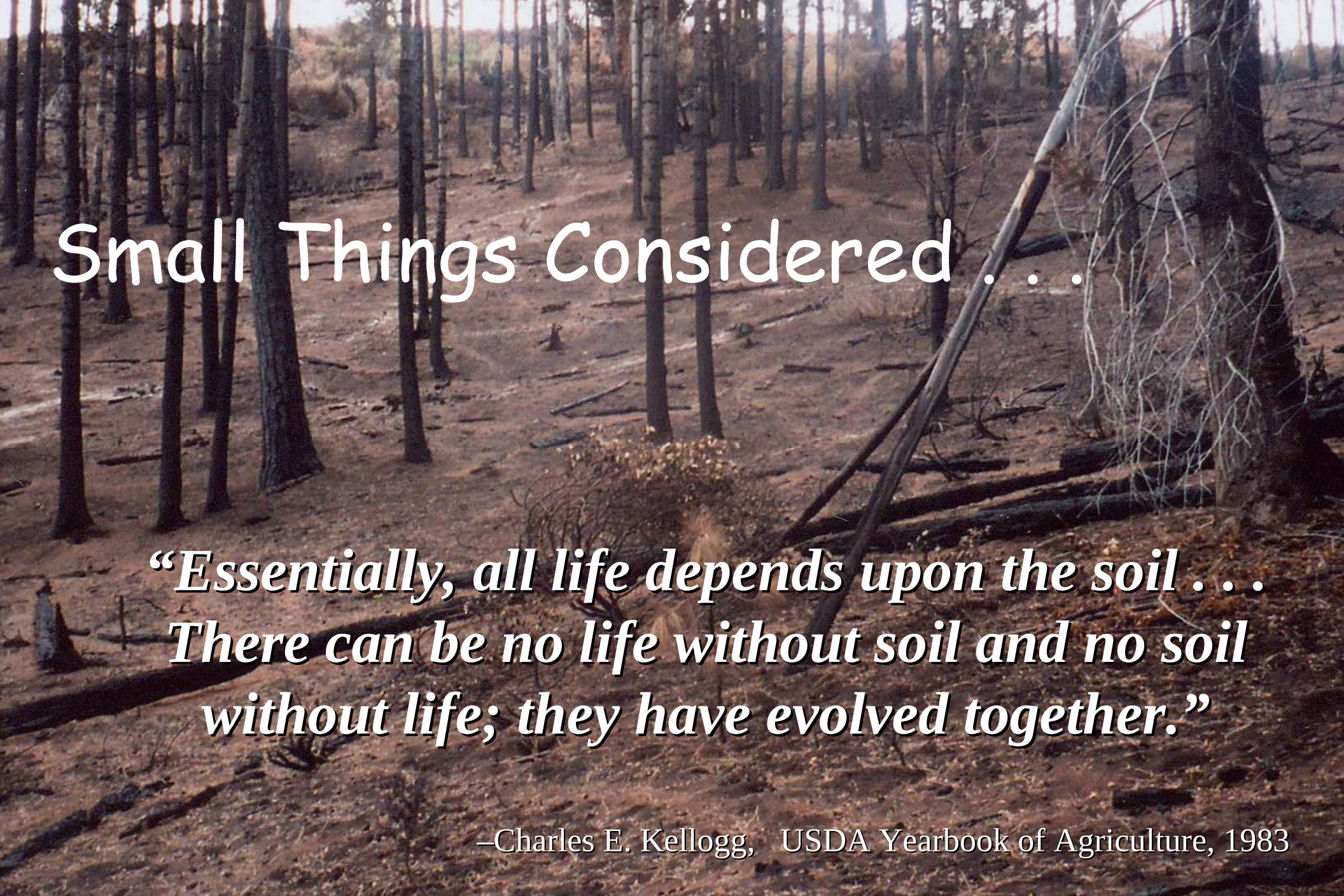
DEATH RIDES
THE FOREST
WHEN
MAN IS
CARELESS

Big questions for forest managers about soil

Why are soil microorganisms important?

What are the effects of stand-replacing wildfire, post-fire logging and prescribed fire on soil microorganisms?

What are the management implications and considerations when reducing fuels?



Small Things Considered . . .

"Essentially, all life depends upon the soil . . . There can be no life without soil and no soil without life; they have evolved together."

–Charles E. Kellogg, USDA Yearbook of Agriculture, 1983

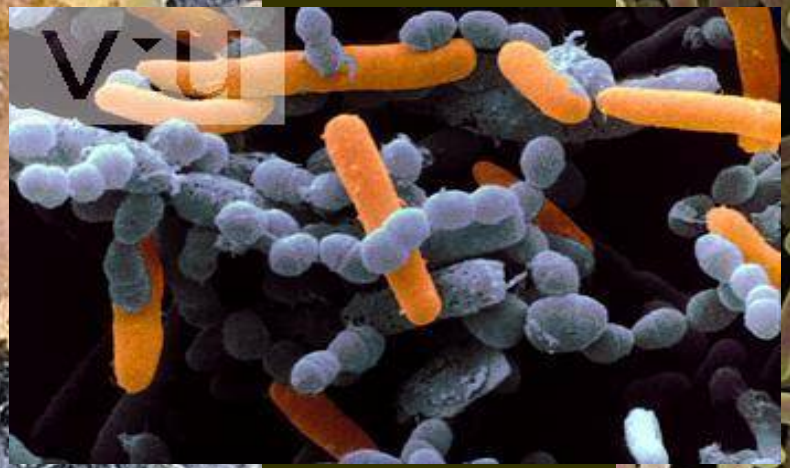
Soil: A complex *living system* consisting of weathered rock, organic matter, and small living organisms.

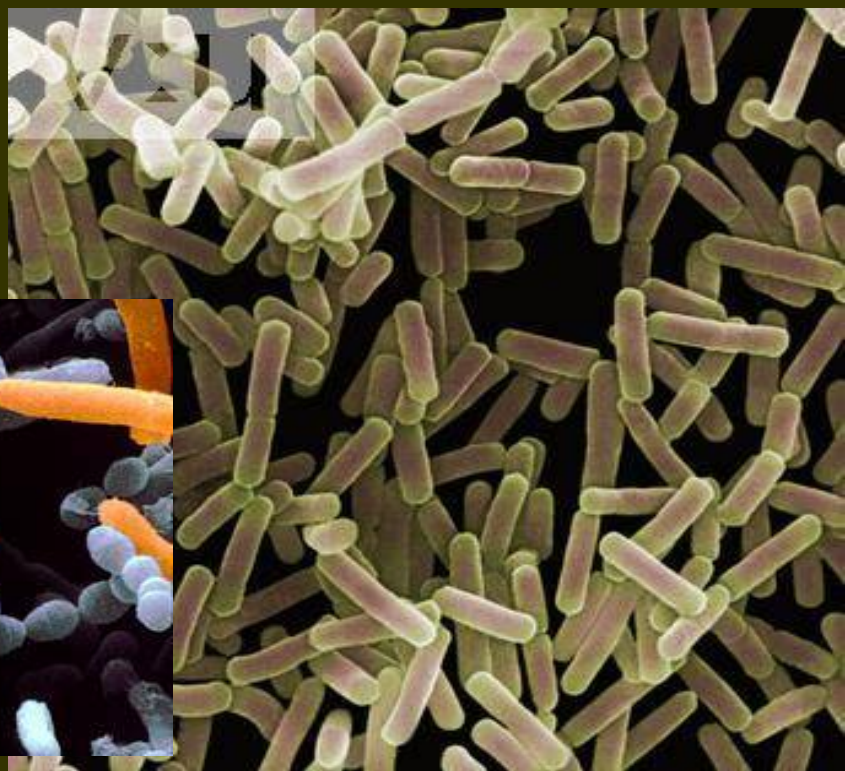
- Basic natural resource ~ crucial to life on earth
- Non-renewable in our lifetime
- Susceptible to natural and land management disturbances

Soil is home to the bulk of forest biodiversity, and its importance cannot be overstated!

Soil bacteria & fungi

- Influence plant productivity
- Transform nutrients from organic to inorganic forms





Varied Ecosystem Functions

Parasites / pathogens: infect trees, creating snags and hollow logs for wildlife

Saprobes: decompose organic matter & cycle nutrients

Mycorrhizal: symbiotic associations with plants and wildlife

Fire effects on soil microorganisms

Despite the importance of soil microorganisms in forest nutrient and carbon cycling processes, there is *relatively little consistent information on their response to fire.*

Depends on:

- Intensity of fire
- Maximum temperatures
- Soil-water content
- Duration of heating
- Depth of heating
- Site conditions
- Pre & post fire weather
- Ecosystem type

Fire effects on the belowground

Wildfire (2003 - 2009)

- High severity stand-replacing fire
- Post-fire salvage logging

Prescribed fire (1997 – 2002)

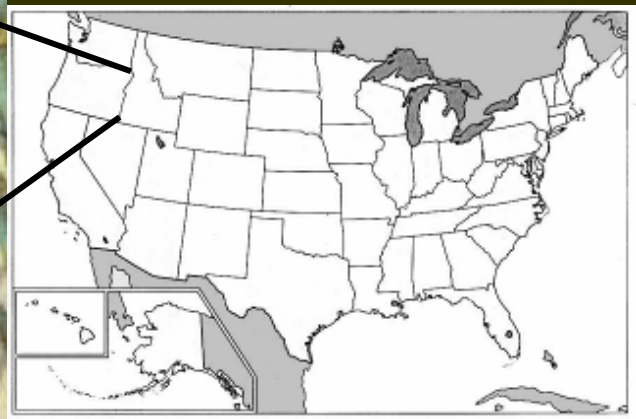
- Fuel reduction methods
- Season of burn

An Eastside Story -

Eastside of the Cascade Range & Blue Mountains, OR

Open dry forests of ponderosa pine & Douglas-fir

Mostly volcanic in origin



Methods

Soil chemistry

Broad microbial groups & estimate microbial biomass

- PLFA (Phospholipid fatty acid analysis)

Fungal & Bacterial species richness

- T-RFLP & RFLP (Terminal) Restriction length polymorphism

Identify species

- Cloning / Sequencing

Assess biological function/activity

- Biolog Ecoplates
- Respiration
- Phosphatase Enzyme Activity

Stand-replacing wildfires

Bear Butte – August 19, 2003

August 2003 - B & B Fire

- 90,000+ acres
- mixed severity

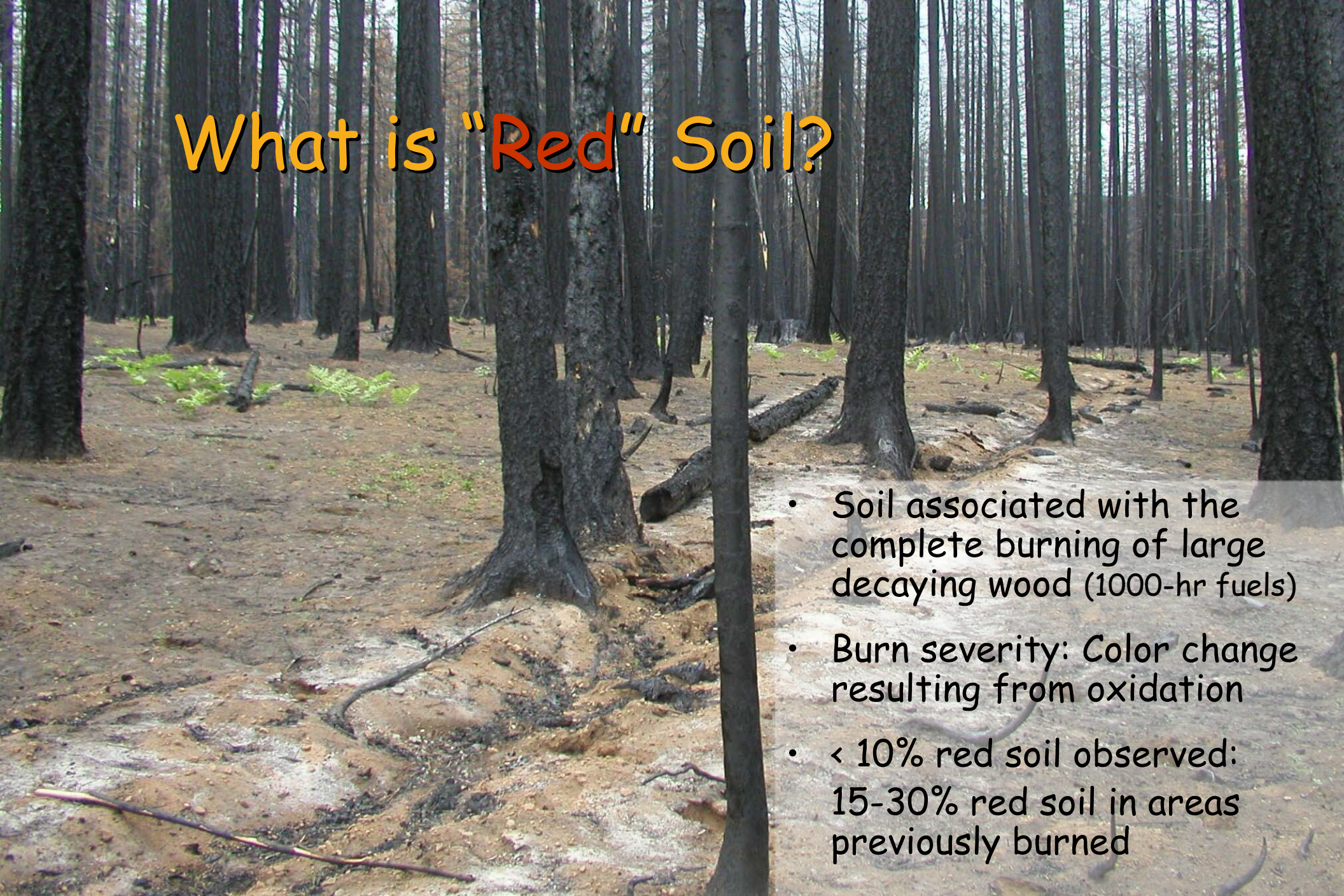
Bear Butte

Booth

Photos: B&B website

In some areas, the B&B fire consumed much of the large down wood, removing the organic horizon and oxidizing the soil to a reddish color.

What is "Red" Soil?



- Soil associated with the complete burning of large decaying wood (1000-hr fuels)
- Burn severity: Color change resulting from oxidation
- < 10% red soil observed:
  15-30% red soil in areas previously burned

"Red" Soil

"Red" soils are thought to be absent or nearly absent of biological activity.

The length of time for recovery of biological functioning is not known.

20 preliminary samples were taken October 2003, before rain.

Paired plots of severely burned "red" soil and less severely burned "black" soil

Ghost logs (1000 hr fuels)

Note color difference!

Spring of 2004 expanded the study area - 5 sites where red soils occurred
Mt. Jefferson
Jefferson Upper
Jefferson Lower
Bucket Hole
Rd 1280
Rd 1210
20
ntiam Highway

5 sites
6 paired plots/site

Severely burned soil

Less severely burned soil

Map of B&B burn

Fire severity

How does fire severity affect soil recovery?

When do soil organisms return to red soils?

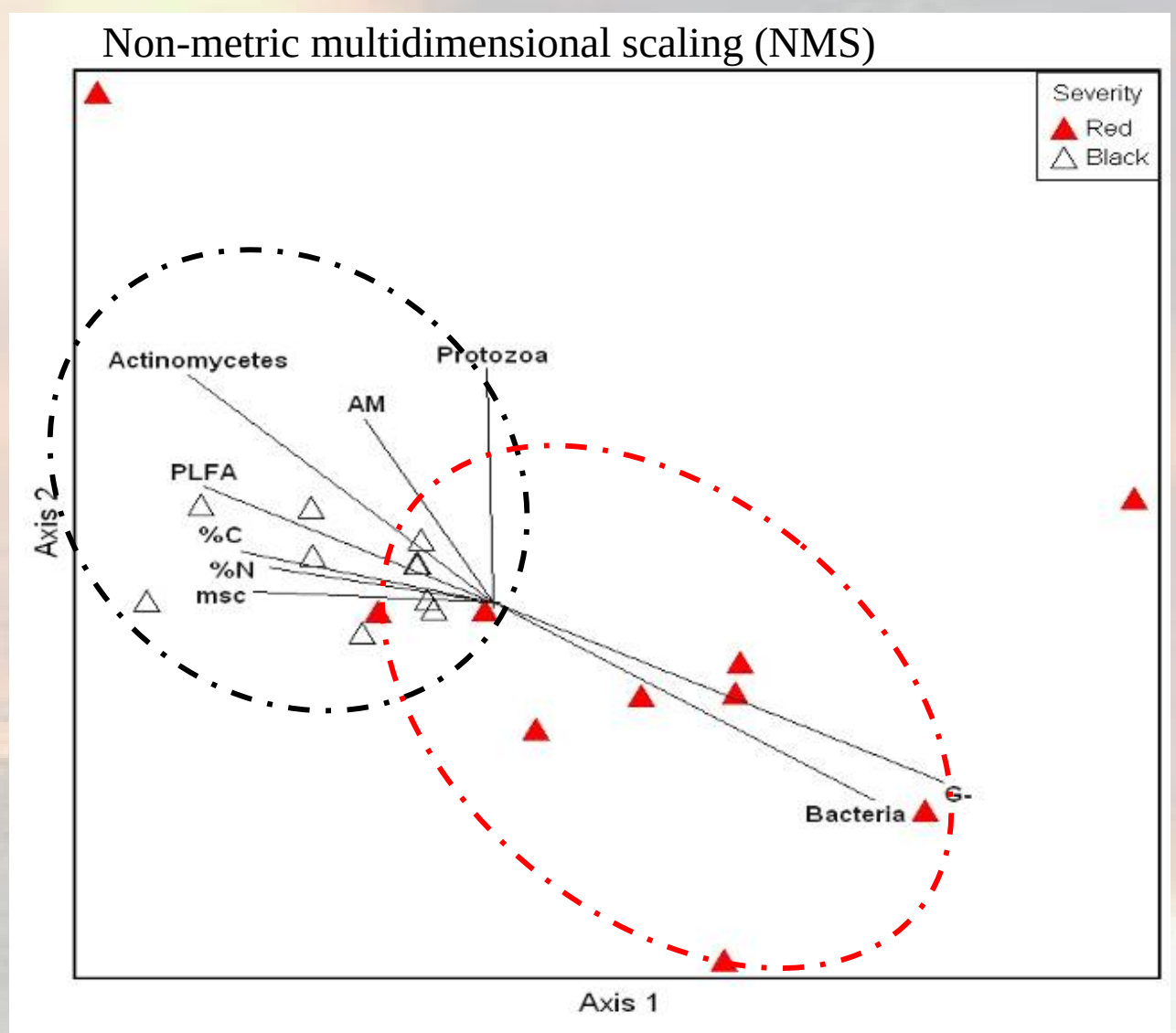
Are red soils sterile?

Fire severity

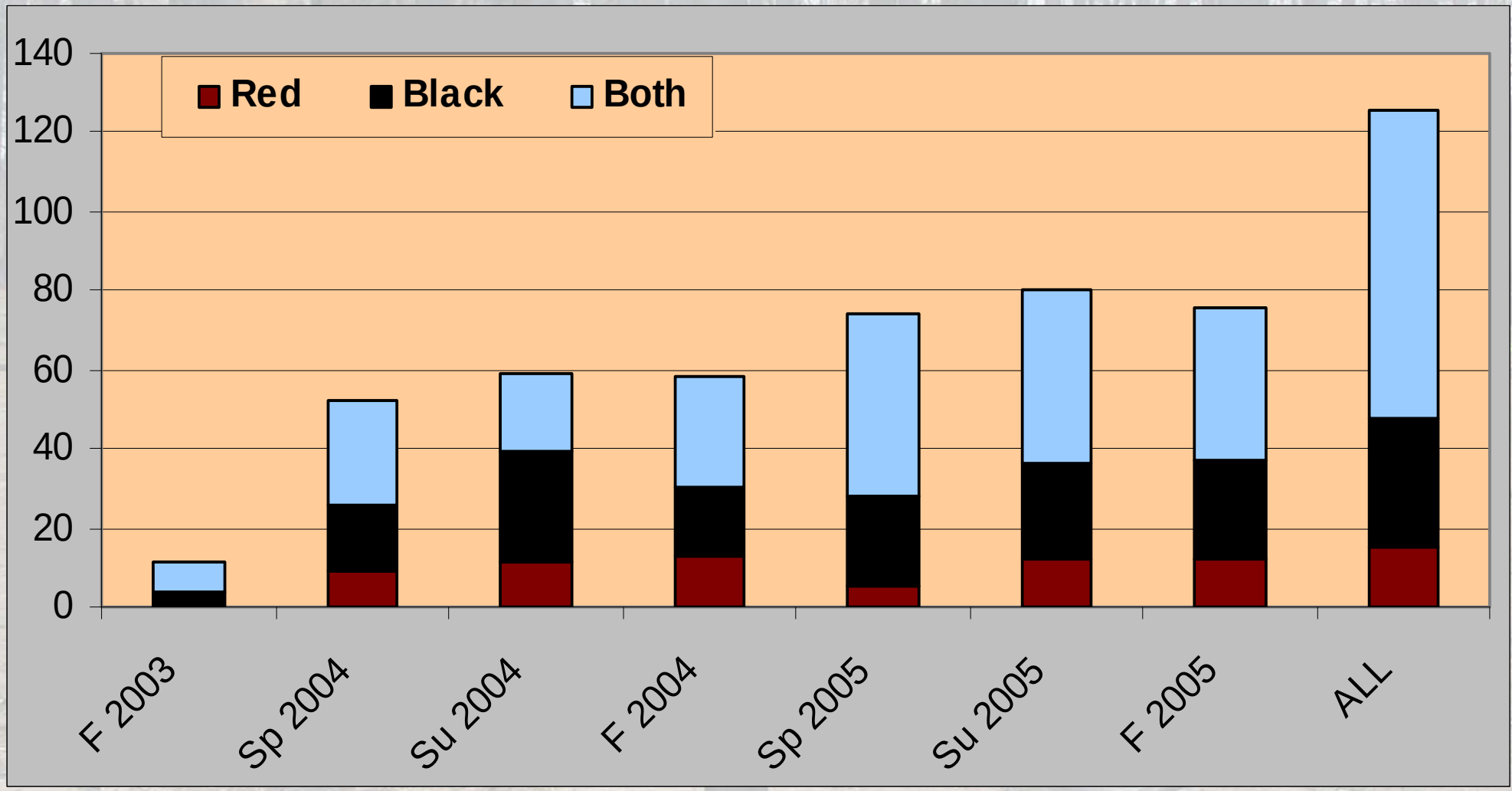
- Significant separation of the microbial community with respect to burn severity.

  - Greater amounts of soil microbes (total PLFA) in black soil.

  - Greater relative abundance of bacteria in red soils.



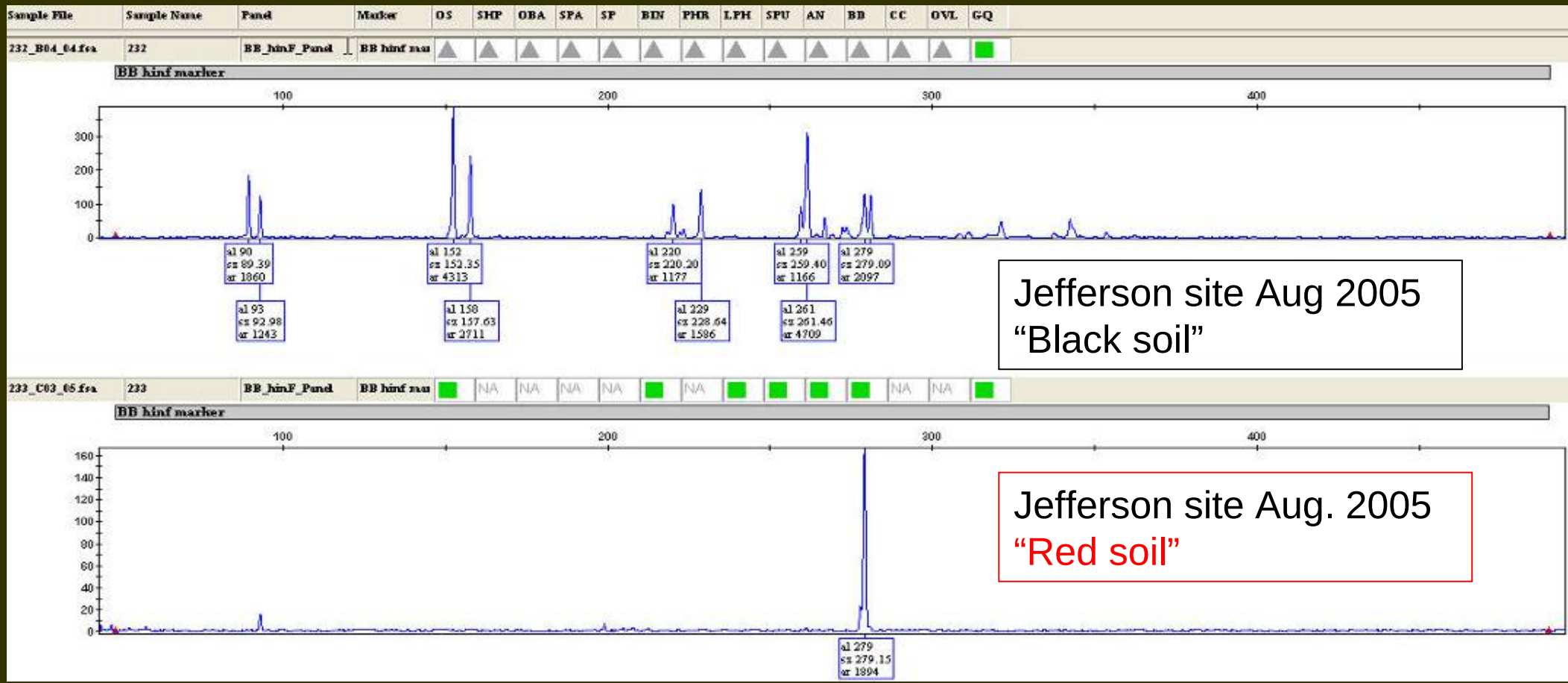
Fungal species richness by season



About 120 T-RFLP species were detected

Many fungal species were common to both the red and black soils

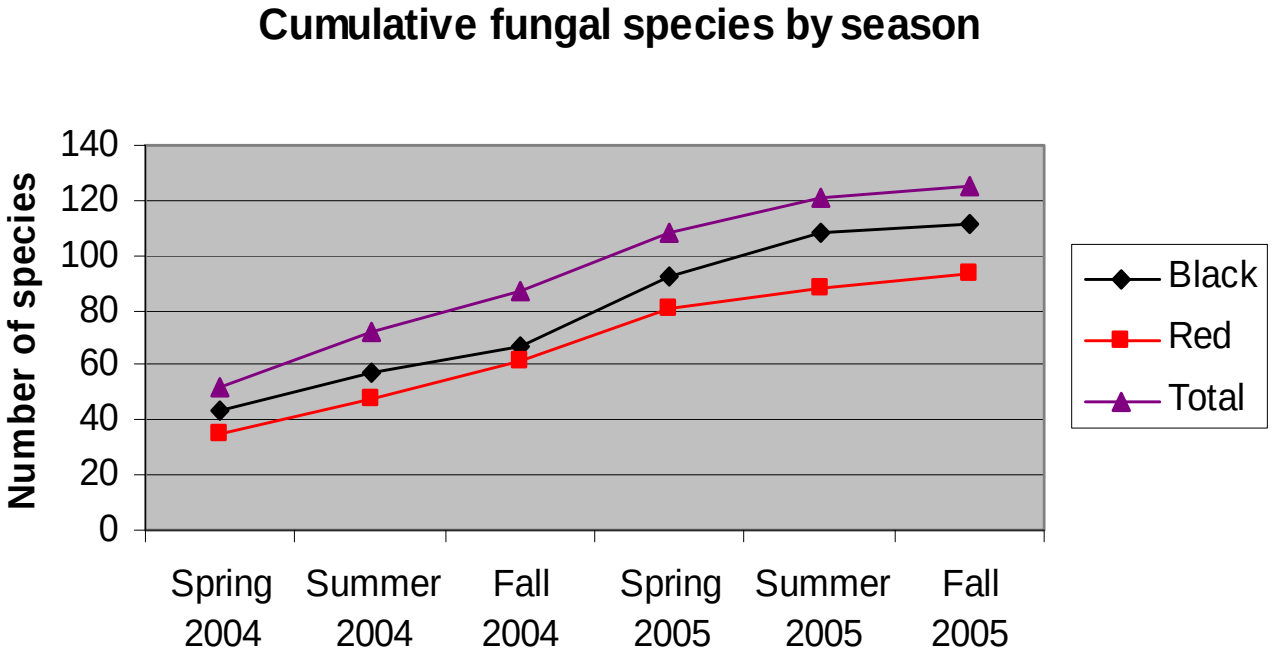
Fungal species richness (T-RFLP) by fire severity



Terminal Base pair fragments were observed in ABI GeneMapper™

Aboveground & belowground recovery

Significantly greater number of fungal species in black compared to red soils



Pholiota

Pyronema

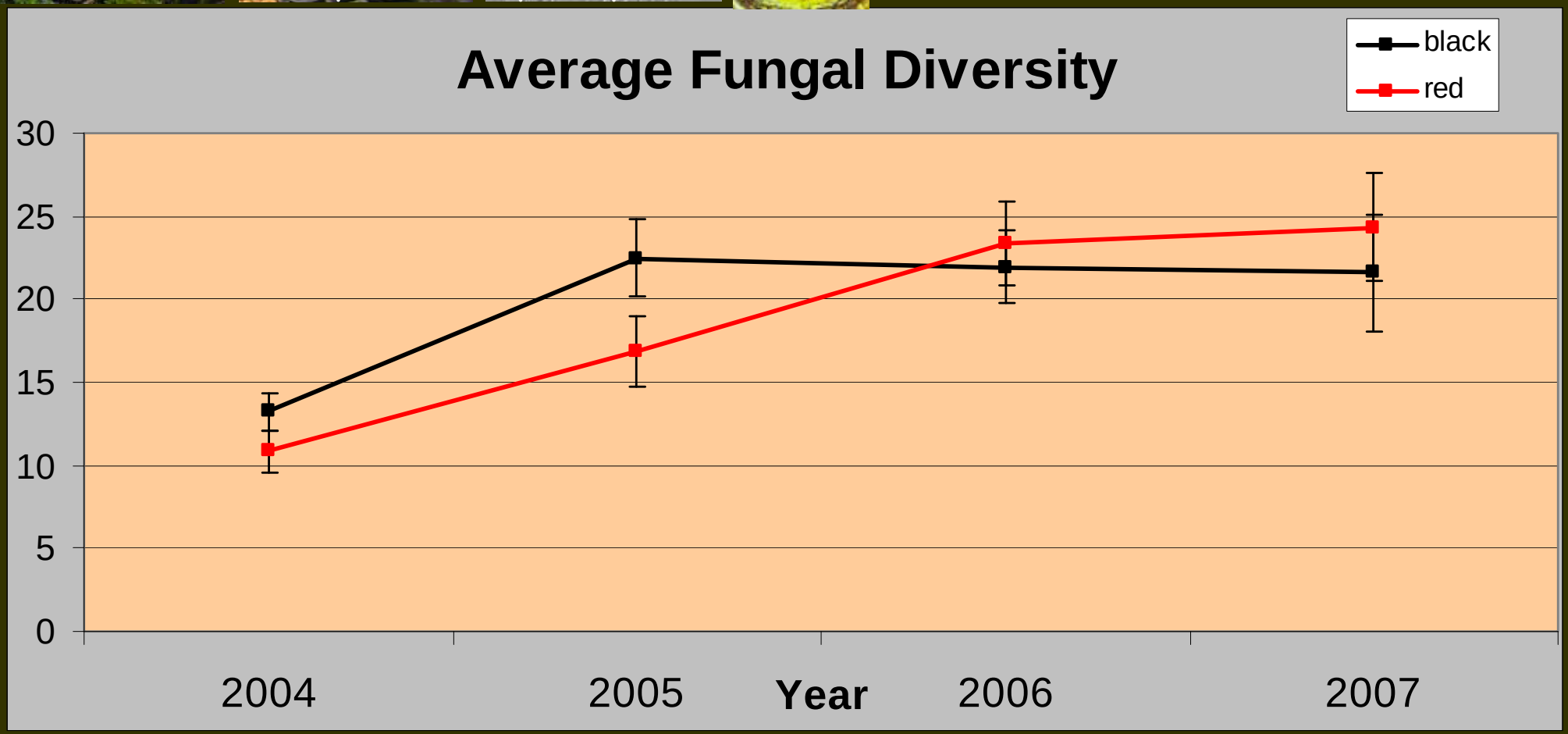
Spizellomyces

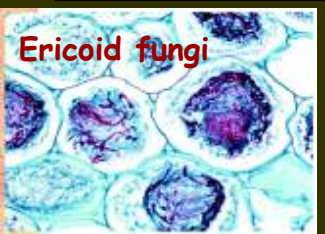
Venturia

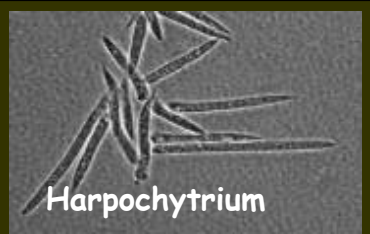
Tomentella

Polyporales

Lecanicillium


Average Fungal Diversity
black
red
30
25
20
15
10
5
0
2004
2005
Year
2006
2007


Ericoid fungi


Harpochytrium

Helotiales

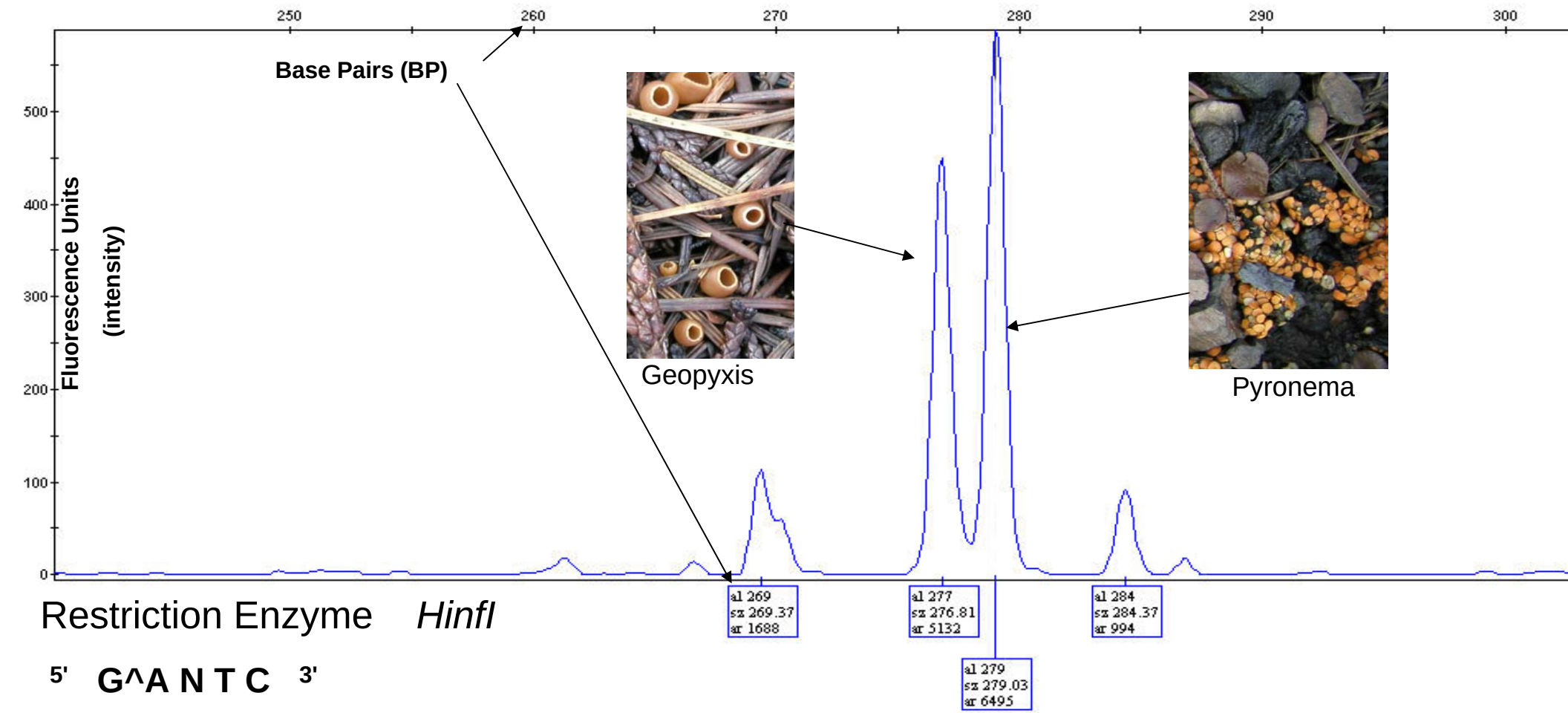
Leucopaxillus

Lyophyllum

Nectria

Soil fungal species richness

Terminal Restriction Fragment Length Polymorphism (T-RFLP)



Restriction Enzyme *HinfI*

5' **G^A N T C** 3'

Cloning & sequencing revealed mostly saprophytic and fire-loving ascomycete fungi in the first 2 years after wildfire

Soil Fungi

Soil fungi in red soils initially were greatly reduced

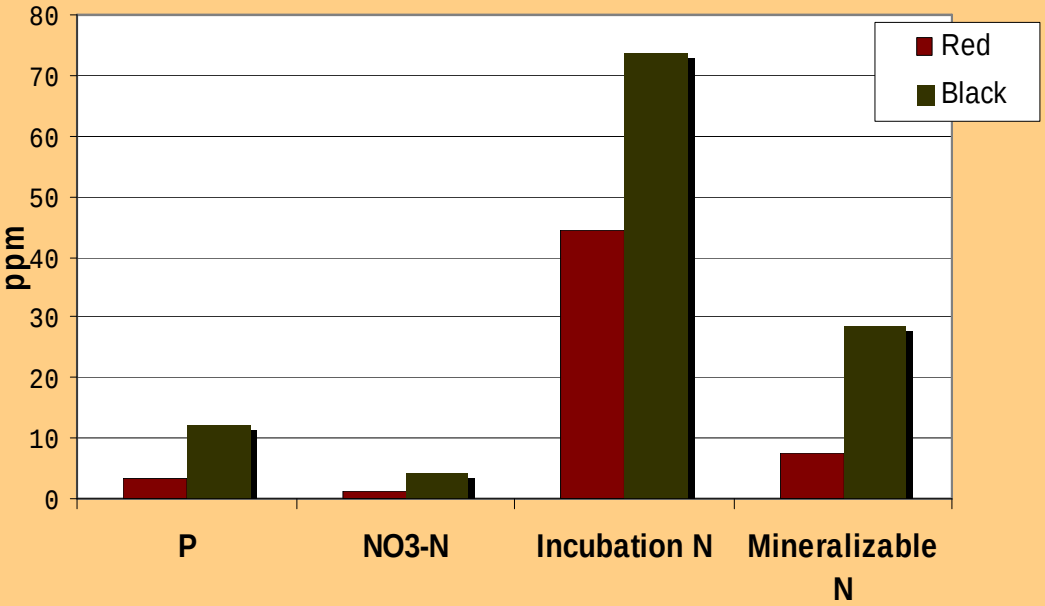
"Fire loving" saprobic fungi first to return to burned soils

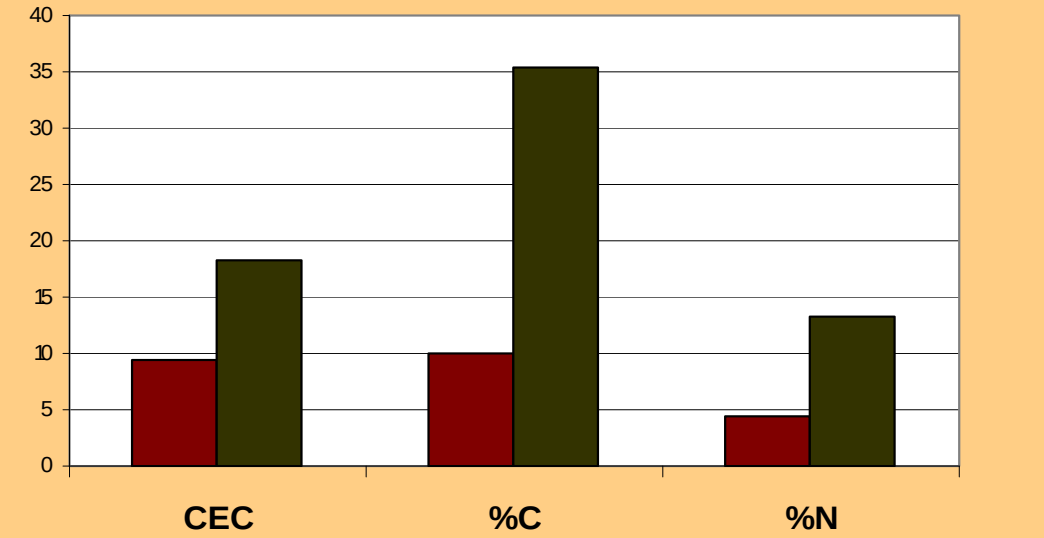
A few mycorrhizal species detected 3 years after fire

Fungal species increased in red soils around year 4

Soil Chemistry

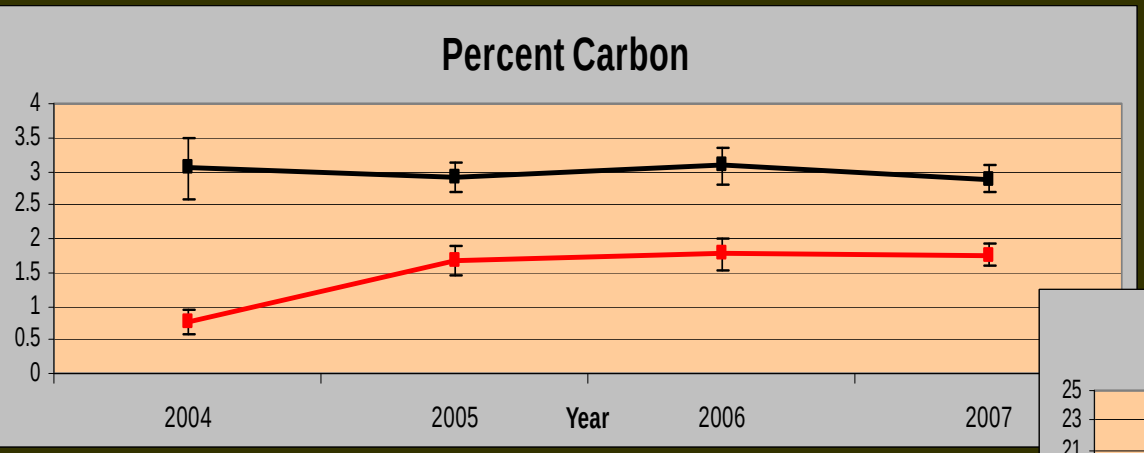
Nutrients significantly lower in red soil

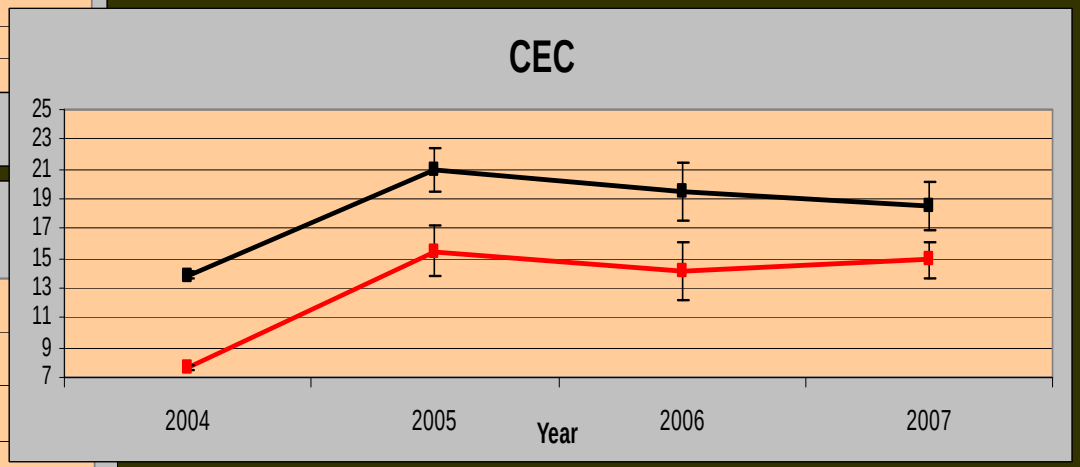


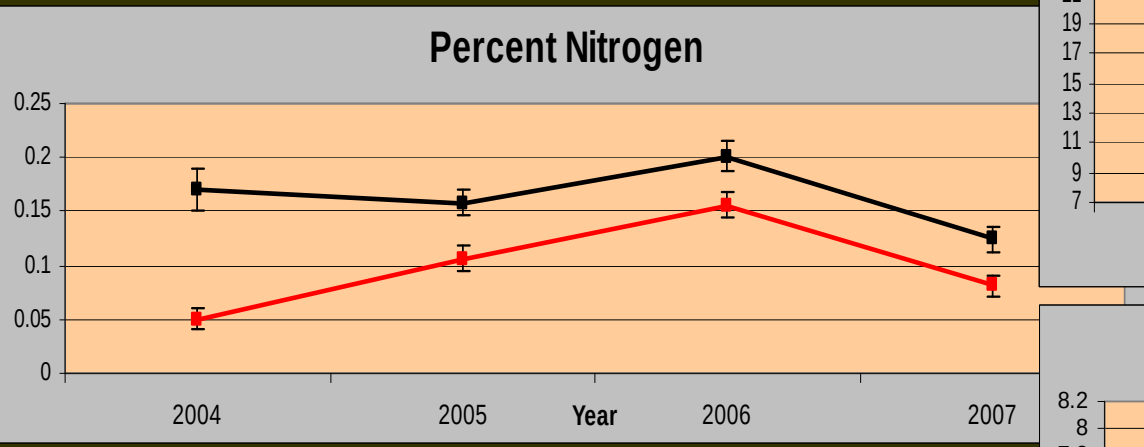


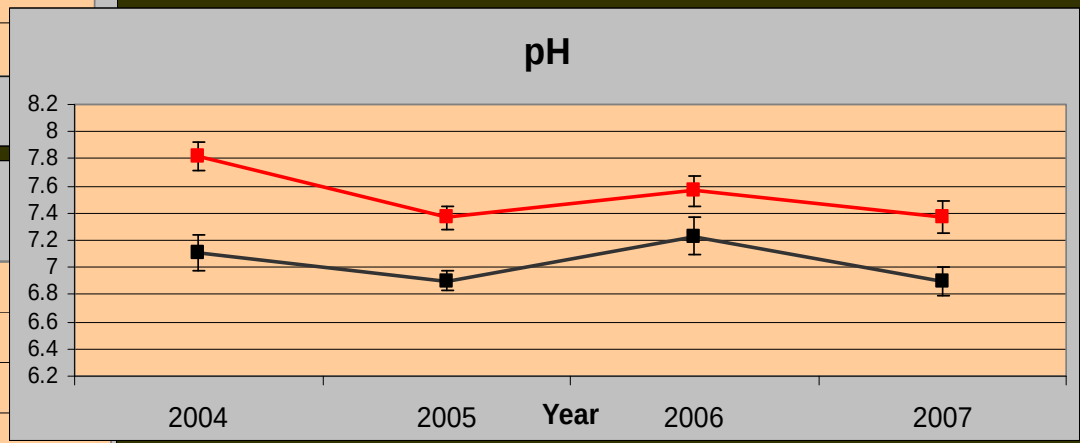
(Hebel et al. 2009. Applied Soil Ecology 42: 150-159)

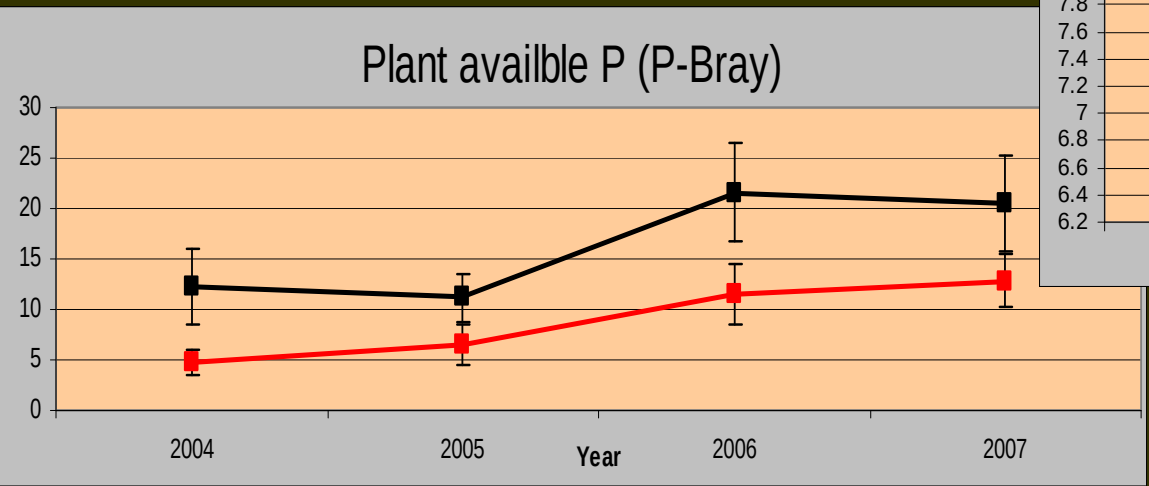
Soil Chemistry











Black
Red

We observed . . .

Soil nutrients and the microbial community were substantially reduced in red soils.

Soil nutrients in red soil have not recovered to black soil nutrient levels after 4 years

Land management considerations

In dry forests of western North America, large wood was limited historically by frequent low severity fires.

Stand replacing wildfires in these forests are creating high levels of large wood.

Forest managers are balancing uncertainty about the impacts of fuel reducing restoration treatments with the probability of stand replacing wildfire.

Photo: C. Halpern

Salvage logging

Salvage logging

- Fire-killed trees harvested to recover economic value before decay
- Removing dead trees slows the buildup of insect pest populations and reduces fuel loads in the event of future fires

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- Fire and salvage logging may negatively impact the abundance, activity, and composition of soil microbial communities
- Ground based logging frequently results in soil compaction

Salvage logging: Study Design

3 treatments x 7 stands x 6 seasons

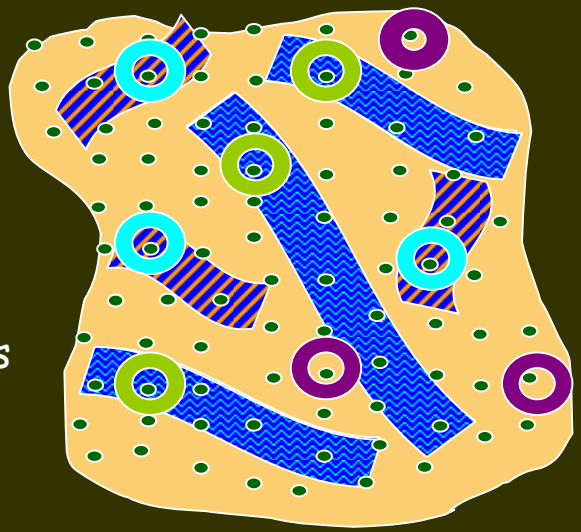
Undisturbed

Compacted

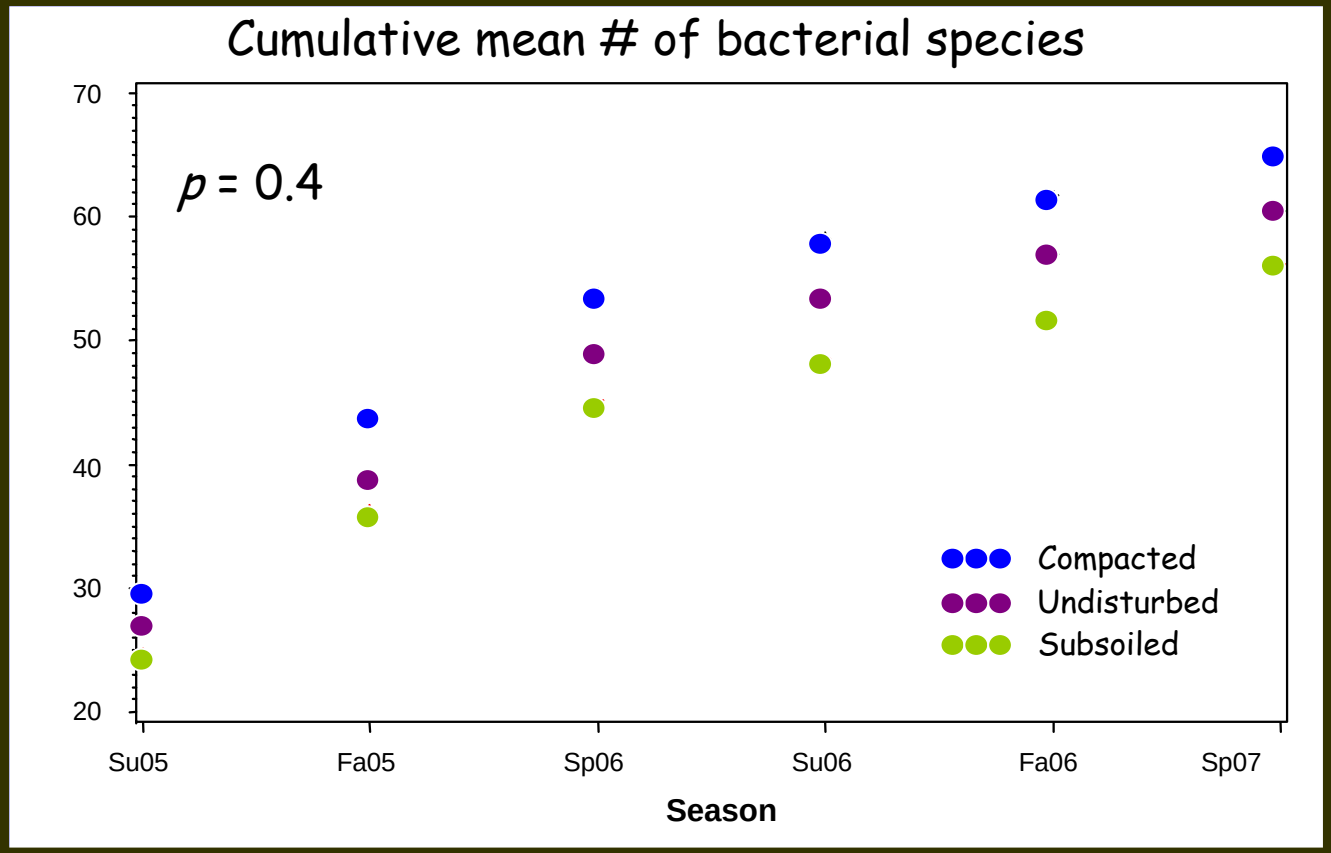
Subsoiled

Planted seedlings

Sampling Plots



Salvage logging: Results



Postfire salvage logging had little effect on soil microbes.

(Jennings et al. 2009. Forest Ecology & Management – submitted)

Salvage logging: Results

Postfire salvage logging in a dry mixed conifer forest with sandy loam volcanic soils had little effect on soil microbial communities and their function.

Annual and seasonal differences seemed to have a more pronounced effect than harvesting treatments on soil biological properties.

Soil microbes in these postfire landscapes appear both tolerant of the occurrence of fires and resilient to disturbance.

(Jennings et al. 2009. Forest Ecology & Management – submitted)

Fuel Reduction Studies

Eastside Ecosystem Restoration

- Reduce potential for stand replacing fire
- Reintroduce fire to the ecosystem
- Produce a future supply of wood products
- Protect long-term soil productivity

Prescribed fire & thinning to reduce fuels

TO THIN

or

TO BURN .....

Spring burn

Fall burn

Prescribed fire - Season of burn

Spring burning

or

Fall burning

Considerations -

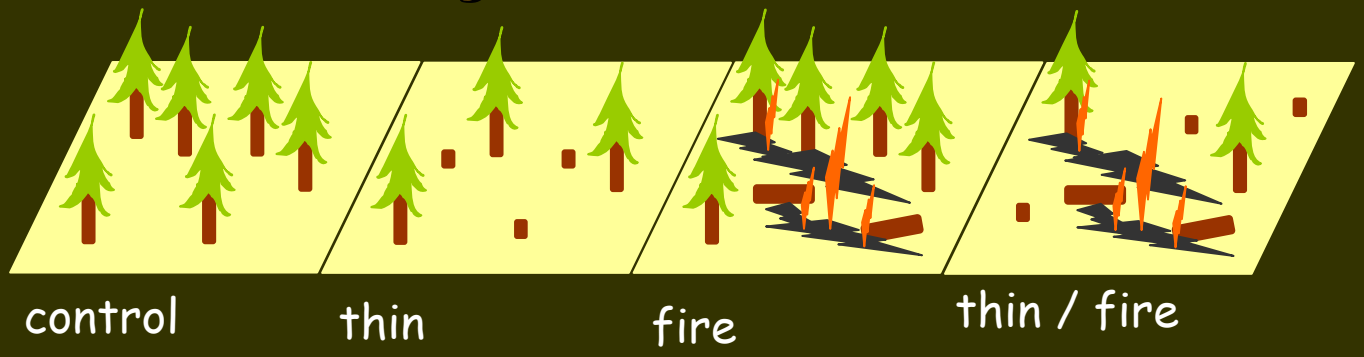
Spring burns differ from Fall burns:

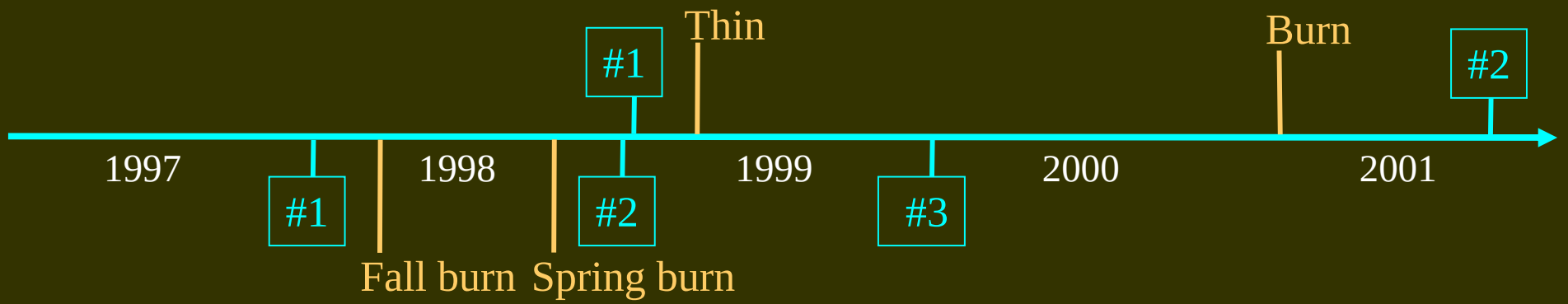
higher fuel moisture levels

actively growing roots

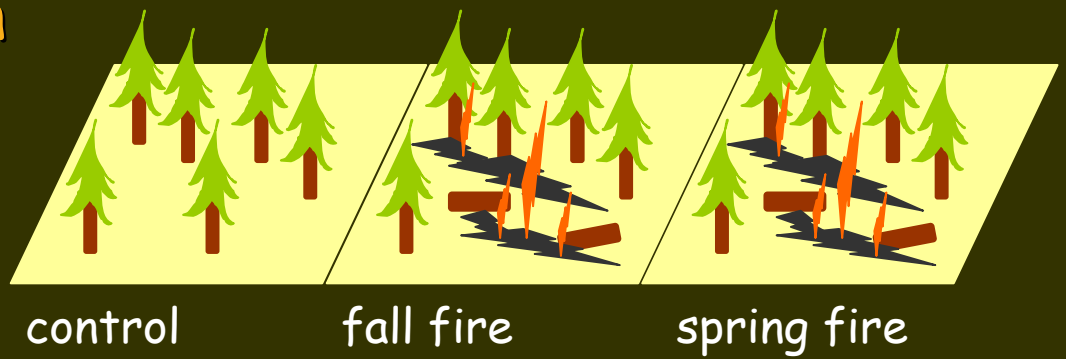
moist soils readily conduct heat

Prescribed fire & thinning





Season of burn



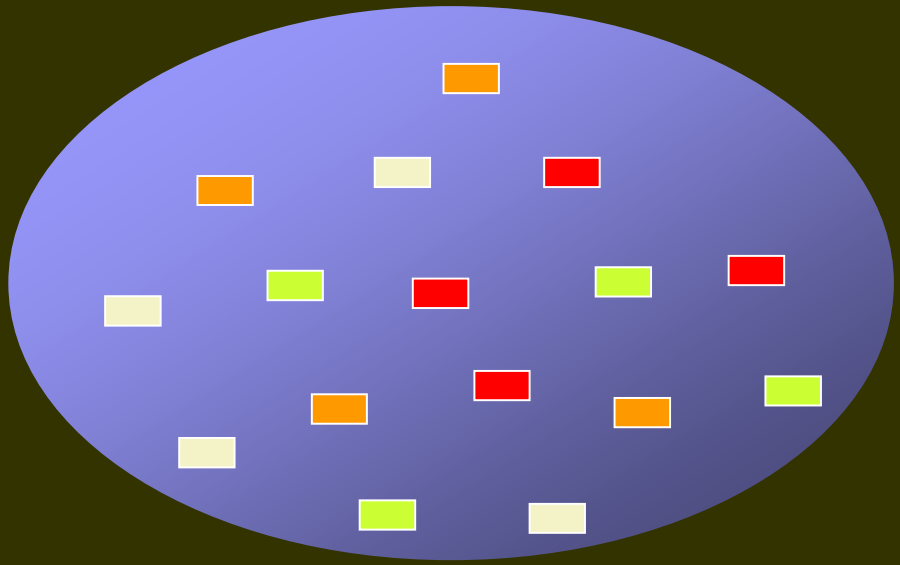
Prescribed fire & thinning

Fuel reducing restoration methods

Complete randomized design

4 stands of each treatment

Control
Burn
Thin
Thin & Burn



Ponderosa pine / Douglas-fir

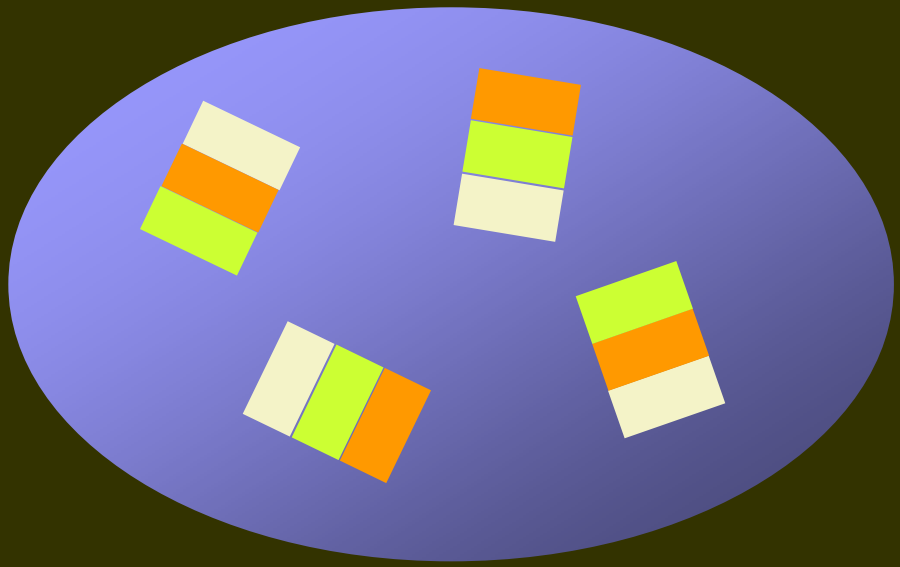
Season of burn

Seasonal burning

Complete blocked design

4 replicates of each block

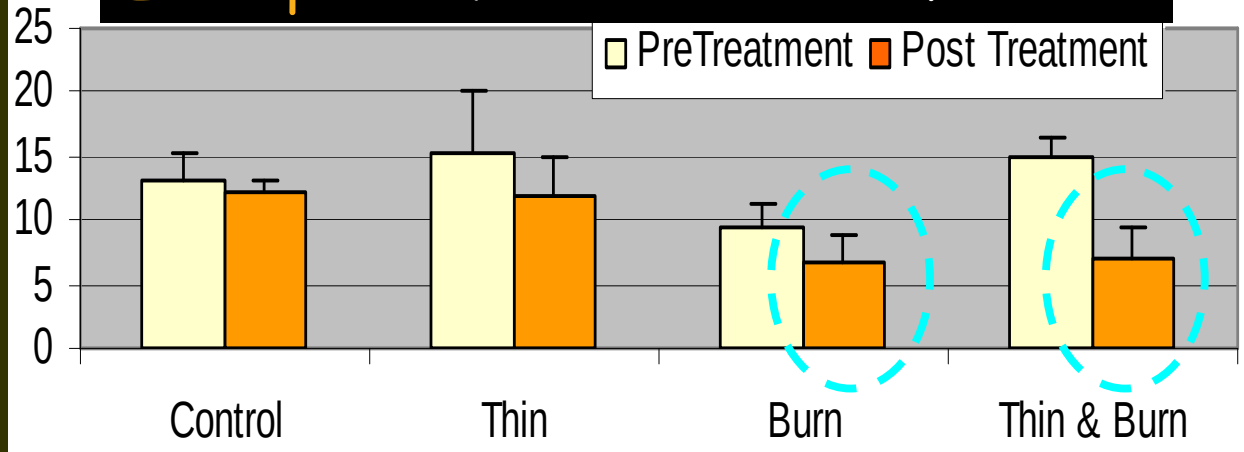
Control
Spring burn
Fall burn



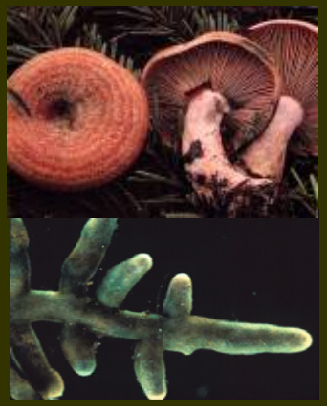
Ponderosa pine

Mycorrhizal fungi species richness

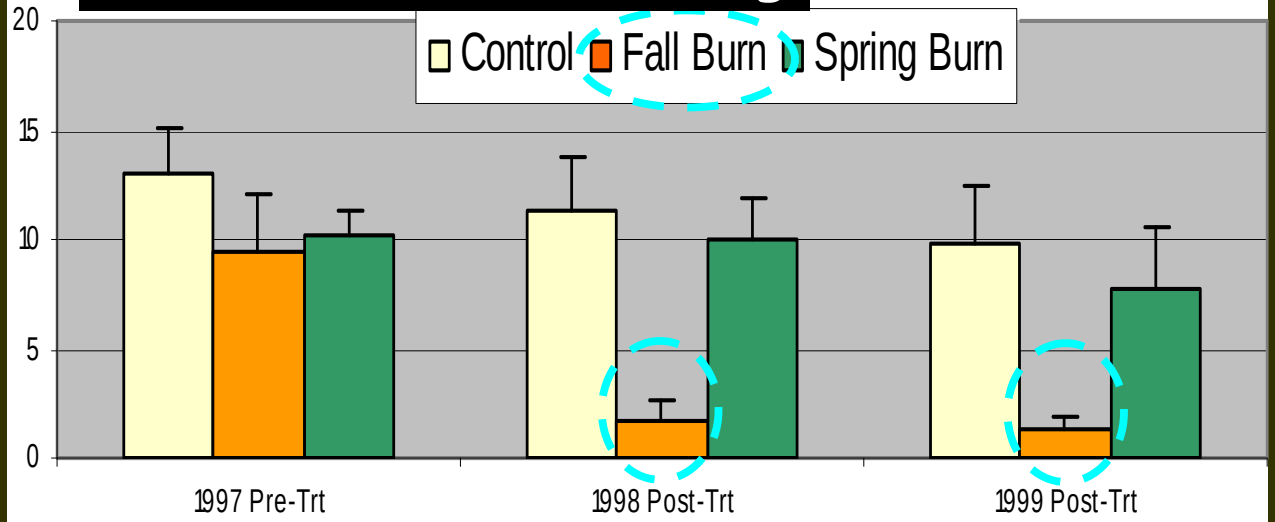
Enterprise: Fuel reduction methods



Burning reduced mycorrhizal species richness compared to non-burn treatments.



Burns: Seasonal burning



Fall burning reduced mycorrhizal species richness for at least 2 years.

(Smith et al. 2004. Can J For Res)
(Smith et al. 2005. Applied Ecology)

Management considerations for large-tree retention with low fuel loads

Gradually reduce, rather than remove, duff accumulations around large trees.

Reintroduce fire at times of the year when fuels are less combustible before returning to a fire regime on the historic fire return frequency and season.

Supporting results from other studies

Mortality of mycorrhizas correlates with burn intensity & tree survival	~Dahlberg *et al.* 2001
Large tree mortality was greater after fall burning compared to spring	~Thies & Niwa 2001
Complete consumption of the litter layer leads to old-growth pine mortality	~Scott 2002

Land management considerations

- Thinning alone increases small diameter fuels on the ground, increasing the risk for high severity wildfire.
- Control stands served as comparisons to treated stands but may not represent the historic condition or what would occur under desired stand conditions.
- Prescribed burns typically are spatially heterogeneous.
- Short term effects.

Fire Effects on Soil Microorganisms

- Long duration, high-intensity fires have greatest effects.
- Low-intensity, rapidly-moving fires have no major effects.
- Burning moist soils has severe effects in some studies, little effect in others.

Conclusions

Restoration treatments using combinations of low-severity spring and fall underburning, or combinations of thinning and burning, or even salvage logging may reduce litter accumulations and the risk of stand-replacing wildfires.

Burning Questions?

Thanks ! ! !

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