



Climate Change Effects to Rangeland Ecosystems

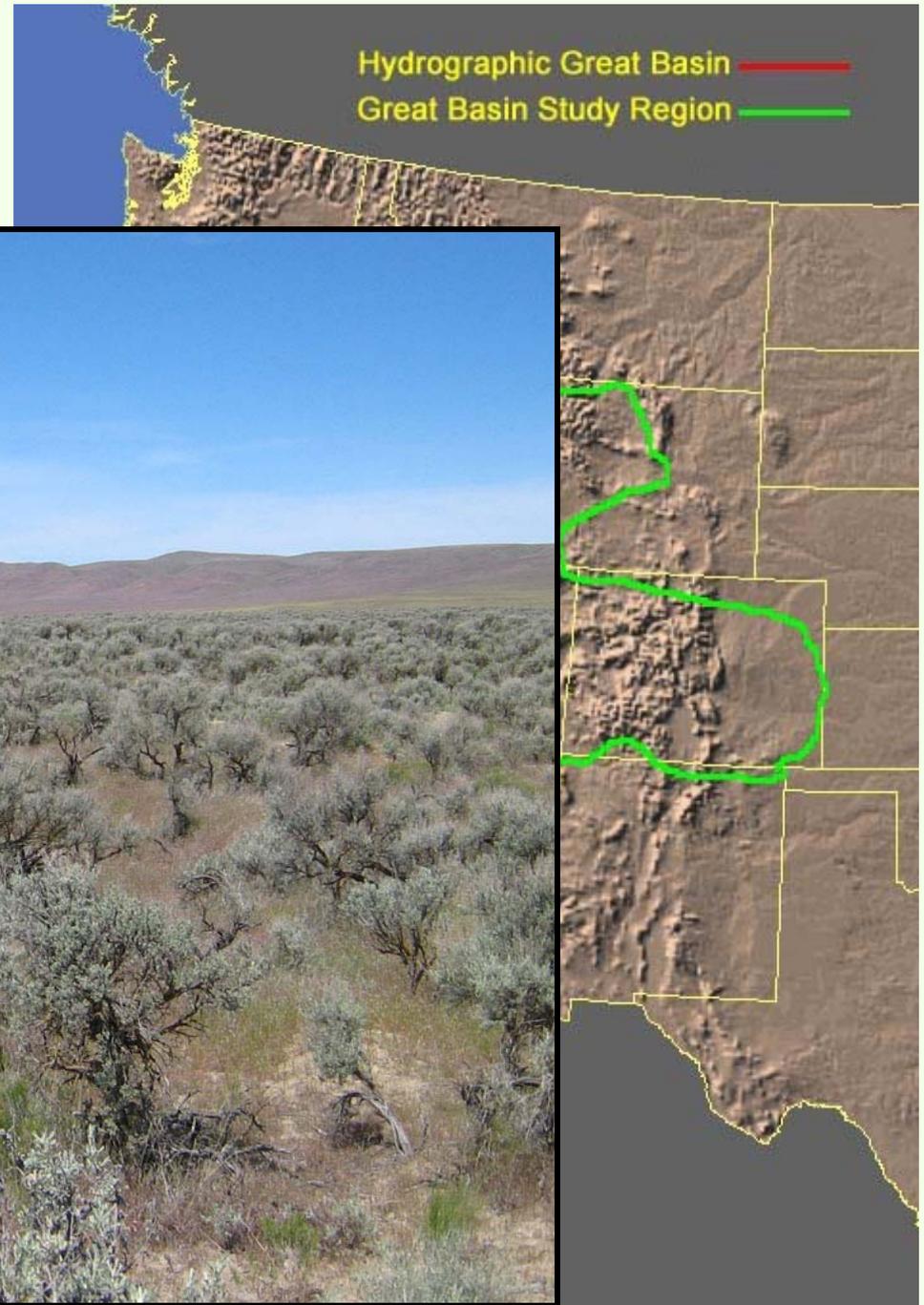
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U.S. Geological Survey

The Story

- 1. Climate change scenarios in rangelands**
- 2. Plant community changes**
- 3. Soil community changes**
- 4. Consequences for ecosystem functioning**

Rangelands of the Intermountain West



Western waterleaf



Longleaf phlox



Indian paintbrush



Leopard lily



Arrowleaf balsamroot



Desert Horned Lizard



Northern Harrier



Pygmy Rabbit

Greater Sage-Grouse



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Mule deer



Pronghorn



Burrowing Owl

Importance to Stakeholders

- **Affects all land uses**
- **Decreasing range productivity**
- **Loss of habitat and species**
- **Increasing numbers of at-risk species**
- **Conflicts with communities and users**



Climate Change Scenarios

- ❖ **Still a great deal of uncertainty as to direction and magnitude of changes**
- ❖ **Important to be aware of possible scenarios**

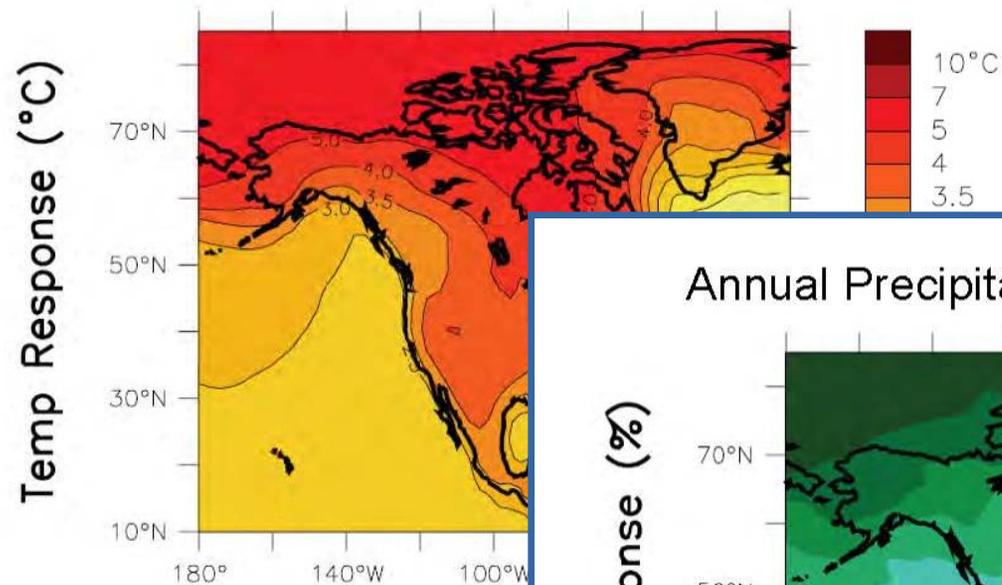
Climate Change Scenarios

Increase in extremes:

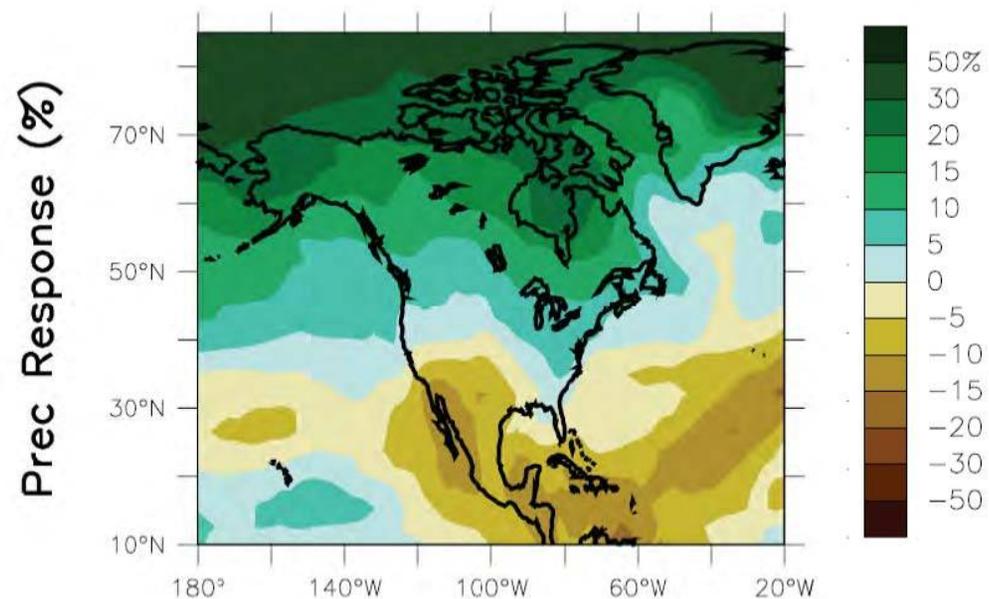
- Higher air temperatures
- Changes in precipitation regimes
- Longer, more frequent droughts
- Shorter fire return intervals
- Continued increase in atmospheric CO₂ levels

Changing Climate: Hotter, Drier

Annual Temperature: End of 21st Century

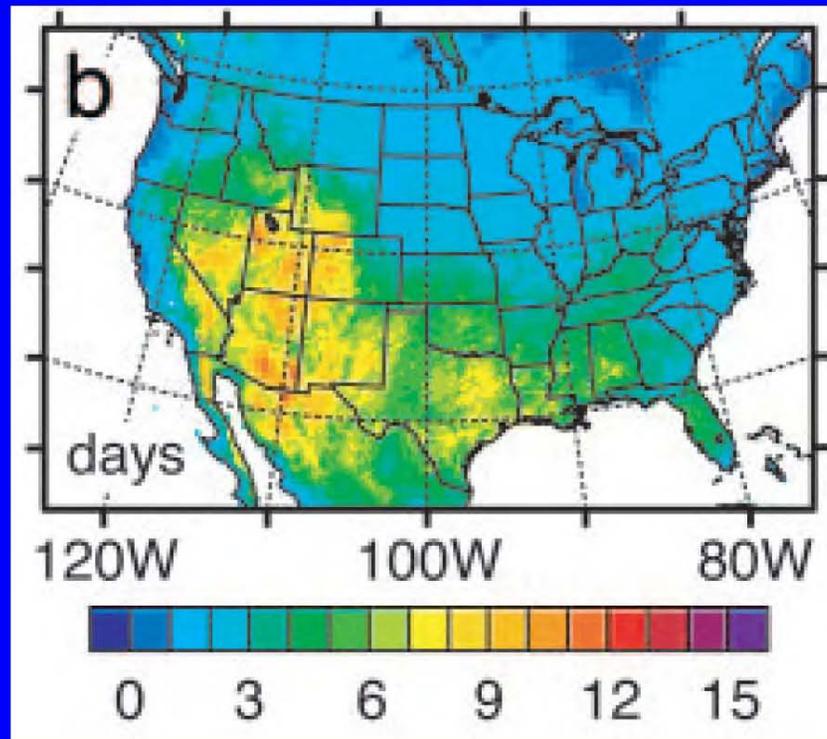


Annual Precipitation: End of 21st Century



IPCC 4th Assessment:
Working Group 1, Chapter 11,
Regional Projections

Changing Climate: Heat Waves



Longer Heat Waves

Diffenbaugh et al., 2005

Proceedings of the National Academy of Science

Climate Change Effects: Water

- **Winter precipitation will fall as rain, not snow**
- **Increased winter flood risks**
- **Earlier snowmelt**
- **Less spring moisture**
- **Reduced groundwater recharge**
- **Warmer spring water temperatures**

Climate Change Effects: Water

- **Could be greater total precipitation, however, due to high temps...**
 - **Decreased effective precipitation**
 - **Greater evapotranspiration**

Climate Change Effects: Plants

- Increased plant growth, cover, biomass
- Expansion of woody tree species

And/Or

- Decreased plant growth and productivity
- Shift from shrublands to grasslands and deserts

Chambers & Pellant 2008

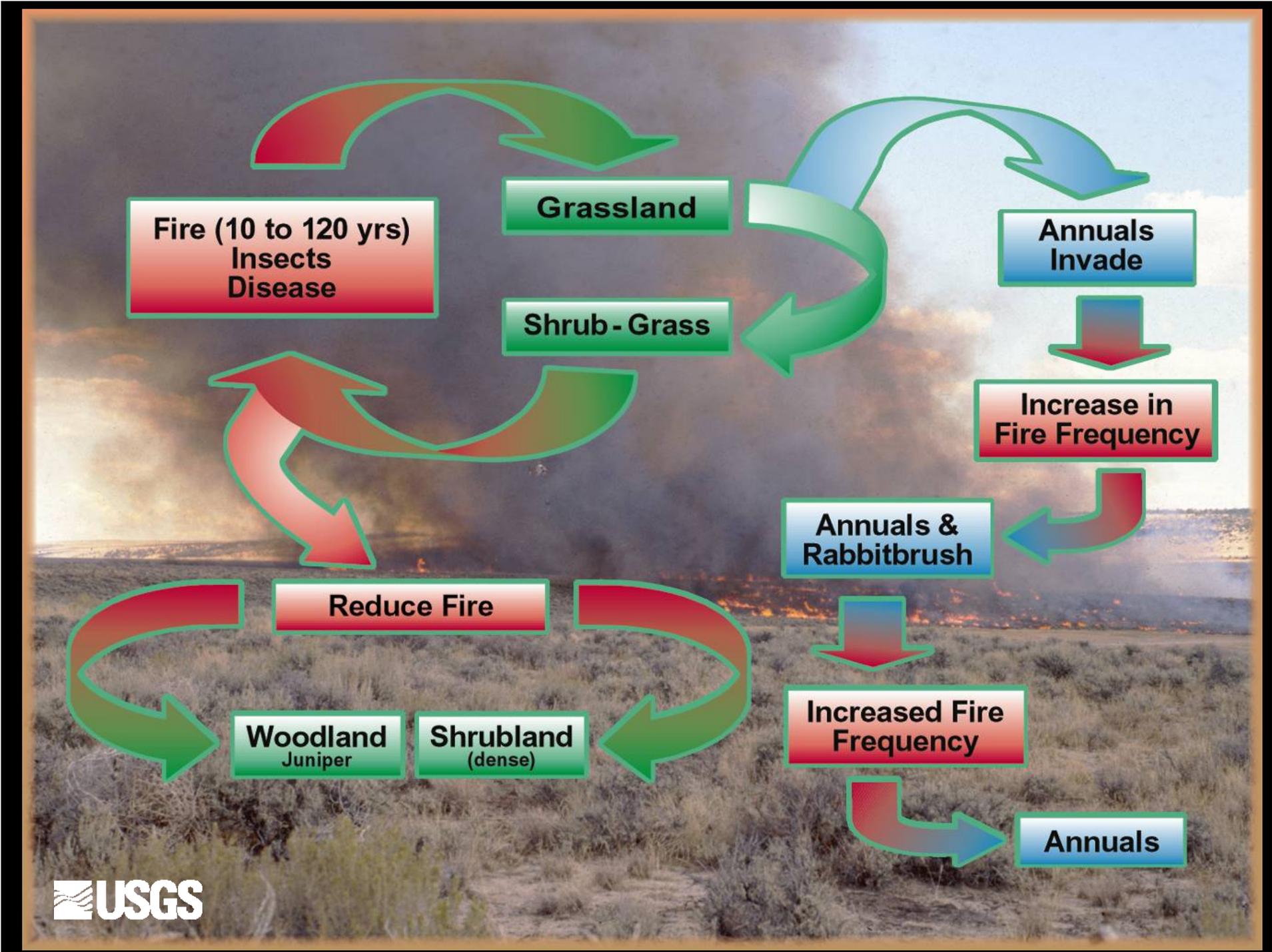
Climate Change Effects: Plants

- **Shifts in species distributions and ranges**
 - **Alpine ecosystems may disappear**
 - **Southern limit for sagebrush may shift to northern Great Basin**
 - **Northern limit of warm-desert species may move to central Great Basin**
- **Elevated CO₂ can increase water-use efficiency and benefit cool season species**

Chambers & Pellant 2008

Climate Change Effects: Fire

- **Highly flammable invasive species can change fire-return intervals to <10 years**
- **Sagebrush species adapted to infrequent fire regimes are unable to survive**
- **Native conifer encroachment increases fuel loads and fire severity**



Direct Effects

Indirect Effects

Higher temperatures

Increased fire frequency

Precipitation changes

Plant community shifts

Winter rain

Dry springs

Changes in SOM storage

Extreme weather events

Microbial community shifts

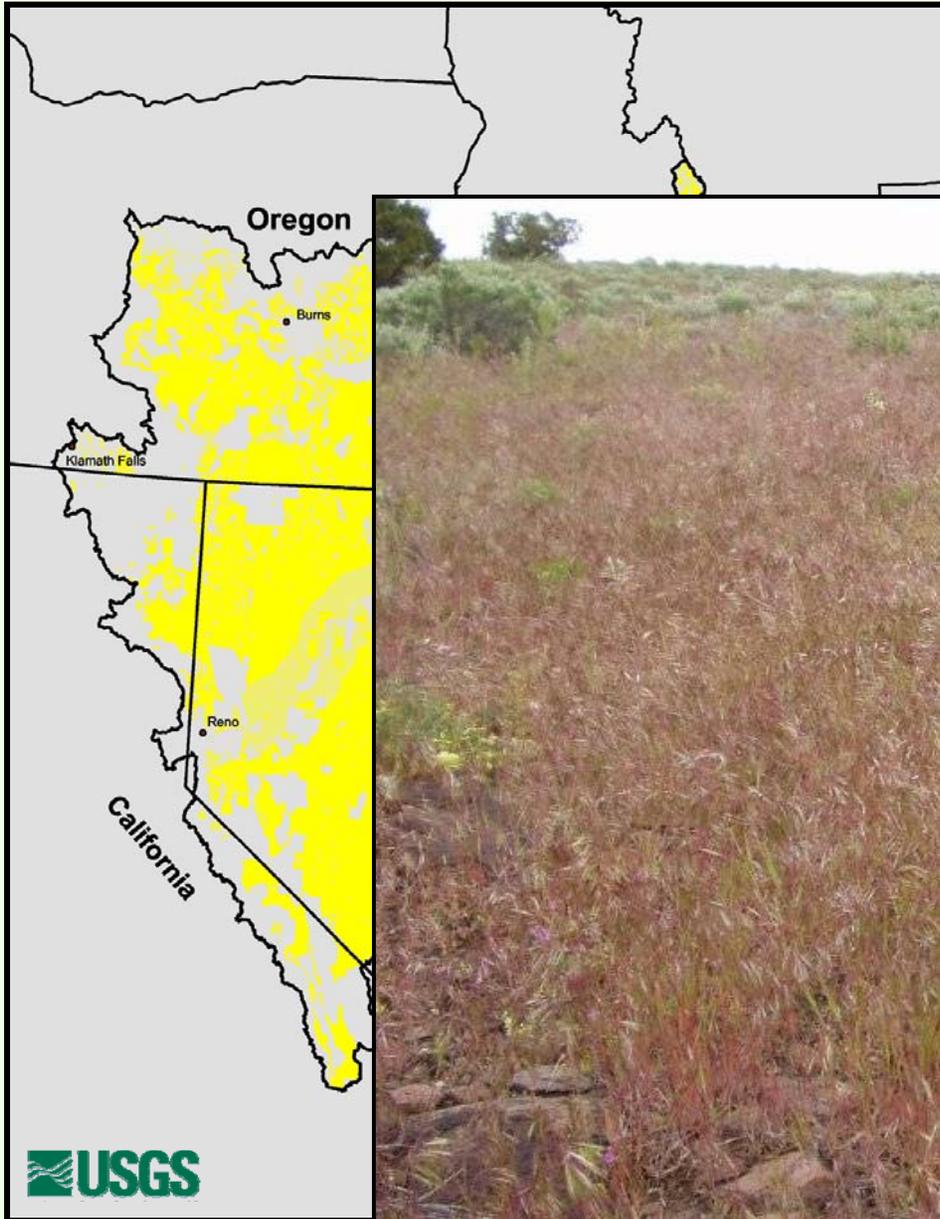
Drought

Flooding

Mineralization rates change

Cheatgrass distribution

Covers 64 million ha
of public lands



Native Site: Eastern Oregon



Annual Site: Snake River Plain



Exotic plant species effects



- **Loss of plant species richness**
- **Loss of structural diversity**
- **Altered litter inputs**
- **Modification of the root zone**
- **Changes in soil moisture and temp regimes**

Effects on soil properties



- **Increased soil porosity and aeration**
- **Faster decomposition rates**
- **Loss of soil organic matter**
- **Changes in availability of nutrients**
- **Increase in soil pH**

Effects on soil communities

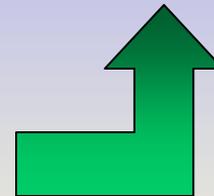
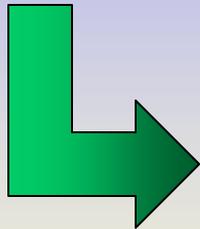
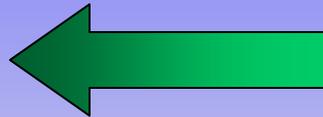


- **Loss of belowground species richness**
- **Shifts in community dominance**
- **Changes in food web structure**
- **Changes in nutrient cycling rates**
- **Decreased resistance and resilience**

Why do soil communities matter?

Growth forms
Nutrient requirements
Nutrient acquisition
Enzymatic potentials
Food web roles

Ecosystem services
Buffering capacity
Plant growth
Plant restoration
Animal forage



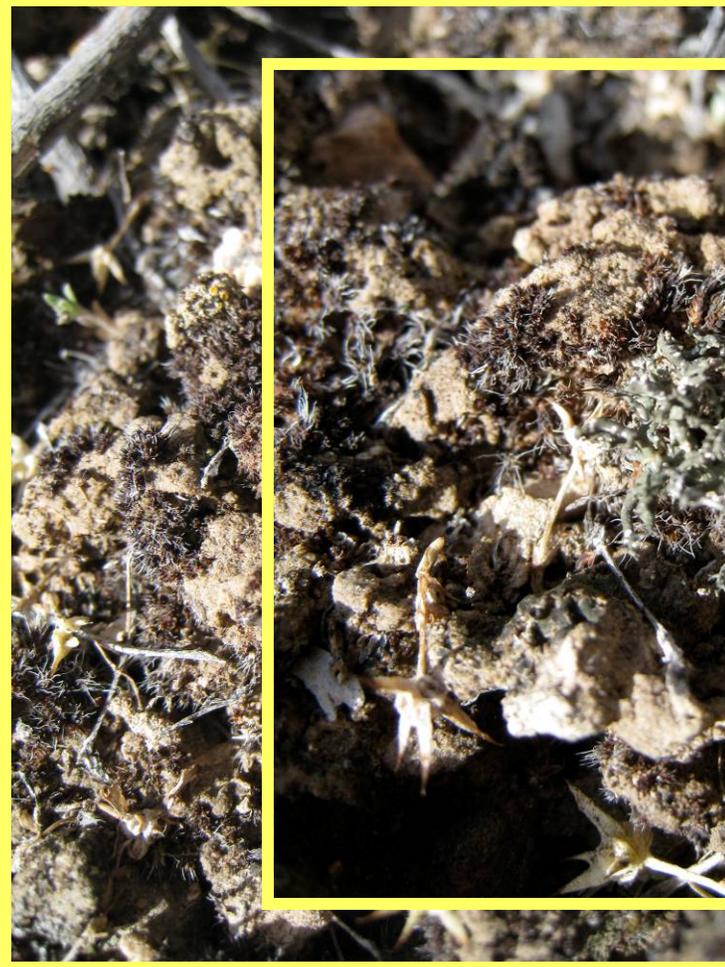
↓ Soil erosion
↑ Soil structure
↑ Organic matter storage
↑ Soil moisture
↑ Soil productivity



Biological Soil Crusts

- **Cyanobacteria**
- **Bacteria**
- **Fungi**
- **Algae**
- **Mosses**
- **Lichens**
- **Liverworts**





 USGS

Ecological Functions of Biological Soil Crusts

- **Soil stabilization**
- **Water infiltration**
- **Nutrient additions**
- **Take up space**



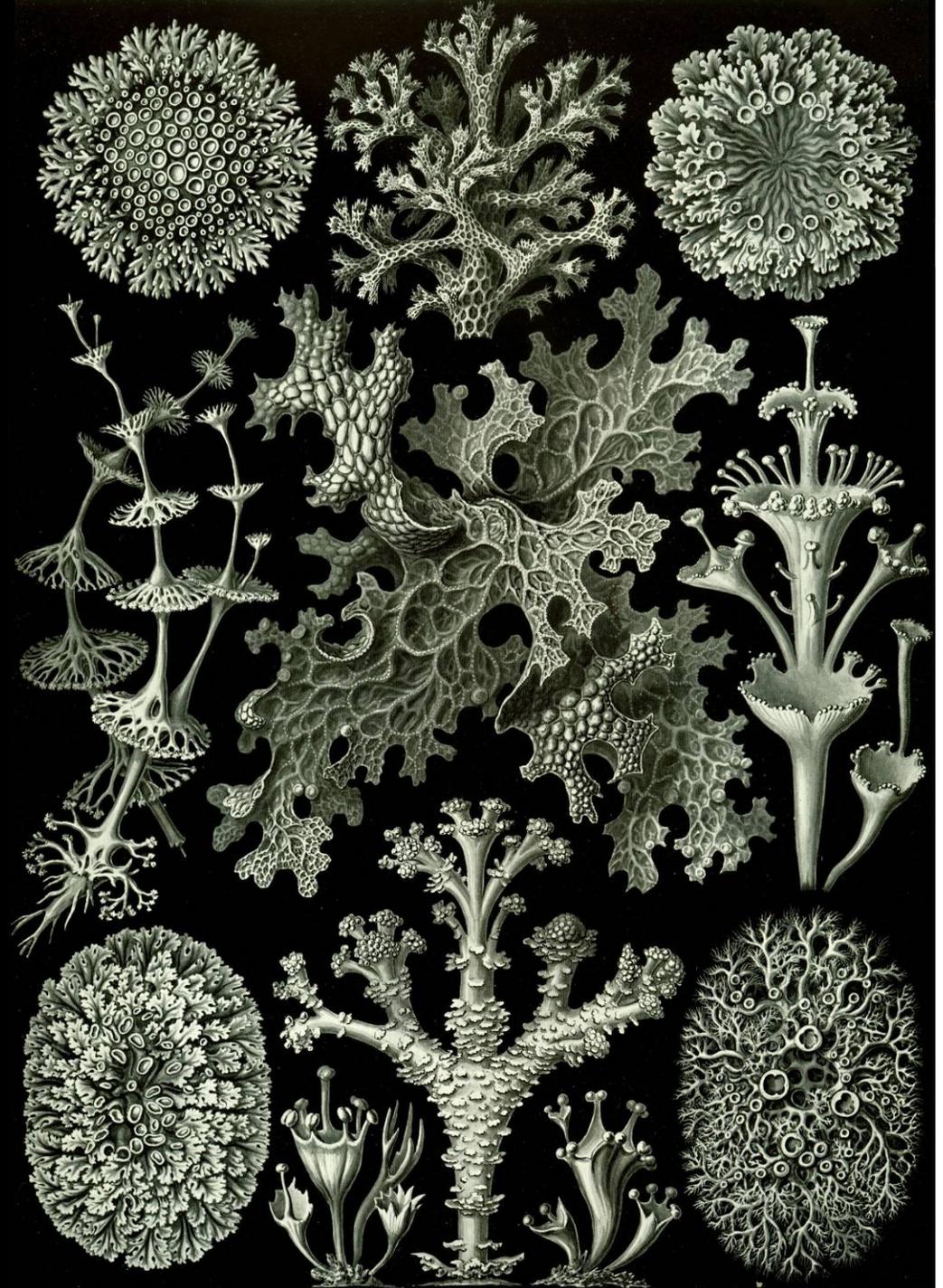
Lichens

**Symbiotic relationship
between fungi and alga
or cyanobacteria**

**Crustose, Foliose,
Fruiting, Squamulose**

**“Lichens are fungi
that have discovered
agriculture.”**

- Trevor Goward



Lichens



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Cladonia



Collema



Acarospora





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Psora

Mosses

Bryophytes

**Non-vascular
plants**

**Survive dry steppe
conditions; begin
photosynthesizing
within minutes of
becoming wet**





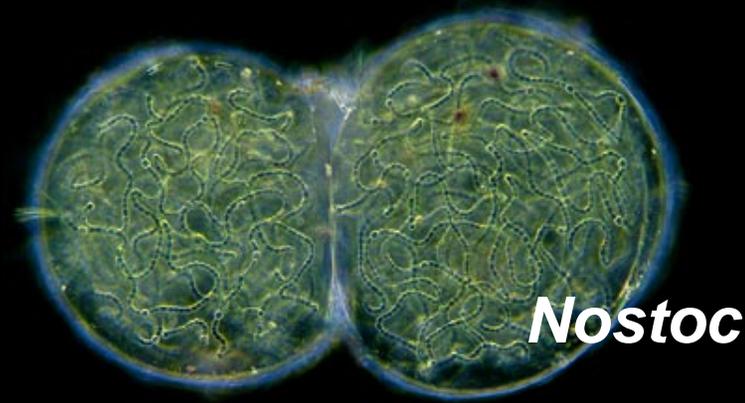
Tortula

Soil Fungi

- **Grow in long strands = hyphae**
- **Free-living and mycorrhizal**
- **Decomposition & nutrient turnover**
- **Bind soil particles together**
- **Contribute to soil aggregate formation**

Soil Bacteria

- Gram+, Gram-
- Actinomycetes
- Nitrogen fixers
- Cyanobacteria

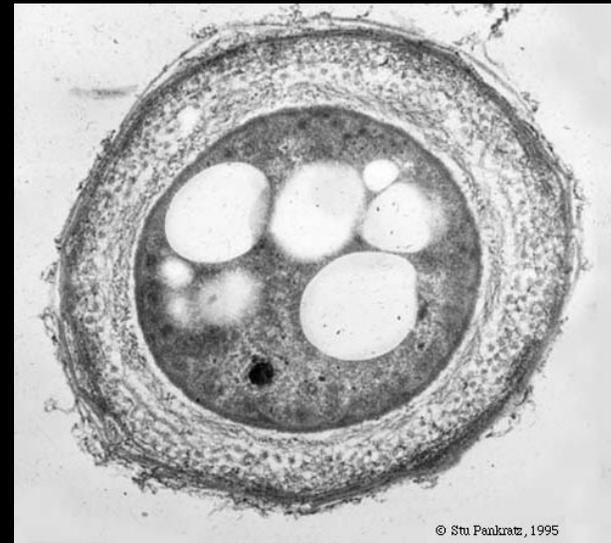


Nostoc

Tens of millions in a single handful of soil



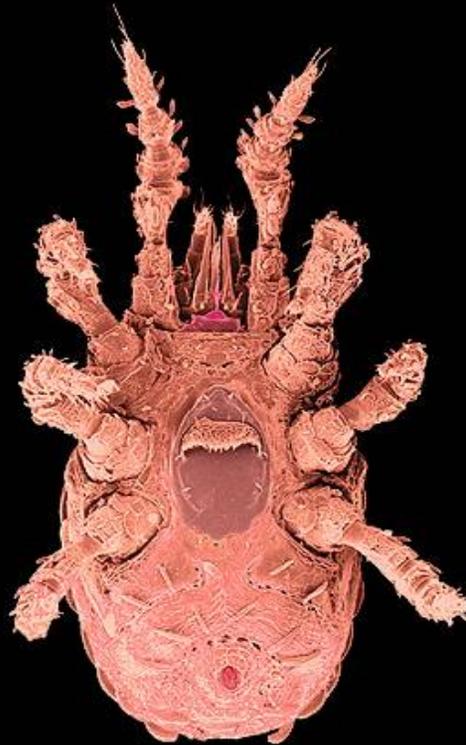
Rhizobium on clover root hair



© Stu Pankratz, 1995

Soil Invertebrates

- Protozoa
- Nematodes
- Mites
- Collembola
- Insects



Climate Change Effects on Soil Communities?



Direct effects: temperature, moisture, fire

Indirect effects: plant community composition

Native sites: Biological Soil Crusts



Native sites: Biological Soil Crusts



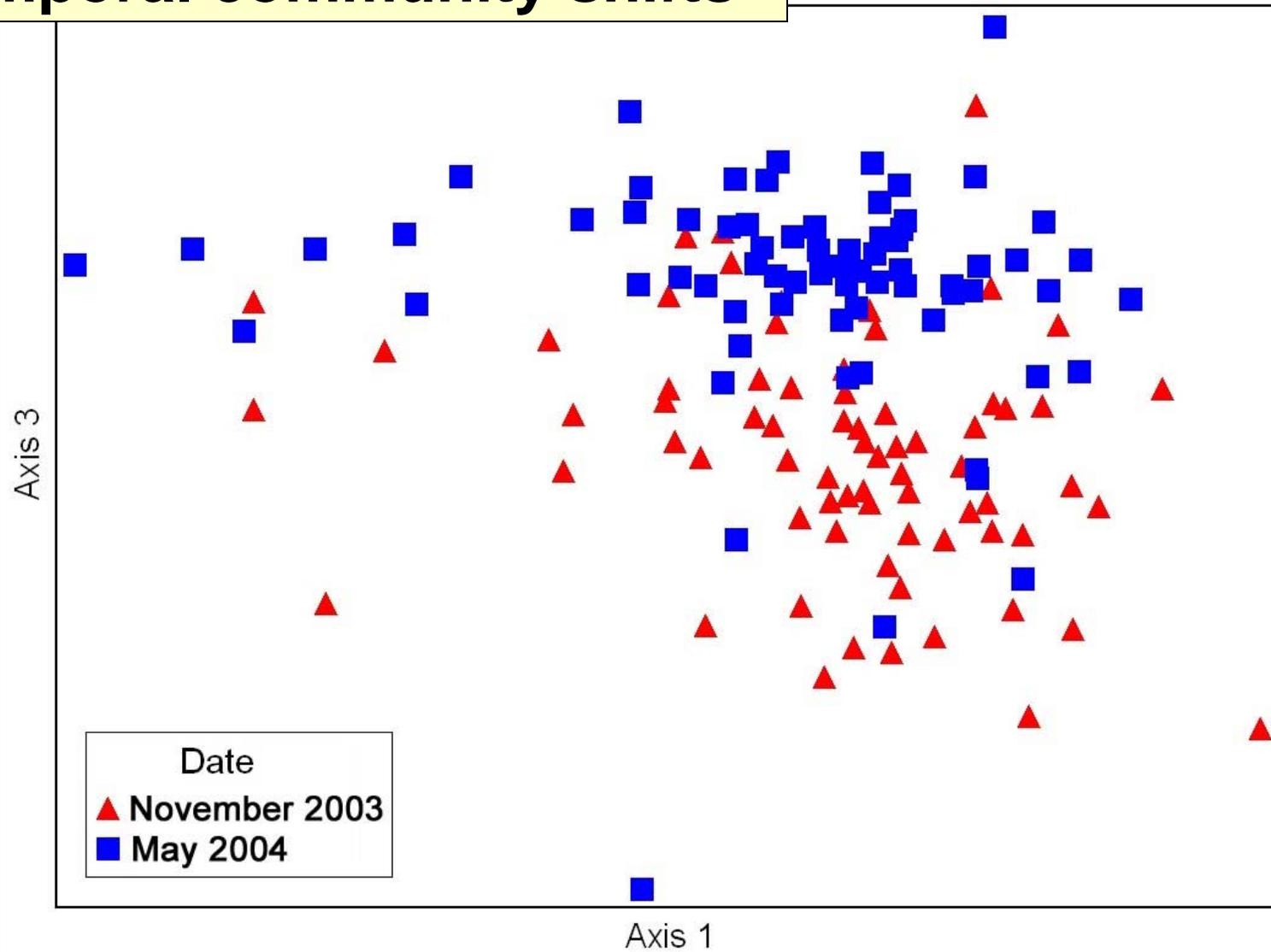
Annual sites: Biological Soil Crusts



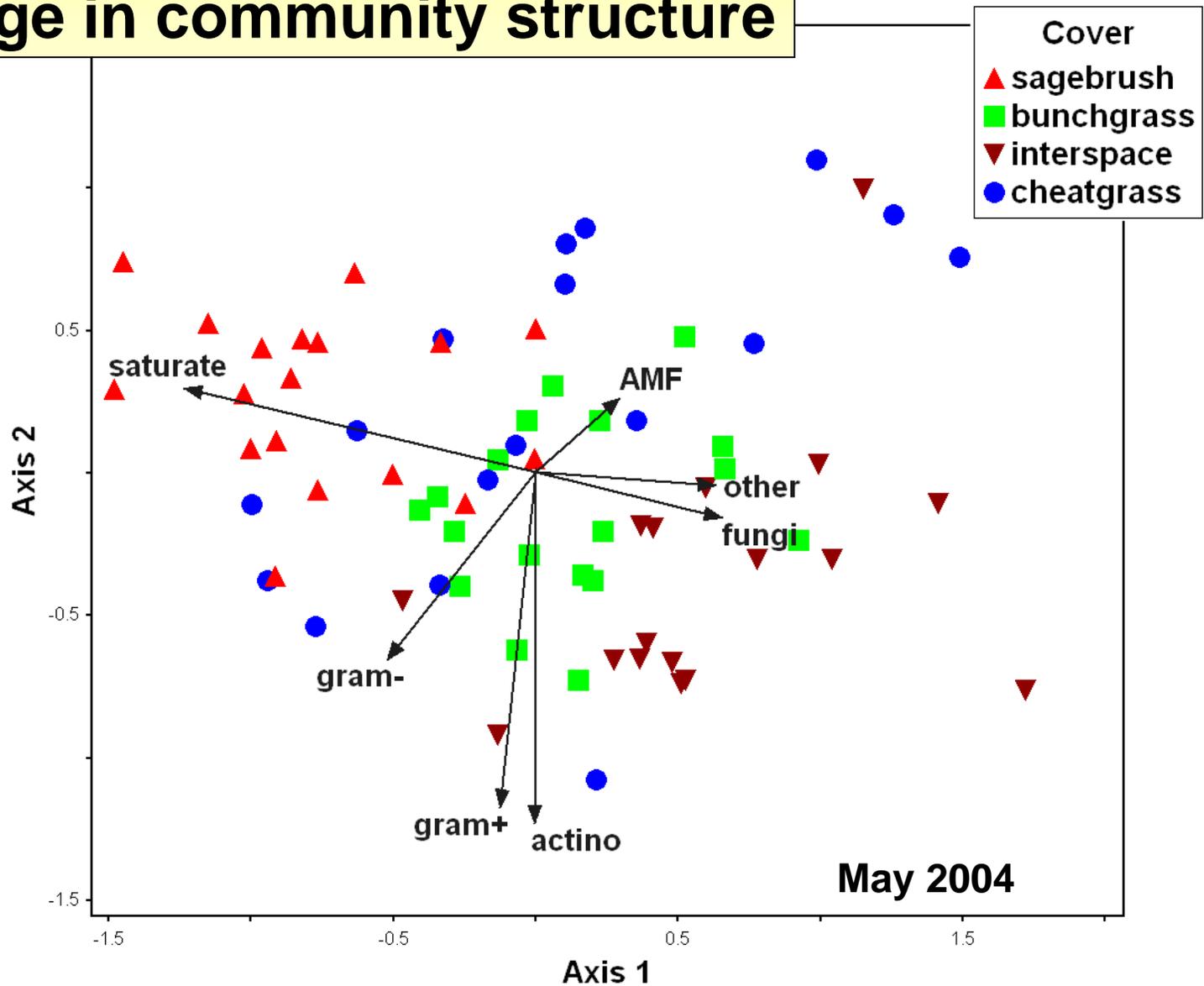
Annual sites: Biological Soil Crusts



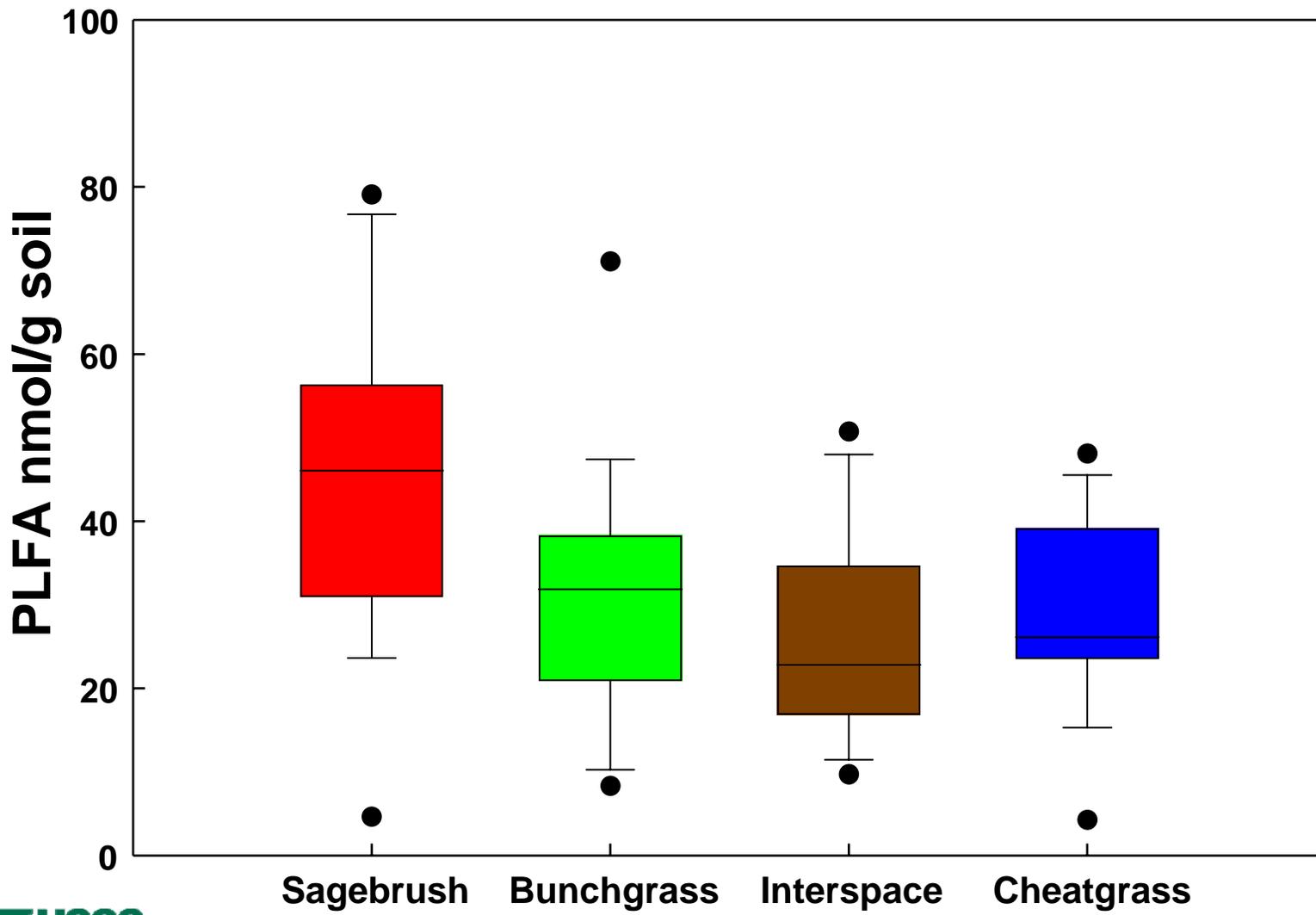
Soil Microbes: Temporal community shifts



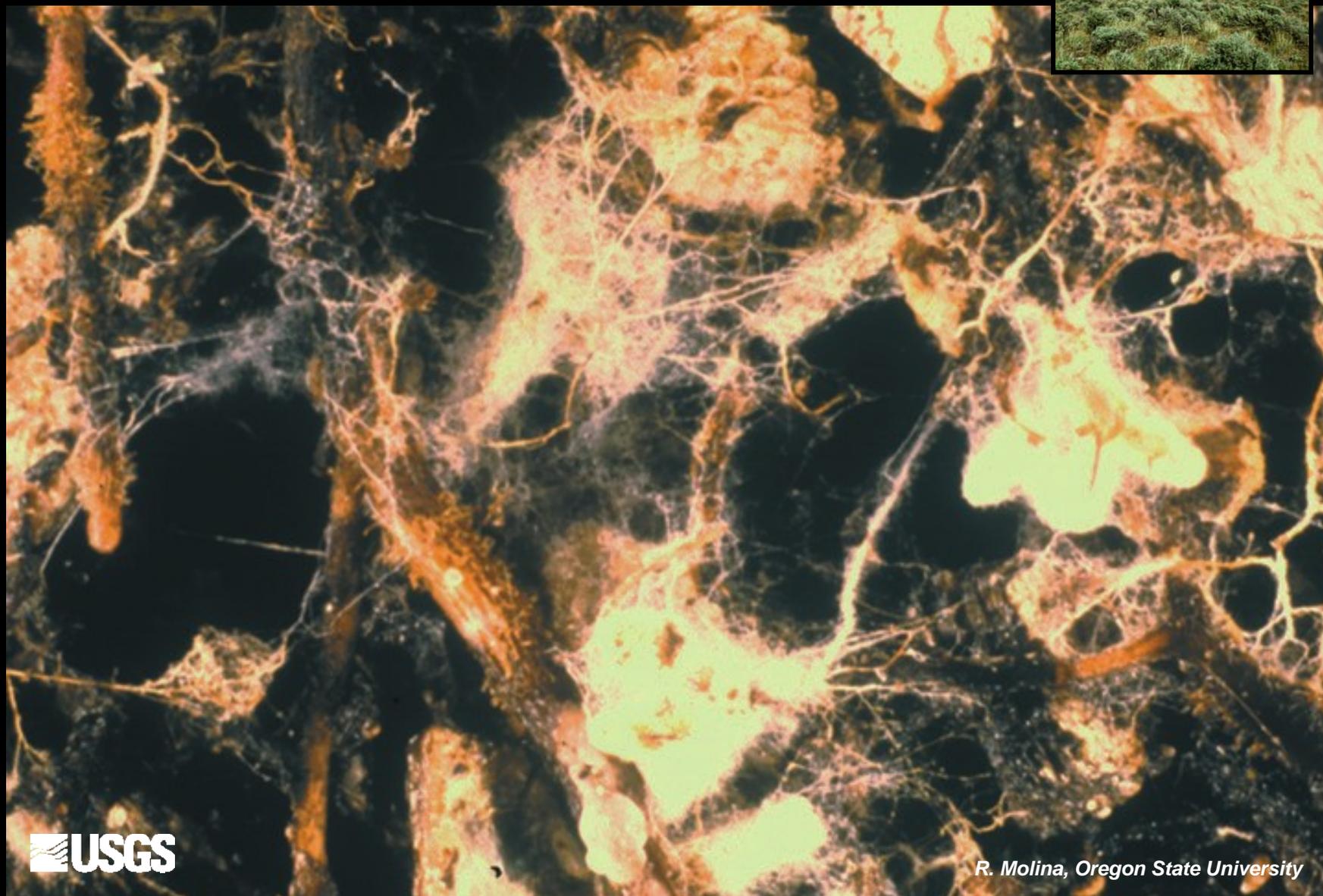
Soil Microbes: Change in community structure



Soil Microbes: Loss of total biomass



Native Sites: Soil Fungi



Annual Sites: Soil Fungi

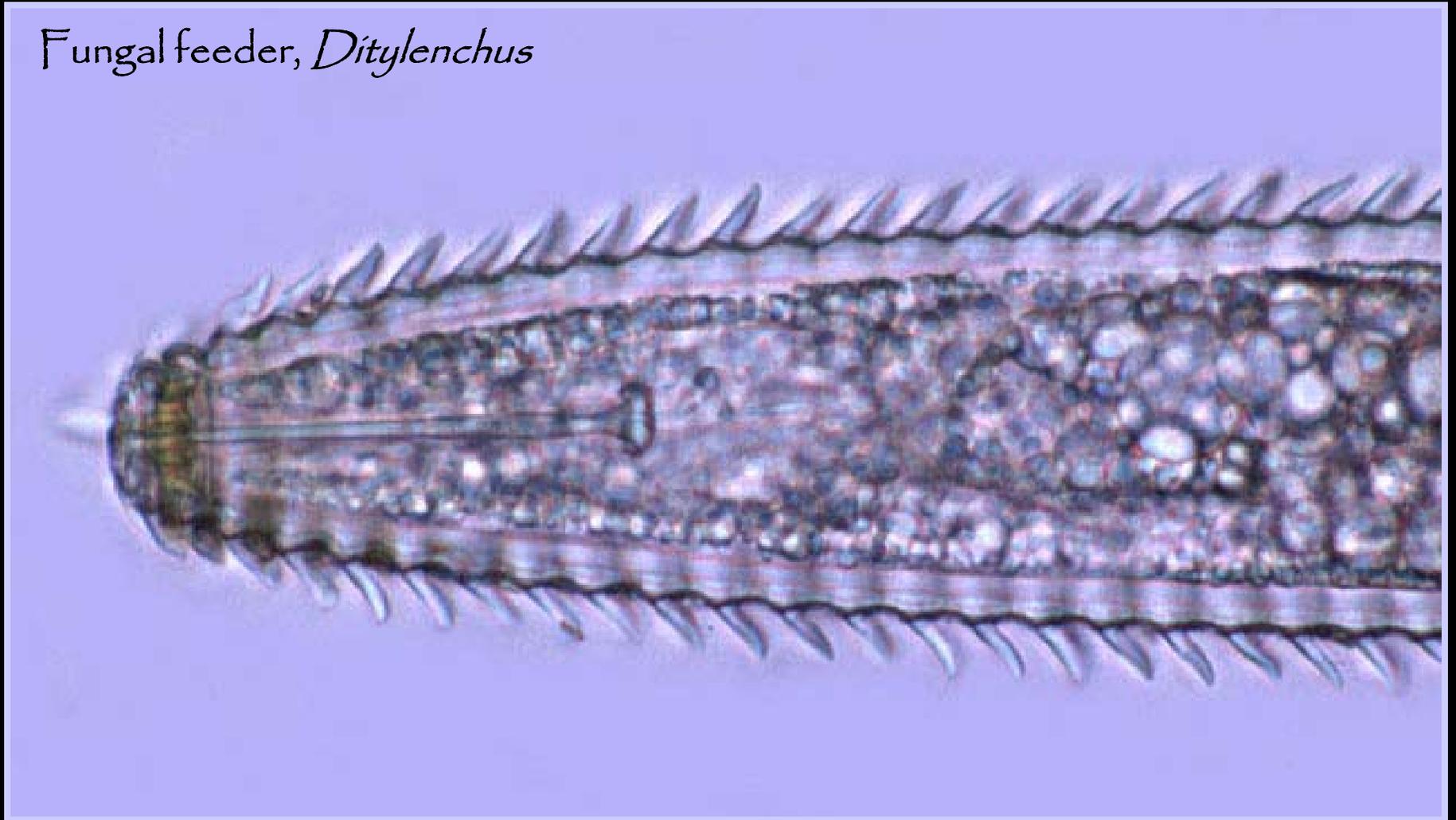


Increase in arbuscular mycorrhizal fungi, which benefits cheatgrass

Native sites: Soil Nematodes

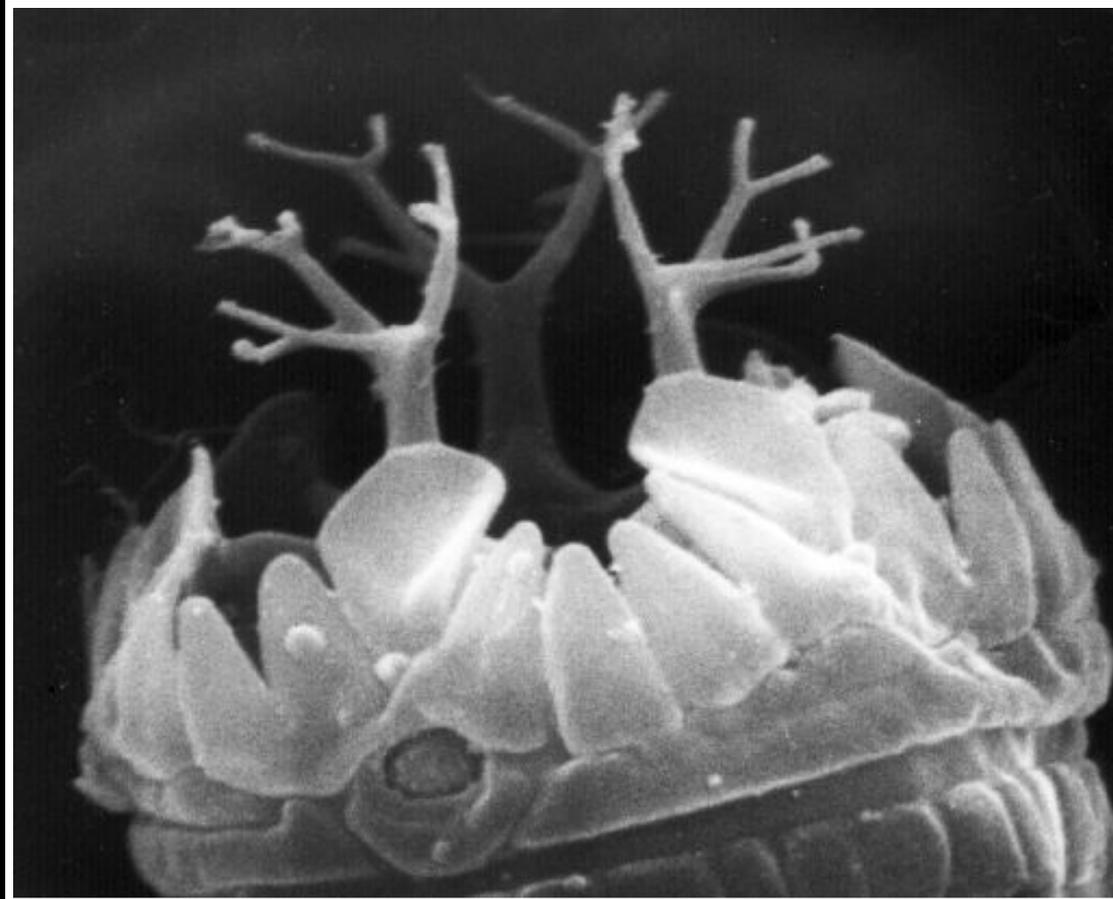


Fungal feeder, *Ditylenchus*

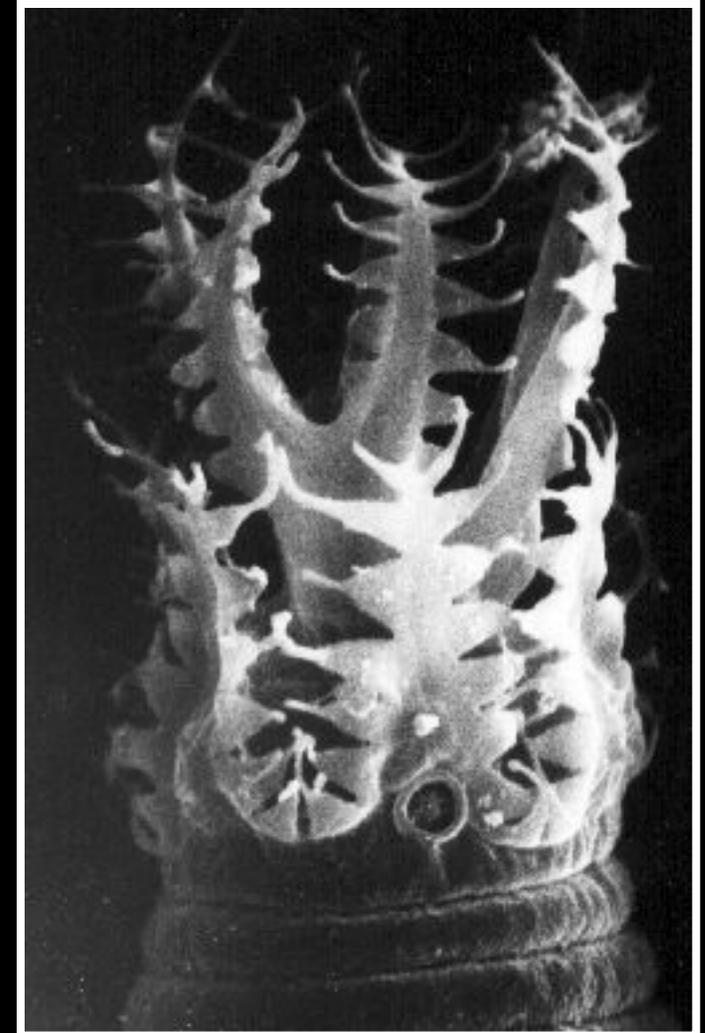


Annual sites: Soil Nematodes

Bacterial feeders, *Cervidellus* and *Acrobeles*



S. Bostrom, Swedish Museum of Natural History



Direct Effects

Indirect Effects

Higher temperatures

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Winter rain

Dry springs

Changes in SOM storage

Extreme weather events

Microbial community shifts

Drought

Flooding

Mineralization rates change

Climate Change Implications

- **Plant and soil communities are shifting in response to climate change factors**
- **Loss of aboveground diversity paralleled by changes in belowground community structure**
- **Ecosystem processes may be affected**
- **Increases complexity of ecosystem management**



Carbon Source or Sink?



Soil Carbon Sequestration

- Strategy to mitigate the effects of climate change
- Increases soil organic matter storage (humus)
- Usually implies re-building past reserves, not adding new ones
- Trade-off: cannot both store C and use it at the same time!



Questions, comments?



S. Shaff, USGS