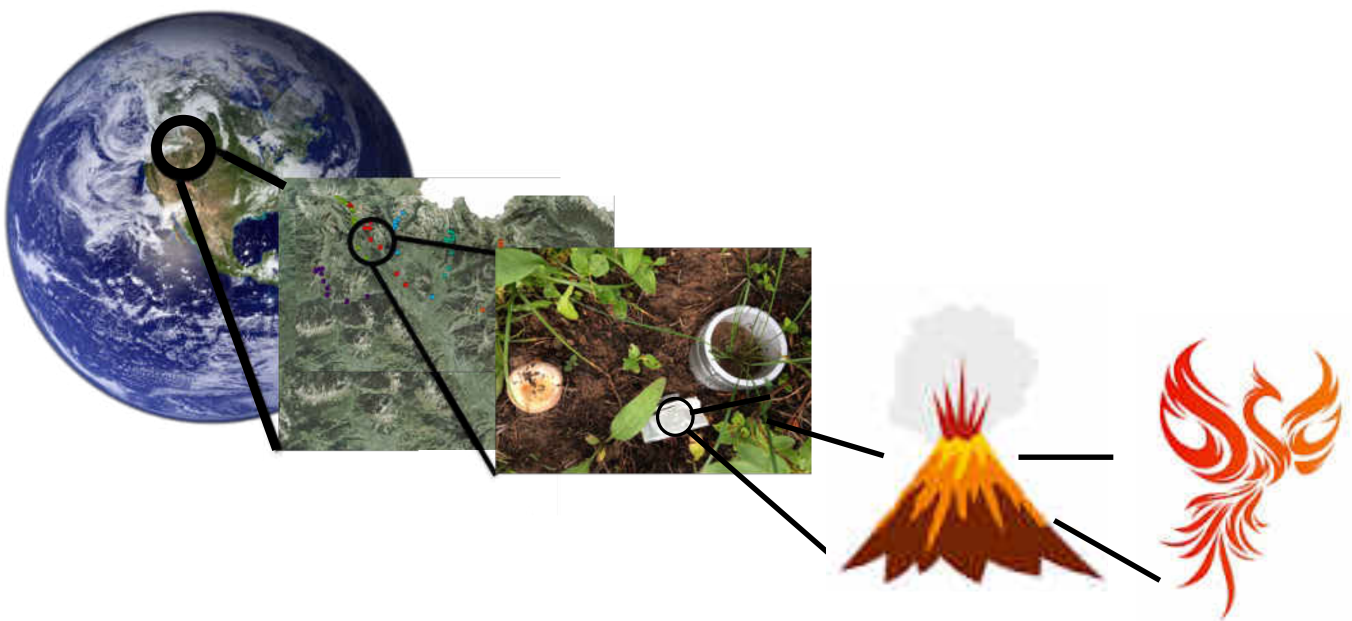
Ashes to ashes:
Fungal communities and ecosystem function

Dr. Mia Maltz
Soil Matters
July 30, 2026



Acknowledgements

Collaborators and contributors:

E. Aronson, E. Allen, M. Allen, K. Treseder, K. McGuire, J. Martiny, S. Kimball, B. Khalili, C. Weihe, K. Schmidt, D. Jackson, B. Pickett, K. Arogyaswamy, S. Saroa, H. Shulman, A. Rose Person, S. Glassman, J. Randolph, L. Dagan, N. Rodriguez, L. Garcia, M. Garrambone, M. Lulow, M. Mitrovich, J. Burger, A. Swanson, M. Major, N. Gregory,

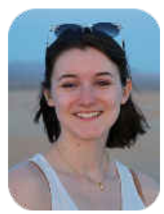


Funding:

National Science Foundation
Kearney Foundation of Soil Science
Natural Communities Coalition
Center for Conservation Biology
Center for Environmental Biology
Irvine Ranch Conservancy
Bureau of Land Management
CT Resource Conservation District
NE SARE, NRCS, USDA






NSF
EarthCube
Center for Conservation Biology
University of California, Riverside
Natural Communities Coalition
restoration | management | partnership
UC Riverside | BREATHE
UNIVERSITY OF CALIFORNIA, RIVERSIDE SCHOOL OF MEDICINE
Center for Environmental Biology
School of Biological Sciences
University of California • Irvine
UCR College of Engineering-Center for Environmental Research & Technology

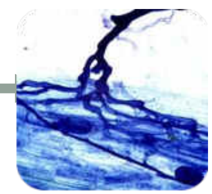

Conserving sensitive habitat is challenging

Fungal processes are important in ecosystems

Fungi

Decomposer fungi

Mycorrhizal fungi



Pathogens

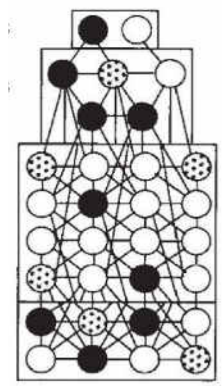
Ecological Monographs, 84(1), 2014, pp. 3–20

A first comprehensive census of fungi in soil reveals both hyperdiversity and fine-scale niche partitioning

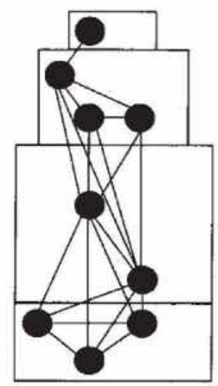
D. Lee Taylor,[1,4] Teresa N. Hollingsworth,[2] Jack W. McFarland,[1,5] Niall J. Lennon,[3] Chad Nusbaum,[3] and Roger W. Ruess[1]

(+) Biodiversity (+) Ecosystem Functioning	(-) Biodiversity (-) Ecosystem Functioning

Naeem et al. 1994 *Nature*



High Diversity



Low Diversity

(+) Biodiversity (+) Ecosystem Functioning	(-) Biodiversity (-) Ecosystem Functioning

√Ecosystem productivity

√Stability

√Resist invasion

√Nutrient retention

√Resilience

√Complexity

√Decomposition

√Enzyme activity

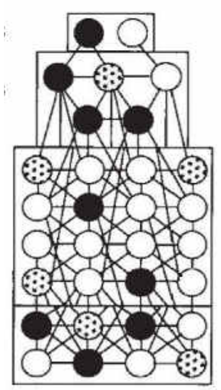
√Soil aggregation

√Nutrient cycling

√Supporting plants

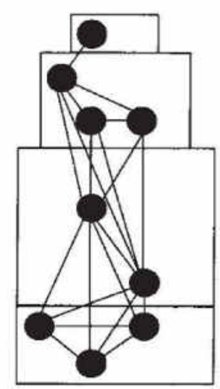
√Water holding capacity

√Community respiration



High Diversity

Naeem et al. 1994 *Nature*

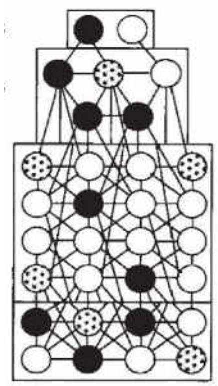


Low Diversity

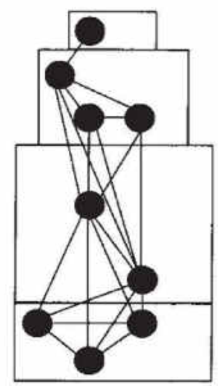
- Less complex
- More vulnerable to threats

(+) Biodiversity (+) Ecosystem Functioning	(-) Biodiversity (-) Ecosystem Functioning

Naeem et al. 1994 *Nature*

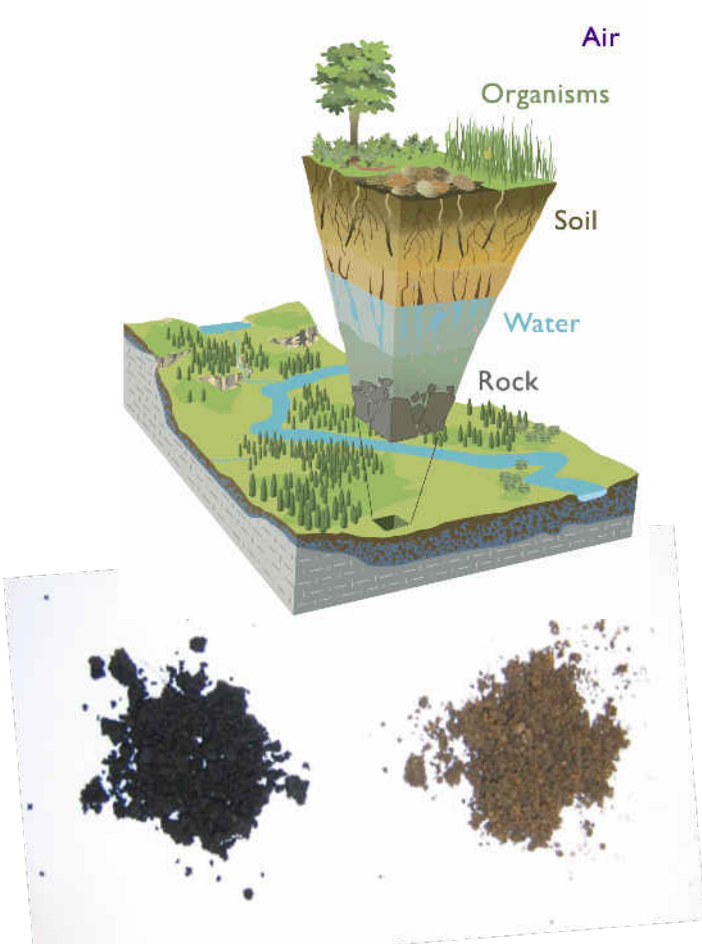


High Diversity



Low Diversity

Soil

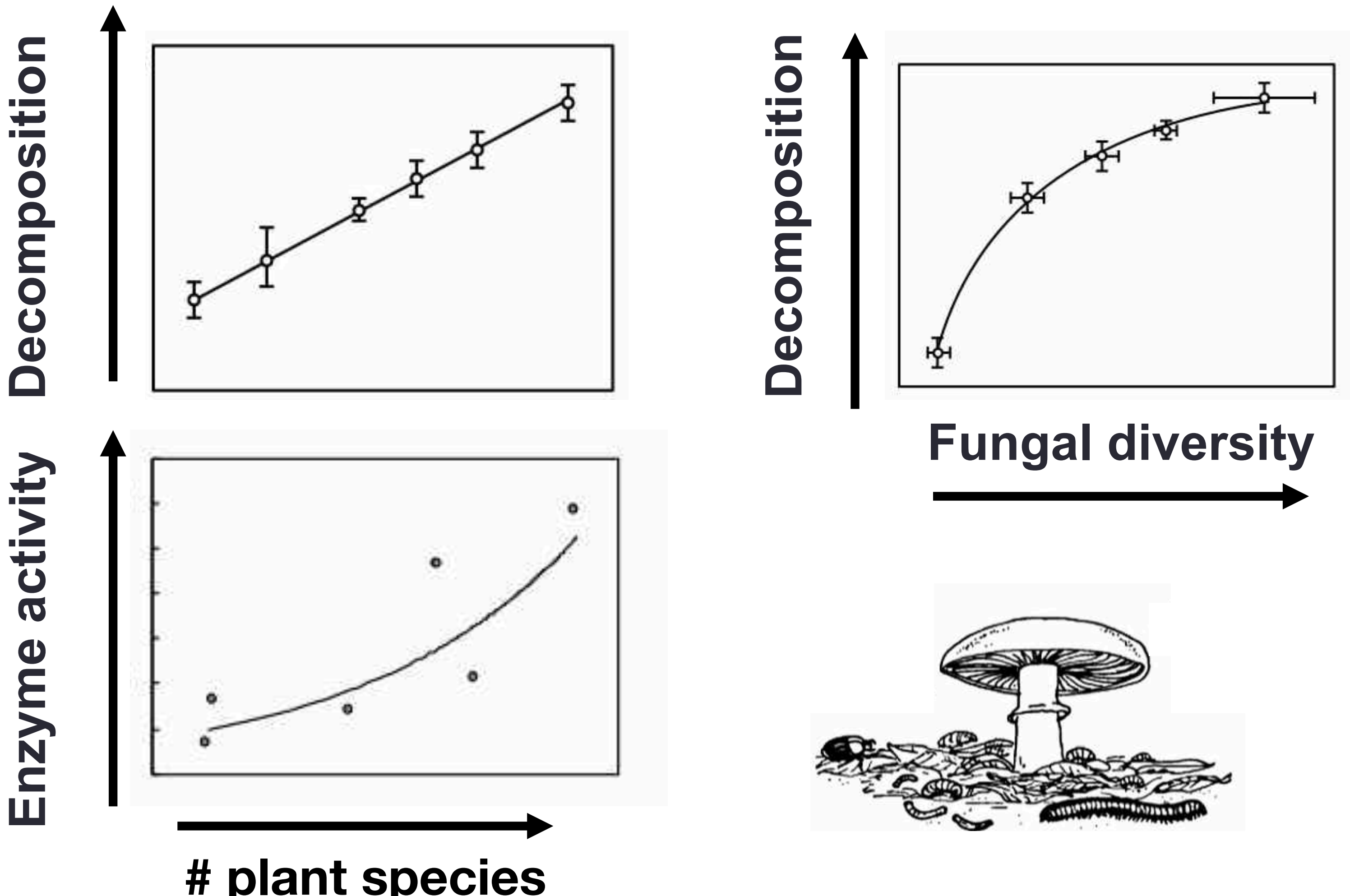


Plant litter

dead plant material

Maltz et al. 2017 *PLoS ONE*

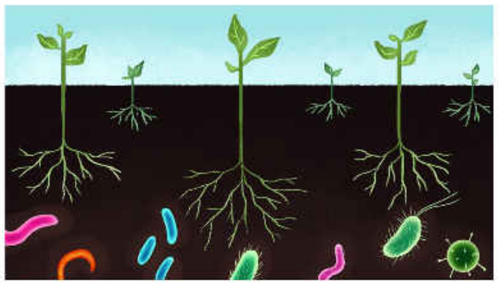
Plant species richness in litter

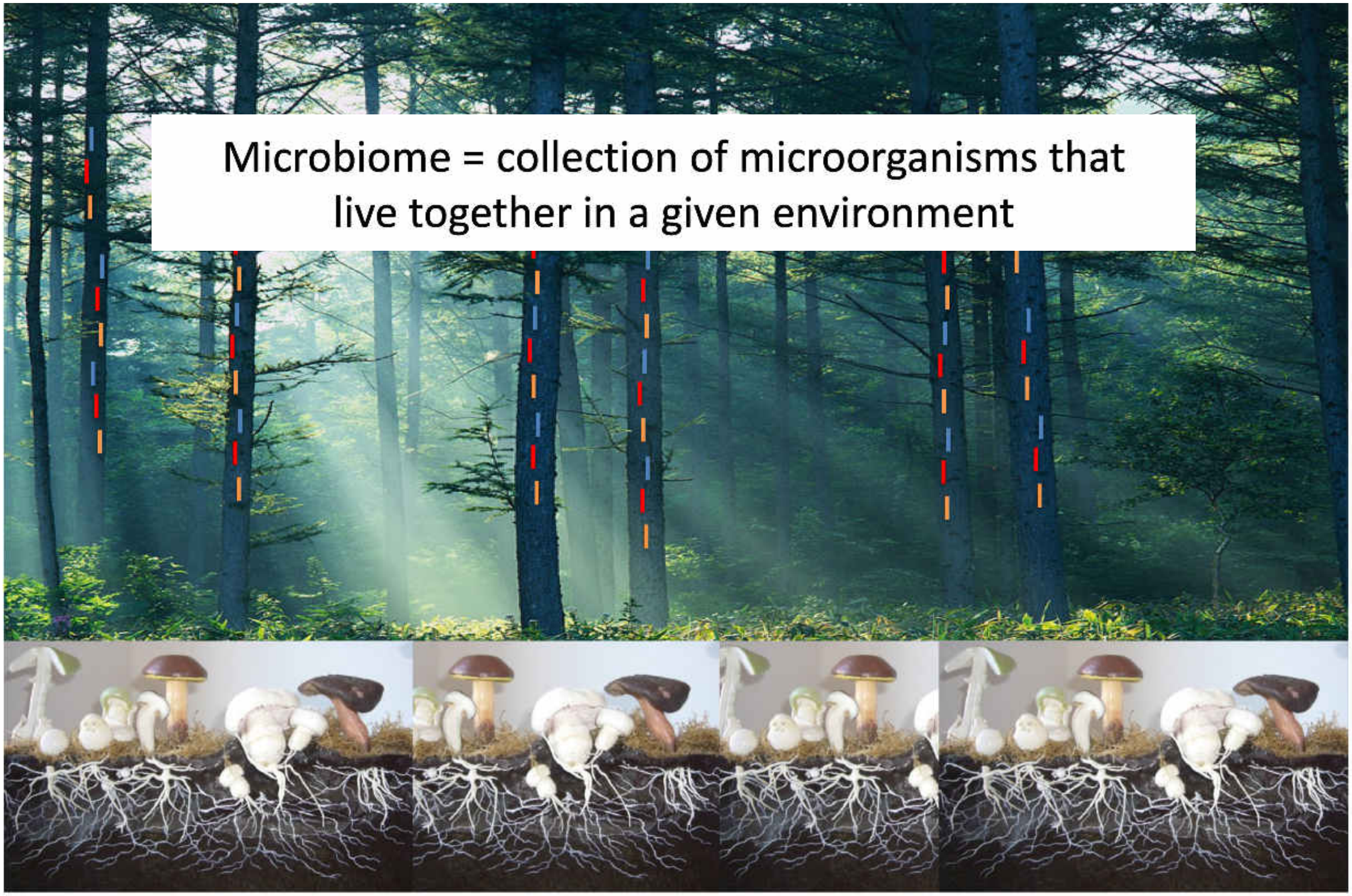


Maltz et al. 2017 *PLoS ONE*

Approach: Fungal responses on different scales

Microbiome = collection of microorganisms that live together in a given environment

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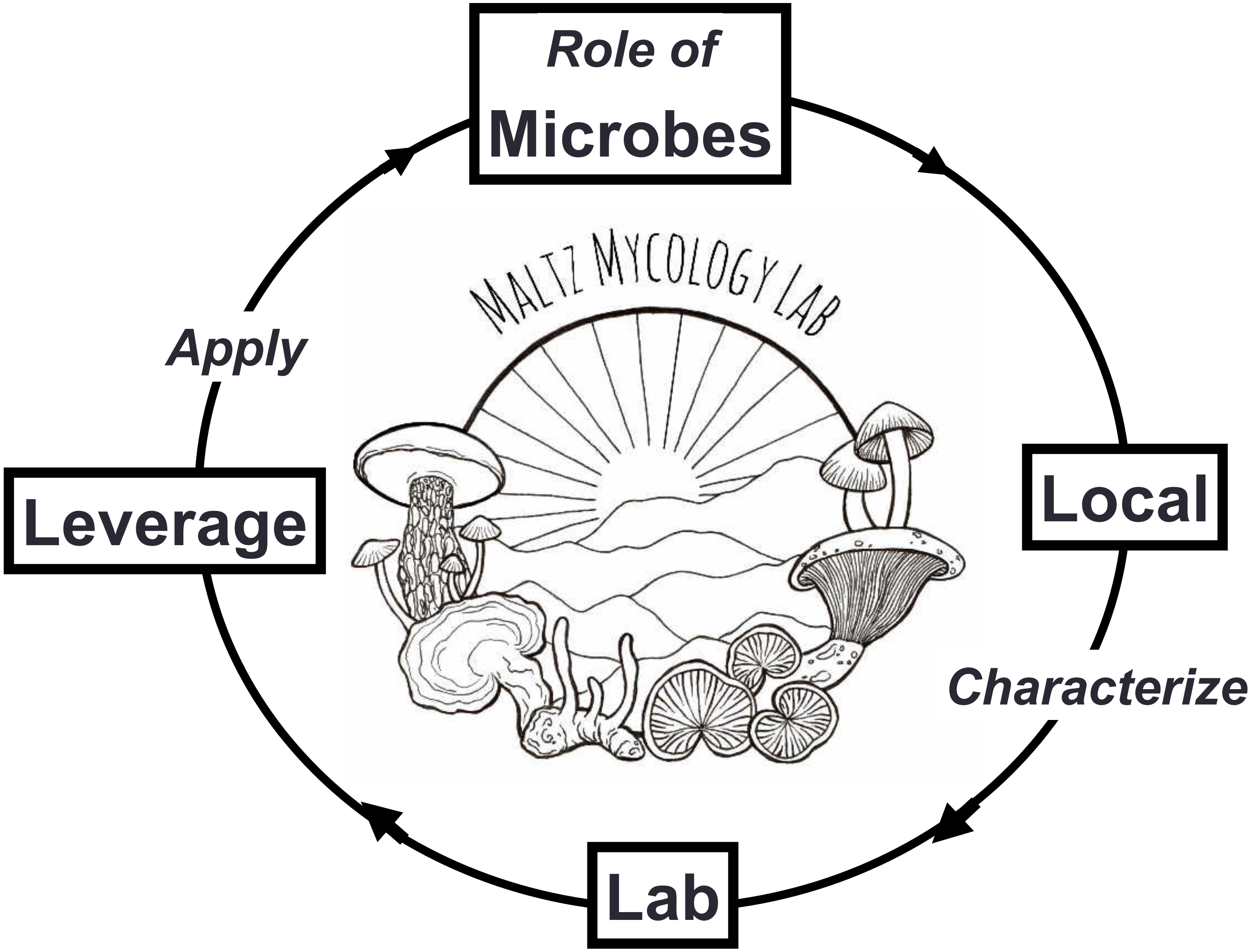
Maltz Mycology Lab


Role of
Microbes
Local
Characterize
Lab
Leverage
Apply
MALTZ MYCOLOGY LAB

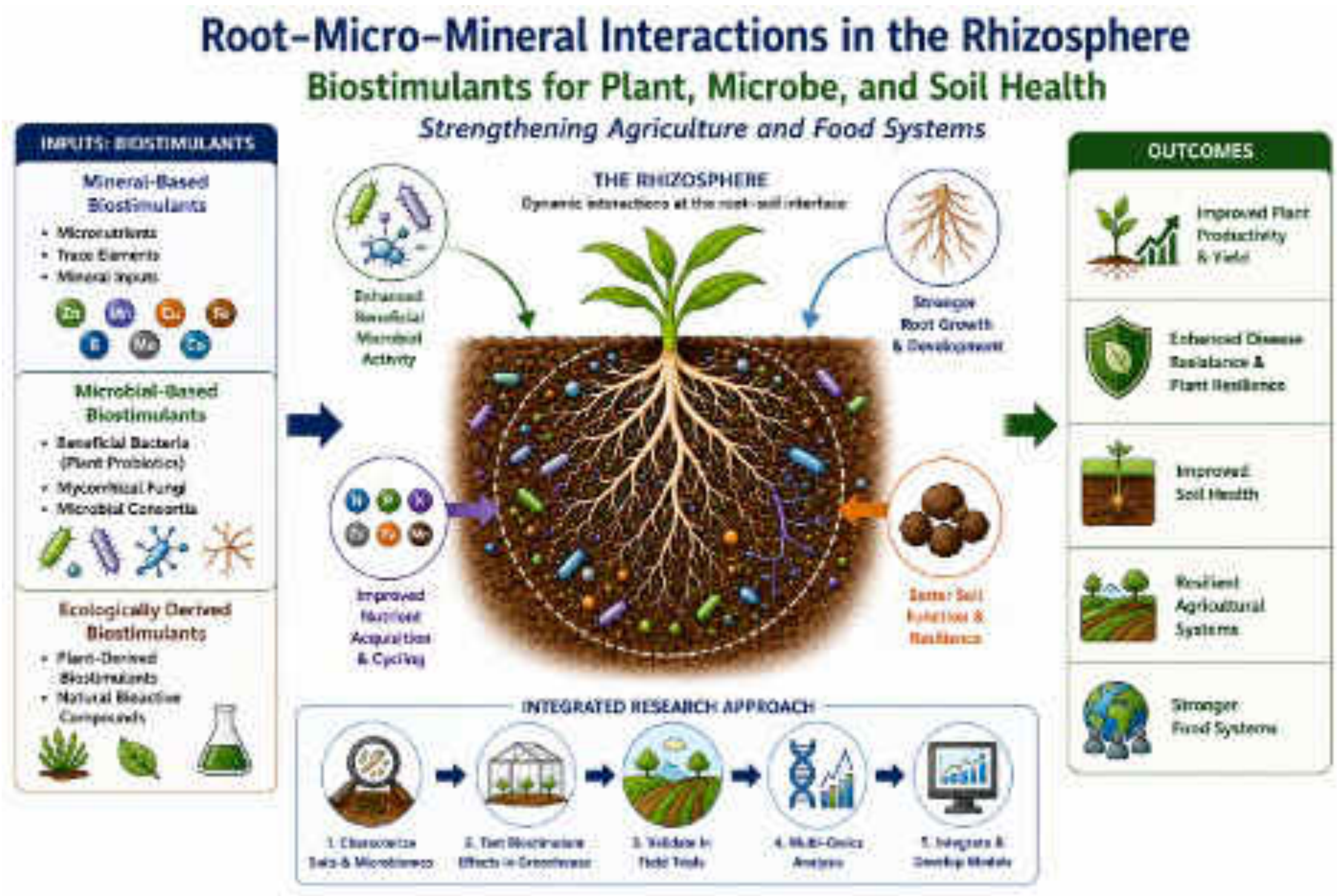
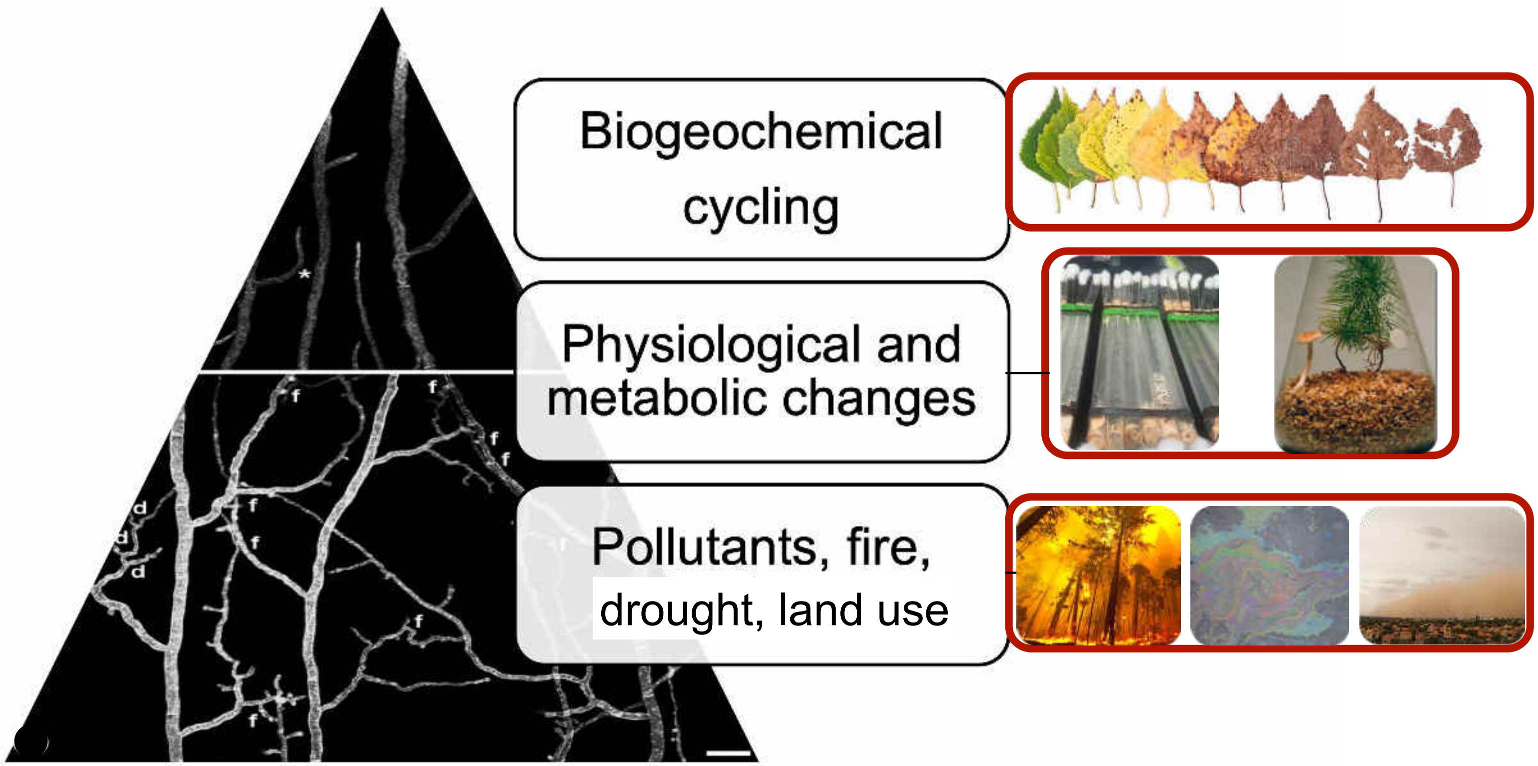


Image Credit: Mary Anne Amalaradjou

Research framework



Disturbance

Press

Pulse

Glaciers melting

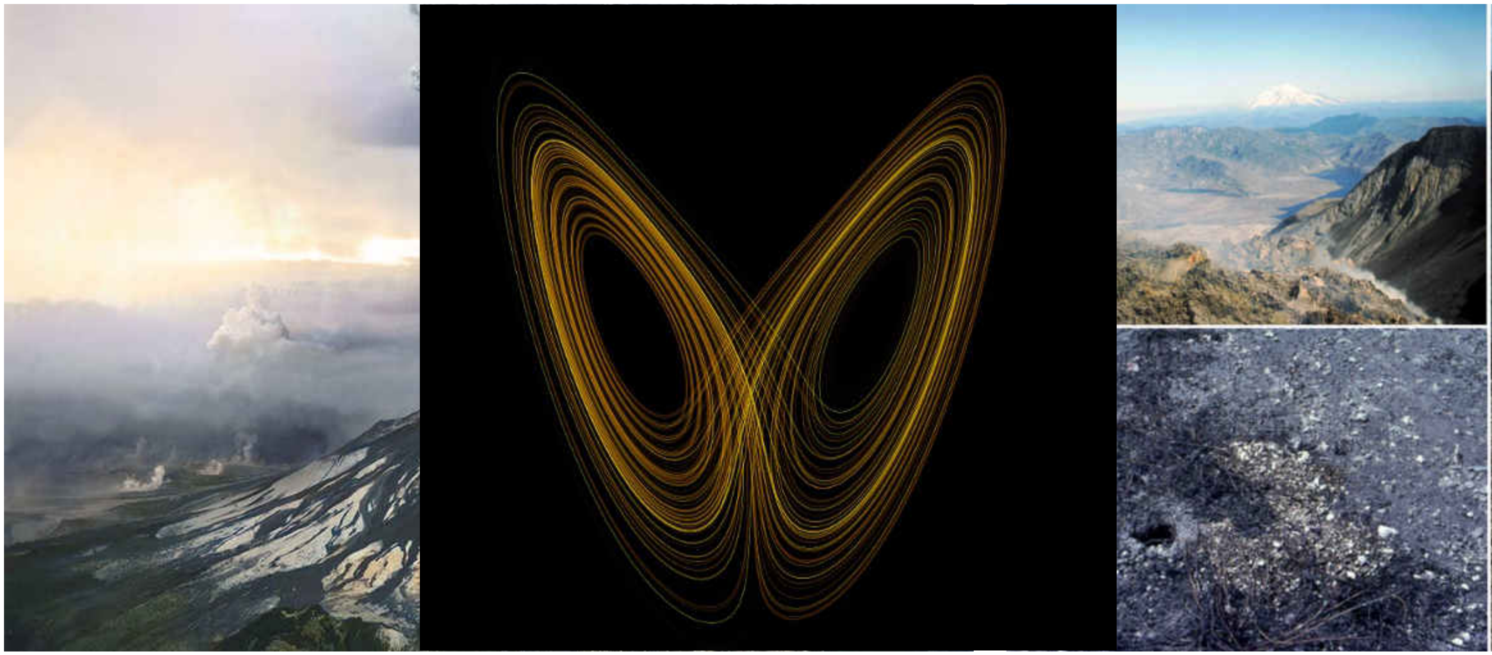
Pedersen Glacier, Alaska

1920s 2005

Camp Fire, Butte County

Woolsey Fire, LA county

The butterfly effect



Edward Norton Lorenz

Depends on *initial conditions*

One Small Change can result in *Large Differences* in a later state

Response and reassembly

Plant and fungal community assembly post-volcanic eruption

Mount St. Helens' mysteries still astound scientists, 40 years after eruption

May 18, 2020 at 6:00 am | *Updated May 18, 2020 at 6:36 pm*

Microorganisms as ecosystem engineers

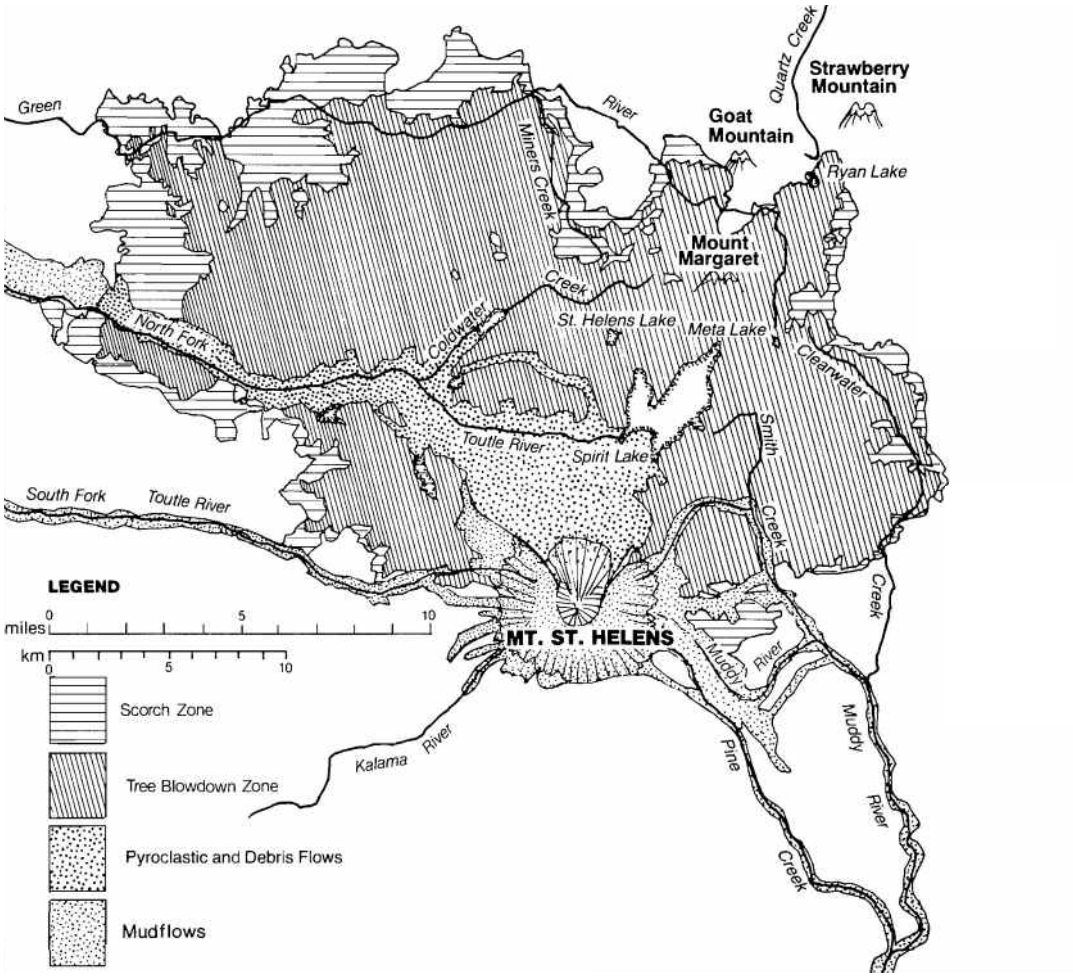


photo credit:
D. Newman

Mount St. Helens Eruption

- Cascades Mountains, Washington USA
- Main eruption
  - 5/18/80, 8:32am, 9 hr. duration
  - Triggered by earthquake (5.1)
- Landslide N. Fork Toutle River Valley
  - Covered 60 km^2
  - Depth 45 m^2
- Destroyed 350 km^2 coniferous forest
- Burned 60,000 hectares forest
- 57 people killed
- Subsequent eruptions

Mount St. Helens Eruption

Before

After

Cascades Mountains, Washington USA

Pioneer species

Lupinus lepidus
Microbial host plant
Symbioses with N-fixers
Biogeochemical cycling

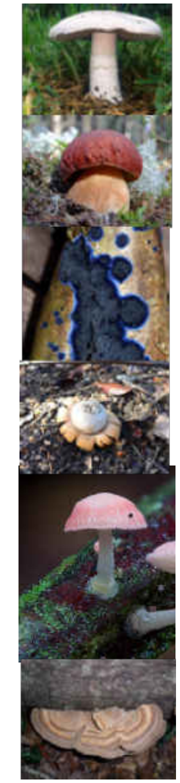
Thomomys talpoides
Burrowing N. pocket gopher
Unearthing organic matter and fungal spores

Forestry management

Clear-cut Old growth

Recovering forests of Mount St. Helens

- Old growth forests will recover different microbial communities than clearcut forests, ostensibly because of mycorrhizal-host interactions



Recovering forests of Mount St. Helens

- Old growth forests will recover different microbial communities than clearcut forests, ostensibly because of mycorrhizal-host interactions

- Historic short-term gopher introductions will result in long-term changes in microbial communities because gophers:
  - Serve as vectors for moving plant propagules, soil organic matter, and mycorrhizal fungi to the surface of pumice plains
  - Create microsite conditions conducive for primary succession and plant establishment



Picture credit:
Mike Allen; Professor Emeritus, UC Riverside

1982: Pocket gophers (*Thomomys talpoides)* were experimentally placed in enclosures within the pumice plain along with established individuals of *Lupinus lepidus* Dougl.

Allen 1987, Allen, McMahon, & Andersen 1988, Allen & McMahon 1988,
Allen 1988, Crisafulli, MacMahon, & Parmenter, in Ed. Dale et al. 2005

Methods

photo credits: R. Hernandez

DNA extraction

photo credit: R. Hernandez

photo credit: N. Rodriguez

Breakthroughs in technology:
Next generation sequencing and bioinformatics

Soil metagenome:

Dual-indexed Targeted amplicon PCR

16S	515F and 806R
SSU	Wanda and AML2
ITS2	ITS4FUN and 5.8S

Illumina Miseq

~20 million sequences

Microbial community composition

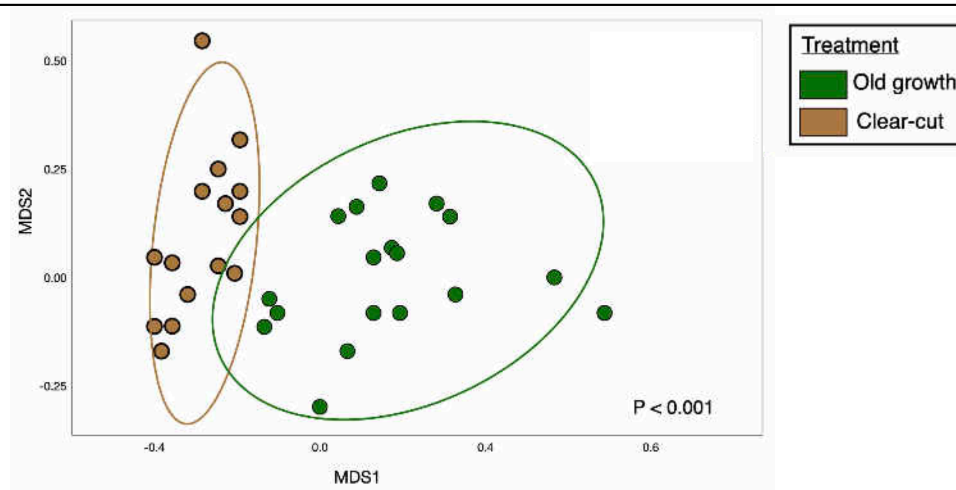
Bacterial communities (Bacteria/Archaea)

Mycorrhizal fungi (AMF)

Fungal communities

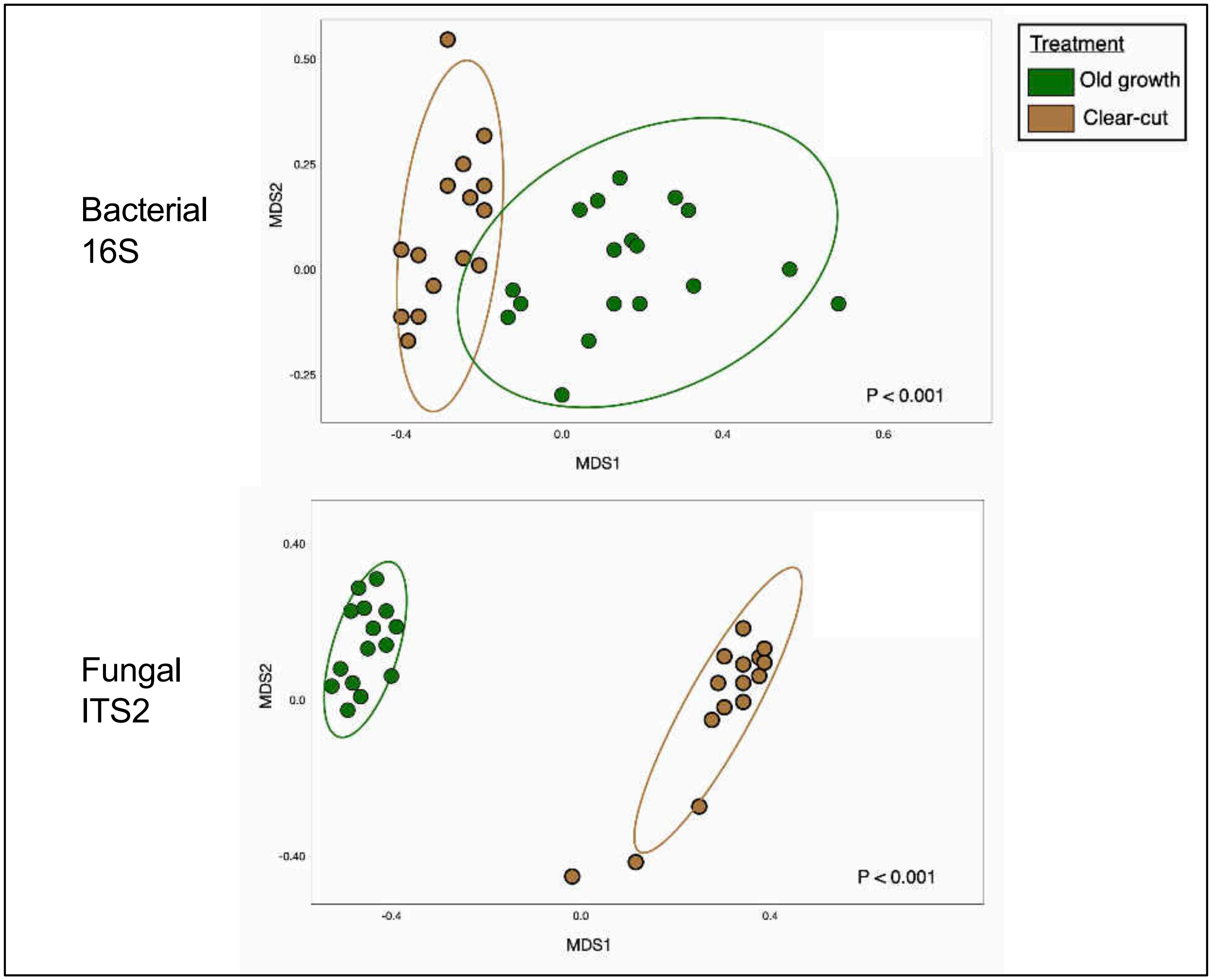
Bacterial beta diversity in old-growth vs. clear-cut forests

Bacterial
16S



Maltz, et al. *Frontiers in Environmental Microbiomes* (In Review)

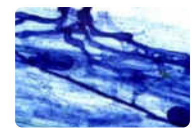
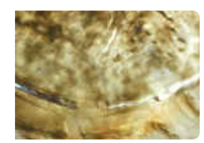
Bacterial and fungal beta diversity in old-growth vs. clear-cut forests



Maltz, et al. *Frontiers in Environmental Microbiomes* (In Review)

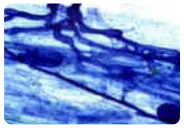
Arbuscular mycorrhizal fungi: Functional groups

Description of AMF guilds.

Guild	Intraradical Hyphae	Extraradical Hyphae	Function	
Rhizophilic ‘root-loving’	High	Low	Pathogen protection	
Edaphophilic ‘soil-loving’	Low	High	Nutrient acquisition	
Ancestral	Low	Low	Stress-tolerance(?)	

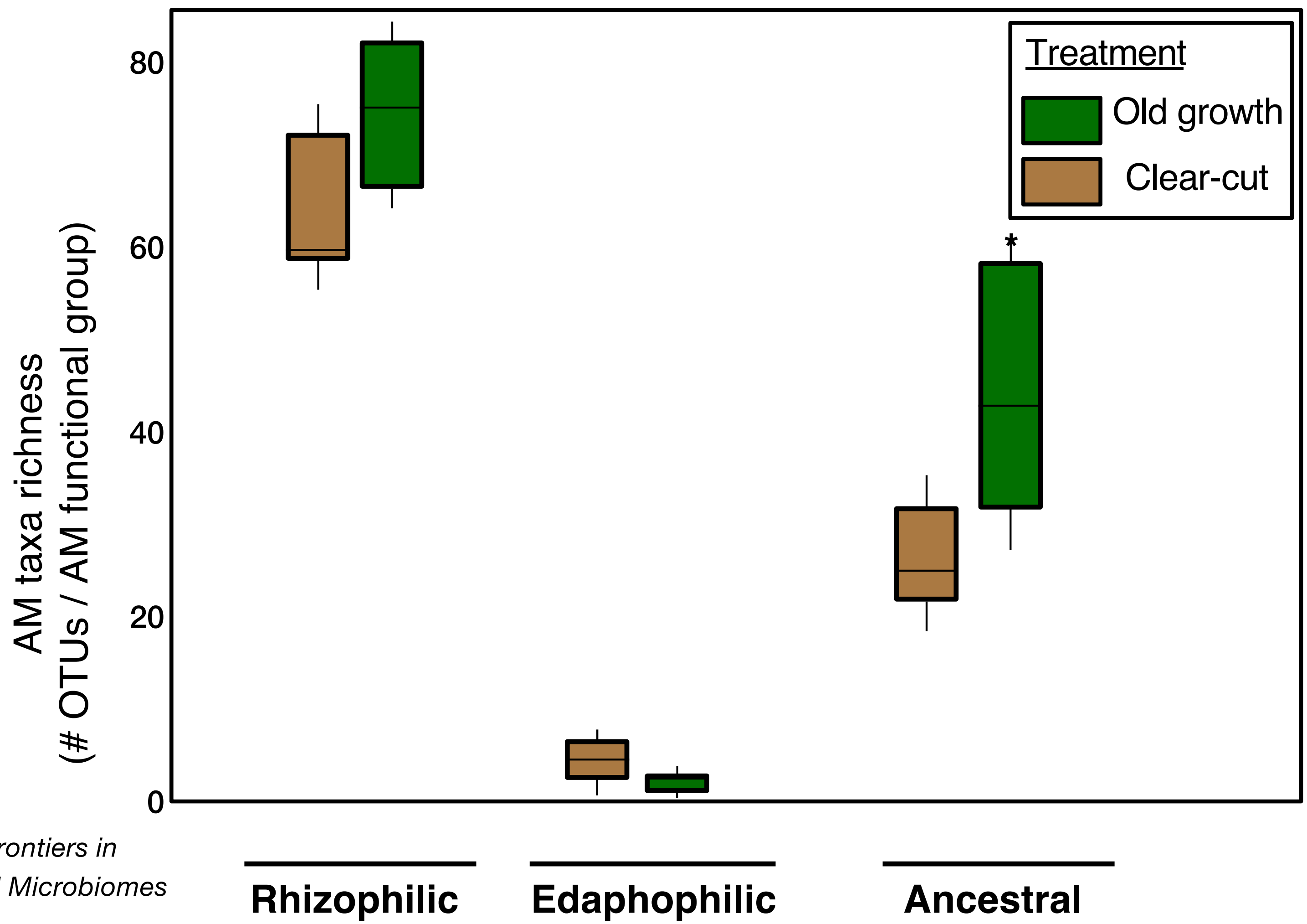
Adapted from Weber et al. 2019 *Fungal ecology*

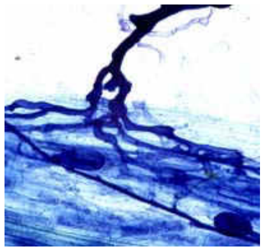
Fungal families within AM functional groups

AM Families	Intraradical Hyphae	Extraradical Hyphae	Function	
Glomeraceae Claroideoglomeraceae Paraglomeraceae	High	Low	Pathogen protection	
Gigasporaceae Diversisporaceae	Low	High	Nutrient acquisition	
Ambisporaceae Archaeosporaceae Acaulosporaceae	Low	Low	Stress-tolerance(?)	

Adapted from Weber et al. 2019 *Fungal ecology*

Ancestral mycorrhizal fungi were more diverse in old-growth forests



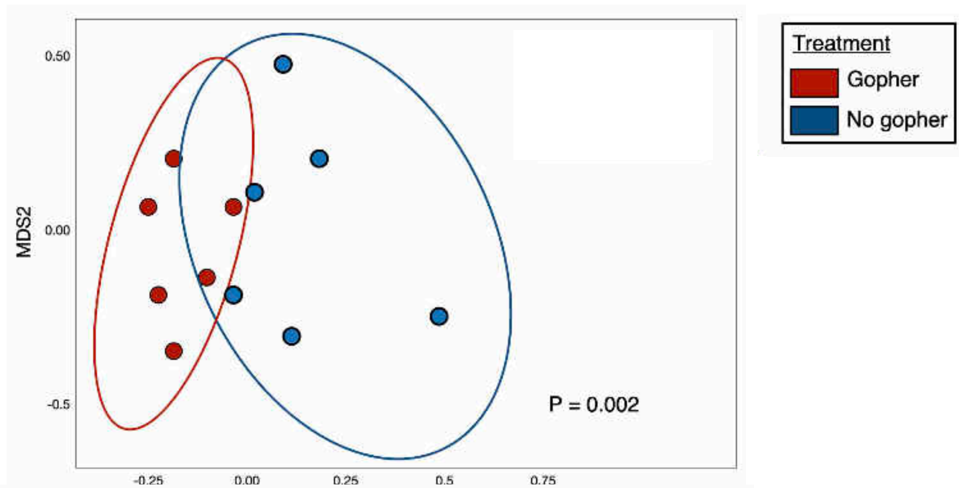


Maltz, et al. *Frontiers in Environmental Microbiomes* (In Review)

Gopher exclosures

Bacterial beta diversity for gopher additions in lupine systems

Bacterial
16S

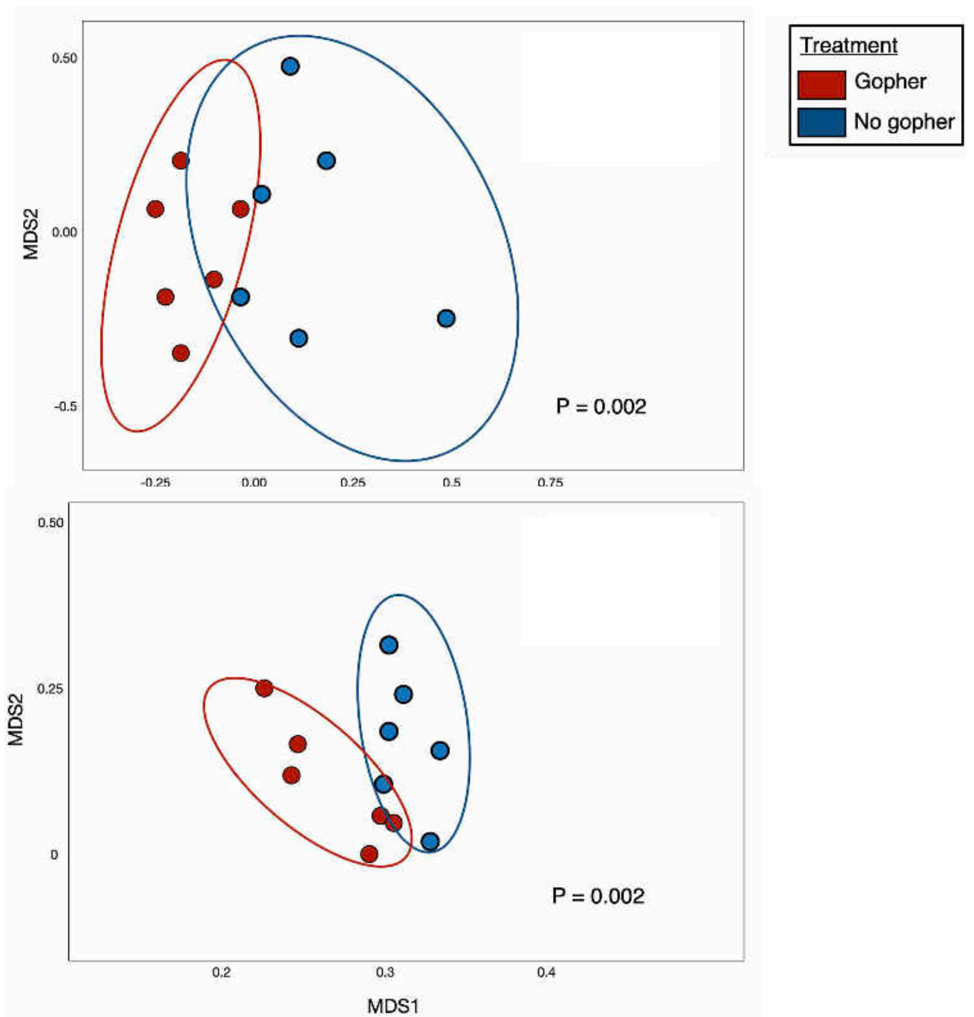


Maltz, et al. *Frontiers in Environmental Microbiomes* (In Review)

Bacterial and fungal beta diversity for gopher additions in lupine systems

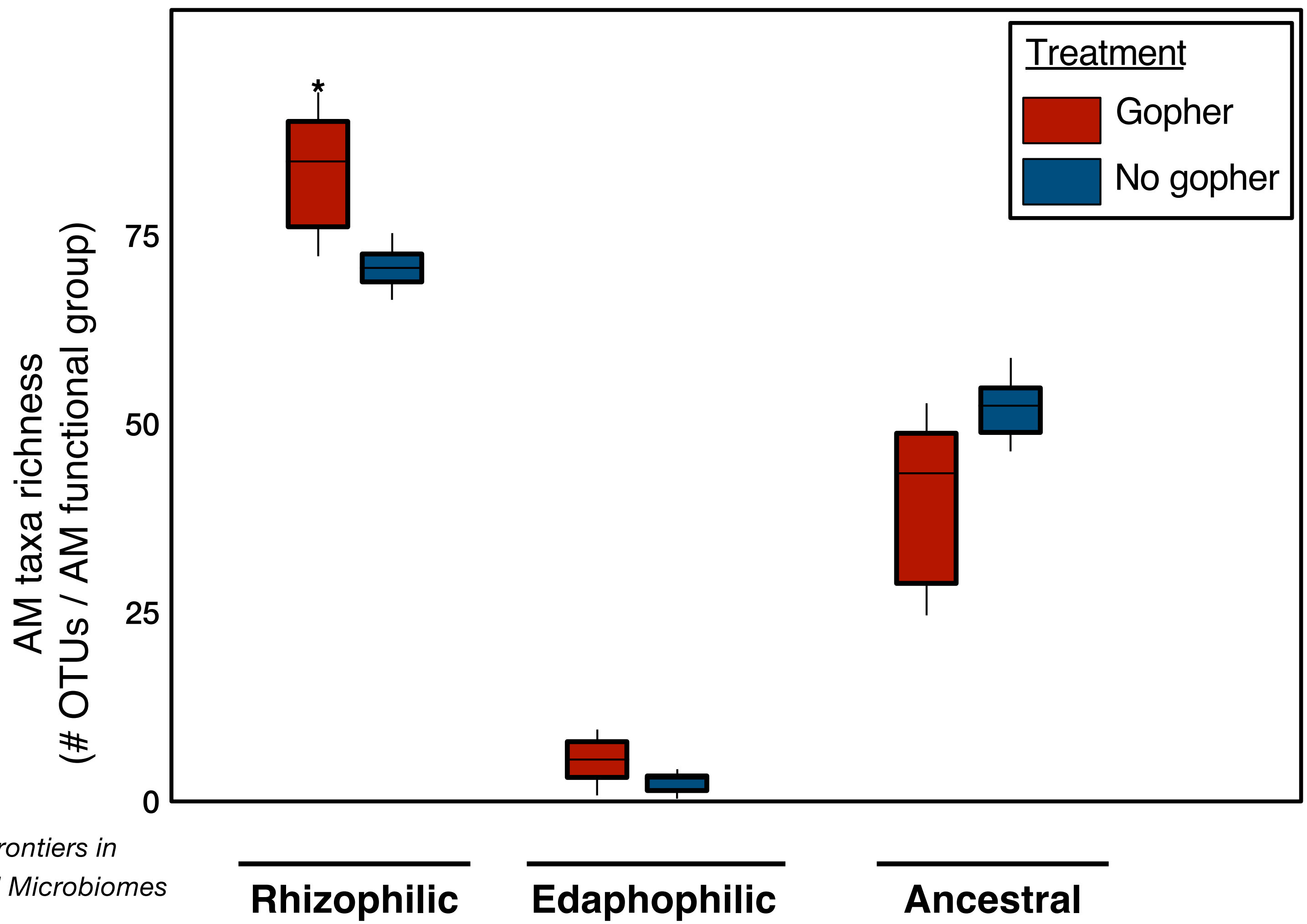
Bacterial 16S

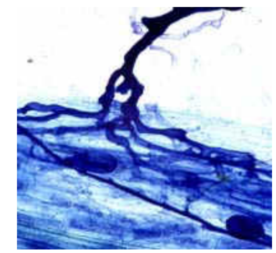
Fungal ITS2



Maltz, et al. *Frontiers in Environmental Microbiomes* (In Review)

Mycorrrhizal functional group diversity differed long term in plots with gophers





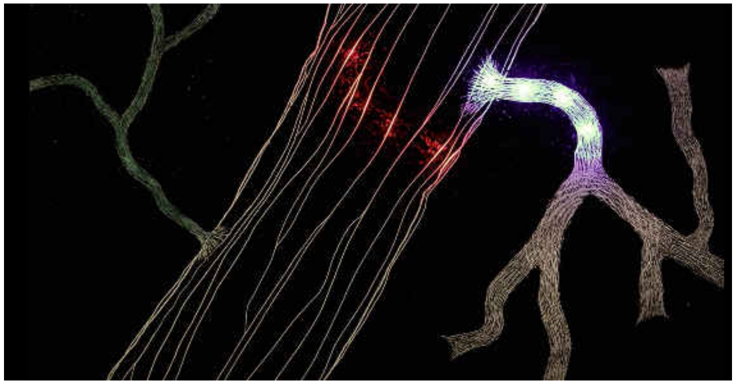
Maltz, et al. *Frontiers in Environmental Microbiomes* (In Review)

Findings

Soil microbiomes differed by forest management methods (Clearcut vs. Old growth and whether gophers were introduced to recovering forests.

Host-symbiont interactions may have been influenced by differences in the variety of mycorrhizal functional groups in this system

Ancestral AM fungi were more common in Old Growth forests, but less common in gopher plots



Findings

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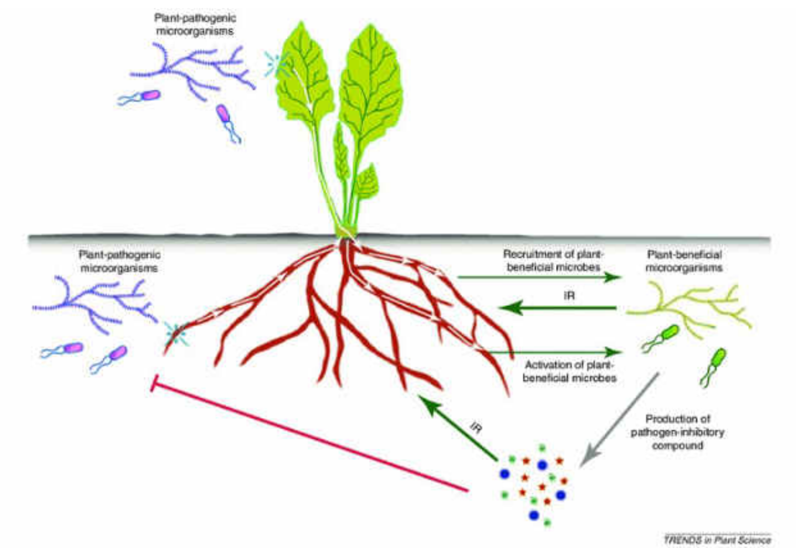
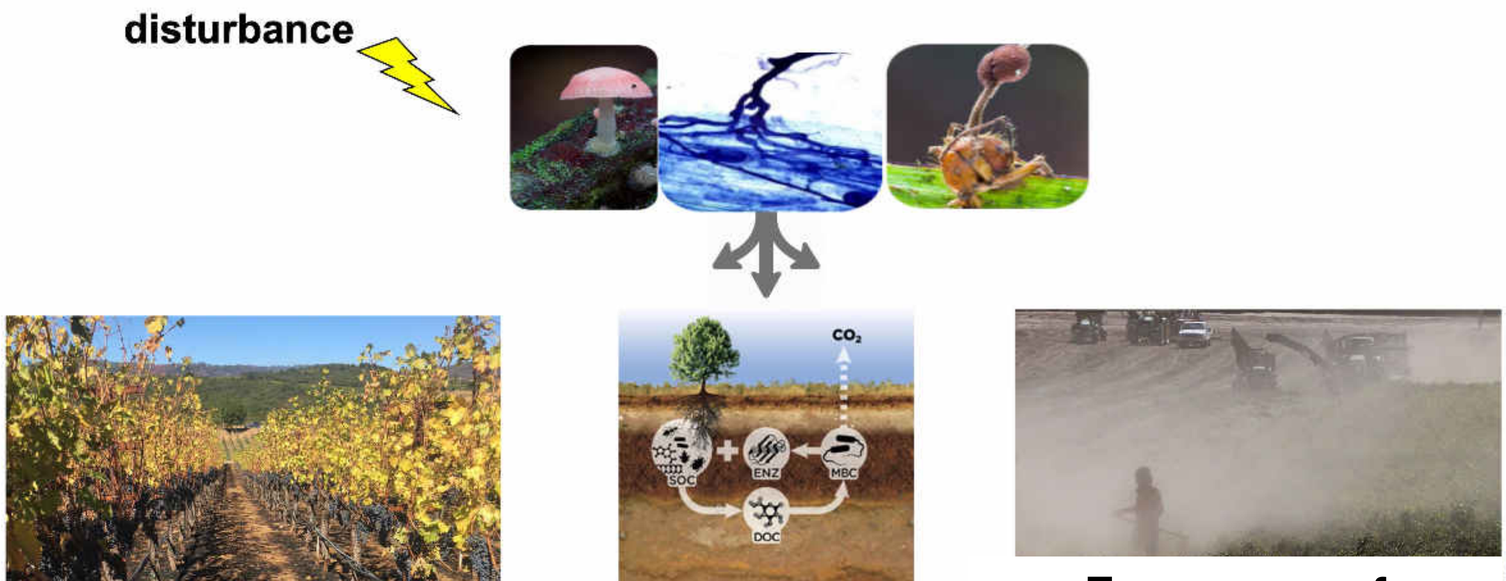
Ancestral AM fungi were more common in Old Growth forests, but less common in gopher plots

In gopher plots, *rhizophilic* AMF may have conferred an advantage to plants establishing in the pumice plain by protecting them from pathogens



Study of Microbes

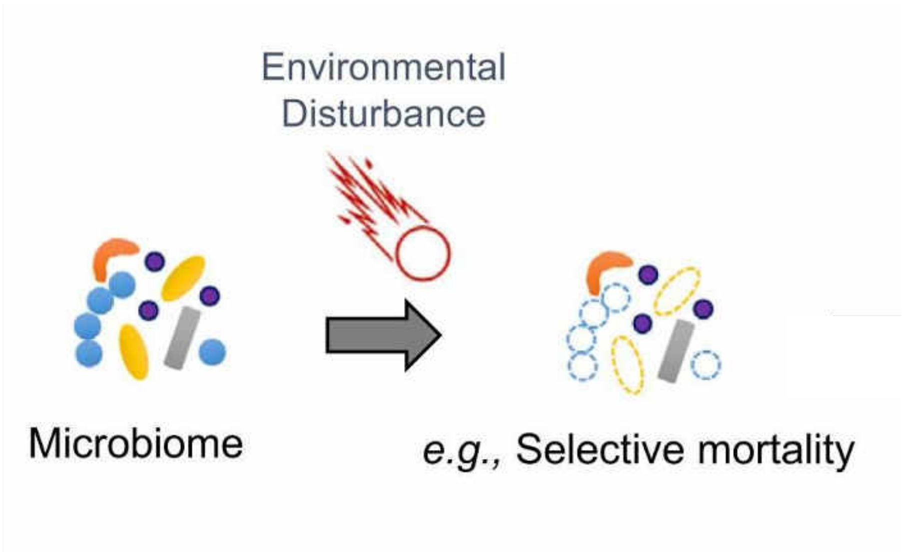


Crop losses

Global change

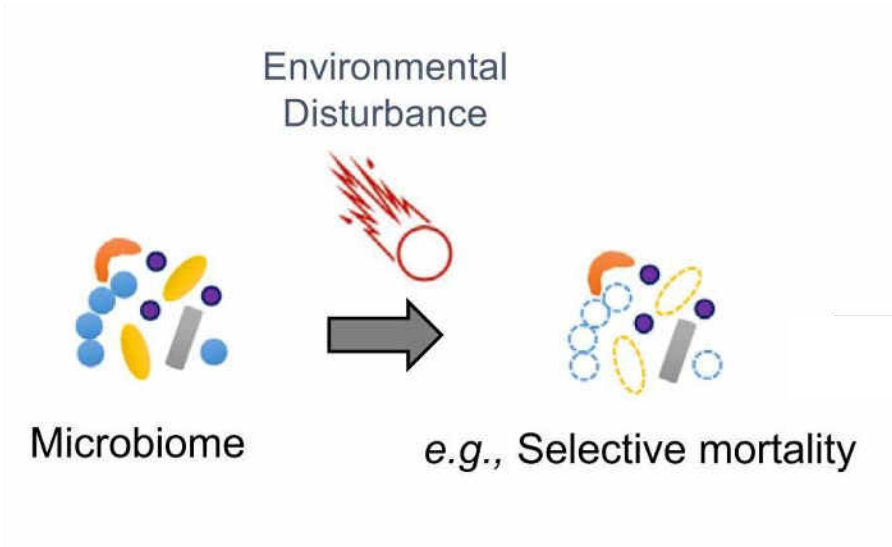
Emergence of pathogens

Resistance, Resilience, Sensitivity



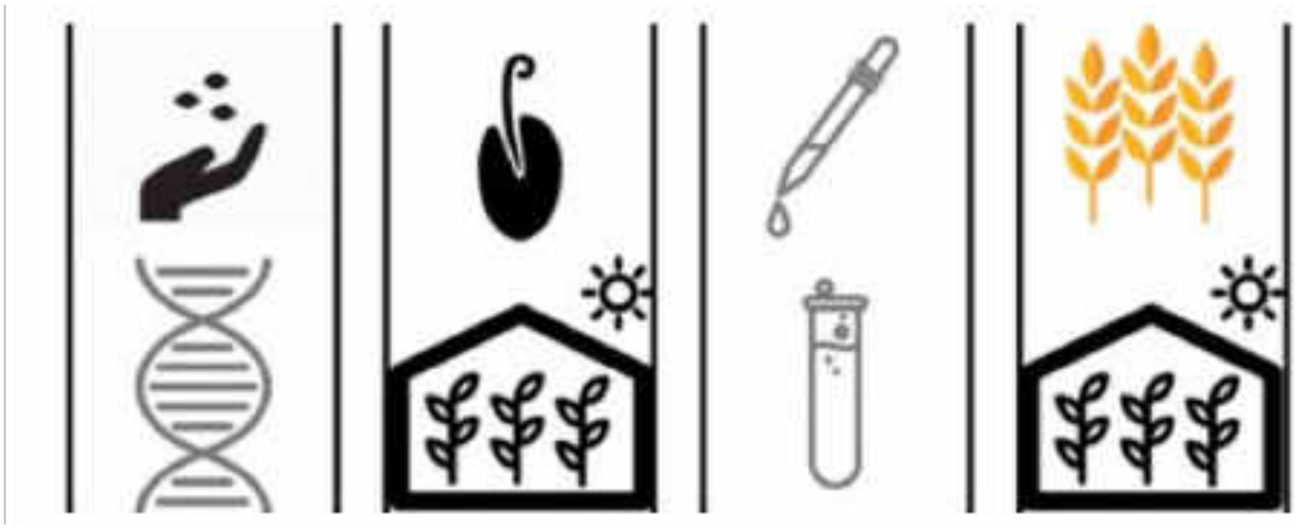
Shade et al.
Current Opinions Microbiology, 2023

Selective Mortality



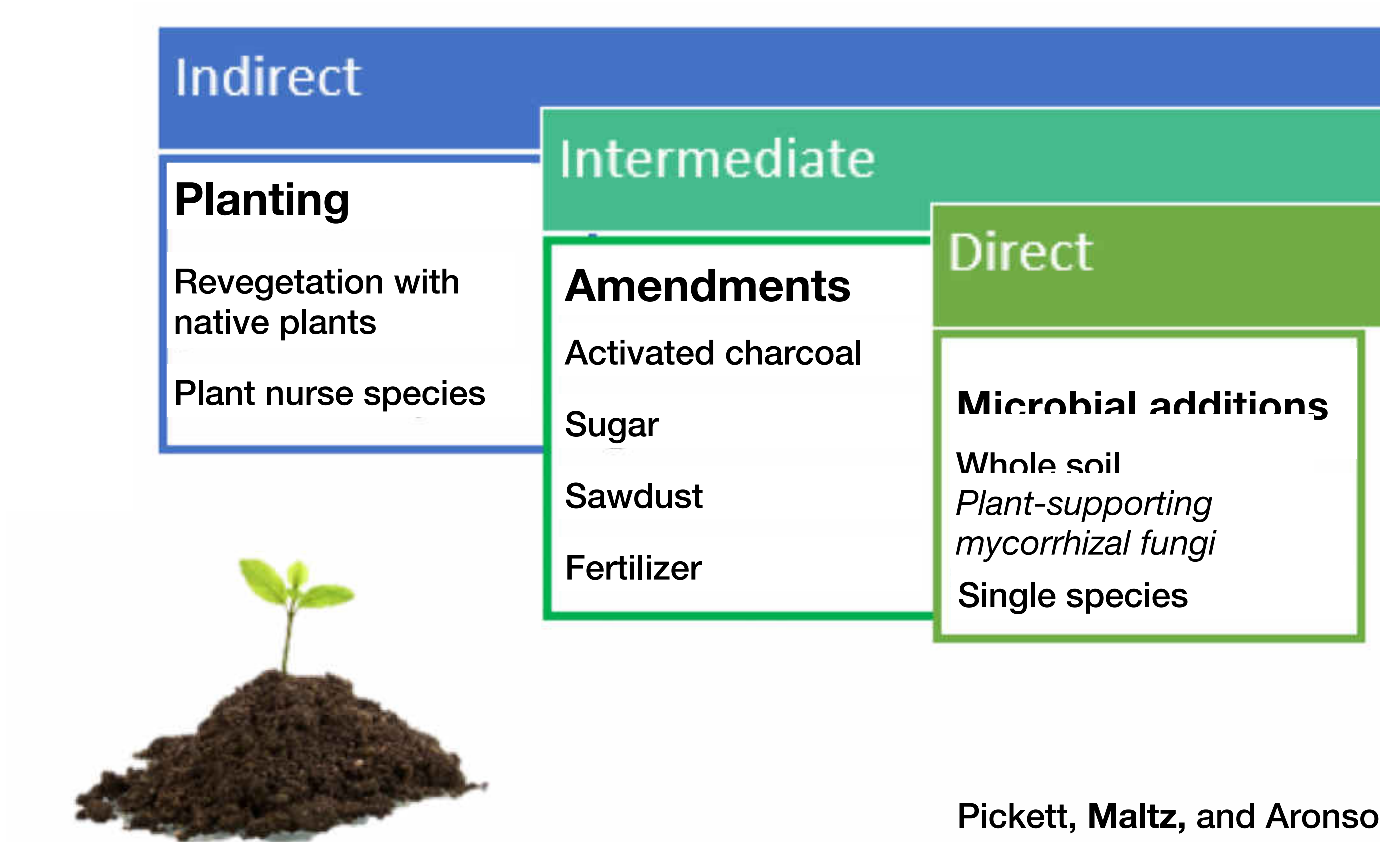
Shade et al.
Current Opinions Microbiology, 2023

Selective enrichment



Pickett, **Maltz,** and Aronson
Invasive Plants 2018

Selective enrichment



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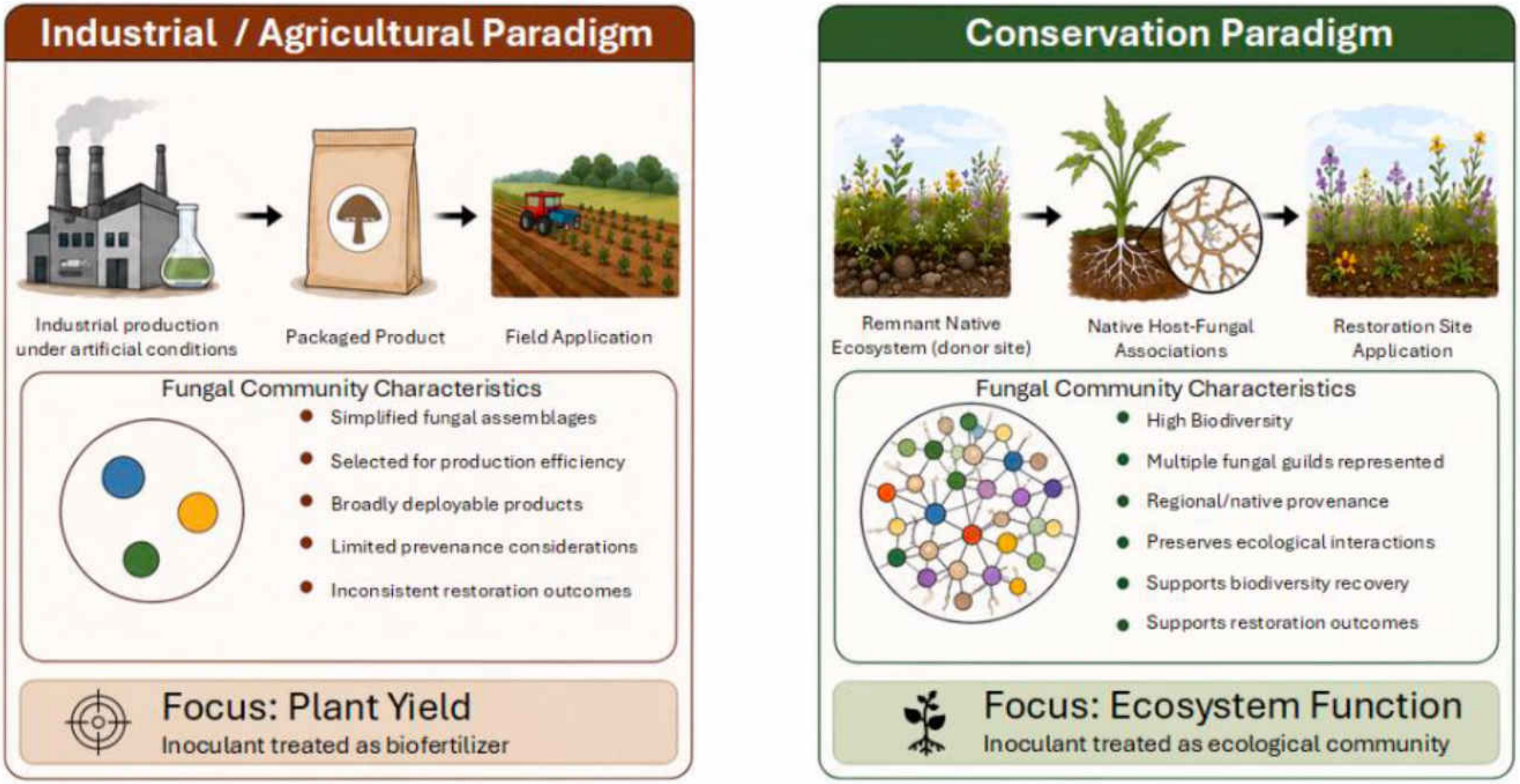
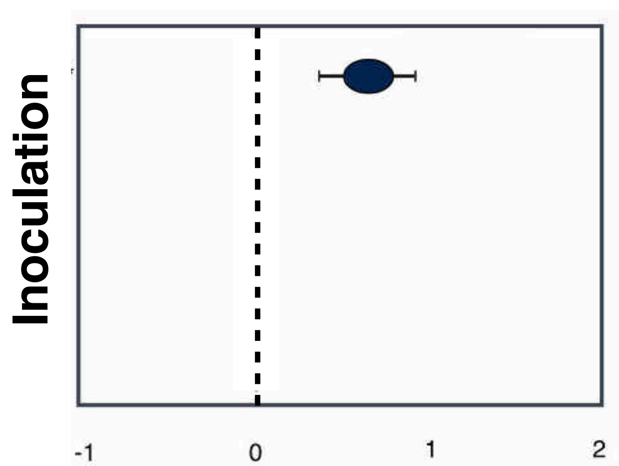
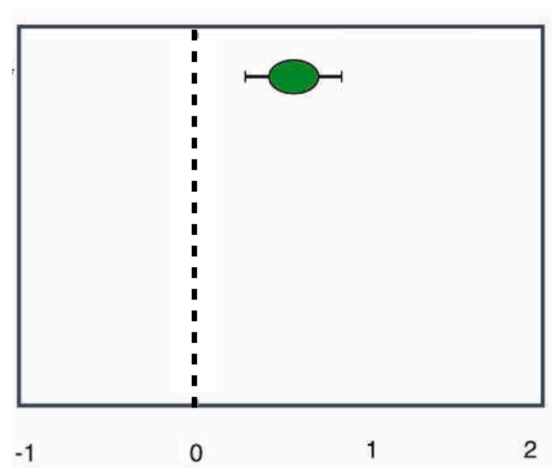


Koziol *in review, Fungal Ecology*

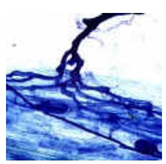
Inoculation yields positive effects



Fisher's z-transform
Mycorrhizal colonization



Fisher's z-transform
Plant performance

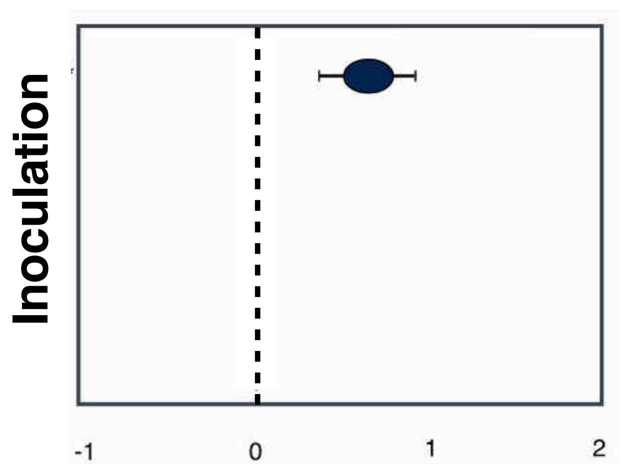


(All studies; P<0.001)*

Maltz & Treseder 2015, Restoration Ecology

Inoculation yields positive effects

Is the corollary true in post-fire systems?



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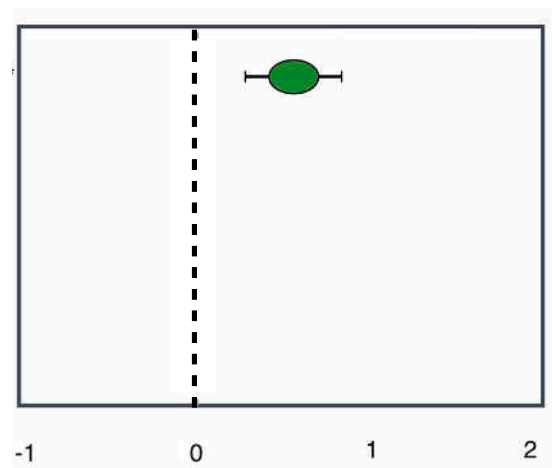

Fisher's z-transform
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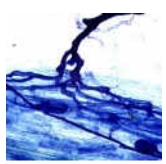

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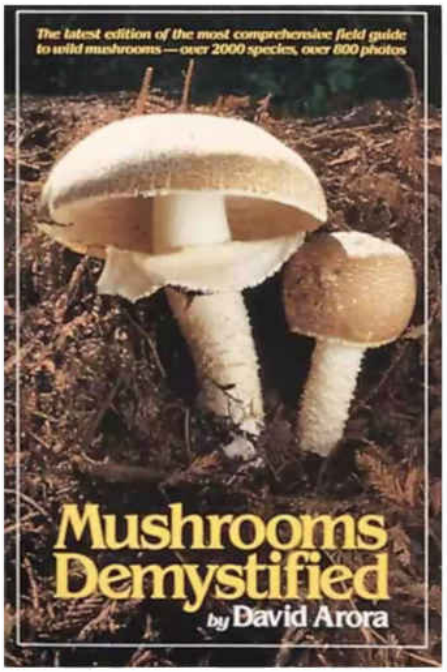
Maltz & Treseder 2015, Restoration Ecology

Phoenicoid fungi



BURNED AREAS

Many plants are adapted to growing in burned-over areas. The cones of the knobcone pine, for instance, release their seeds only when subjected to extreme heat. Similary, certain mushrooms fruit only in burnt ground, and others show a definite fondness for it. After the eruptions of Mt. St. Helens, mushrooms were among the first organisms to "colonize" the devasted slopes of the volcano, and the most reliable way to cultivate morels is still to set fire to some woods and return the following spring! (This practice actually had to be outlawed in Europe.)

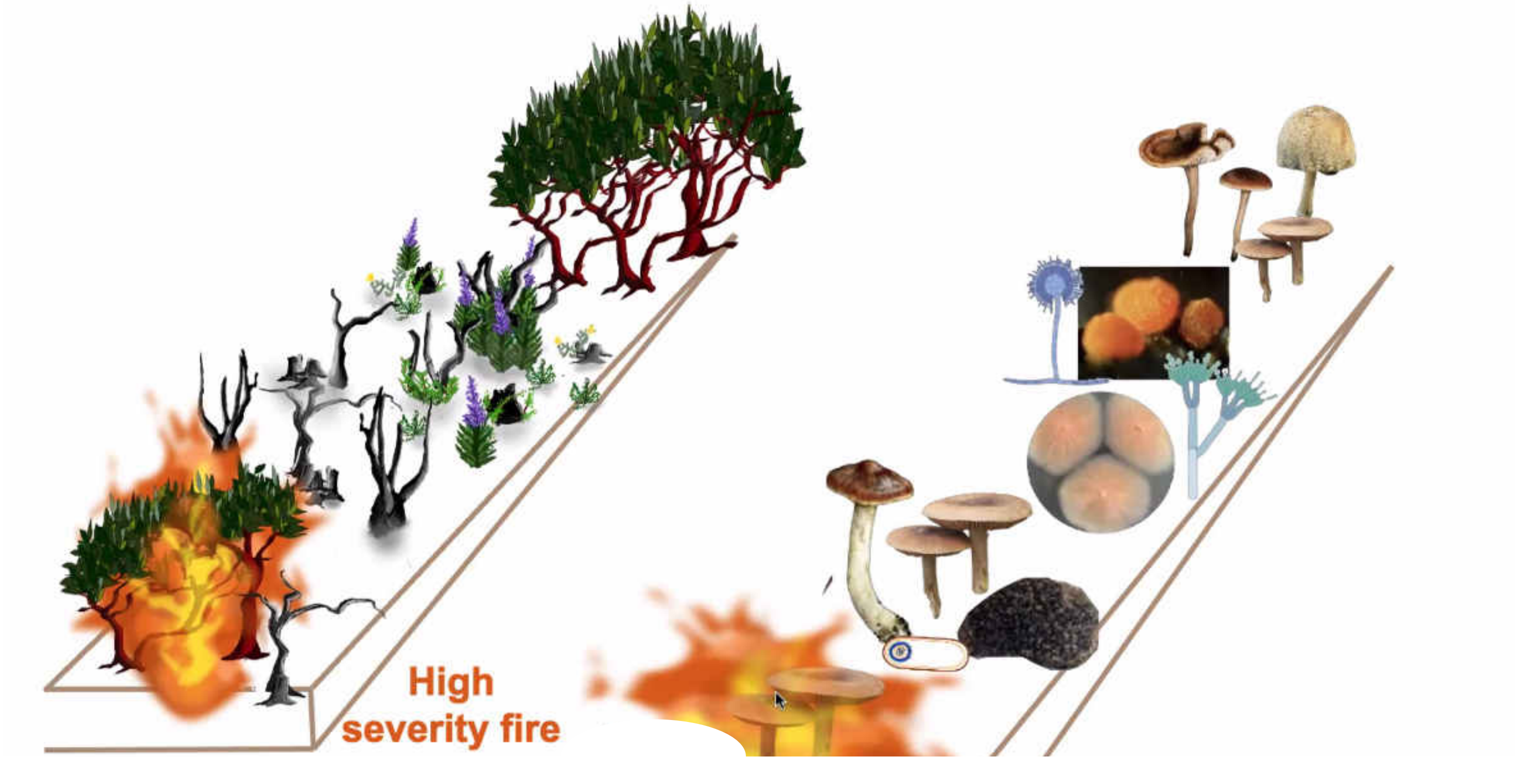
Anthracobia species
Ascobolus carbonarius
Coltricia species
Coprinus species
Geopyxis species
Lyophyllum species
Morchella species
Myxomphalia maura
Peziza praetervisa
Peziza proteana
Peziza violacea
Pholiota brunnescens
Pholiota carbonaria
Pholiota fulvozonata
Pholiota highlandensis
Plicaria species
Psathyrella carbonicola
Psathyrella species
Pulvinula species
Pyronema omphalodes
Rhizina undulata
Tarzetta species

= Cup fungi in the ascomycete order Pezizales, contains Pyronemataceae

Mushroom identification bible, p 45

Temporal dynamics:

Plants and microbial communities assemble over time



Dove[+], **Maltz** et al. 2020, *Env Research Letters*

Treseder**, Maltz** et al. 2019, *Ecology Letters*

Maltz et al. *2019 Fungal Ecology*

Brewer[+], **Maltz** et al. 2019*, mBio*

Maltz et al. 2017*, PLoS ONE*

Maltz et al. 2022*, Frontiers in Microbiology*

Aarons**, Maltz** et al. 2019*, Aeolian Research*

Looby[+]**, Maltz** et al. 2017*, Ecology and Evolution*

Fire reduces fungal richness and changes fungal community composition …

Fungal taxa richness / diversity

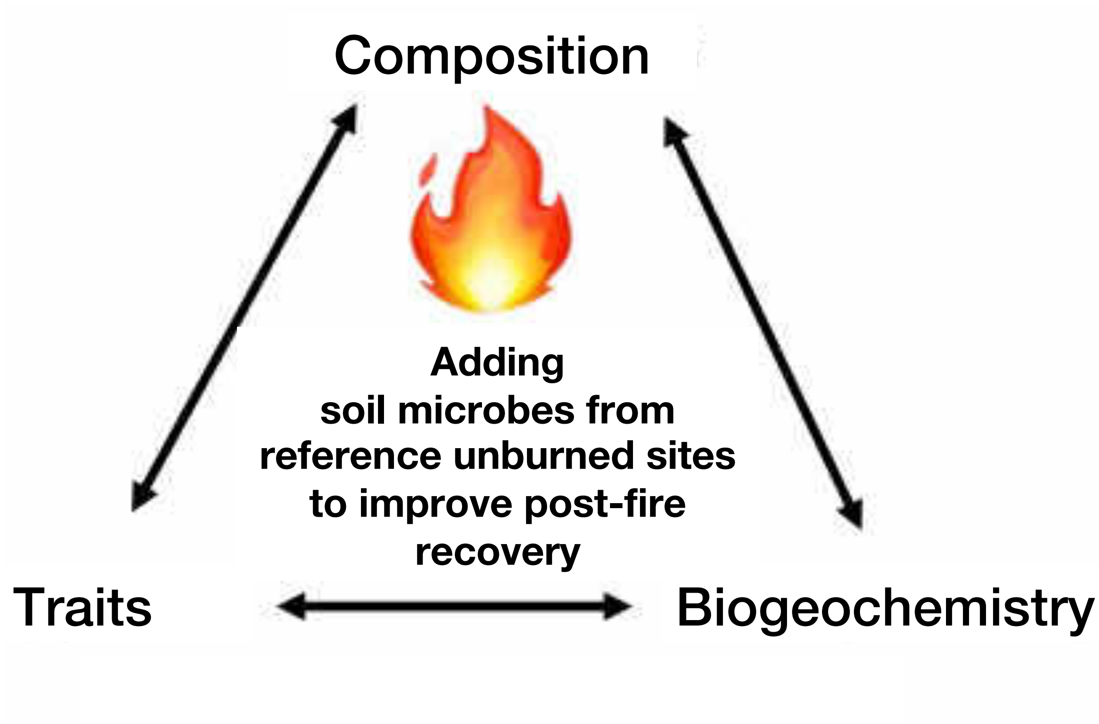
Dove & Hart,
Fire Ecology (2017)

… would inoculation of native taxa accelerate fungal post-fire restoration?

Fungal taxa richness / diversity

Dove & Hart,
Fire Ecology (2017)

Microbial facilitation post-fire

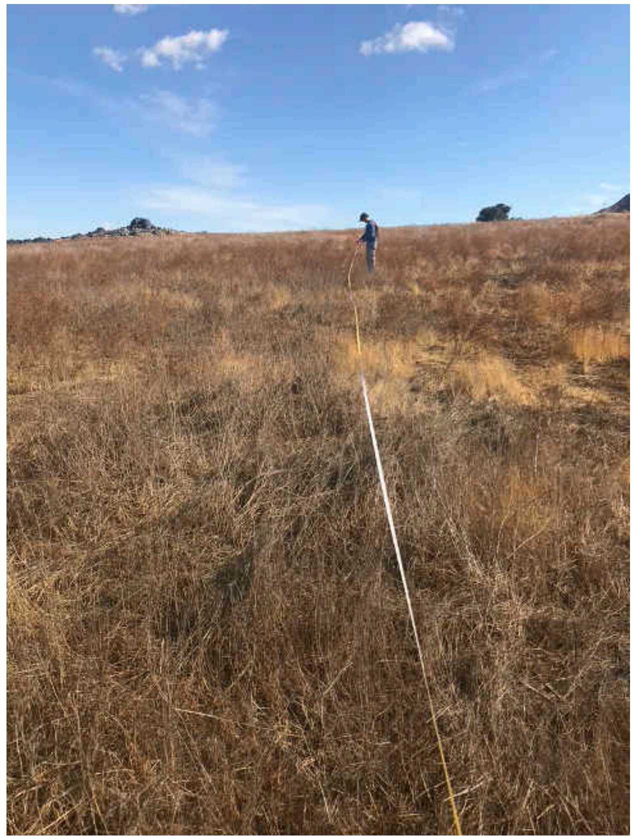


Bureau of Land Management awarded to Sydney Glassman’s Fungal Ecology Lab at UC Riverside

Stephens’ Kangaroo Rat (*Dipodomys stephensi*) Preserve, at Lake Mathews Estelle Mountain Reserve.

Fire crews from the California Desert Interagency Fire Program treating public lands with prescribed fire in the Lake Mathews-Estelle Mountain Stephens’ Kangaroo Rat Reserve in western Riverside County. (Photo by James Gannon)

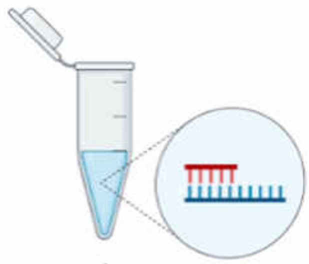
Preliminary site survey site: Line transects



3 Lines - Fall Burn; 3 lines Spring Burn

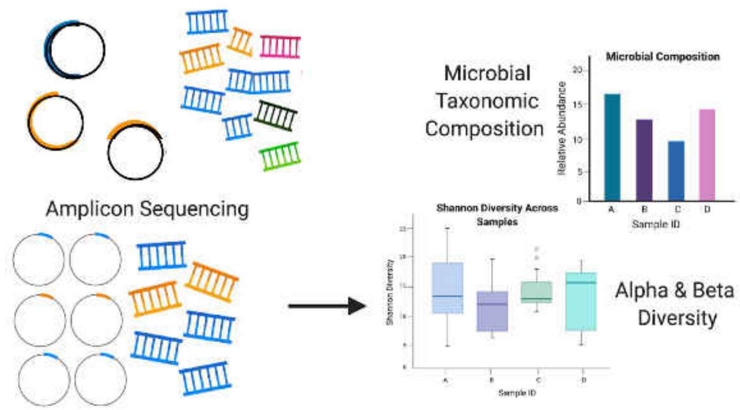
Environmental sample workflow

Soil samples



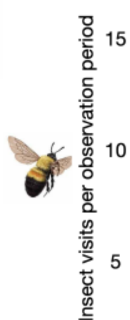
DNA extract

qPCR



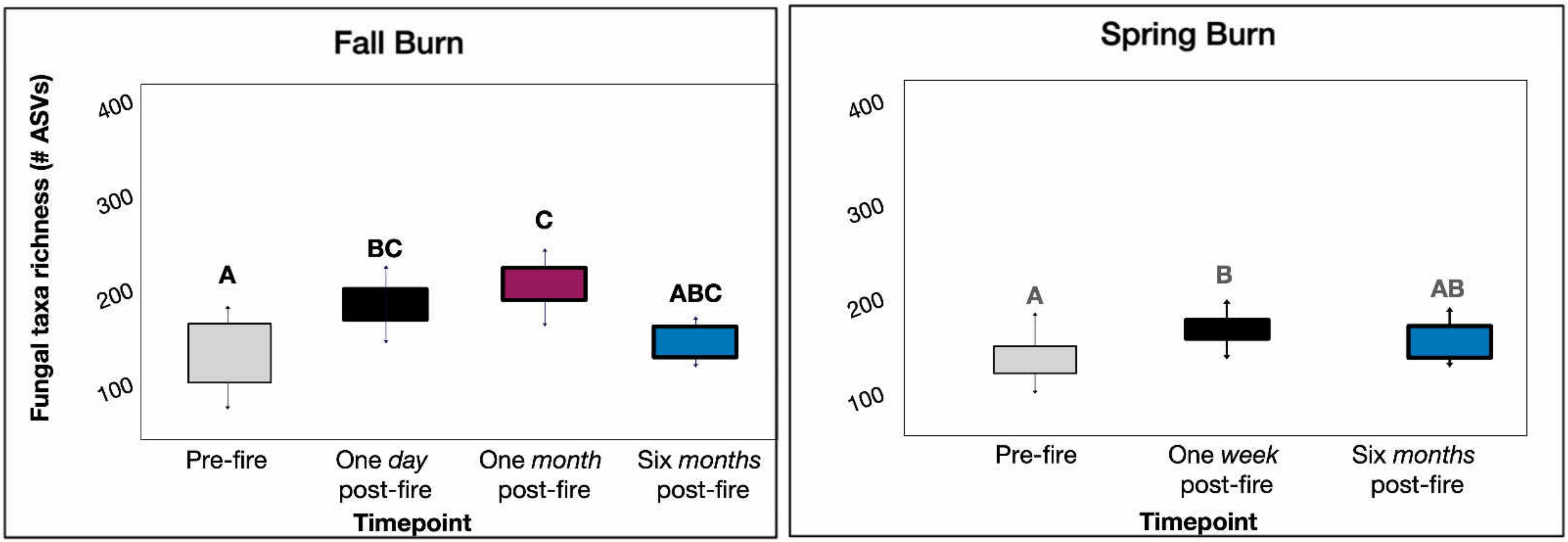
Amplicon sequencing
16S
ITS2

Pollinator visitation



Plant community monitoring

Prescribed fire marginally increased fungal richness initially

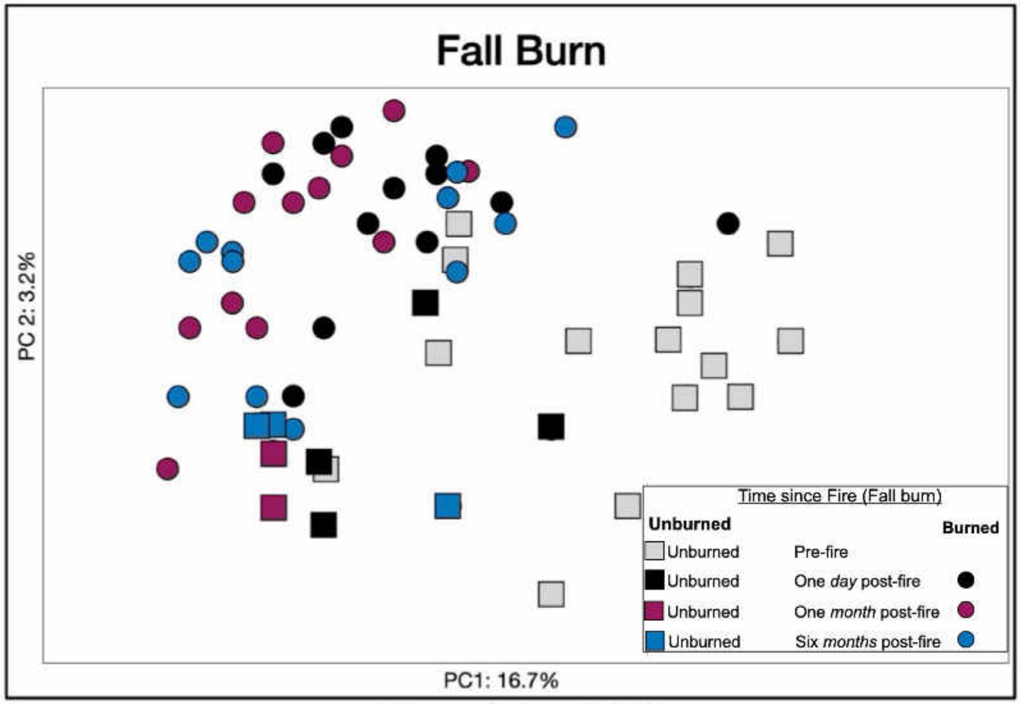


Fungal taxa richness over time in Fall and Spring burns

Fungal richness Pre-fire vs. one week post-fire = $p<0.001$ Fungal richness Pre-fire vs. one week post-fire = $p=0.046$

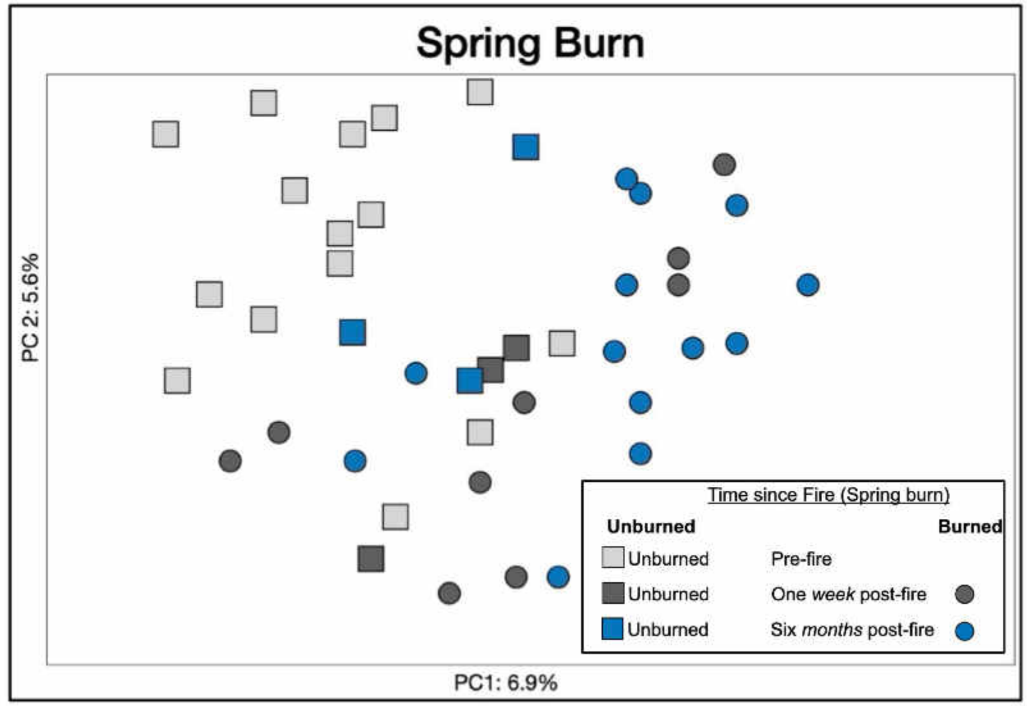
Fungal composition shifted in burned plots over time

Untreated control plots - burned vs. unburned



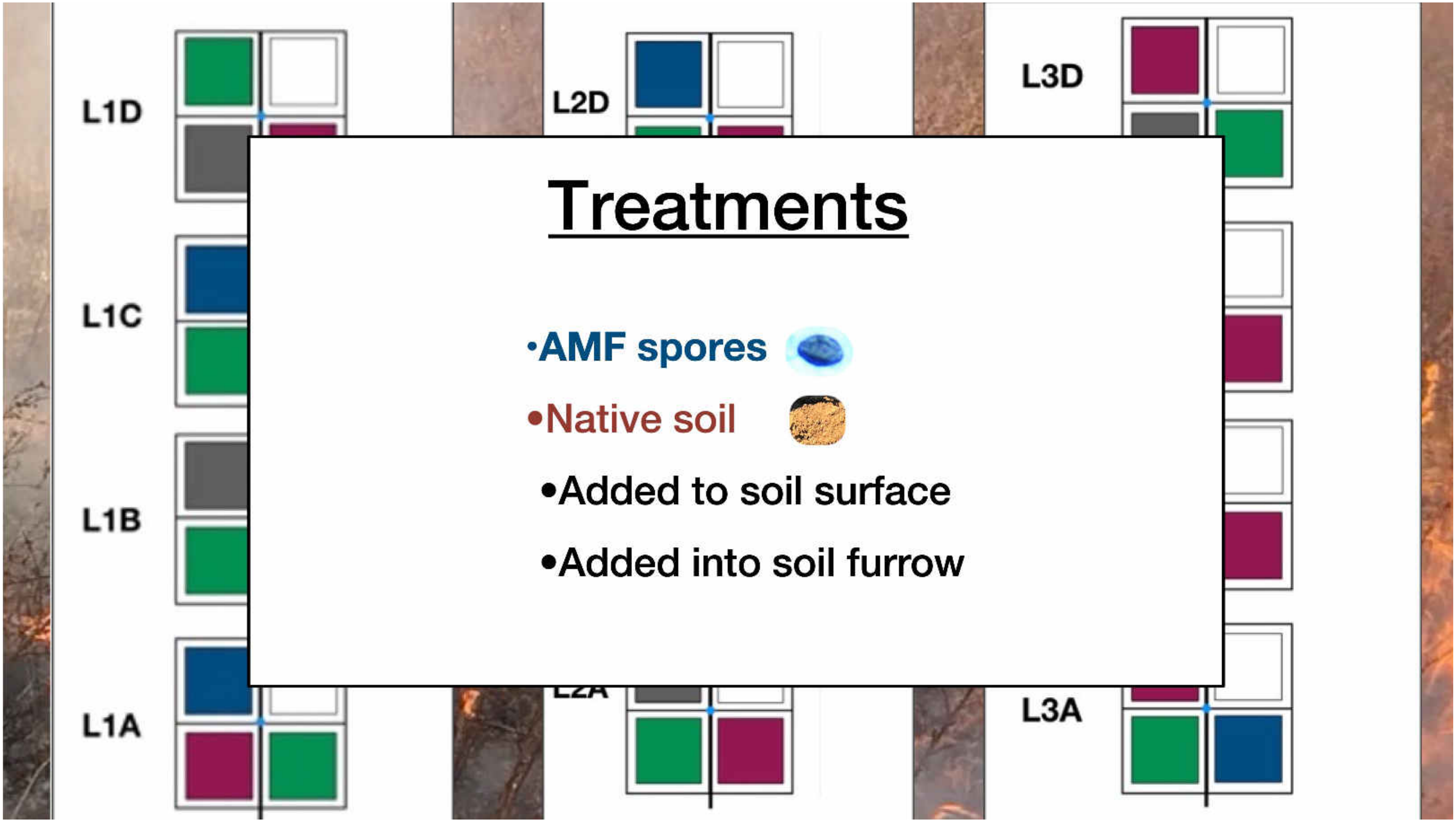
Timepoint: $p<0.001$

Burn vs. unburned: $p=0.02$



Timepoint: $p<0.001$

Burn vs. unburned: $p=0.004$



Treatments

- AMF spores
- Native soil
  - Added to soil surface
  - Added into soil furrow

Prepare inocula

Collect native soil at Lake Mathews

Extract AM fungal spores from native soil at Lake Mathews

Sucrose density centrifugation

Soil, NO Furrows

Added to soil surface

AM spores

With Furrows

Added into soil profile

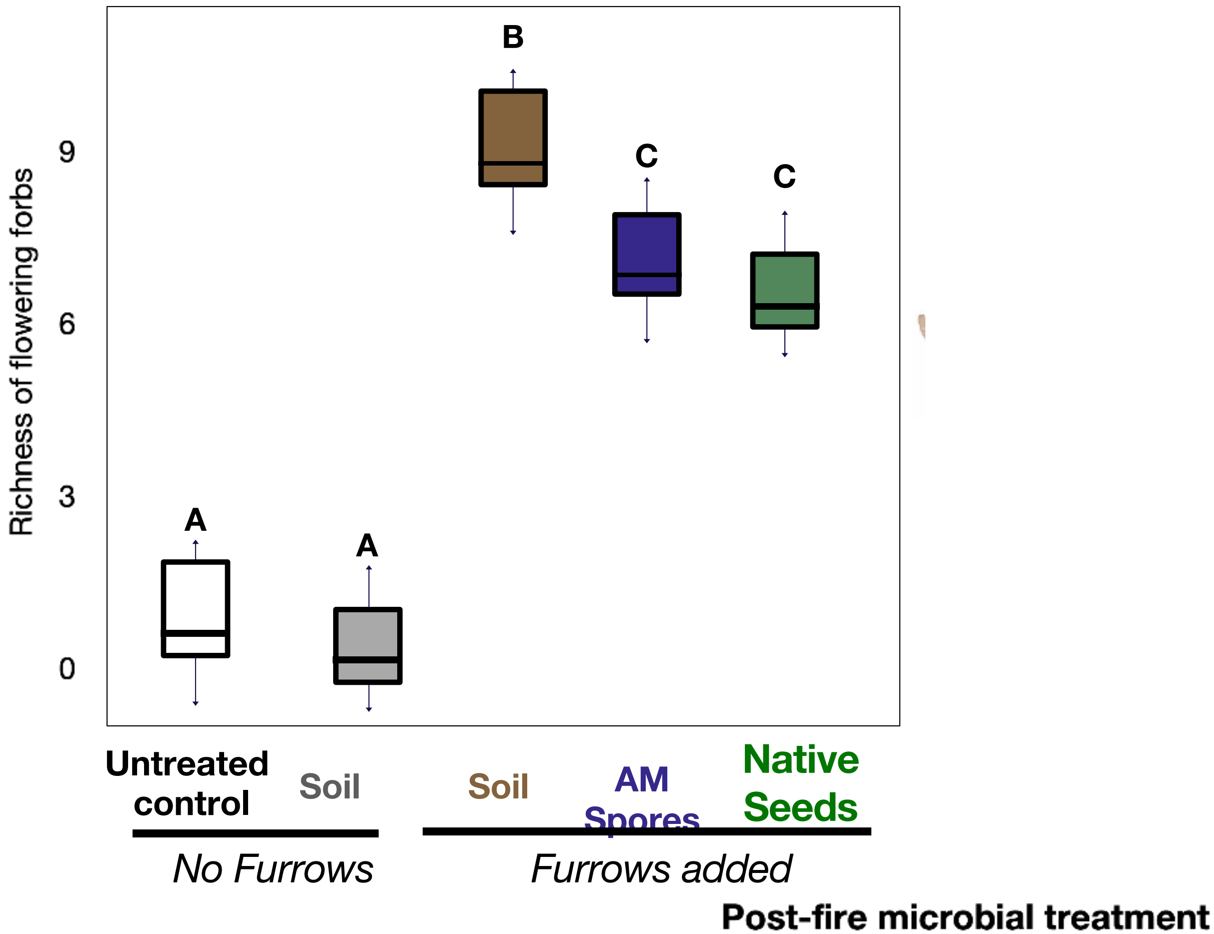
Soil With Furrows

Added into soil

profile

Adding native soil and fungal spores

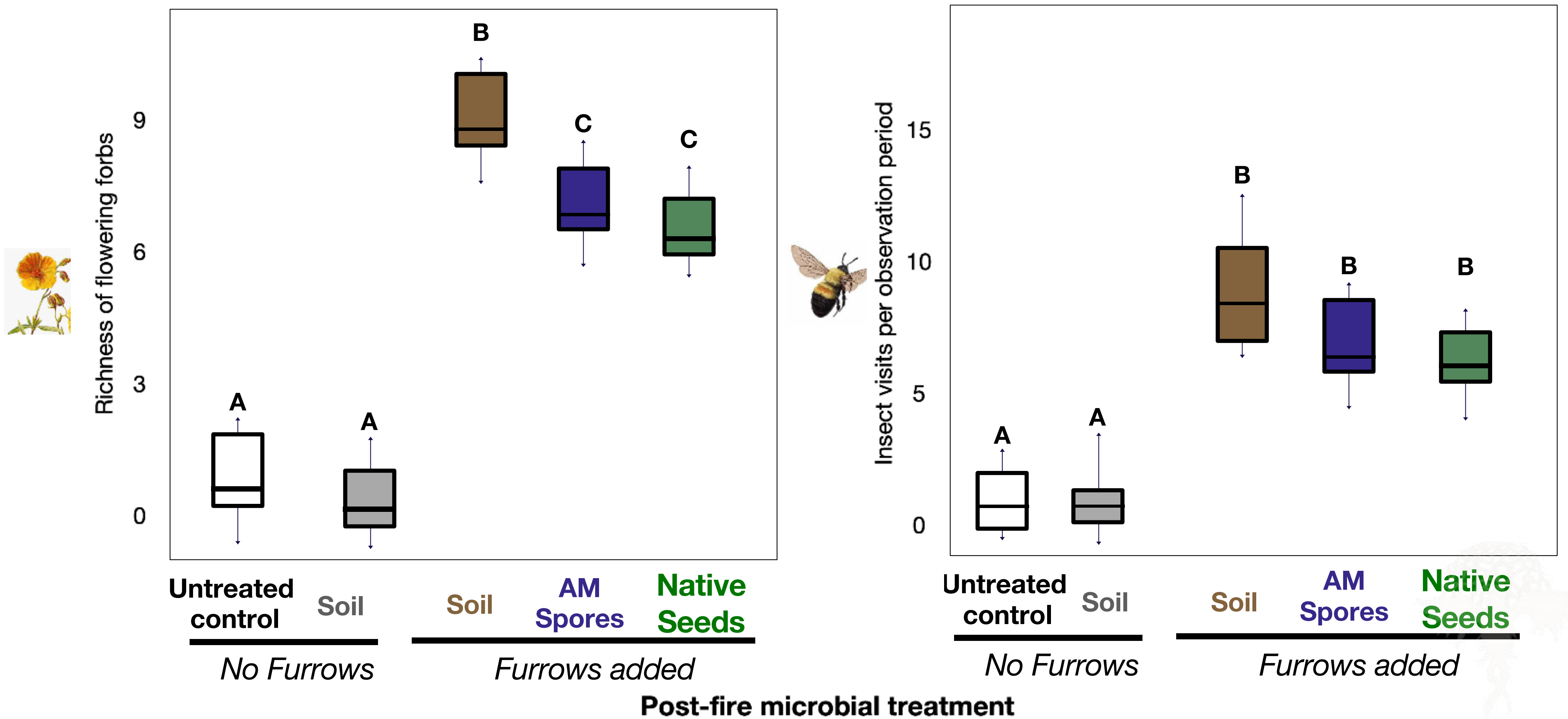
Inoculation treatments with and without furrows



Maltz, et al. *Applied Soil Ecology* (In prep)

Figure credit: modified from Annika Rose Person

Adding native soil and fungal spores increased plant-pollinator interactions in post prescribed burn sites

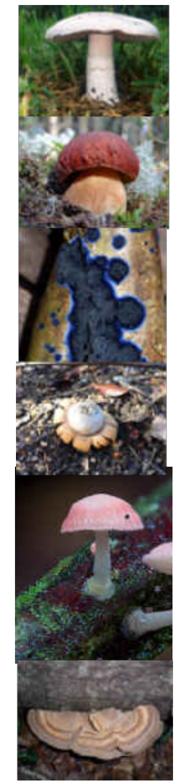


Maltz, et al. *Applied Soil Ecology* (In prep)

Figure credit: modified from Annika Rose Person

Prescribed fire and fungi in an arid grassland chaparral system

- Time since fire and burn season affected fungal community composition
- Fungal richness ephemerally increased post-fire
- Revegetation and strategic management approaches to amending post-fire soils with native microbes may support ecosystem functioning



Fire History in New England

- Fire as an evolutionary factor:
  - Humans cause 95% of fires in the Eastern US.
  - Lightning strikes have caused fires for millions of years.

- Indigenous people and oral accounts.
    - Lewis Henry Morgan 1983 interview with indigenous elders in Albany, NY indigenous uses of fire.

- USFS 1910 No-Burn Policies.
  - The Big Blowup, 1910 across Montana burned approximately 3 million acres in 2 days.
    - 'Only total fire suppression can prevent such an event from occurring again'
    - 1980s lightning fires created public outrage.
    - This no-burn sentiment continues within the public and across municipal fire departments in New England.

Pile burns at UConn



Photo credit: Dr. Milton Levin

Our “Burning” Questions

How do fires in New England affect soil function, health, and physicochemical properties in hardwood stands?

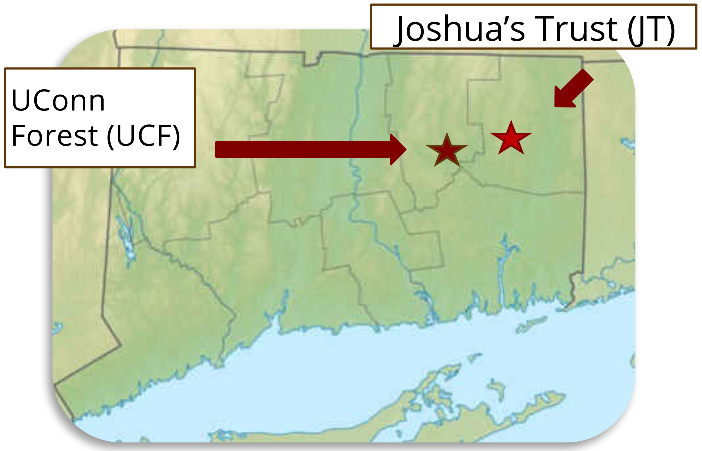
How does fire affect fungal community composition and soil biodiversity in New England forests?

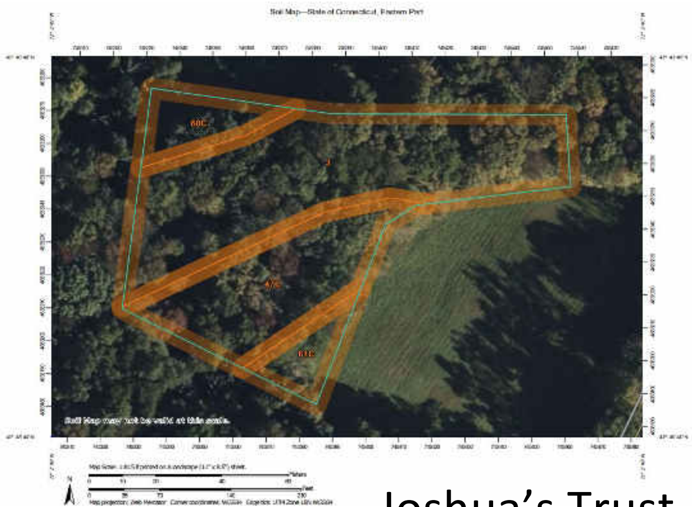
Would post-fire microbial inoculation (PFMI) benefit regeneration efforts of blight-resistant chestnuts?

Collecting inoculum from the chestnut grove

Study System

UConn Forest (UCF)





Joshua's Trust

Methods

Suitable burn locations are identified and sampled at T0

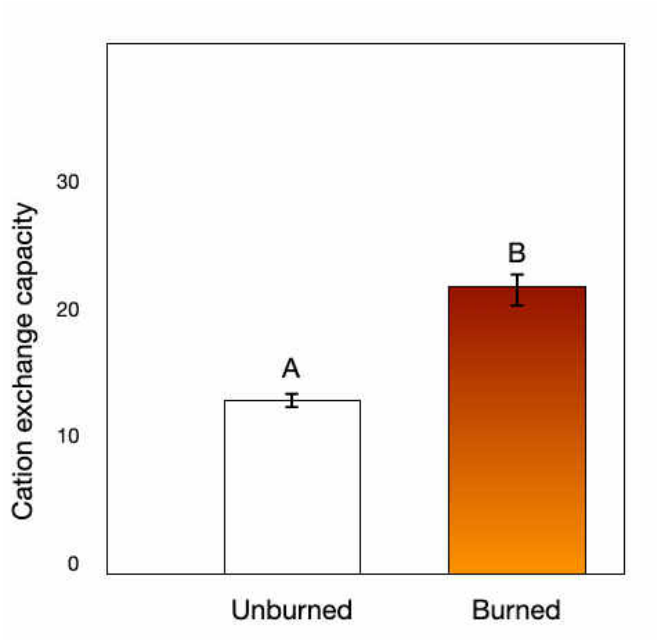
Burn operations occur

Inoculation and sampling at day 2, and sampling at day 29

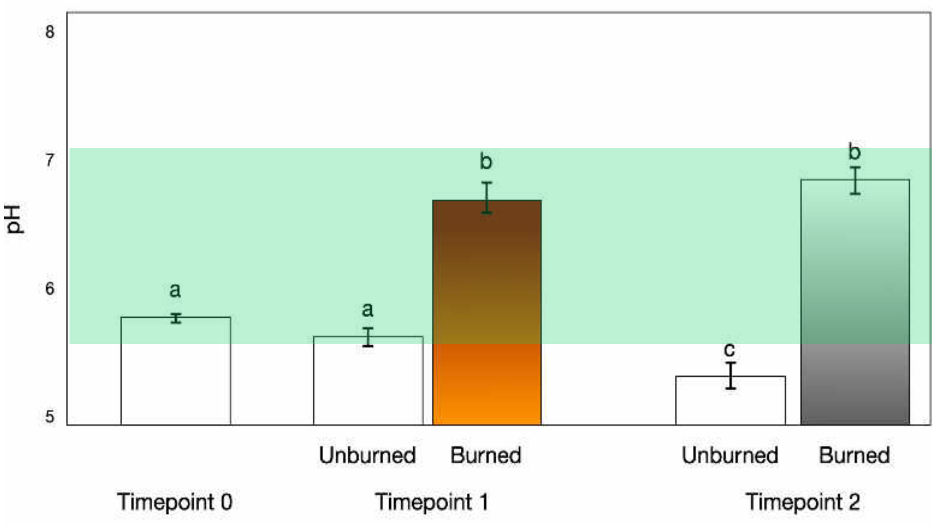
Physical, chemical, and biological assays are performed

Photo credit:
Dr. Milton Levin

Cation Exchange Capacity and pH Levels

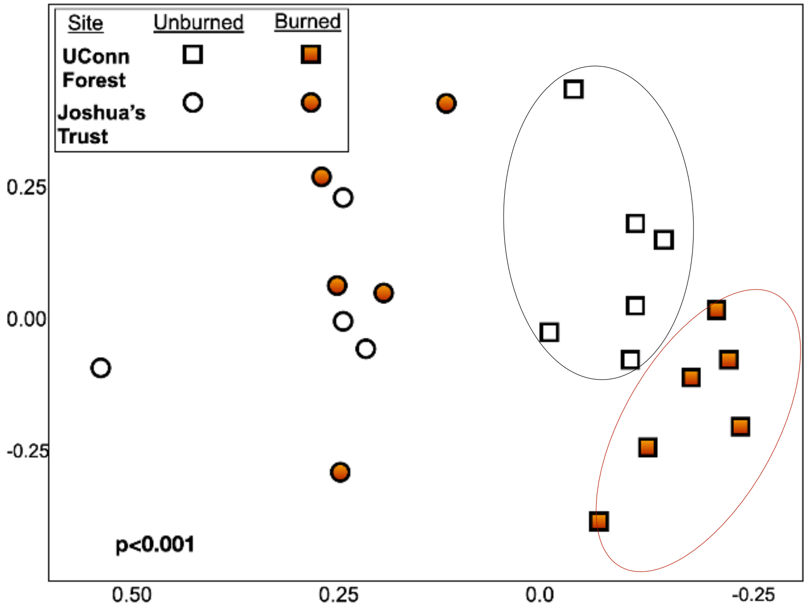


Cation exchange capacity (CEC) increased after the fire at UCF.



Soil pH was higher in burned plots. Desirable zone for soil pH for American chestnut regeneration is highlighted.

Fungal Communities



Soil fungal communities varied between sites.
Fire status affected fungal communities at UCF.

Ir

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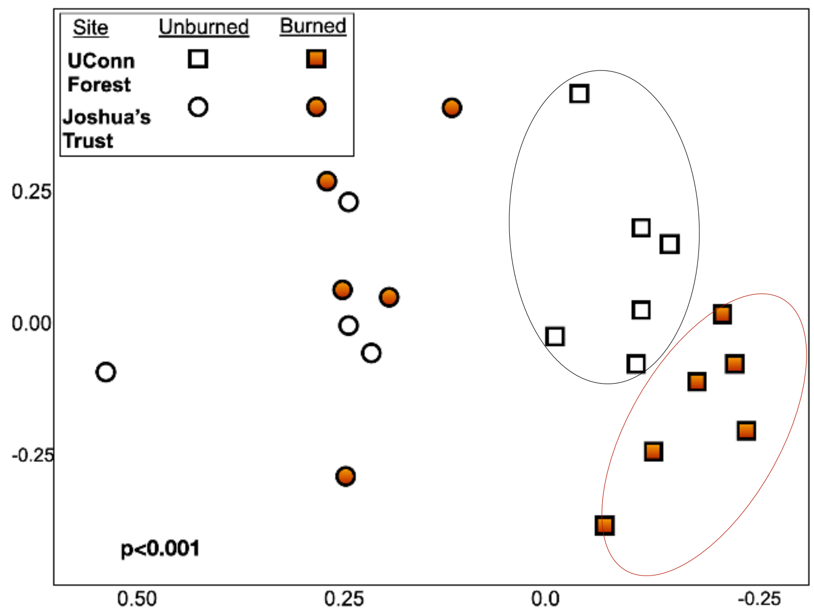
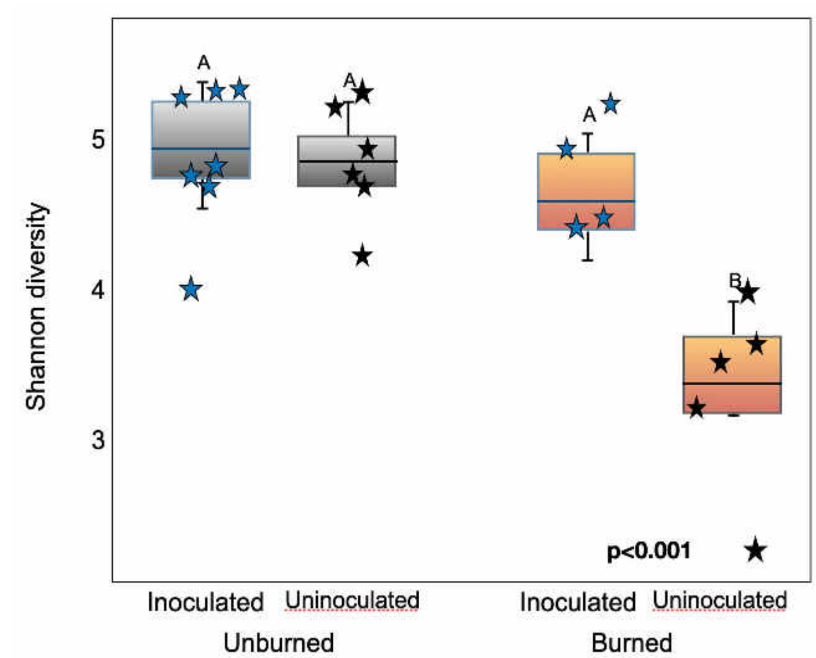
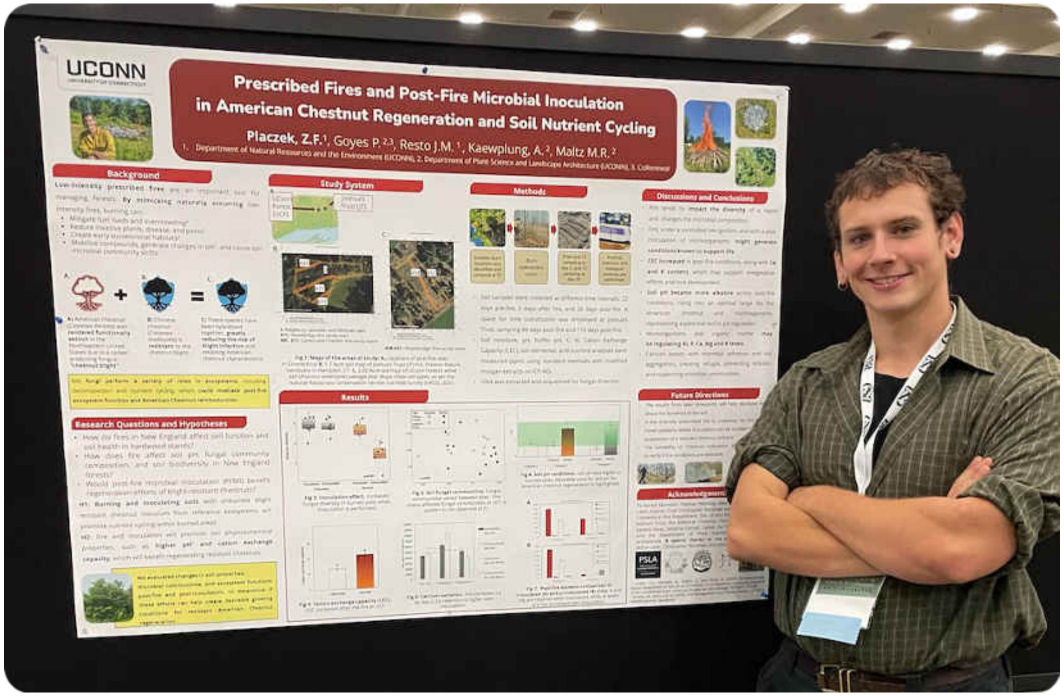
Fungal Communities



Soil fungal communities varied between sites. Fire status affected fungal communities at UCF.

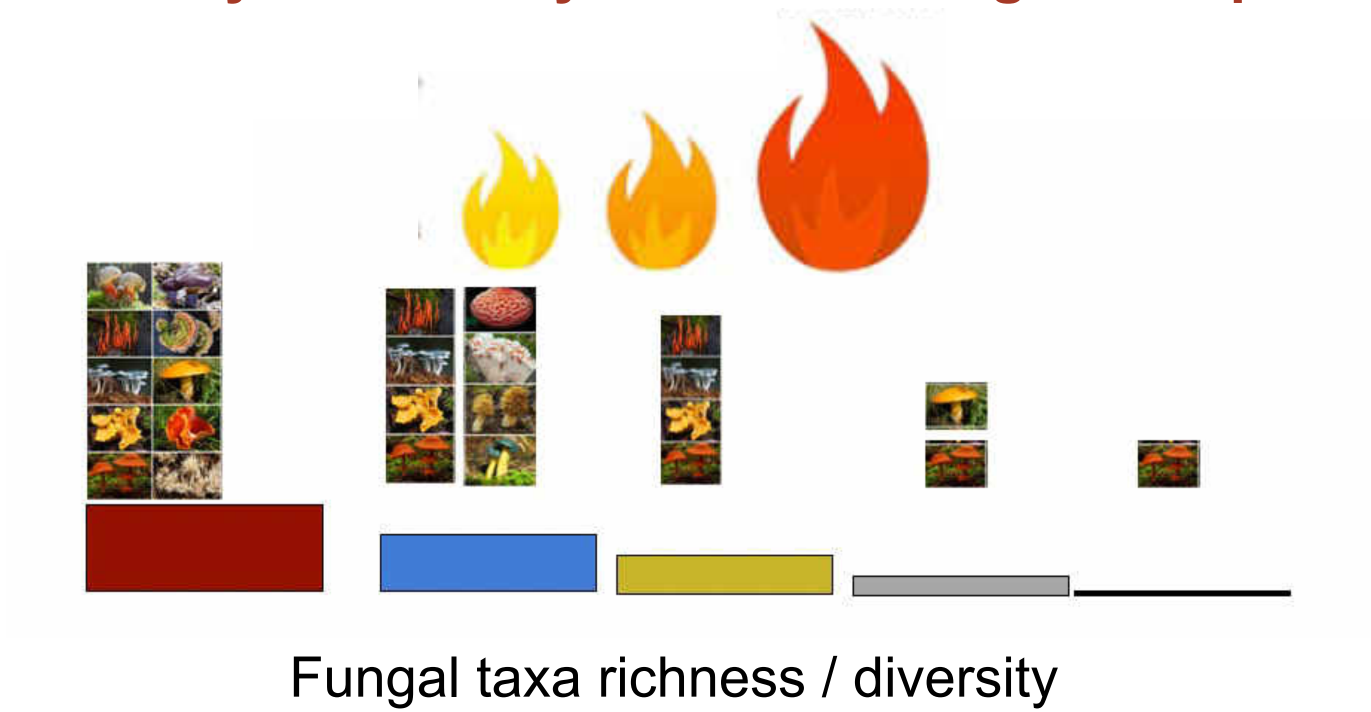


Inoculation increased fungal diversity in burned plots

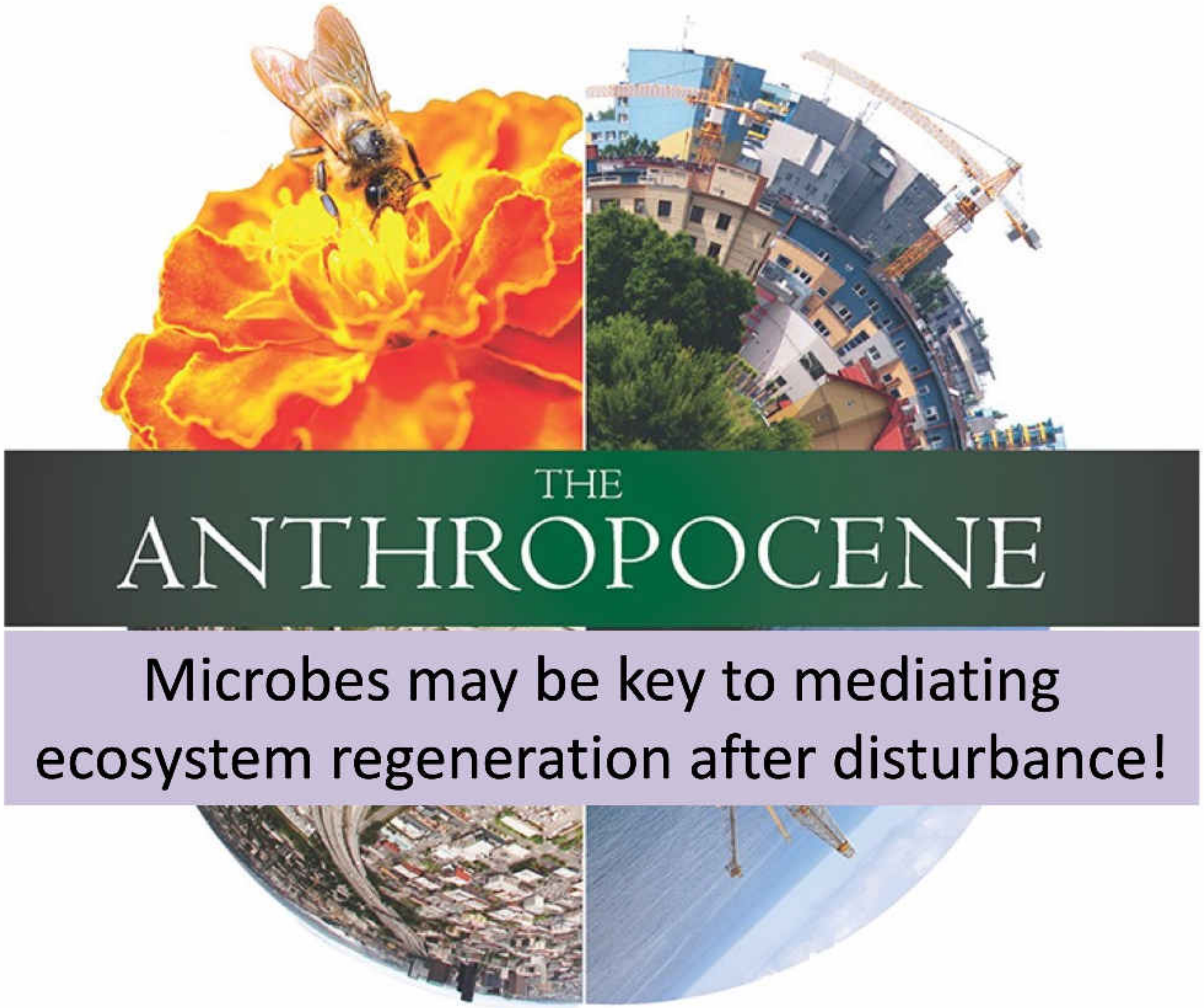

UCONN
Prescribed Fires and Post-Fire Microbial Inoculation
in American Chestnut Regeneration and Soil Nutrient Cycling
Placzek, Z.F.1, Goyes P.2,3, Resto J.M.1, Kaewplung, A.2, Maltz M.R.2
Background
Study System
Methods
Discussions and Conclusions
Results
Research Questions and Hypotheses
Future Directions
Acknowledgements

Fungal richness varied following prescribed burns vs. wildfires

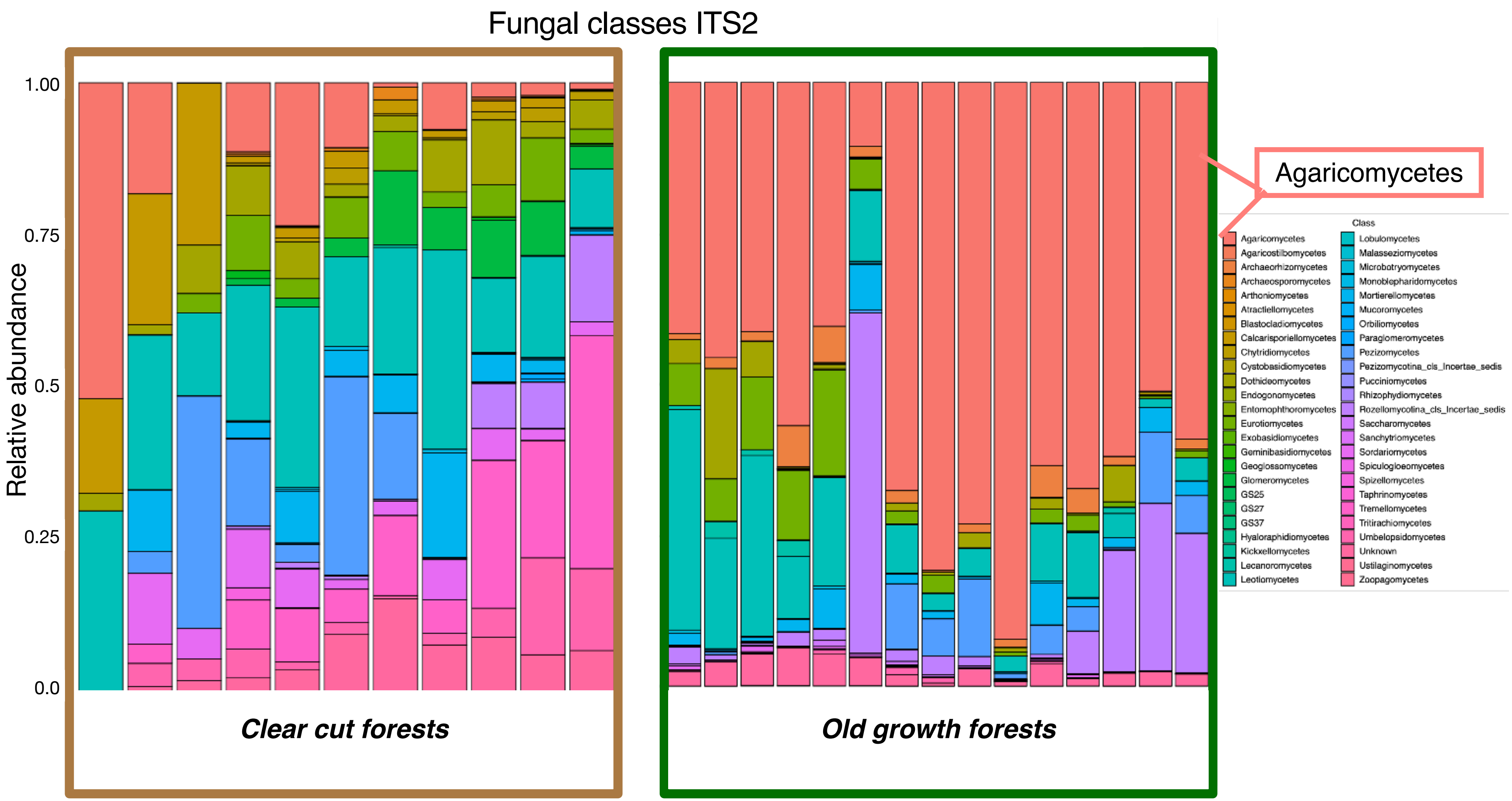
Inoculation may affect ecosystem functioning in unexpected ways

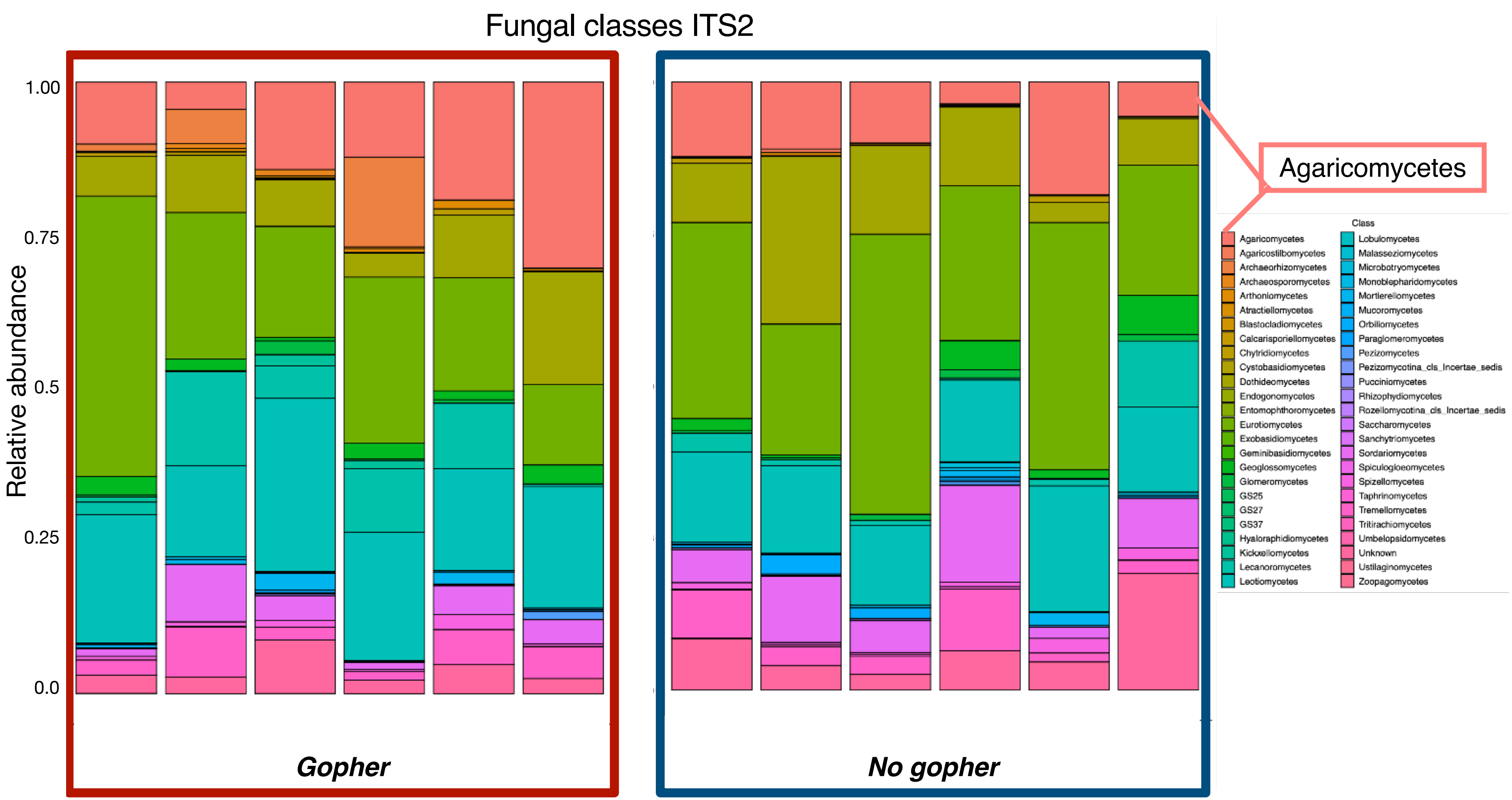


Dove & Hart,
Fire Ecology (2017)


THE ANTHROPOCENE
Microbes may be key to mediating ecosystem regeneration after disturbance!

Thank you!


Fungal classes ITS2
Relative abundance
1.00
0.75
0.5
0.25
0.0
Clear cut forests
Old growth forests
Agaricomycetes
Class
Agaricomycetes
Agaricostilbomycetes
Archaeorhizomycetes
Archaeosporomycetes
Arthoniomycetes
Atractiellomycetes
Blastocladiomycetes
Calcarisporiellomycetes
Chytridiomycetes
Cystobasidiomycetes
Dothideomycetes
Endogonomycetes
Entomophthoromycetes
Eurotiomycetes
Exobasidiomycetes
Geminibasidiomycetes
Geoglossomycetes
Glomeromycetes
GS25
GS27
GS37
Hyaloraphidiomycetes
Kickxellomycetes
Lecanoromycetes
Leotiomycetes
Lobulomycetes
Malasseziomycetes
Microbotryomycetes
Monoblepharidomycetes
Mortierellomycetes
Mucoromycetes
Orbiliomycetes
Paraglomeromycetes
Pezizomycetes
Pezizomycotina_cls_Incertae_sedis
Pucciniomycetes
Rhizophydiomycetes
Rozellomycotina_cls_Incertae_sedis
Saccharomycetes
Sanchytriomycetes
Sordariomycetes
Spiculogloeomycetes
Spizellomycetes
Taphrinomycetes
Tremellomycetes
Tritirachiomycetes
Umbelopsidomycetes
Unknown
Ustilaginomycetes
Zoopagomycetes



Fungal classes ITS2
Relative abundance
1.00
0.75
0.5
0.25
0.0
Gopher
No gopher
Agaricomycetes
Class
Agaricomycetes
Agaricostilbomycetes
Archaeorhizomycetes
Archaeosporomycetes
Arthoniomycetes
Atractiellomycetes
Blastocladiomycetes
Calcarisporiellomycetes
Chytridiomycetes
Cystobasidiomycetes
Dothideomycetes
Endogonomycetes
Entomophthoromycetes
Eurotiomycetes
Exobasidiomycetes
Geminibasidiomycetes
Geoglossomycetes
Glomeromycetes
GS25
GS27
GS37
Hyaloraphidiomycetes
Kickxellomycetes
Lecanoromycetes
Leotiomycetes
Lobulomycetes
Malasseziomycetes
Microbotryomycetes
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Pezizomycotina_cls_Incertae_sedis
Pucciniomycetes
Rhizophydiomycetes
Rozellomycotina_cls_Incertae_sedis
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Sordariomycetes
Spiculogloeomycetes
Spizellomycetes
Taphrinomycetes
Tremellomycetes
Tritirachiomycetes
Umbelopsidomycetes
Unknown
Ustilaginomycetes
Zoopagomycetes