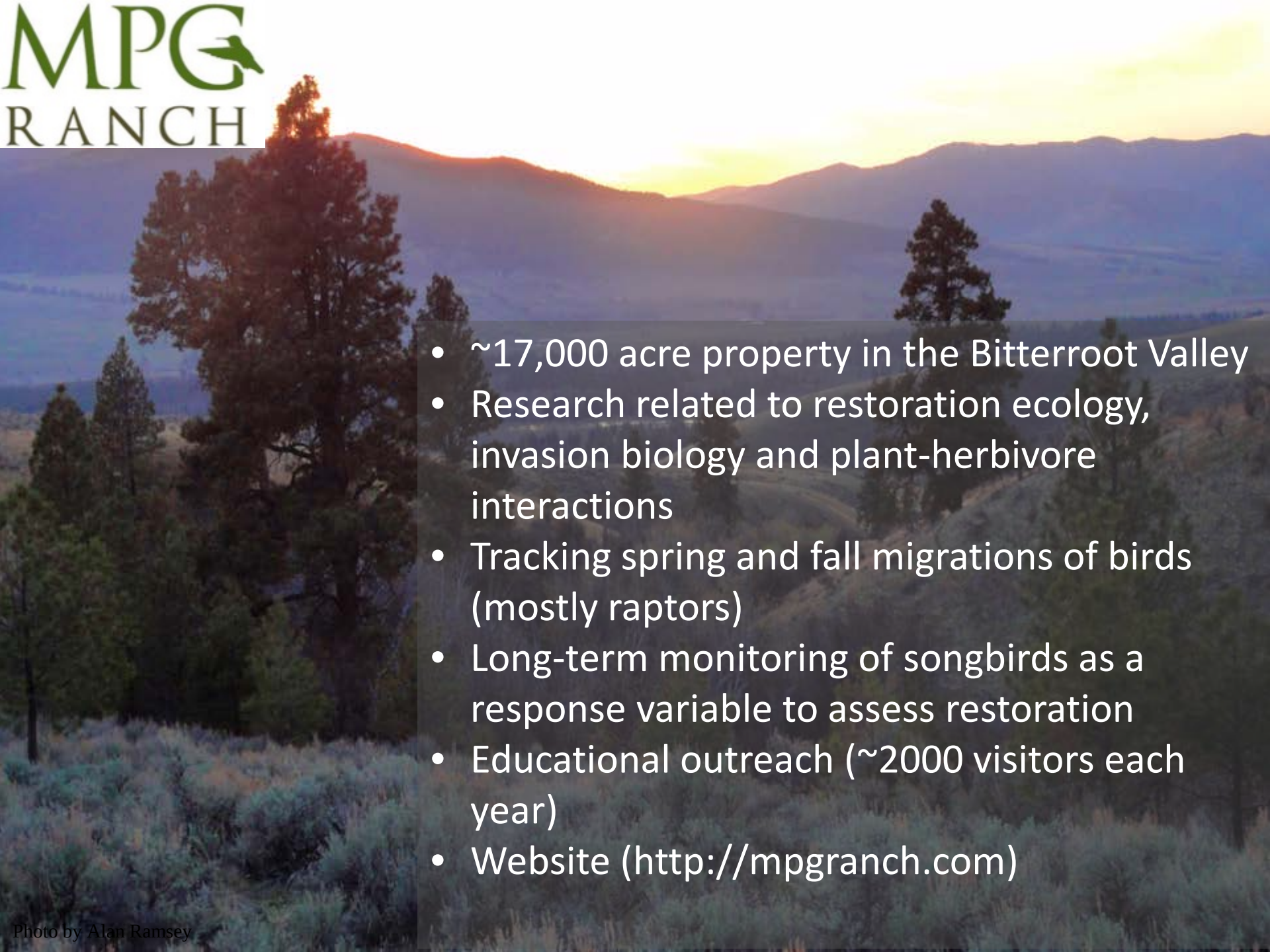
Invader impacts on soil ecosystems– what every restoration practitioner should know


Photo: Sue Brown


Photo : Dean Pearson

Ylva Lekberg
(ylekberg@mpgranch.com)



MPG RANCH

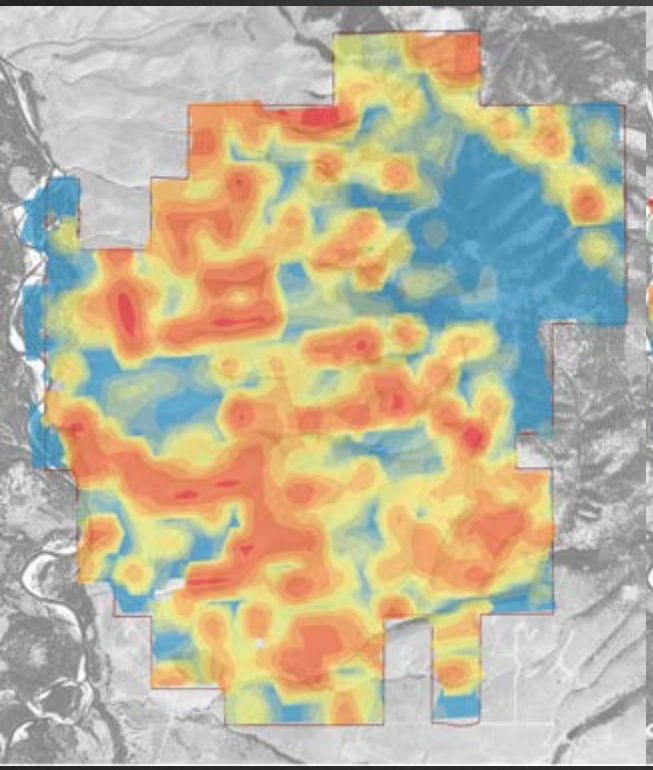
- ~17,000 acre property in the Bitterroot Valley
- Research related to restoration ecology, invasion biology and plant-herbivore interactions
- Tracking spring and fall migrations of birds (mostly raptors)
- Long-term monitoring of songbirds as a response variable to assess restoration
- Educational outreach (~2000 visitors each year)
- Website (http://mpgranch.com)

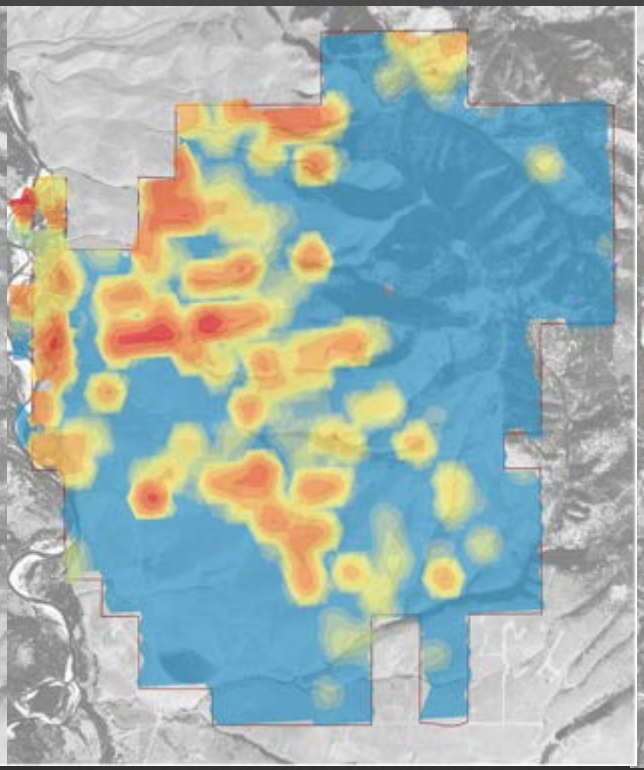
Photo by Alan Ramsey

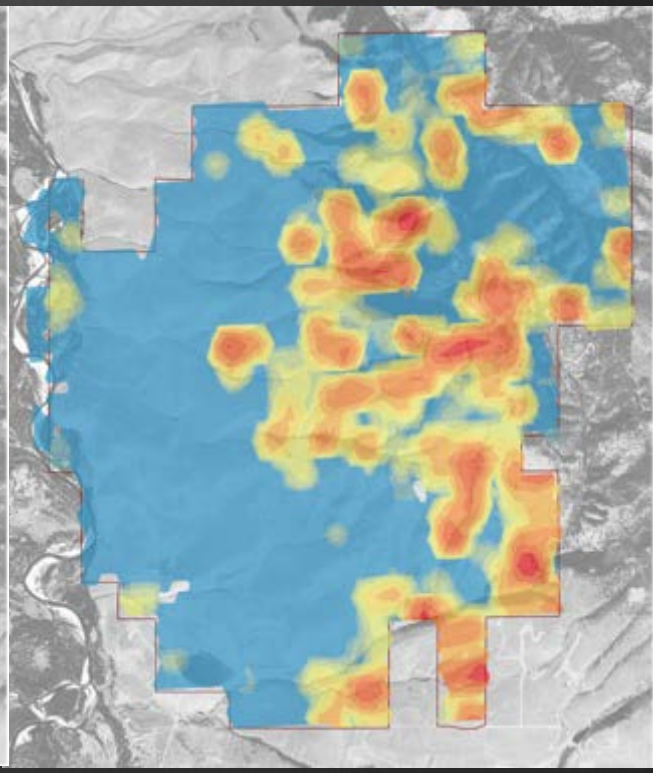
Cheatgrass (*Bromus tectorum*)

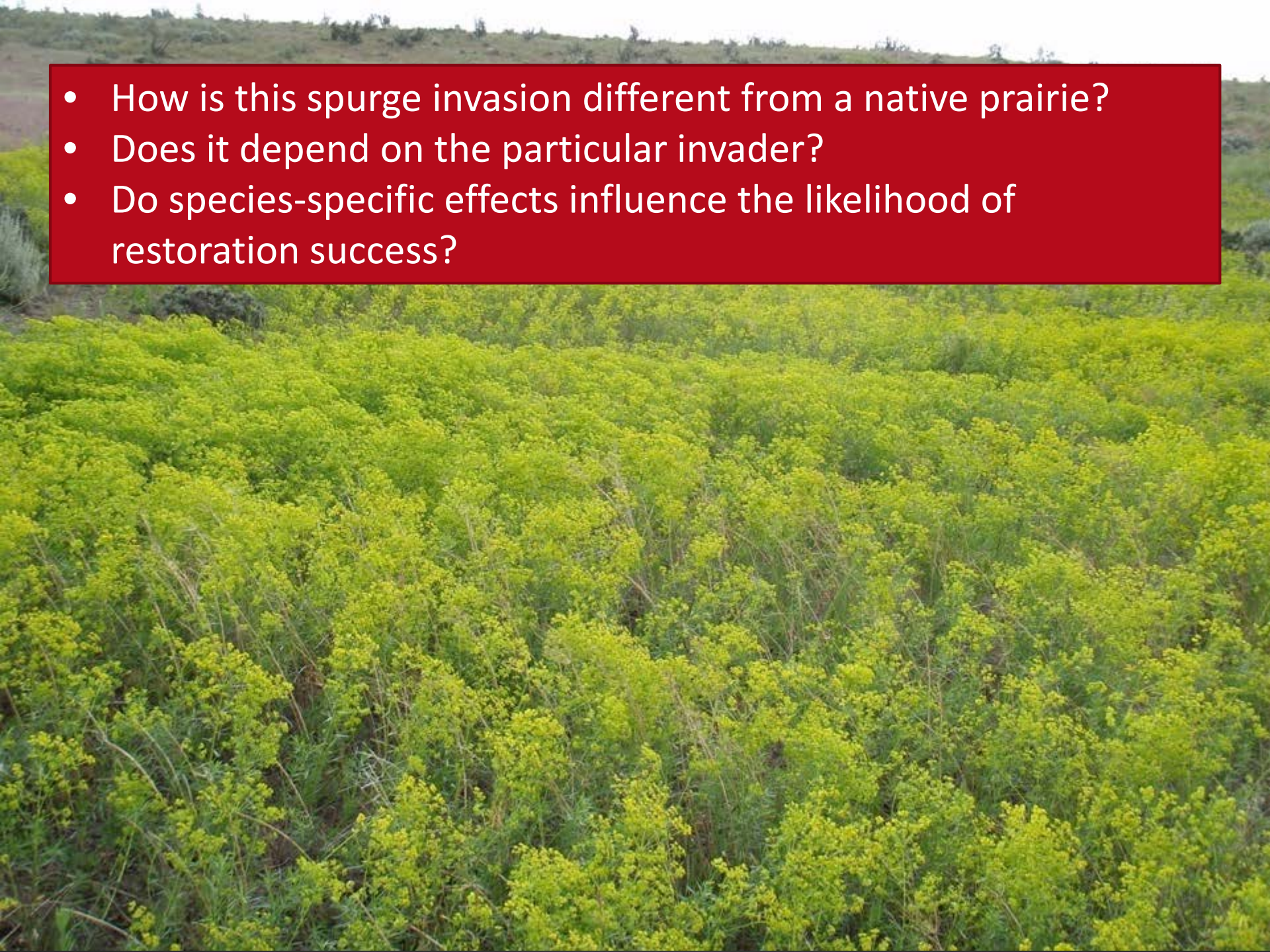
Spurge (*Euphorbia esula*)

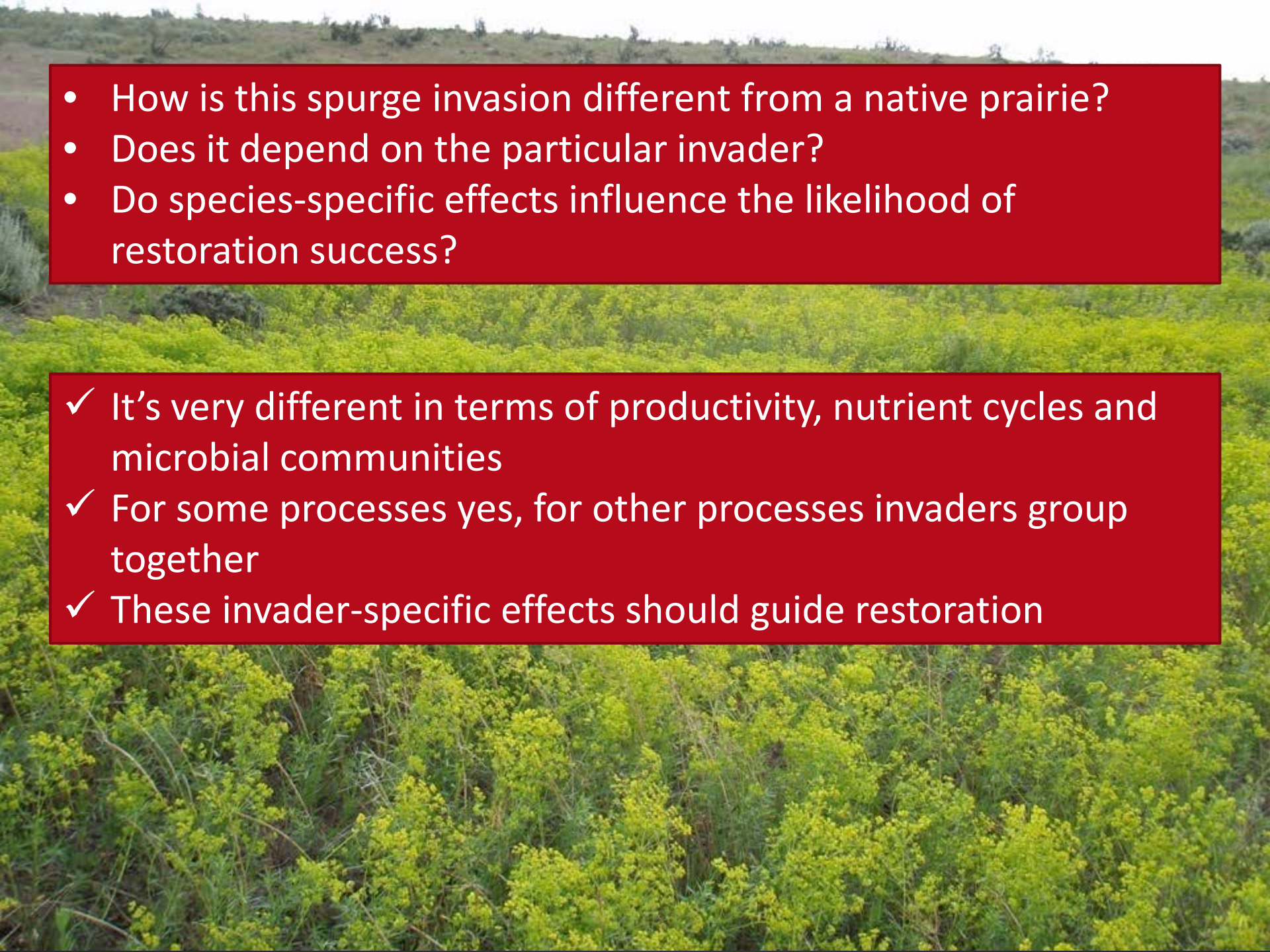
Knapweed (*Centaurea stoebe*)








• How is this spurge invasion different from a native prairie?
• Does it depend on the particular invader?
• Do species-specific effects influence the likelihood of restoration success?

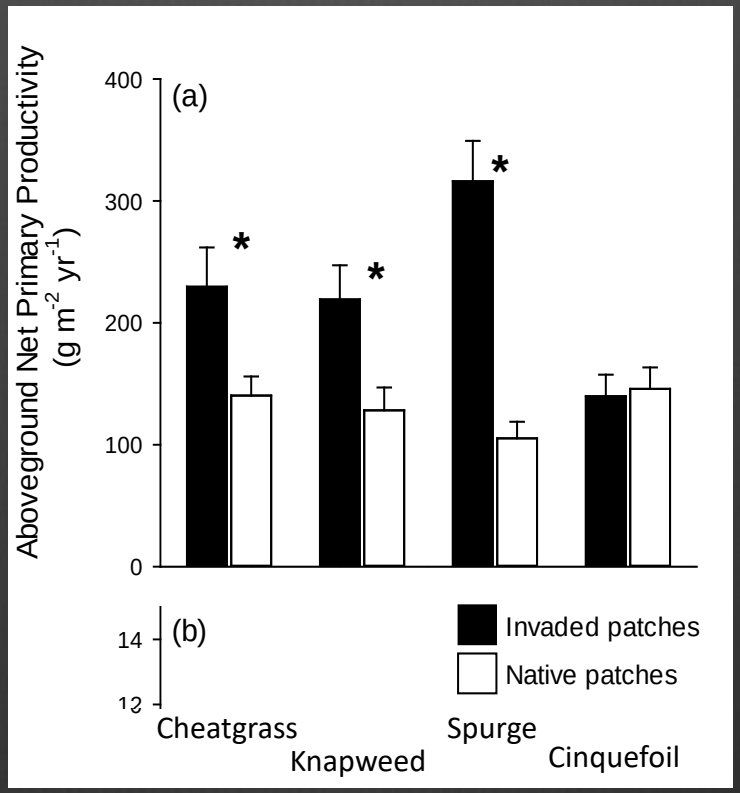


- How is this spurge invasion different from a native prairie?
- Does it depend on the particular invader?
- Do species-specific effects influence the likelihood of restoration success?

- ✓ It’s very different in terms of productivity, nutrient cycles and microbial communities
- ✓ For some processes yes, for other processes invaders group together
- ✓ These invader-specific effects should guide restoration

How do these evolutionary naïve exotics outperform locally adapted native species?

- Summaries of invasion studies show that productivity can double with invasions globally (Liao et al. 2008, Vila et al. 2011)



McLeod *et al.*, J Ecol. 2016

Morgan McLeod

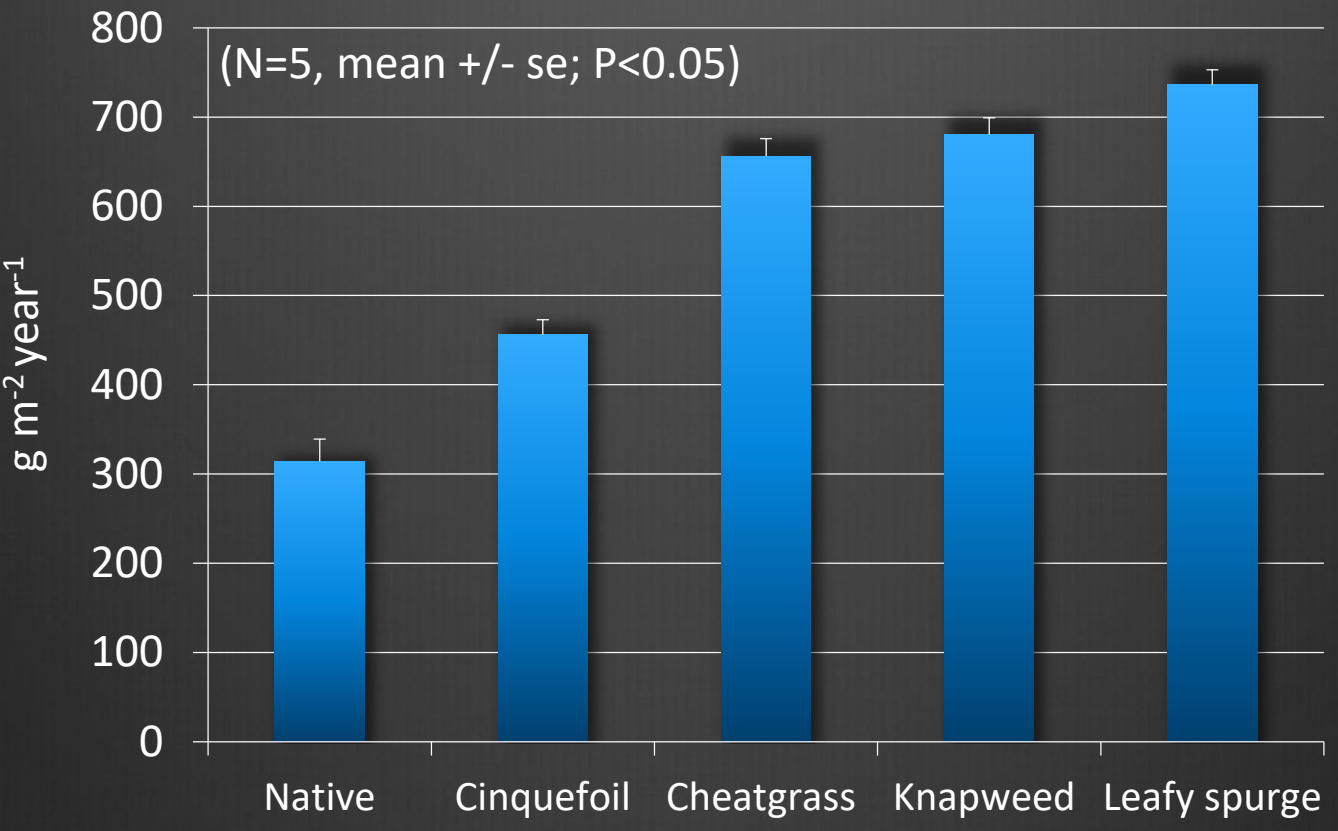
Common gardens at MPG Ranch

Kelly LaFlamme

Morgan McLeod

Photo credit: Alan Ramsey

Invasive plants produce more biomass in common gardens

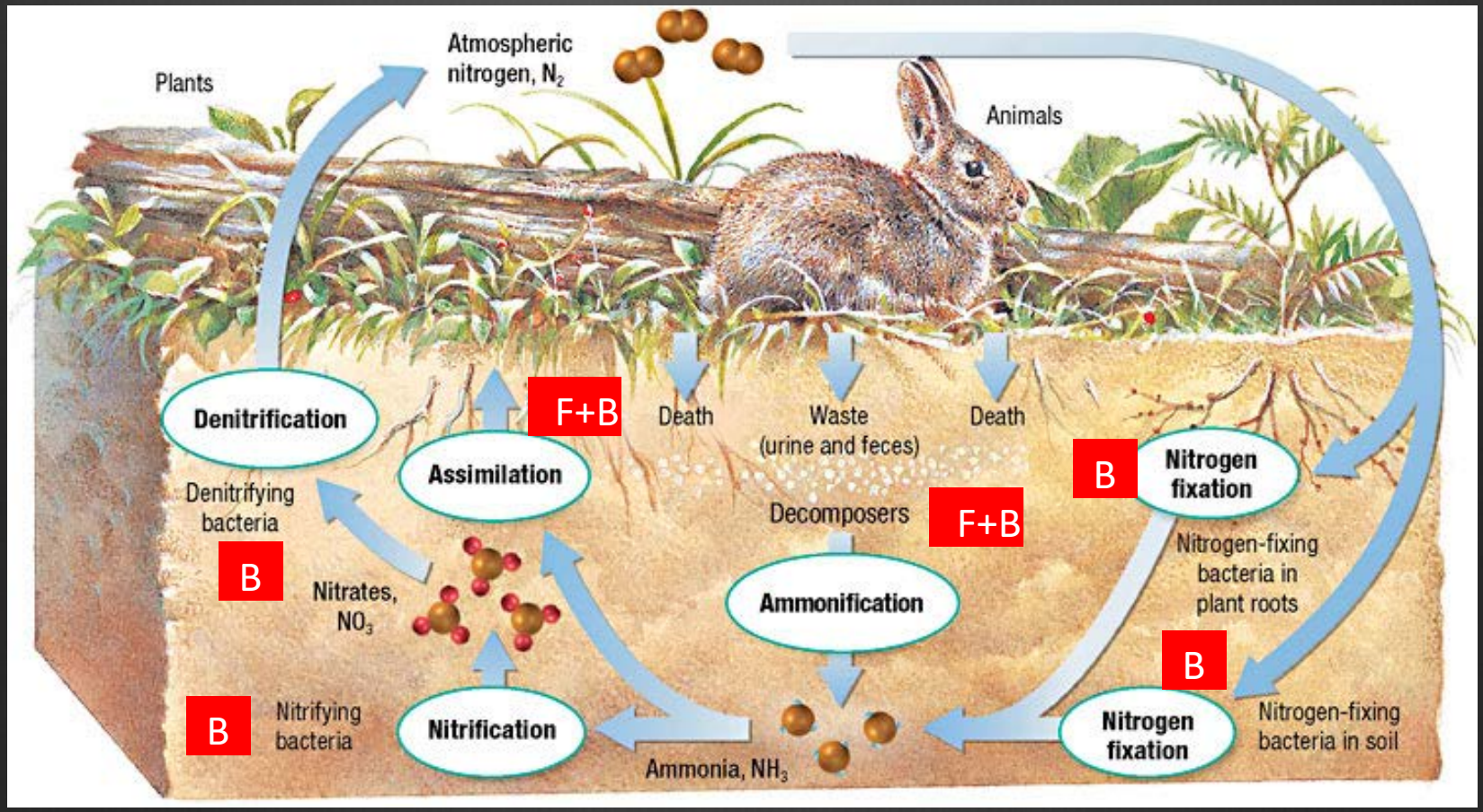


What's the potential role of soil microbes?

1 tsp of soil can contain:

- One billion bacteria
- Several yards of fungal filaments
- Thousands of protozoa
- 10-100 nematodes

Bacteria and fungi are involved in many nutrient transformations in soils

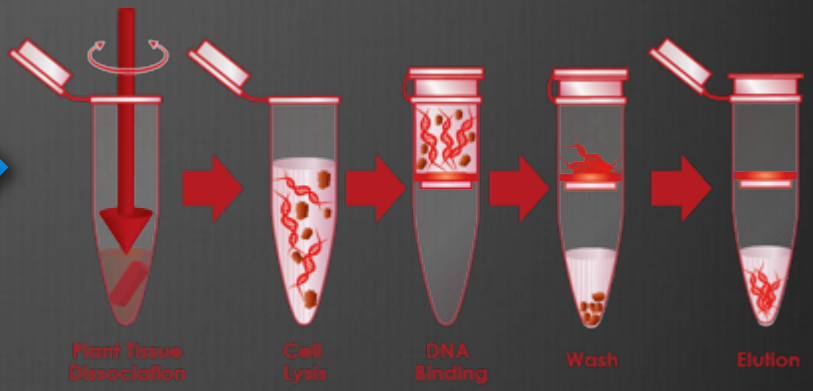


How do we characterize microbes?

Brief method for community assessments

1. Take root or soil samples

2. Extract and amplify selected DNA (fungi/bacteria)



3. Sequence DNA using NGS

4. Match with curated databases

Contents lists available at ScienceDirect

Fungal Ecology

journal homepage: www.elsevier.com/locate/funeco

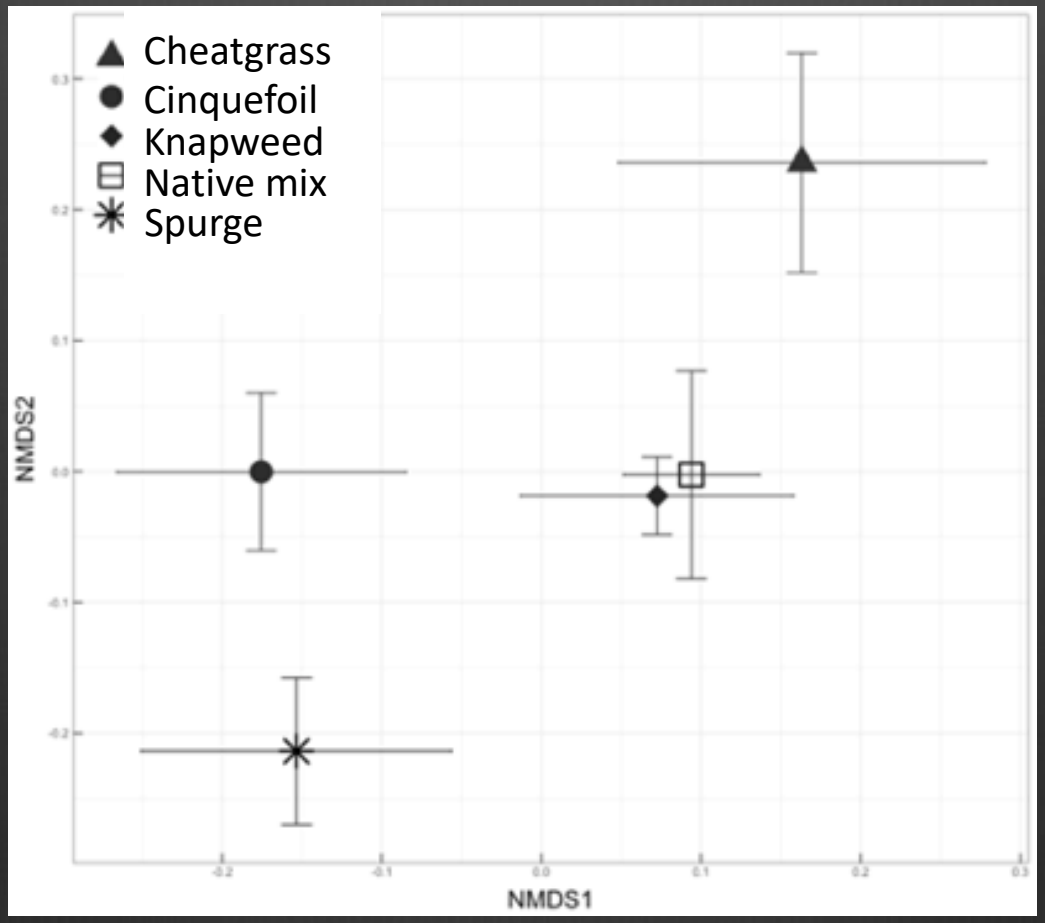
ELSEVIER

FUNGuild: An open annotation tool for parsing fungal community datasets by ecological guild

Nhu H. Nguyen [a,*], Zewei Song [b], Scott T. Bates [b], Sara Branco [c], Leho Tedersoo [d], Jon Menke [e], Jonathan S. Schilling [a], Peter G. Kennedy [a,f]

Invaders change bacterial communities in common gardens

Lorinda Bullington

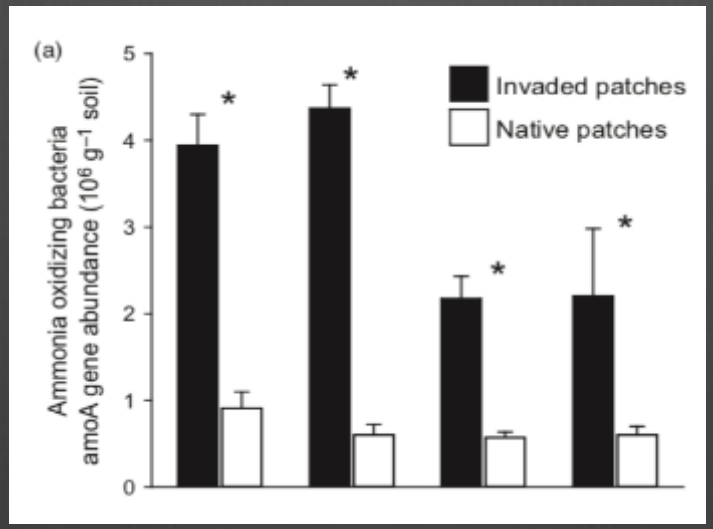


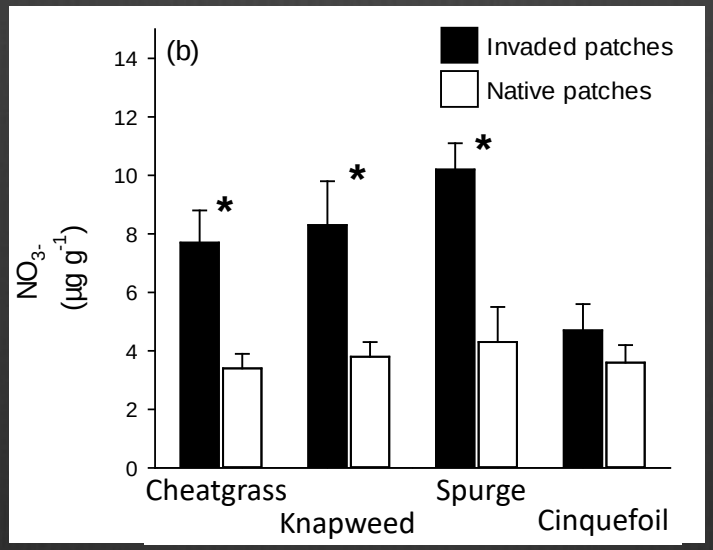
McLeod et al. in review.

Exotics promote bacteria and change soil nutrient cycles

Ammonia oxidizing bacteria

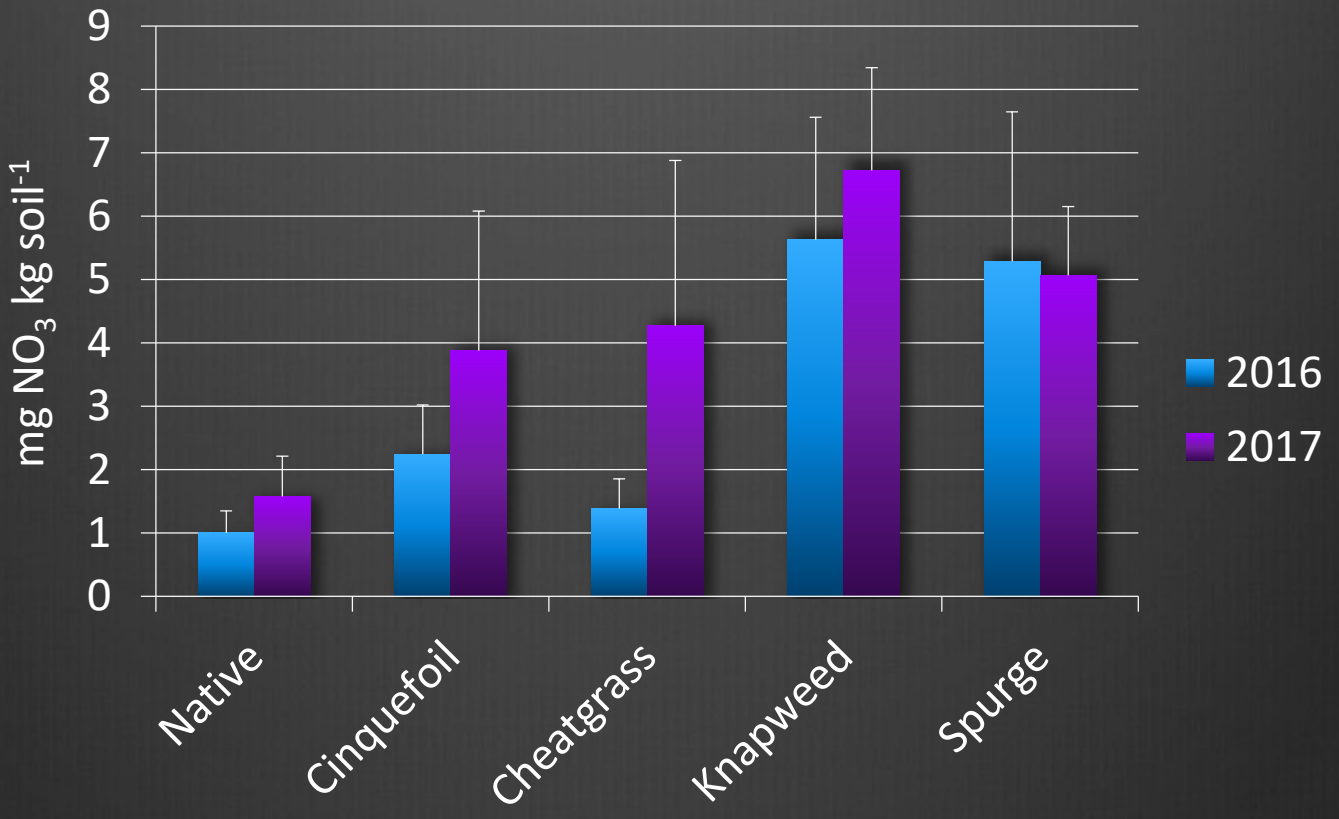
$NH_4^+ \rightarrow NO_3^-$





McLeod *et al.*, J Ecol. 2016

Invaders can alter N-availabilities in common gardens

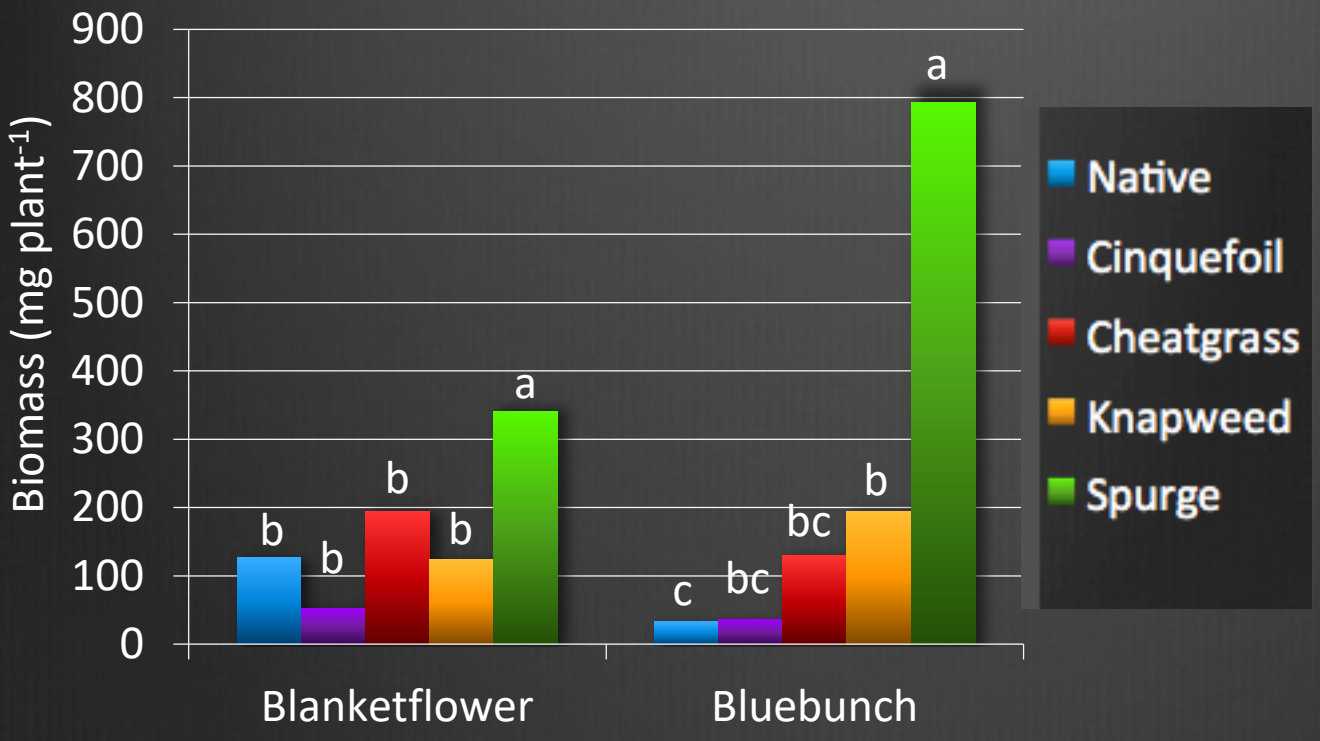


$P_{(Plant\ communities)}$ <0.10 both years

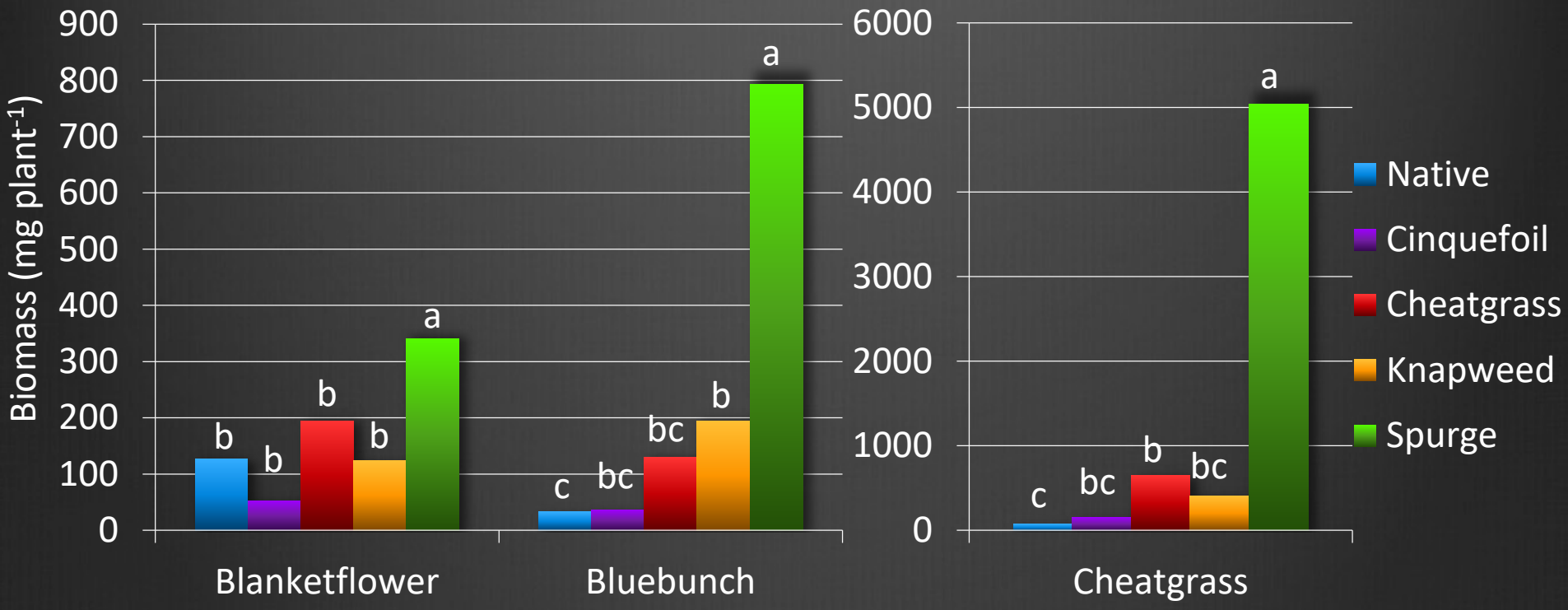
Soil legacy effects on subsequent growth

Leila Marsh

Biomass of natives differ depending on community



….but cheatgrass outgrows them all, which may help explain invasion meltdown....



Invaders can promote productivity by increasing N-availability. Shifts in bacterial communities likely involved

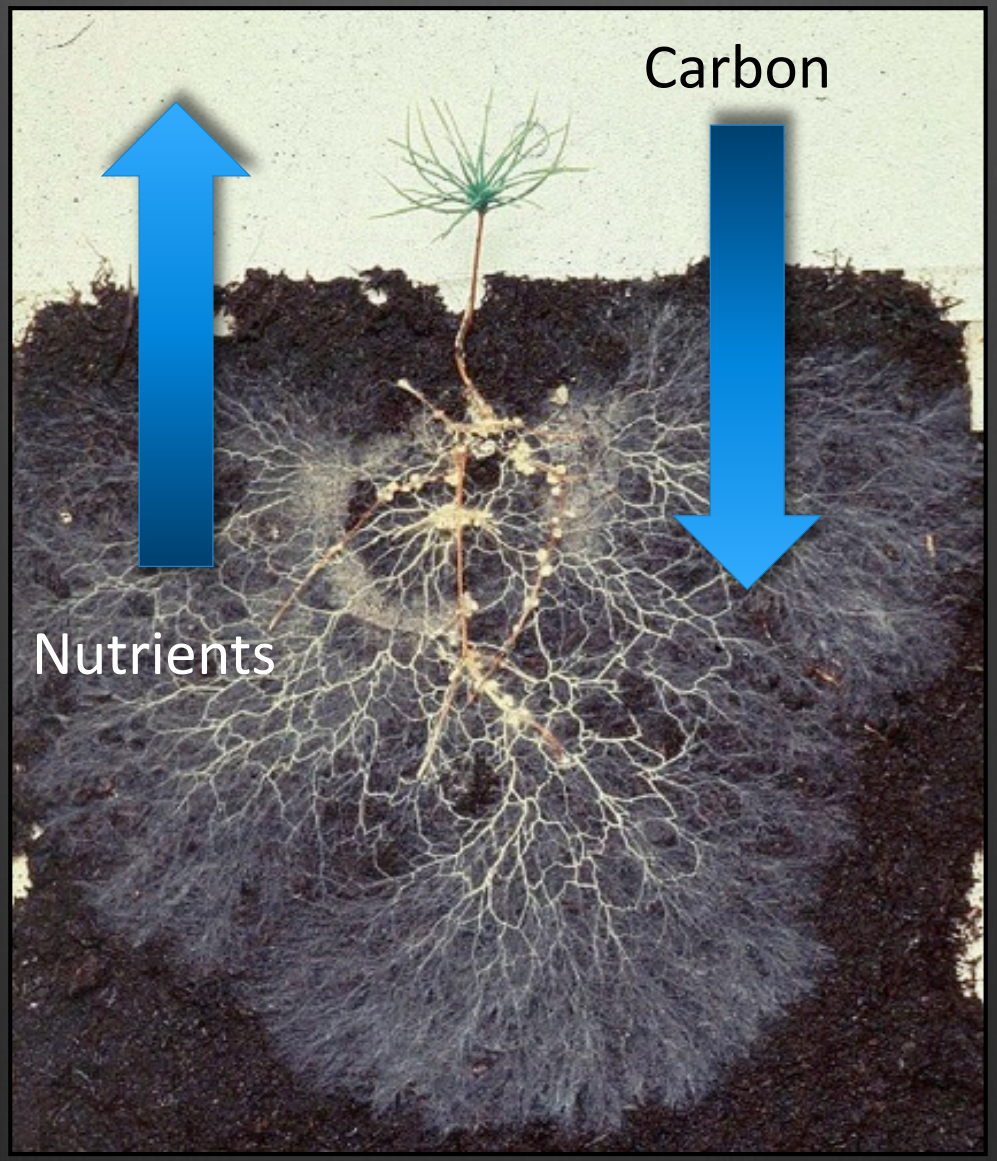
For restoration practitioners:

- Know that nutrient availabilities are likely higher compared to the native communities.
- Consider how this may influence restoration success vs. invasion meltdown (apply saw dust or something that binds the N if manageable size?).
- Unknown: How long does the legacy persist?

What about other soil biota?

Mycorrhizal fungi

Myco – rhiza = Fungus root



Arbuscular mycorrhizal fungi (AMF)

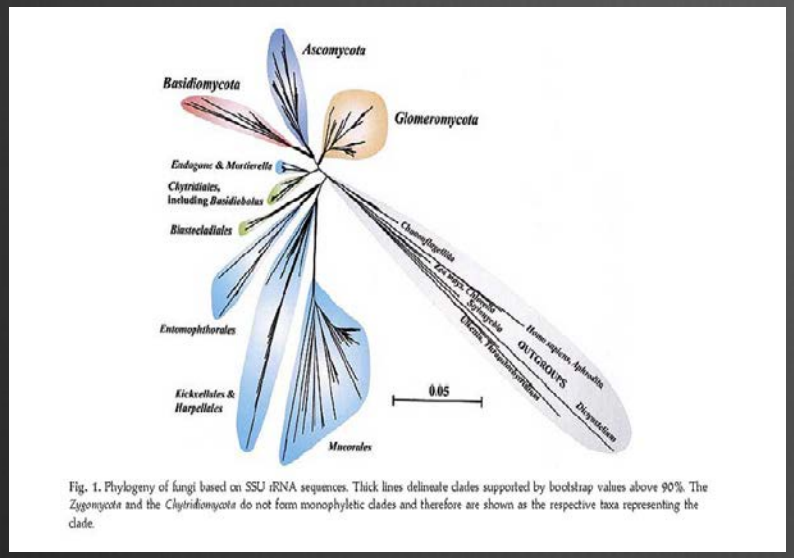
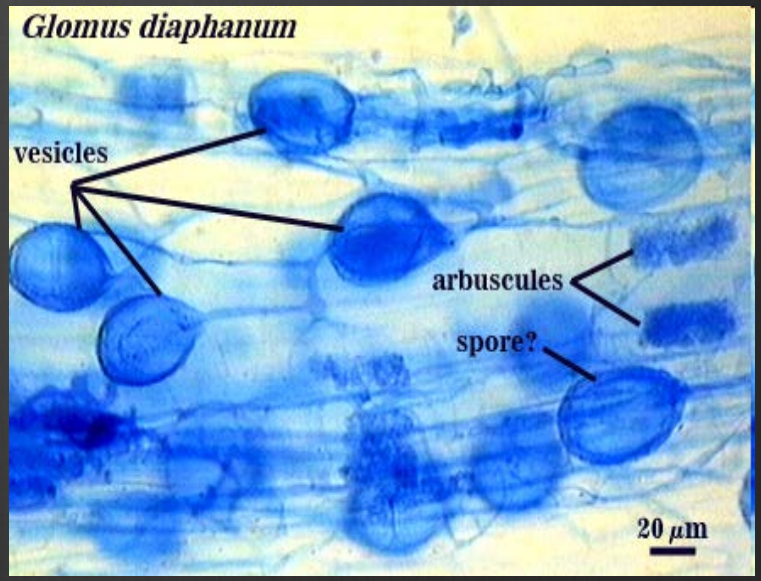


Fig. 1. Phylogeny of fungi based on SSU rRNA sequences. Thick lines delineate clades supported by bootstrap values above 90%. The *Zygomycota* and the *Chytridiomycota* do not form monophyletic clades and therefore are shown as the respective taxa representing the clade.

- AMF colonize 90% of all plant families
- “Plants don’t have roots, they have mycorrhizas”
- Fungi receive C from plant in exchange for nutrients and other services
- Due to the high abundance and location in the root-soil interface, AMF can influence ecosystem properties (carbon and nutrient cycling)



Mycorrhizal fungi can promote plant growth

-M +M

….improve soil structure

…. and drought tolerance

Fig. 2.2 Plant growth of trifoliate orange inoculated with *Diversispora versiformis* (AMF) under well-watered (WW) and drought stress (DS)

Enhanced mutualism hypothesis (Reinhart and Callaway, 2004)

- Mycorrhizal-mediated increased competitive ability of invader

Spotted knapweed (*Centaurea stoebe*)

Degraded mutualism hypothesis (Vogelsang et al., 2005)

- Decreased competitive ability of mycotrophic natives

Garlic mustard (*Allaria petiolata*)

Do invaders shift mycorrhizal fungal communities and are shifts invader-specific?

Søren Rosendahl

Sean Gibbons

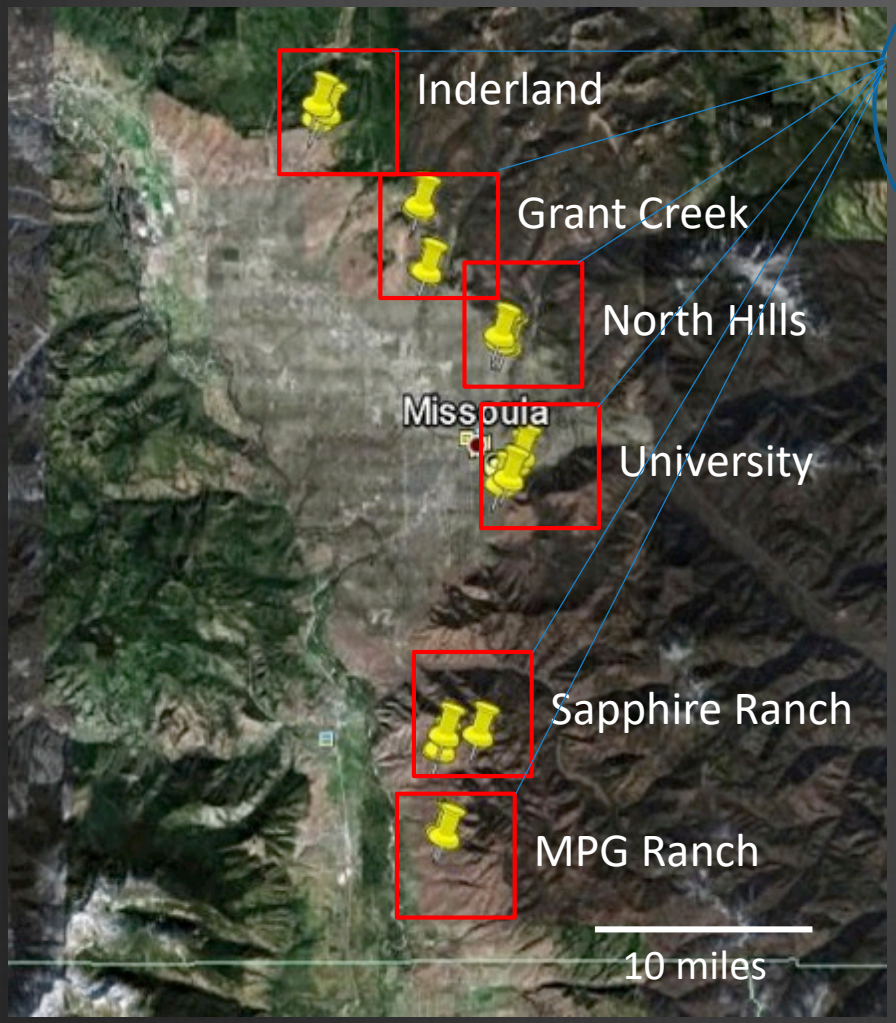
Philip Ramsey

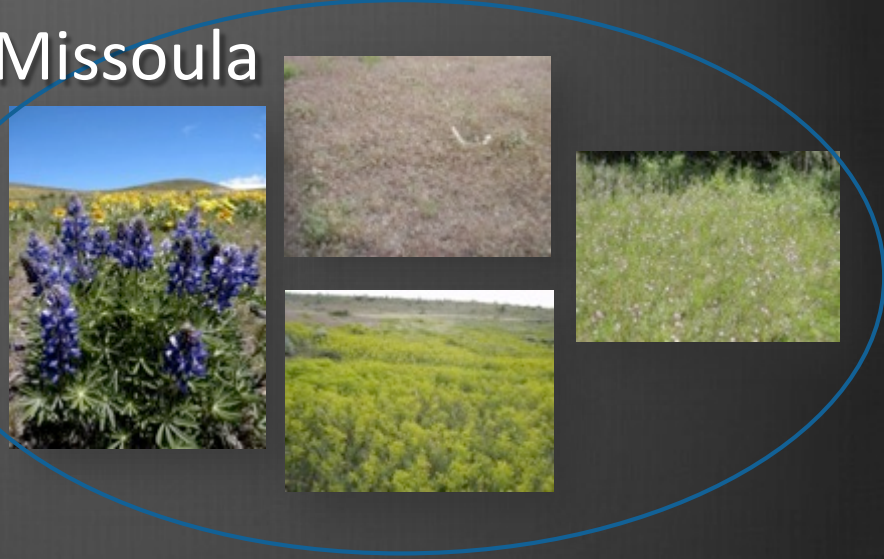
Cheatgrass (*Bromus tectorum*)

Leafy spurge

Knapweed

Survey of six locations around Missoula





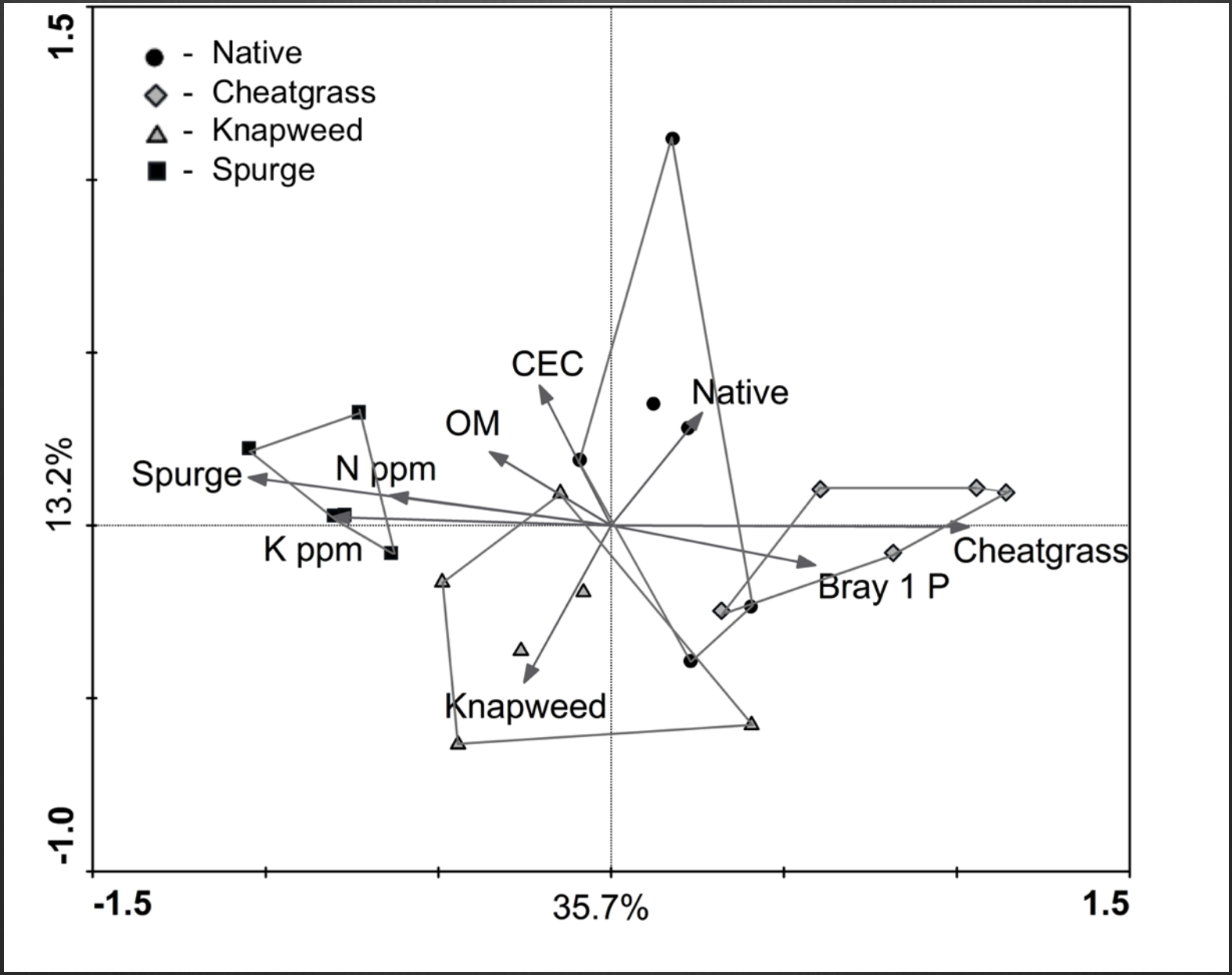
- Sampled roots from 6 locations per community
- Representative grasses and forbs collected from native communities
- AMF communities were characterized using molecular techniques

Fungal richness and diversity is higher with some invaders

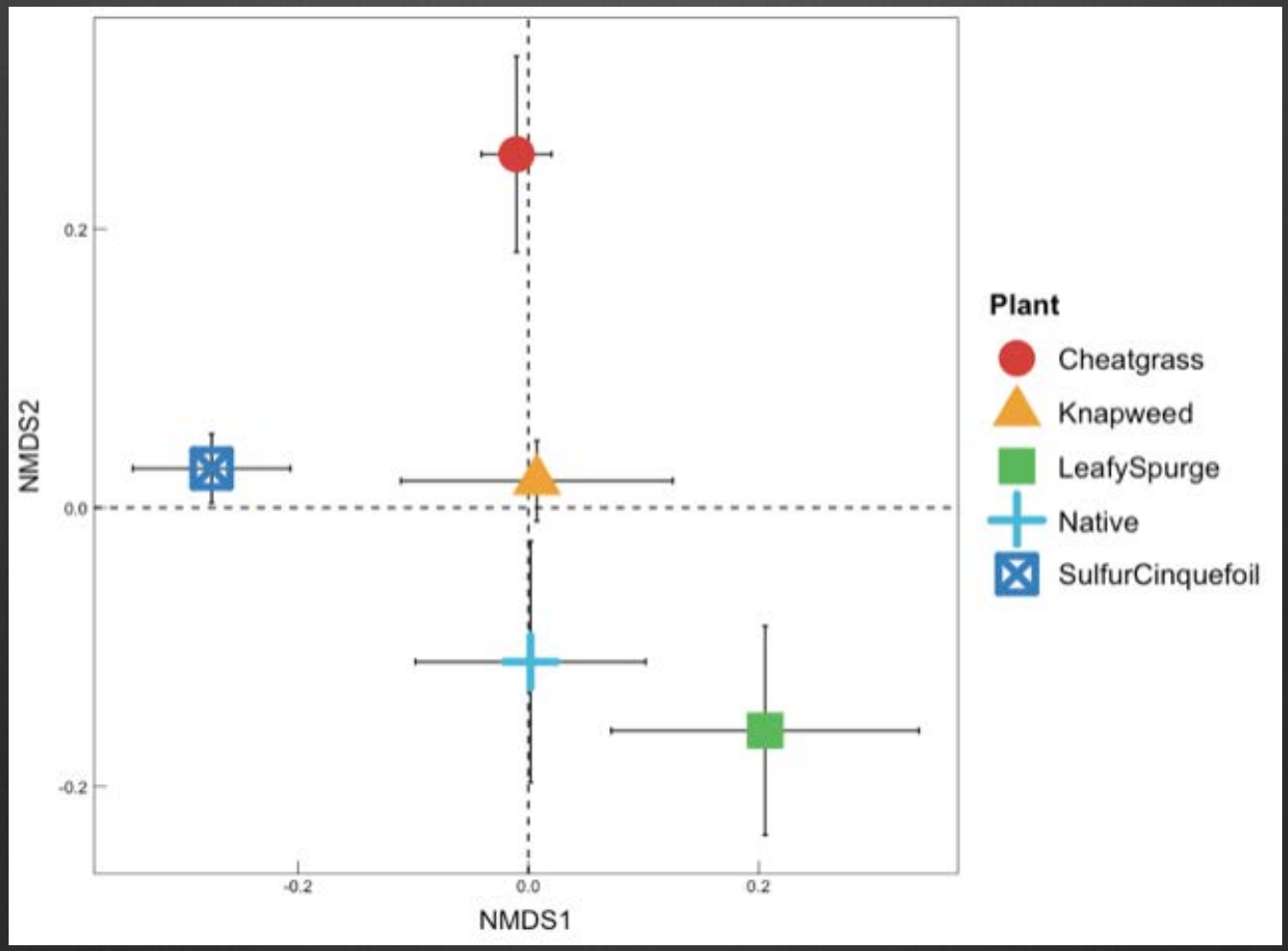
Plant community	n	AMF richness	Diversity (H)
Native mixed	6	13.0 (1.03)^{c}	1.85 (0.03)^{b}
Cheatgrass	5	14.6 (0.87)^{c}	1.49 (0.19)^{c}
Knapweed	6	24.2 (1.08)^{a}	2.27 (0.06)^{a}
Spurge	5	20.4 (1.47)^{b}	2.10 (0.10)^{ab}

Lekberg et al., ISME 2013

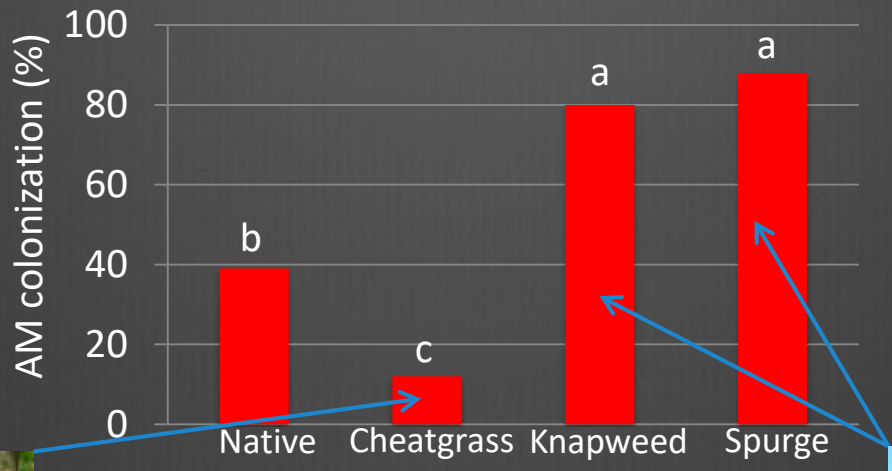
Community composition shifts and is invader-specific



Invaders cause these shifts

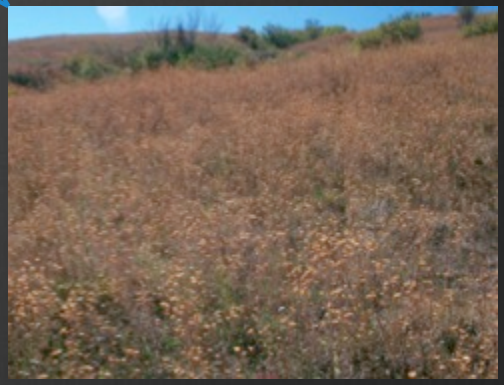


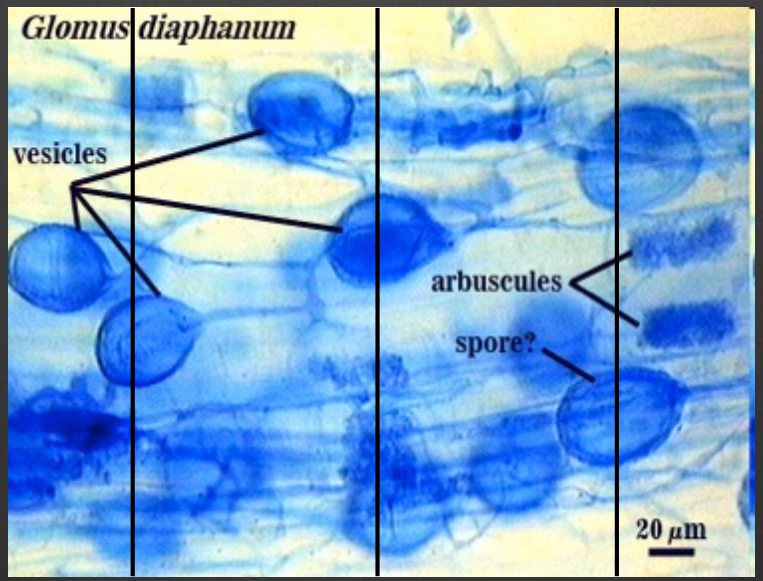
Consistent, and invader-specific shifts in fungal abundance

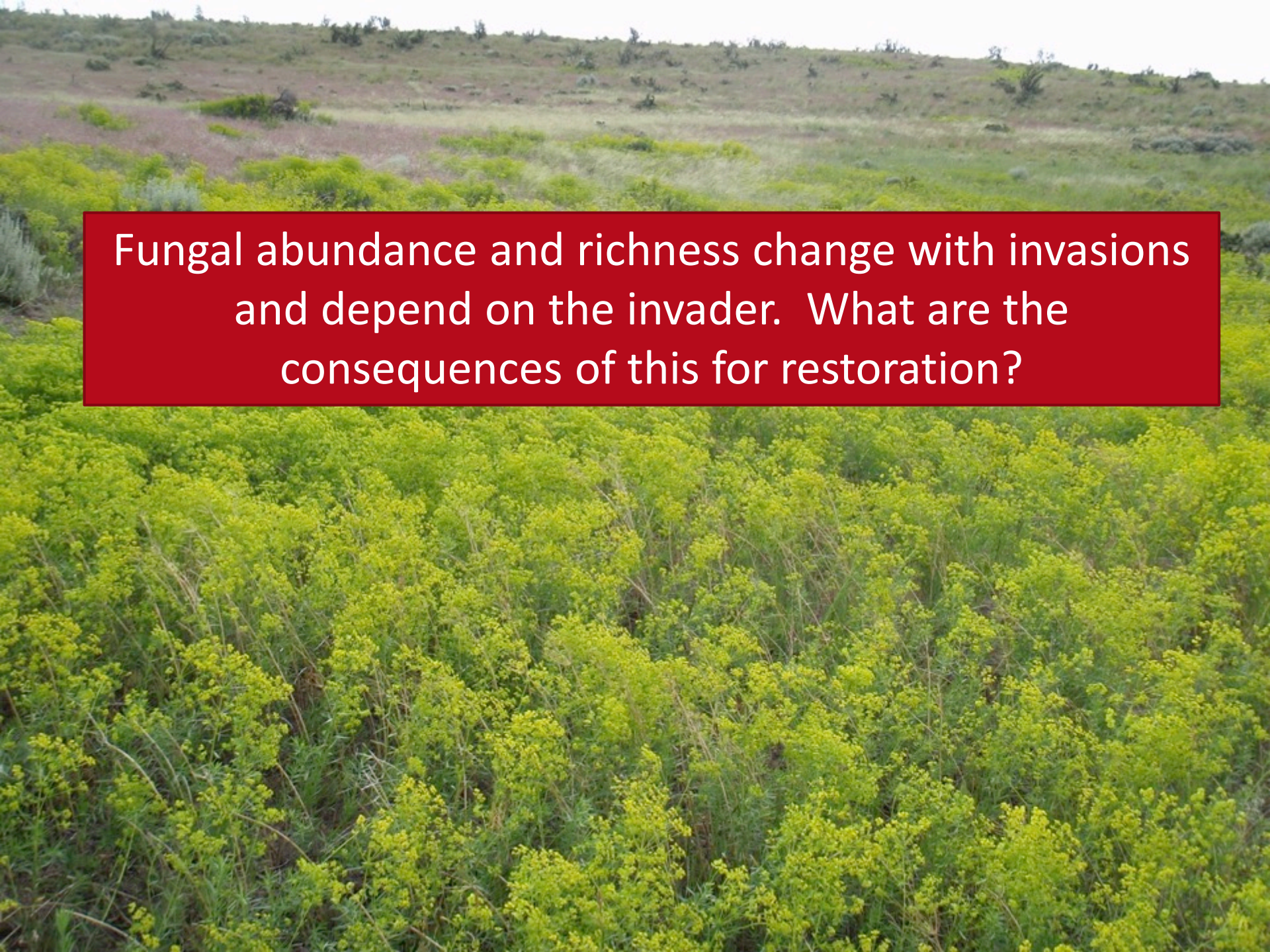


Degraded mutualism hypothesis

Enhanced mutualism hypothesis



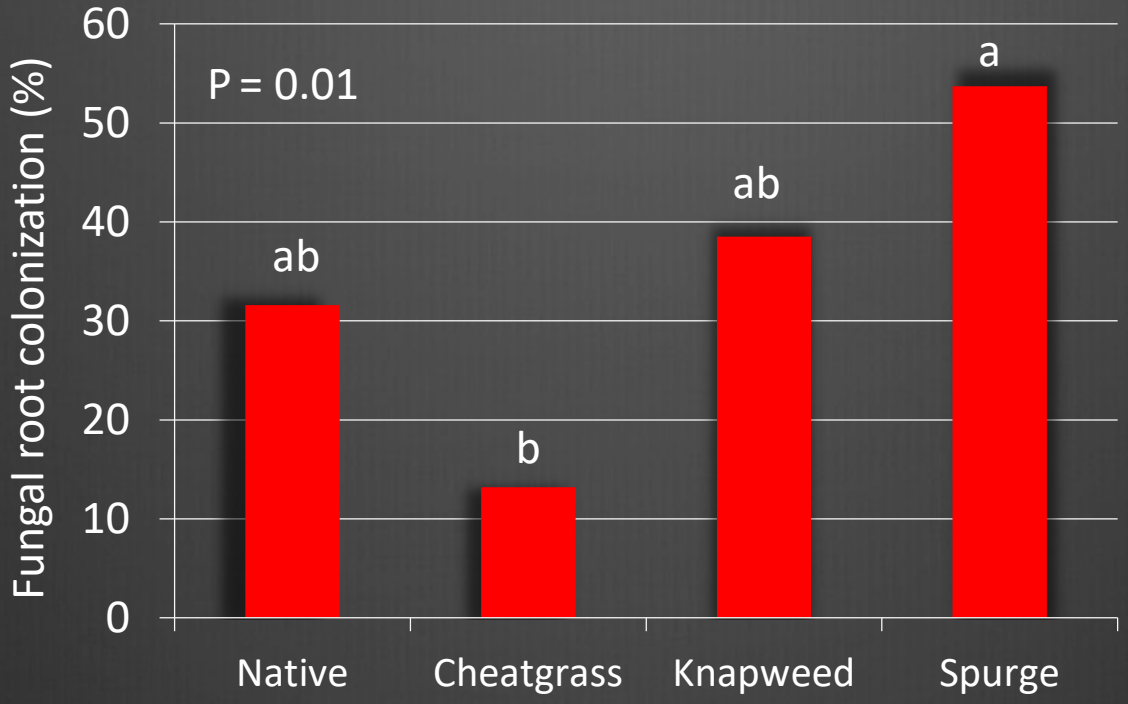



Fungal abundance and richness change with invasions and depend on the invader. What are the consequences of this for restoration?

Invasion legacies on fungal colonization on blanketflower

Blanket flower was planted in all communities to assess differences in fungal communities among plots

Root colonization follow the same pattern as abundances



- Shifts in AMF abundances caused by the invaders
- This translates to differences in AM colonization of native plant
- Could influence restoration of native communities
- How long does this legacy last?

Do you need to inoculate with mycorrhizal fungi?

Restoration Ecology
THE JOURNAL OF THE SOCIETY FOR ECOLOGICAL RESTORATION INTERNATIONAL

RESEARCH ARTICLE

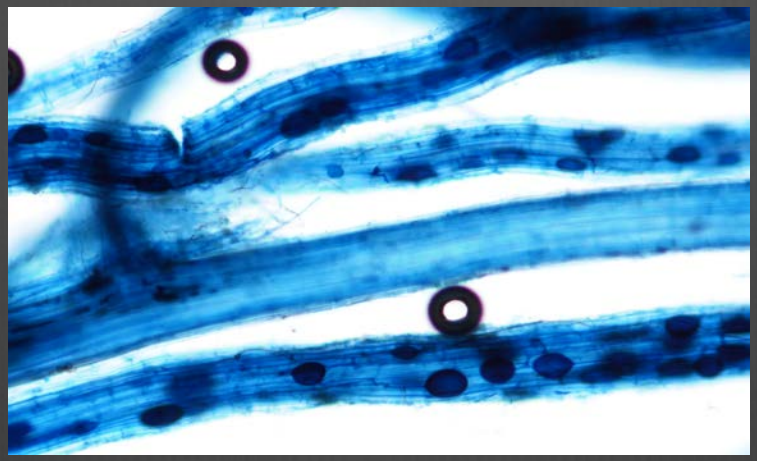
The Influence of Soil Inoculum and Nitrogen Availability on Restoration of High-Elevation Steppe Communities Invaded by *Bromus tectorum*

Helen I. Rowe,[1,2] Cynthia S. Brown,[3] and Mark W. Paschke[4]

- Should be the absolute last resort as it is expensive, may not work and introduce foreign fungi that are not locally adapted and may outcompete local fungi

Are mycorrhizal fungi there?

- Measure root colonization of existing roots (Milltown floodplain)



- Measure the activity in the soil (requires a greenhouse)

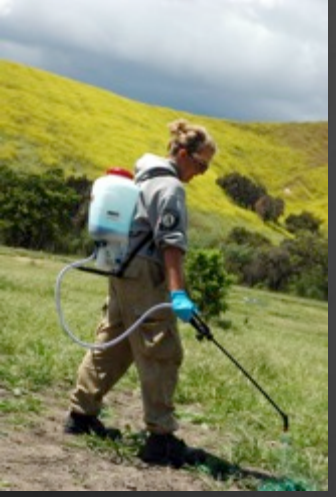
How can inoculations be done?

Dan Mummey

Chuck Casper

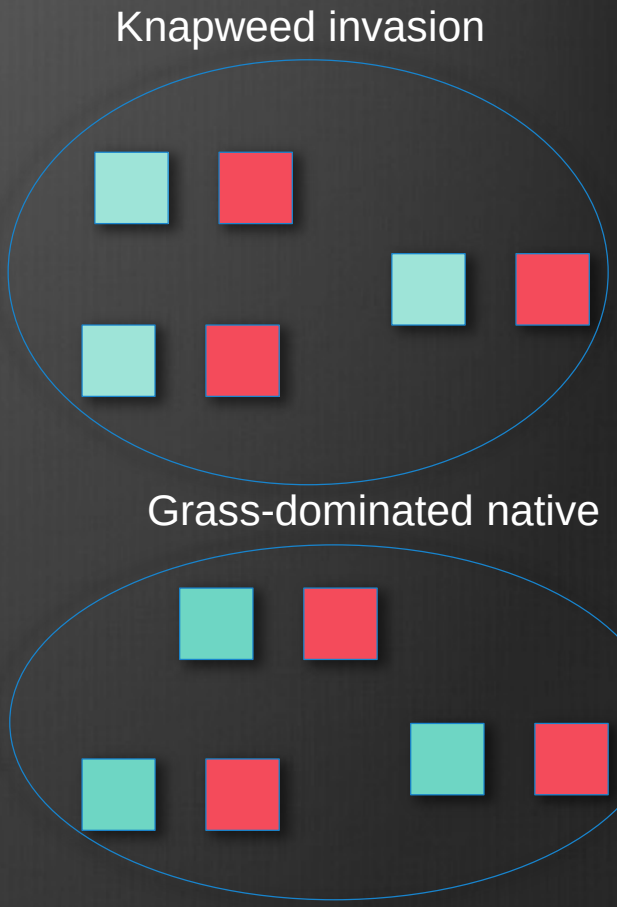
Sasha Victor

Contains seeds and mycorrhizal fungi

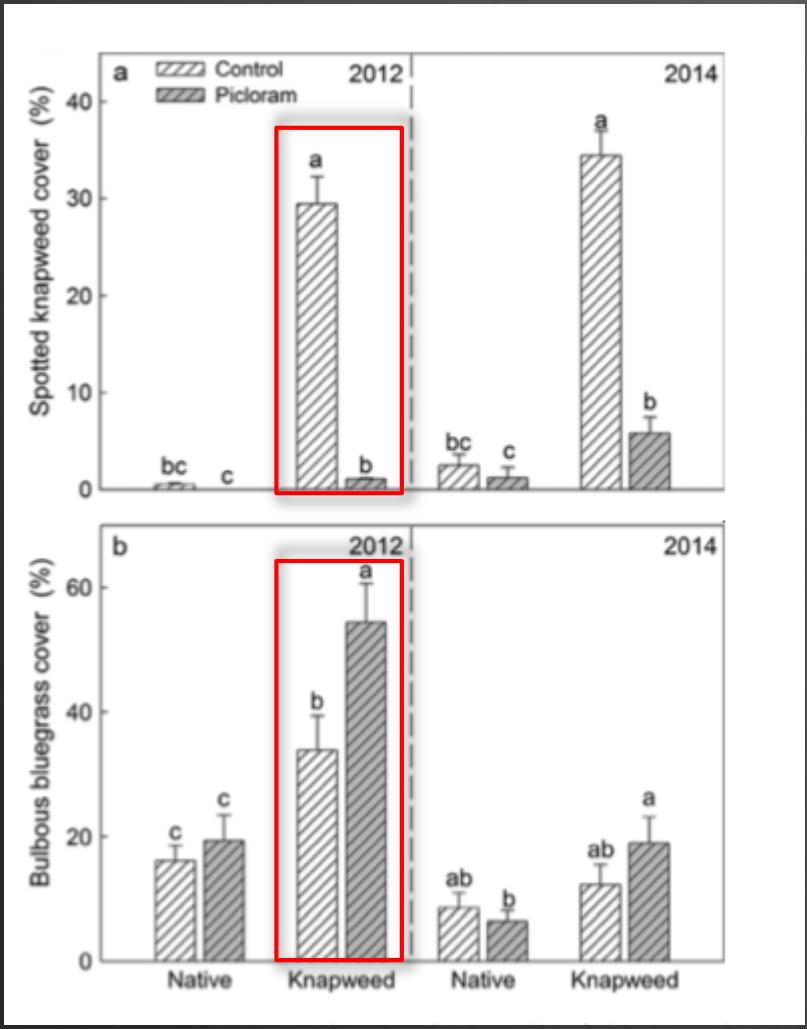


Direct and indirect effects of herbicides

- Direct effects evaluated from responses in grass communities
- Indirect effects evaluated from responses in knapweed communities



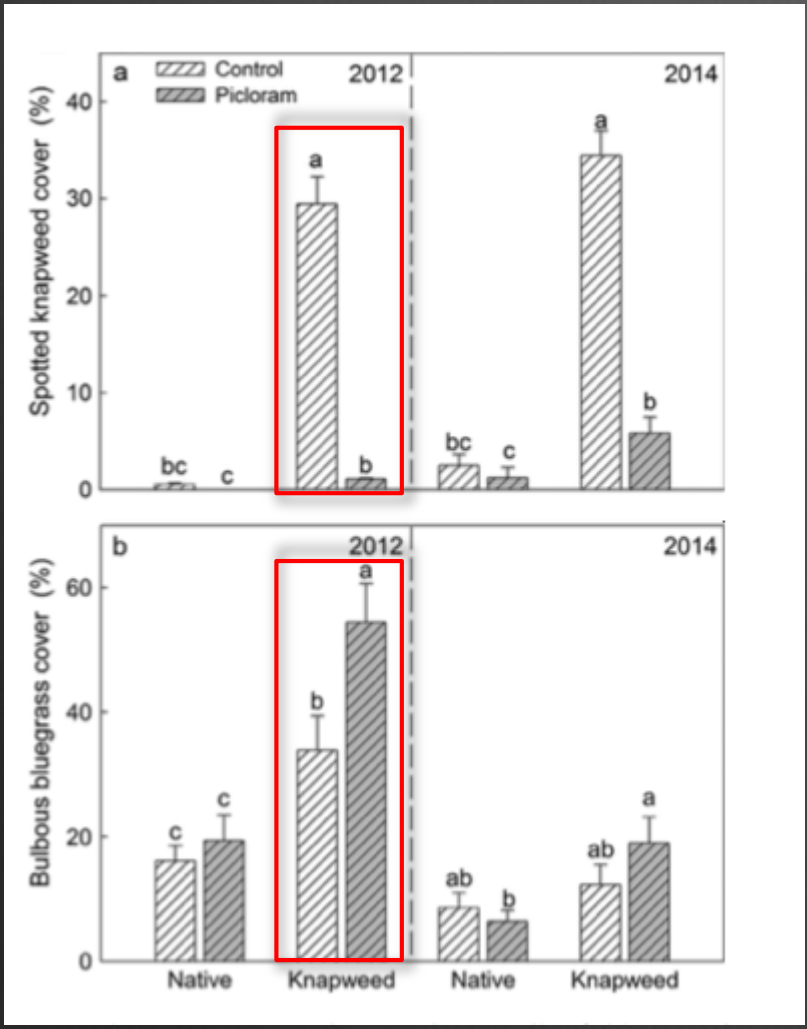
Picloram change the plant community composition

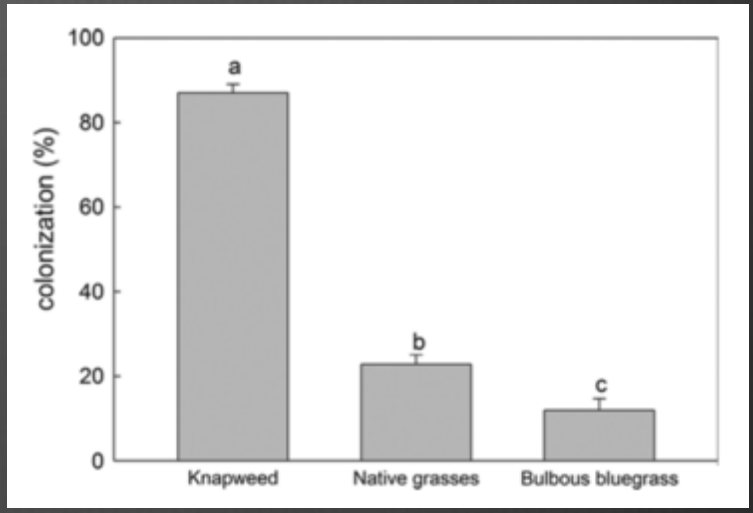


Knapweed is replaced by bulbous bluegrass (*Poa bulbosa*)

Lekberg et al. Ecological Appl. 2017.

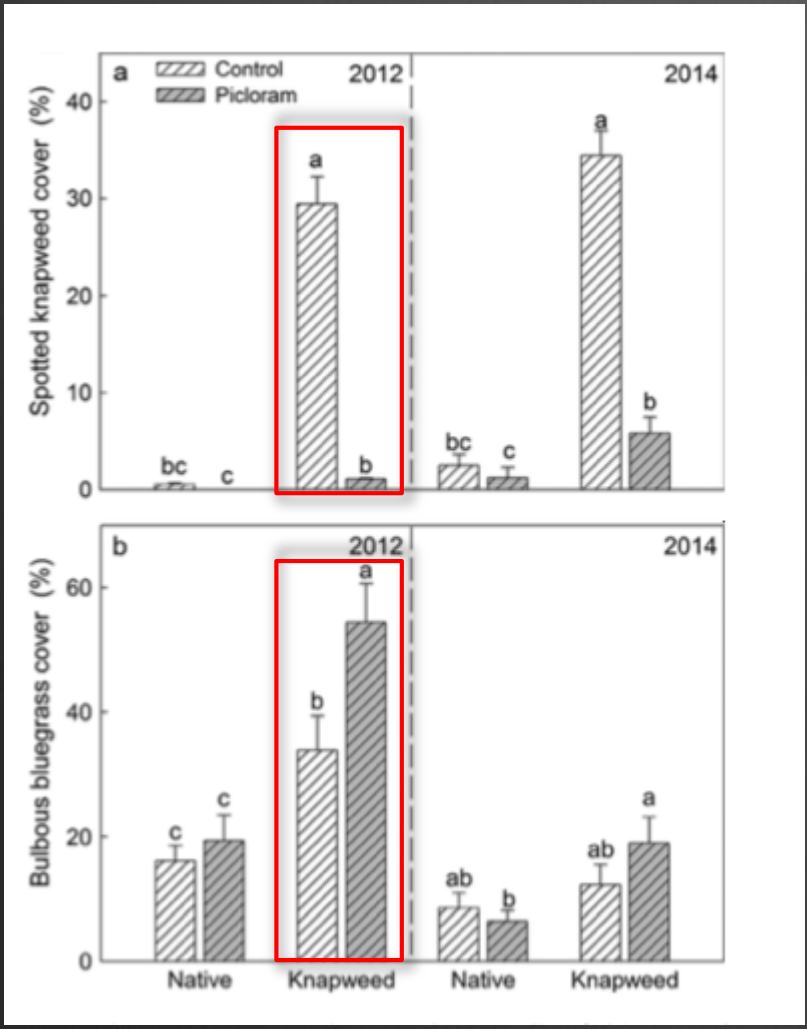
This reduces AMF host quality

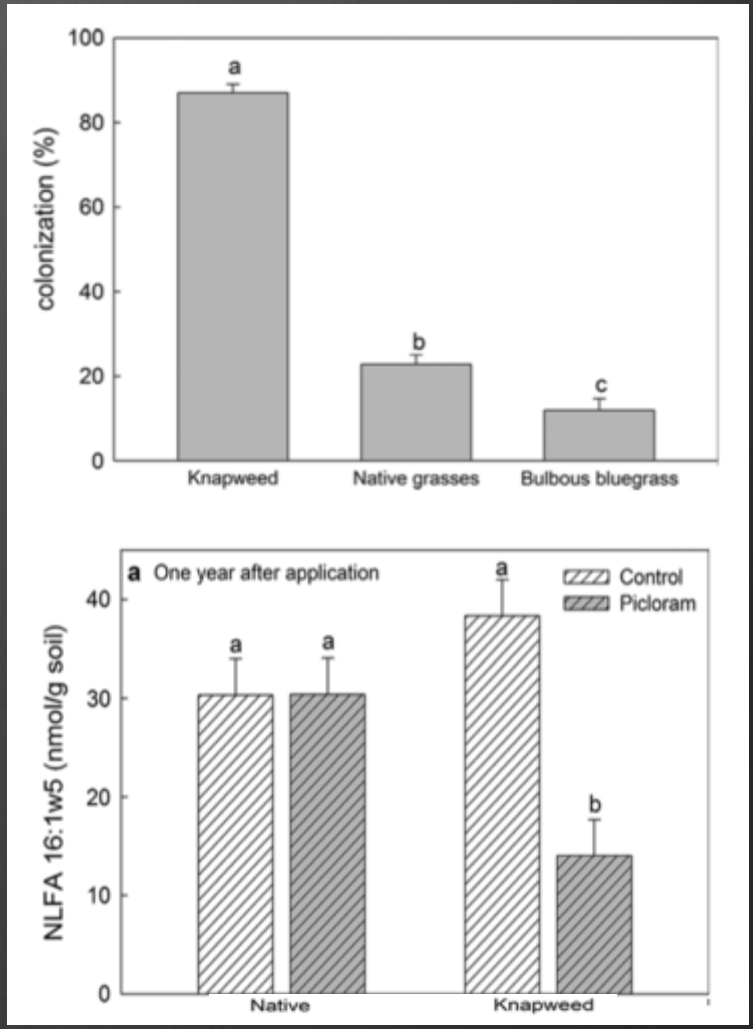




Lekberg et al. Ecological Appl. 2017.

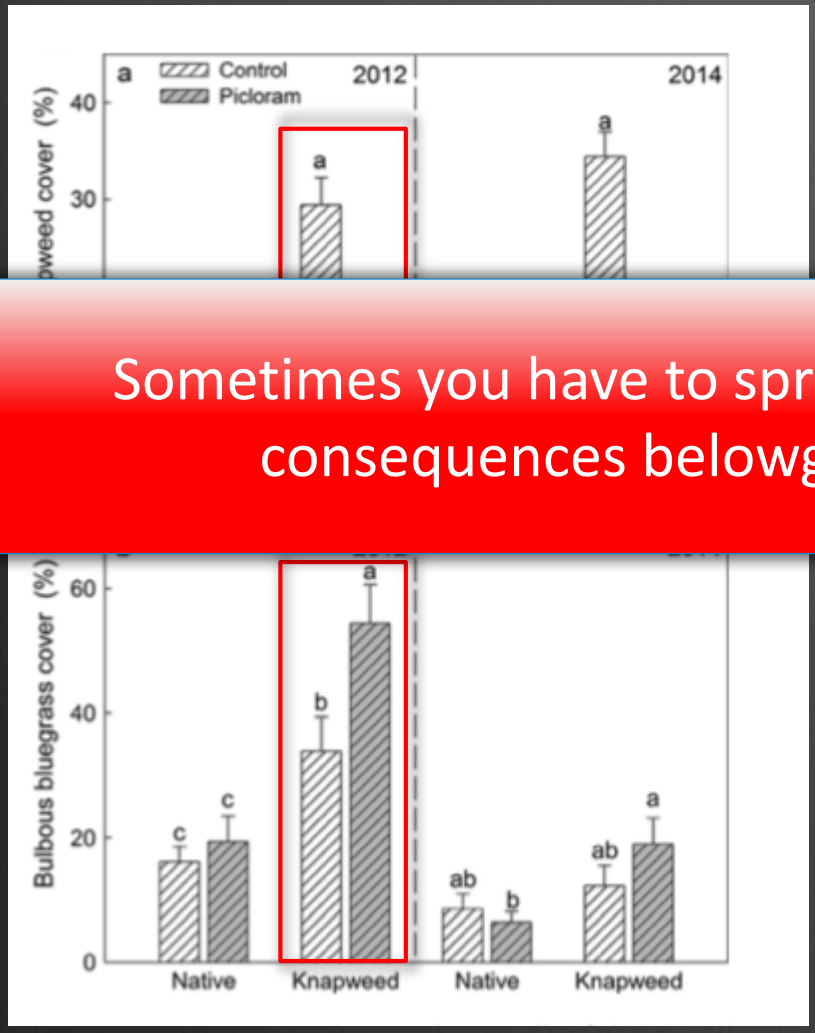
Which in turn reduces AMF abundance

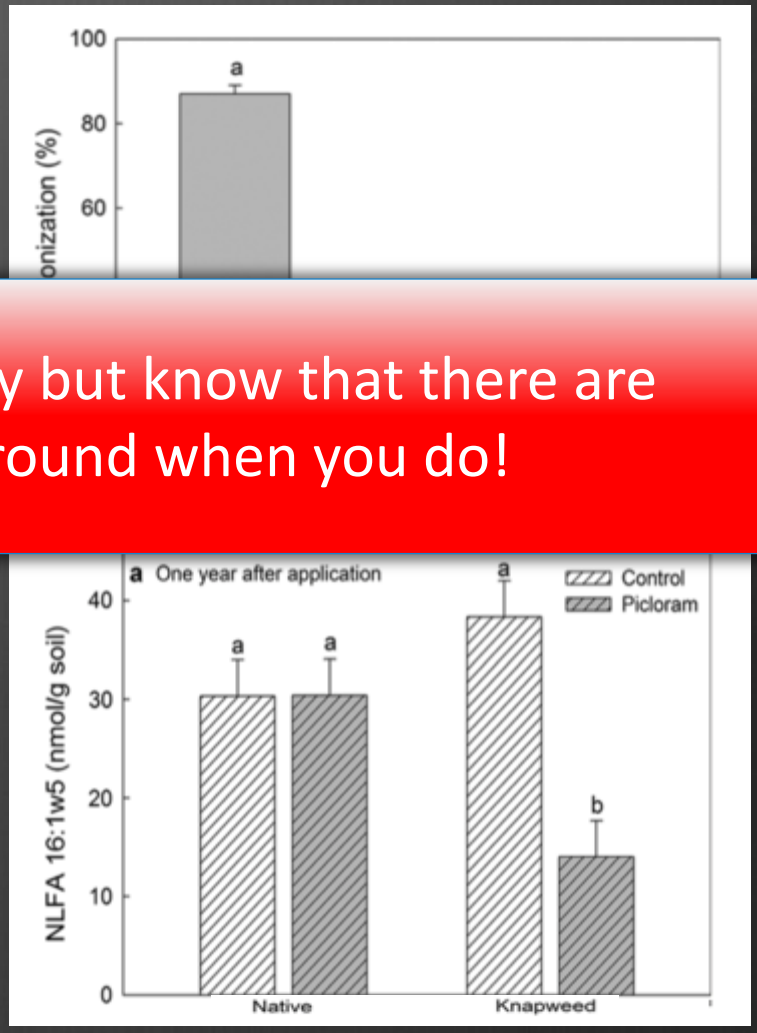




Lekberg et al. Ecological Appl. 2017.

Which in turn reduces AMF abundance





Sometimes you have to spray but know that there are consequences belowground when you do!

Lekberg et al. Ecological Appl. 2017.

Summary

- Microbial communities differ among invaders, are invader-specific and predictable, and are caused by the invader

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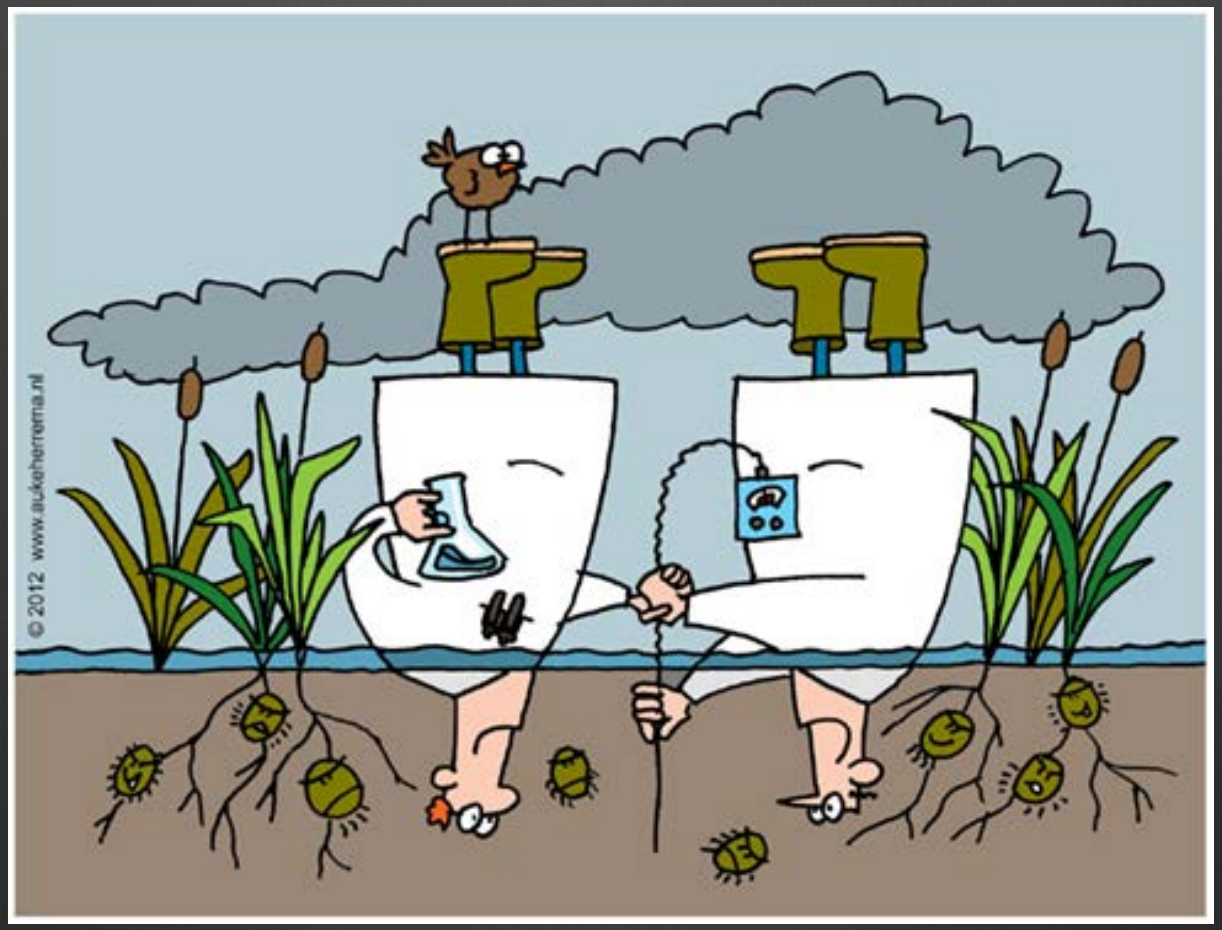
- Microbial communities differ among invaders, are invader-specific and predictable, and are caused by the invader
- These shifts affects ecosystem processes

Summary

- Microbial communities differ among invaders, are invader-specific and predictable, and are caused by the invader
- These shifts affects ecosystem processes
- These changes can result in strong legacy effects, but how long they last and implications for restoration is little known

Remember the belowground and you will be better off for it!



MPG RANCH

W.A. FRANKE COLLEGE OF FORESTRY & CONSERVATION
UNIVERSITY OF MONTANA

Questions?