Understanding and mitigating soil legacies to improve restoration success

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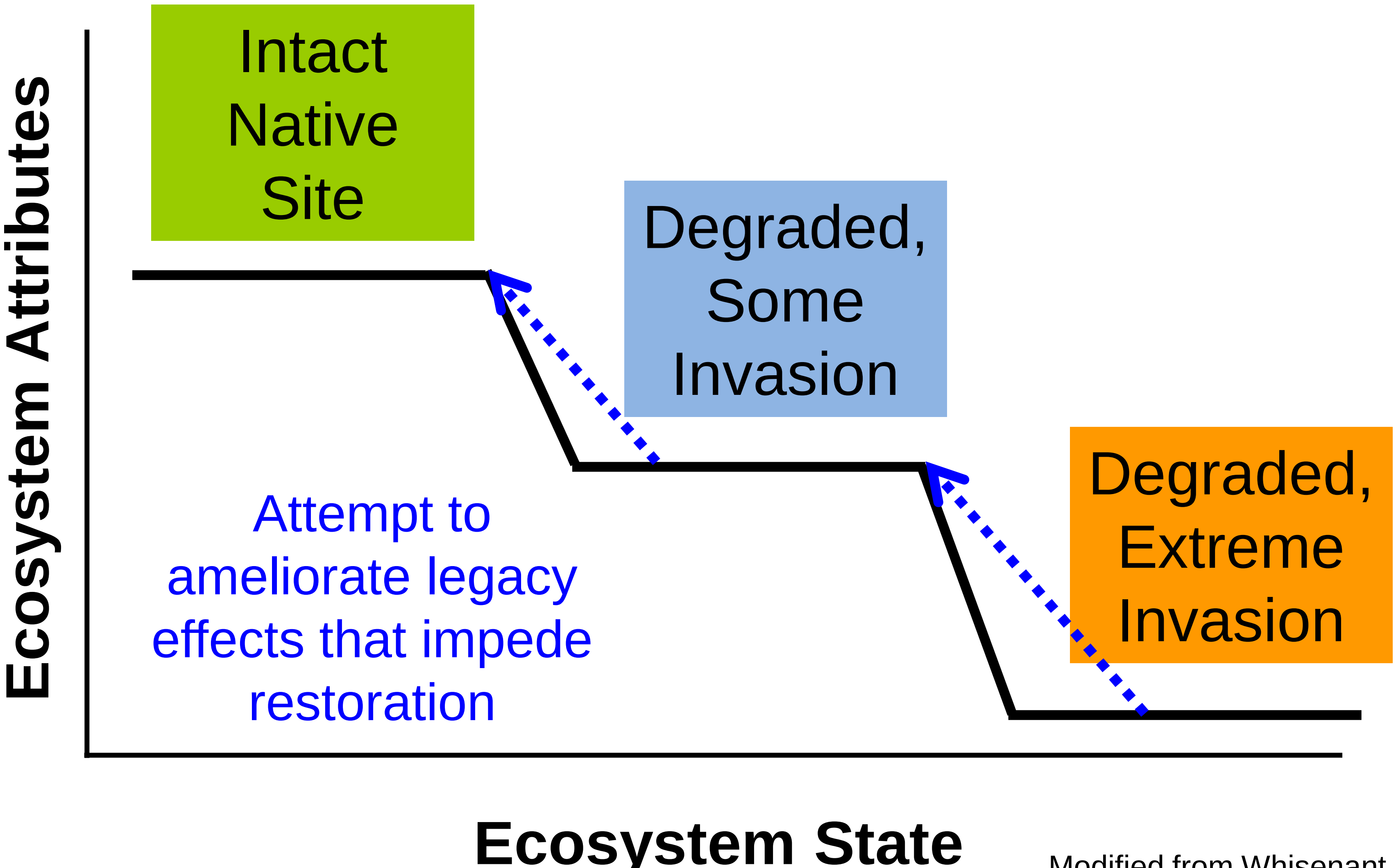
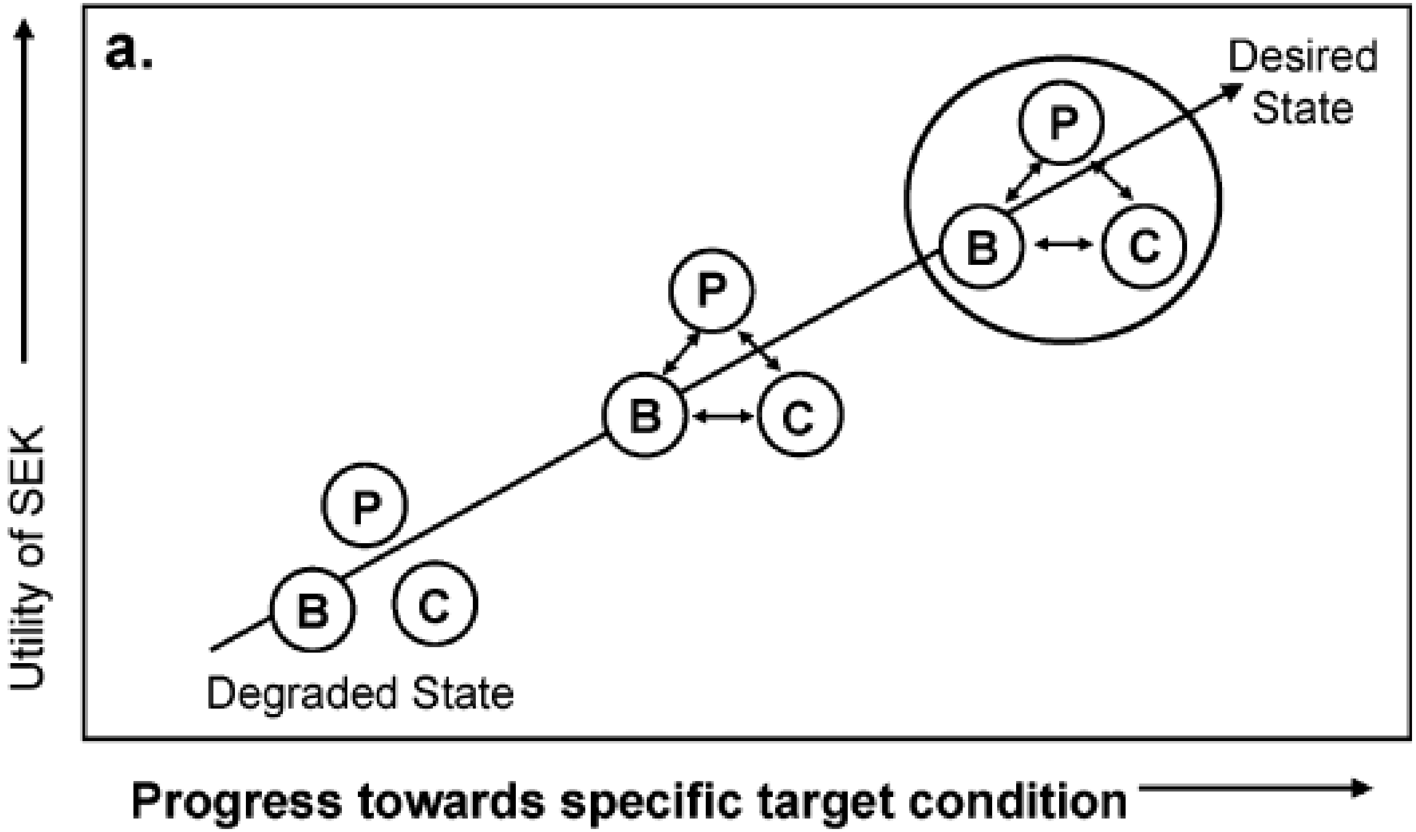
Targeting legacies in restoration



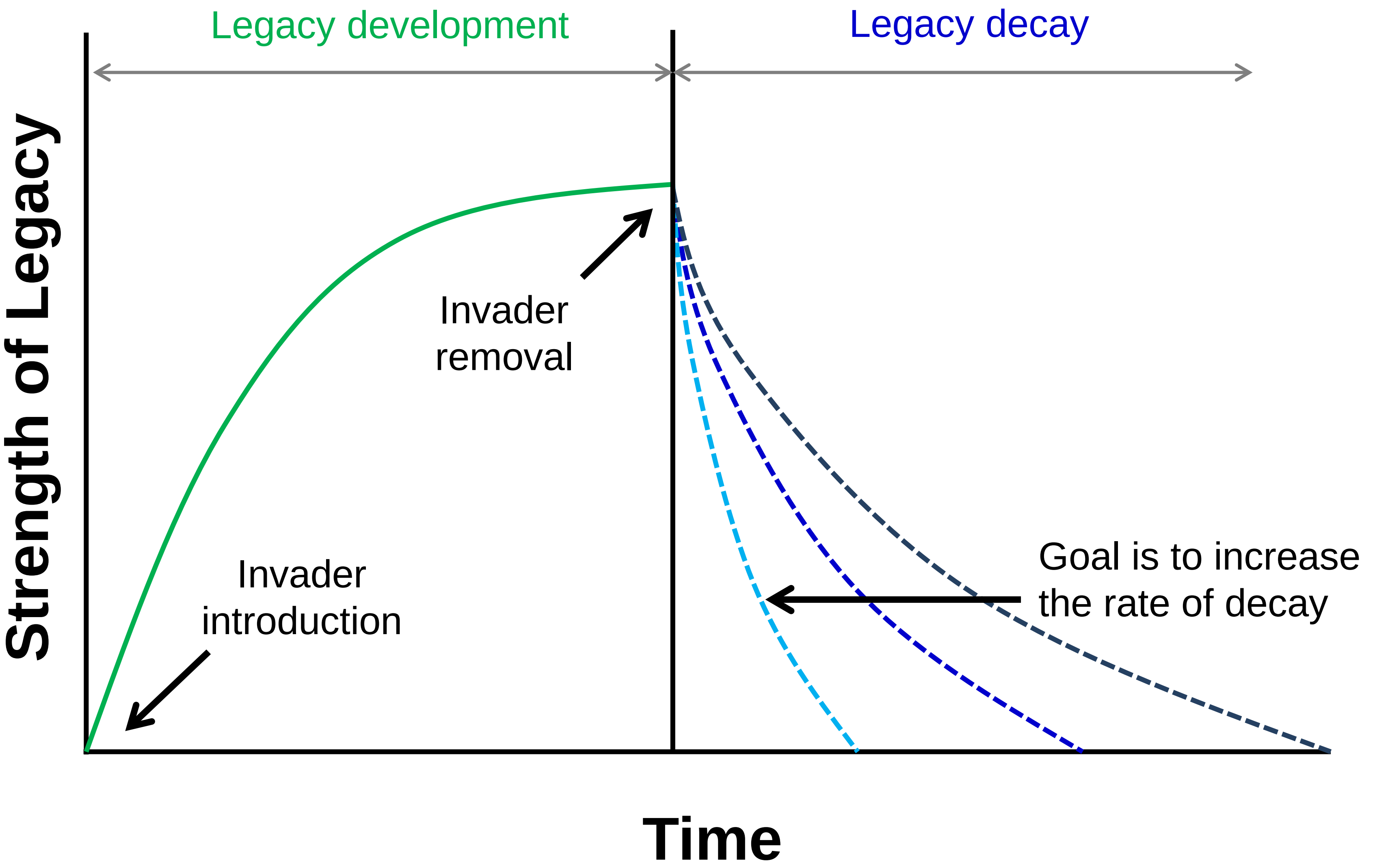
Modified from Whisenant 1999

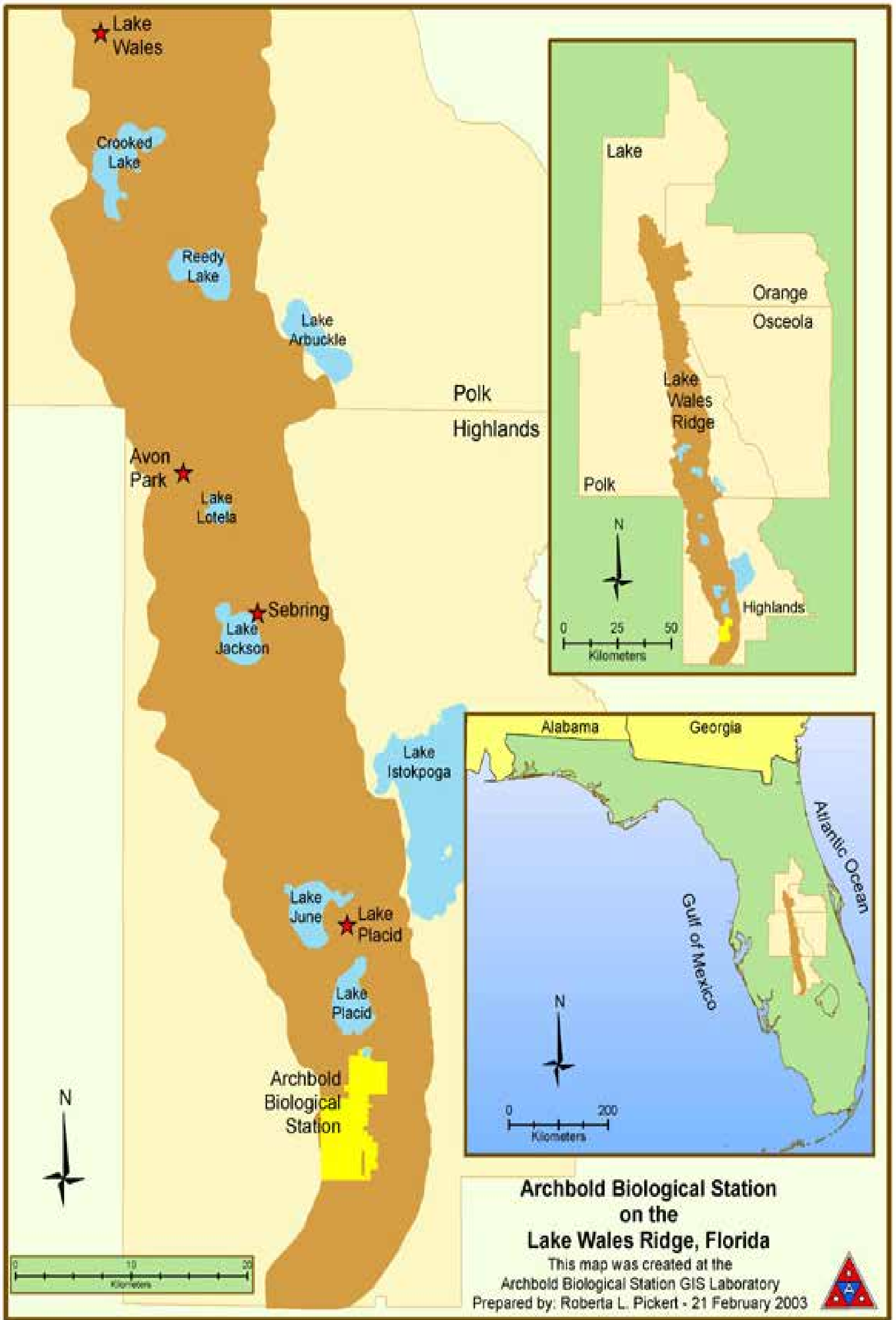
Need to target legacy effects explicitly

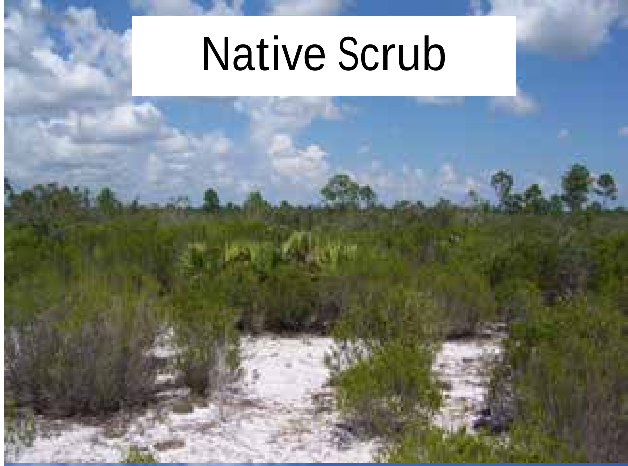


Heneghan et al. 2008 Rest Ecol

Can we change rate of legacy decay?



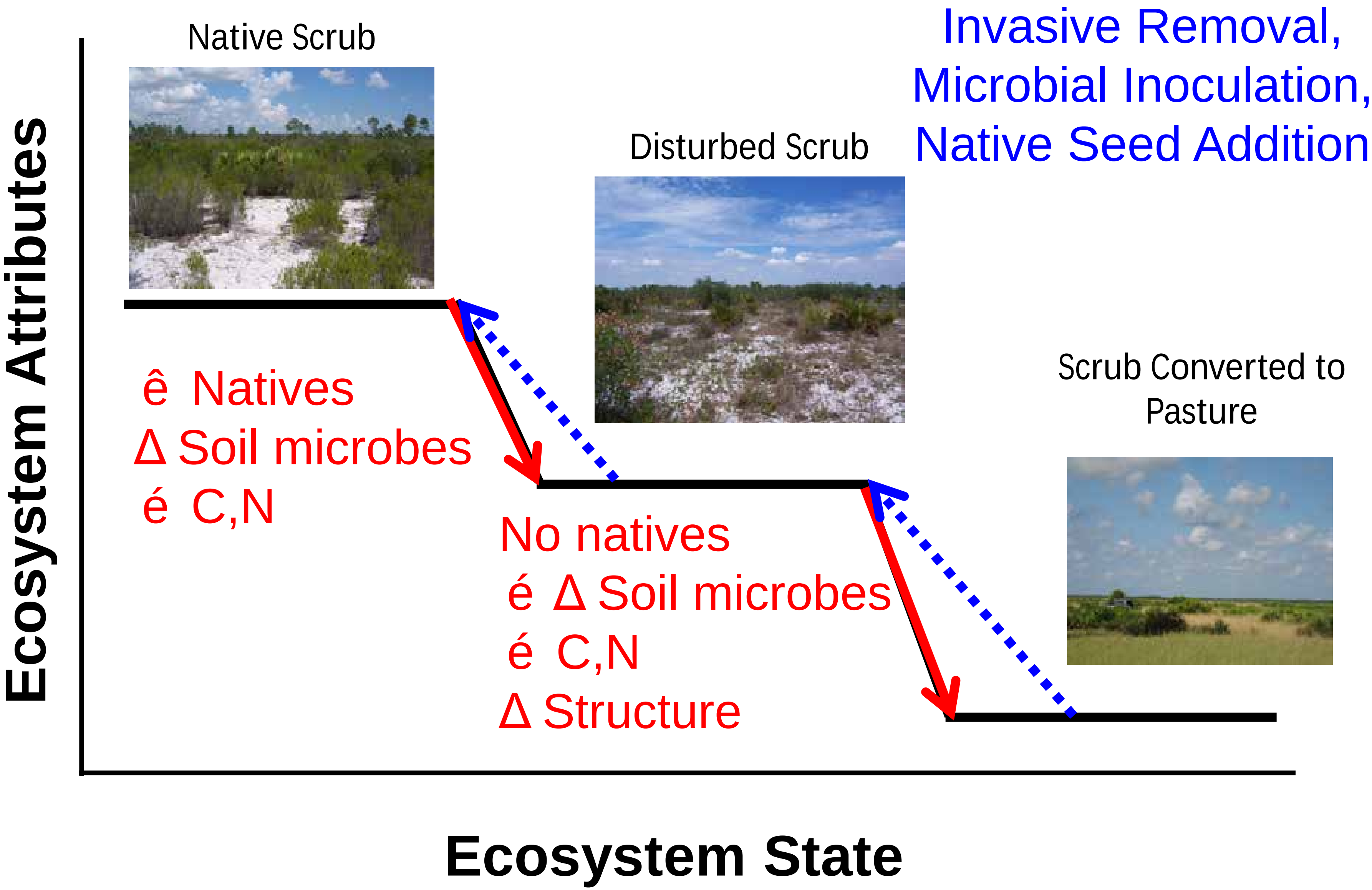

Lake Wales
Crooked Lake
Reedy Lake
Lake Arbuckle
Polk
Highlands
Avon Park
Lake Lotela
Sebring
Lake Jackson
Lake Istokpoga
Lake June
Lake Placid
Lake Placid
Archbold Biological Station
N
Lake
Orange
Osceola
Lake Wales Ridge
Polk
Highlands
N
0 25 50
Kilometers
Alabama
Georgia
Atlantic Ocean
Gulf of Mexico
N
0 200
Kilometers
0 10 20
Kilometers
Archbold Biological Station
on the
Lake Wales Ridge, Florida
This map was created at the
Archbold Biological Station GIS Laboratory
Prepared by: Roberta L. Pickert - 21 February 2003


Native Scrub


Disturbed Scrub


Scrub Converted to Pasture

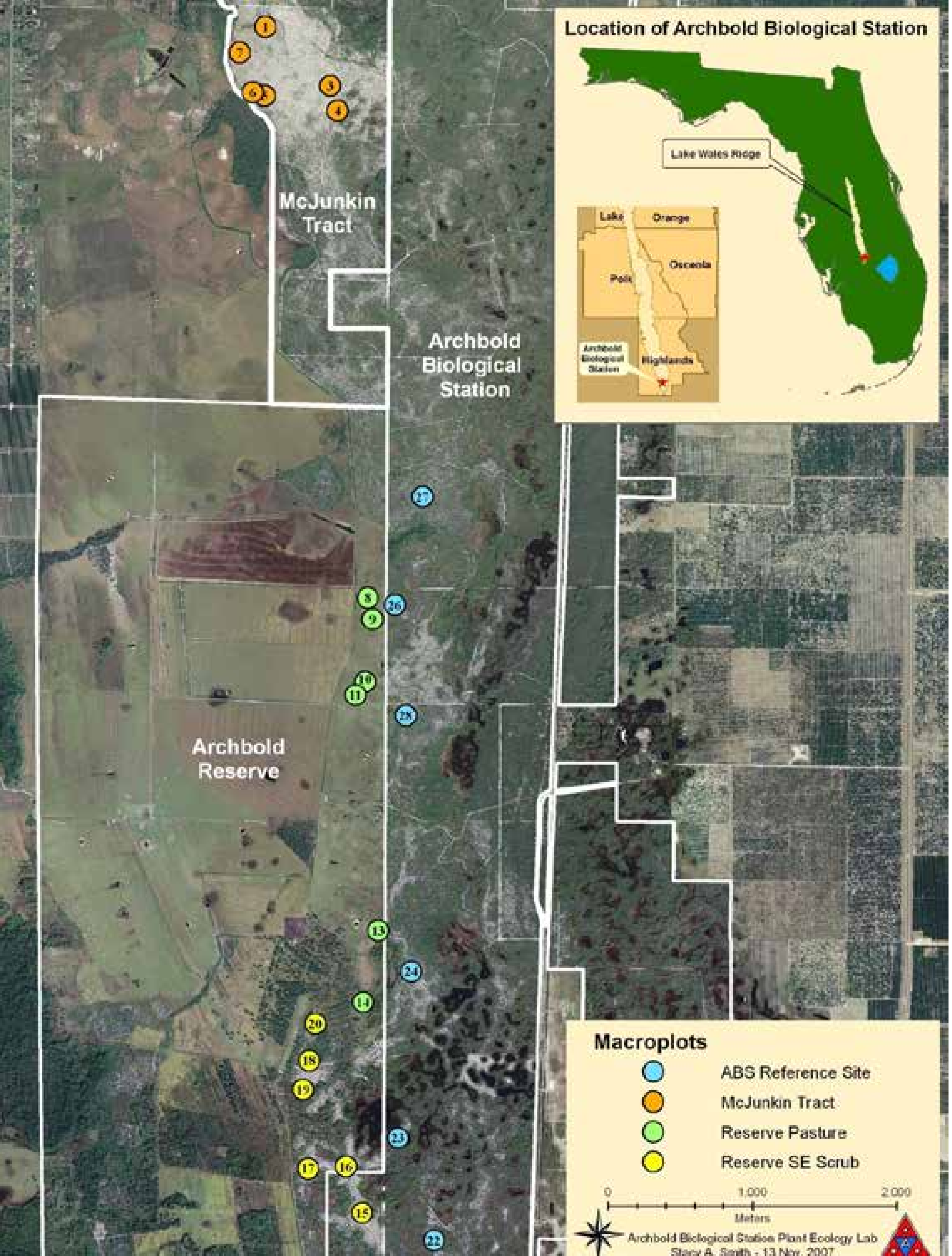
Targeting legacies in restoration



Restoration
community & ecosystem goals

- Mitigate structural, biogeochemical, and microbial legacies

- Initiate self-sustaining native populations

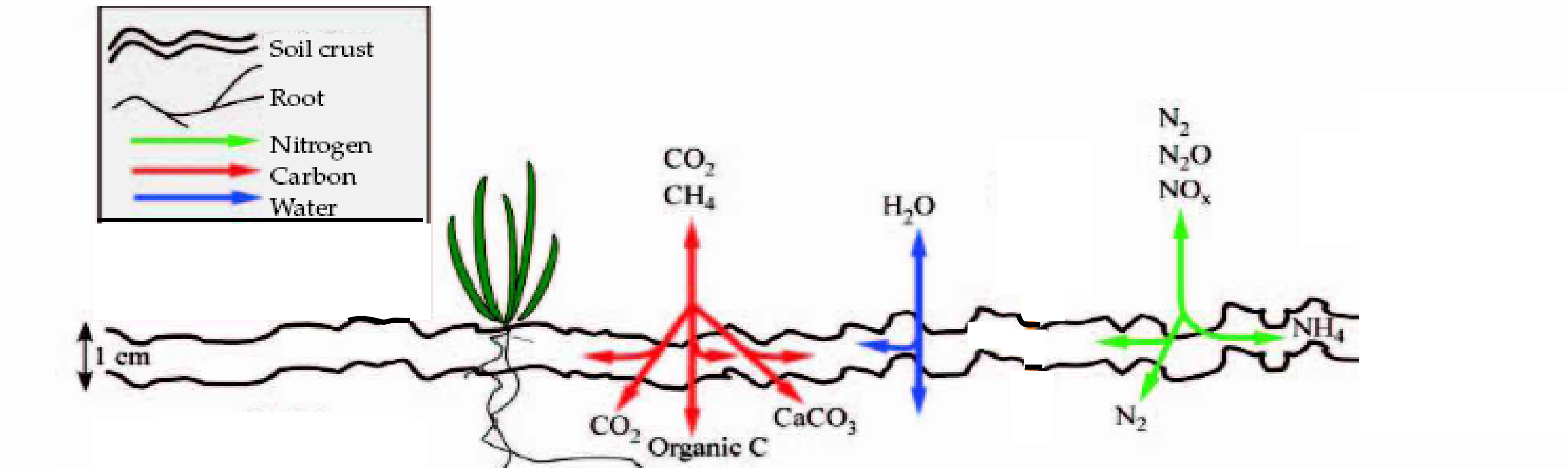


Restoration sites
-disturbed
-pasture

Native sites
-undisturbed
scrub patches

Restoration treatments: herbicide

Restoration treatments: soil microbial addition



Restoration experiment

Native Scrub

Disturbed Scrub

Pasture

Control

Herbicide

Control

Microbial Addition

Plots were set up in fall 2006 and tracked through spring 2010.

Measuring restoration success

- Return site characteristics?
- Reduce nutrient legacies?
- Improve plant recovery?

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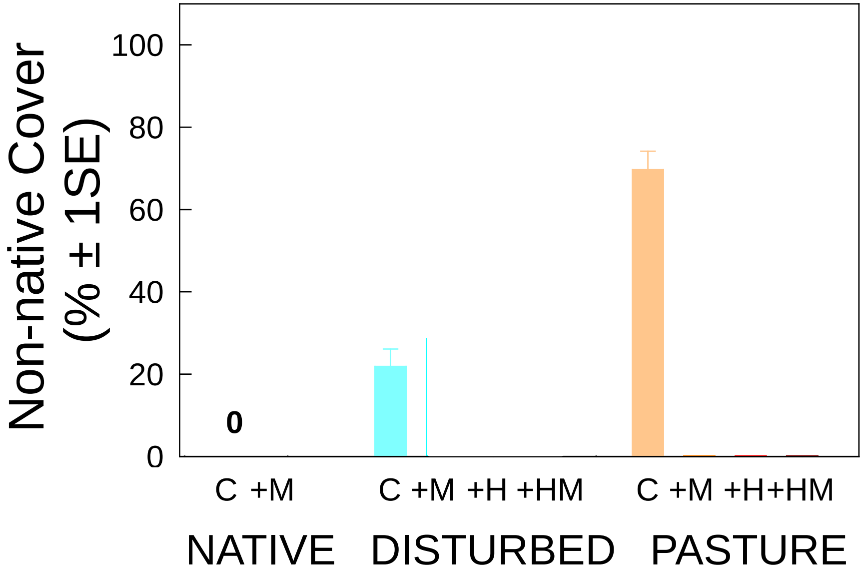
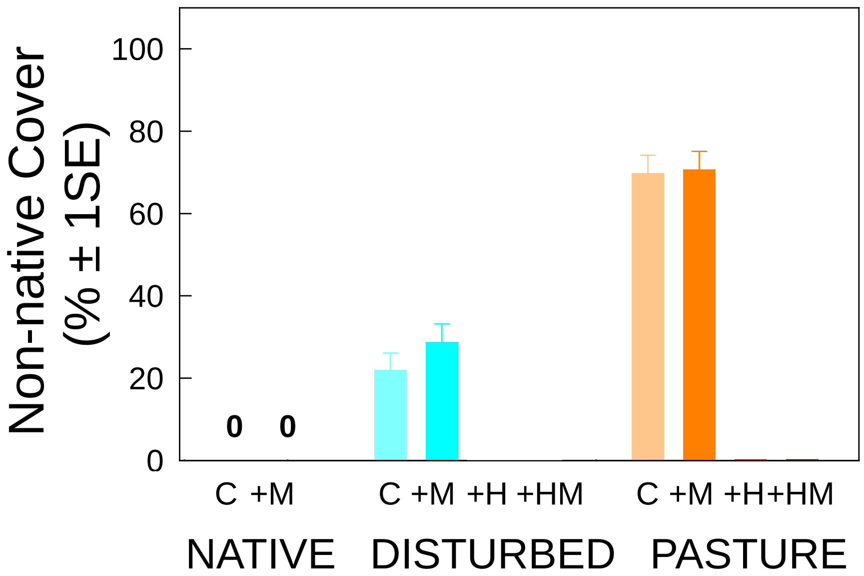
Success on some (visible) fronts: plant removals largely restore structure



Success on some (visible) fronts: plant removals largely restore structure



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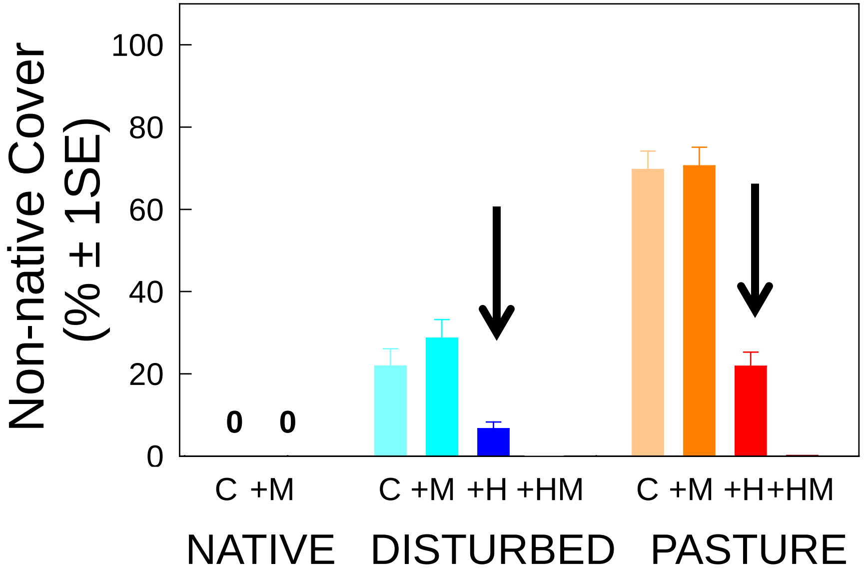

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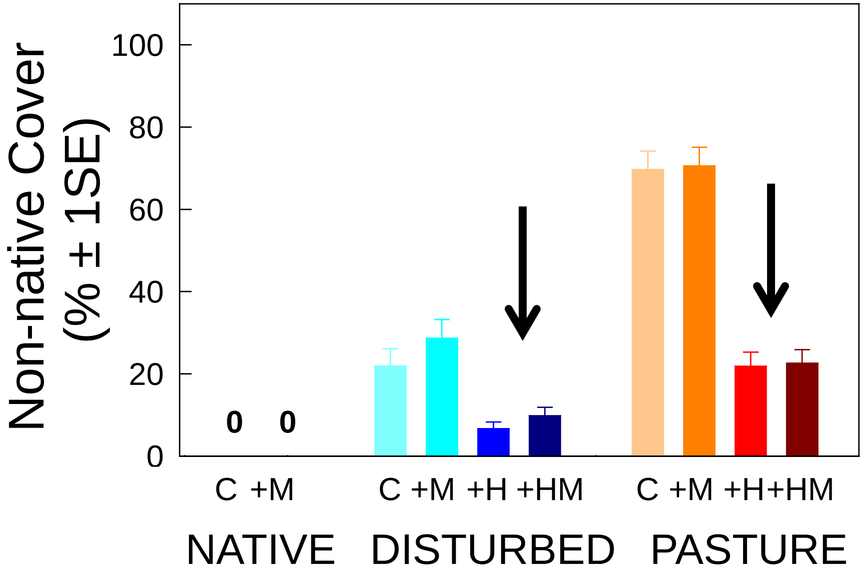

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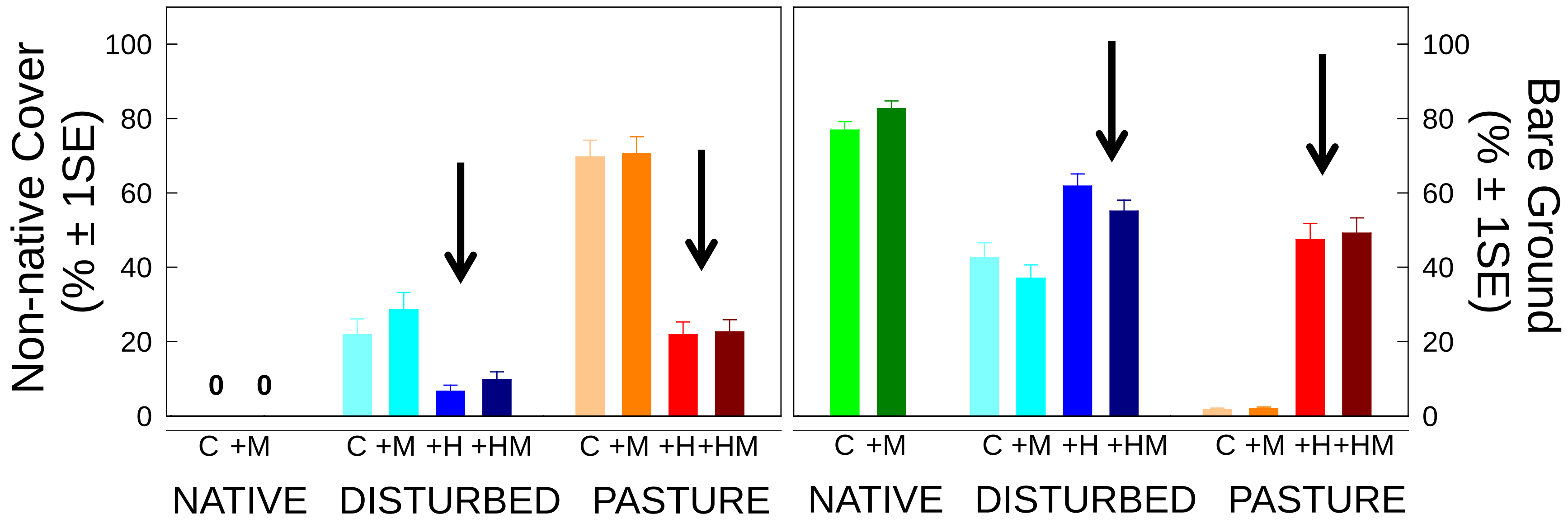

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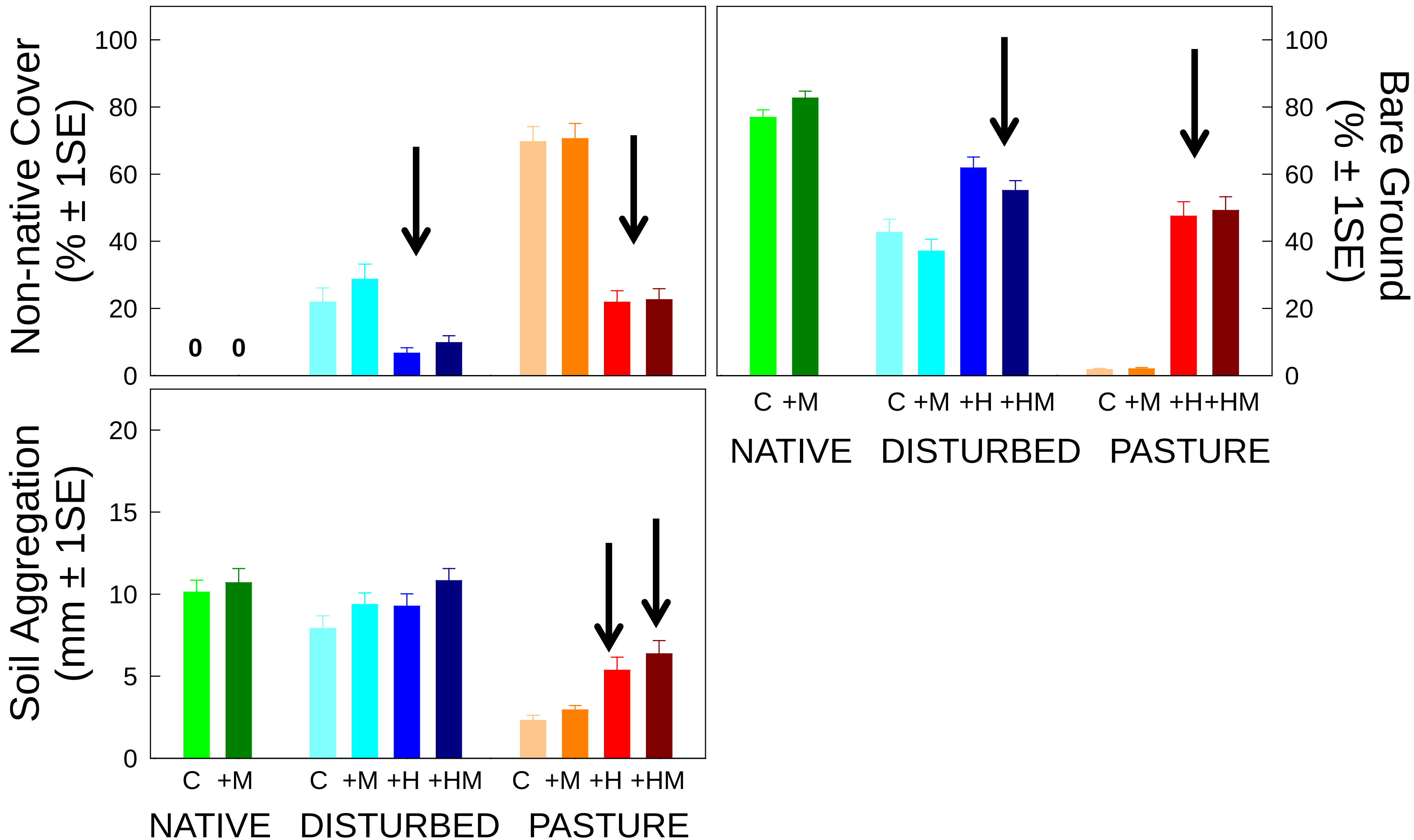
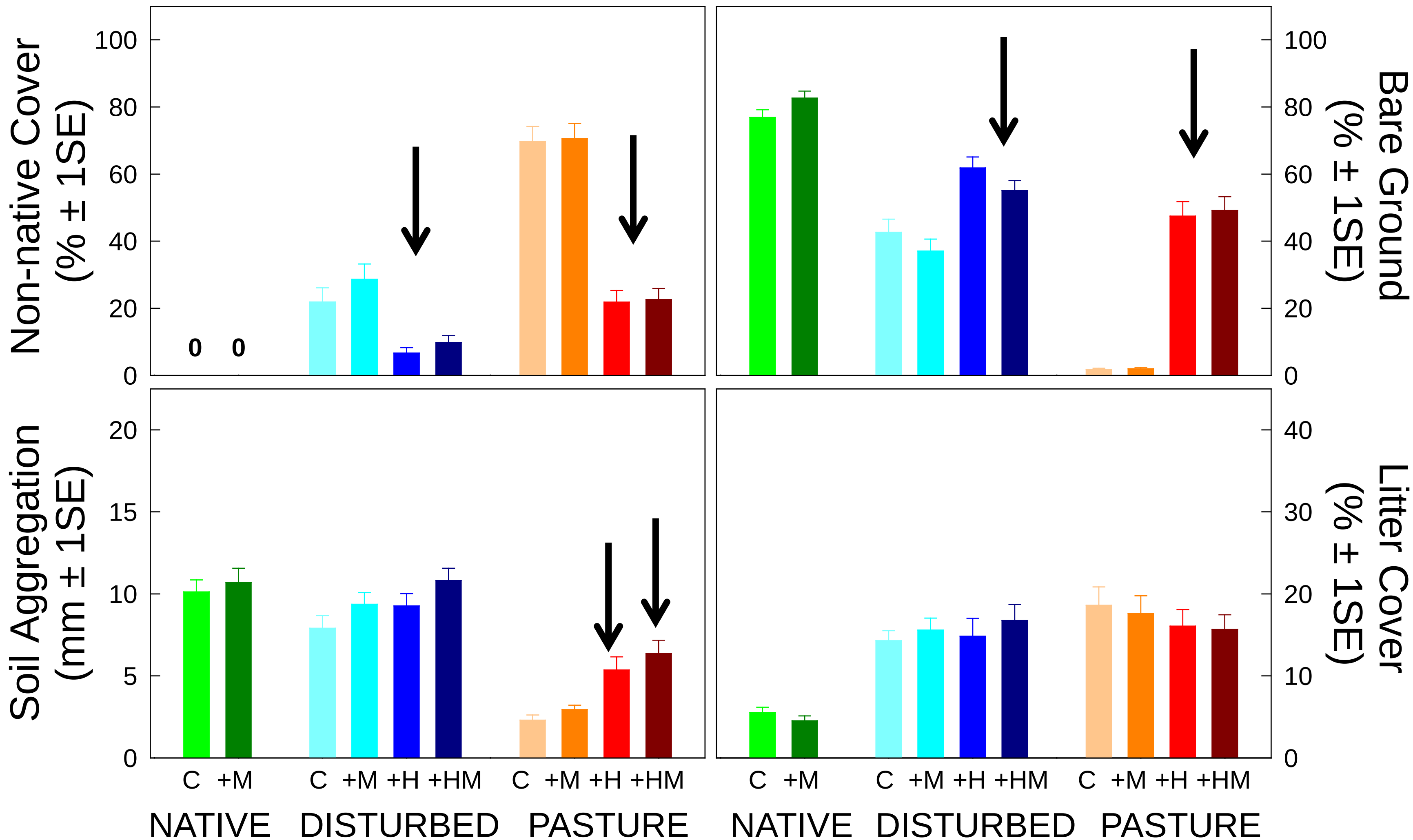


Success on some (visible) fronts: plant removals largely restore structure



Measuring restoration success

- Return site characteristics?
  - Yes, site cover, openness, & soil crust aggregation were improved in degraded sites
- Reduce nutrient legacies?

- Improve plant recovery?

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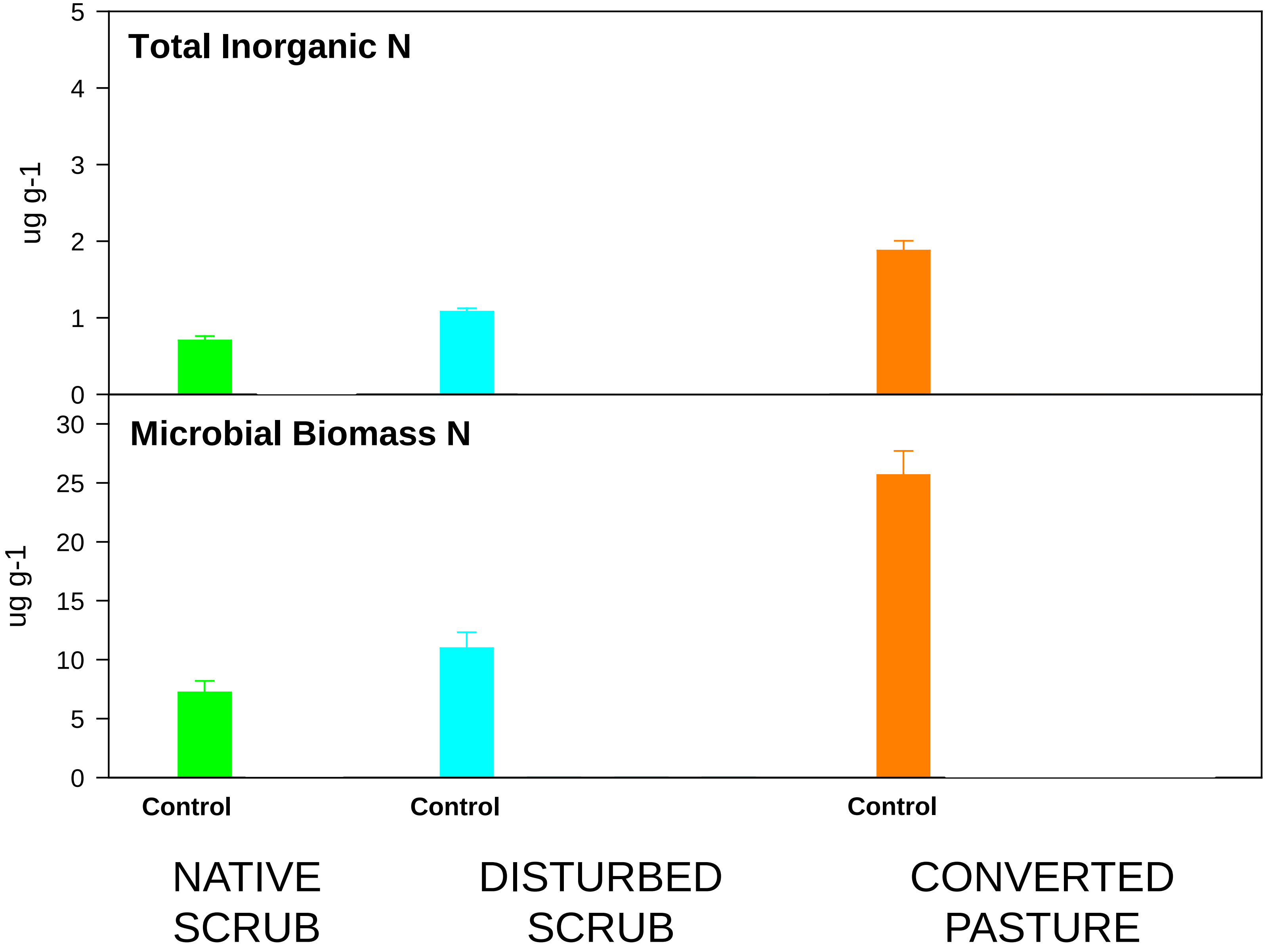
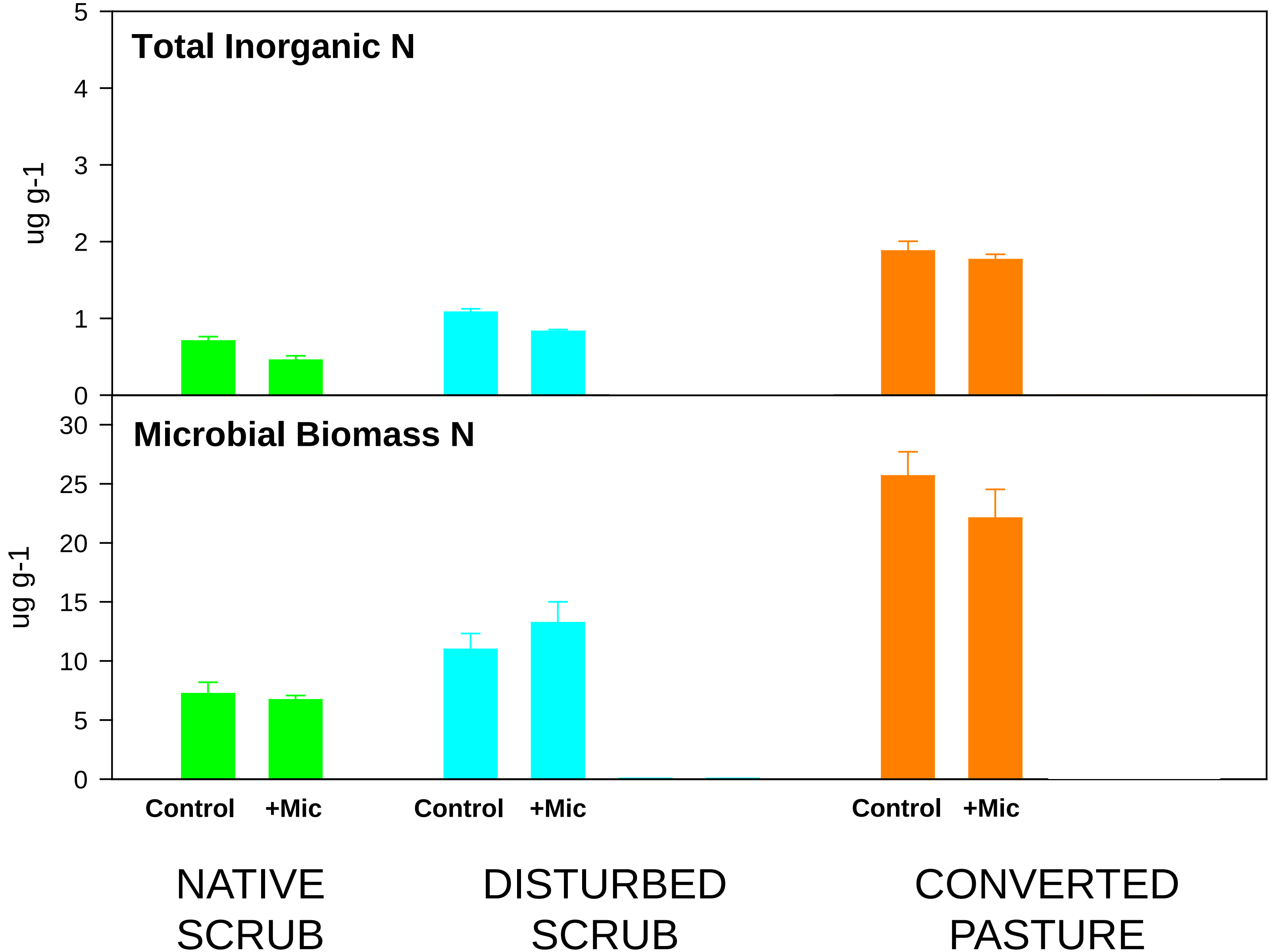
Soil N differs among veg types



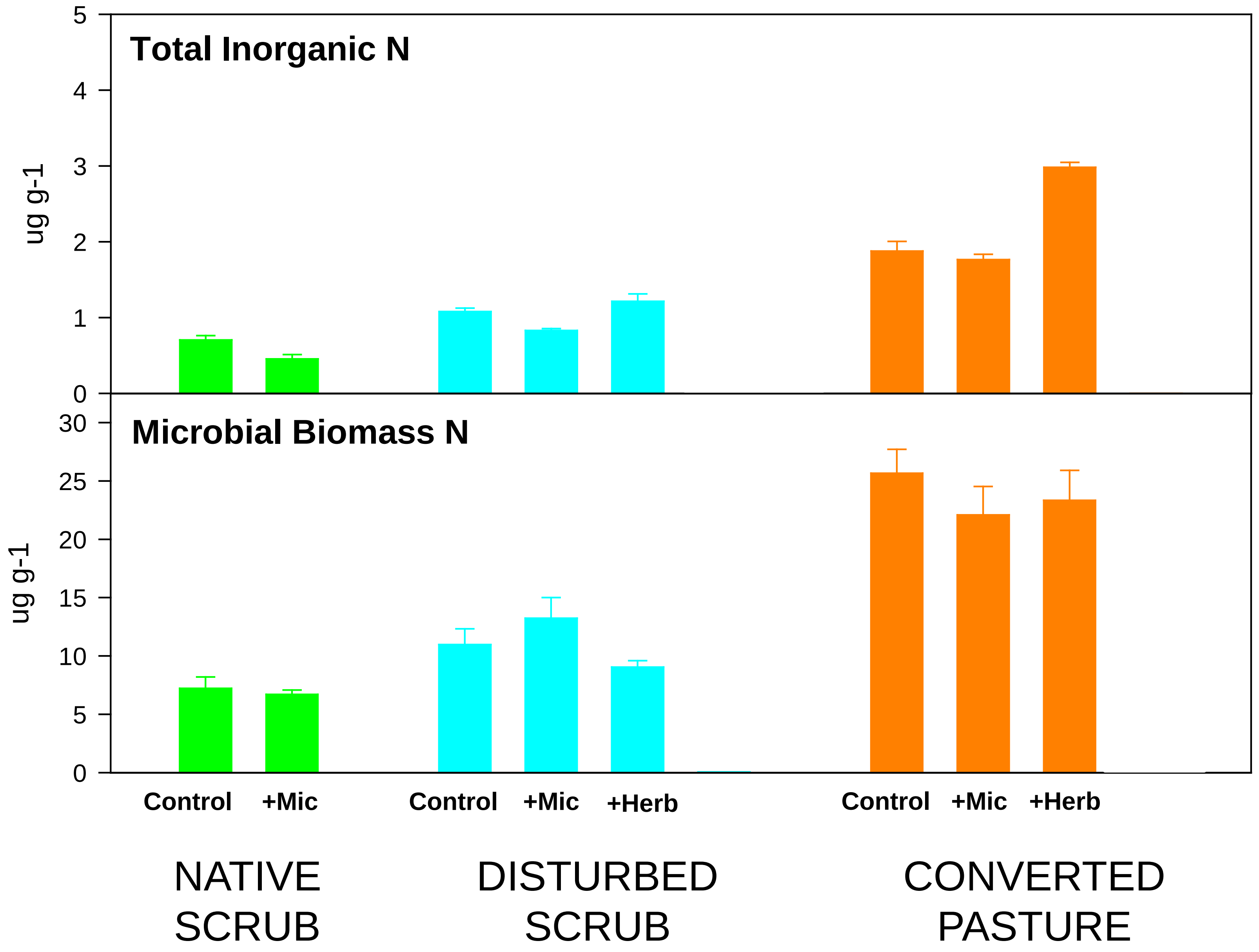
Hamman & Hawkes 2013 Rest Ecol

Microbial additions have little effect on N



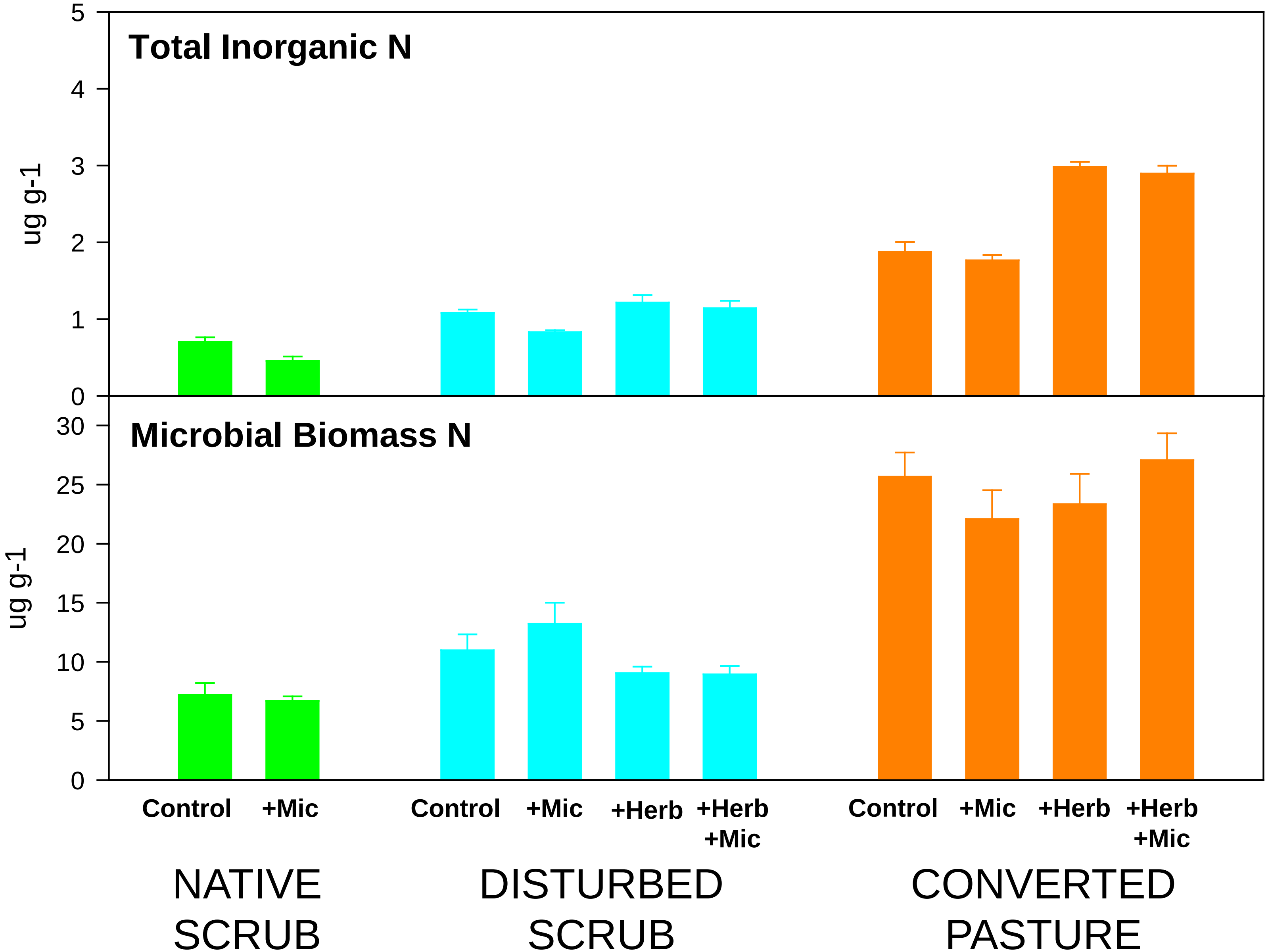
Hamman & Hawkes 2013 Rest Ecol

High N persists after veg removal



Hamman & Hawkes 2013 Rest Ecol

Treatments do not change N legacies



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Measuring restoration success

- Return site characteristics?
  - Yes, degraded site cover, openness, & soil crust aggregation were improved.
- Reduce nutrient legacies?
  - No. May need more time. Possibly remove topsoil if N reduction is necessary.
- Improve plant recovery?

Measuring restoration success

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The cast of characters

*Hypericum cumulicola****

*Eryngium cuneifolium****

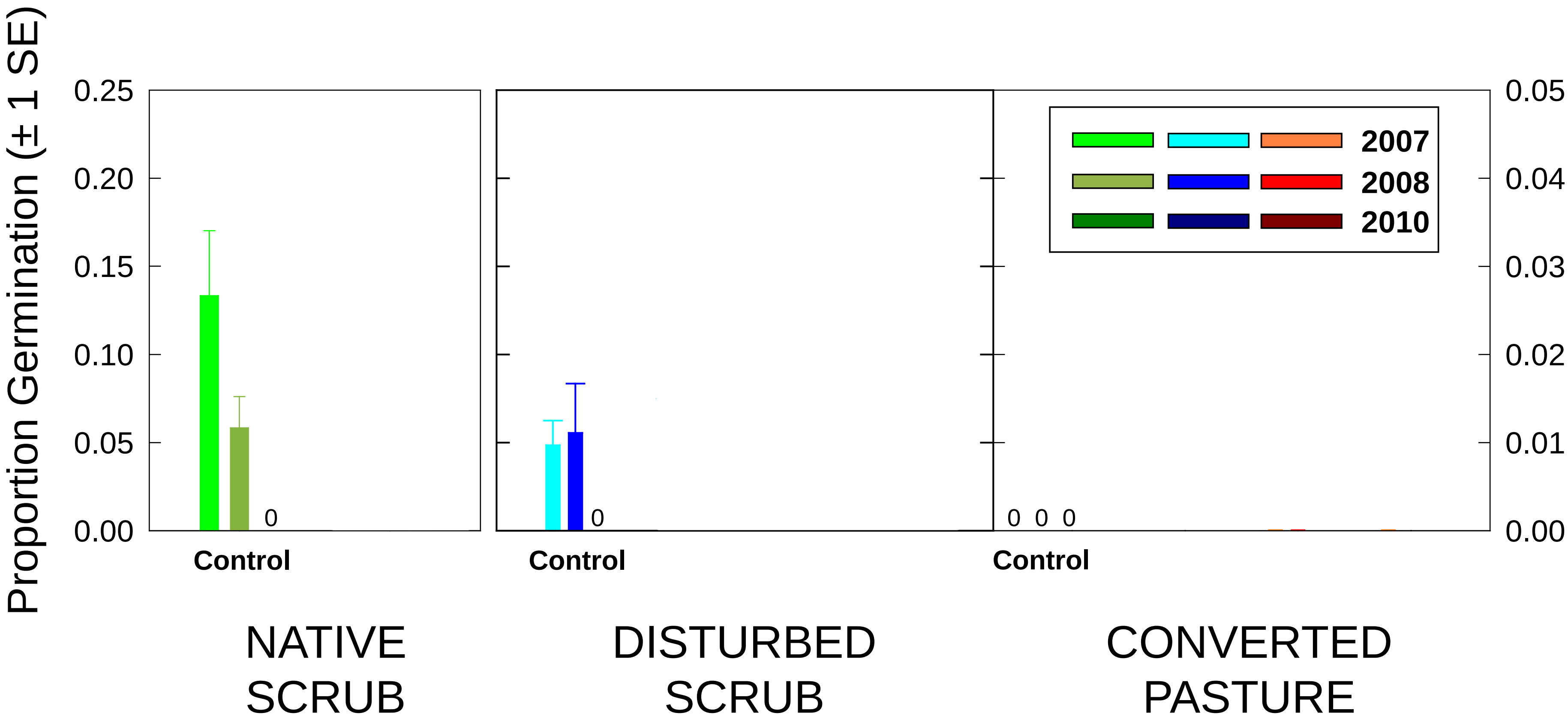
*Lechea cernua**

Lechea deckertii

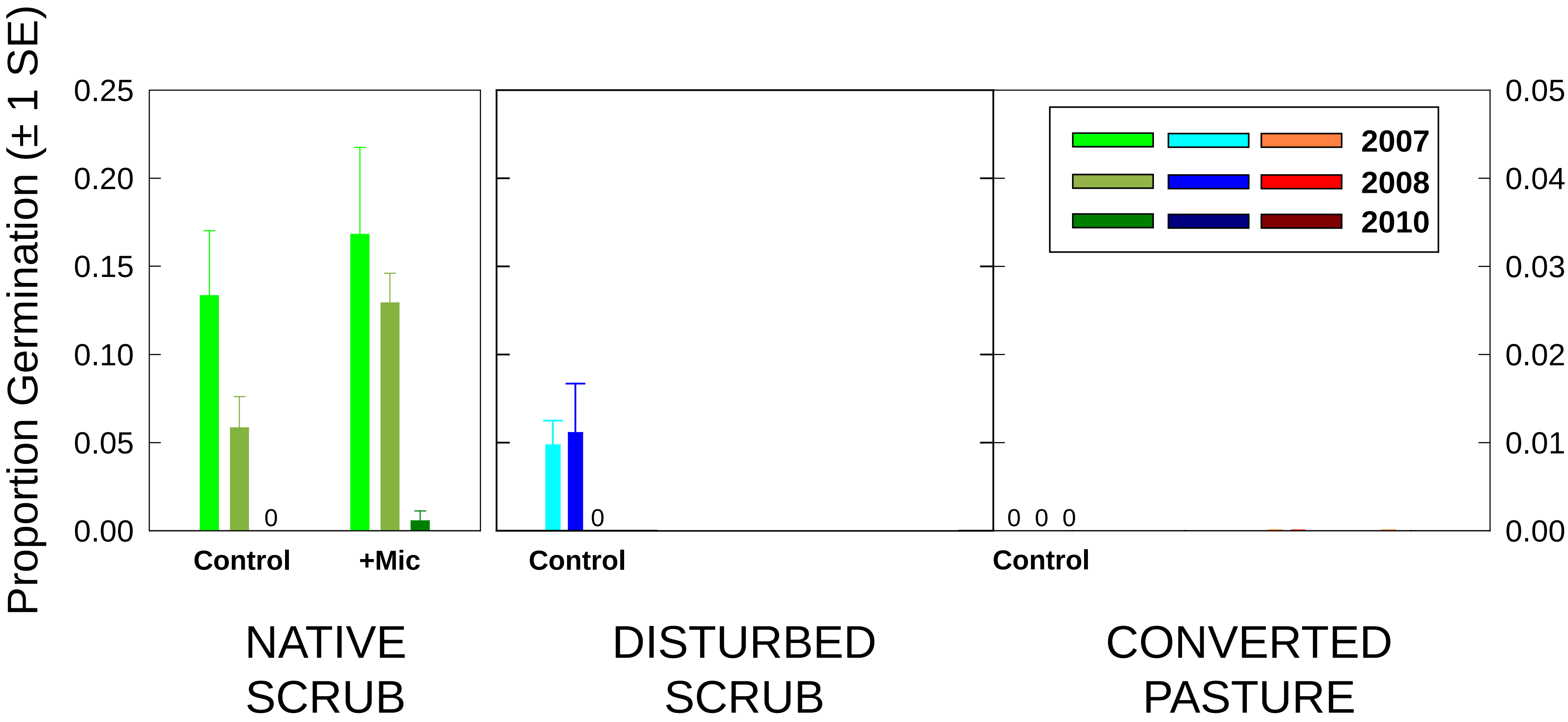
Polygonella basiramia**

Paronychia chartacea*

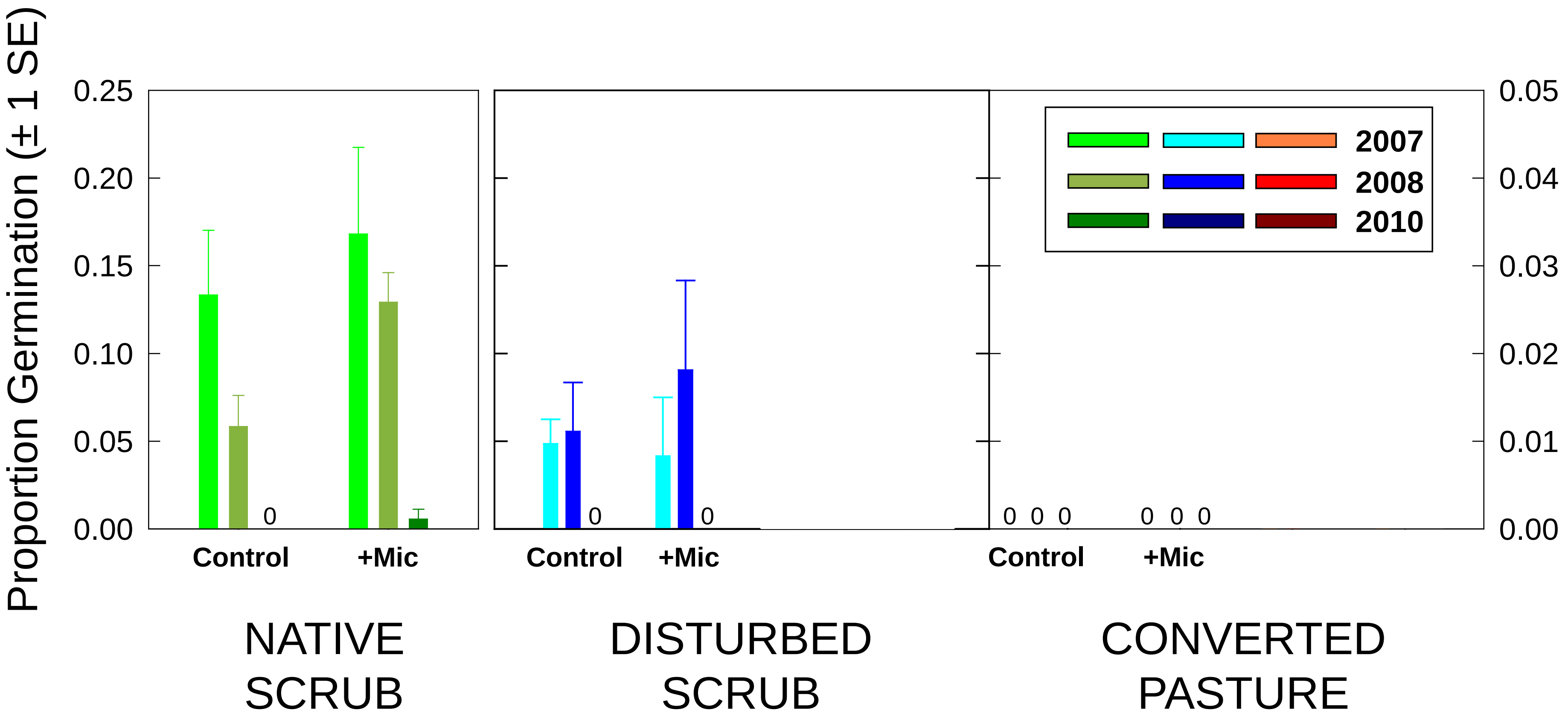
More germination in native sites



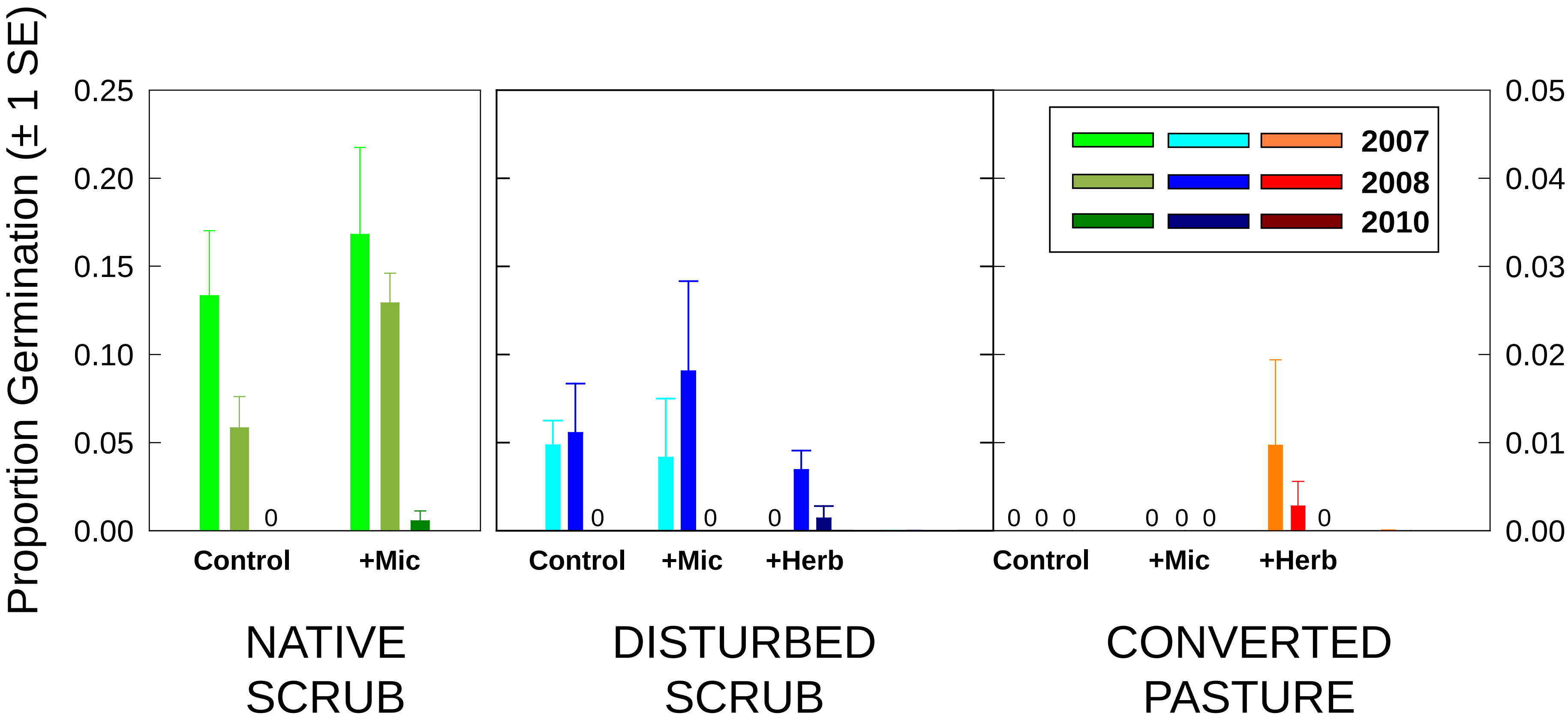
More germination in native sites



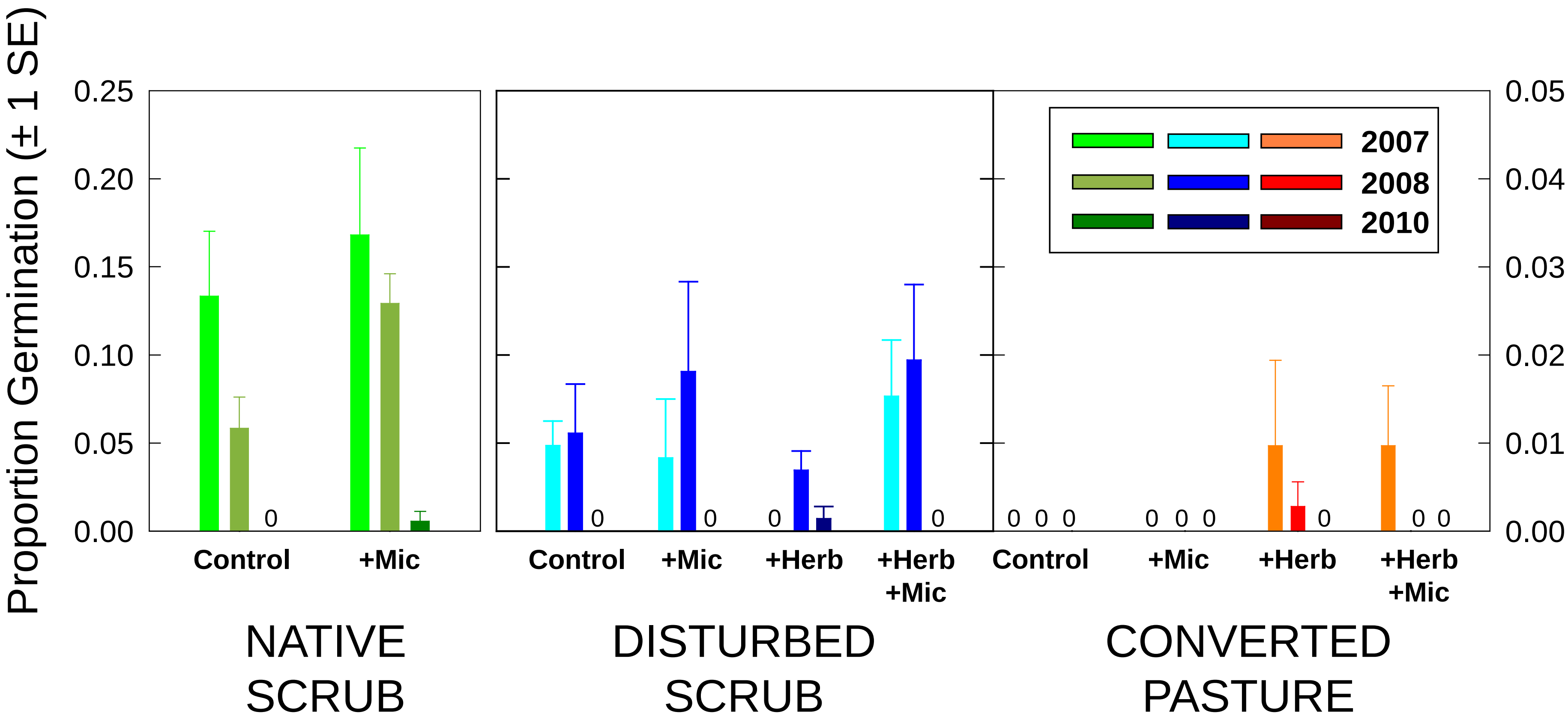
Microbial additions alone do not improve germination



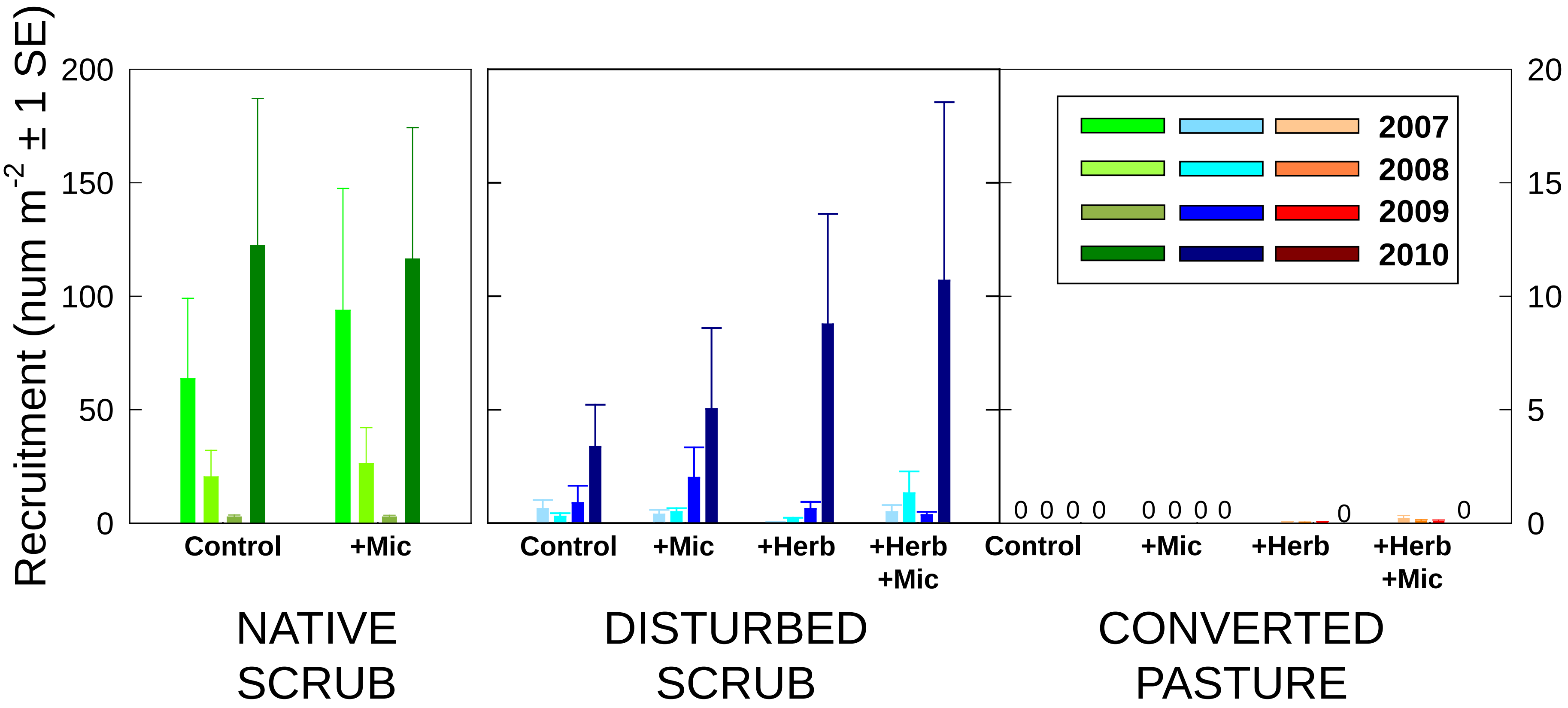
Plant removals improve germination only in pastures



Plant removals with microbial additions recover germination in disturbed sites



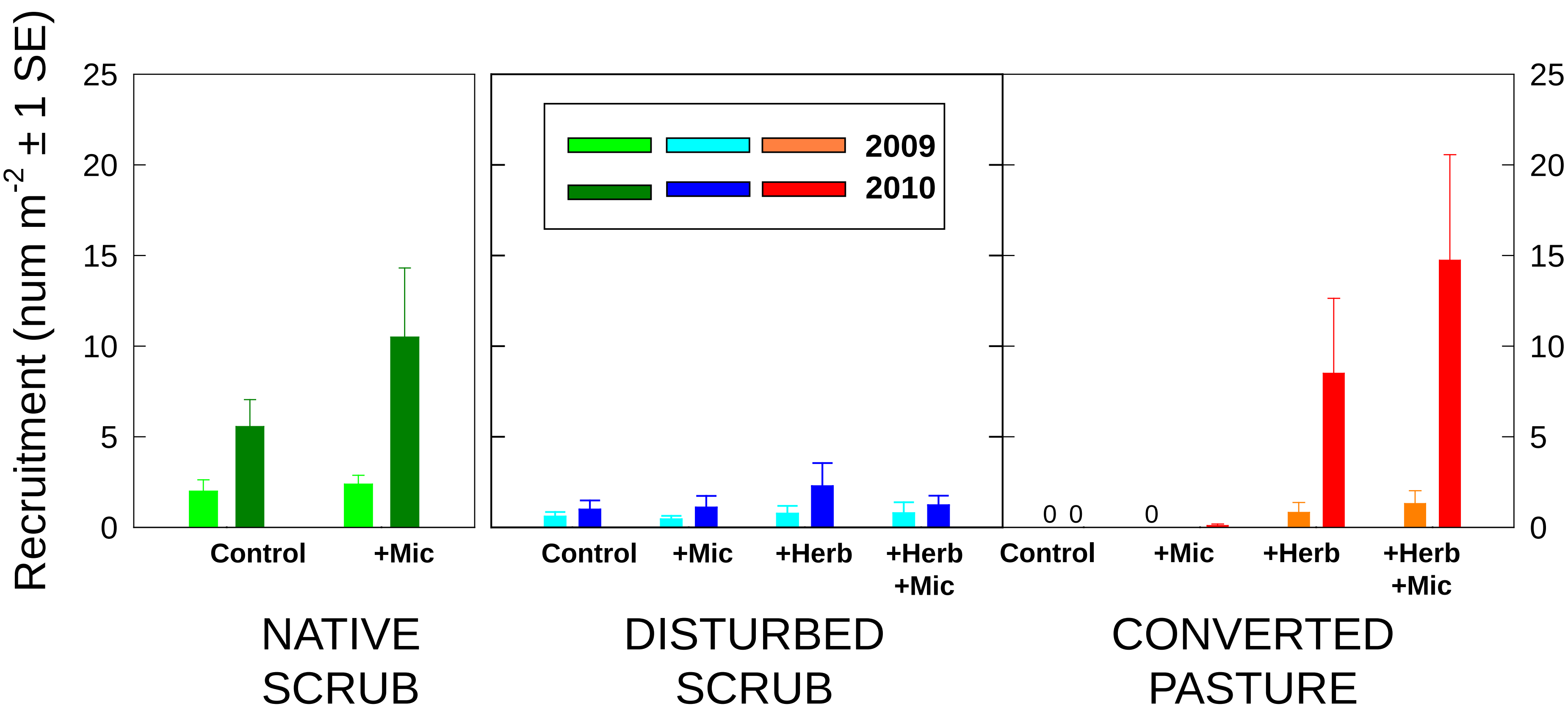
Substantial native background recruitment, but not in pastures



Open space, moisture, and non-native veg cover explain 38% of variation in recruitment

Background recruitment of non-targeted species

Opportunities created for recruitment of non-targeted species in pastures



Open space and soil aggregation explain 43% of variation in non-target recruitment

What does this mean for population viability?

- Demographic modeling of taxa to estimate population growth rates

- Started with one of the most abundant plant species, *Polygonella basiramia*

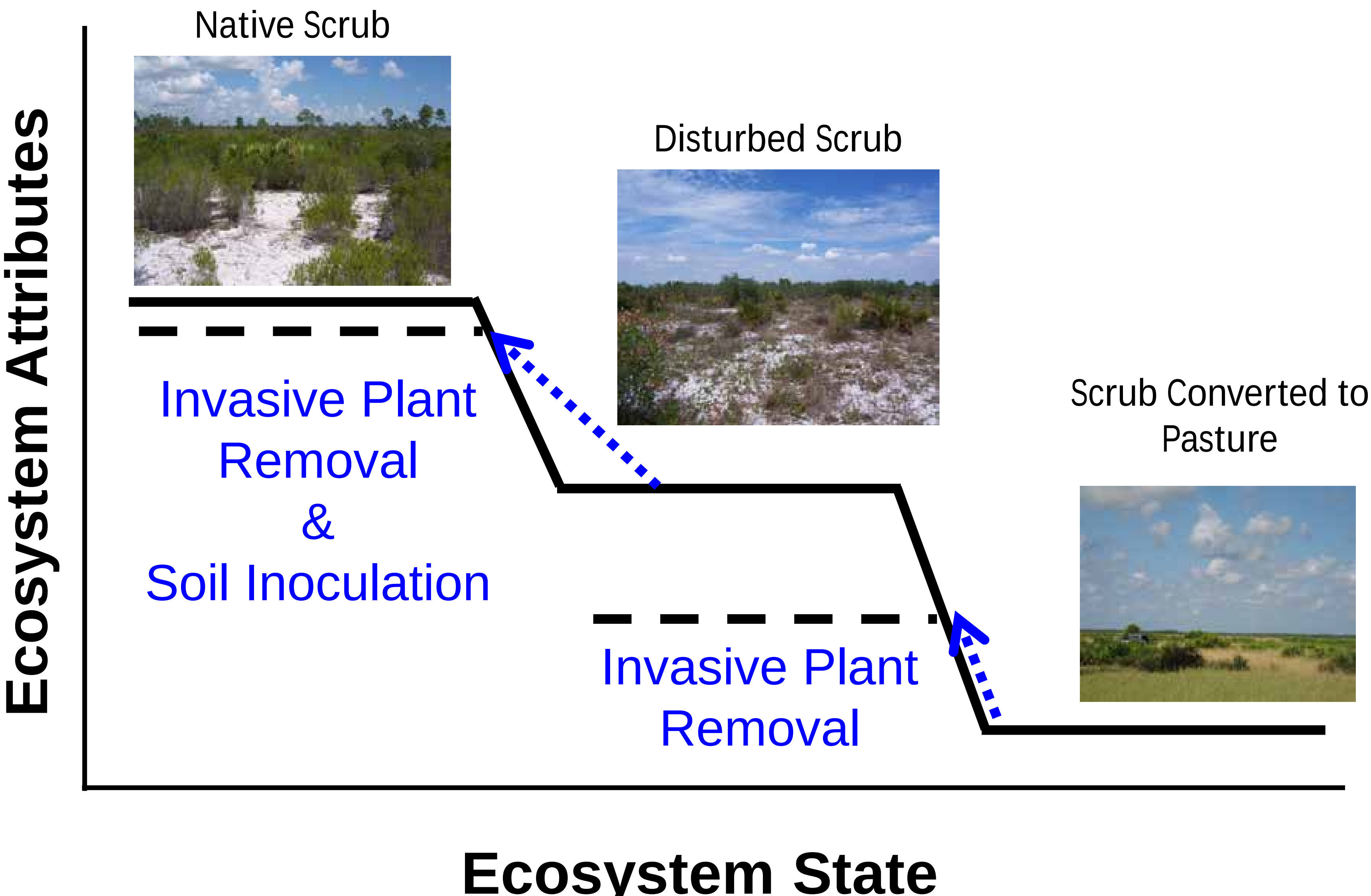
Polygonella population growth rates increased with restoration treatments

VEGETATION	TREATMENT	Δ LAMBDA RELATIVE TO CONTROLS
Disturbed Scrub	Microbes	0
	Herbicide	0
	Herbicide+Microbes	+2.8%
Converted Pasture	Microbes	0
	Herbicide	+2.5%
	Herbicide+Microbes	+1.1%

Measuring restoration success

- Return site characteristics?
  - Yes, degraded site cover, openness, & soil crust aggregation were improved.
- Reduce nutrient legacies?
  - No. May need more time. Possibly remove topsoil if N reduction is necessary.
- Improve plant recovery?
  - Yes, but veg-specific effects on germination, establishment, and population trajectories.

The probability of successful restoration differs among sites



Can we open up the soil black box?

- How do microbial communities differ among native, disturbed, and pasture sites?
- Do those differences persist?

- Can we use what we learn to further enhance restoration success?

Focus on fungi

- Root fungi
  - Involved in nutrient and water uptake
- Soil fungi
  - Responsible for decomposition and nutrient recycling in soil
- Both abundant in this ecosystem and should play important functional roles given the low nutrient, xeric soils

Can we open up the soil black box?

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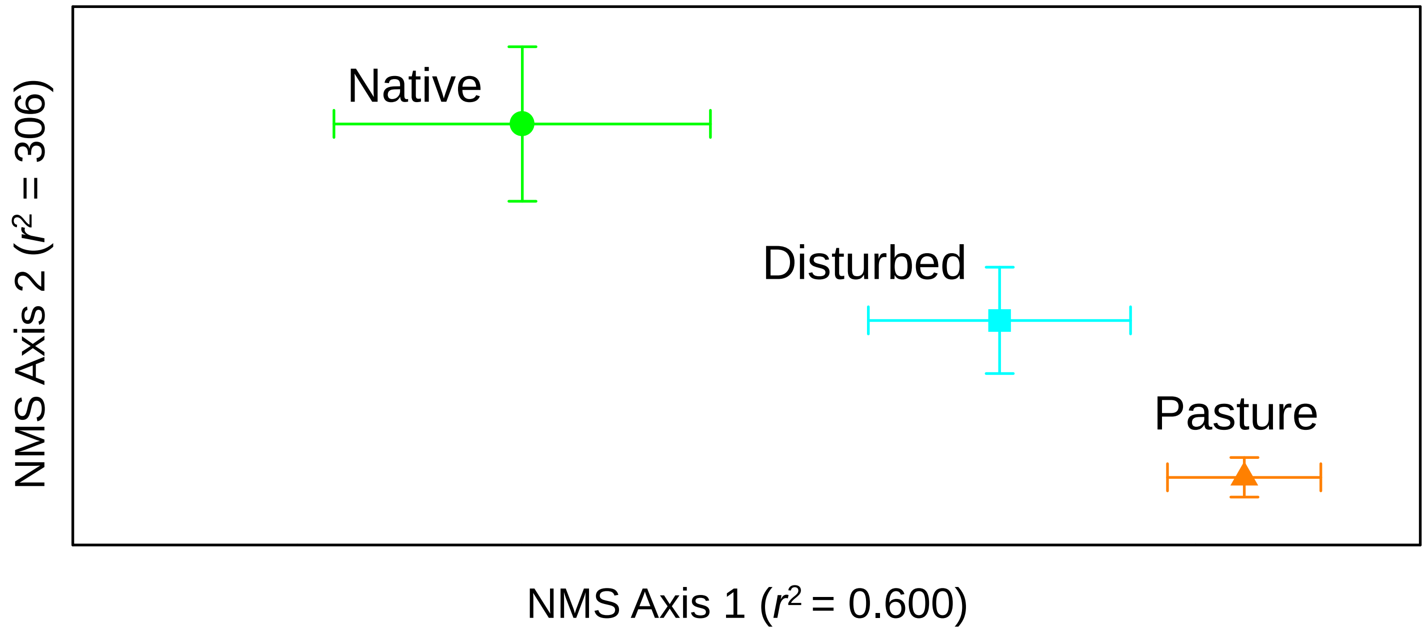
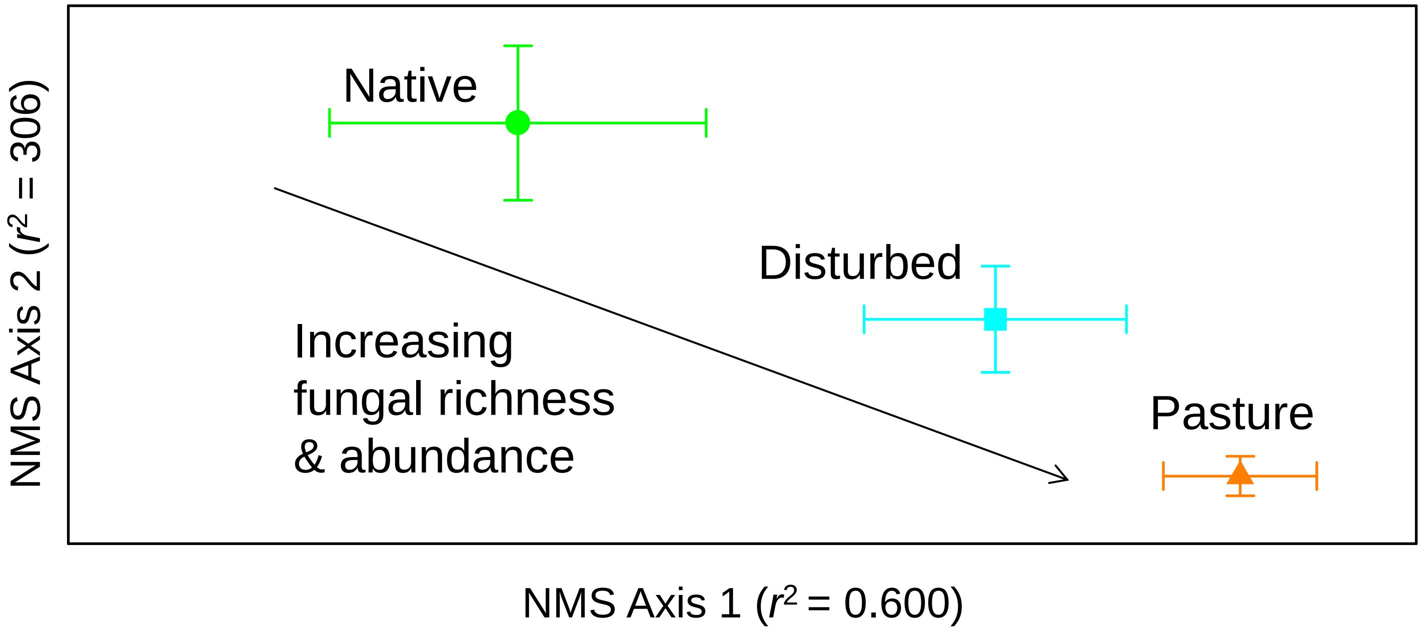
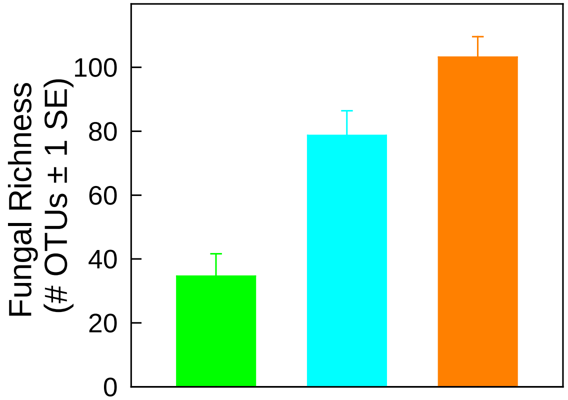
Soil fungi had little overlap among veg types regardless of treatment

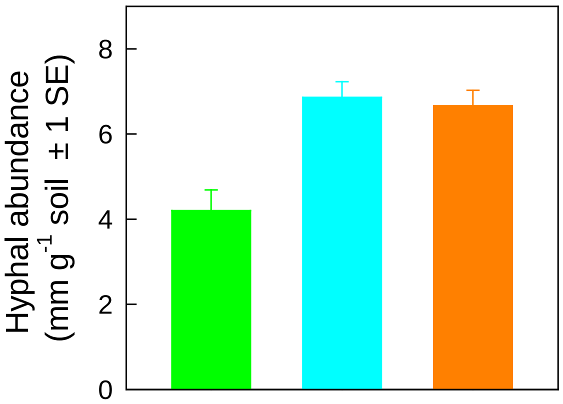


Glinka & Hawkes, in review

Native sites have lower diversity and fewer fungi

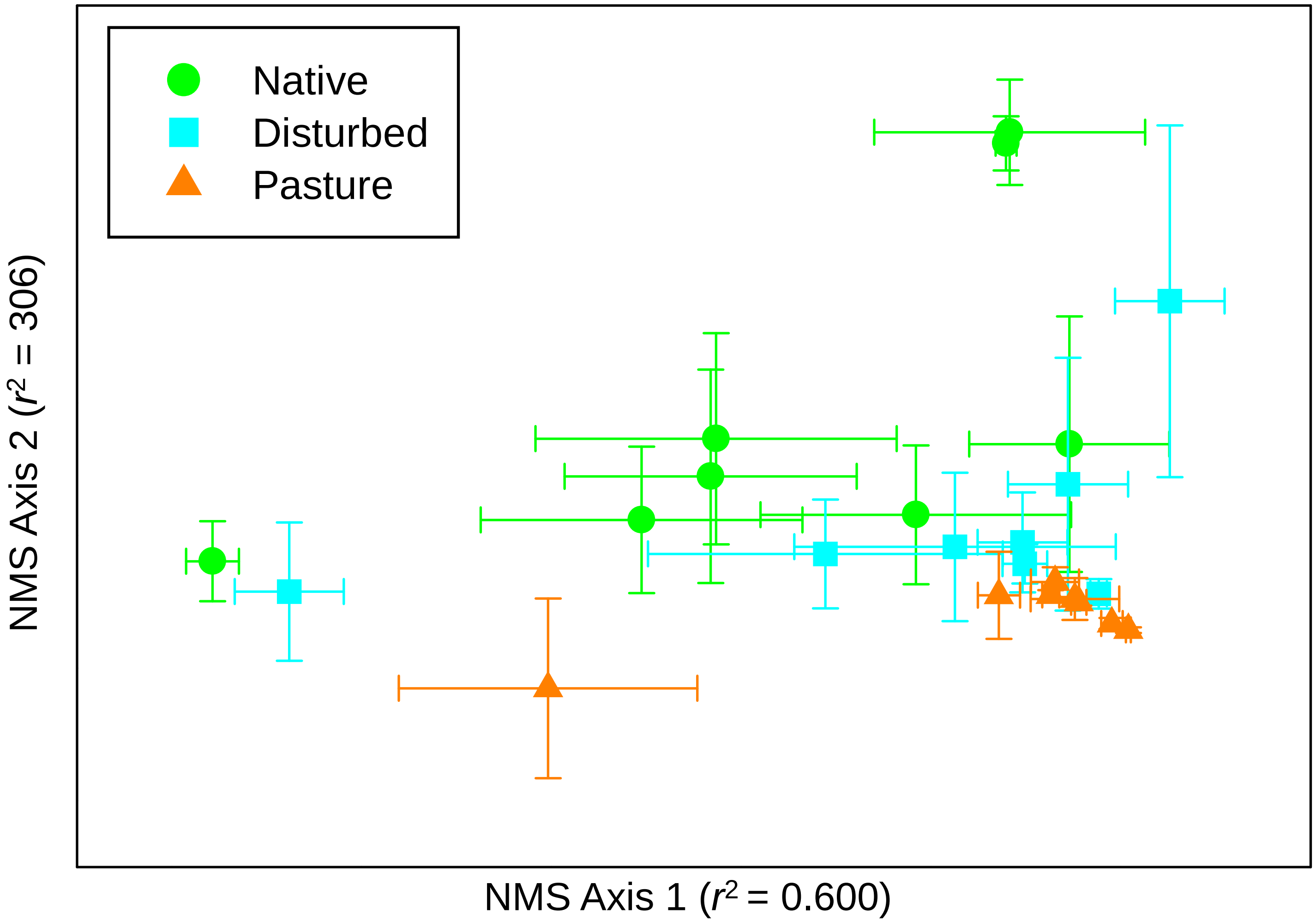






Glinka & Hawkes, in review

Strongest fungal legacy in pastures



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Can we open up the soil black box?

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  - Yes! There are strong differences over three years, likely related to changes in soil organic matter.
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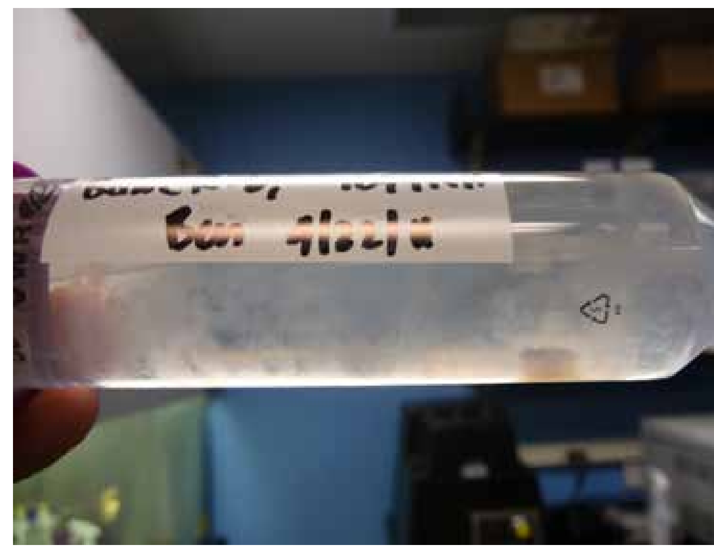
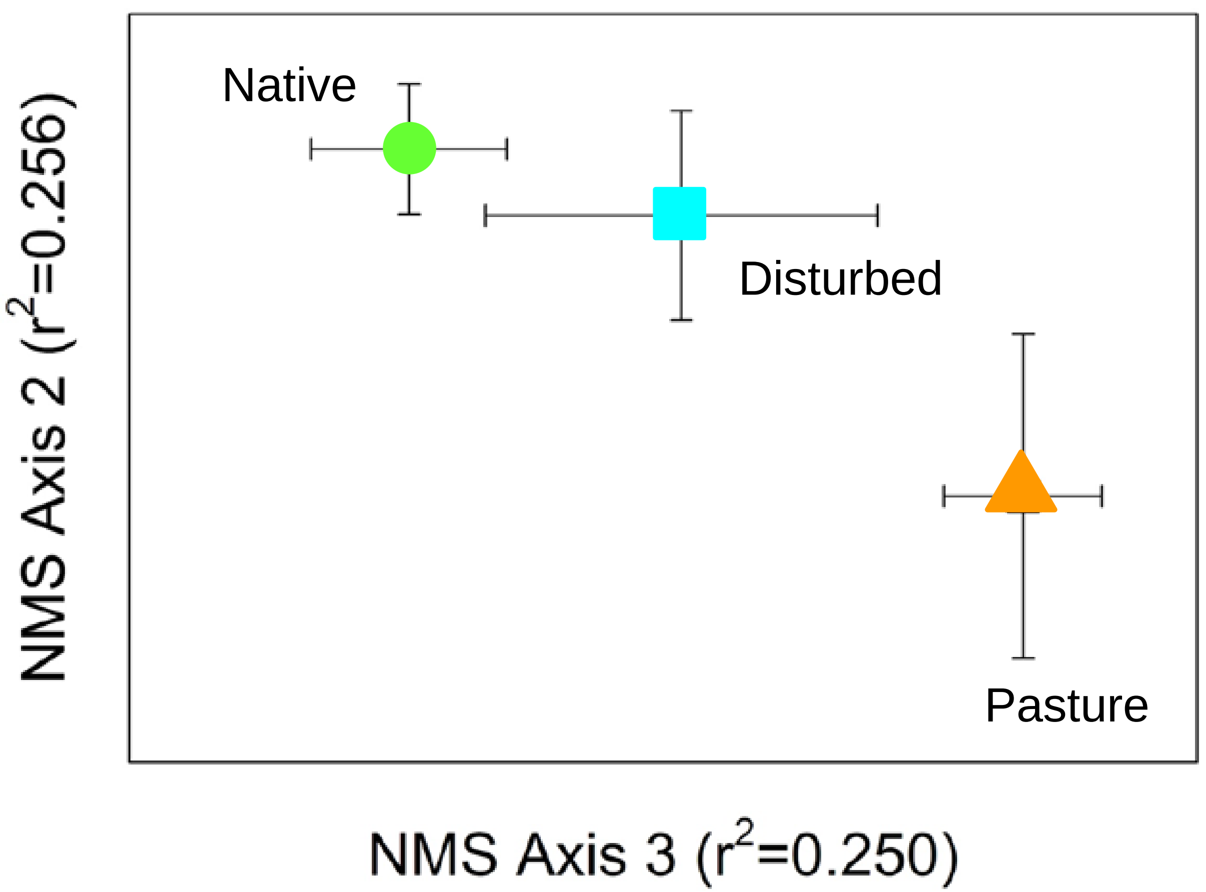
Manipulating specific fungi

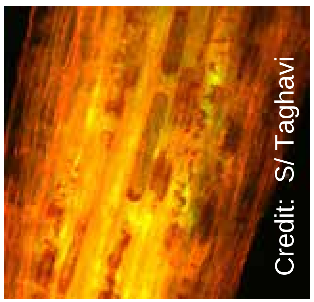


Cultured fungi reflect whole community patterns

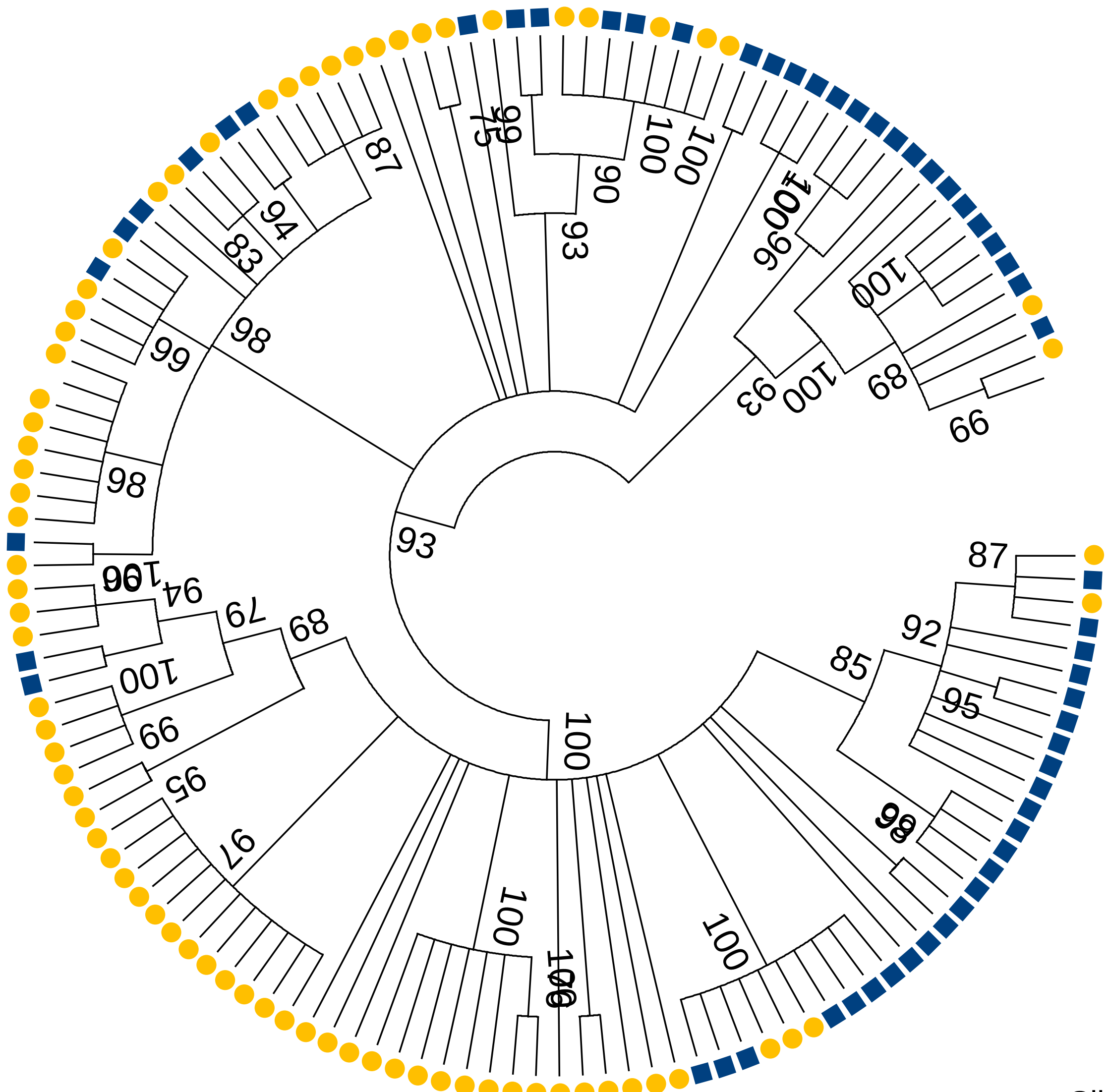


Sikes & Hawkes, unpublished

Cultured root fungi and soil fungi are phylogenetically distinct



Root fungi



Soil fungi

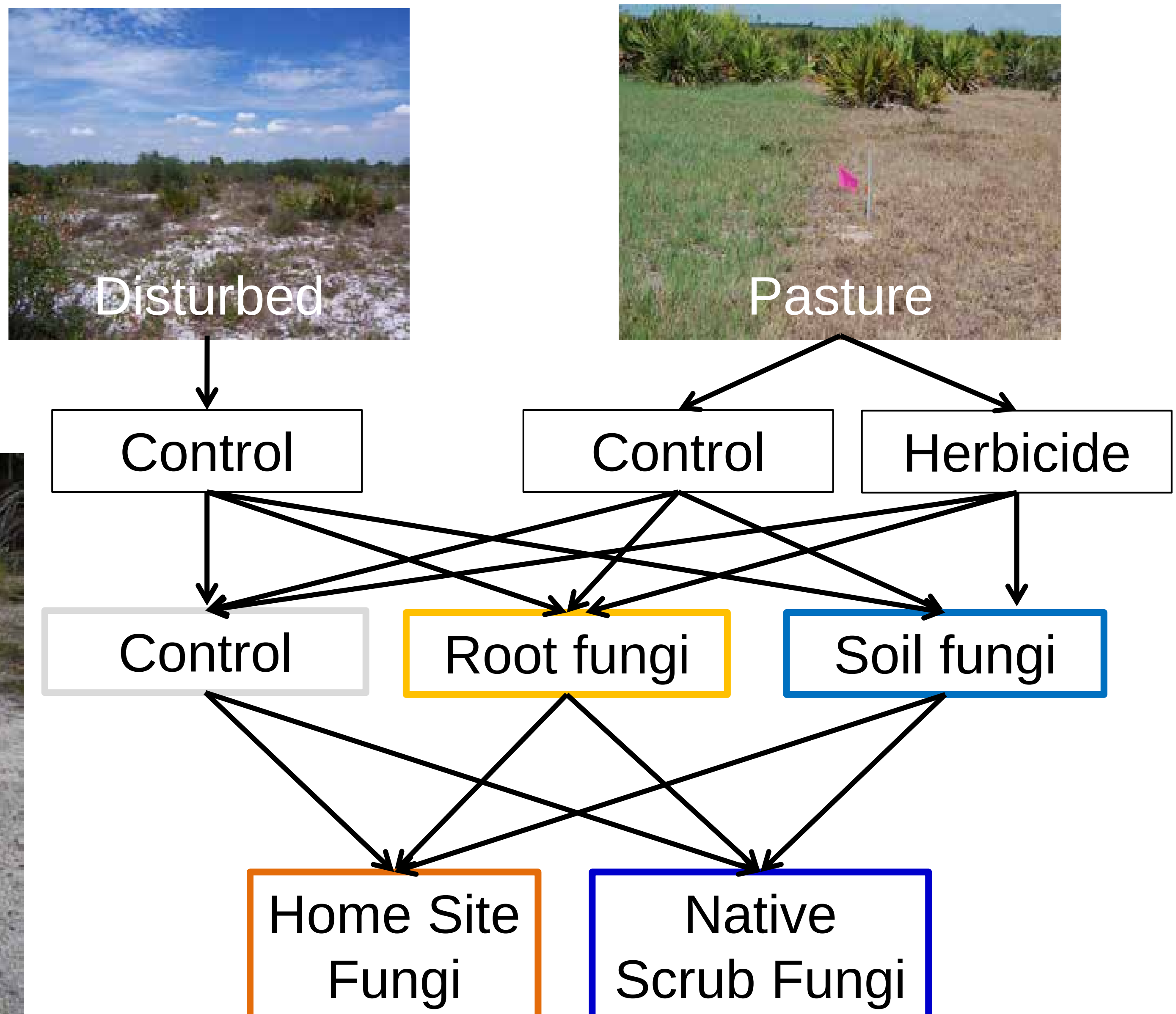
Sikes & Hawkes, unpublished

Select fungi for amendments

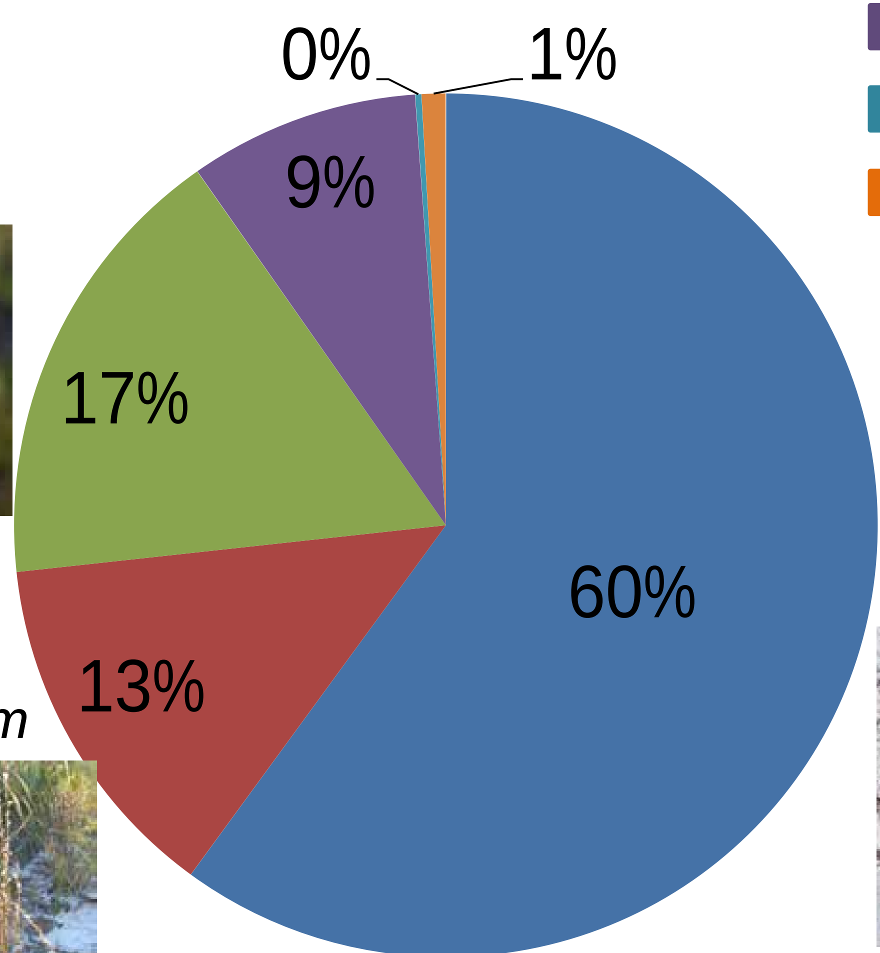
- Fungi selected for variable function based on prior tests of competition and decomposition
- 8 root and 5 soil fungal isolates per site type




Testing fungal effects on restoration efforts



Overall native plant germination was dominated by three species

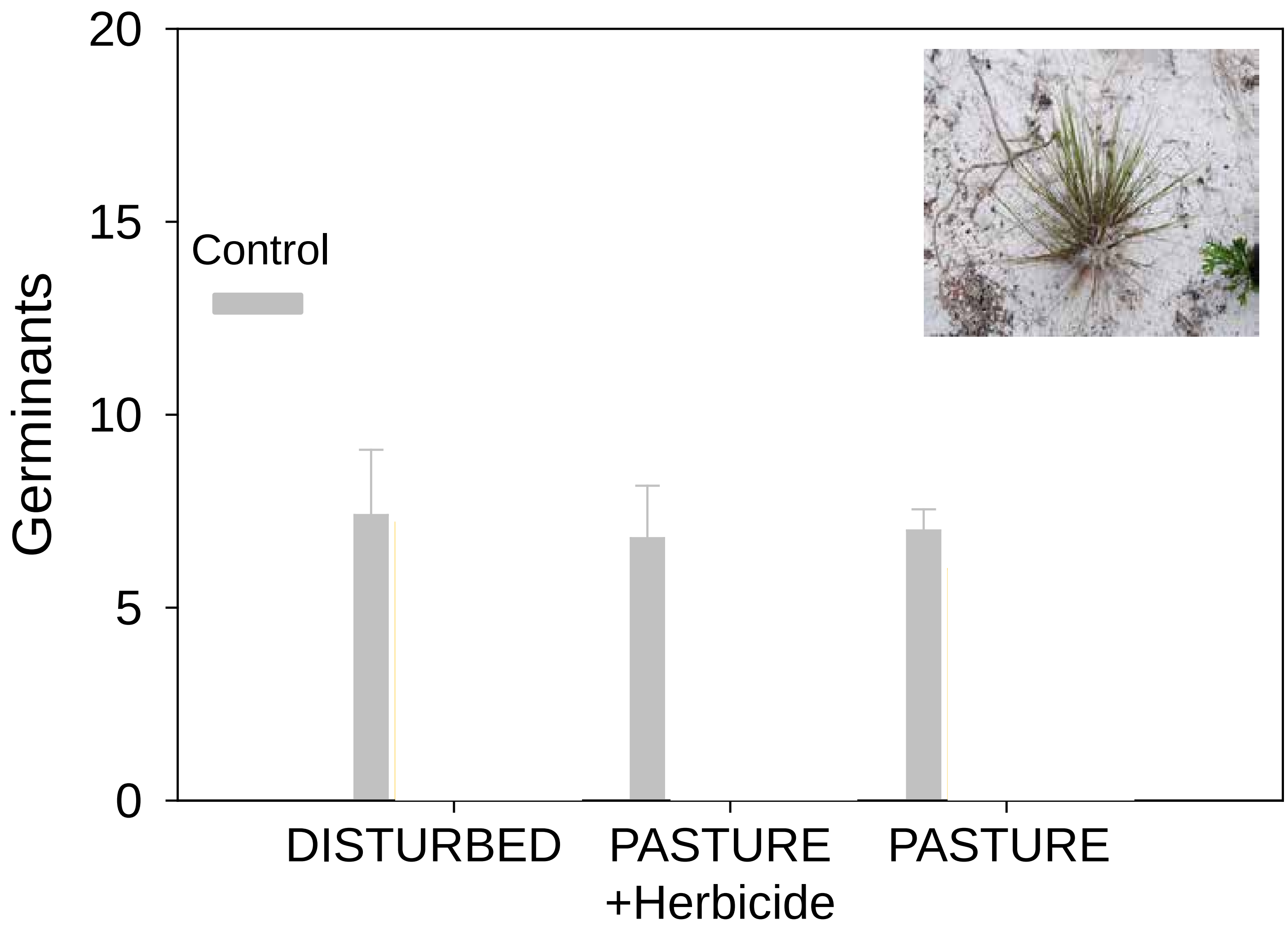


Palafoxia feayi

Schizachyrium niveum

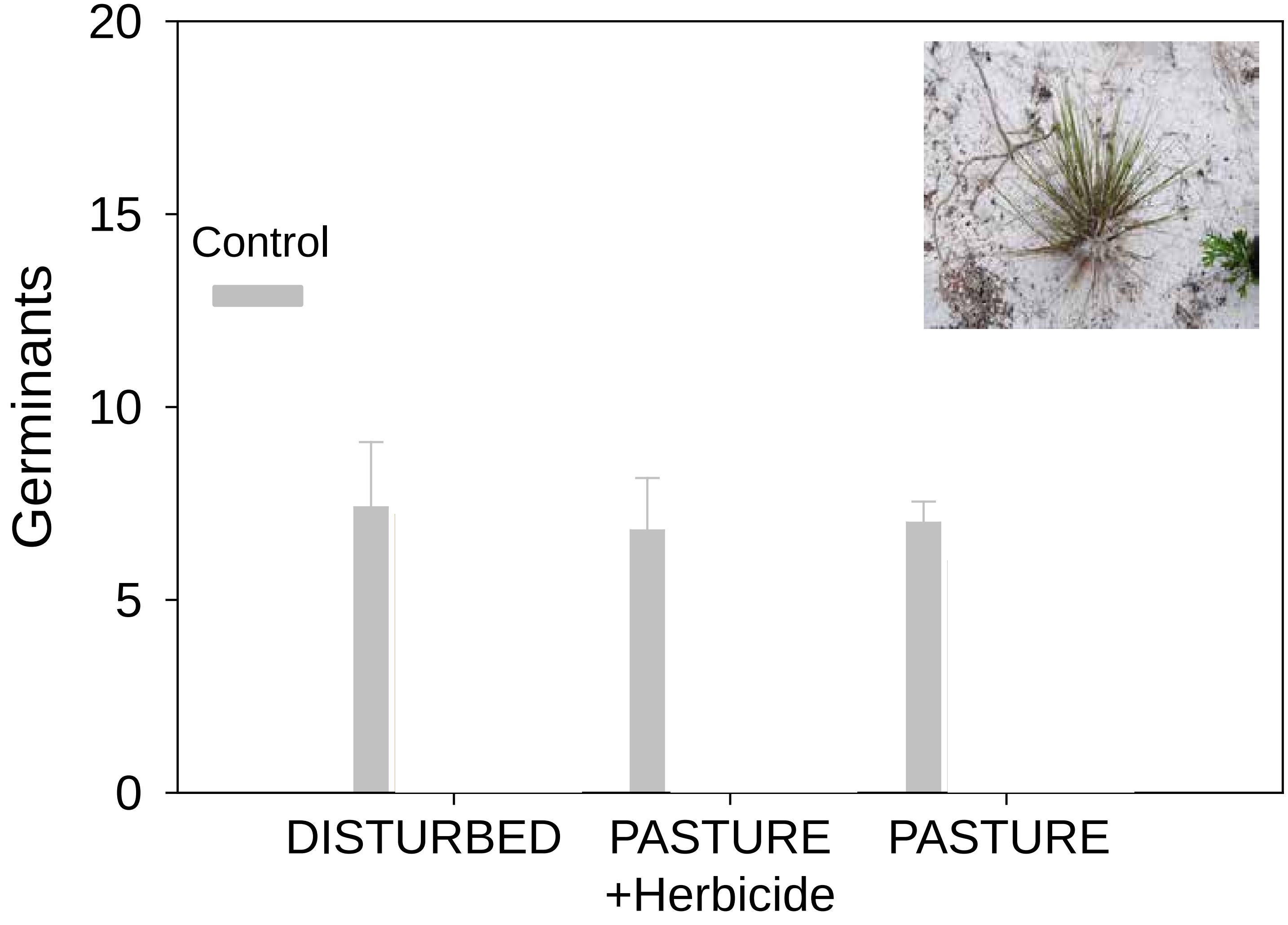
Aristida gyrans

No variation in *Aristida* in the absence of fungi



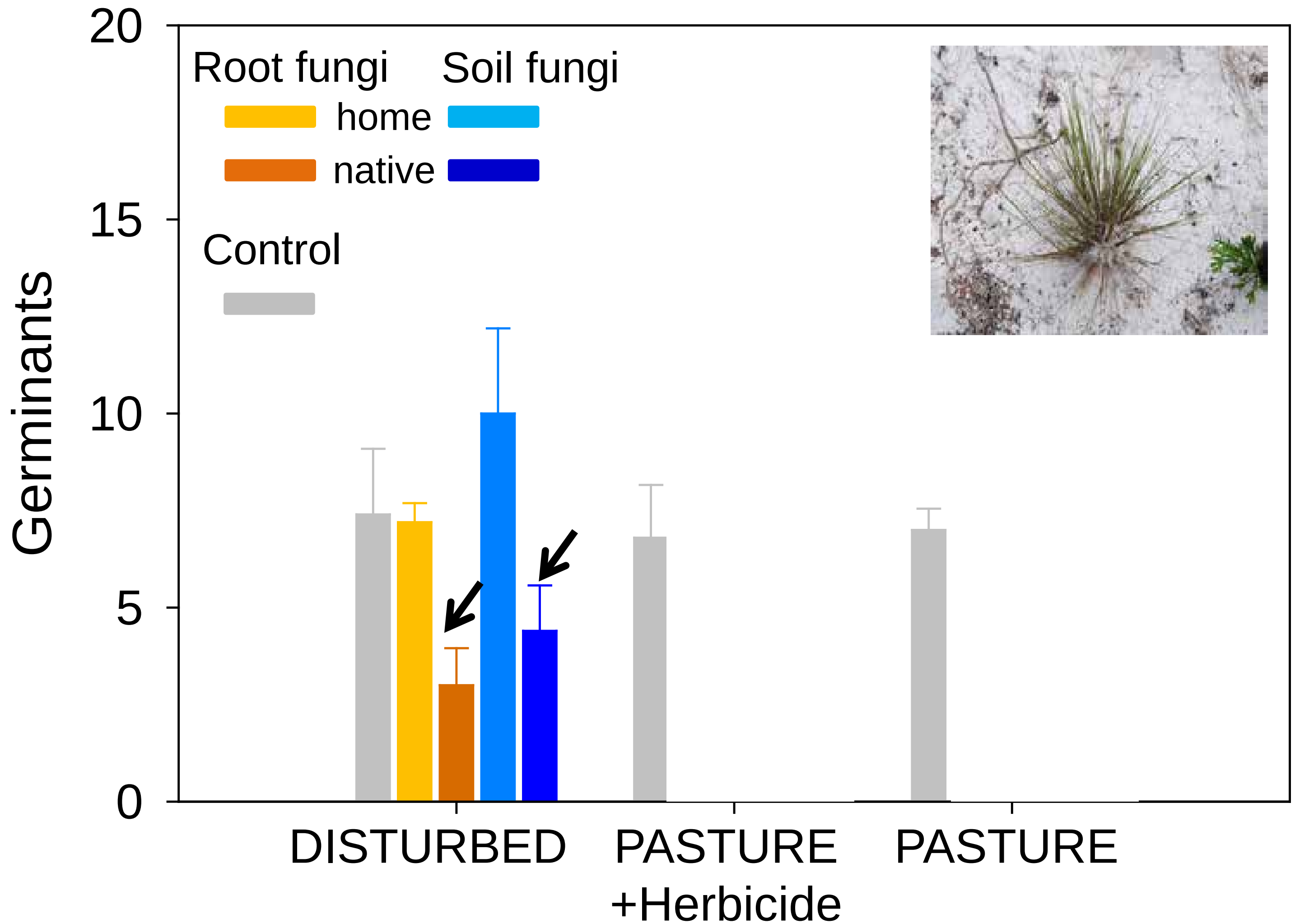
Sikes et al. unpublished data

Fungal effects on *Aristida* were highly context dependent



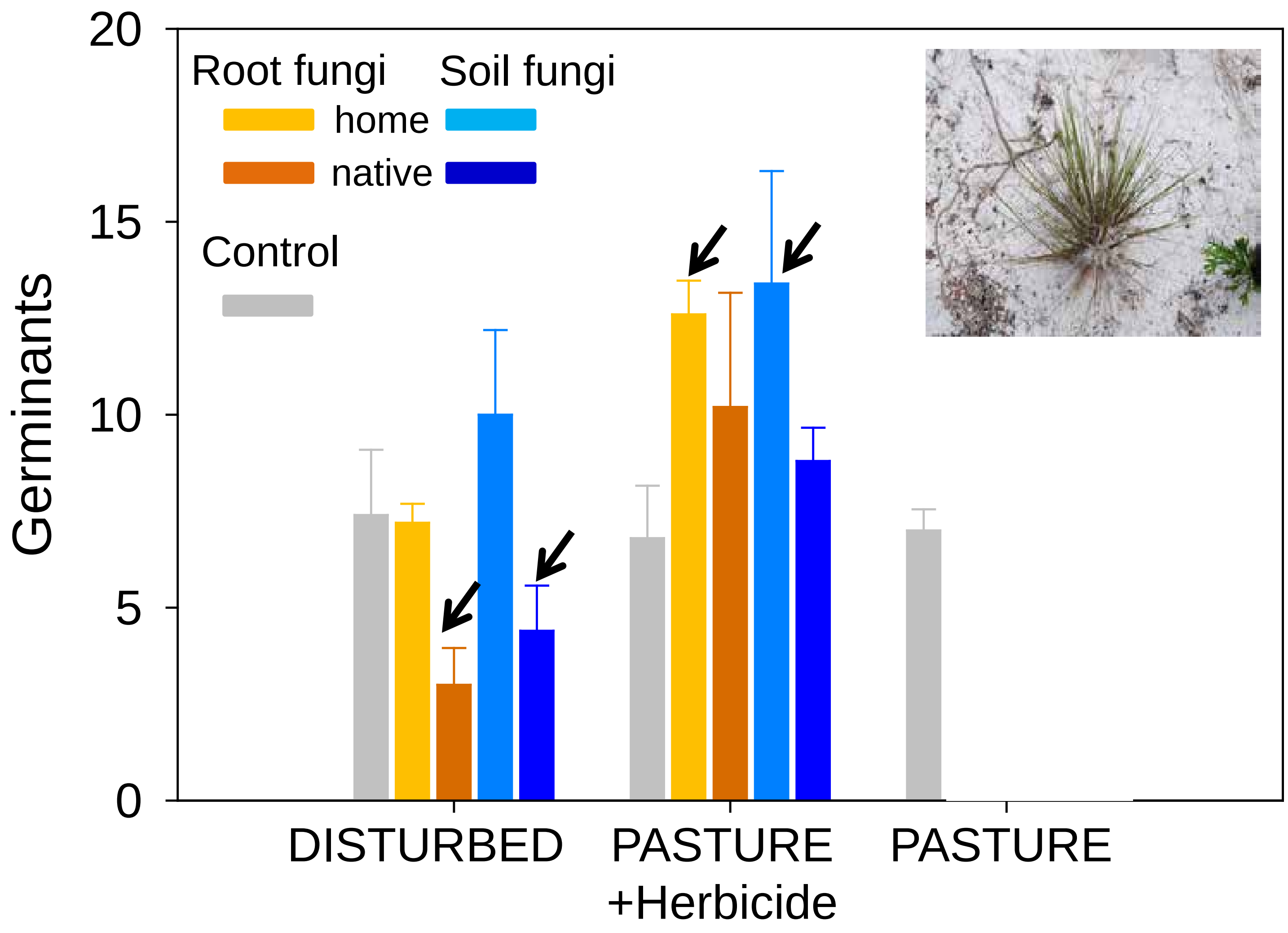
Sikes et al. unpublished data

Aristida germination inhibited in disturbed sites by fungi from native scrub



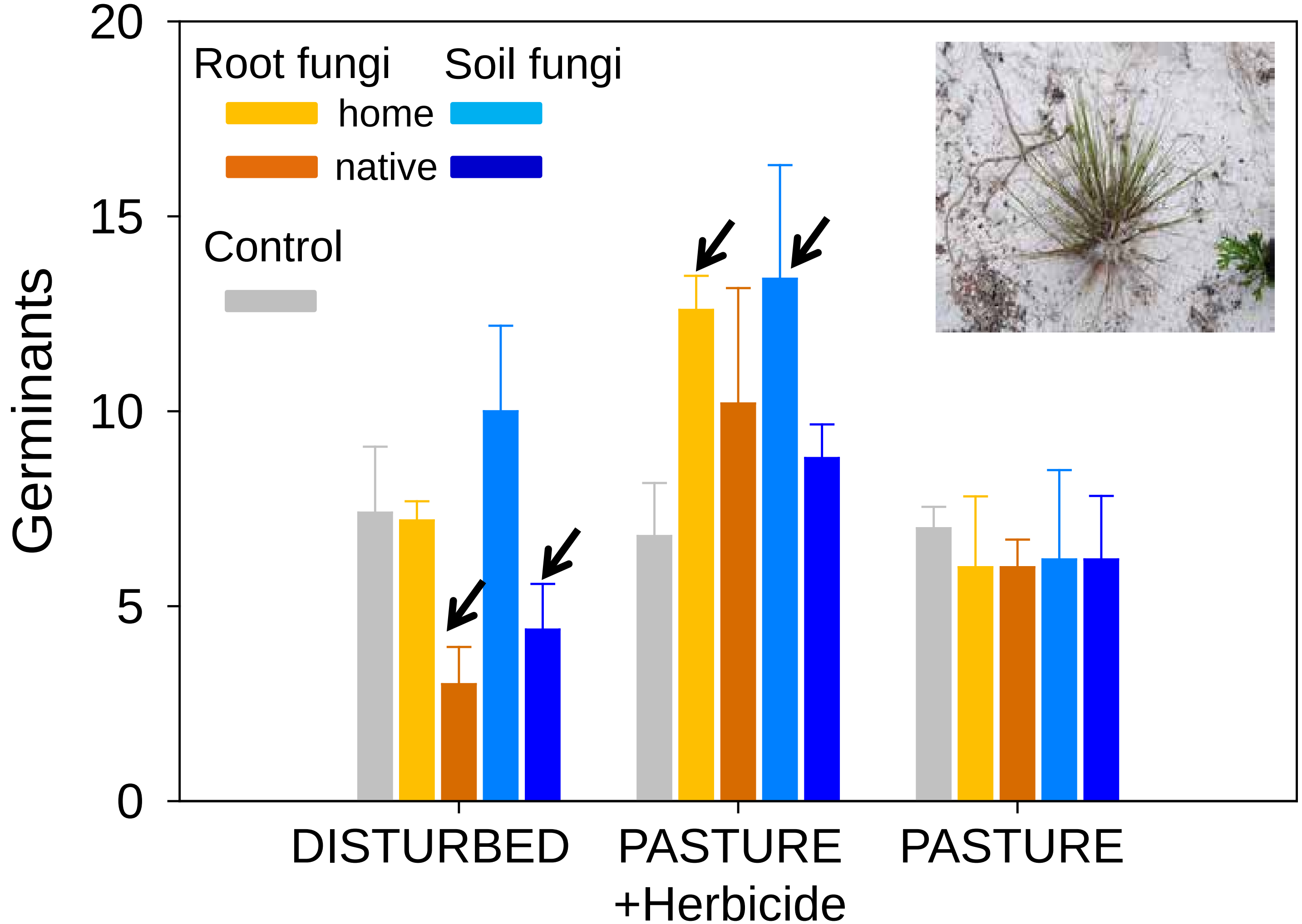
Sikes et al. unpublished data

Fungi from pastures improved *Aristida* germination in pastures with veg removed



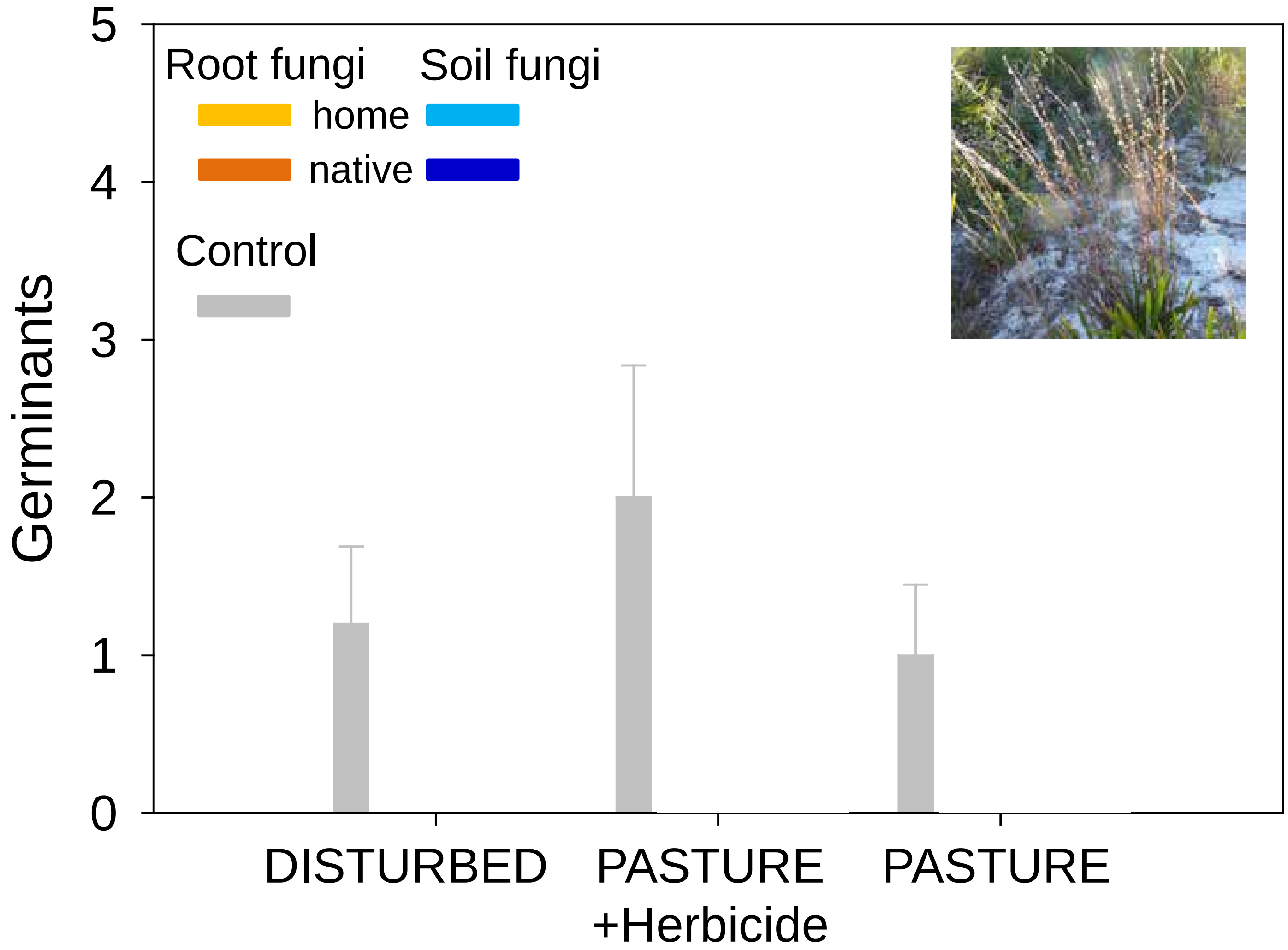
Sikes et al. unpublished data

Fungi had no effect on *Aristida* germination in pastures when grasses were not removed



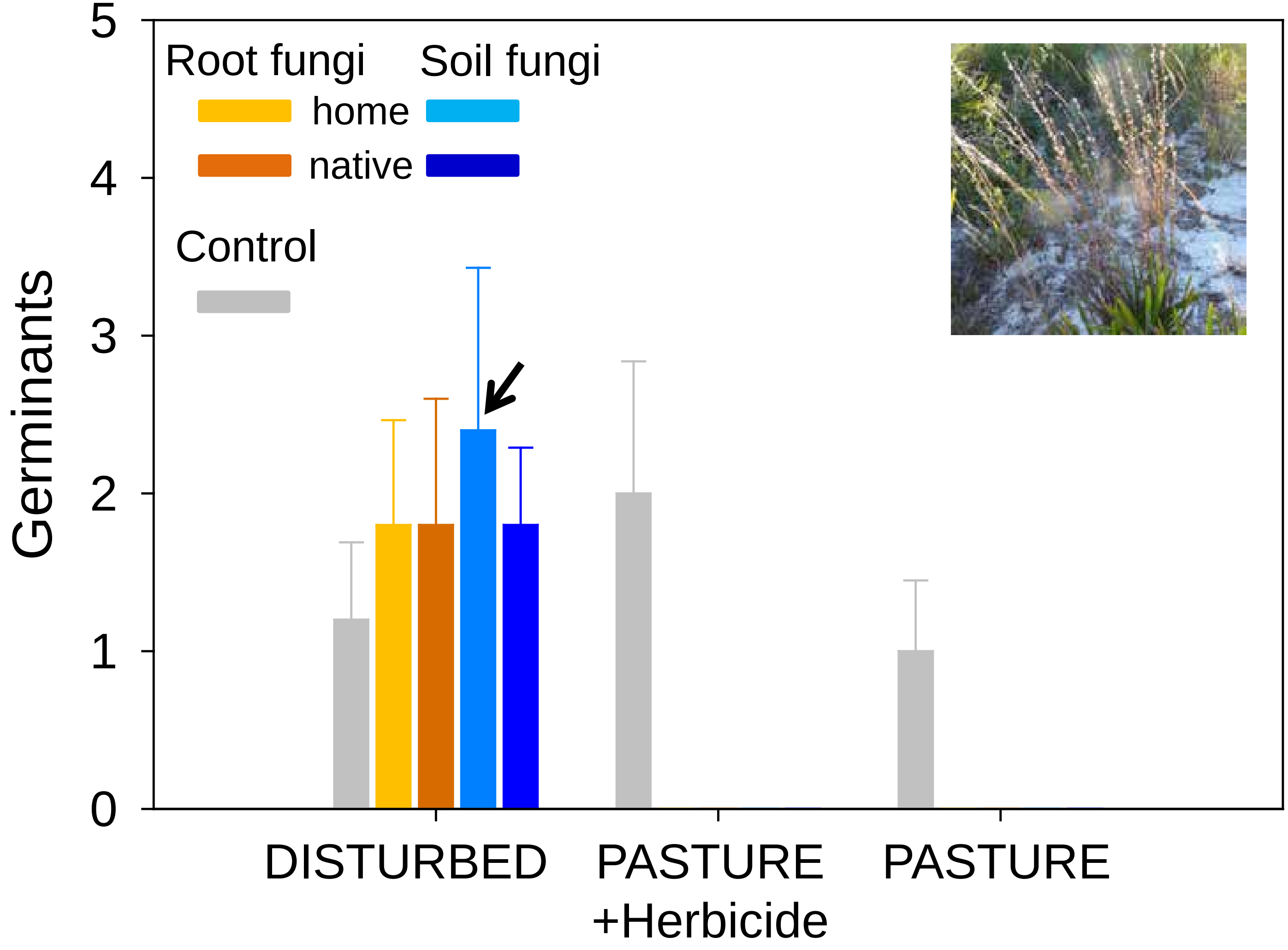
Sikes et al. unpublished data

Without fungi, *Schizachyrium* germination varied little across sites



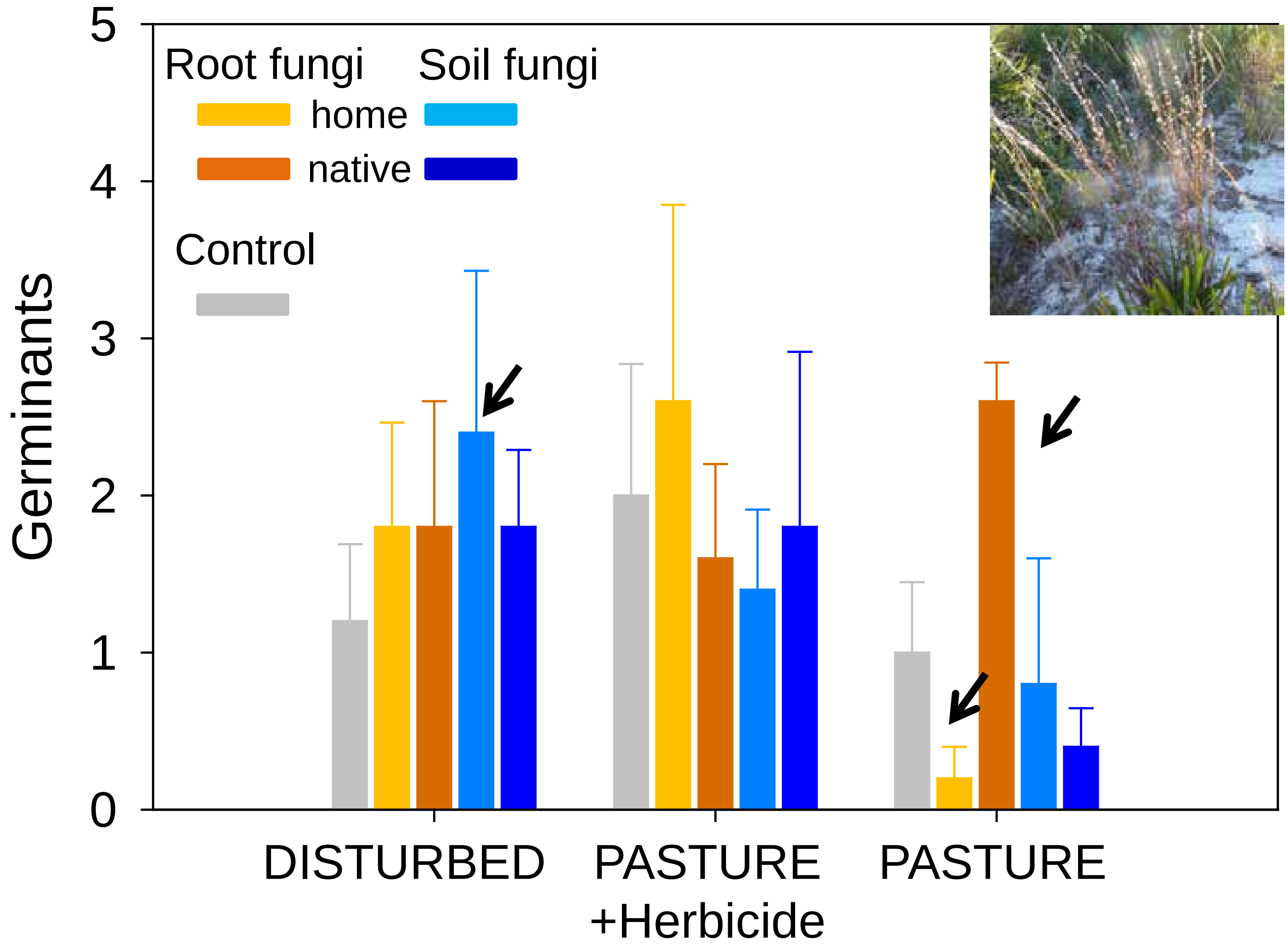
Sikes et al. unpublished data

Fungi from disturbed sites improved *Schizachyrium* germination in disturbed sites



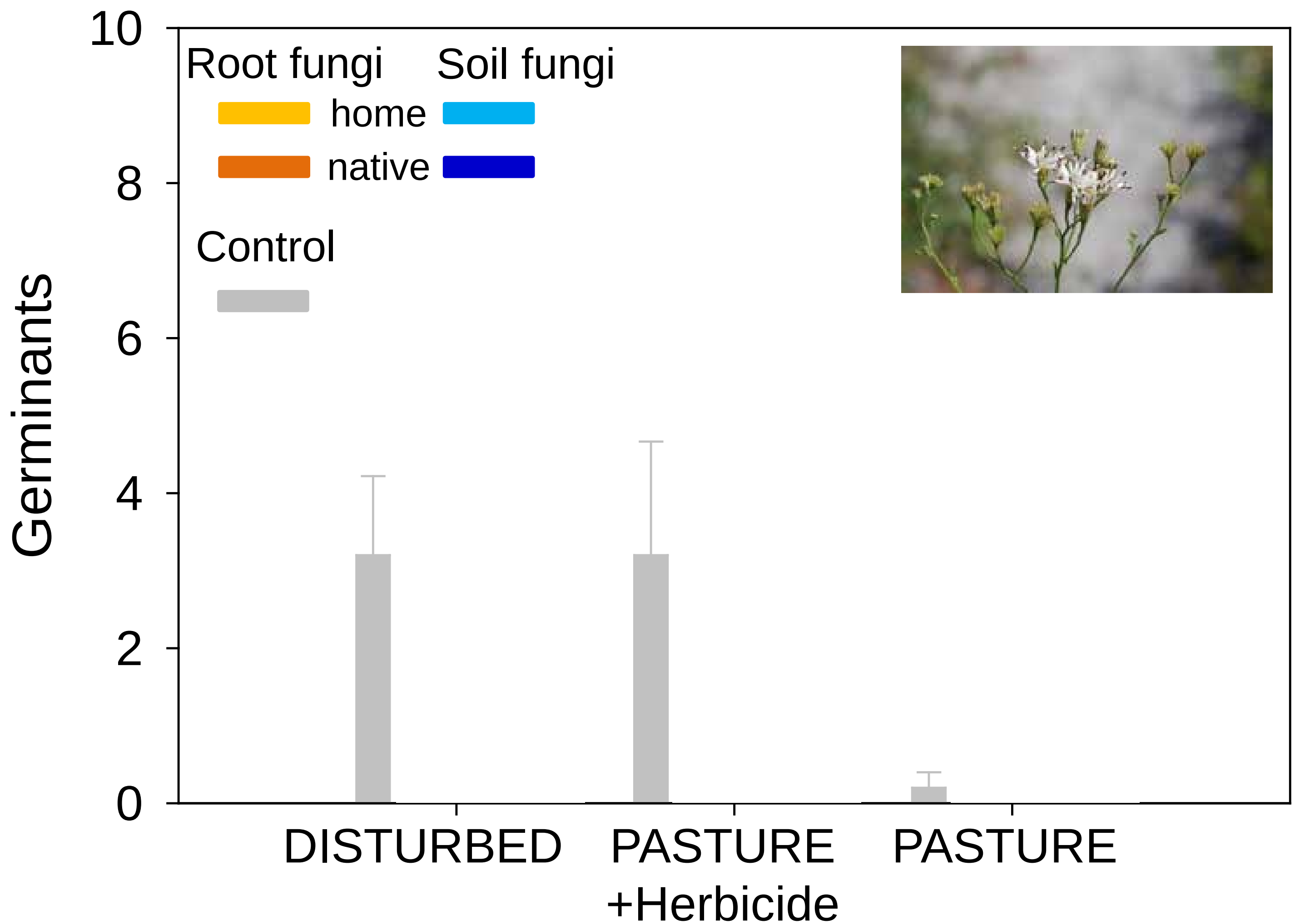
Sikes et al. unpublished data

In pastures, root fungi from native scrub improved *Schizachyrium* germination



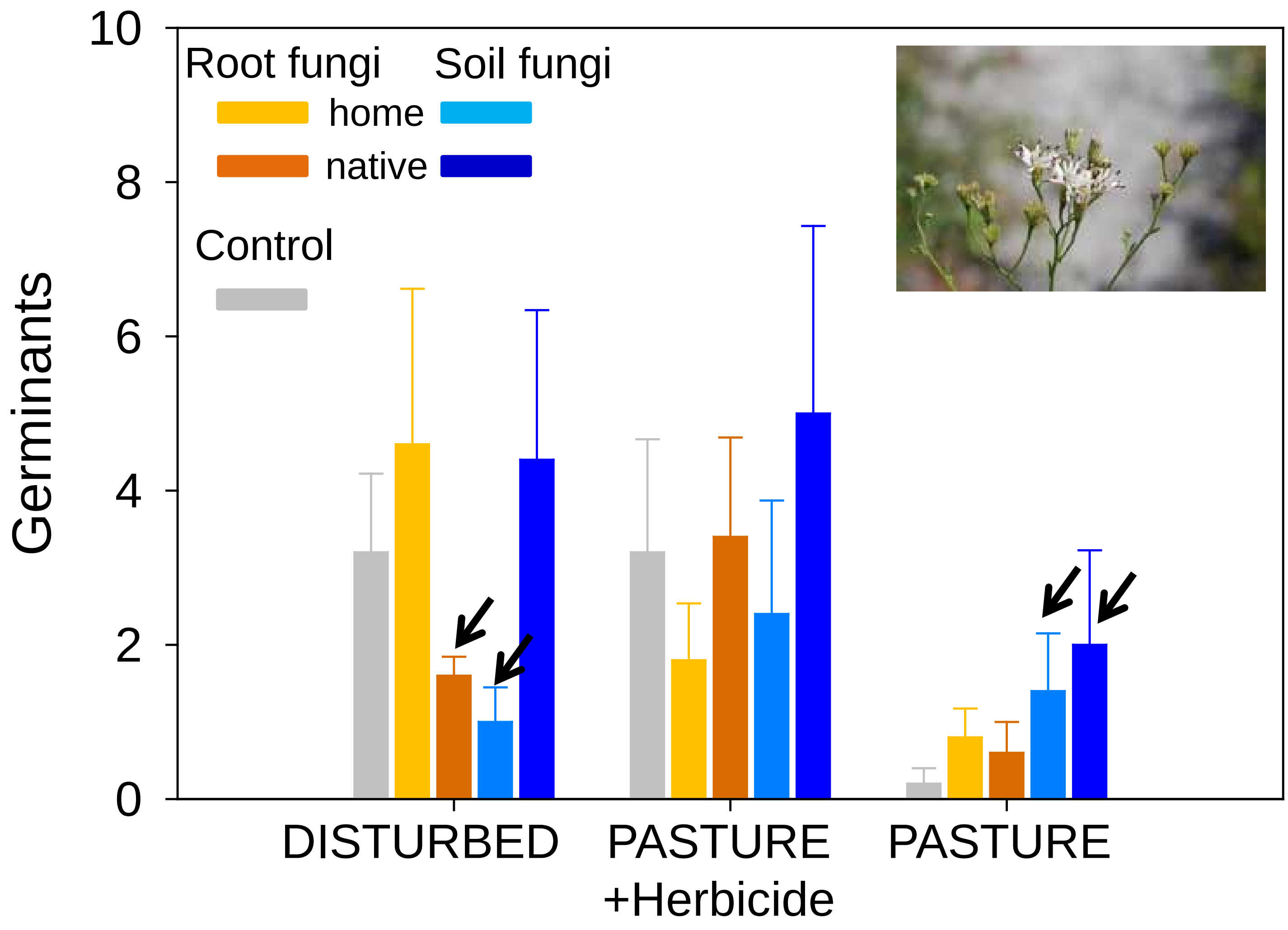
Sikes et al. unpublished data

Palafoxia germination lower in pastures without fungi



Sikes et al. unpublished data

Fungal effects on *Palafoxia* are also highly context dependent



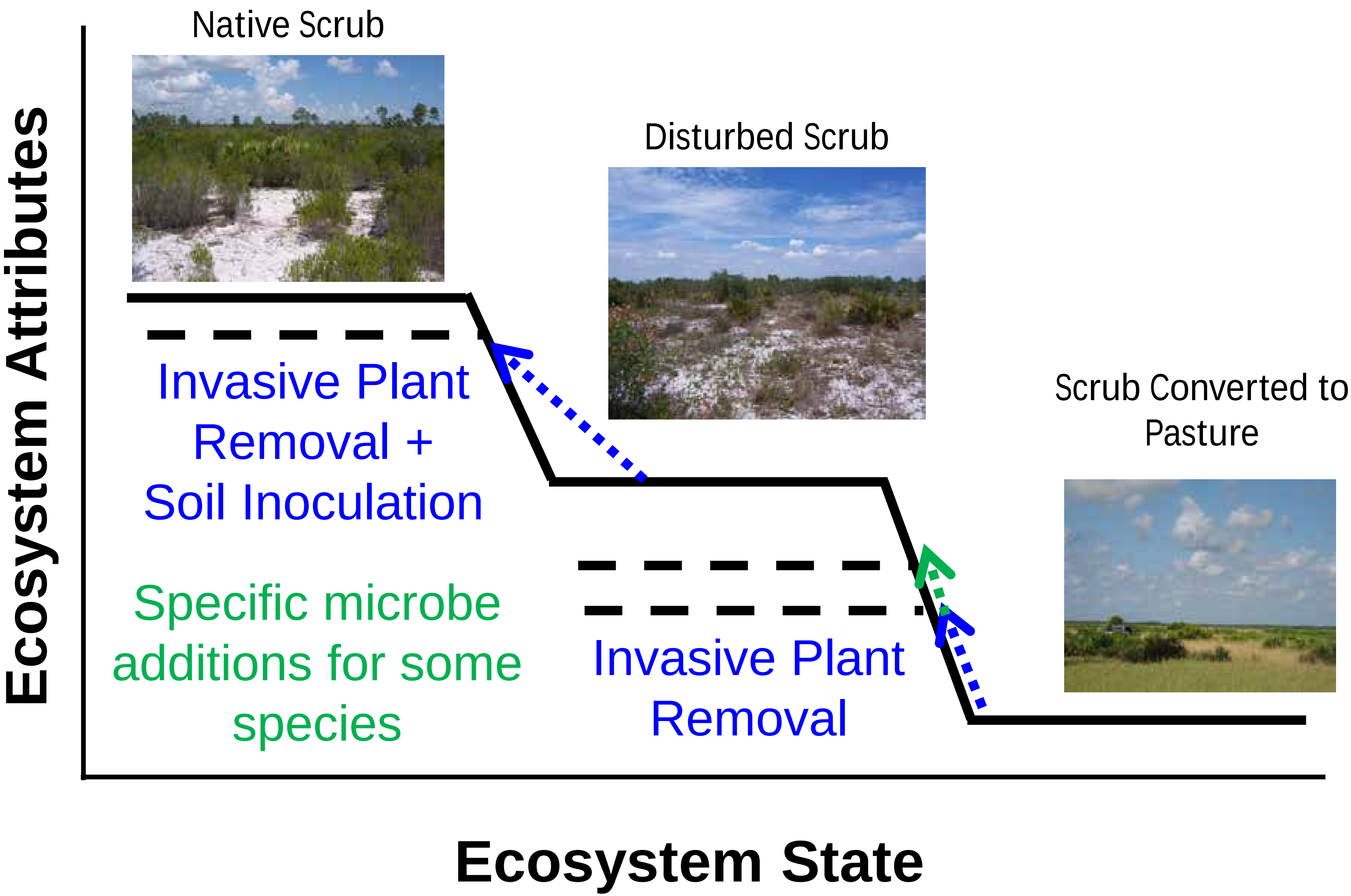
Sikes et al. unpublished data

Can we open up the soil black box?

- How do **fungal** communities differ among native, disturbed, and pasture sites? Do those differences persist?
  - Yes! There are strong differences over three years, likely related to changes in soil organic matter.

- Can we use what we learn to further enhance restoration success?
  - Potentially, but it is not straightforward and may be both species- and site-specific

Different approaches overcome legacies to different degrees

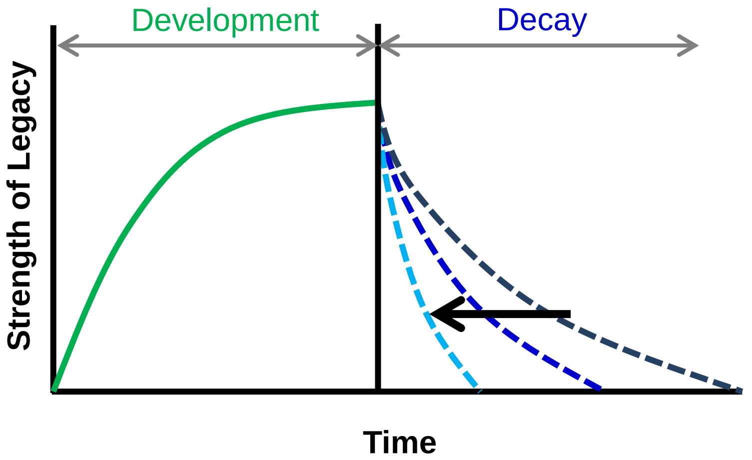


When should we address legacy effects?

- Amount of effort should be based on the balance of resources required, potential efficacy, and degree of need

- Many new studies coming out manipulating microbes and finding improved restoration, but the field is still in its infancy

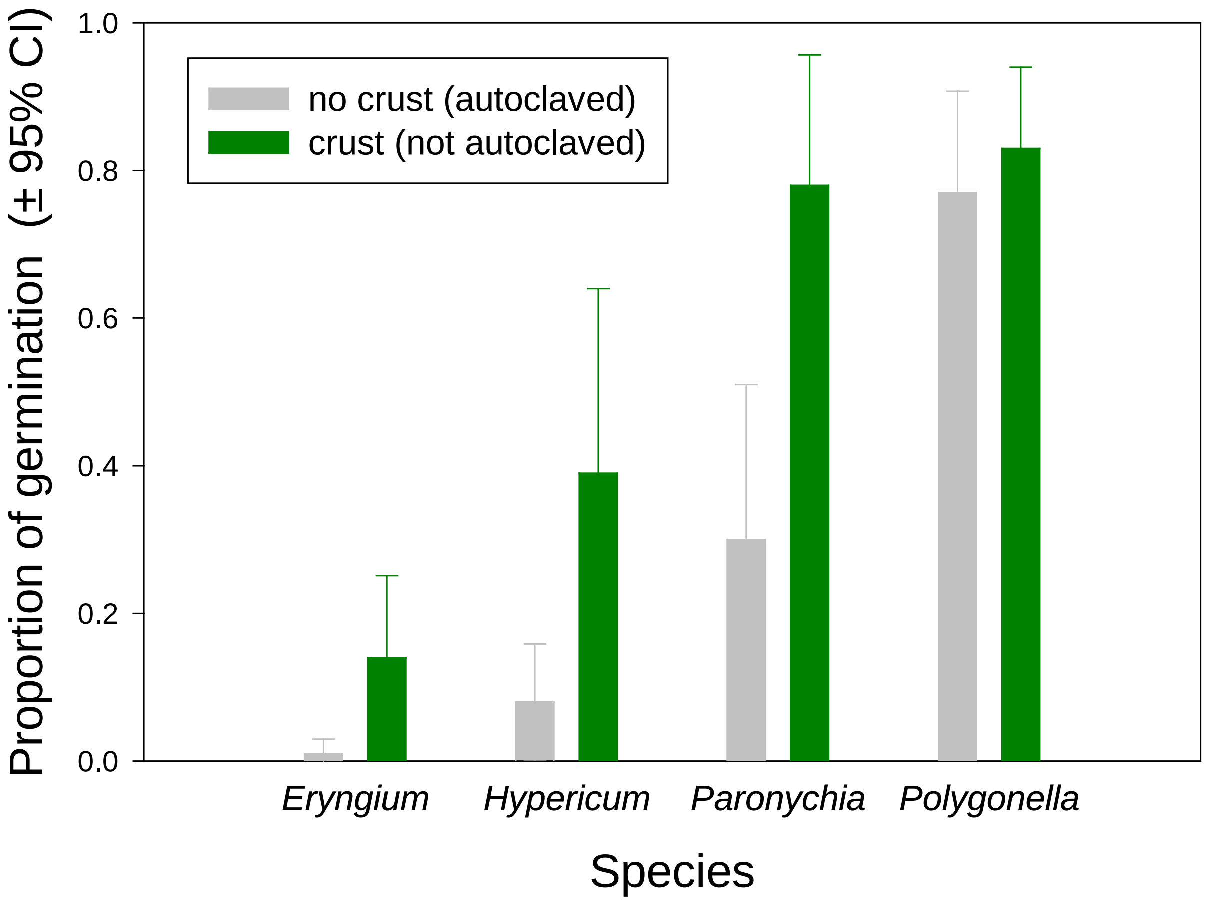
- General rules?



Thank you!

- Hawkes Lab
  - Erin Brault
  - Clare Glinka
  - Nick Johnson
  - Ben Sikes
- Archbold Biological Station
  - Eric Menges
  - Hilary Swain
  - Patrick Bohlen
  - Stacy Smith
- USDA NRI Managed Ecosystems Program
- Smith Fellows Program

Four of these species were also differentially sensitive to microbes



Hawkes 2004 Plant Ecology