Identifying and Remediating the Microbial Legacy Effects of Invasive Grasses for the Purposes of Improved Restoration

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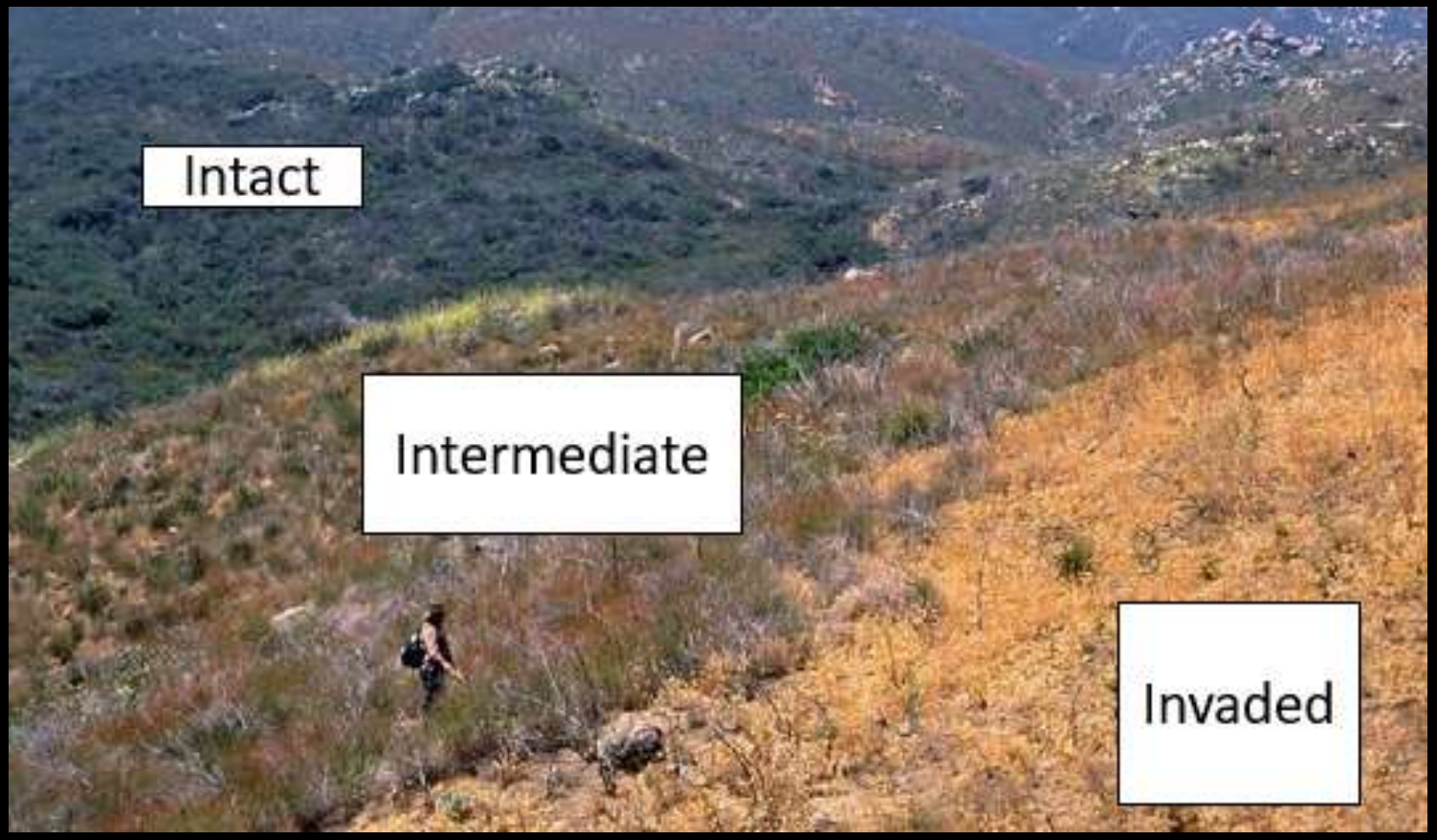


Plant Invasion

Invasive Grasses

- 90% decrease in native shrub cover
- **But how do invasive plants alter the soil microbial community?**

1. Disrupt microbial mutualistic associations with native plants
2. Take advantage existing microbes

- How does this impact native plant growth?
- If it does, how do we restore after microbial alterations?

Background

- *Phalaris aquatica* is an invasive perennial bunchgrass in the Santa Monica Mountains of California
- 8 years of removal over 25 acre, but native species recruitment was minimal
- Does lack of native growth suggest soil legacy effects of *Phalaris*?
- Legacy effects

Greenhouse Project

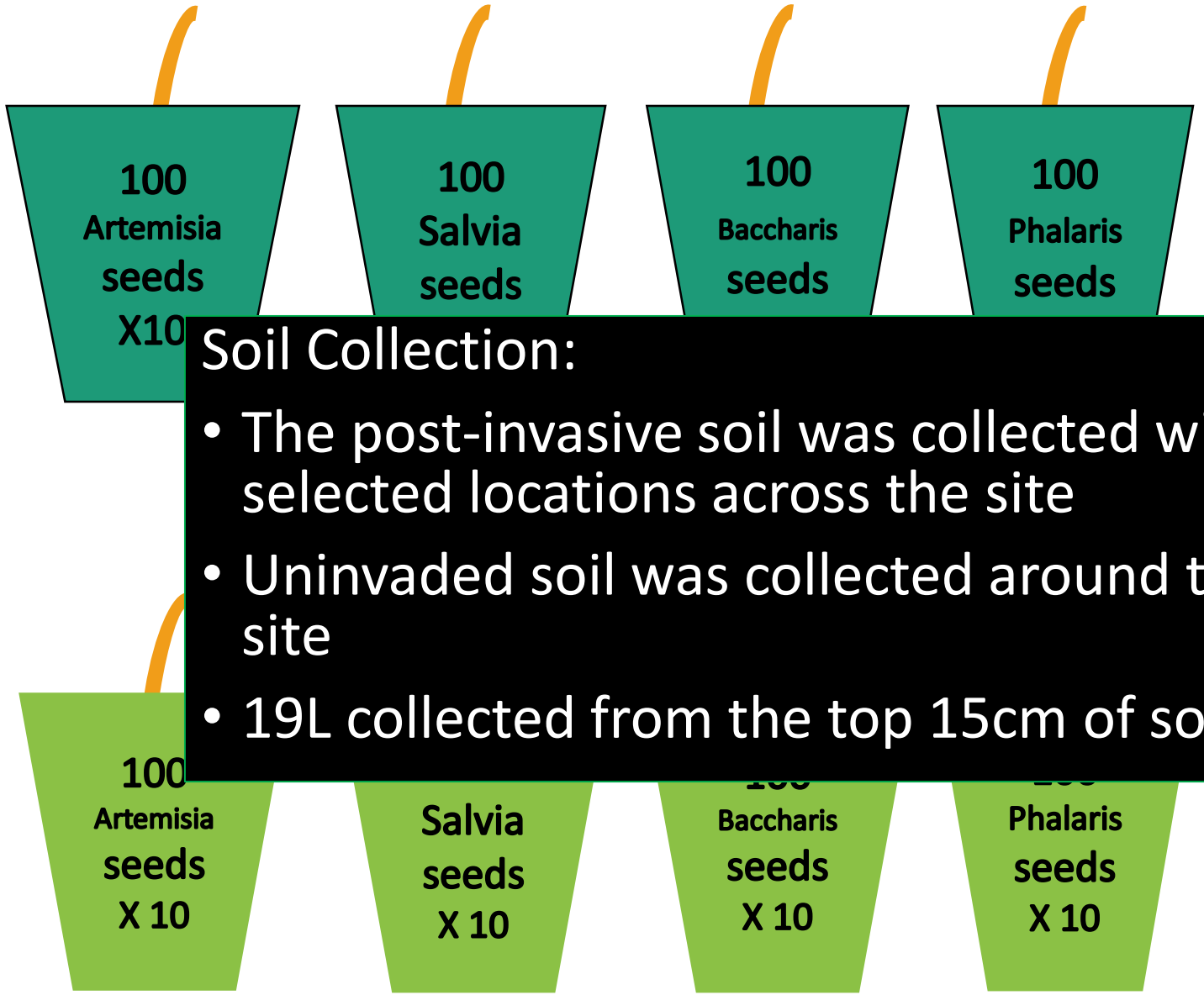
Do native and invasive plants differ in growth rate and size in uninvaded vs. post-invasive soil?

Which native species will survive best in the soil after invasive removal?

Pickett B, Irvine IC, Bullock E, Arogyaswamy K, Aronson E (2019) Legacy effects of invasive grass impact soil bacteria and native shrub growth. *Invasive Plant Science and Management*. 12:32-35.

Three CSS Native Species and One Invasive Species Grown in Post-invasive or Uninvaded Soil

- *Artemisia californica*
- *Salvia leucophylla*
- *Baccharis pilularis*
- *Phalaris aquatica*



Soil Collection:

- The post-invasive soil was collected within ~10 randomly selected locations across the site
- Uninvaded soil was collected around the 25 acre post-invasive site
- 19L collected from the top 15cm of soil

Greenhouse Setup

1. Collected post-invasive and uninvaded soil

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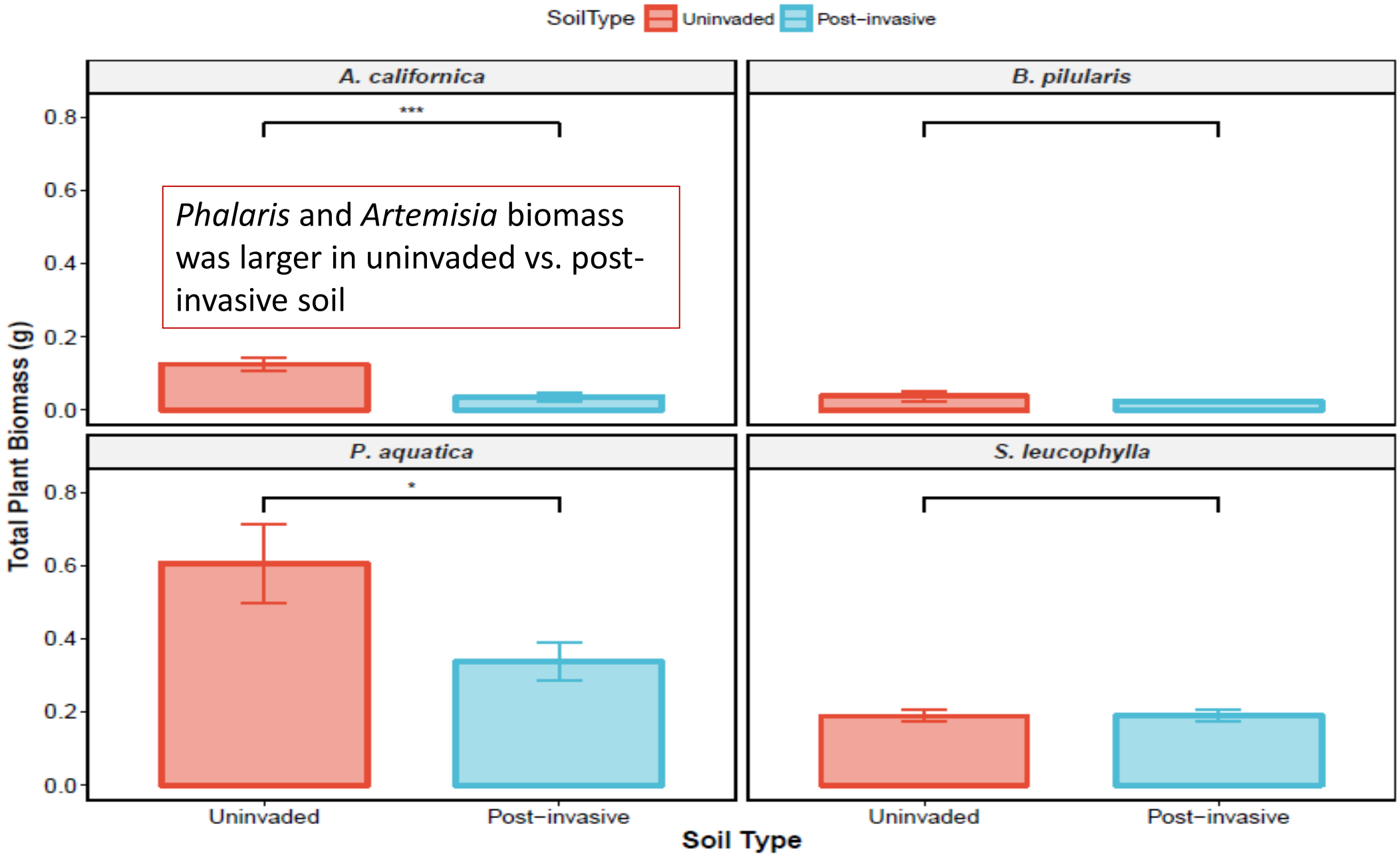
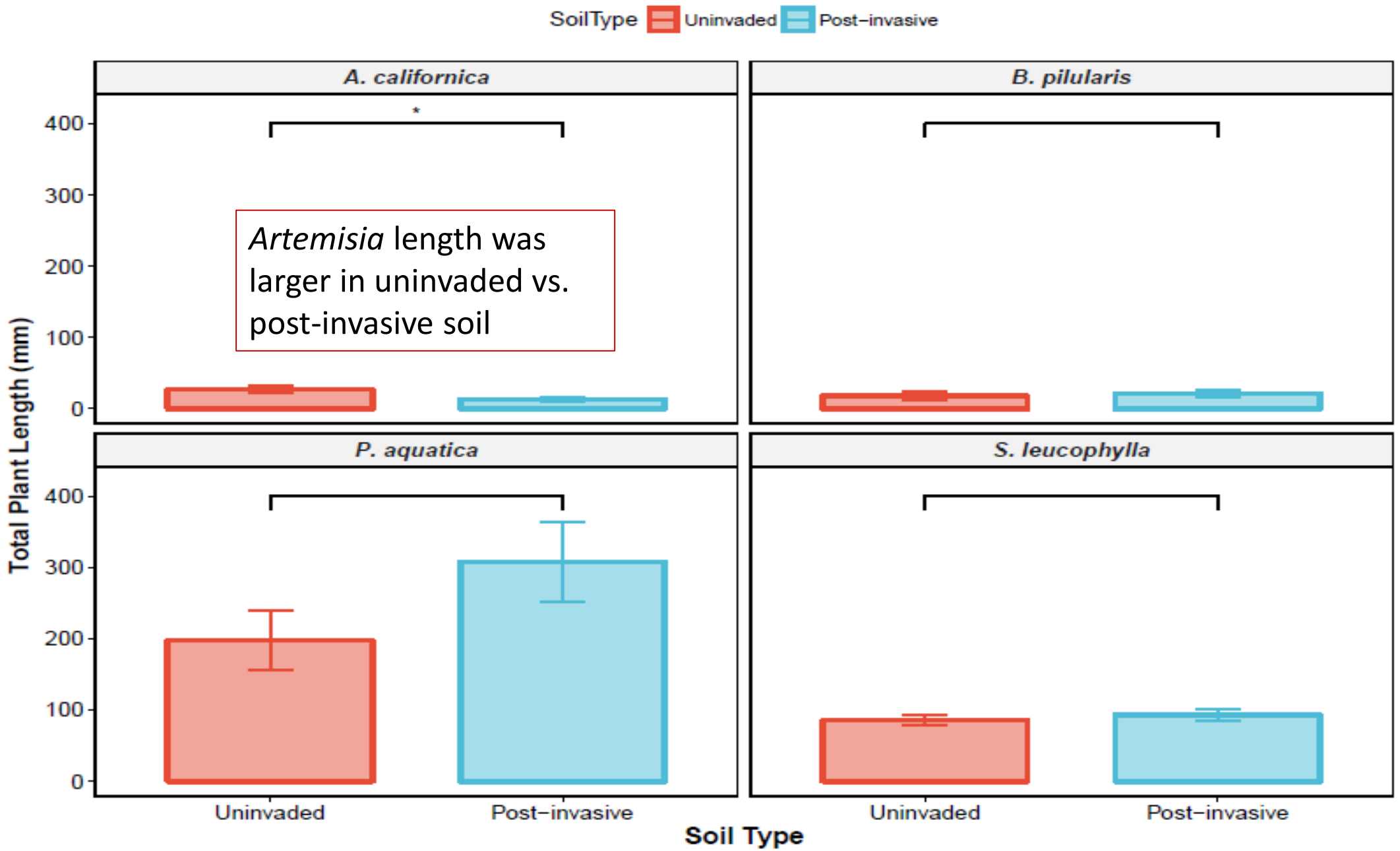
3. After seven months of growth in the greenhouse, the seedlings were dried and measured

Mean Total Seedling Biomass by Species in Soil Type



Phalaris and *Artemisia* biomass was larger in uninvaded vs. post-invasive soil

Mean Total Seedling Length by Species in Soil Type



Artemisia length was larger in uninvaded vs. post-invasive soil

Visual Representation of Graphs: Change in plant growth with soil type

Artemisia californica

Phalaris aquatica

Results

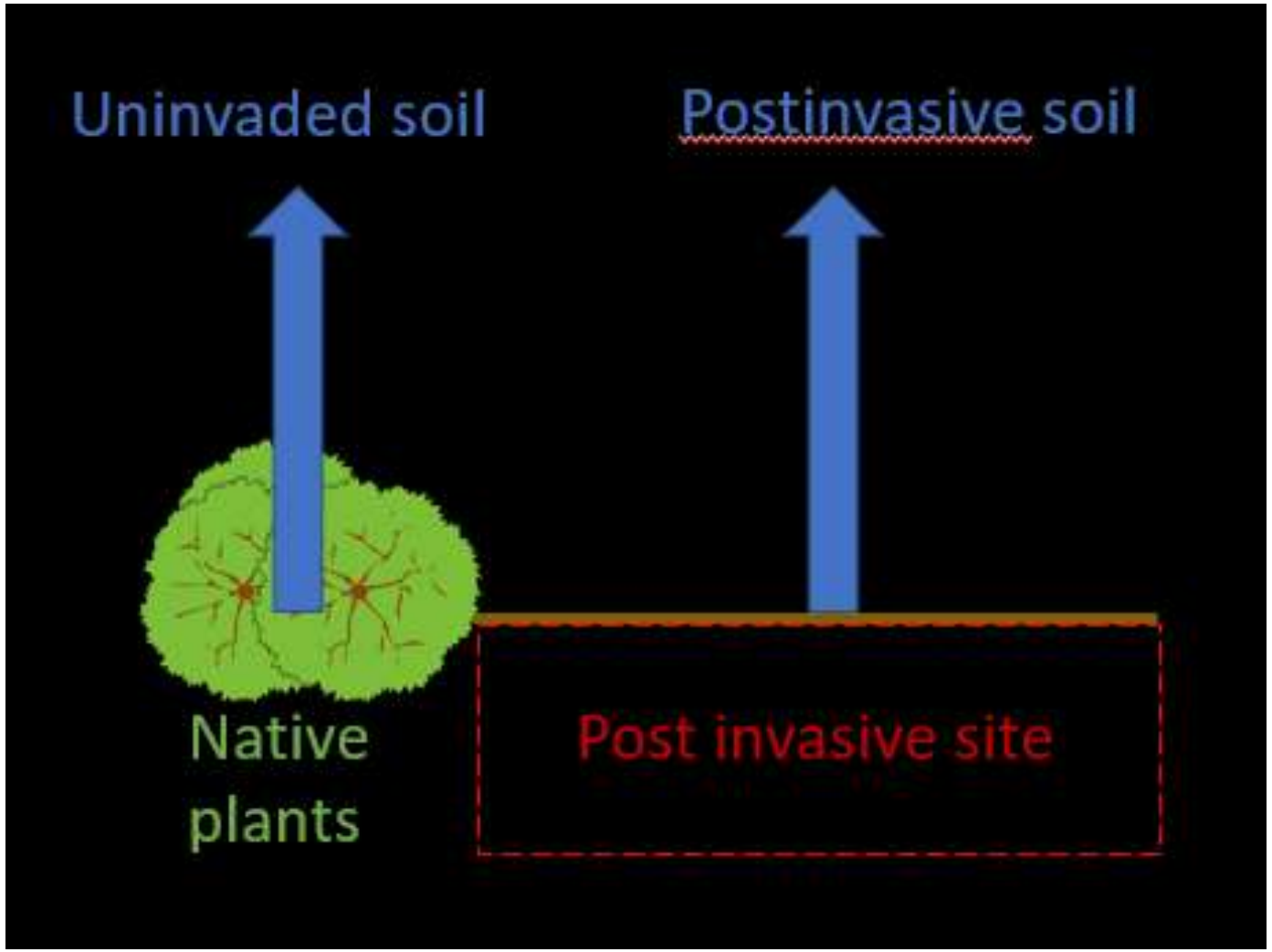
- The soil type (uninvaded or post-invasive) did have an effect on plant species growth
- *Salvia* and *Baccharis* were not affected by soil type
- *Phalaris* and *Artemisia* had the greatest growth in uninvaded soil
- Microbial basis of results? -> Field Project

Next Questions

Is the microbial composition of the uninvaded soil different than the post-invasive soil?

Are microbial changes in soils associated with *P. aquatica* (legacy effect) inhibitory to native plants?

Two Soil Types Collected



Month	Treatment	Site	# of Cores	Total Cores
February	Post-invaded	Block 1	3	
		Block 2	3	
		Block 3	4	10
	Uninvaded	Block 4	3	
		Block 5	3	
		Block 6	4	10
April	Post-invaded	Block 1	3	
		Block 2	3	
		Block 3	4	10
	Uninvaded	Block 4	3	
		Block 5	3	
		Block 6	4	10
July	Post-invaded	Block 1	3	
		Block 2	3	
		Block 3	4	10
	Uninvaded	Block 4	3	
		Block 5	3	
		Block 6	4	10

Soil Core Collection

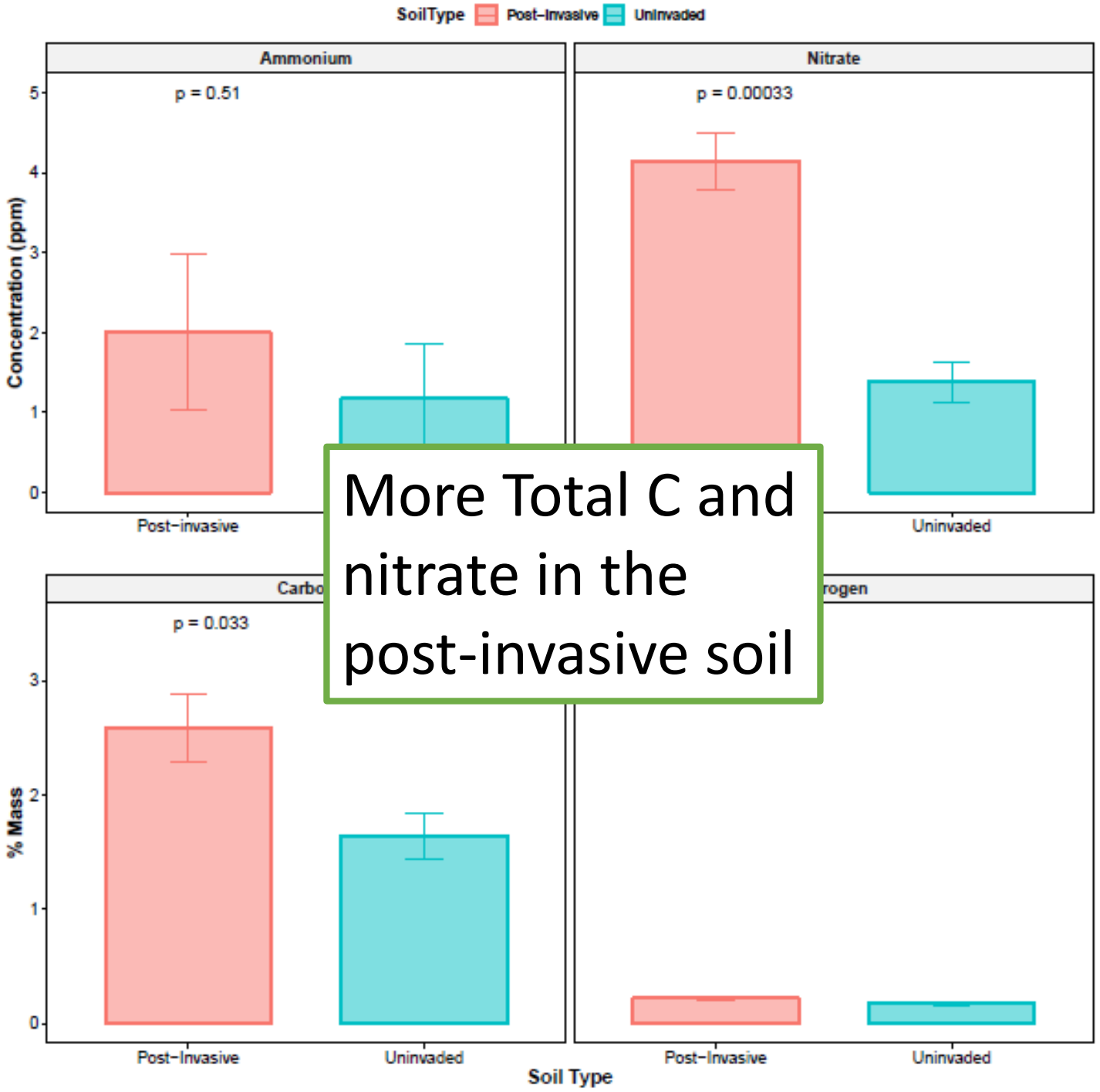
- Cores collected over 3 months
- Each month 10 cores were collected in post-invasive soil and 10 in uninvaded soil
- Soil cores for N were collected in July. Again, 10 cores per soil type

Soil Assays

- Nitrogen extraction was performed on the same day as soil collection
- Nitrate and ammonium analysis
- Total C and N using an elemental analyzer
- Soil moisture and pH were similar

Soil Assays Cont.

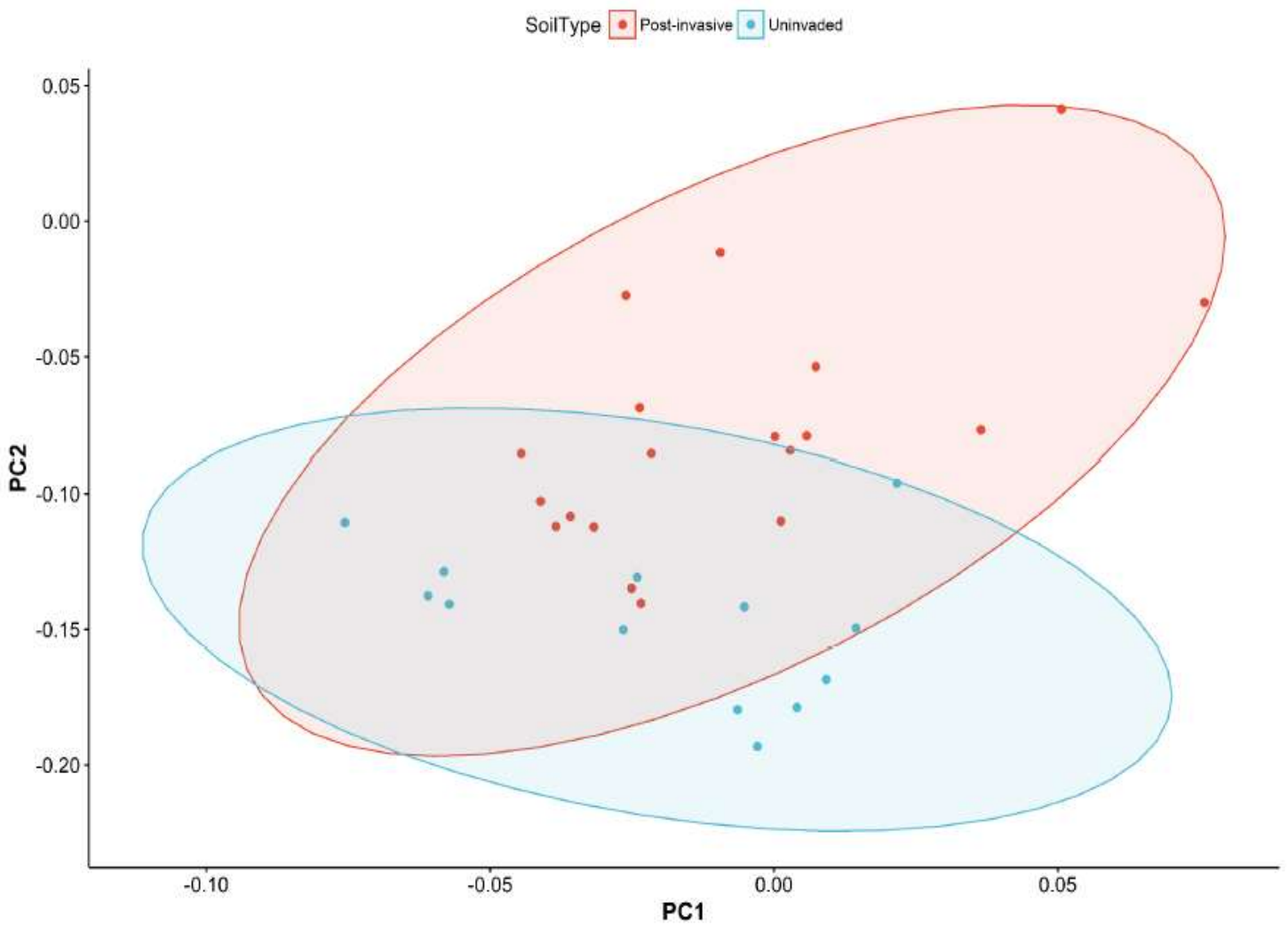
- More nitrate, total C and total N in the post-invasive soil
- Increased C: the elaborate root system left behind by *P. aquatica* after if was exterminated
- Increased Nitrate: the low C:N ratio of the plant litter



More Total C and nitrate in the post-invasive soil

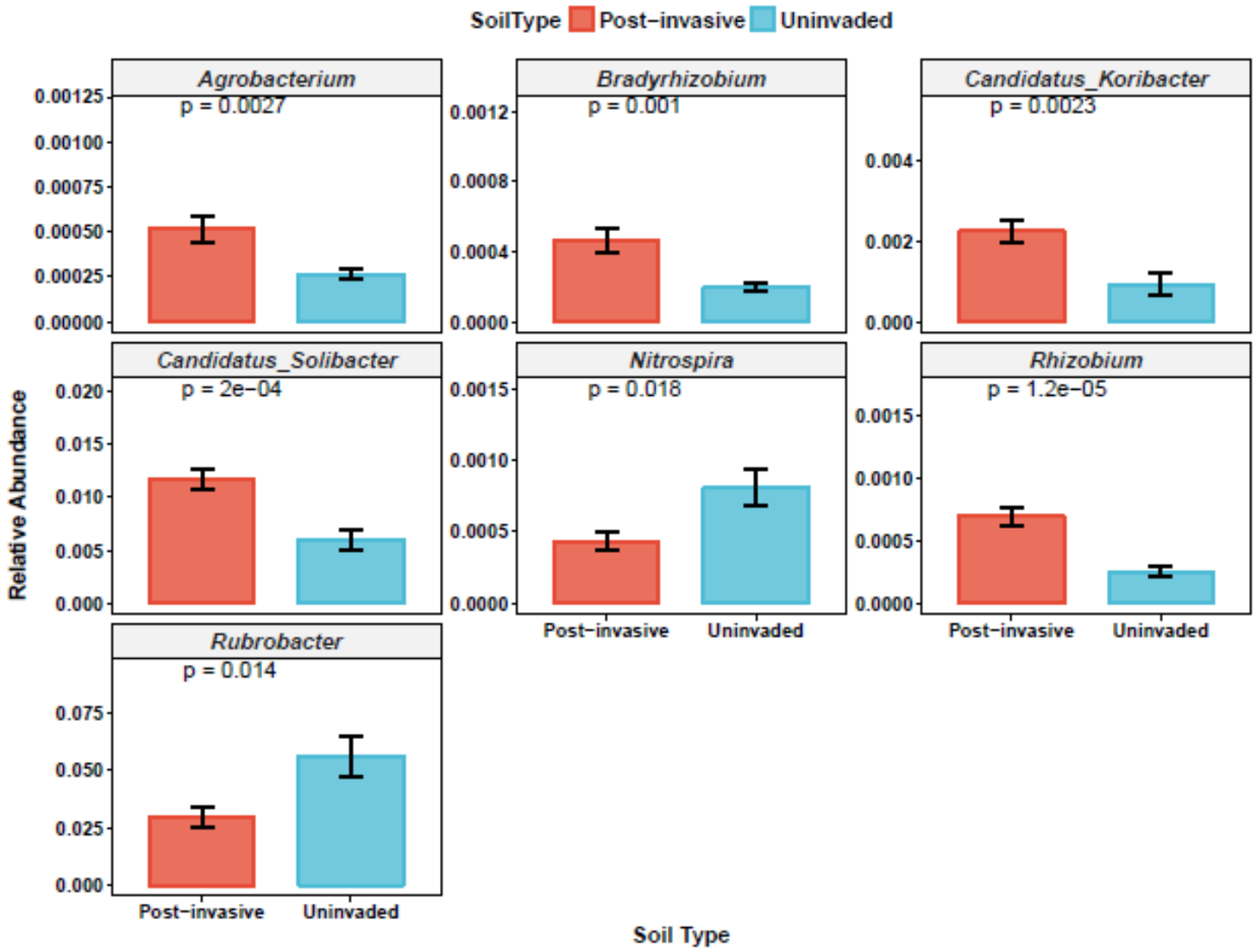
Bacterial Results

Bacterial Composition of Soils



The total bacterial composition and richness, as measured with alpha-diversity metrics, of the uninvaded and postinvasive soils did not differ ($P > 0.05$).

Abundance of Genera



More *Agrobacterium, Bradyrhizobium, C. koribacter, C. solibacter,* and *Rhizobium* in post-invasive soil and more *Nitrospira* and *Rubrobacter* in uninvaded soil.

Bacterial Genera

- *Rubrobacter* is well-adapted to living in semi-arid, exposed soils.
- *C. koribacter* and *C. solibacter* are nitrate reducers.
- *Bradyrhizobium* and *Rhizobium* are symbiotic nitrogen fixers. They only associate with legumes.

Bacterial Conclusions

Nitrate reducers more abundant in post-invasive soil due to increased amount of nitrate

Rubrobacter more abundant in uninvaded soil because it is indicative of a healthy soil community

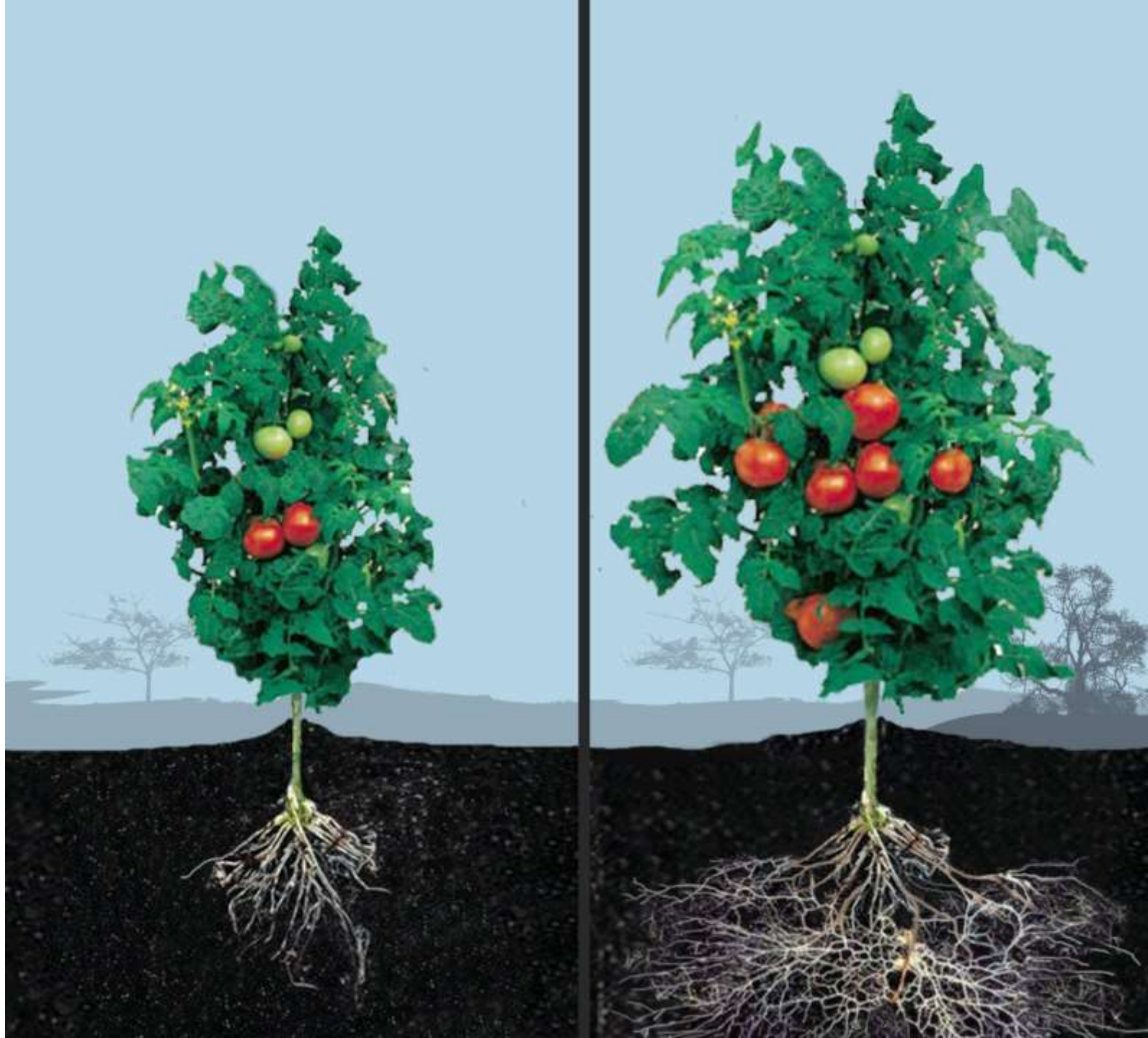
Symbiotic N-fixers more abundant in post-invasive soil -> maybe *P. aquatica* is associating with free-living N-fixers

AMF Results

Arbuscular Mycorrhizal Fungi (AMF)

AMF are the most common plant mutualistic symbionts. They provide:

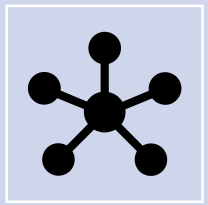
1. Important nutrients for plant growth
2. Phosphorus
3. Resistance to pathogens
4. Stabilization of soil aggregates
5. Amelioratation of the allelopathic effect of some invasive plants



AMF Guilds

Weber et al. 2018

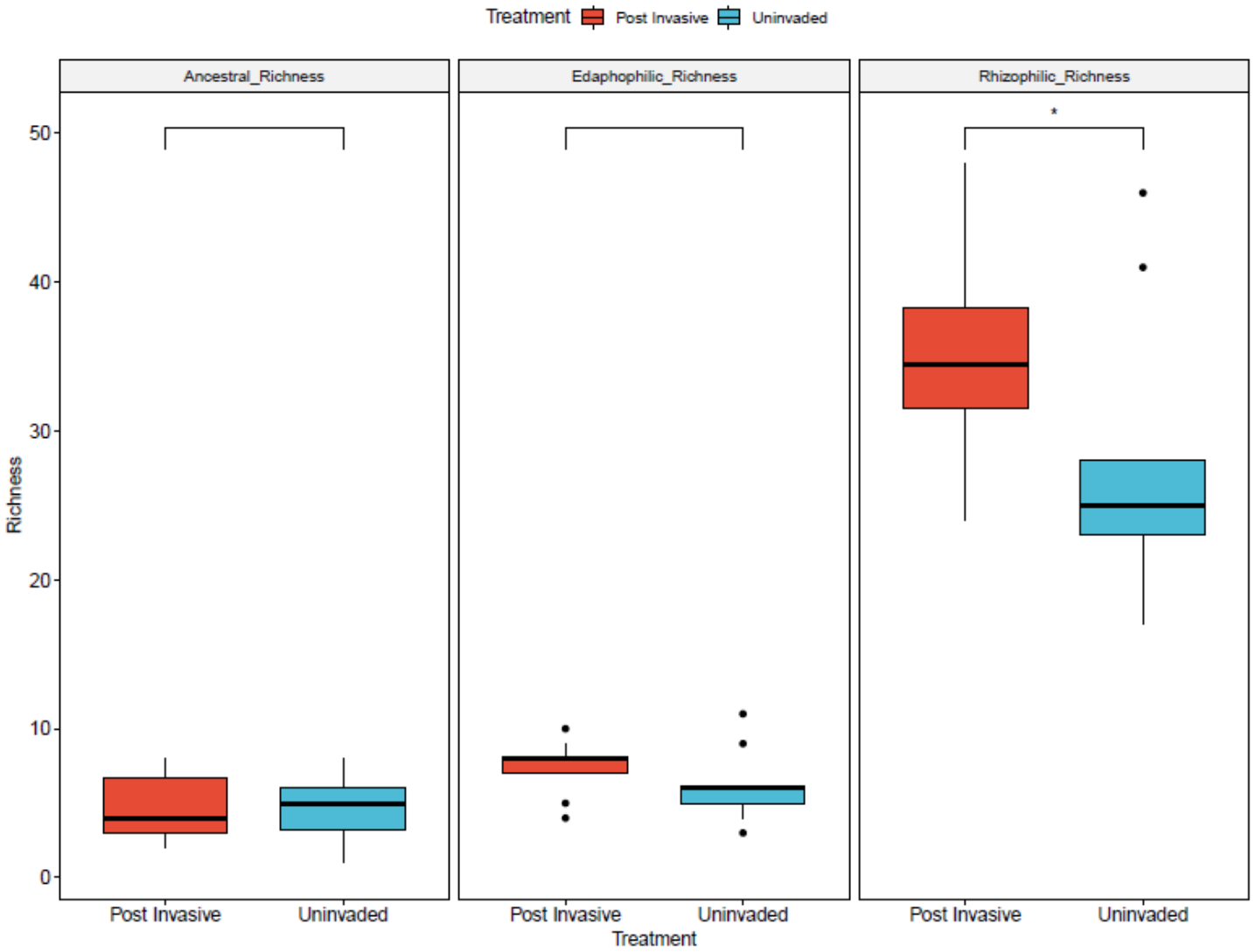
Rhizophilic: high allocation to root colonization. These type may protect roots from pathogens.



Edaphophilic: high allocation to extra-radical hyphae. These type generally improve plant nutrient uptake.

Ancestral: lower allocation to root colonization and soil hyphae than the other two groups

AMF Richness



Post-invasive soil has more rhizophilic AMF than uninvaded soil. Rhizophilic AMF protect roots from pathogens.

AMF Conclusions

The higher amount of Rhizophilic AMF in the post-invasive soil could indicate a few things:

The invasive grass brought these over with it or recruited them from the soil

This could have helped the invasive grass to invade

Over time, soil nutrients were depleted so the invasive grass grew better in the uninvaded soil

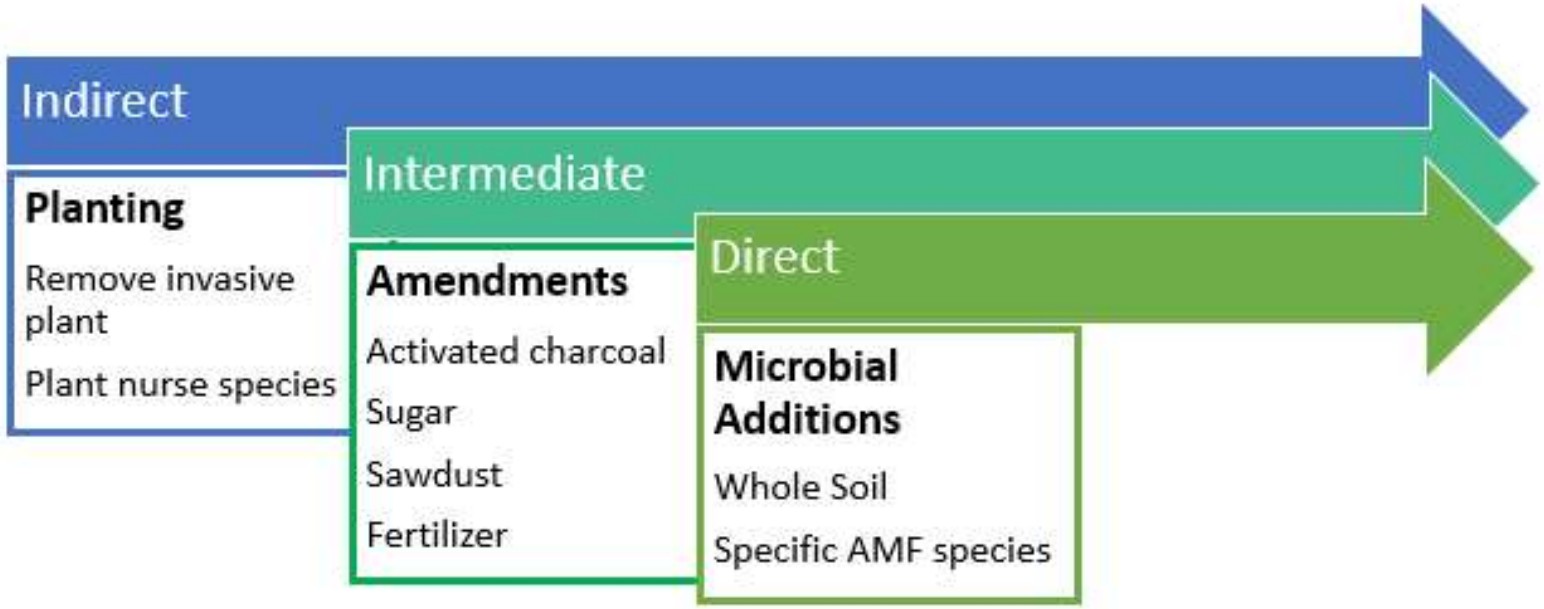
A. californica didn't do well because it is sensitive to high N soil (despite more rhizo. AMF)

Restoration starts with the soil

- This ensures native plant establishment in post-invasive sites
- Perhaps isolate and use certain microbes for inoculations in restorations
- Greater understanding of plant/microbe symbioses in invaded habitats may improve restoration

Biotic Soil Restoration

Pickett B, Maltz M, Aronson E (2019) "Impacts of Invasive Plants on Soil Fungi and Implications for Restoration." *Invasive Plants.* London: IntechOpen.



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