Abiotic and biotic soil legacies of *Cytisus scoparius* impact reforestation

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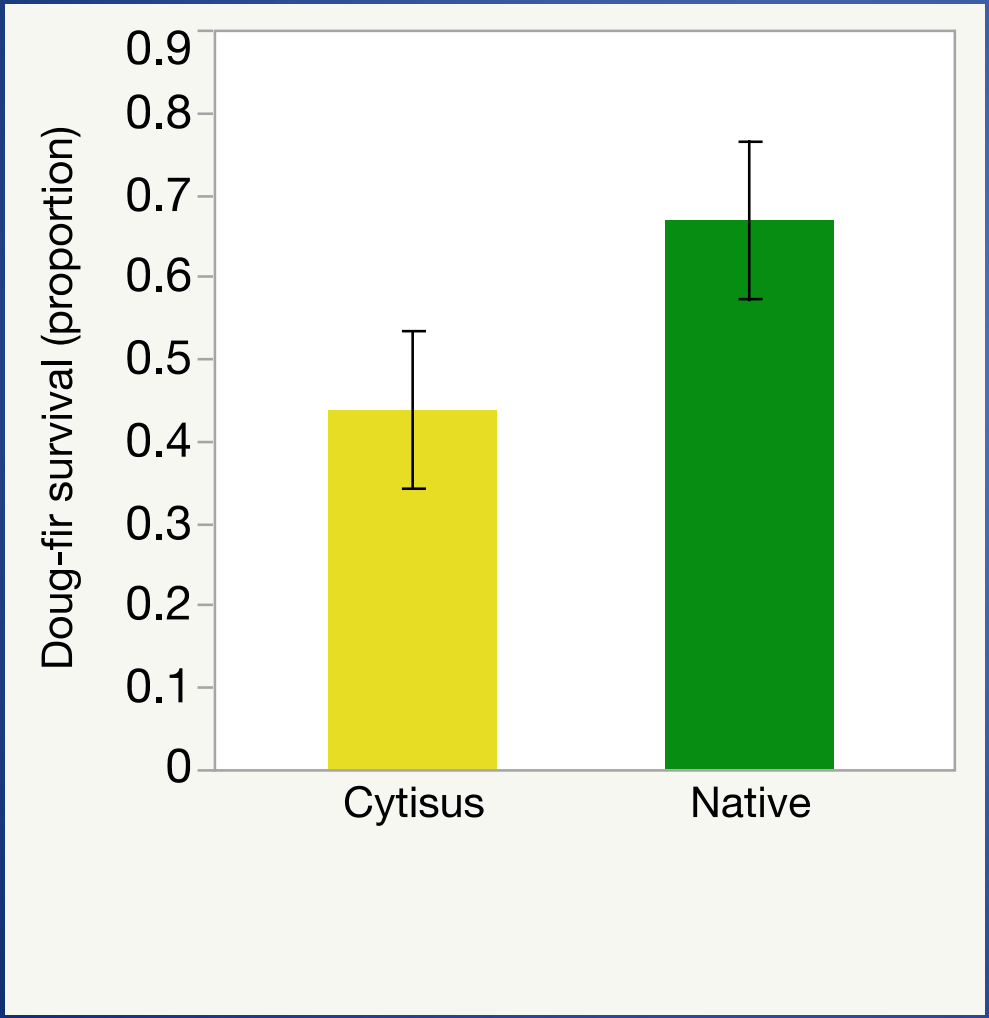
Typical Doug-fir survival is >80%

In broom invaded sites mortaility is catastrophic

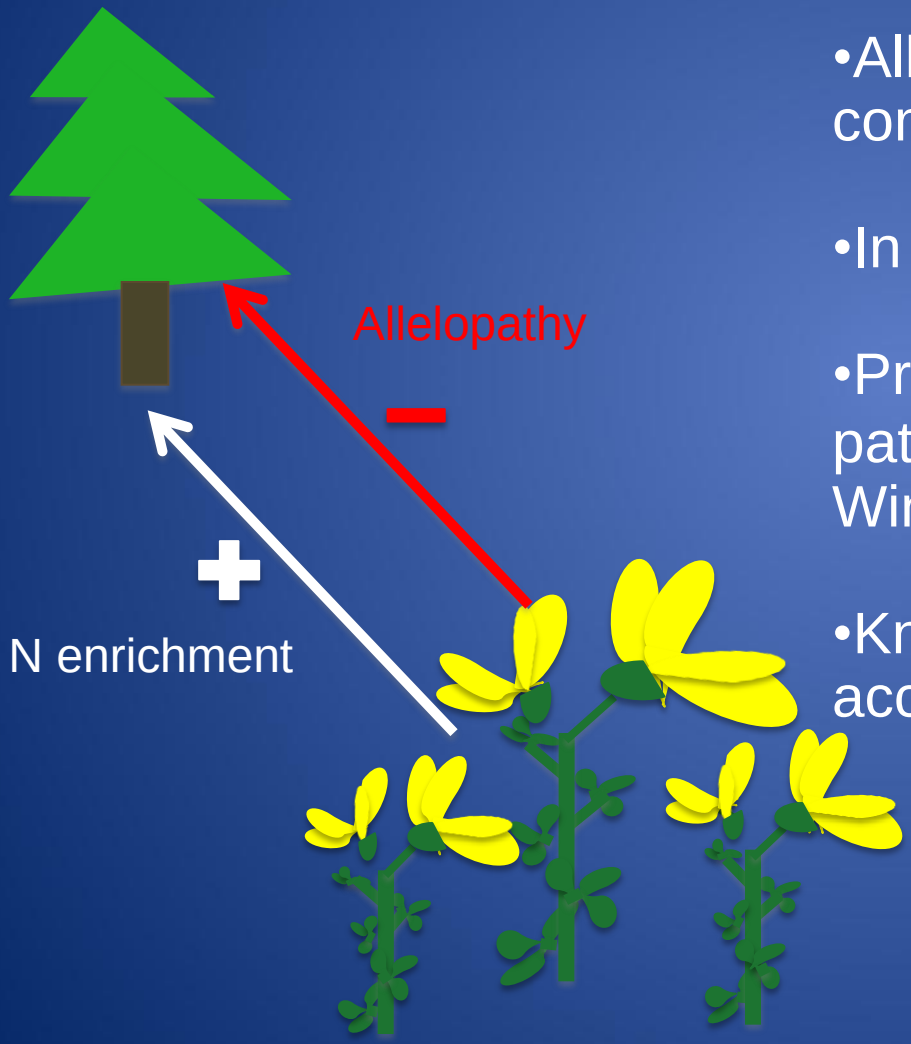
Broom has been removed, NOT direct competition killing Doug-fir

Mortality was higher in broom invaded areas



- Replicated in 10 clearcuts (JBLM, WA-DNR & Green Diamond)
- Removed patches of native vegetation & broom
- Planted Douglas-fir seedling

Potential **direct** pathways for soil legacy effects

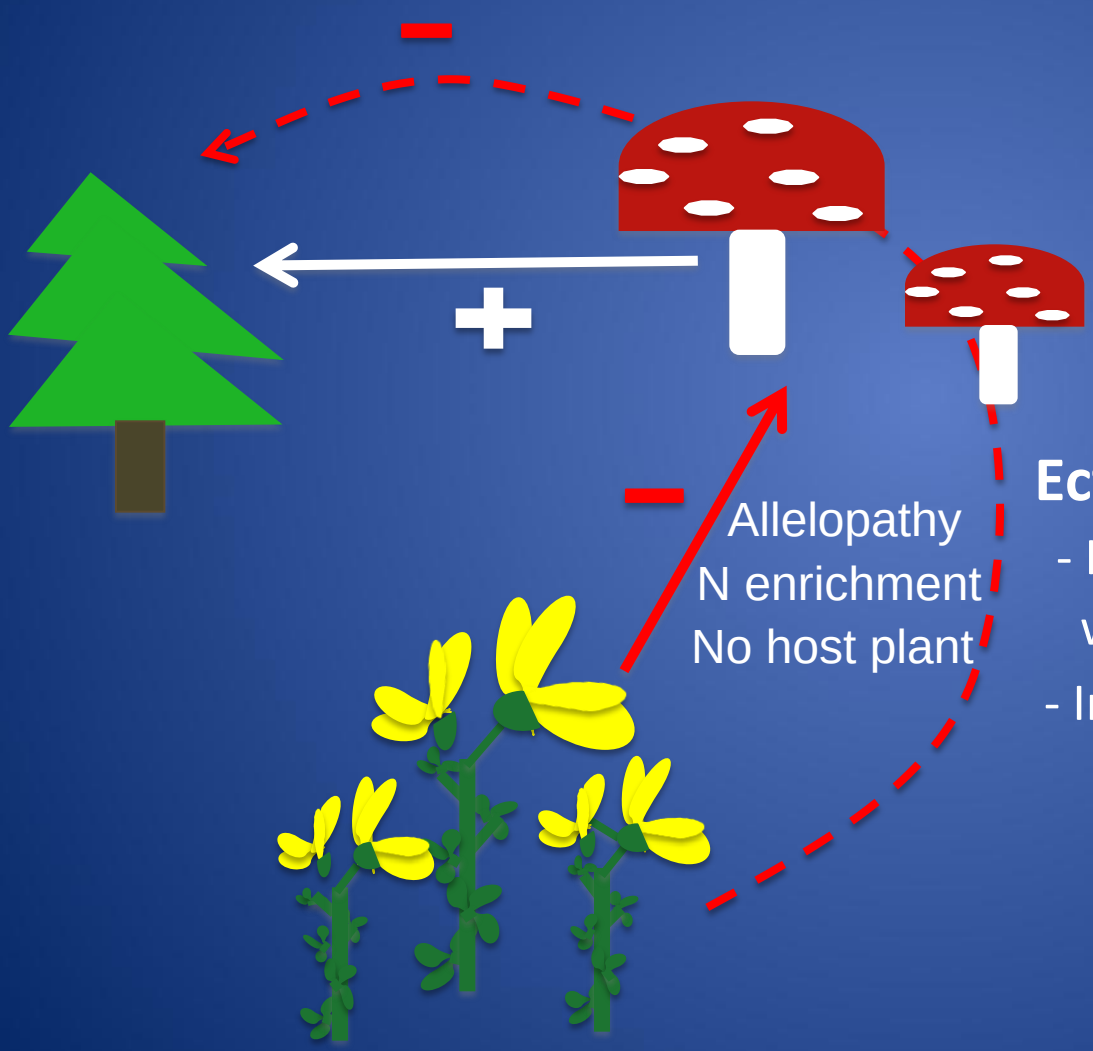


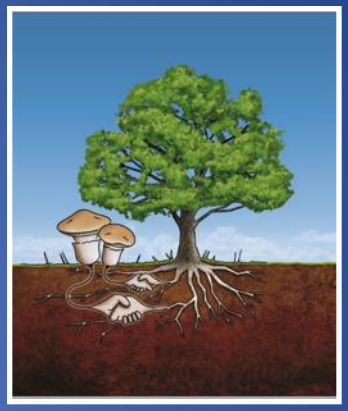
Sparteine:

- Alkaloid secondary defense compound
- In leaf and stem tissues
- Protects against herbivores and pathogens (Küçükboyacı et al. 2012, Wink, 1982)
- Know virtually nothing about how it accumulates or persists in the soil

Potential **INDIRECT** pathways for soil legacy effects

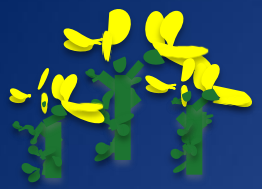
Via disruption of the mycorrhizal mutualism





Ectomycorrhizal mutualism

- Increase access to soil nutrients and water
- Increase drought tolerance



Evidence of a soil legacy effect

findings from a greenhouse experiment

Soil Legacy Effects:

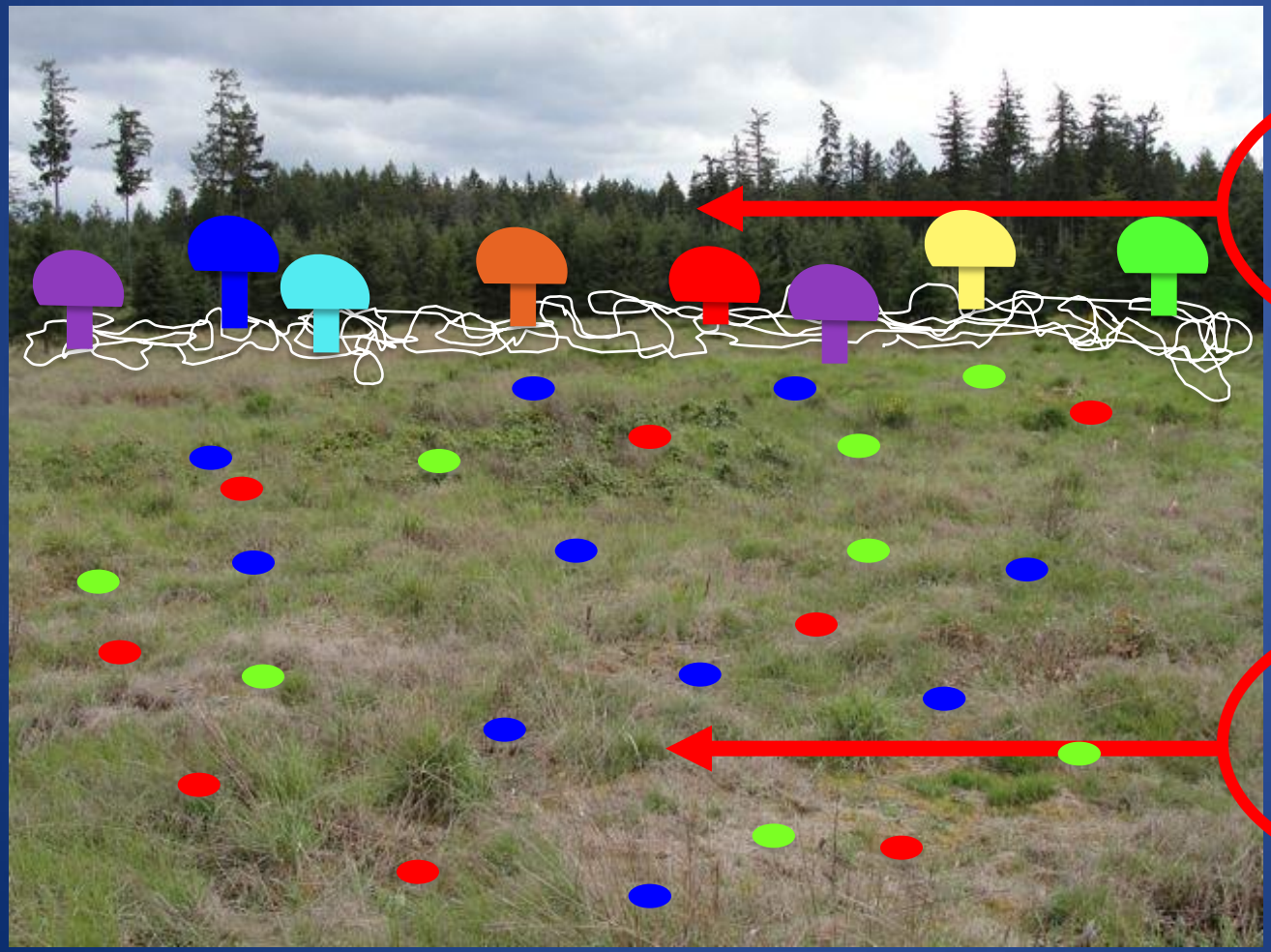
Trees grown in broom invaded soil were **SMALLER** than trees grown in uninvaded forest soil

Trees grown in broom invaded soil had **LESS** ectomycorrhizal colonization than trees grown in forest soil

Adding Scotch broom mulch to forest soil **SUPPRESSED** tree growth and EMF

Grove et al. 2012

Do ectomycorrhizal fungi at the forest edge mitigate the broom legacy and can the mutualism be restored with forest soil inoculation ?

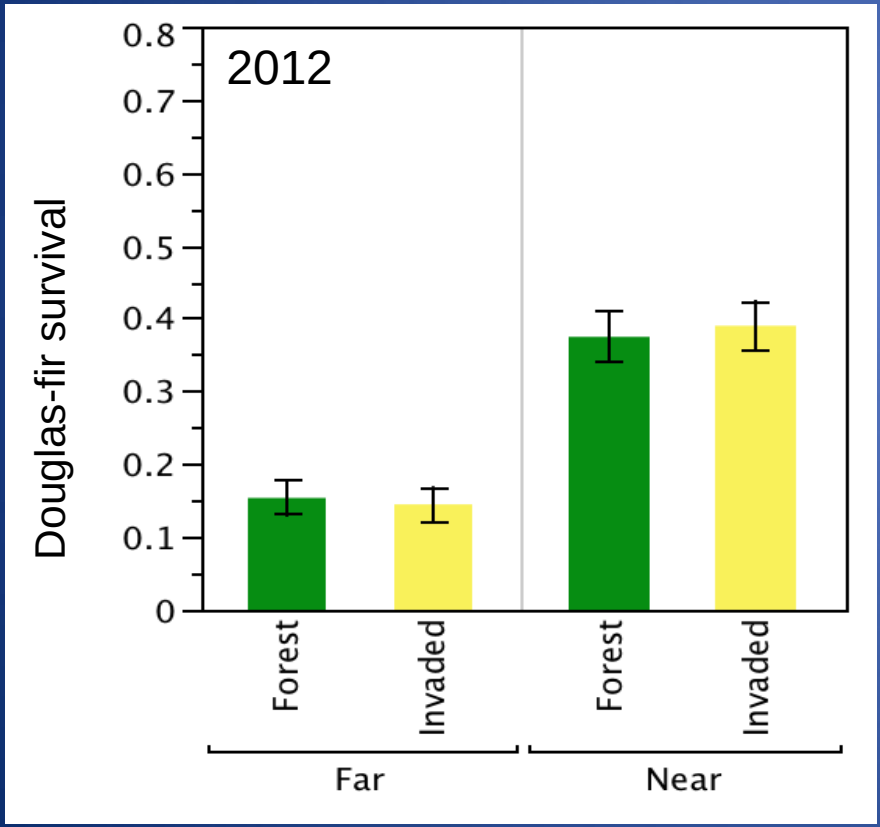


Why did these trees make it,

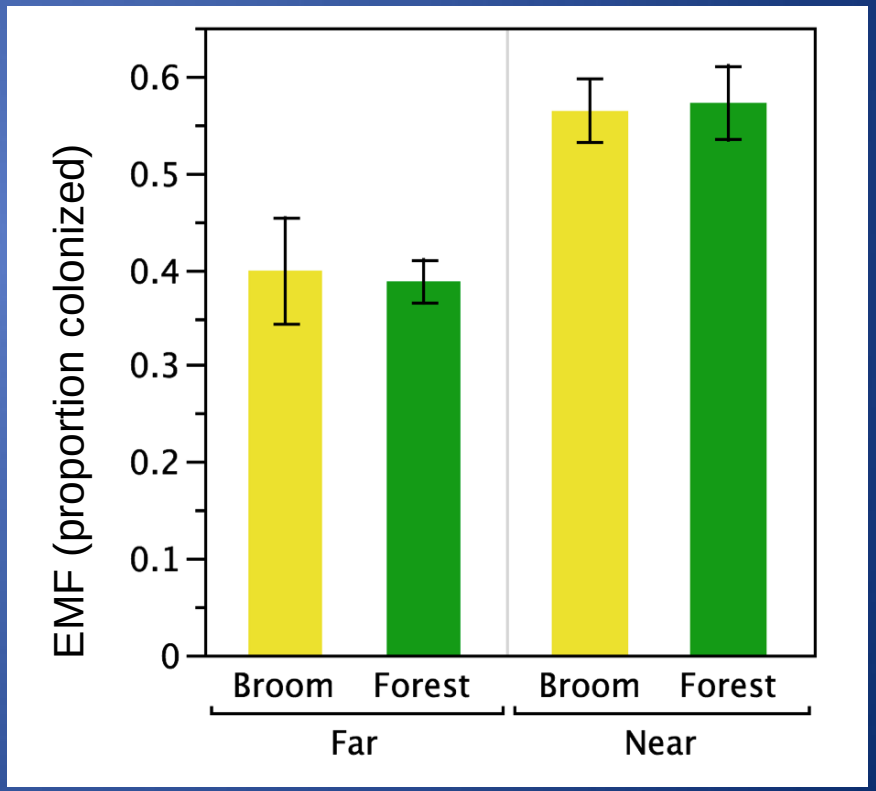
When nothing survived out here?

Doug-fir survival and EMF abundance were greater near forest edge, but were not improved by forest soil inoculation

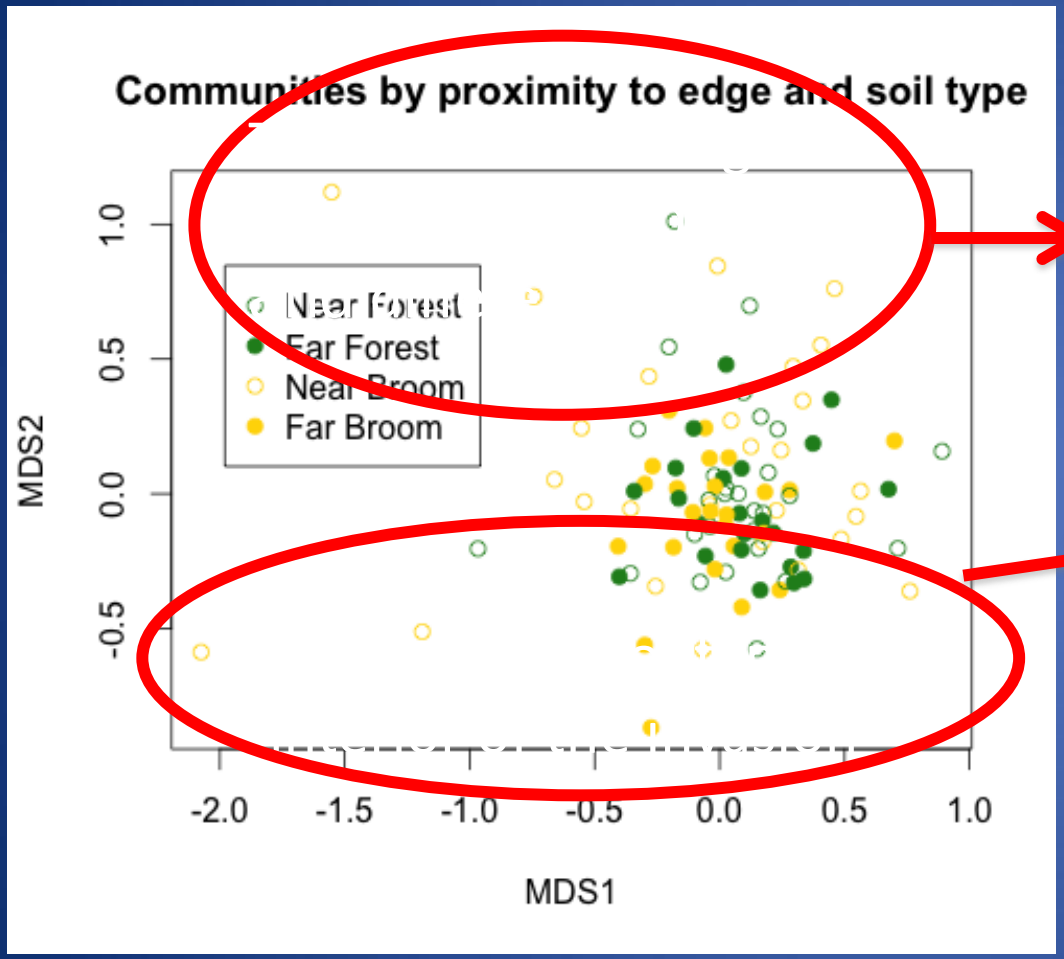
N =1000 seedlings

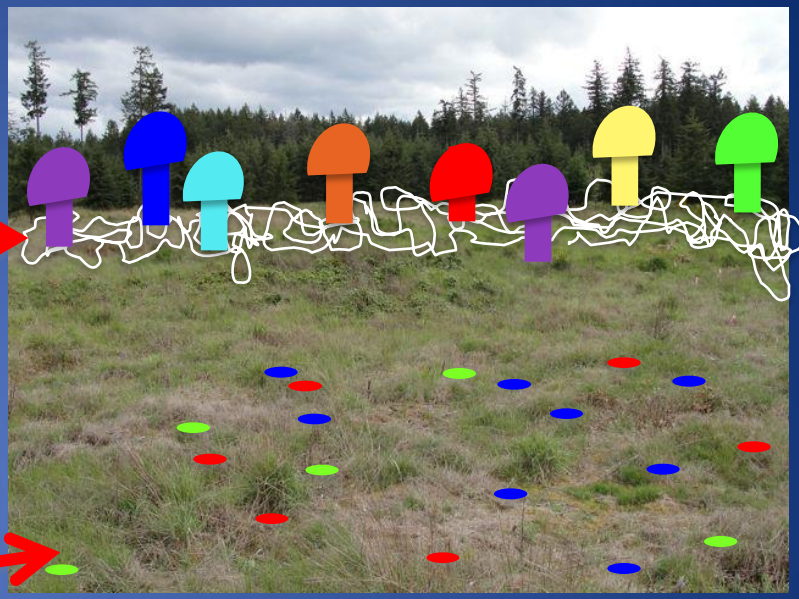


Edge: P < 0.0001
Soil transplant: NS



Proximity to edge: P < 0.0001
Soil type (forest/broom): NS



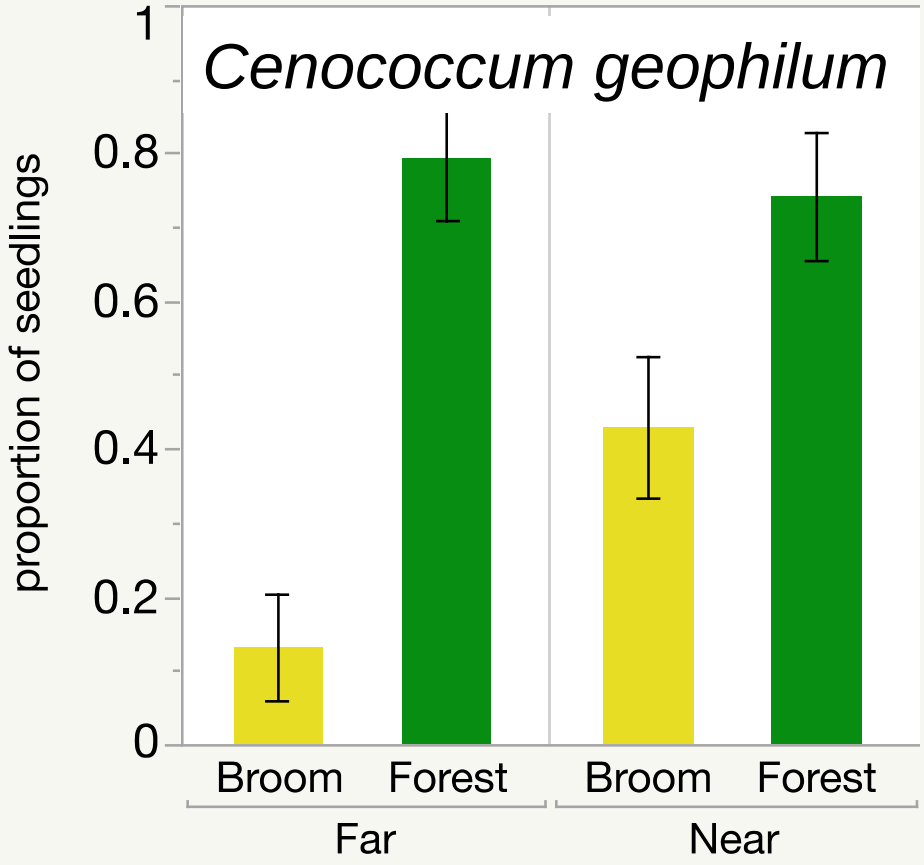


Permanova Term	P value
Edge Proximity	0.005 **
Soil	0.04 *
Edge Proximity x Soil	0.28

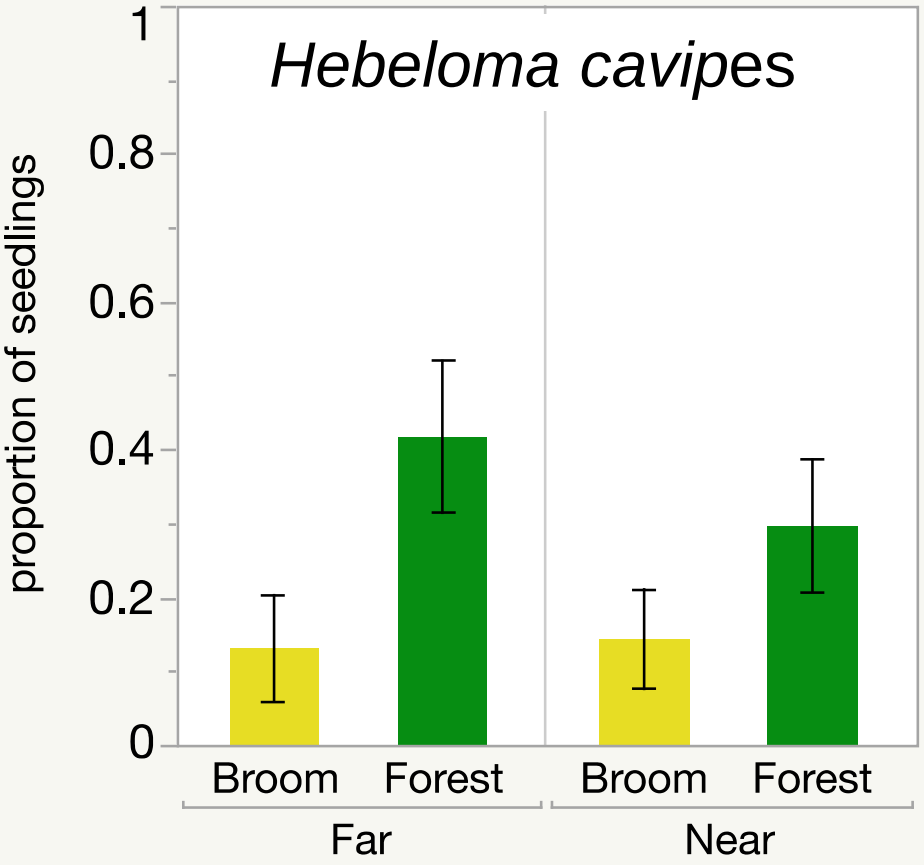
Only 2 dominant taxa responded to soil inoculation or proximity to edge

	% Douglas-fir seedlings colonized				
10 Most Abundant Taxa	**Forest Near**	**Broom Near**	**Forest Far**	**Broom far**	**P value**
Wilcoxina mikolae	84	82	83	91	NS
Rhizopogon rogersii	88	82	88	87	NS
Tuber sp.	76	71	71	61	NS
Leucangium carthusianum	60	61	50	56	NS
Inocybe lilacina	52	46	54	52	NS
Tuber anniae	52	39*	46	43	NS
Tomentella coerulea	44*	43	21*	39	NS
Amanita sp.	28*	25*	20*	30*	NS
Hebeloma cavipes	32*	14*	42	13*	0.002
Tomentella sp.	48*	42	42	35	NS
Cenococcum geophilum	80	43	79	13*	0.0001
Inocybe sp.	52	29	33*	30*	NS

Emerging as potentially important EMF species impacted by broom invasion

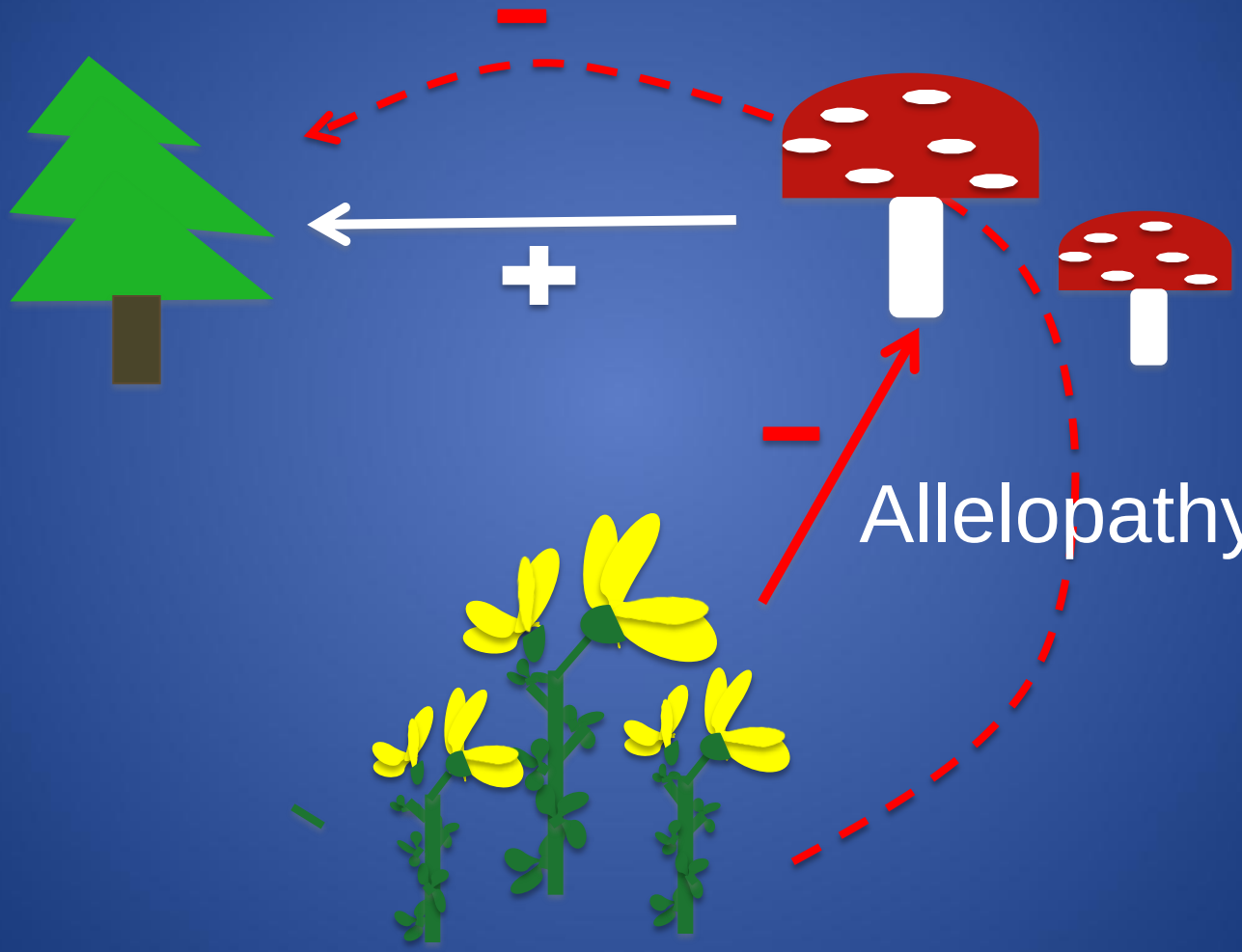


Proximity 0.16
Soil <.0001*
Proximity*Soil 0.05*

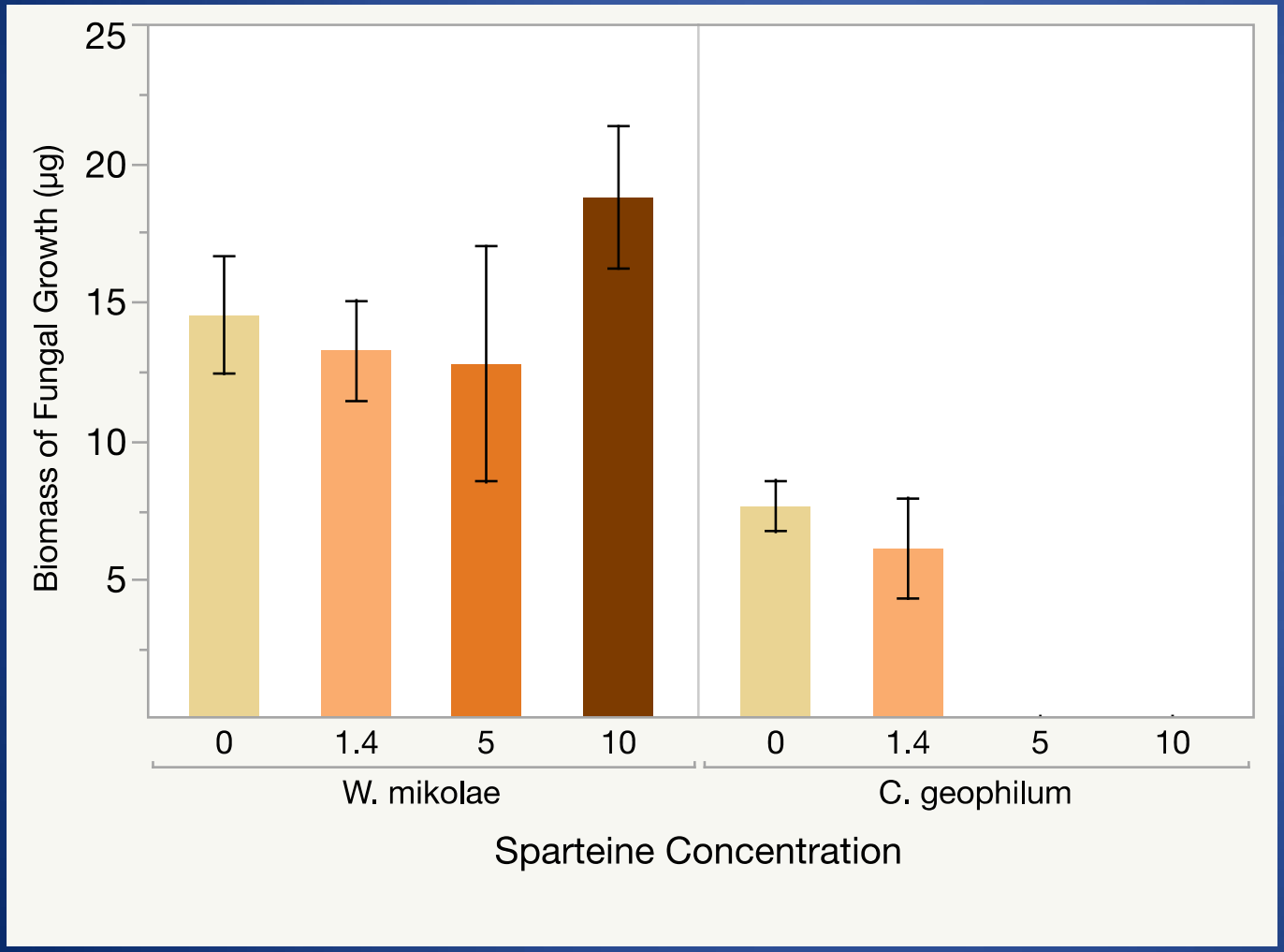


Proximity 0.34
Soil <.0001*
Proximity*Soil 0.28

Is allelopathy a mechanism for changes in the ectomycorrhizal community?

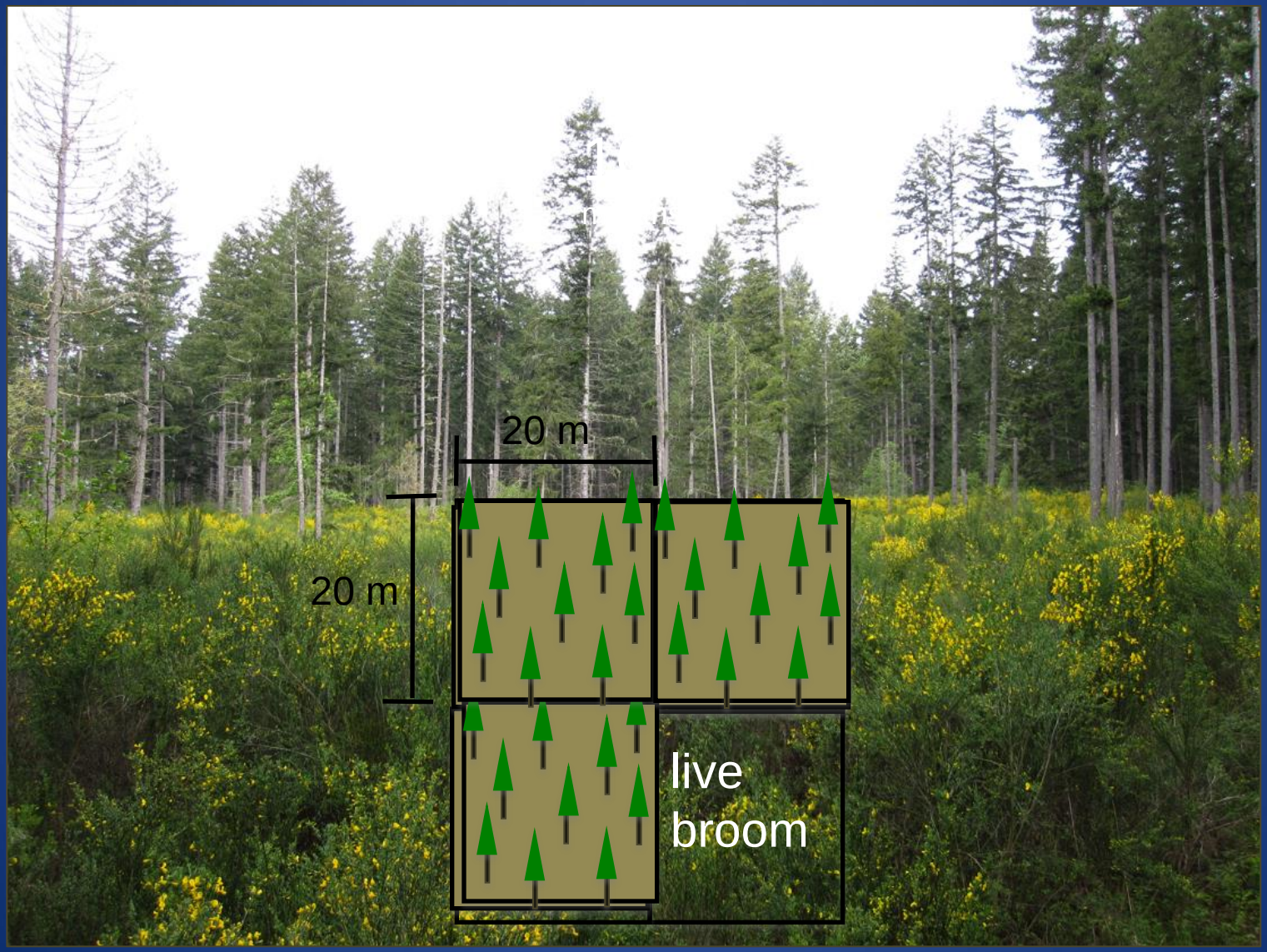


Sparteine effects on ectomycorrhizal fungi vary across species

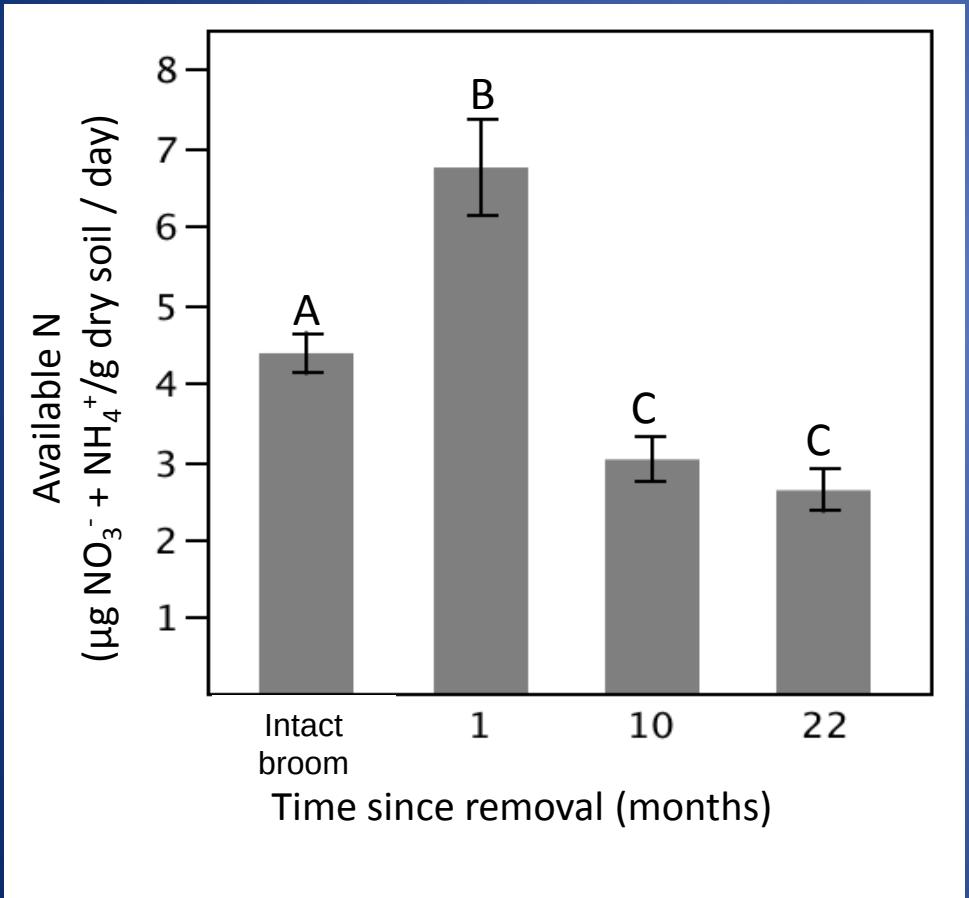


Jennifer Thompson, UCSC undergraduate thesis

How long does the nitrogen legacy effect of persist after broom removal?



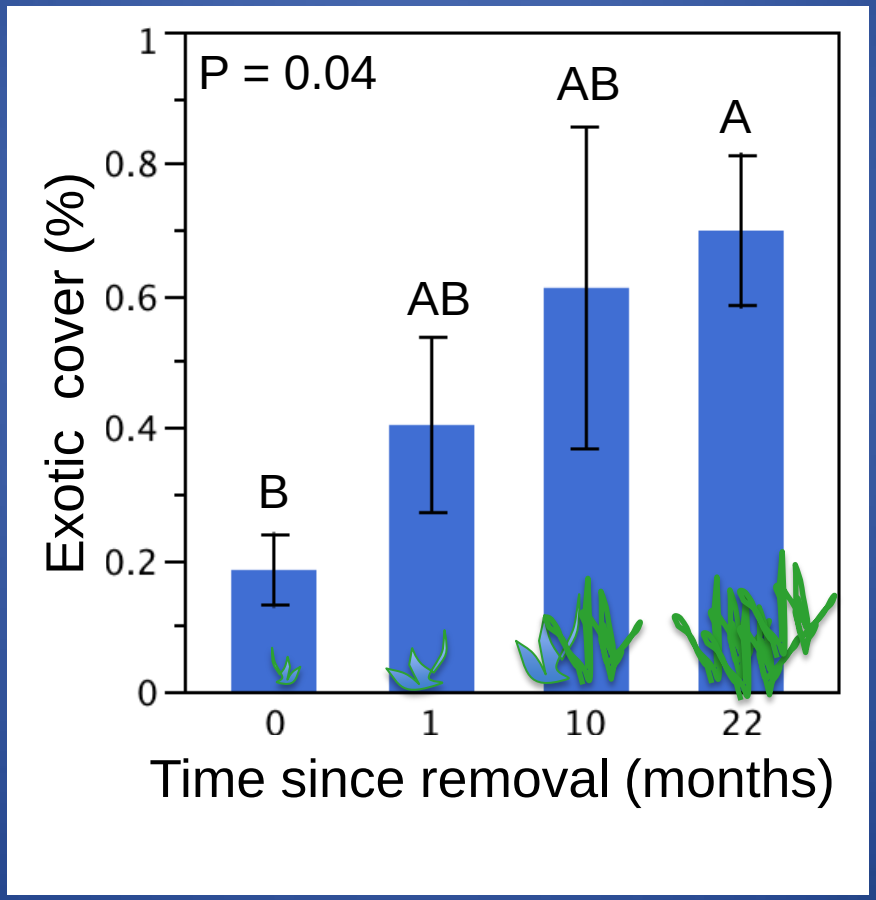
How did **N** change following broom removal?



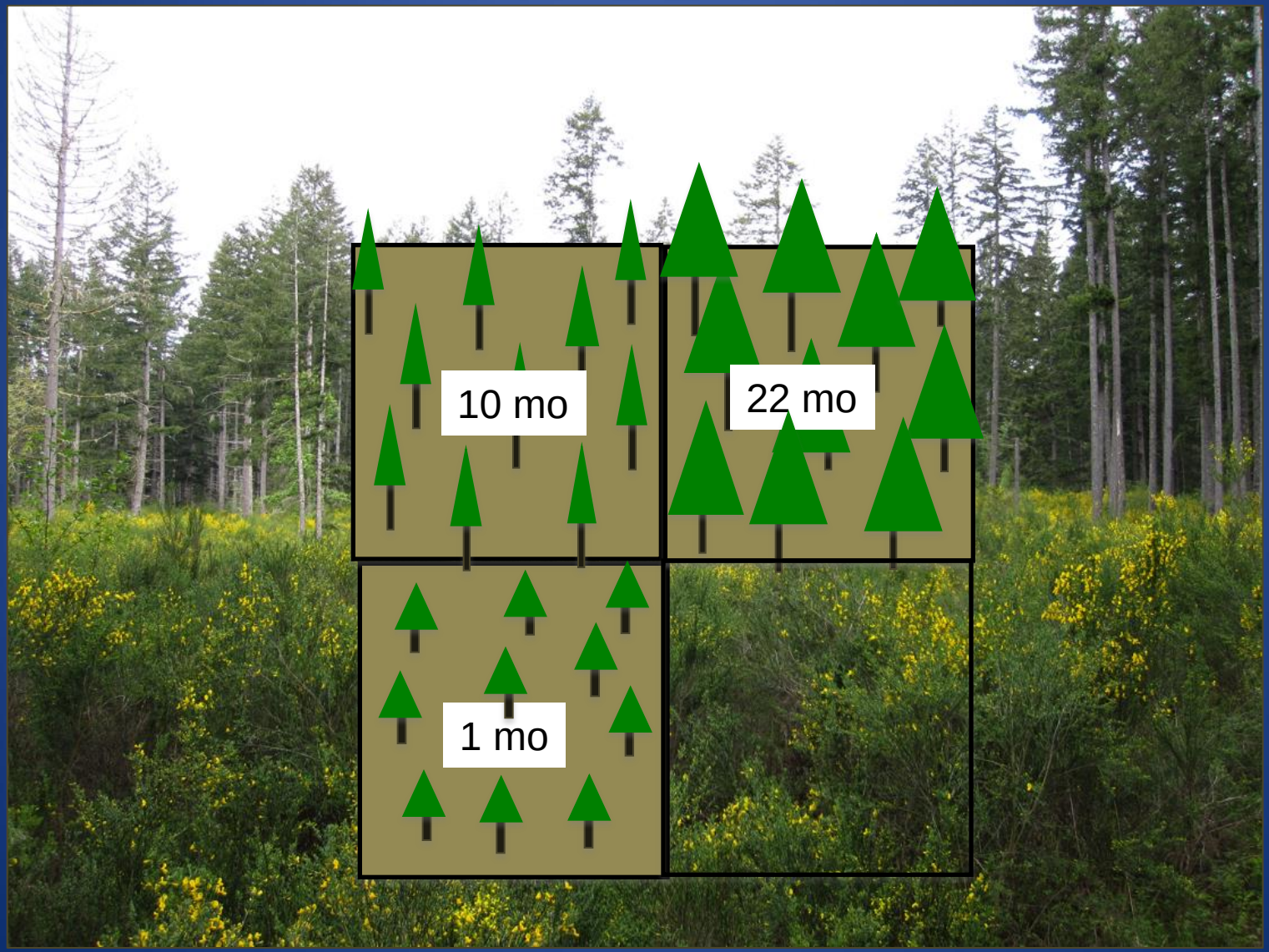
- An initial increase in N followed by a rapid drop at 10 months
- Rate of decline is either stabilizing or slowing.
- Continuing to follow these plots
- BUT two years after removal, N is still elevated compared to N values reported in uninvaded Doug-fir soils throughout the region

Grove et al. 2015

Exotic herbaceous species increased with time following broom removal

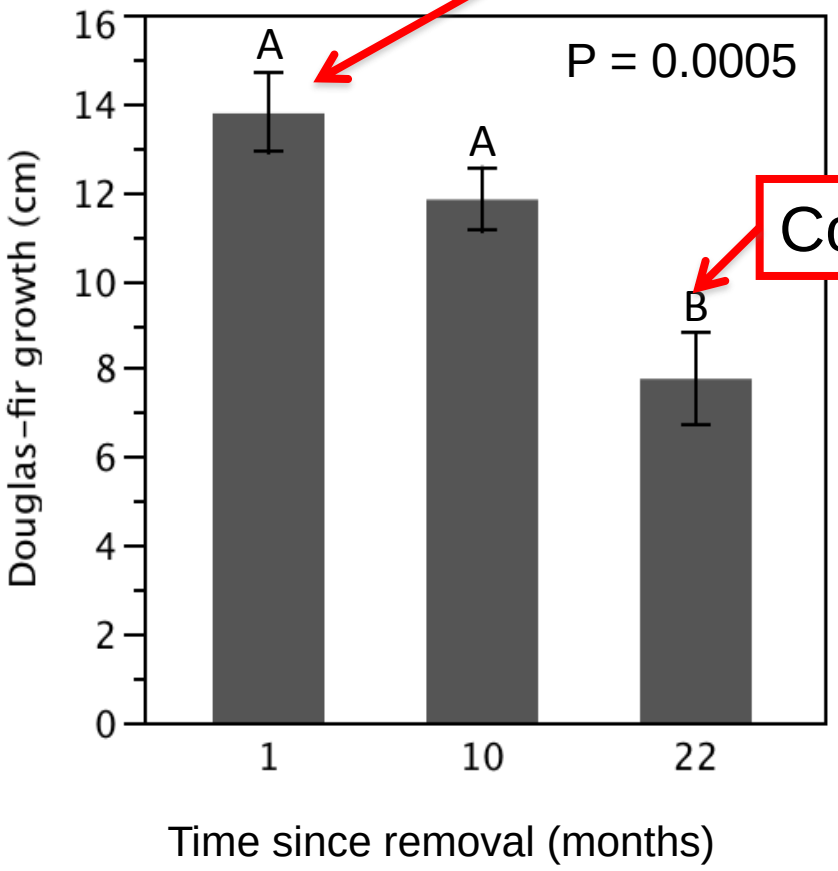


Expected soils to recover following removal, and trees to grow better were broom had been absent the longest



Doug-fir seedling growth

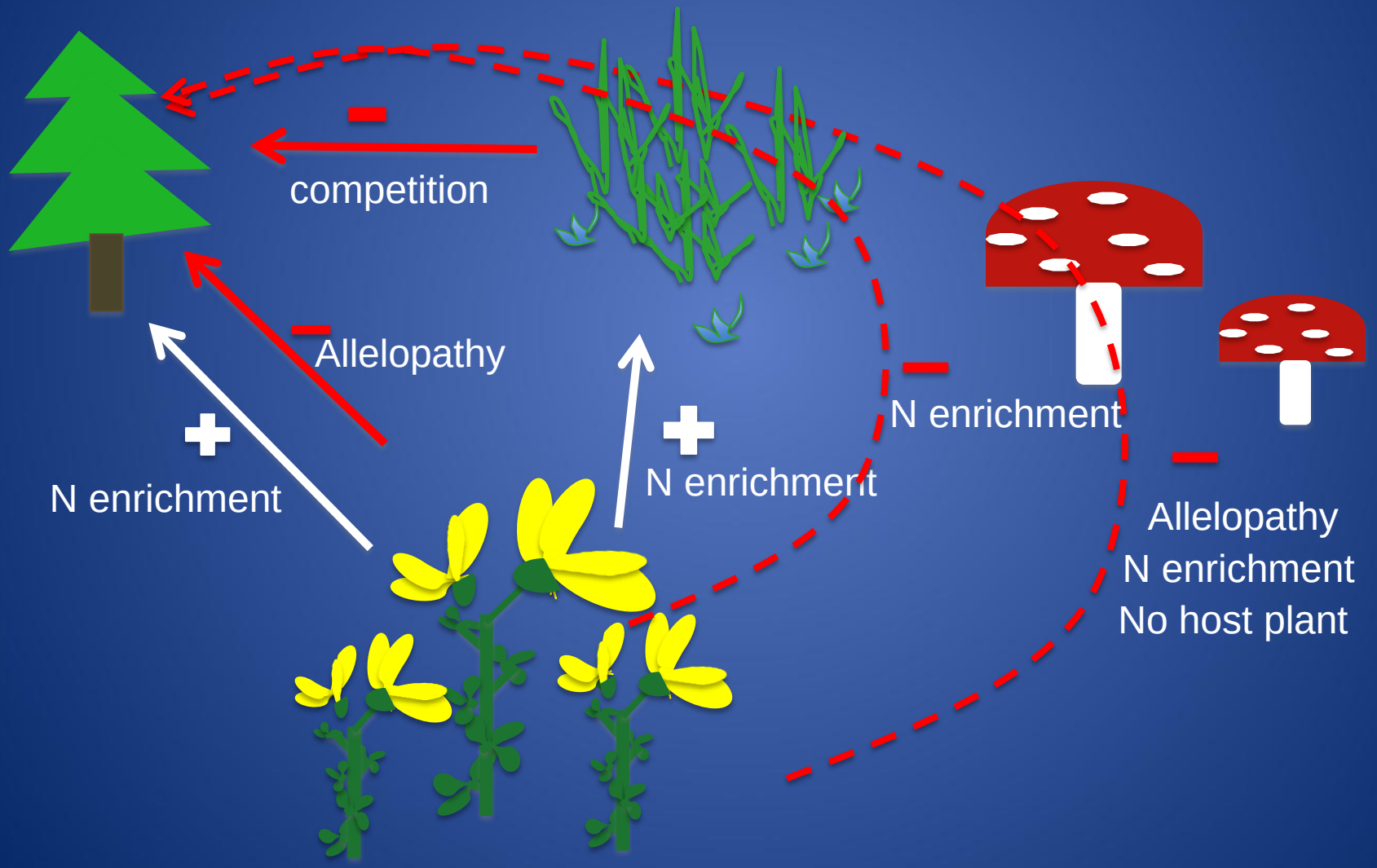
Elevated N?



Competition with exotics?

- Doug-fir grew larger in soils where broom was more recently removed.
- After broom has been gone for ~2 years growth is suppressed

Scotch broom imparts positive and negative soil legacies



Acknowledgements

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UCSC greenhouse staff: Jim Velzy & Denise Polk

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JBLM

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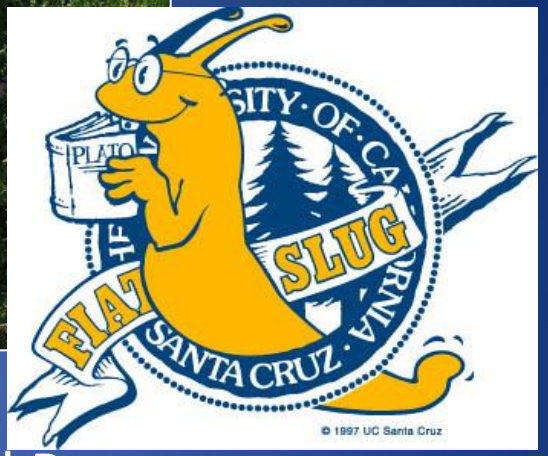
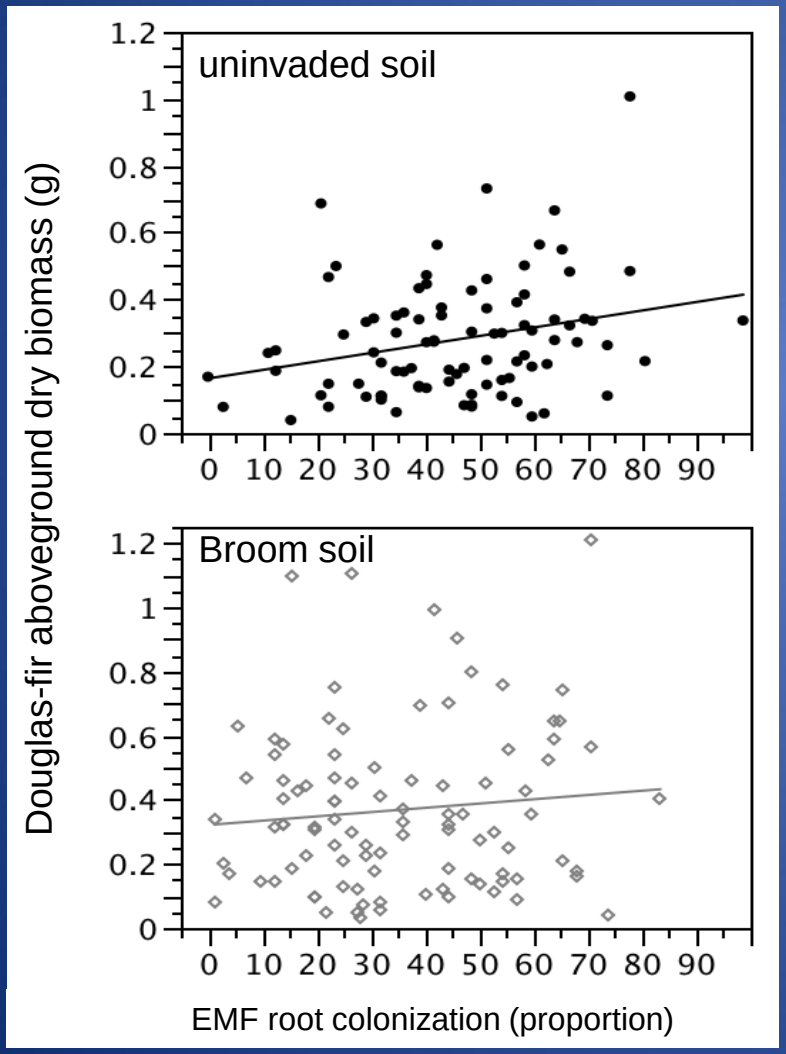
California Native Plant Society

Jean Langenheim Fellowship in Plant Ecology

American Association of University Women



Importance of EMF to Doug-fir growth is context dependant



- In uninvaded clearcut soils Doug-fir **grow more** as EMF abundance increases

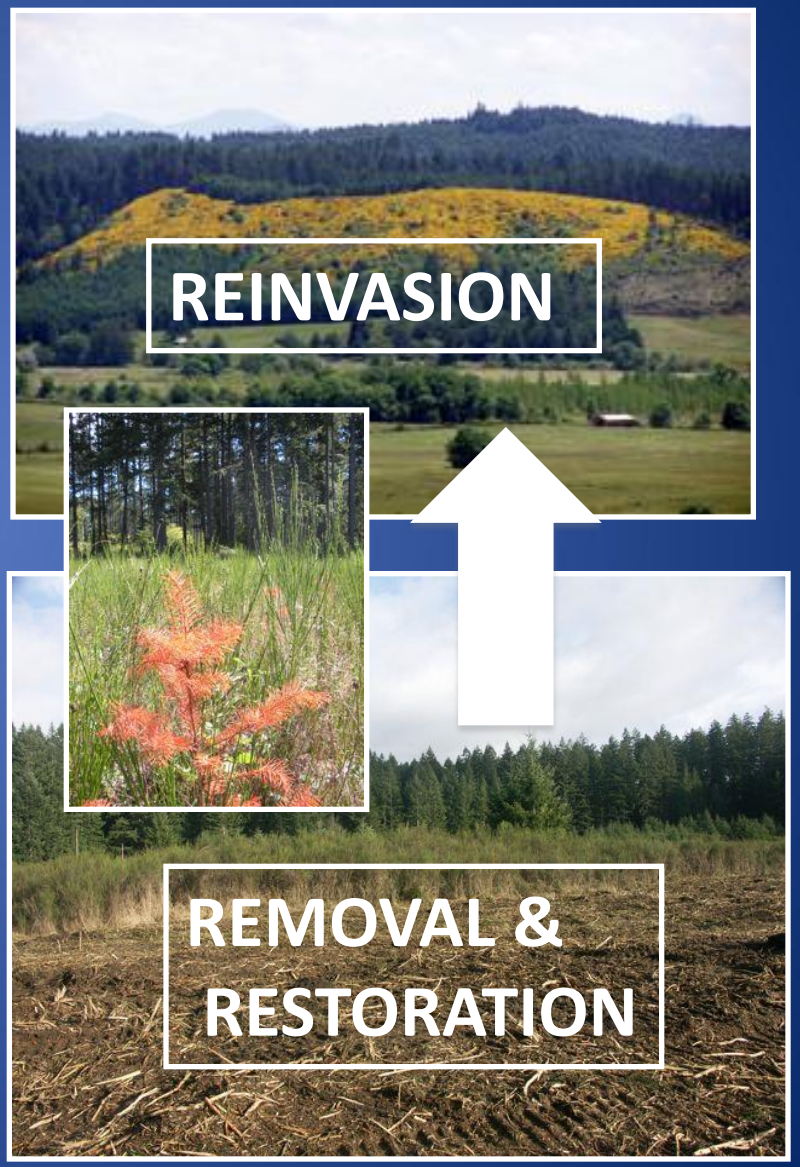
- In broom invaded clearcut soils Doug-fir **do not benefit** from increased EMF abundance

Possible explanation:

Primary role of EMF is to provide N. When N readily available the mutualism loses value & and Doug-fir abandon the fungi

Invasions & Alternative Stable States

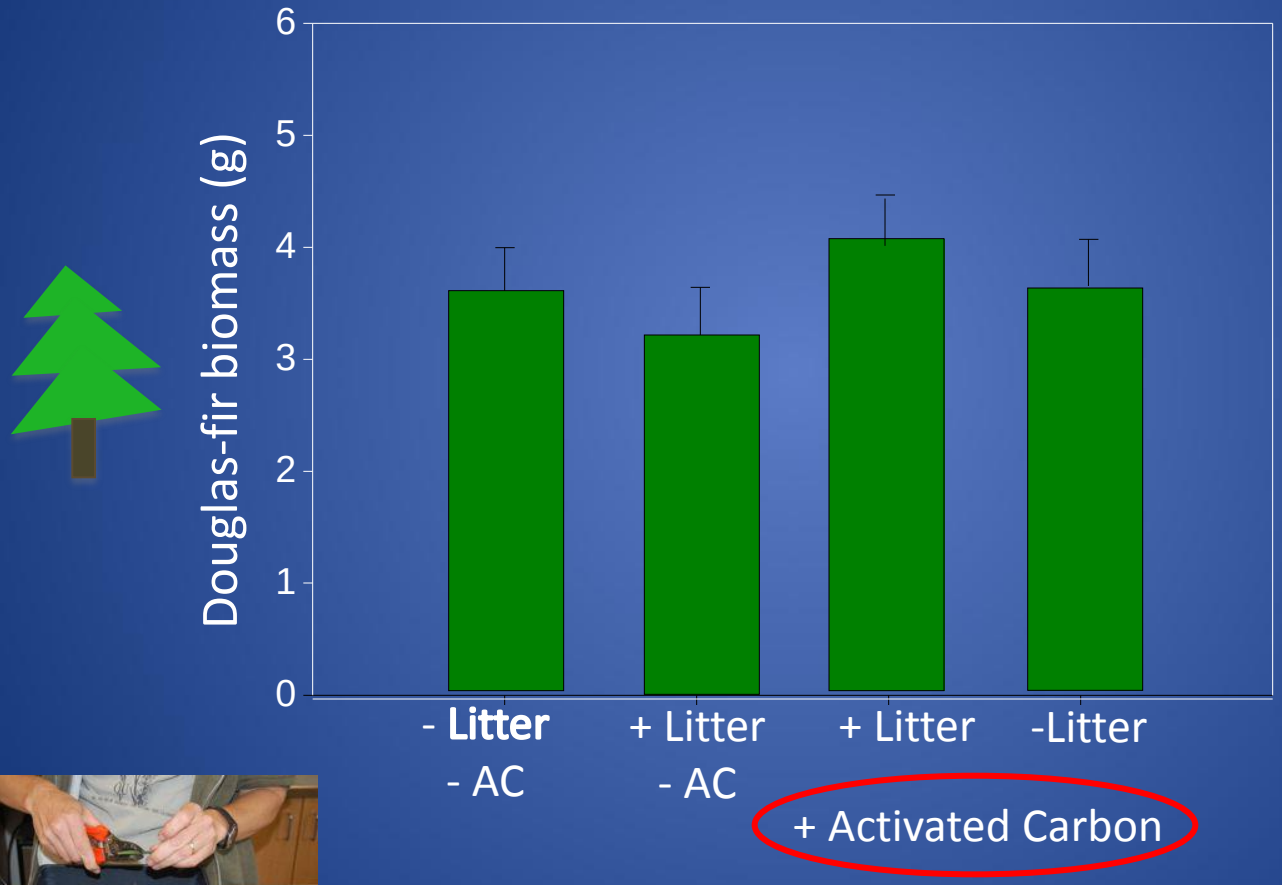
- Useful concept for prioritizing management
- Difficult to measure alternative stable states
  - can look for signs of feedbacks that promote self reinforcement
- Assuming an invasion is irreversible could result in unnecessary abandonment of impacted areas and further degradation of natural resources



Scheffer et al 2001, Suding and Hobbs 2009

Evidence for Allelopathy

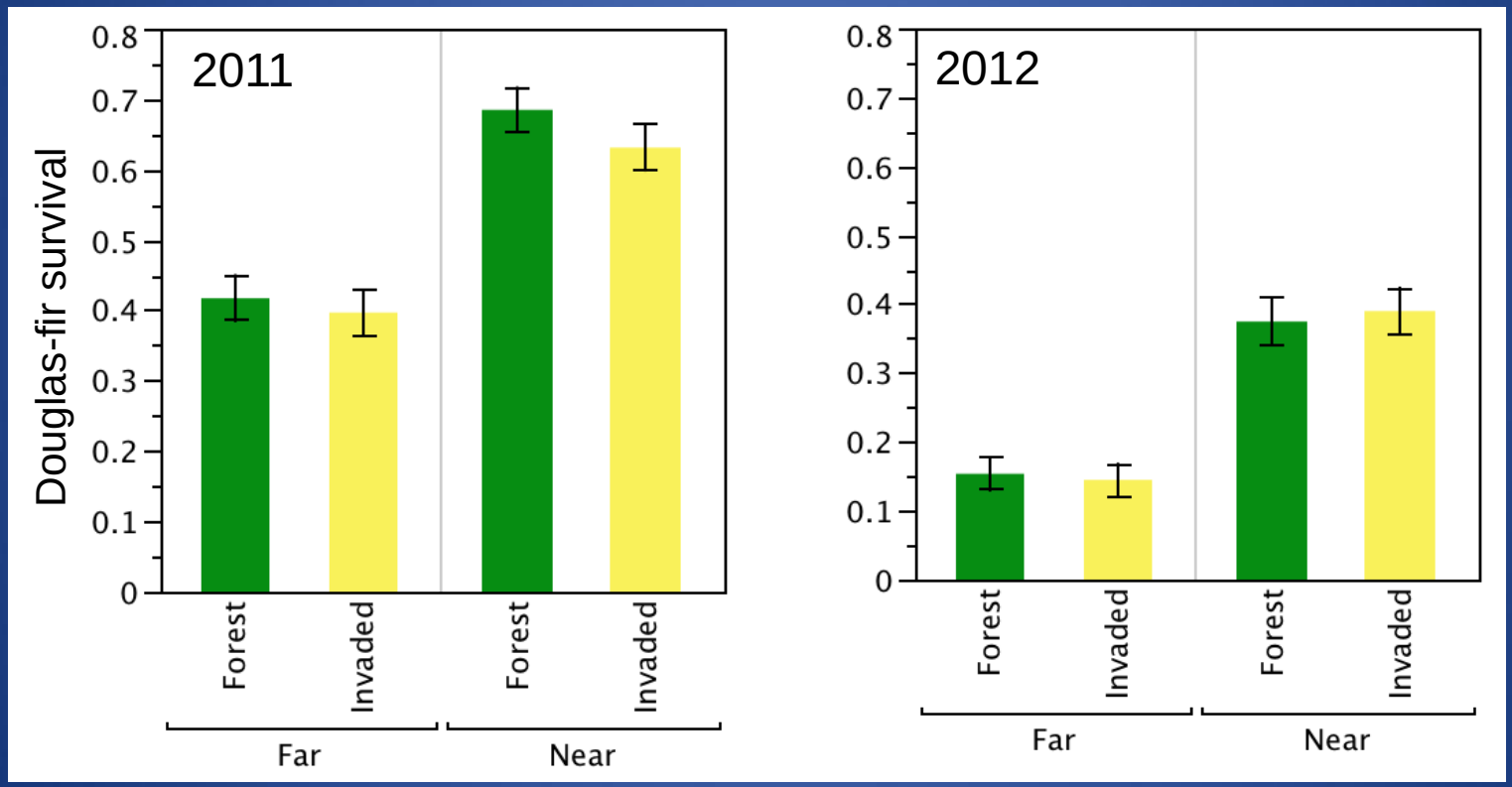
results from a broom mulch addition experiment



Forest soil

Grove et al. 2012

Doug-fir survival greater near forest edge, but not improved by forest soil inoculation

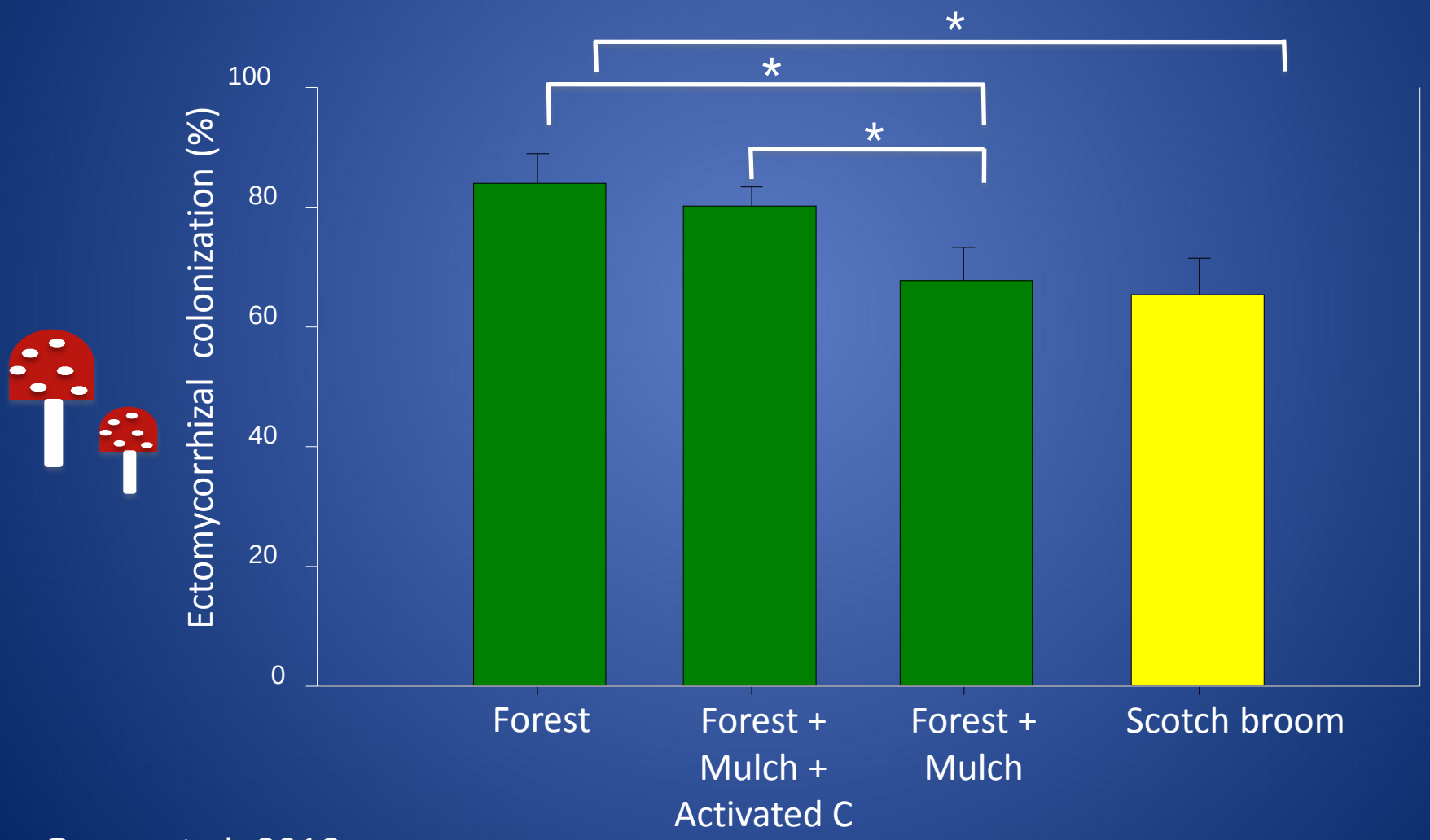


Edge: P < 0.0001
Soil transplant: P = 0.10

Edge: P < 0.0001
Soil transplant: NS

N =1000 seedlings

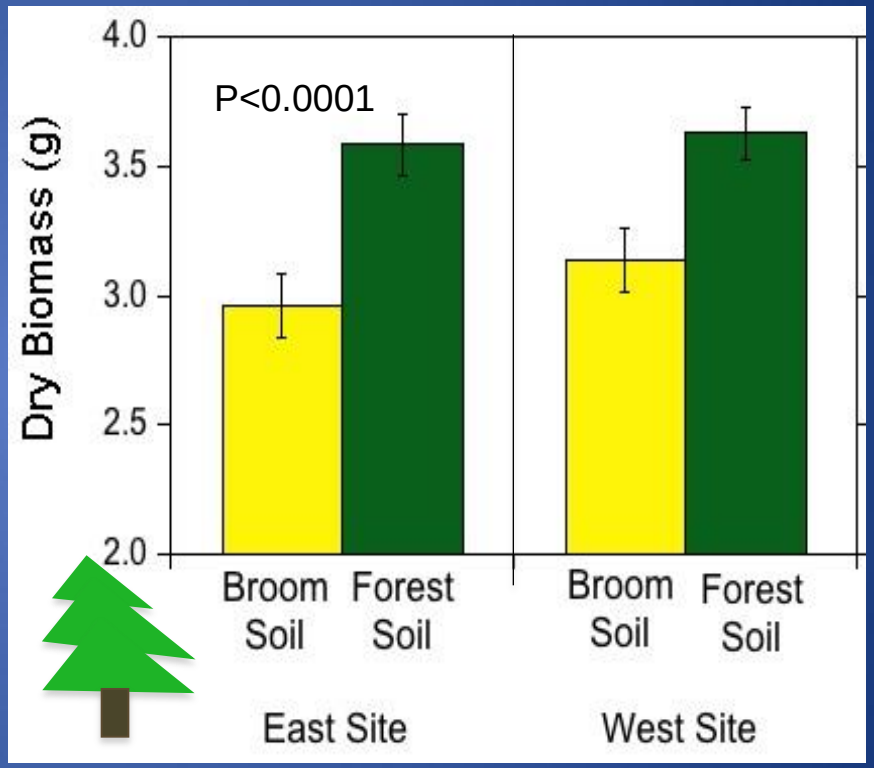
Reduction in the abundance of ectomycorrhizae



Grove et al. 2012

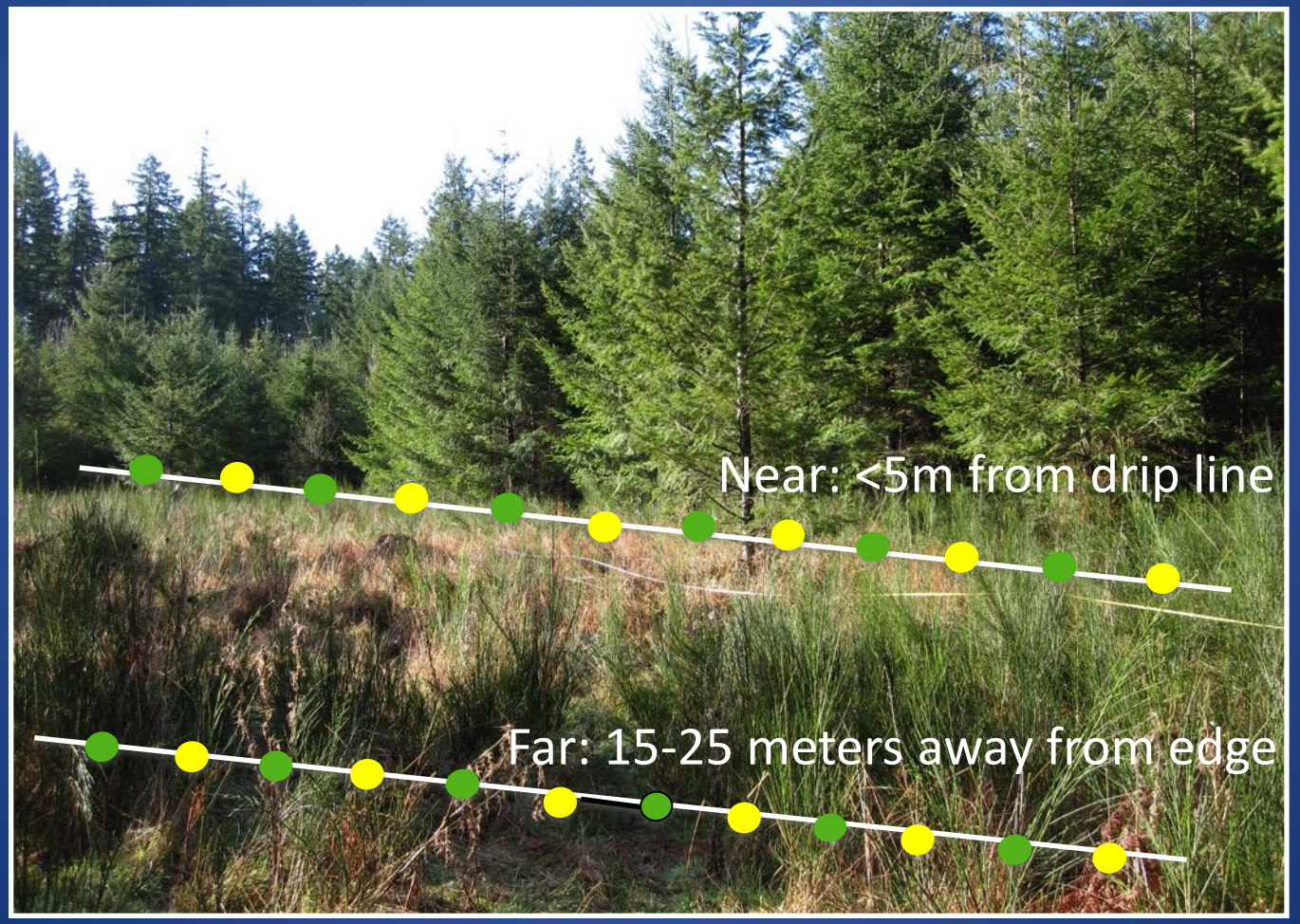
Evidence for a soil legacy effect

Broom-invaded soils inhibited Douglas-fir growth



Evidence for a legacy effect, but what is the mechanism?

Can inoculating invaded sites with forest soil or planting close to forest edges restore the mycorrhizal mutualism and improve Douglas-fir survival?



N = 1000 trees

Exotic herbaceous species increased