

Genetic Consequences of Seed Sourcing Strategies for Ecological Restoration



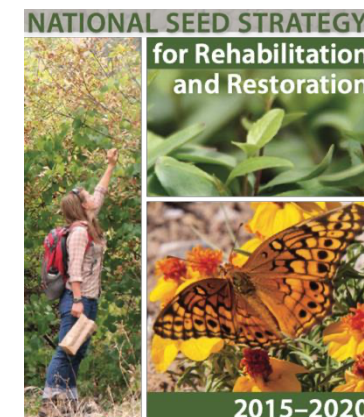
Rob Massatti & Trevor Faske
Landscape Stewardship Collective
July 14th, 2026



Ecological restoration requires genetically appropriate native plant material



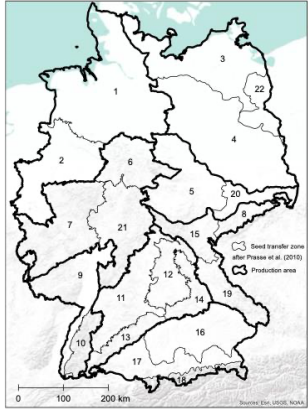
Gann et al. 2026



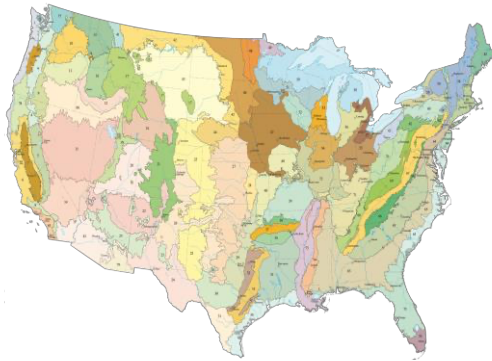
What tools are available to guide genetically appropriate seed sourcing?

Ecological zones

(based on regional environmental data)



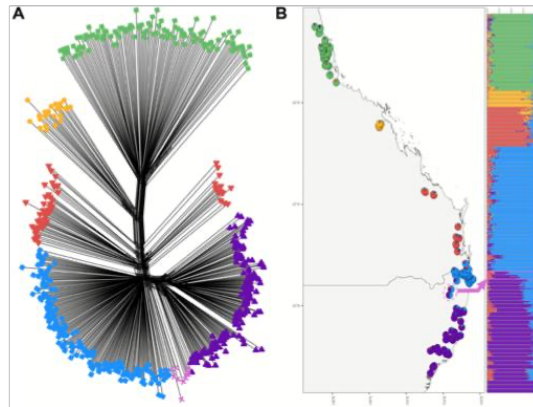
Prasse et al. 2010



U.S. EPA 2013

Genetic neighborhoods

(based on species-specific genetic data)



Dimon et al. 2026

Seed transfer zones

Provisional

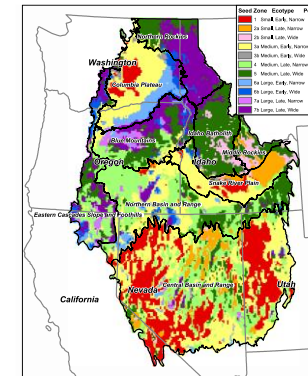
(based on environmental data)



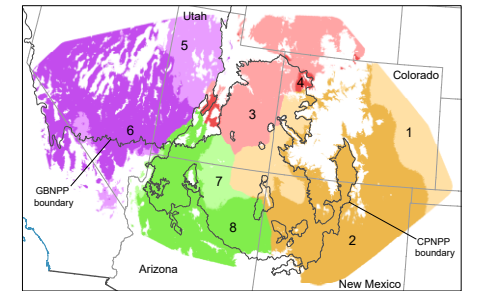
Bower et al. 2014

Empirical

(based on environmental data and species-specific field or genetic data)



St. Clair et al. 2014



Massatti 2019

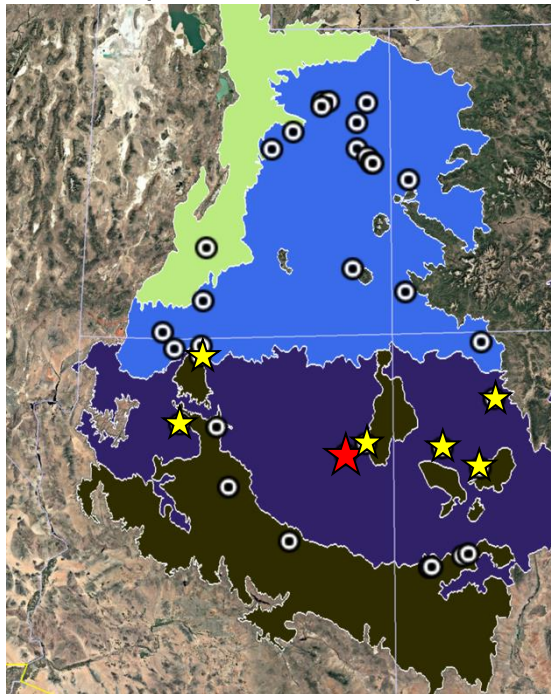
Tools directly or indirectly account for adaptation and/or patterns of genetic diversity & differentiation

Each tool identifies a different set of seed sources!

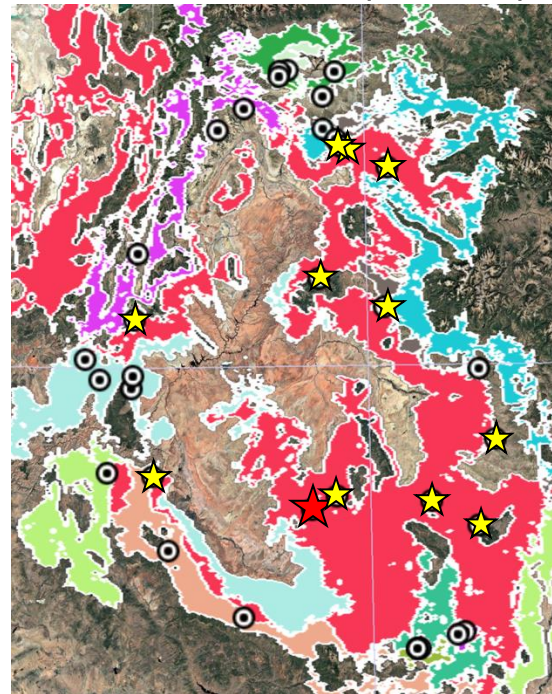
Let's assume seed is available from any of these wild populations...



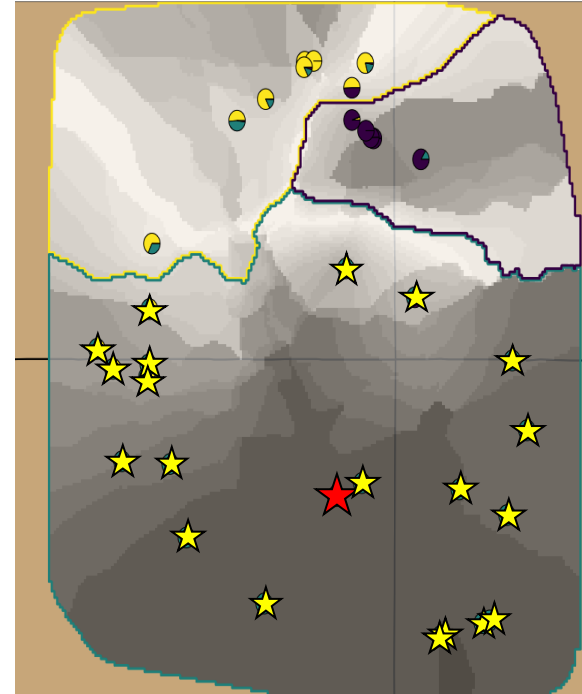
Ecoregions
(Omernik LIII)



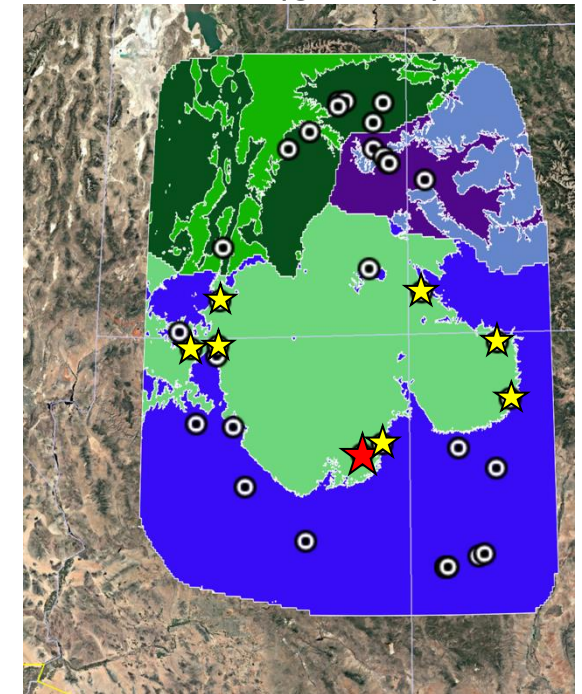
Provisional seed
transfer zones (pSTZs)



Genetic neighborhood (GN)



Genetic seed transfer
zone (gSTZs)

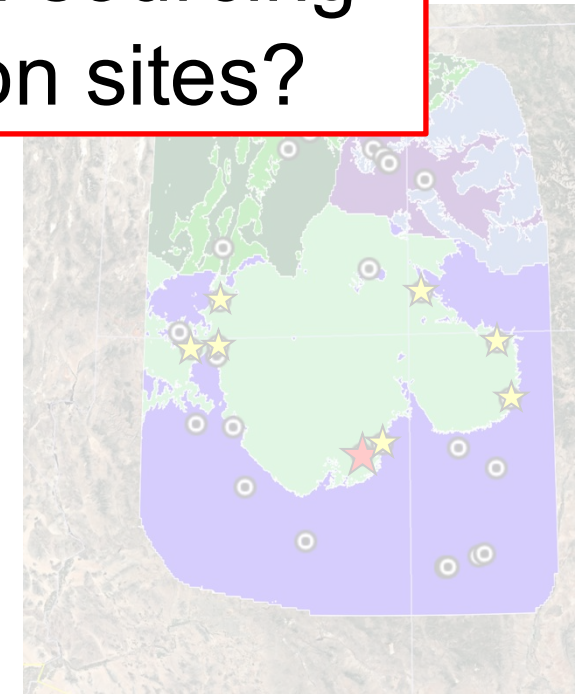
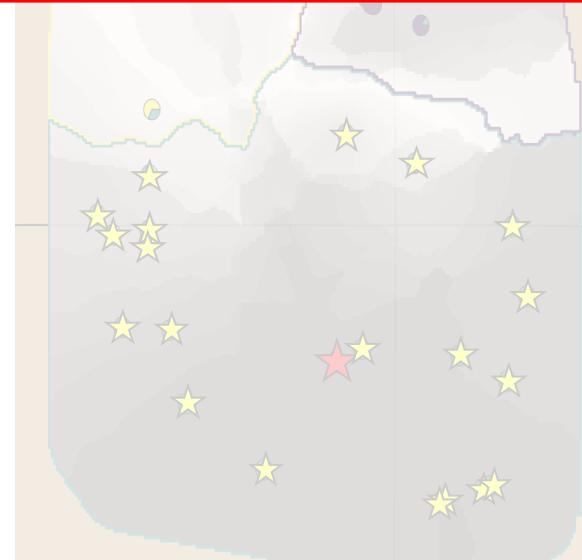
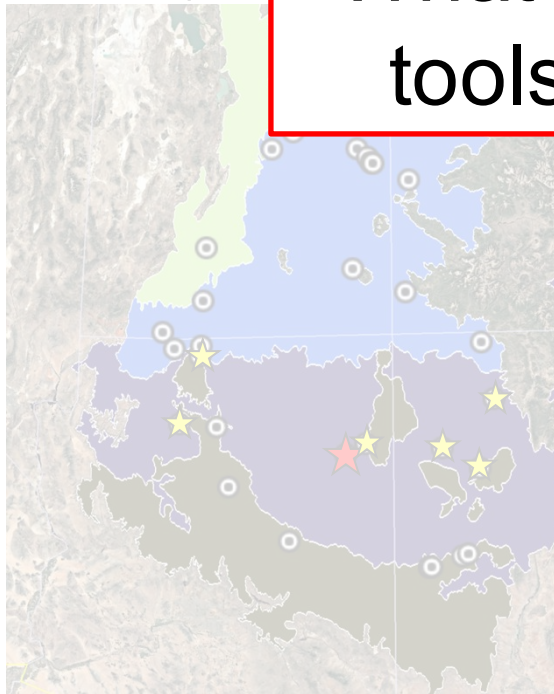


Each strategy identifies a different set of seed sources!

Let's assume seed is available from any of these wild populations...

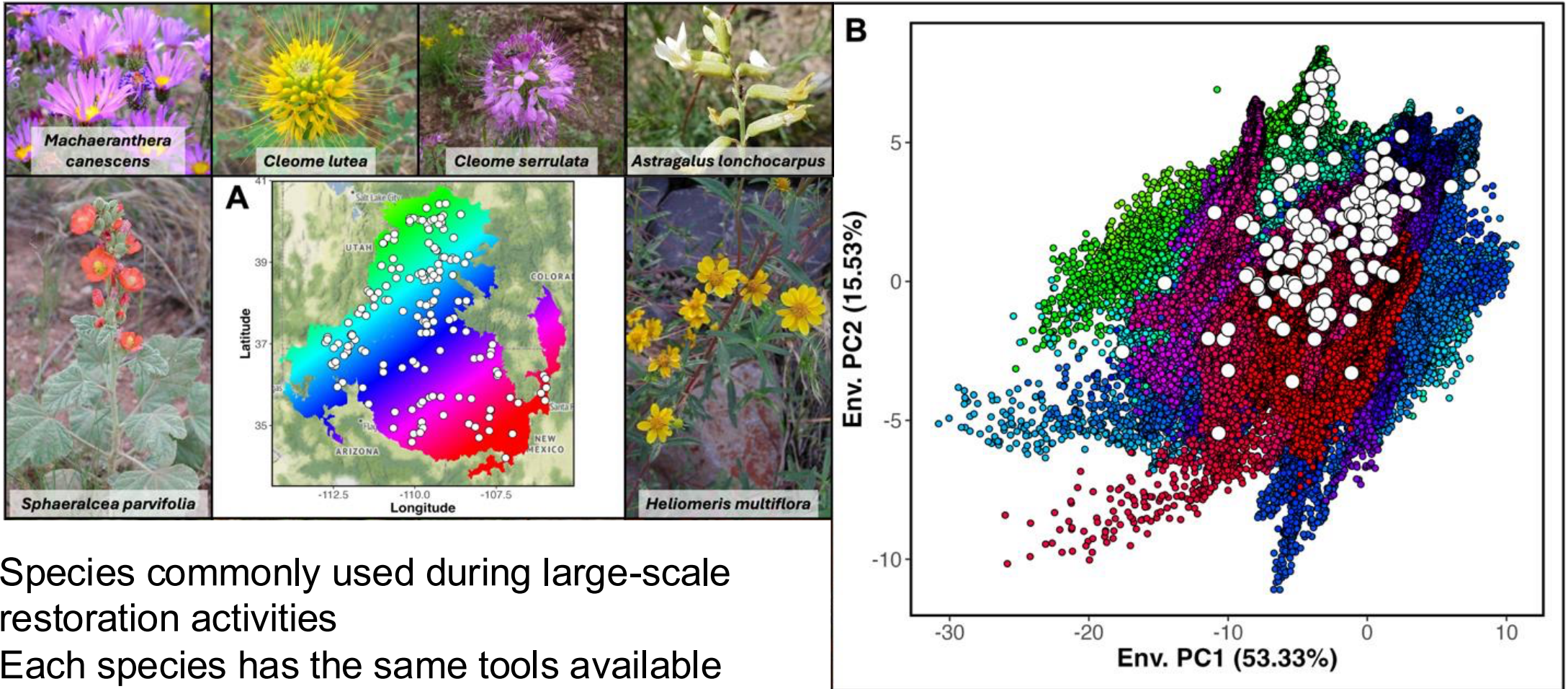


What are the potential impacts of seed sourcing tools on genetic patterns at restoration sites?



Environmentally and geographically co-distributed forbs on the Colorado Plateau

We used landscape genomic datasets from six co-distributed species:

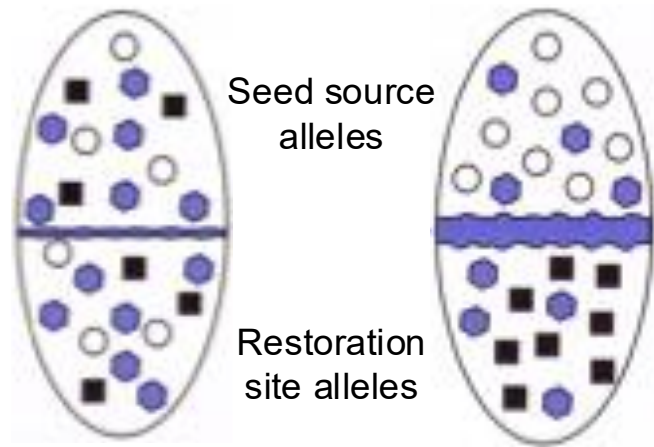


- Species commonly used during large-scale restoration activities
- Each species has the same tools available (ecoregion, pSTZ, GN, gSTZ)

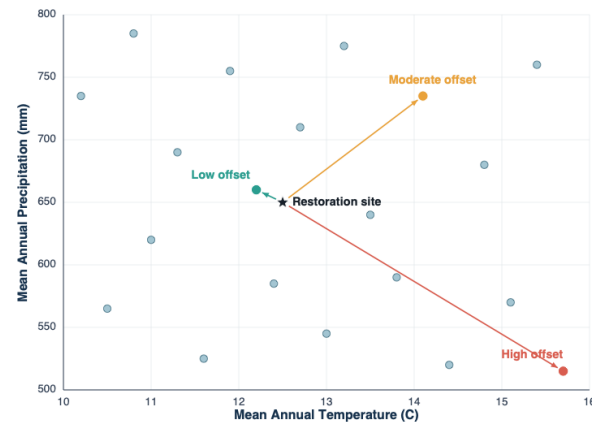
What are the potential impacts of seed sourcing tools at restoration sites?

- ➔ Genetically appropriate restoration means that seeds are adapted to restoration sites, protect within-species diversity, and support community interactions
- ➔ Practitioners need tools that minimize genetic and environmental differences between seed sources and restoration sites

Genetic differentiation (F_{ST})

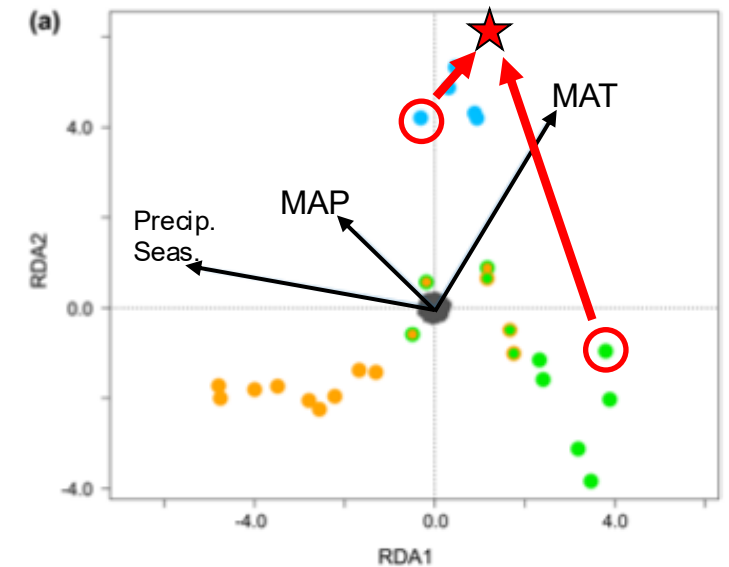


Environmental offset



Genetic offset

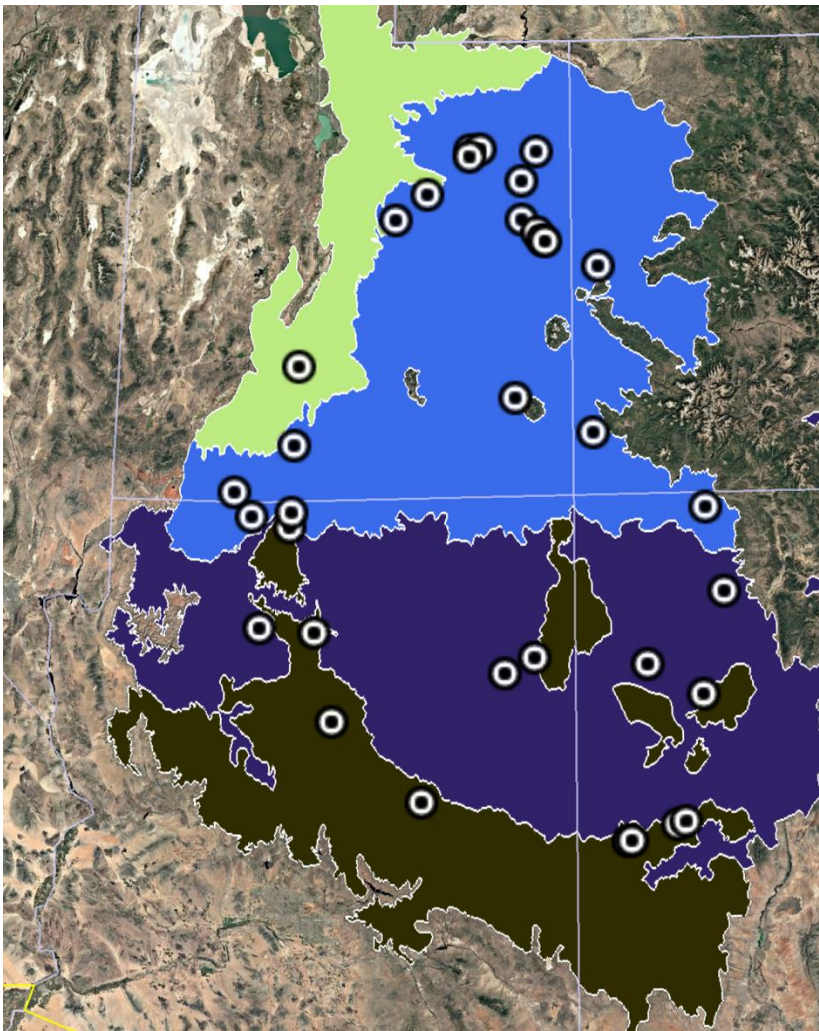
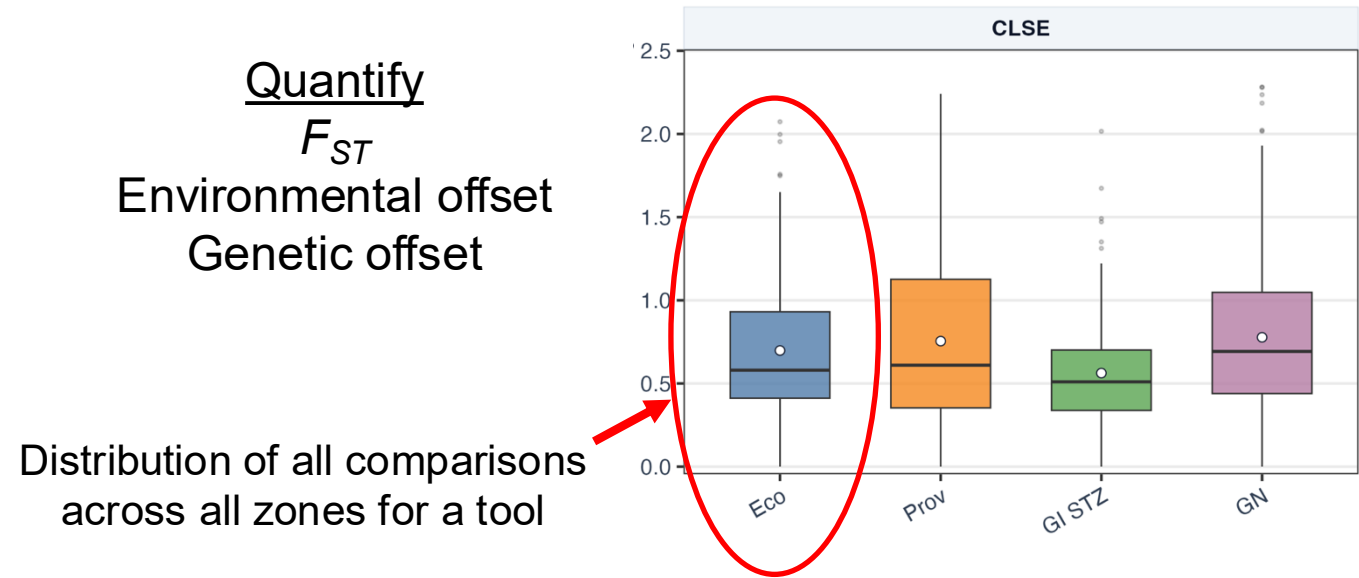
How different the adaptive alleles are between a seed source and the expected alleles at a restoration site (**climate variables influencing alleles have higher weights**)



Study design

For each species:

- each empirical site used as the reference restoration site
- all other sites within zone treated as potential seed sources
- tools: LIII ecoregions, pSTZS, GNs, and gSTZs

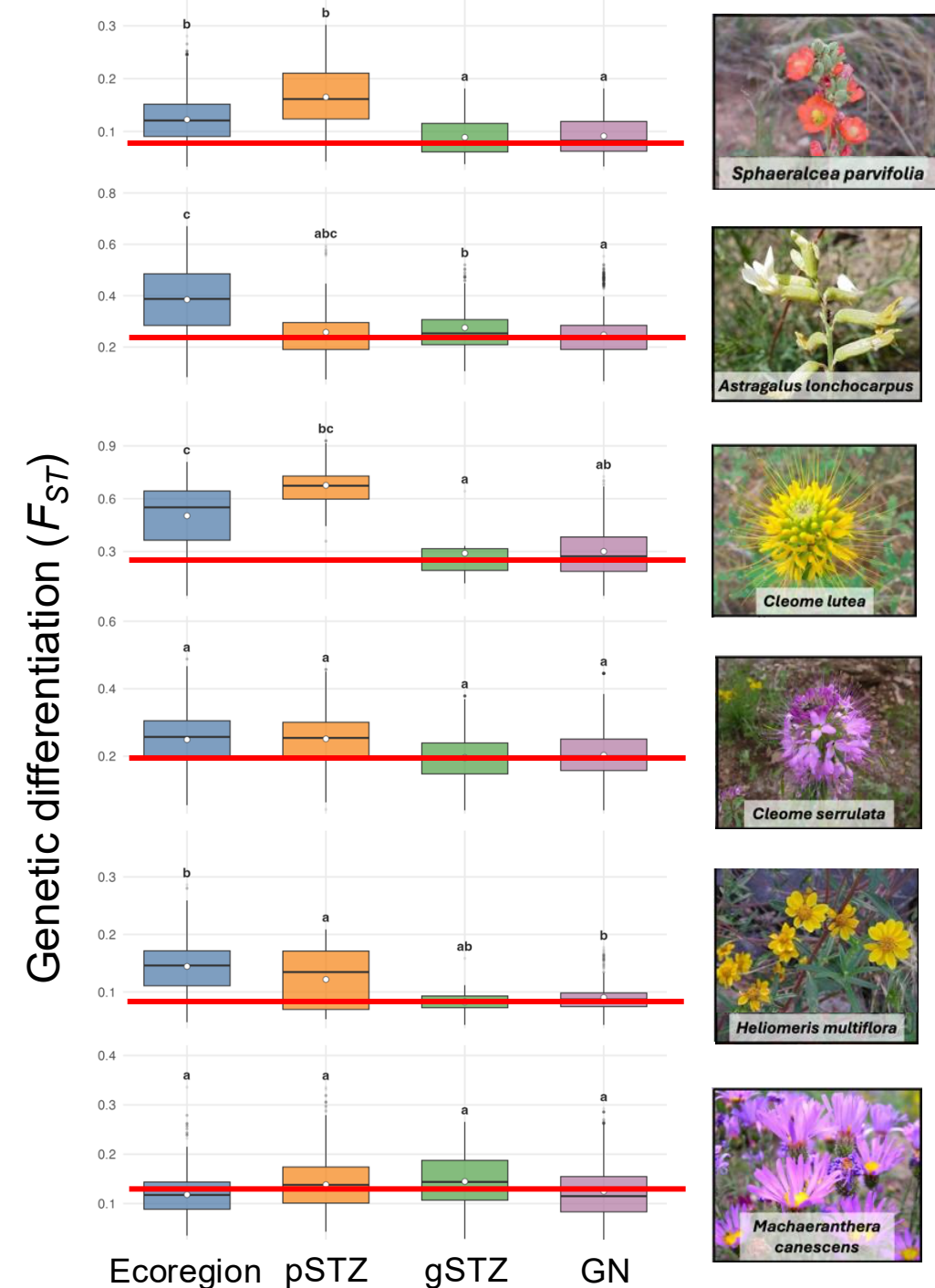


Results – Genetic differentiation

In General:

- GNs & gSTZs result in mixing less genetically differentiated seed sources and restoration sites
 - This is what we expect!
- Approaches are variable species to species

When ecoregions or pSTZs support low genetic differentiation, genetic patterns are by chance lining up with environmentally defined zones



Results – Environmental offset

Environmental offset – How environmentally different the seed source's location is from the potential restoration site (**all climate variables contribute equally**)

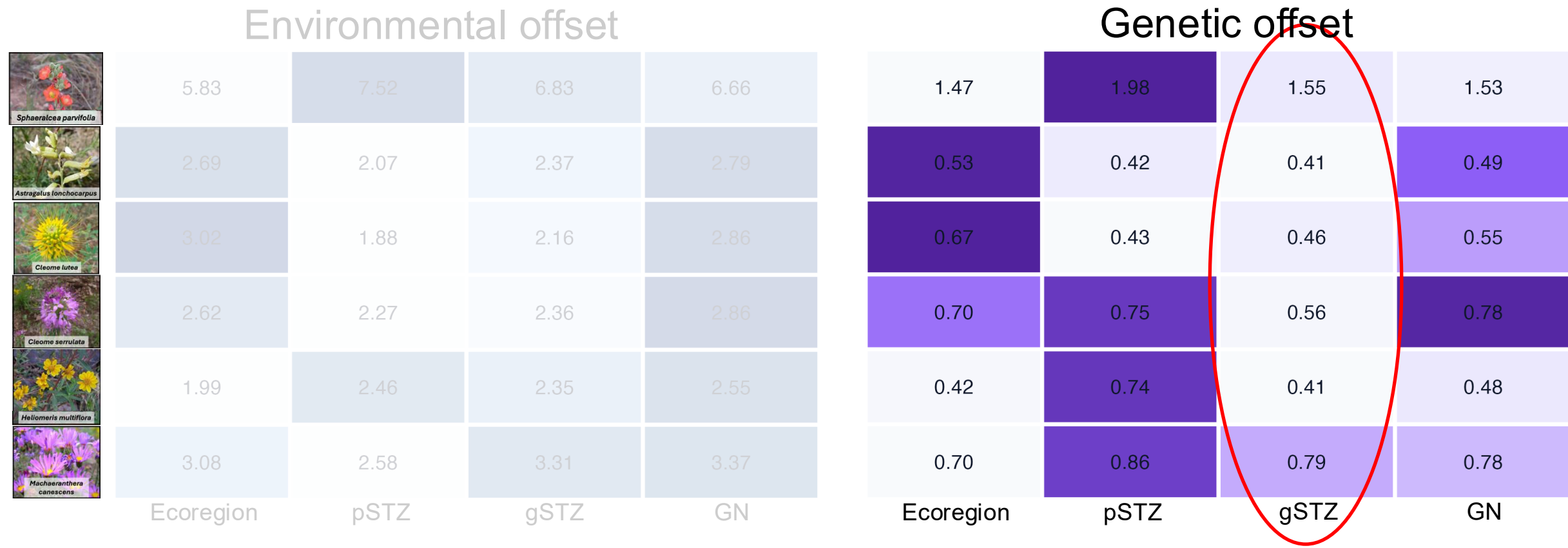
Environmental offset

 <i>Sphaeralcea parvifolia</i>	5.83	7.52	6.83	6.66
 <i>Astragalus lanchoarpus</i>	2.69	2.07	2.37	2.79
 <i>Cleome lutea</i>	3.02	1.88	2.16	2.86
 <i>Cleome serrulata</i>	2.62	2.27	2.36	2.86
 <i>Helioeris multiflora</i>	1.99	2.46	2.35	2.55
 <i>Machaeranthera canescens</i>	3.08	2.58	3.31	3.37
Ecoregion		pSTZ	gSTZ	GN

pSTZs tend to minimize environmental difference between a seed source and restoration site

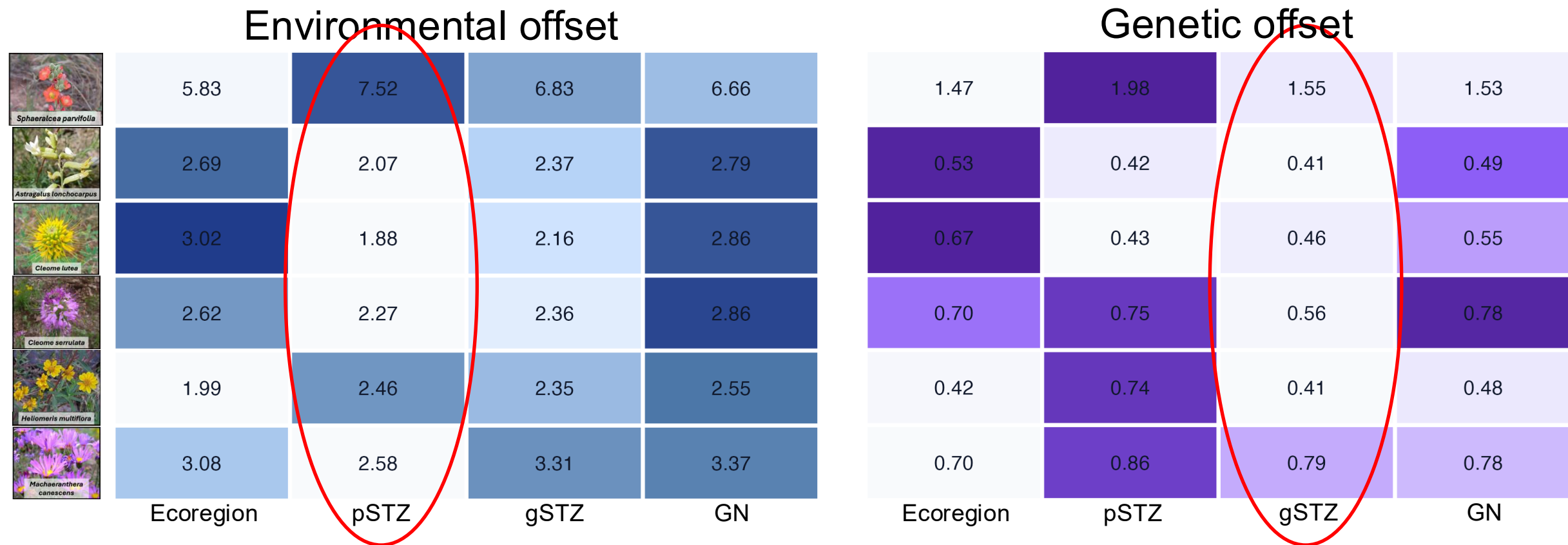
Results – Genetic offset

Genetic offset – How different the climate matched alleles are between a seed source and the expected alleles at a restoration site (**climate variables influencing alleles have higher weights**)



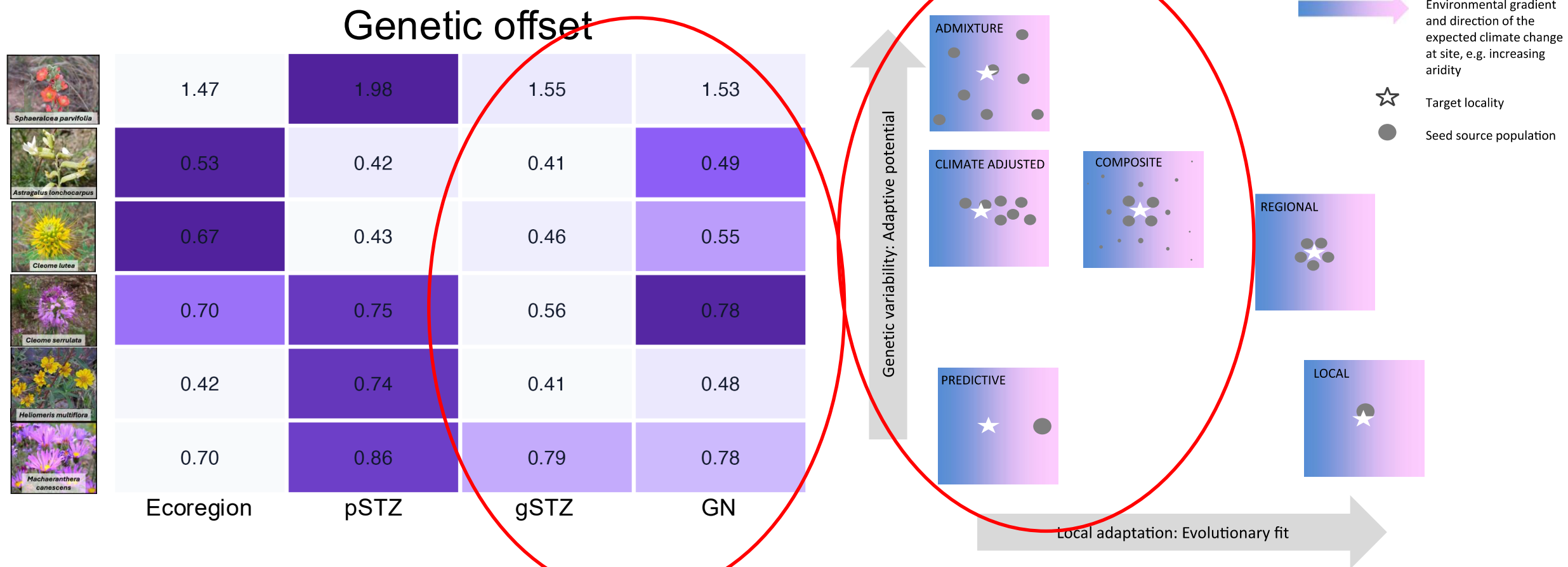
gSTZs tend to minimize “adaptive” difference between a seed source and restoration site

Results – Environmental & genetic offsets



Results are not surprising, but now we have quantified patterns and can see species-specific differences!

The most important message of this talk



Bucharova et al. 2019

- Restoration in future environmental conditions can use variation *WITHIN* genetic neighborhoods
 - Minimizing genetic differentiation protects biodiversity, supports co-evolved community relationships, reduces risks of outbreeding

What does this all mean?

What are the potential impacts of seed sourcing tools at restoration sites?

➔ We know that the same restoration site can get very different candidate seed sources depending on whether we use ecoregions, pSTZs, gSTZs, or GNs

- gSTZs and GNs most consistently increase probability of minimizing genetic differentiation and ensuring adaptive environmental match
- The differences between pSTZs and gSTZs result from species responding uniquely to their environments
- It is possible to choose seed sources that minimize genetic differentiation while also supporting different levels of putative adaptive breadth, depending on restoration goals



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Reach out!

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