Eelgrass Restoration: Source and Genetic Considerations

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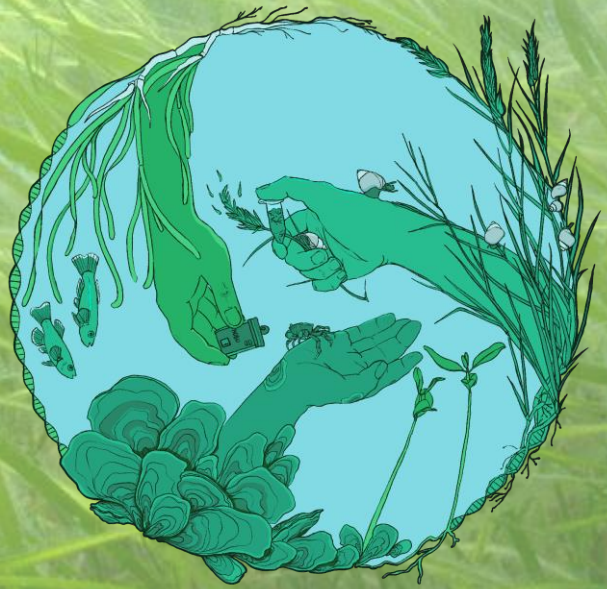

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Marine Science Center

Coastal Sustainability Institute
at Northeastern University

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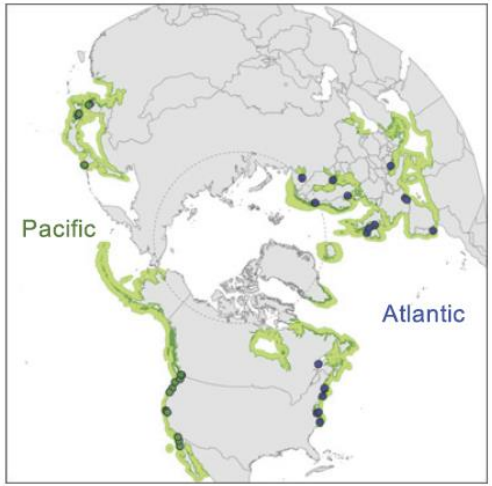
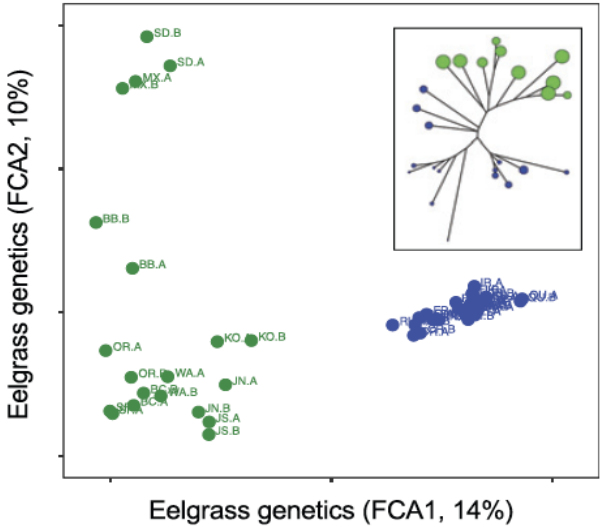
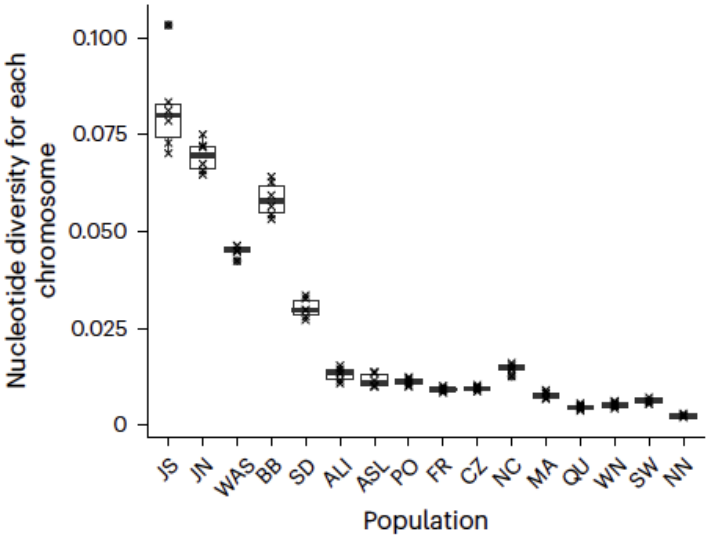
Eelgrass genetic diversity and composition shaped by broad spatial and temporal scales

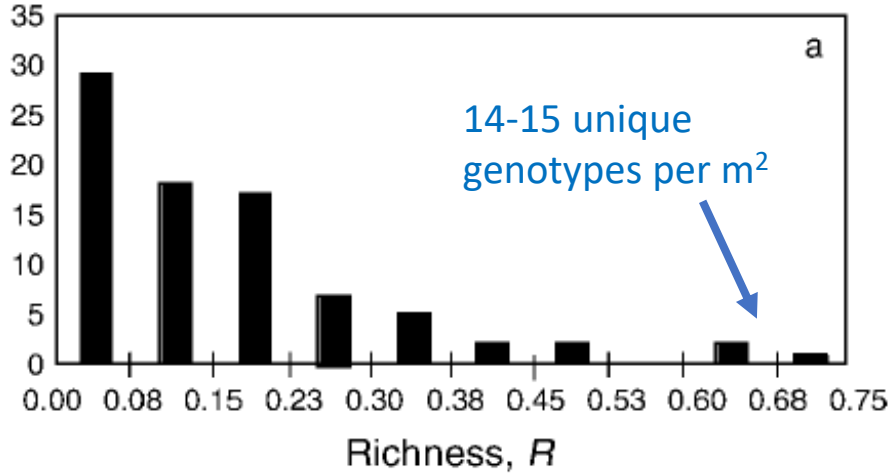


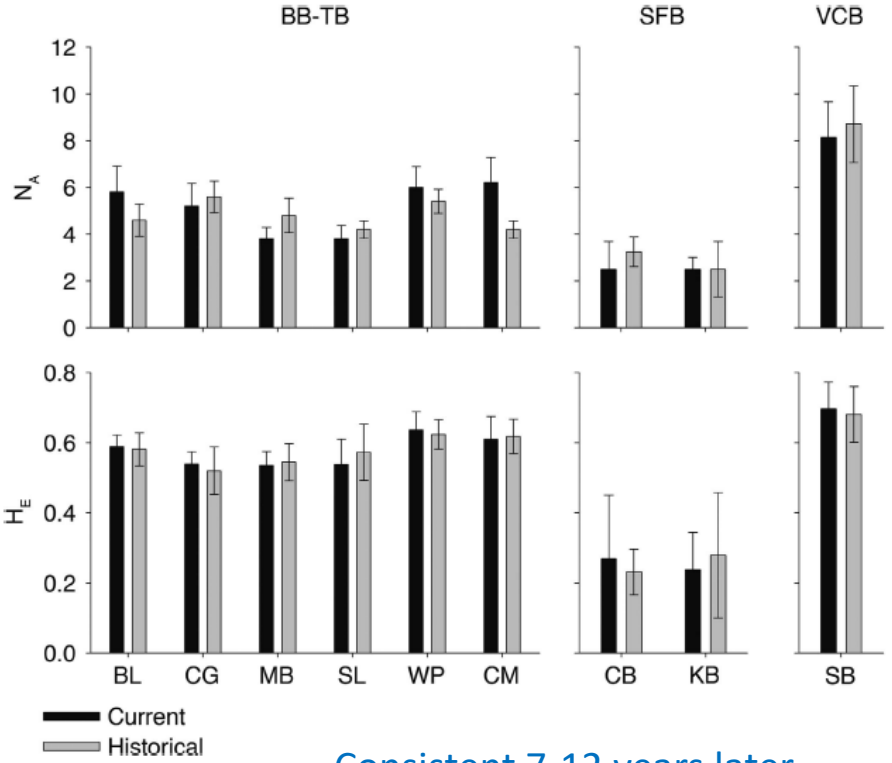




Duffy et al. 2022 PNAS, Yu et al. 2023 Nature Plants

Diversity can also be substantial, and stable through time, at small spatial scales





Consistent 7-12 years later

Hughes and Stachowicz 2009 Ecology, Reynolds et al. 2017 Heredity

Small-scale diversity provides resilience to a range of stressors, benefitting biomass and production

Grazing

Heat wave

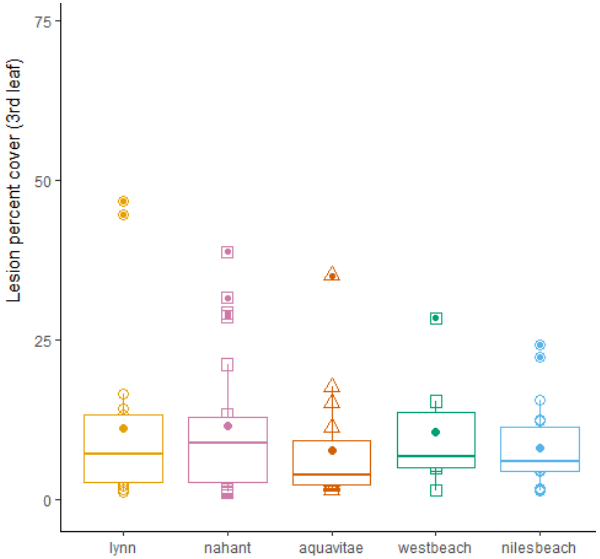
Macroalgal bloom

Controlled disturbance

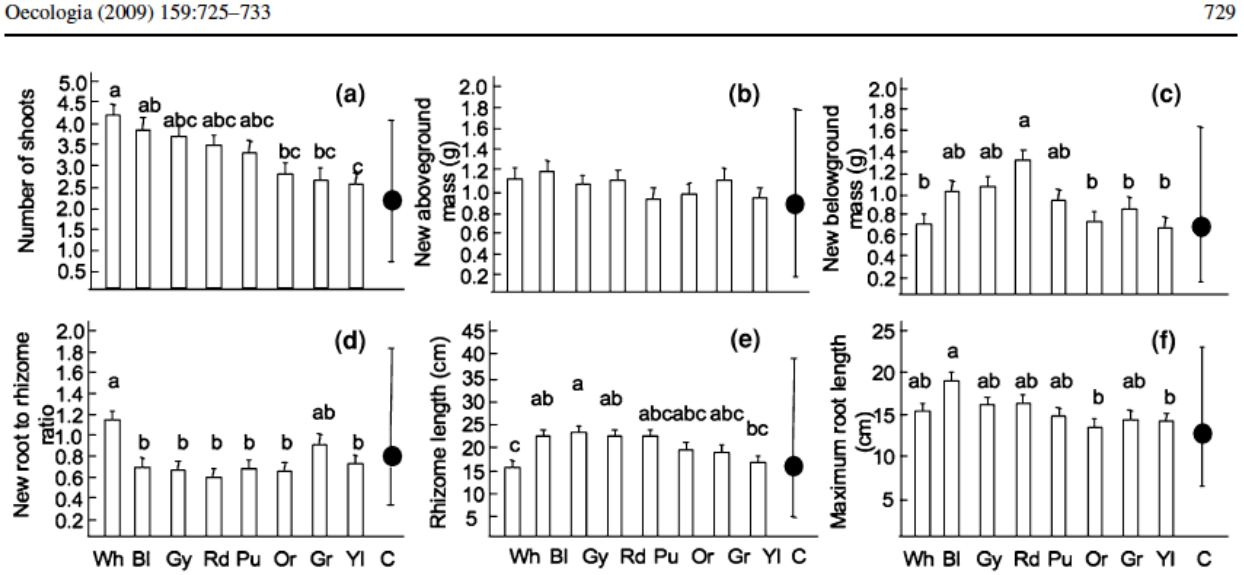
Natural populations

Hughes and Stachowicz 2004 PNAS, 2009 Ecology, 2011 J Ecology; Reusch et al. 2005 PNAS

Heritable differences across genotypes and populations underlie positive effects of diversity



Population

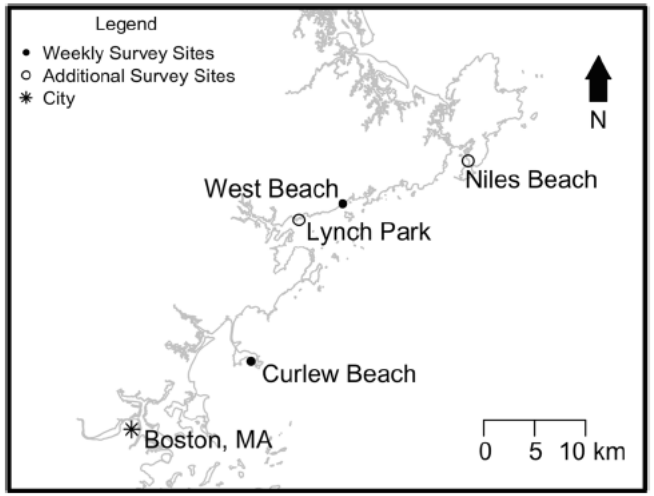


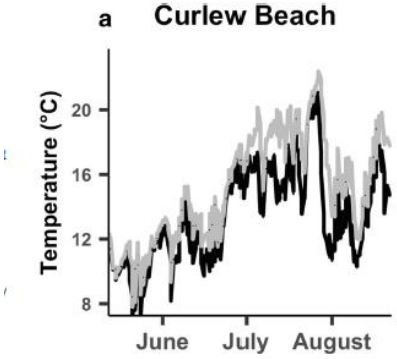
Genotype

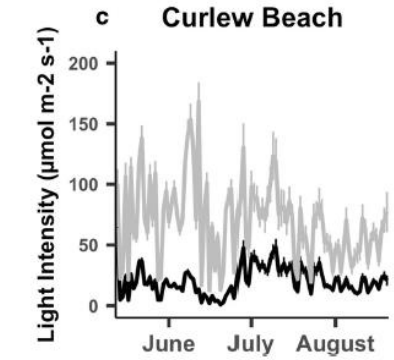
Hughes et al. 2009 Oecologia, Schenck and Hughes unpublished

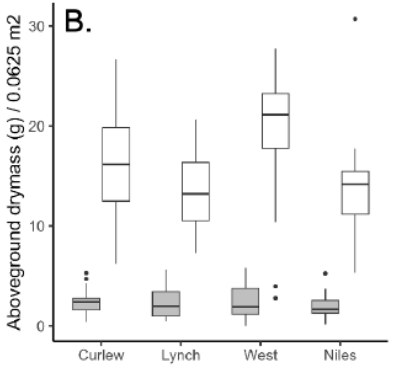
What drives small-scale genetic variation and corresponding traits?

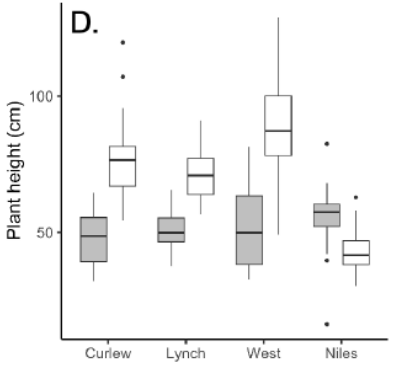
Do we see consistent genetic and (heritable) trait differentiation within meadows across the depth gradient?





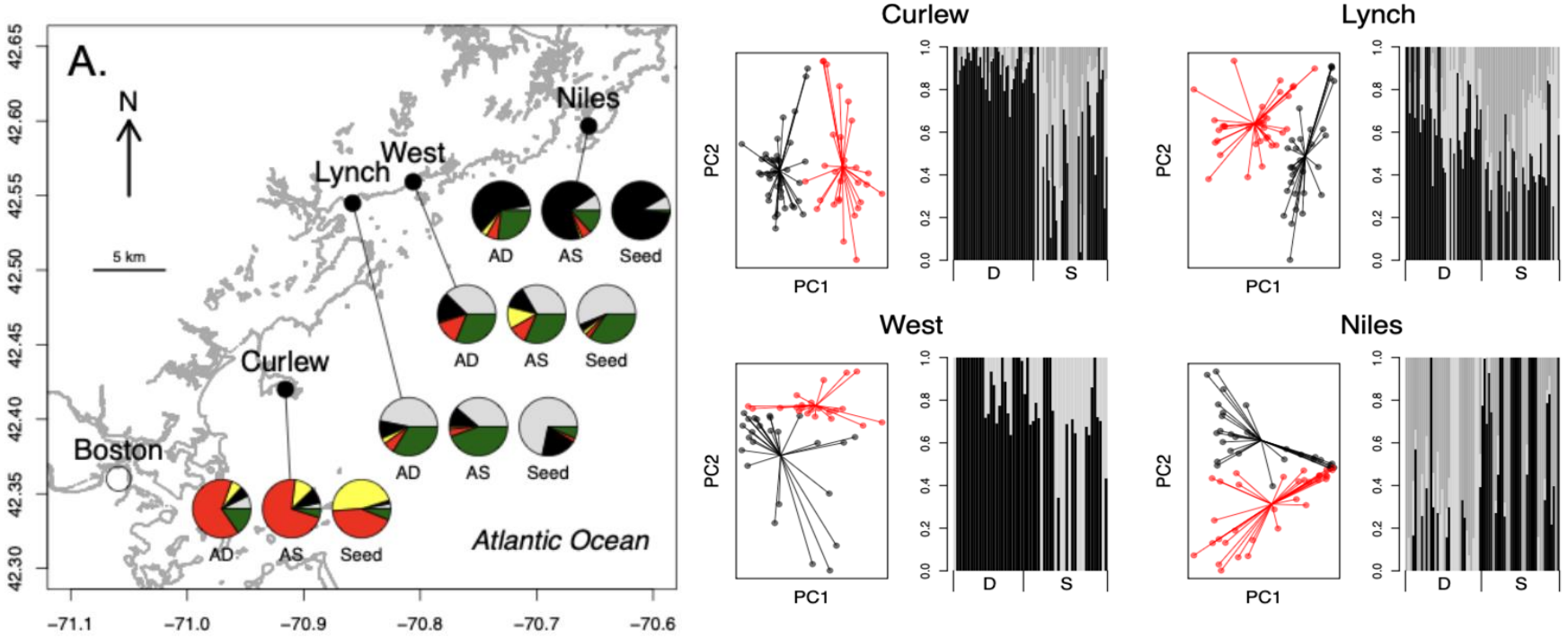






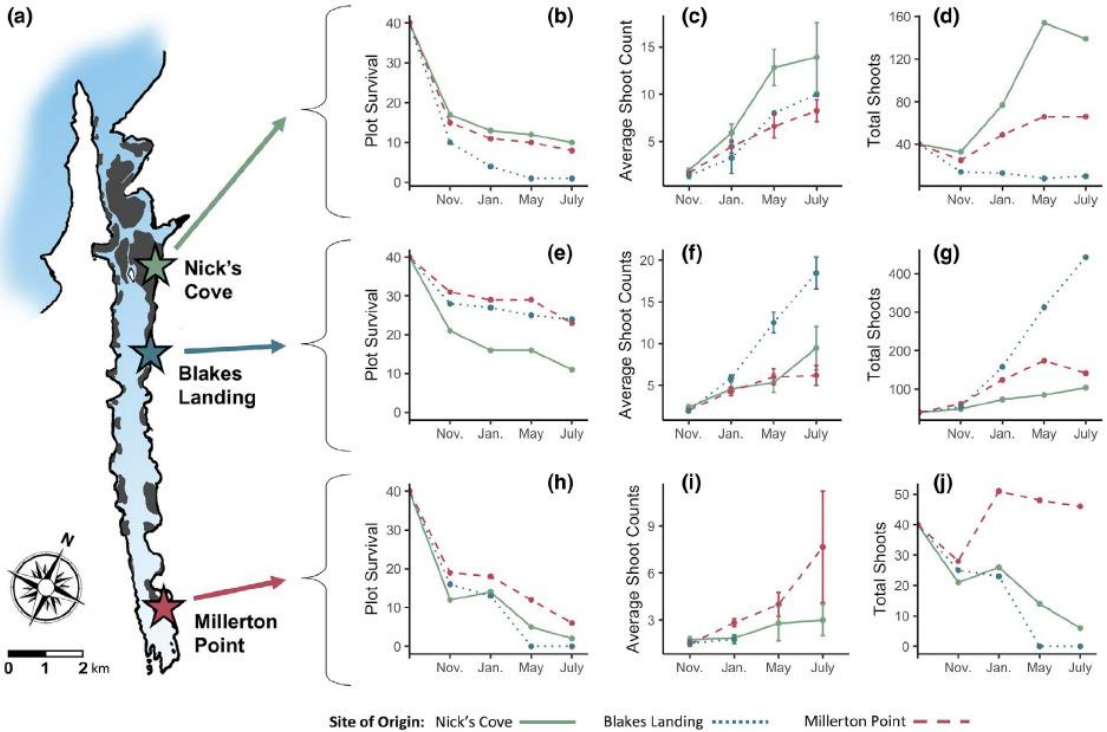
Von Staats et al. 2021 Estuaries and Coasts, Hays et al. 2021 Estuaries and Coasts, Sotka et al. In Revision Mol Ecology

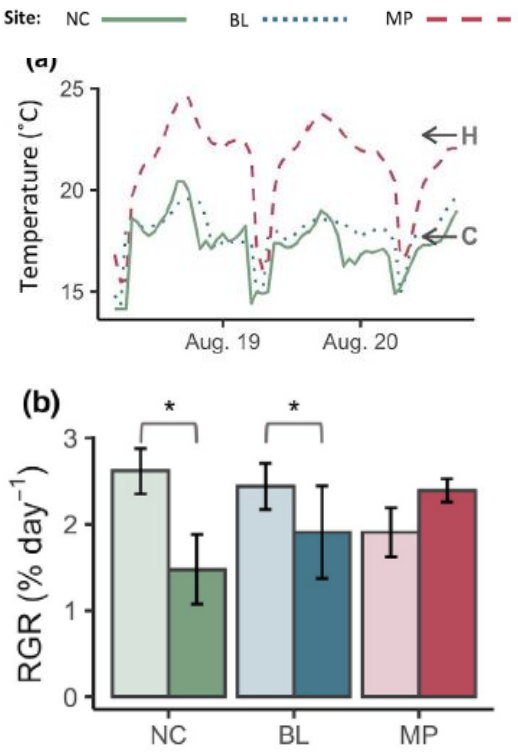
Genetic divergence across small spatial scales suggests local adaptation could occur



Sotka et al., In Revision, Molecular Ecology

Adaptation across estuarine gradient suggests source environment can predict traits / resilience

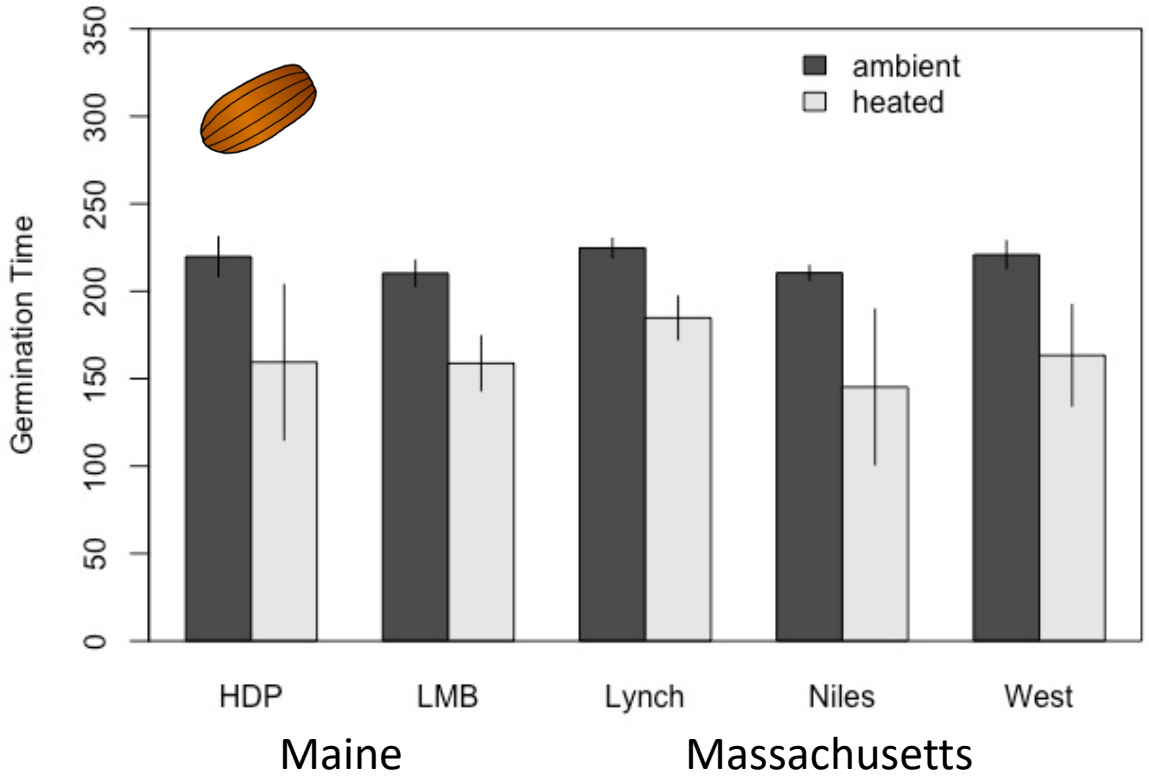




DuBois et al. 2022 Global Change Biology

These results are promising… AND

- We need more tests to know how generalizable these results are
- We should expect that some traits will be conserved

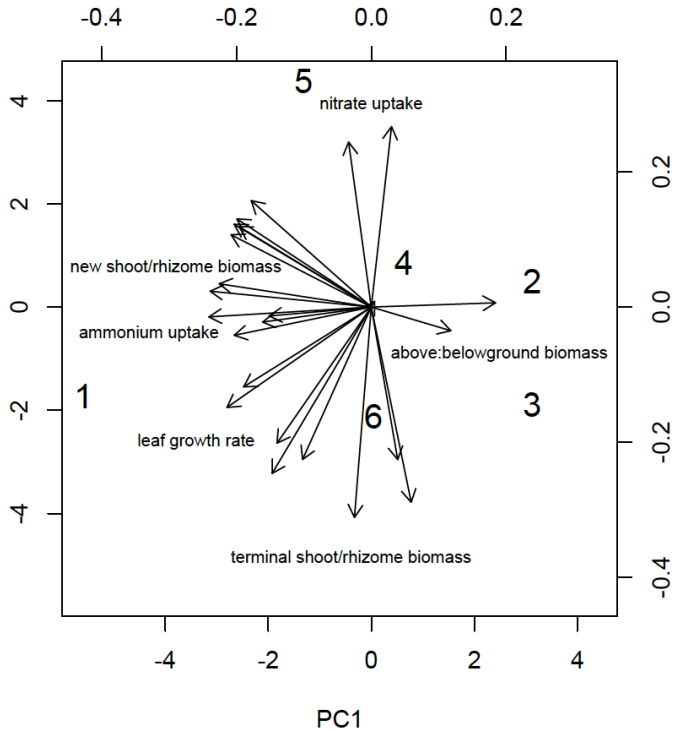


Nadeau, DuBois, Kollars, and Hughes, unpublished

How can we use what we know to benefit restoration NOW?

A single “best” source is likely a unicorn

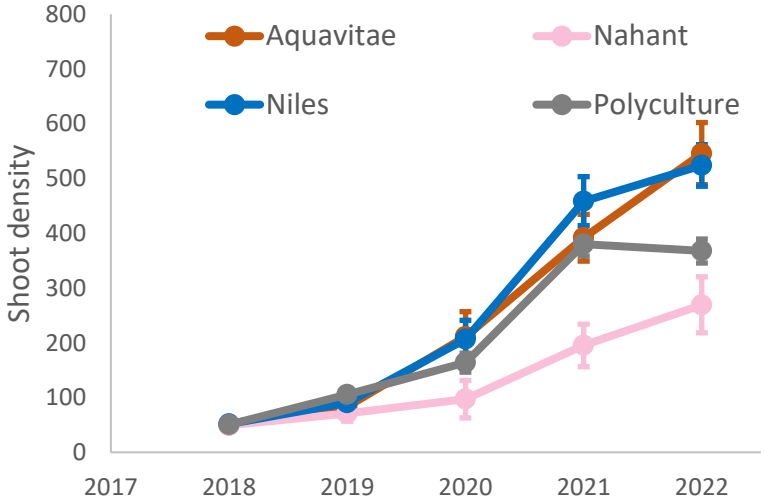
Population

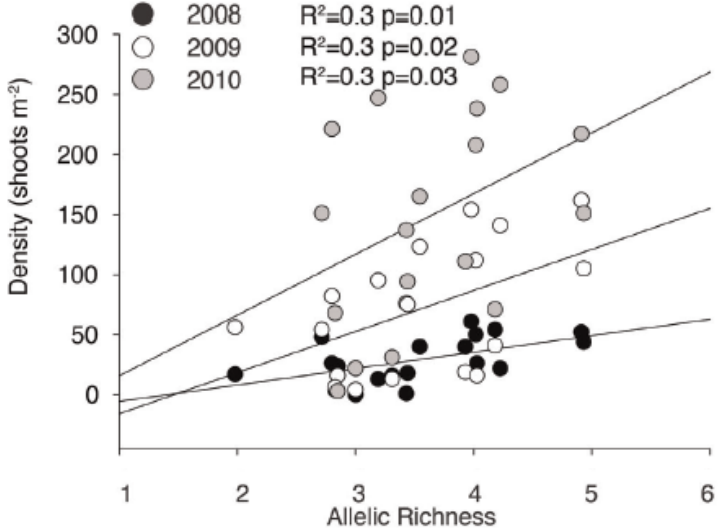


Genotype

Schenck, Hughes, et al. unpublished, Hughes et al. 2009 Oecologia, Abbott et al. 2016 Ecology

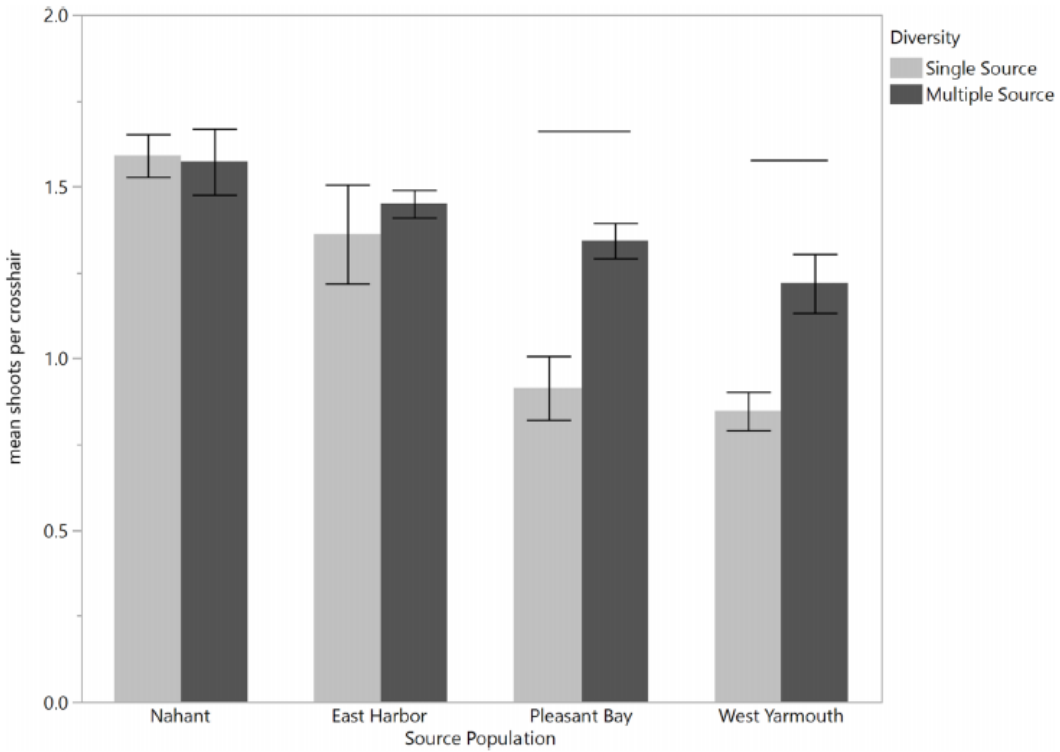
Multiple sources from different environments can help us hedge our bets





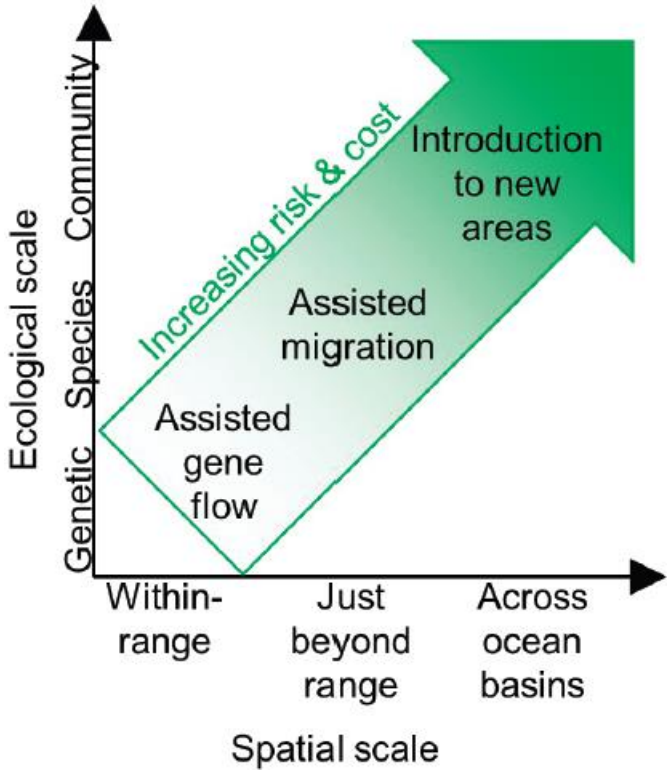
Schenck, Hughes, et al. unpublished, Reynolds et al. 2012 PLoS One

Using multiple sources does not always result in a benefit, but it also rarely has a cost



Novak et al. 2017 PeerJ

The risks associated with moving plants or seeds increase with spatial scale

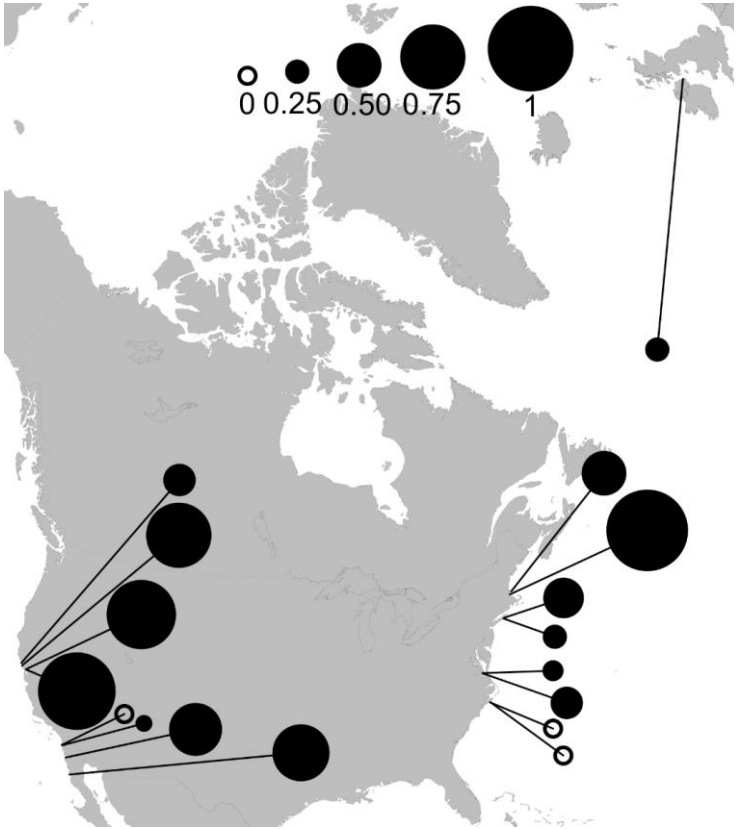


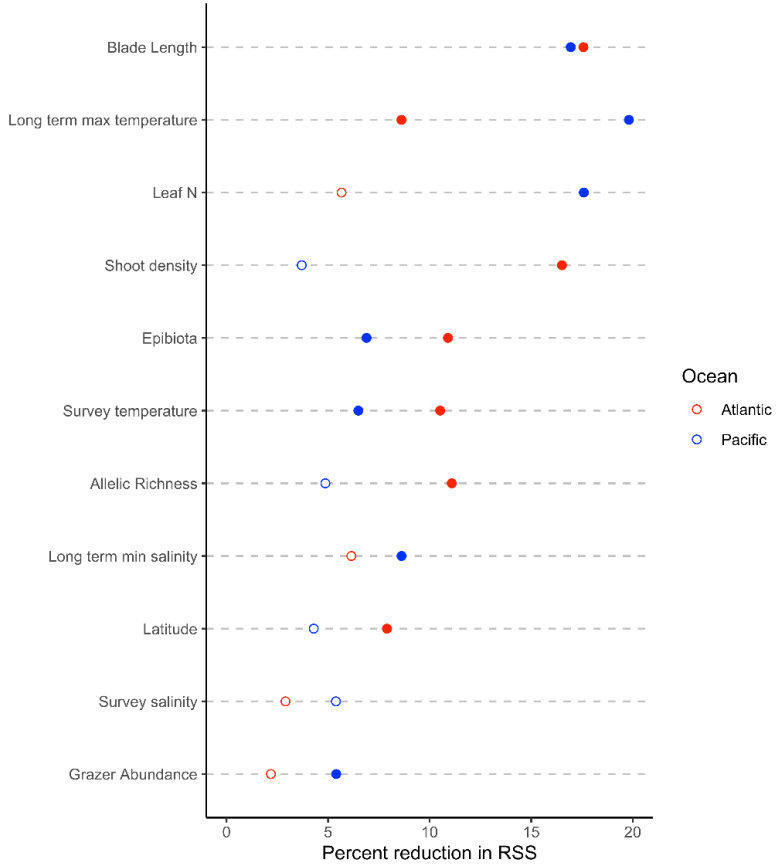
We should take advantage of local/regional environmental variation when possible

NASEM 2019 Review of interventions to increase the persistence and resilience of coral reefs

Potential risk of shoots: Wasting disease

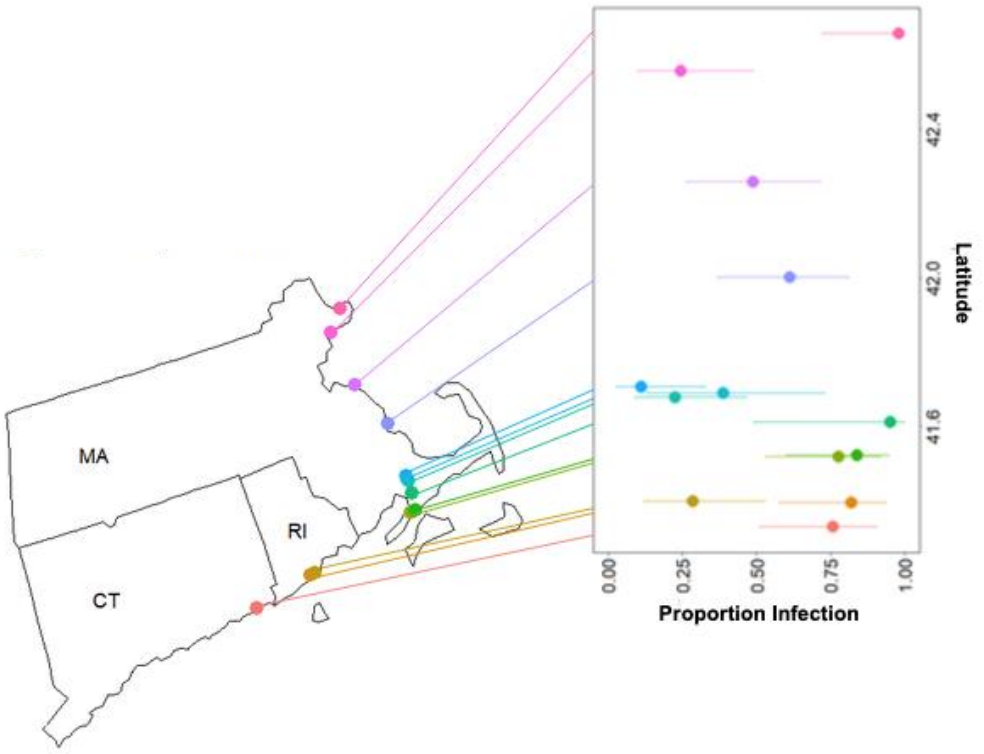
Labyrinthula zosterae

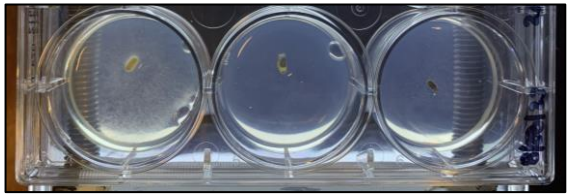




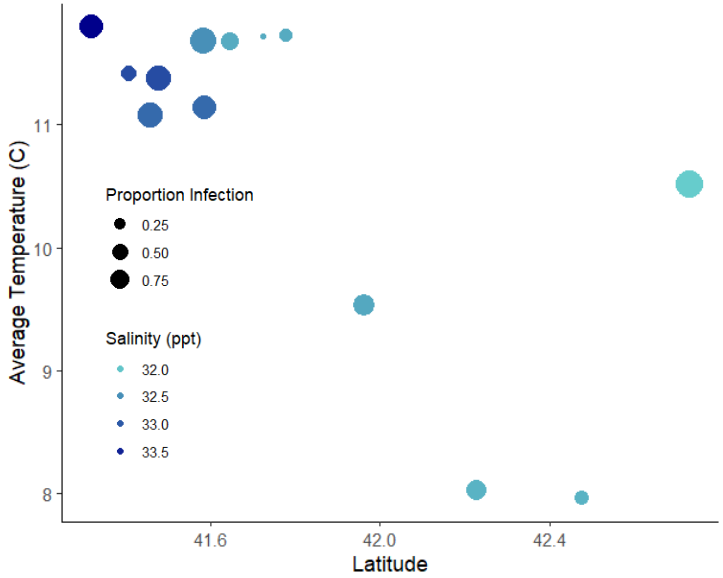
Schenck et al., unpublished

Potential risk of seeds: Phytophthora



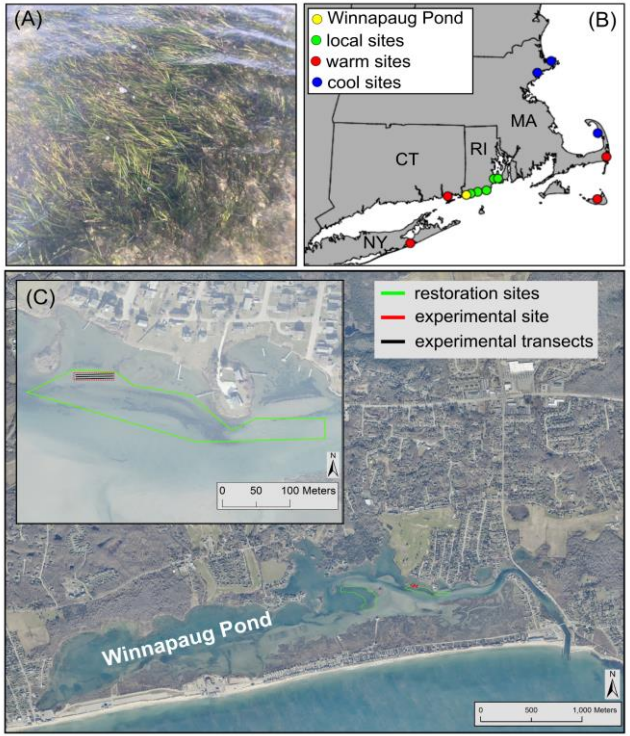


Phytophthora spp.



Carlston, Schenck, and Hughes, unpublished

Seeds themselves can be risky (with potential for high reward)

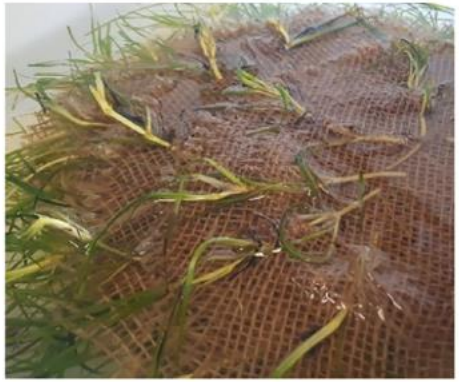


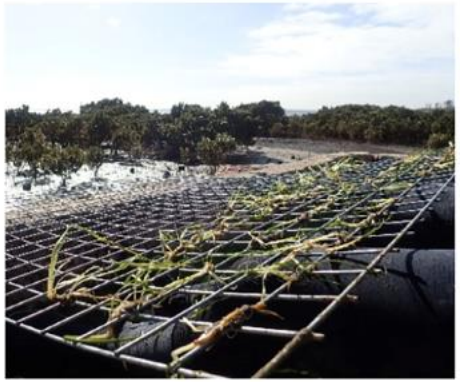
Nadeau et al. 2024 Biological Conservation

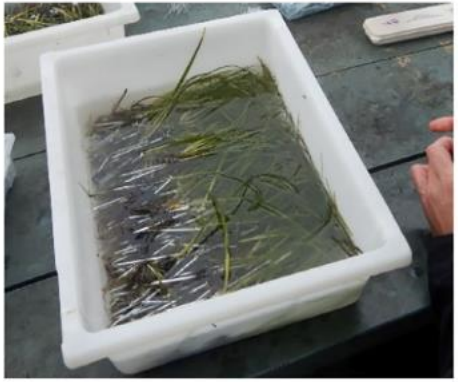
Testing seeds and shoots in an experimental framework can maximize learning and success

Implications for Practice

- Shoot- and seed-based techniques are the two main approaches used in seagrass restoration, and which approach is more appropriate is dependent upon the system.
- There is a need to undertake experimental trials during the early stages of a restoration program to understand and validate whether shoot-, seed-based, or a combination of both approaches are suitable for a particular system.
- The experimental approaches used in this study highlights that seed-based approaches are the most appropriate and scalable for temperate *Zostera muelleri*.
- Improvements in the efficiency of seed collection and storage, and exploring techniques to increase seedling establishment and survival can help improve the viability and scalability of seed-based restoration.







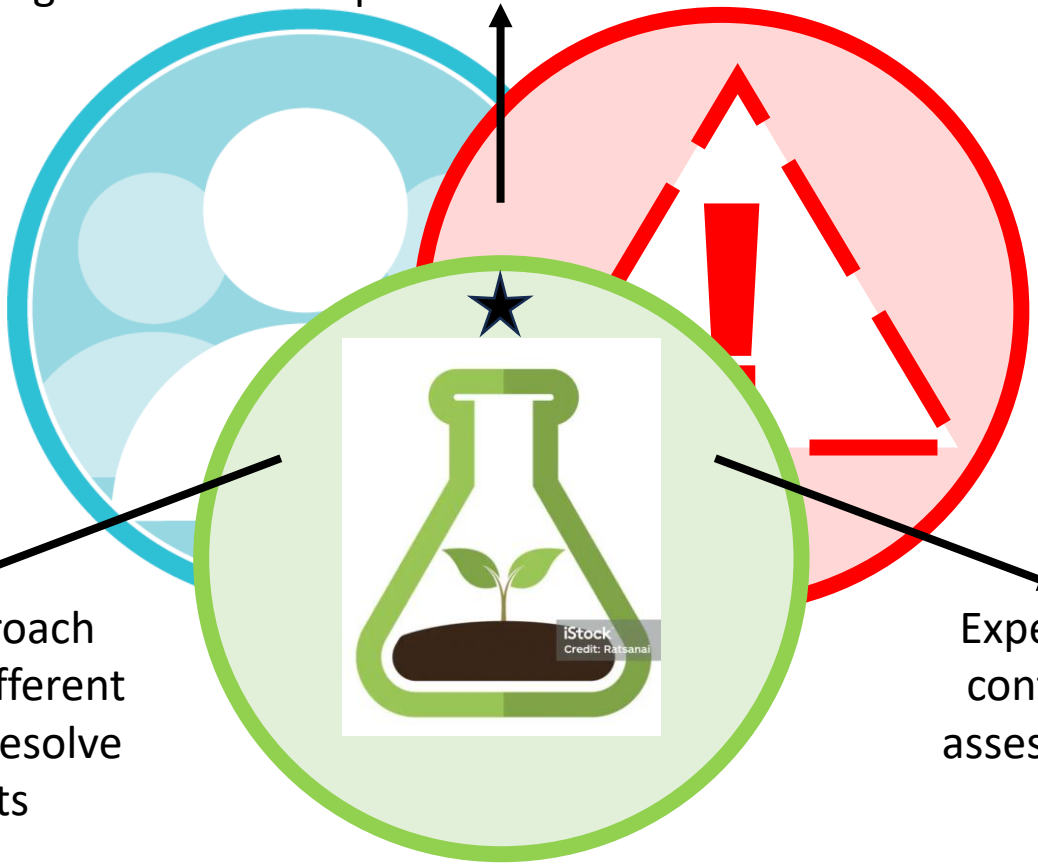
Tan et al. 2023 Restoration Ecology

How can we use what we know to benefit restoration NOW?

- We should incorporate multiple sources to hedge our bets
  - A single best source across sites/conditions is unlikely
- Planting common gardens and/or reciprocal transplants can help us test the generality of local adaptation vs plasticity
  - Source environment may be a reliable predictor of population traits
- We should take advantage of substantial local and regional genetically-based trait variation
  - Long-distance sourcing may be unnecessary to generate desired traits
- We need to be mindful of risks and of testing multiple approaches
  - Seeds are not likely to be a panacea and we don't want "all our eggs in one basket"

Participatory, experimental, transparent process will facilitate long-term success

Specifying risks allows all partner concerns to be heard and tested



Experimental approach allows for testing different strategies, helping resolve partner conflicts

Experiments also include controls to evaluate and assess risks and learn from failure

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