Modeling restoration outcomes to optimize native plant establishment in wetlands

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Seed-based restoration is a promising revegetation strategy

- Less expensive (huge area to restore!)
- Less labor intensive to install
- Increased adaptive potential
  - Maintenance of genetic diversity
  - Resilient and resistant communities

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SYNTHESIS

Seed supply for broadscale restoration: maximizing evolutionary potential

Linda M. Broadhurst,[1] Andrew Lowe,[2] David J. Coates,[3] Saul A. Cunningham,[4] Maurice McDonald,[5] Peter A. Vesk[6] and Colin Yates[3]

Restoration Seed Banks—A Matter of Scale
David J. Merritt and Kingsley W. Dixon (April 21, 2011)
Science **332** (6028), 424-425. [doi: 10.1126/science.1203083]

Vol. 448: 223–233, 2012
doi: 10.3354/meps09386
MARINE ECOLOGY PROGRESS SERIES
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Published February 23

Contribution to the Theme Section 'Eelgrass recovery'

OPEN ACCESS

Eelgrass restoration by seed maintains genetic diversity: case study from a coastal bay system

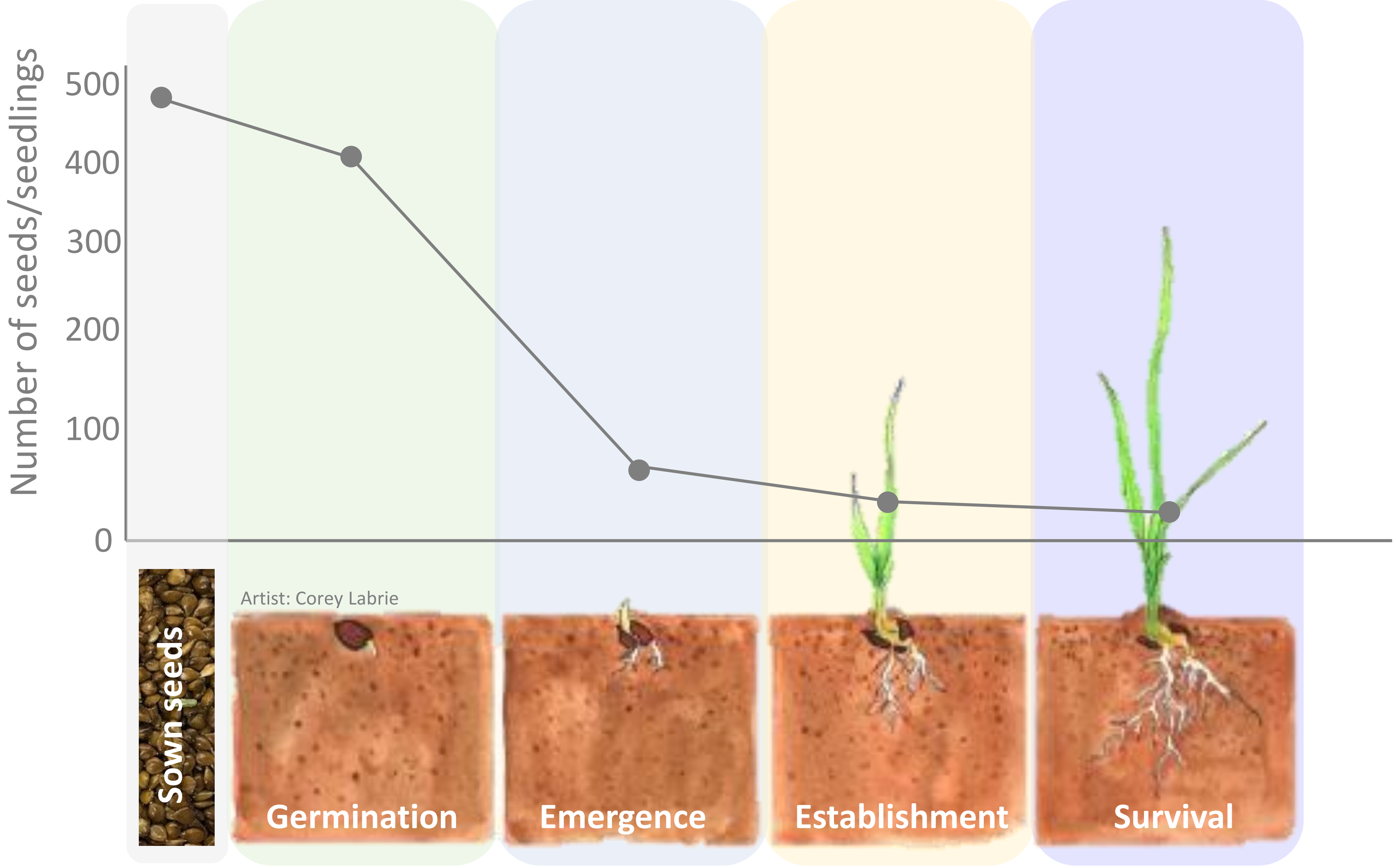
Laura K. Reynolds[1,*], Michelle Waycott[2], Karen J. McGlathery[1], Robert J. Orth[3], Joseph C. Zieman[1]

However:

Seeding outcomes are unpredictable and largely unsuccessful

- 5-10% establishment!

Limited wetland-specific research



How can we overcome this bottleneck in recruitment to maximize native plant establishment after seeding?

Plant functional traits

- Morphological or physiological characteristics that impact plant growth, reproduction, and survival


Plant height


Root length and structure


Aerenchyma

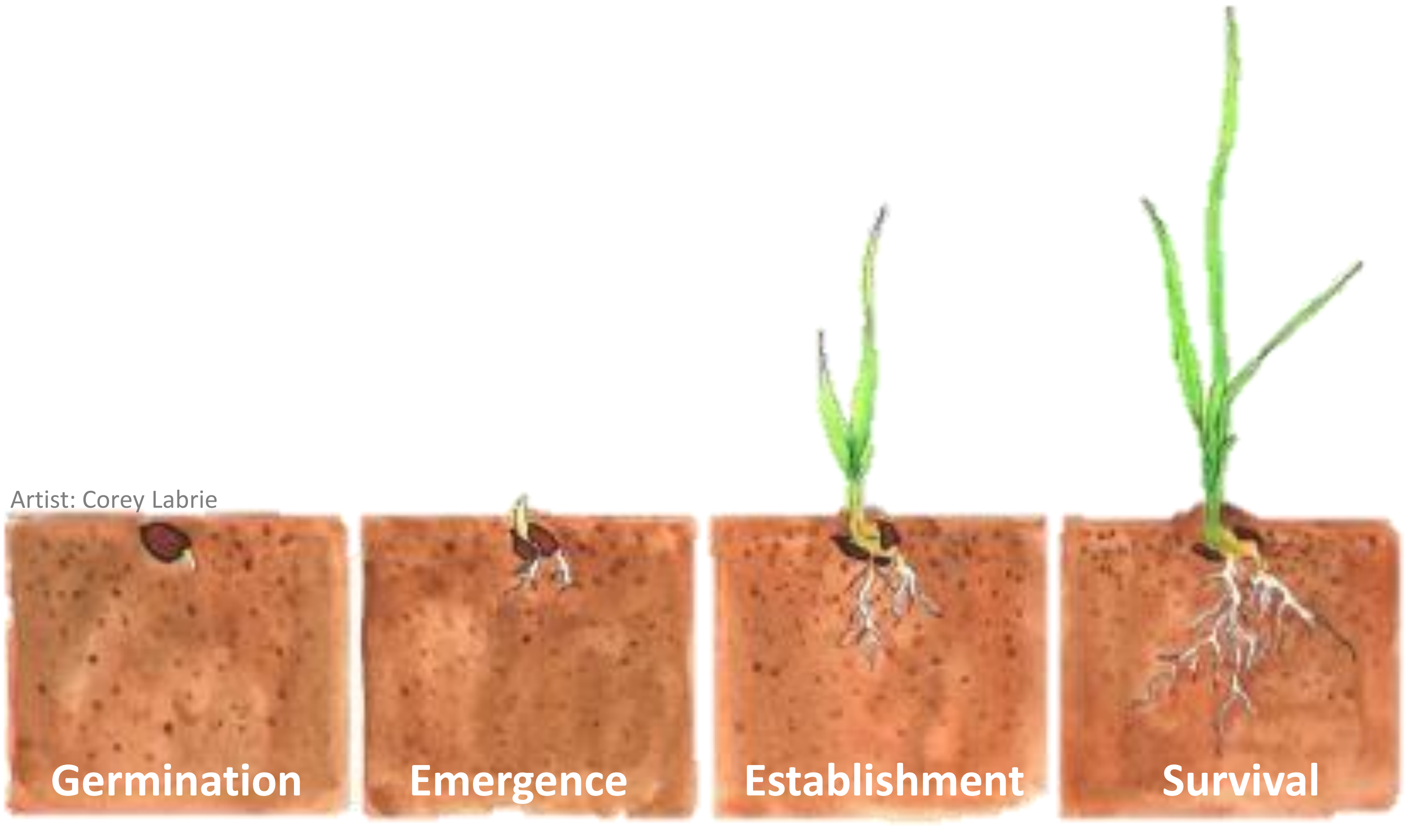

Leaf mass per area

Photo: Jes Braun


# of seeds produced

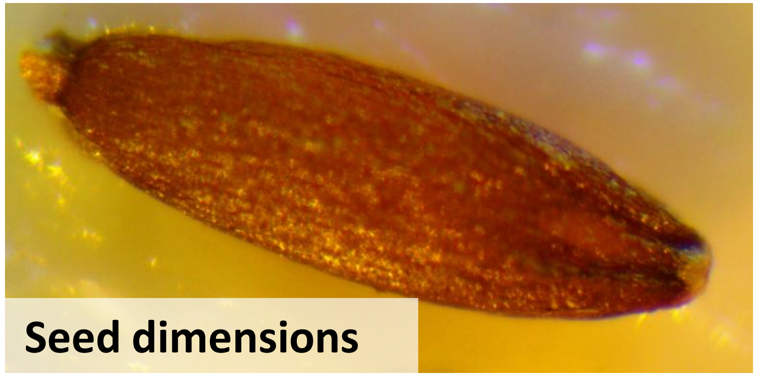
Functional traits driving regeneration

- Morphological or physiological characteristics that impacts plant germination, emergence, establishment, and seedling survival



Functional traits driving regeneration

- Functional traits inherent to the seed



Three-square bulrush seeds

Functional traits driving regeneration

- Functional traits that vary across environmental conditions

Root elongation rate

Relative growth rate

Time to germination

Understanding these traits = more targeted restoration decisions

Which species to seed

- Species that germinate faster or more reliably = better competitors against *Phragmites*
- Species that have higher growth rates in seedlings = better competitors against *Phragmites*; more access to light
- Species that have faster root elongation rate = better competitors against *Phragmites*; can withstand drier conditions

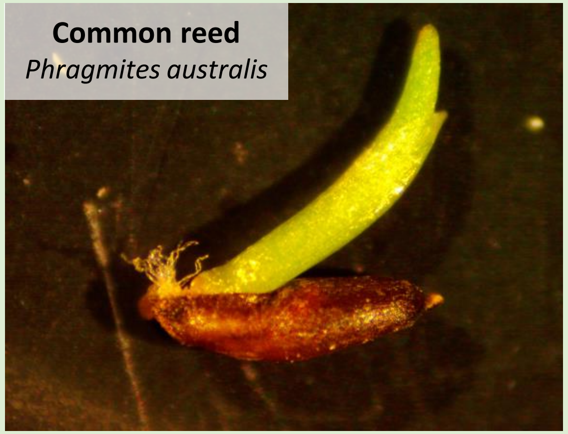
Alkali bulrush
Bolboschoenus maritimus

Saltgrass
Distichlis spicata

Common spikerush
Eleocharis palustris

Hardstem bulrush
Schoenoplectus acutus

Arctic rush
Juncus arcticus

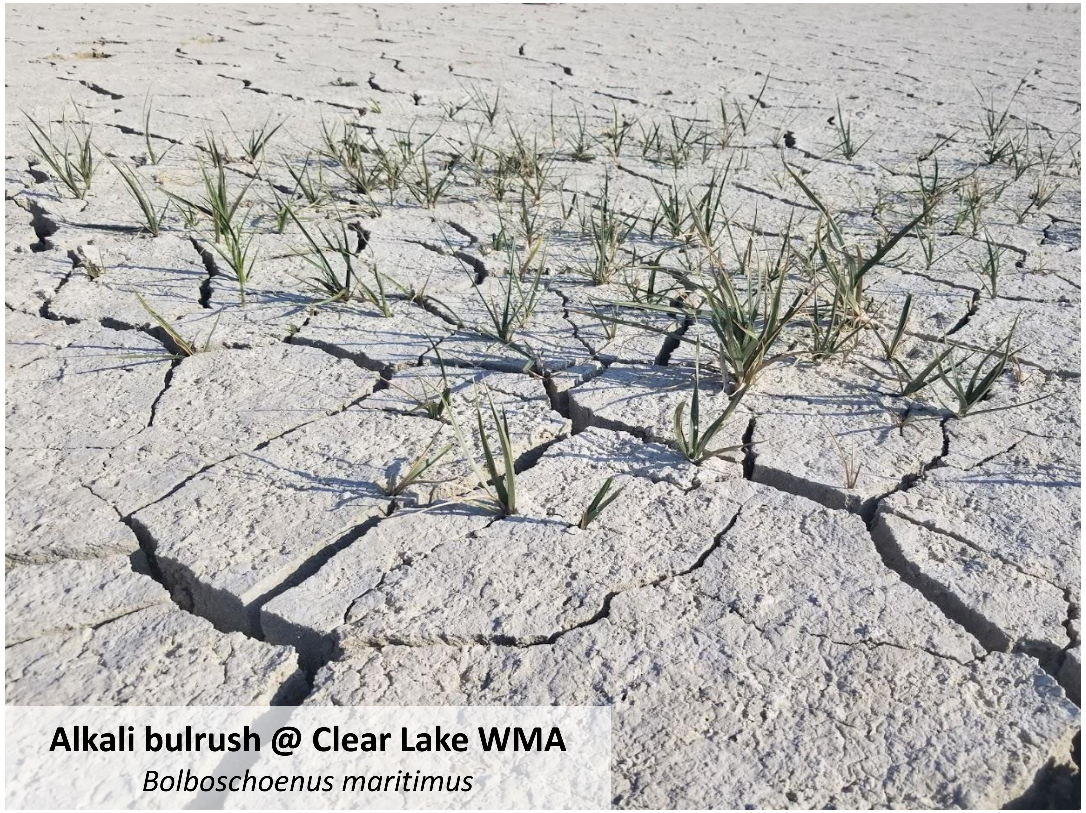


Common reed
Phragmites australis

Threesquare bulrush
Schoenoplectus americanus

Where to source seed

- Within a species, we would expect to see variation in regeneration traits across source populations
- Seed sources that experience drier, hotter conditions = better survival in dry, hot conditions

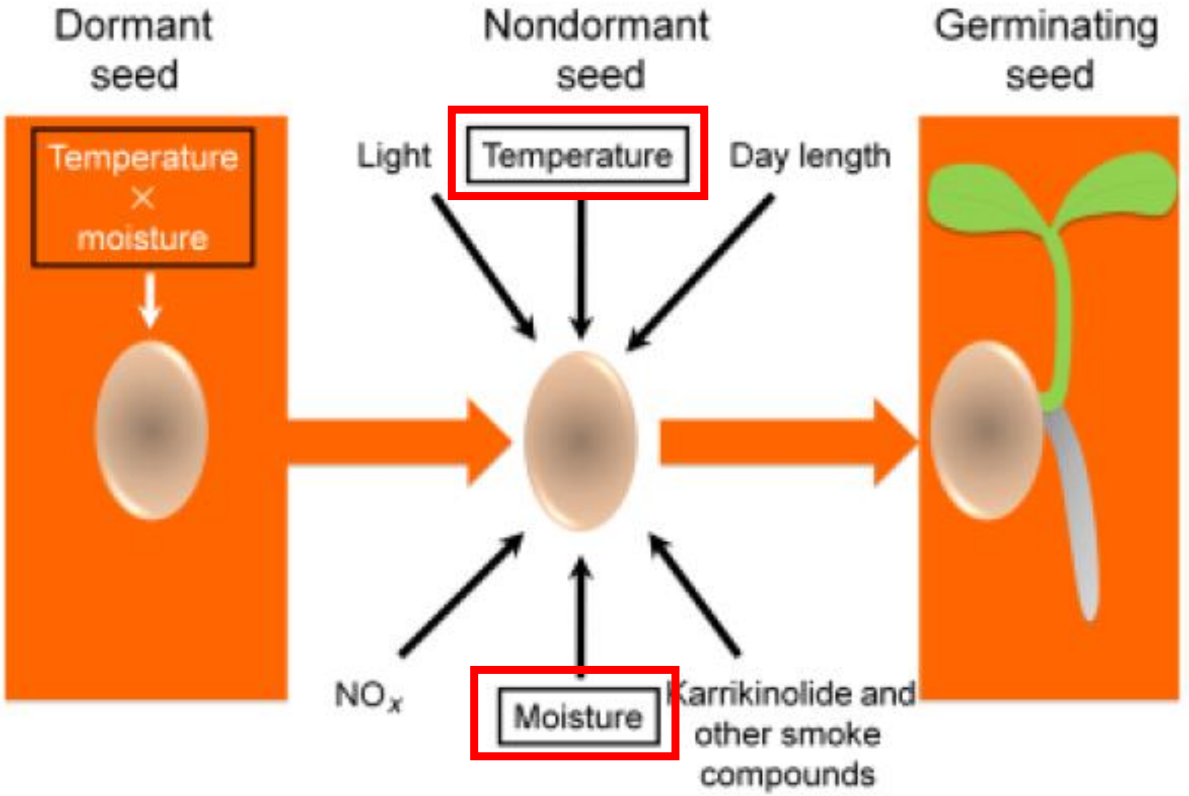


Alkali bulrush @ Clear Lake WMA
Bolboschoenus maritimus

Alkali bulrush @ Warm Springs WMA
Bolboschoenus maritimus

What environmental conditions will maximize seedling recruitment

- How to maximize recruitment of desired species by targeting the ideal environmental conditions
- How to minimize recruitment of *Phragmites* by identifying environmental conditions that negatively impact establishment



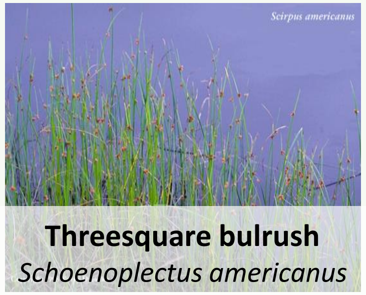

Global Change Biology (2011) 17, 2145–2161, doi: 10.1111/j.1365-2486.2010.02368.x
REVIEW
Climate change and plant regeneration from seed
JEFFREY L. WALCK*, SITI N. HIDAYATI*, KINGSLEY W. DIXON†‡, KEN THOMPSON§ and PETER POSCHLOD¶

Objectives

- How much variation of regeneration traits exist within and between species?
- How are regeneration traits linked to plant performance in wetland restorations?
- Can we predict when seed-based restoration will succeed?
- Can we manipulate conditions at sites to improve restoration outcomes?

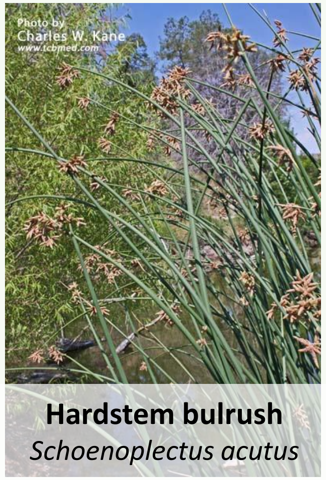
Methods

Variation between species



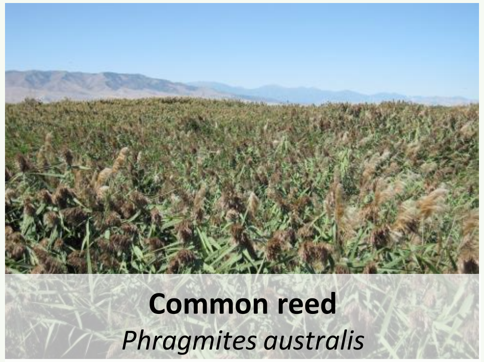
Threesquare bulrush
Schoenoplectus americanus

Alkali bulrush
Bolboschoenus maritimus



Hardstem bulrush
Schoenoplectus acutus

Arctic rush
Juncus arcticus

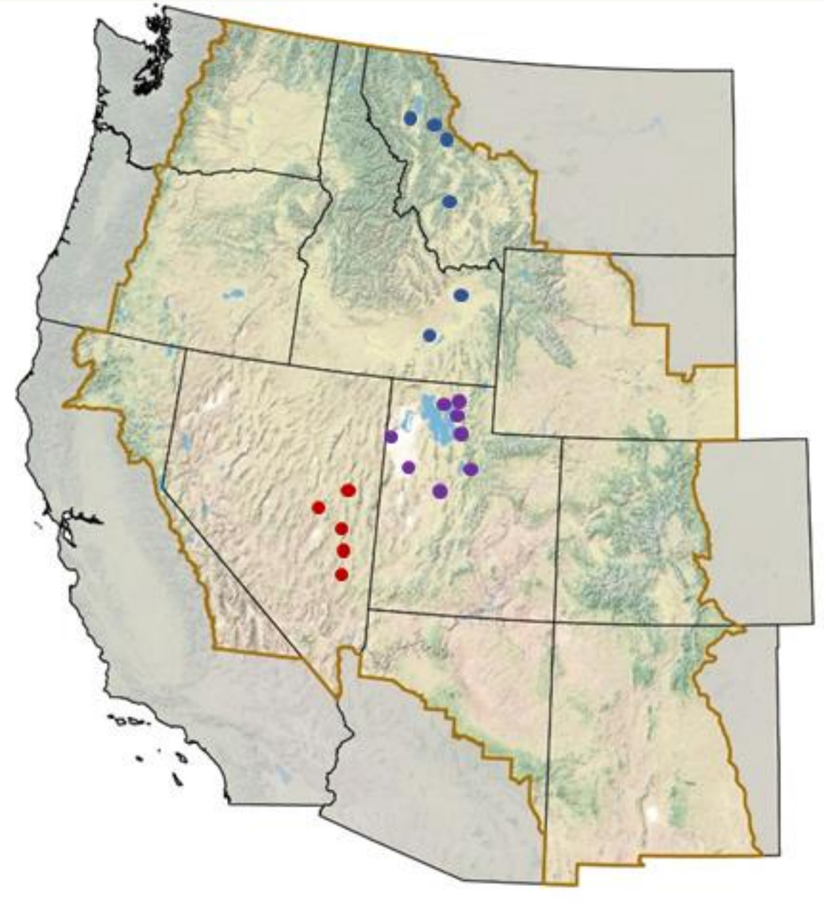


Common reed
Phragmites australis

Saltgrass
Distichlis spicata

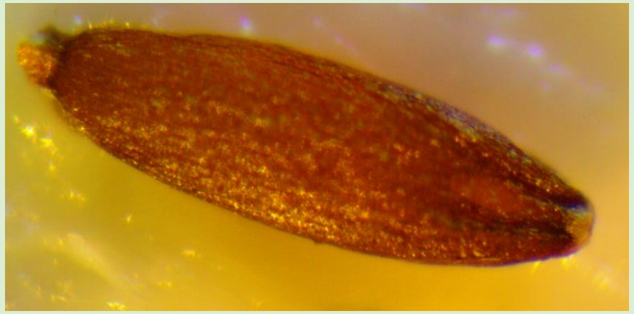
Common spikerush
Eleocharis palustris

Variation within species



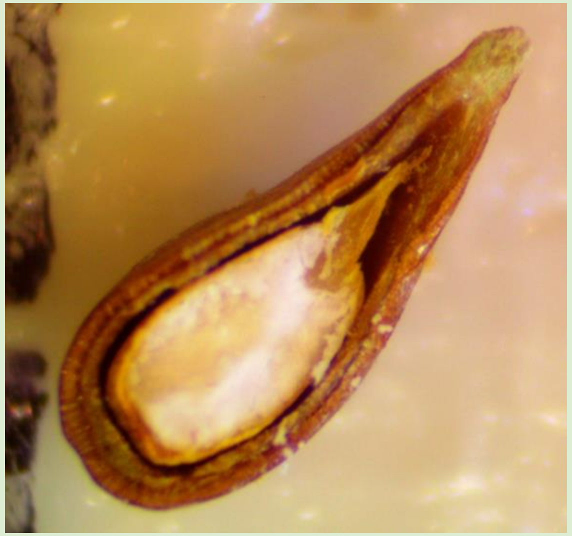
- Sourced from areas with different conditions
- Selective pressures results in variation of traits
- Informs seed source selection

Seed Trait Measurements



Seed Dimensions

Seed Mass



Seed Coat Thickness

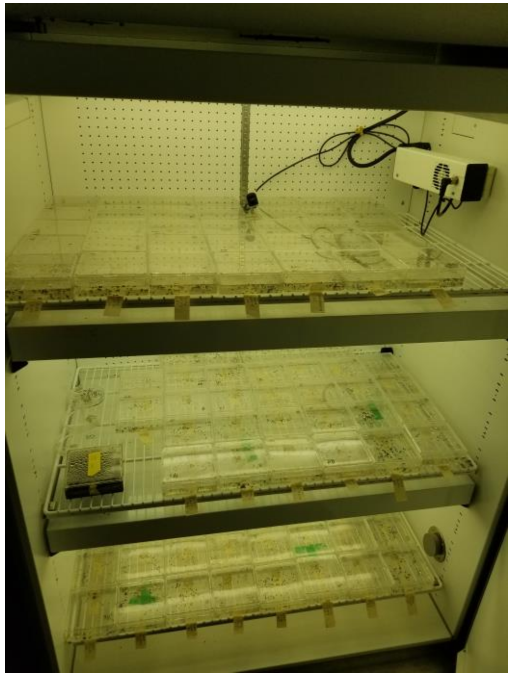
Seed Trait Measurements

Seed Buoyancy

- How well do seeds disperse via water?

Depth of Dormancy

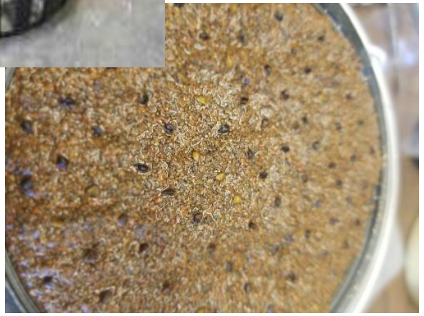
- How deep is dormancy?
  - How much effort is needed to break dormancy prior to seeding?

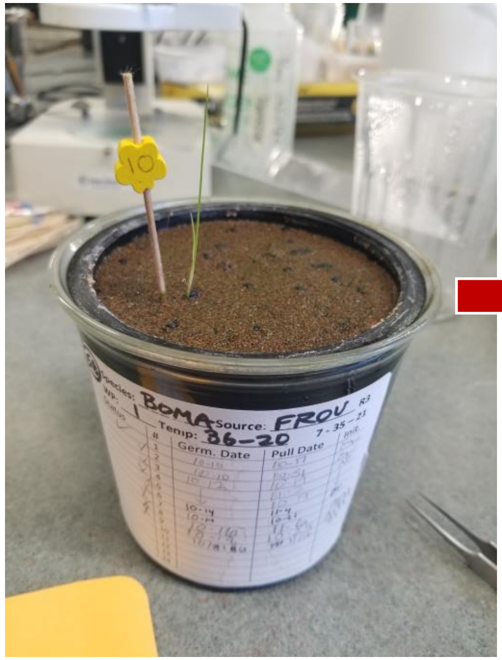


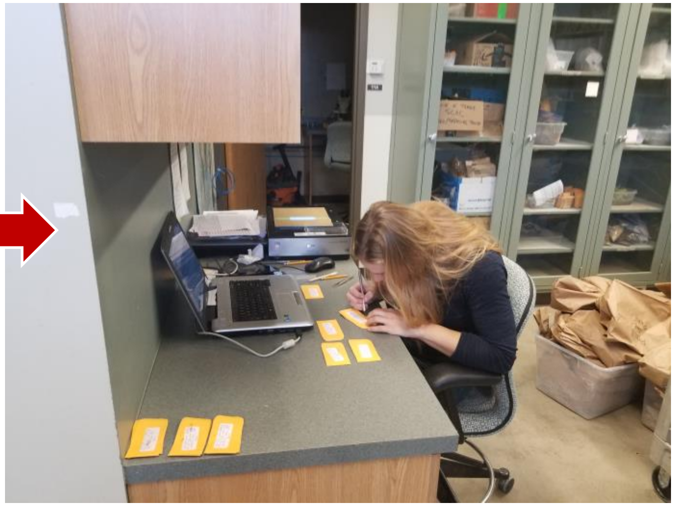
Seedling Trait Measurements

3 Temperatures:
- Cool (82/50 °F)
- Warm (90/59 °F)
- Hot (97/68 °F)

2 Moisture levels:
- Saturated (0 MPa)
- Dry (-0.6 MPa)







Seedling Traits

Relative growth rate

Root elongation rate

Germination rate

Upcoming Greenhouse Experiment

- Subset of species x sources
- 2 temperatures x 2 moisture levels

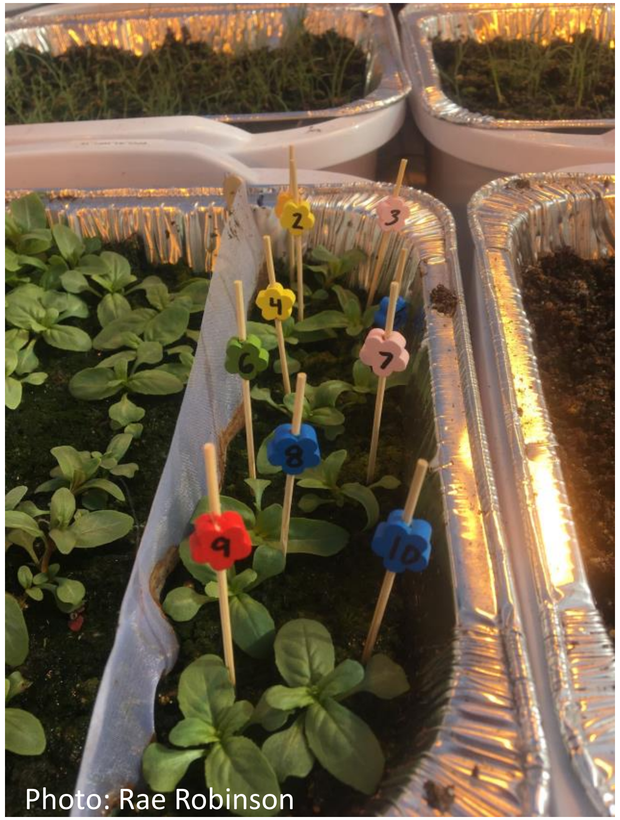
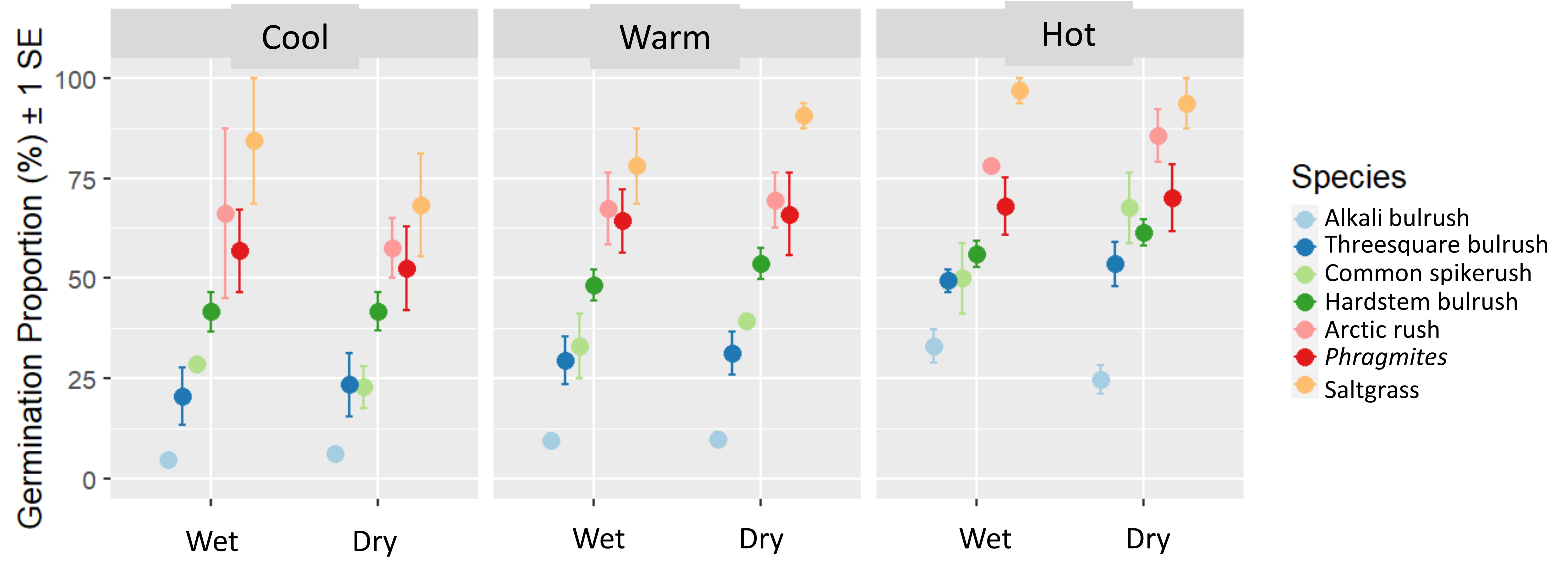


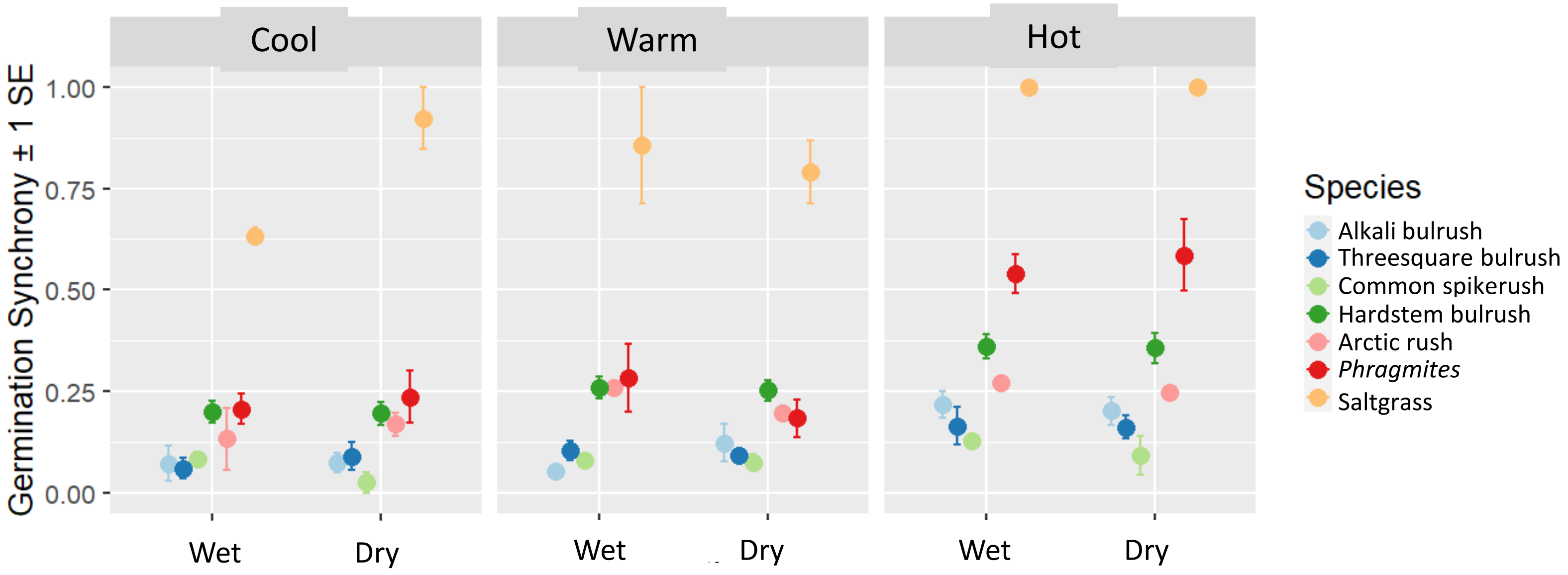
Photo: Rae Robinson

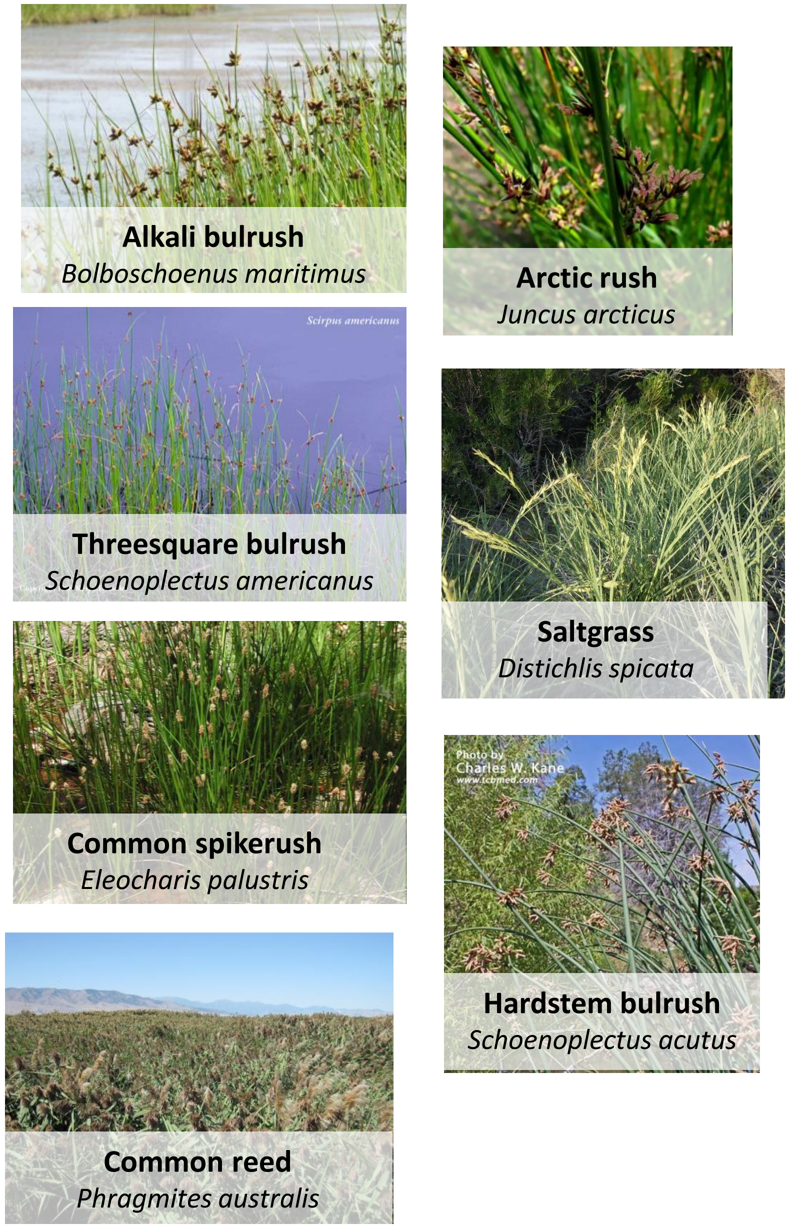
- Tracking life-stage transitions:
  - X # of seeds sown
  - X germinated
  - X established
  - X survived
  - X died

- Measuring end-of-season percent cover

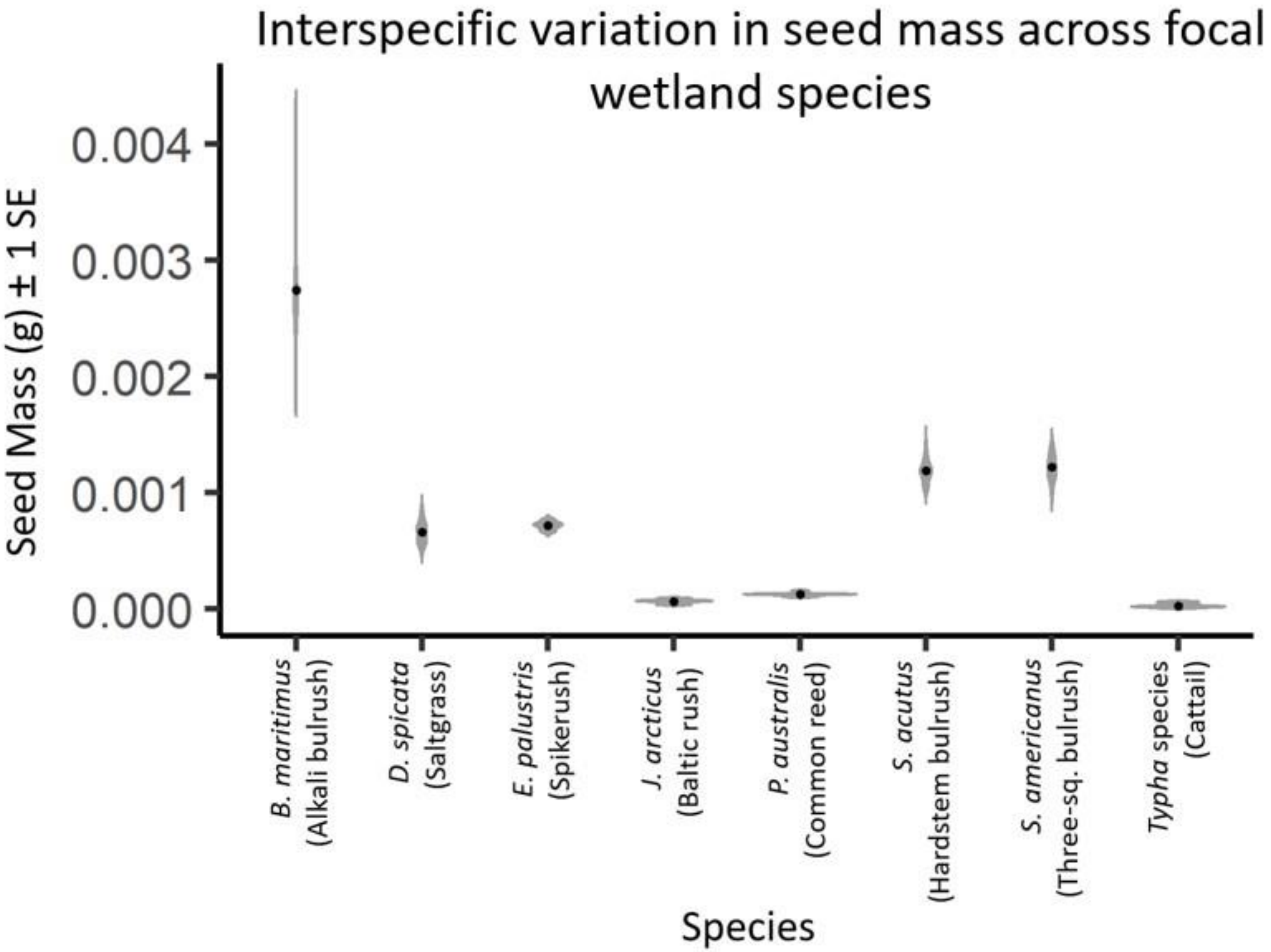
What we've found (so far) – variation across species





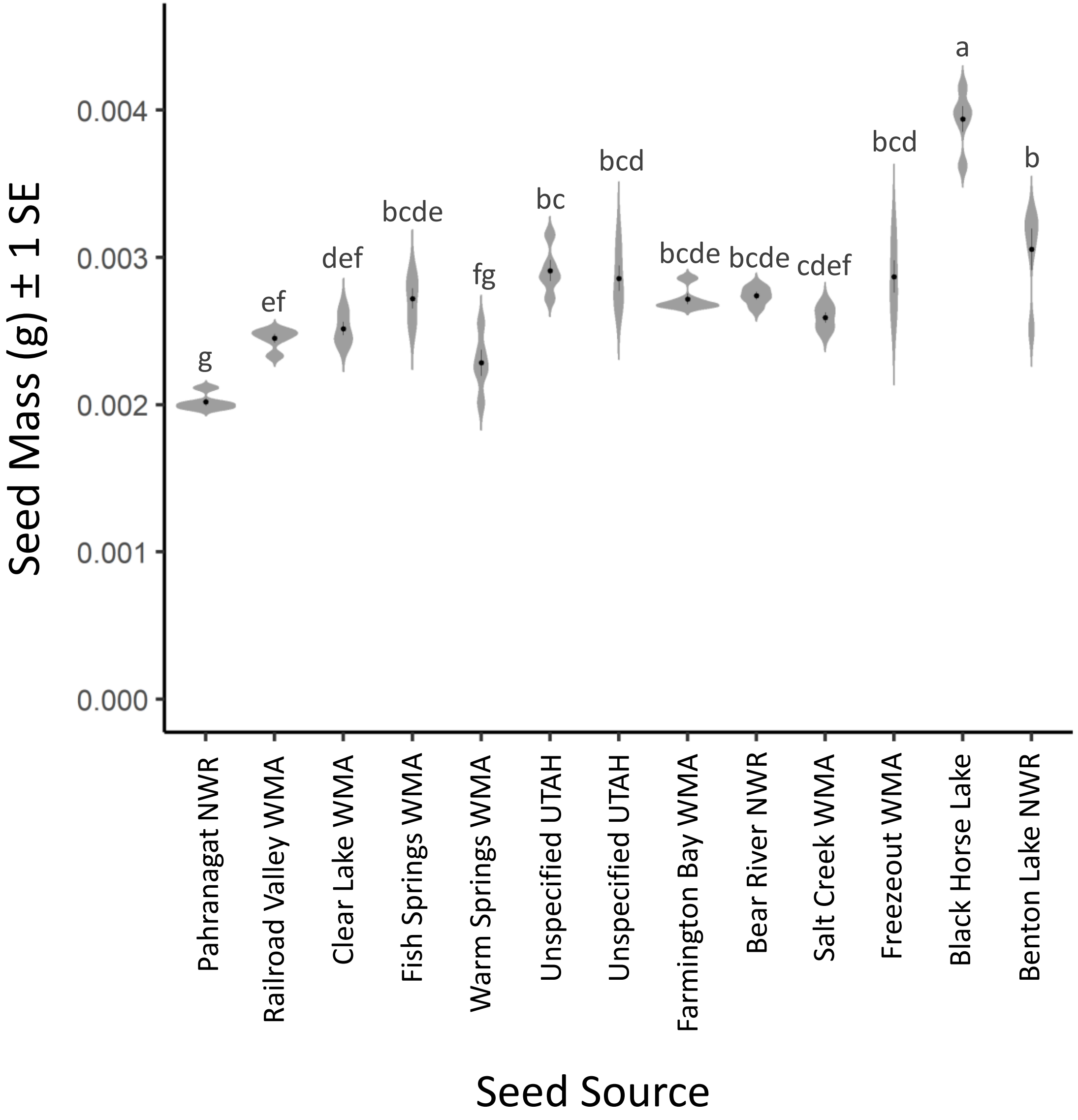


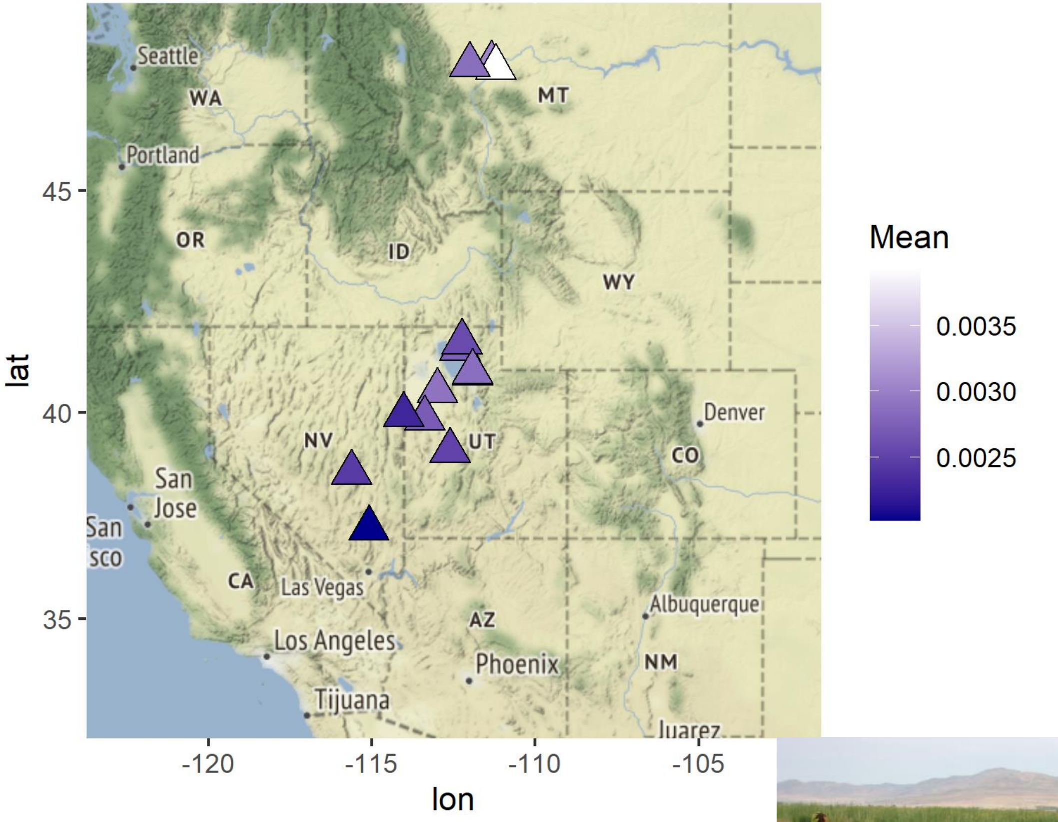
What we've found (so far) – variation across species



What we've found (so far) – variation within species

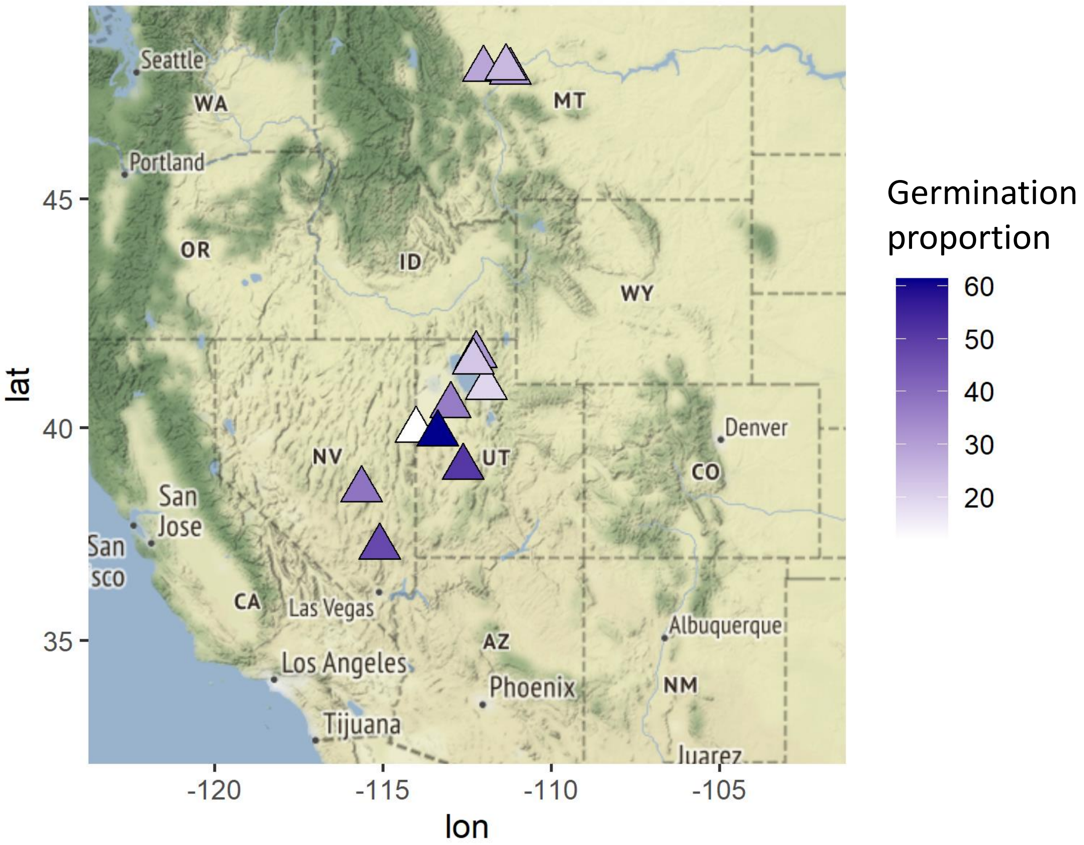
Intraspecific variation in *B. maritimus* seed mass



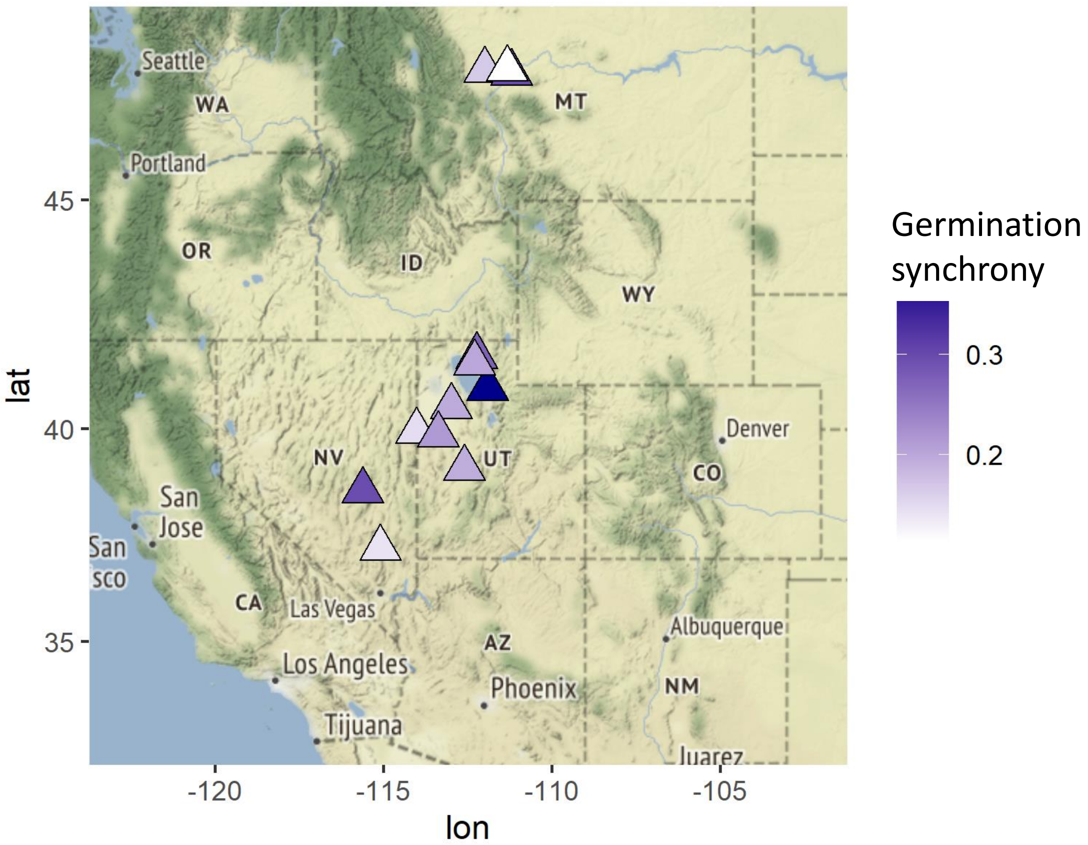


What we've found (so far) – variation within species

Alkali bulrush

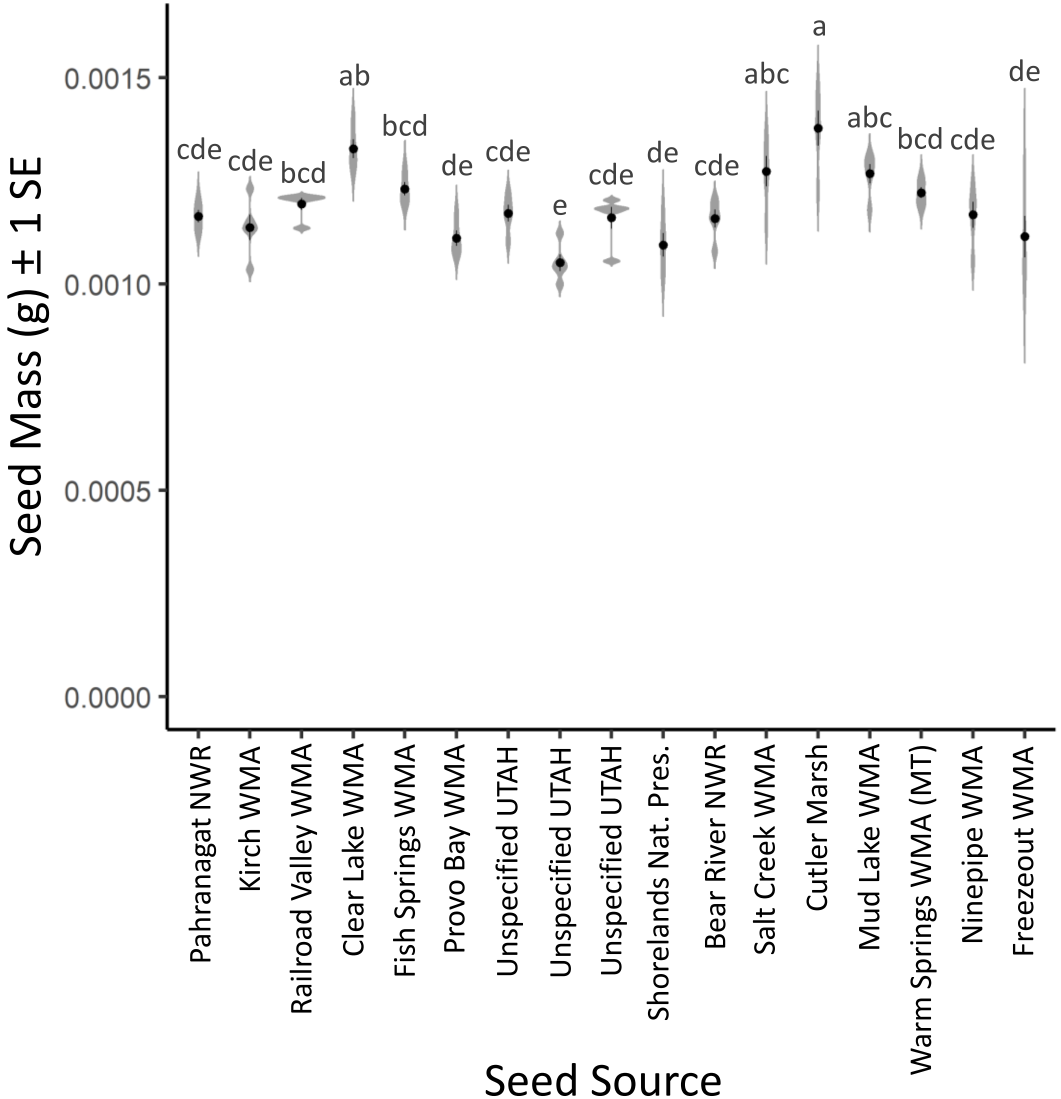


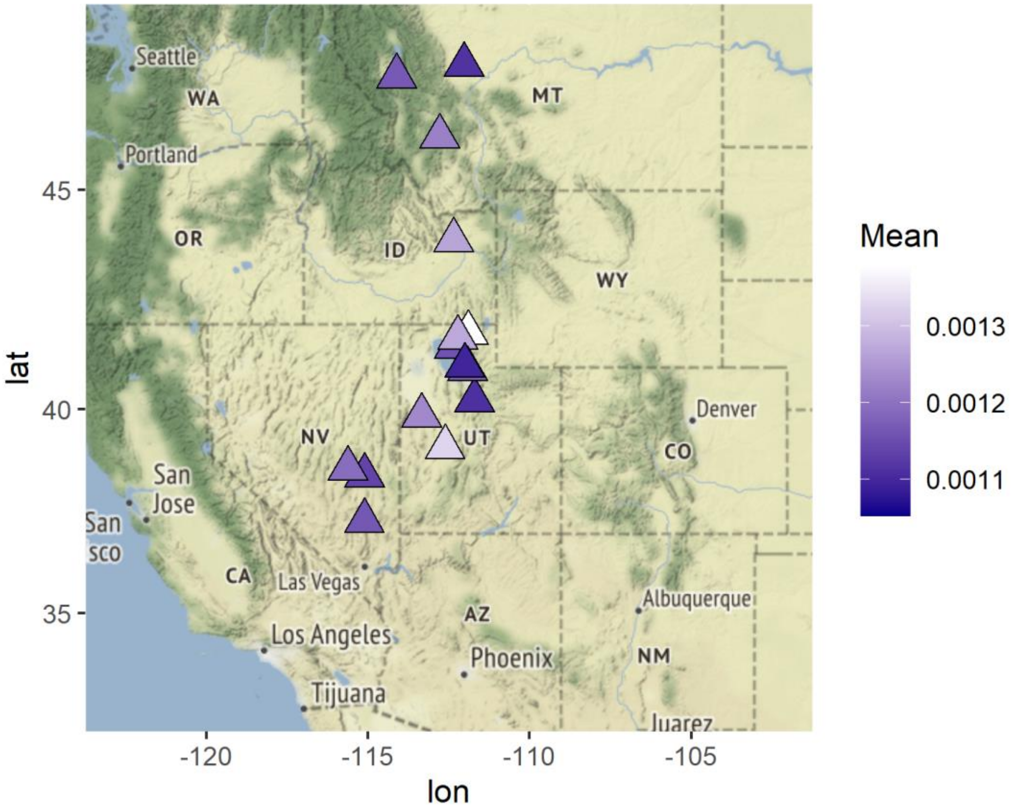
Alkali bulrush



What we've found (so far) – variation within species

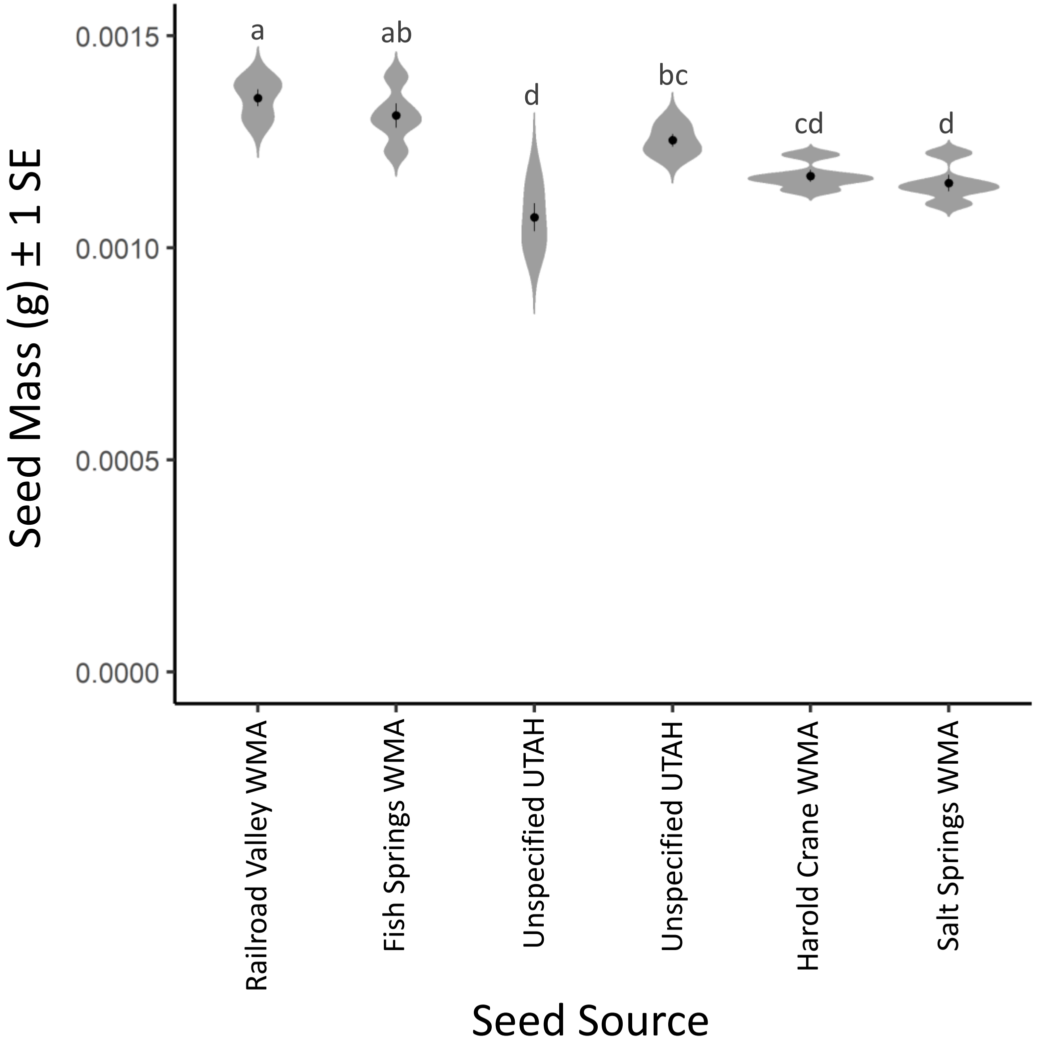
Intraspecific variation in *S. acutus* seed mass

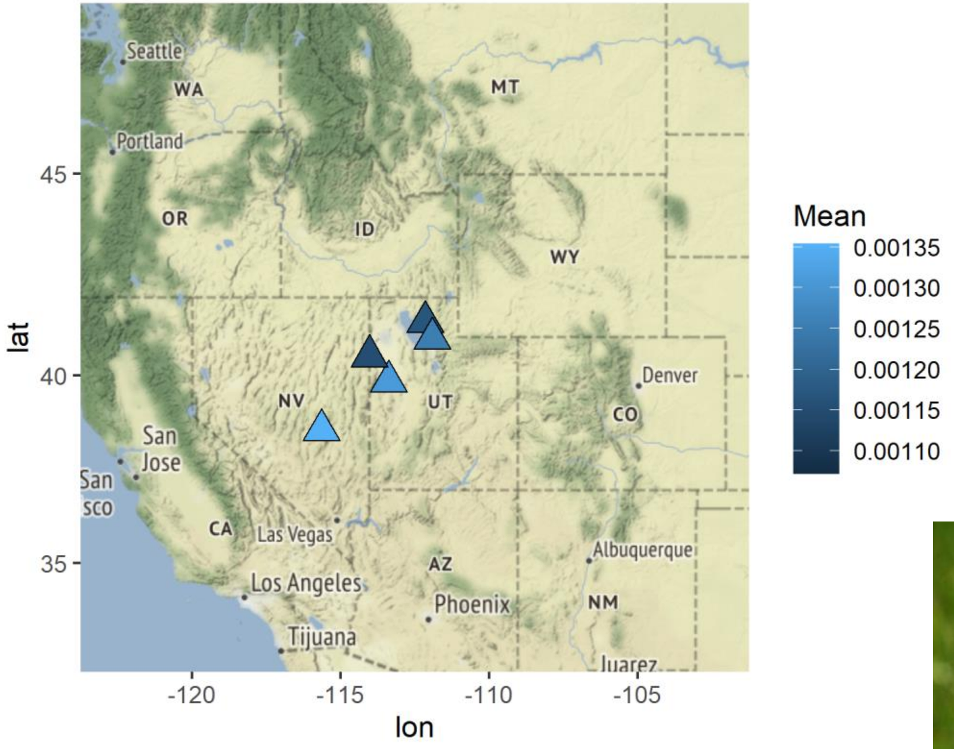




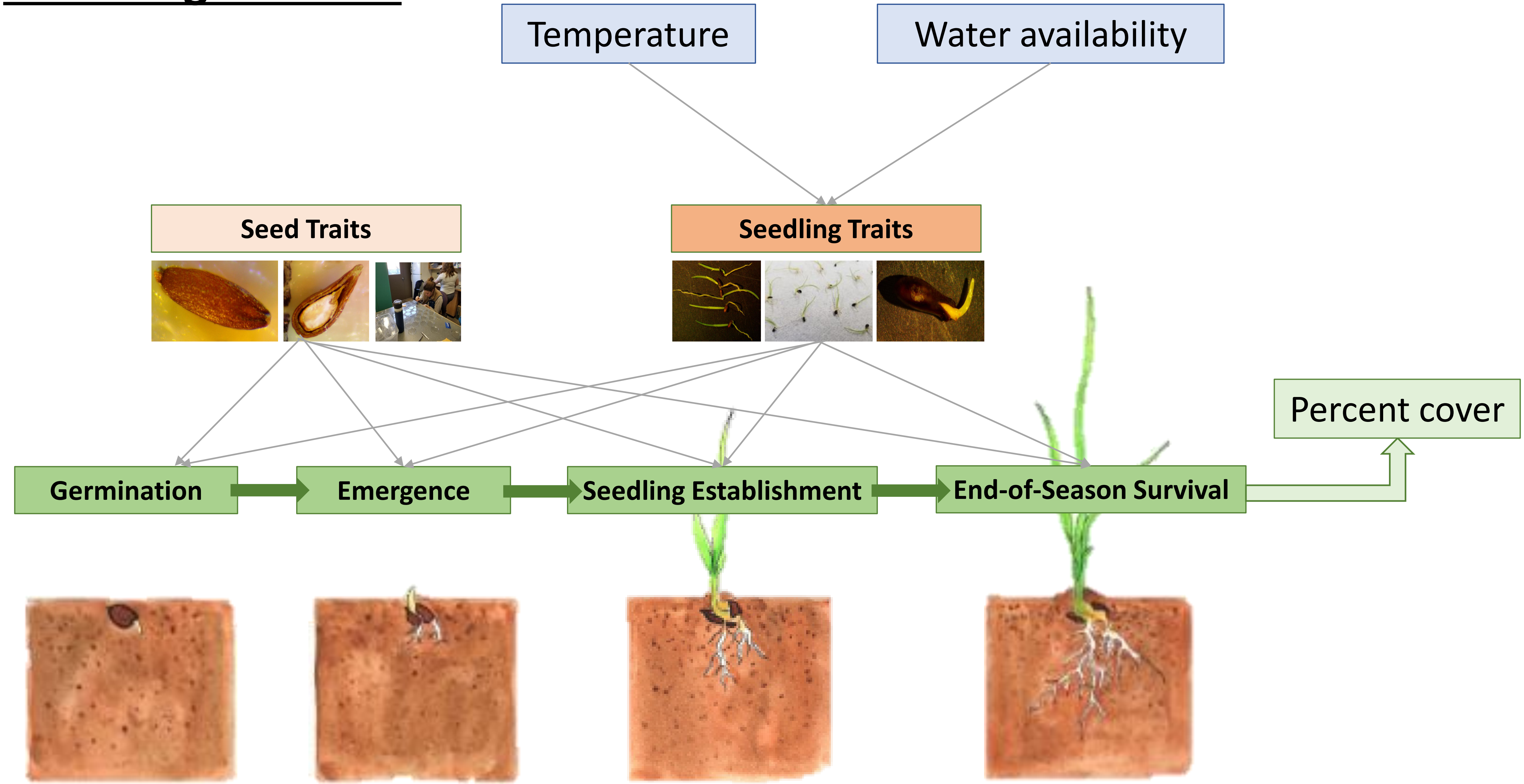
What we've found (so far) – variation within species

Intraspecific variation in *S. americanus* seed mass





Modeling our data



Watercolor: Corey Labrie

Integrated population model

- Allows us to model how regeneration traits may influence demographic processes in a population

1. Which environmental conditions should be manipulated through restoration action?

2. Which native species and which seed sources possess trait values that result in high recruitment given a site's environmental conditions?

Model uses

- Here is my budget and restoration size; what species/sources should I use and what are the ideal environmental conditions to maximize native cover?

Inputs

- Budget
- Restoration area

Outputs

- Best species & sources
- Water requirements
- Sowing time (temp.)
- Sowing Density
- % Cover

Seeding Restoration Scenario 1

Max Budget: 5000

Restoration Area (square km): 5

Show 25 entries

Search:

Species	Source	Water Req.	Temp	Sowing Density	% Cover
Hardstem	FISP	wet	32-15	1.35	100
Hardstem	RRVA-BW	wet	36-20	1.2	98
Alkali	RRVA-BW	wet	32-15	1.05	95
Hardstem	SCHACU	wet	36-20	1.6	94
Alkali	SACR	wet	32-15	1.15	89
Species	Source	Water Req.	Temp	Sowing Den	% Cover

Showing 1 to 5 of 5 entries

Previous 1 Next

Model uses

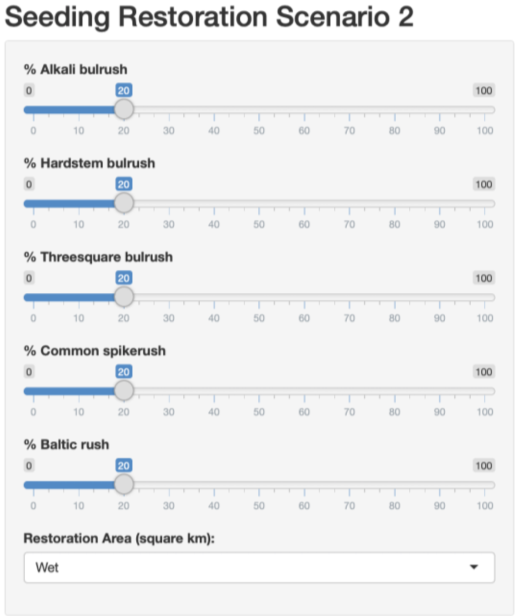
- Here is my desired species (and water availability at the site), what seed/source should I choose and when should I seed to maximize native cover?

Inputs

- Desired species composition
- Water availability

Outputs

- Seed mix options
- Sowing time (temp.)
- Estimated price for a high and low sowing density options
- % Cover



Show 25 entries Search:

Temp	SCAC	% SCAC	BOMA	% BOMA	SCAM	% SCAM	JUBA	% JUBA	ELPA	% ELPA	Low Density Price ($/sq m)	High Density Price ($/sq m)	% Cover
32-15	SCAC FISP	0.25	BOMA ALK2	0.25	SCAM SASP	0.25	JUBA JUNBAL	0.13	ELPA THNA	0.12	3	6.2	98
36-20	SCAC RRVA-BW	0.21	BOMA FISP	0.2	SCAM SASP	0.26	JUBA JUNBAL	0.17	ELPA THNA	0.16	4	8.5	98
28-10	SCAC RRVA-BW	0.25	BOMA ALK2	0.25	SCAM FISP	0.25	JUBA JUNBAL	0.13	ELPA THNA	0.12	3.5	6	91

Showing 1 to 3 of 3 entries

Previous 1 Next

Adaptive and iterative!

- New native species
- Different environmental conditions (salinity, light, etc.)
- Spatially explicit recommendations
- Accounting for competition

Summary

- Seeding native species following *Phragmites* treatment is a promising revegetation strategy
- We can better target restoration strategies by understanding how regeneration traits drive seedling outcomes
  - Which species to choose
  - Where to source seeds
  - What environmental conditions maximize native recruitment (and/or minimize *Phragmites* recruitment)

Summary

- Functional traits vary between species
  - Saltgrass = faster and more uniform germination; does well across environmental conditions

- Functional traits vary within species (across source populations)
  - Alkali bulrush = higher latitudes have higher seed mass

- Modeling these data can provide science-based guidance on how to optimize native plant establishment in Great Salt Lake wetlands



Acknowledgements

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  - Chad Cranney, Christine Rohal, David England, Rae Robinson, Coryna Hebert, Maggie Hallerud, Amanda Mast, Cole Patton, Brandon Thomas, Bailey Holdaway, Audree Provard, Gabby Nelson, Matt Nay
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