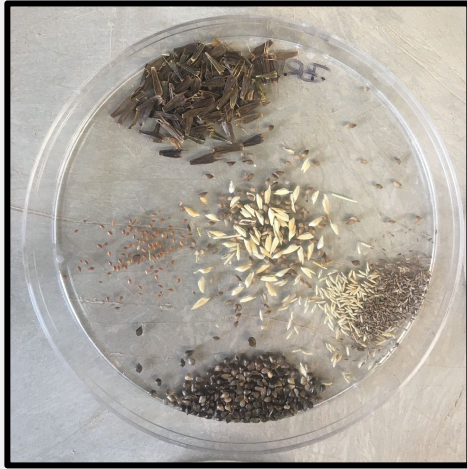


Revegetation following *Phragmites australis* removal: effects of seed mix composition, sowing density, and seedling survival in Great Salt Lake wetlands



Great Salt Lake Wetlands

- 75% of Utah wetlands
- Continental significance
IWJV Implementation Plan (2013)



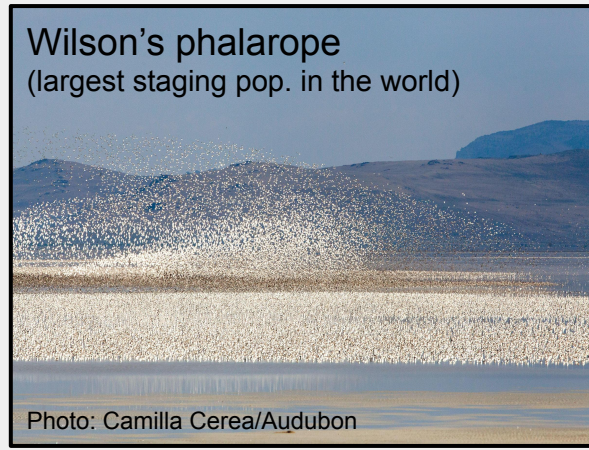
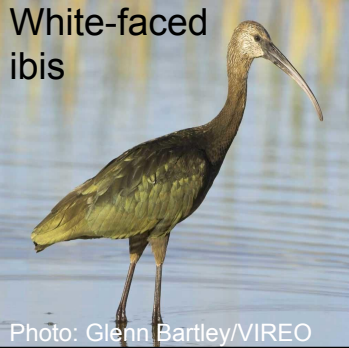
Great Salt Lake Bird Species

Priority Bird Species

Species	Group	*Foraging Habitat	*Breeding Habitat
American avocet	Shorebird	<div><div></div><div></div><div></div></div>	<div><div></div></div>
American white pelican	Waterbird	<div><div></div><div></div></div>	
Black-necked stilt	Shorebird	<div><div></div><div></div><div></div></div>	<div><div></div></div>
Black tern	Waterbird	<div><div></div><div></div></div>	<div><div></div><div></div></div>
Cinnamon teal	Waterfowl	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div></div>
Forster's tern	Waterbird	<div><div></div><div></div></div>	<div><div></div><div></div></div>
Franklin's gull	Waterbird	<div><div></div><div></div></div>	<div><div></div></div>
Green-winged teal	Waterfowl	<div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div><div></div></div>
Long-billed curlew	Shorebird	<div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div></div>
Long-billed dowitcher	Shorebird	<div><div></div><div></div><div></div><div></div></div>	
Marbled godwit	Shorebird	<div><div></div><div></div><div></div><div></div></div>	
Redhead	Waterfowl	<div><div></div><div></div></div>	<div><div></div></div>
Snowy plover	Shorebird	<div><div></div></div>	<div><div></div></div>
Tundra swan	Waterfowl	<div><div></div><div></div></div>	
Western grebe	Waterbird	<div><div></div><div></div></div>	<div><div></div></div>
Western sandpiper	Shorebird	<div><div></div></div>	
Wilson's phalarope	Shorebird	<div><div></div><div></div></div>	<div><div></div></div>
White-faced ibis	Shorebird	<div><div></div><div></div><div></div><div></div><div></div></div>	<div><div></div><div></div></div>

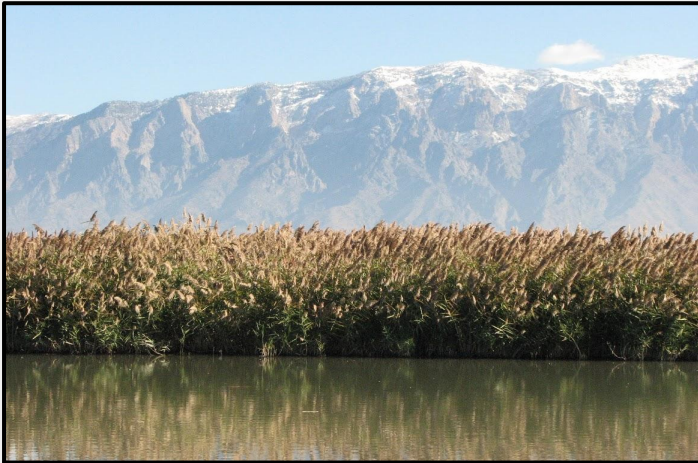
Wetland Plants of
Great Salt Lake
 (Downard et al. 2018)

Submergent
 Emergent
 Meadow
 Playa



Phragmites Threatens Great Salt Lake Wetlands

- *Phragmites australis*, common reed
- 93 km² and spreading! (Long et al. 2017)
- Replaces native vegetation and open water (Kettenring et al. 2012)



Previous Research

- Techniques for killing *Phragmites*

(Summarized in Rohal et al. 2017)



- Managers rely on passive revegetation (Rohal et al. 2018)

- Need active revegetation (Rohal et al. 2017)



Active Revegetation

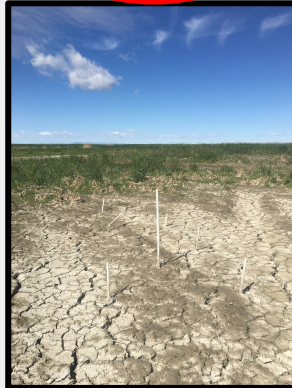
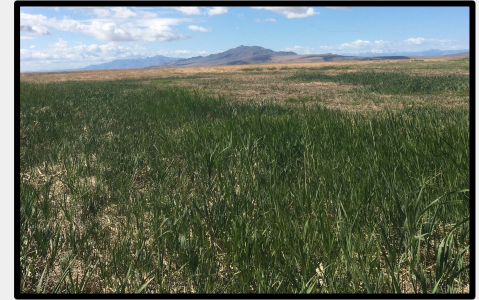
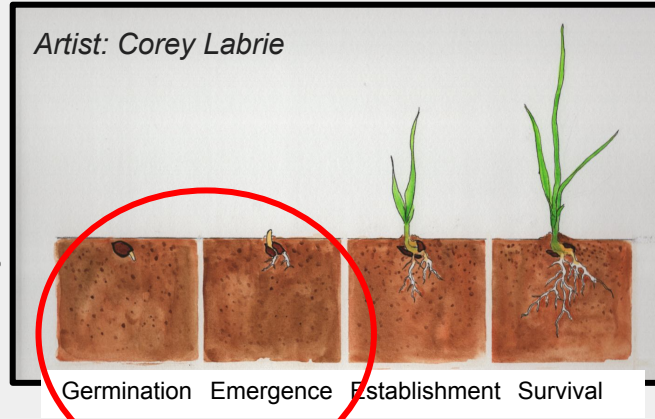
Seeding

- Logistically feasible
- Cost-effective
- Increases genetic diversity
- Promising strategy in a variable wetland environment



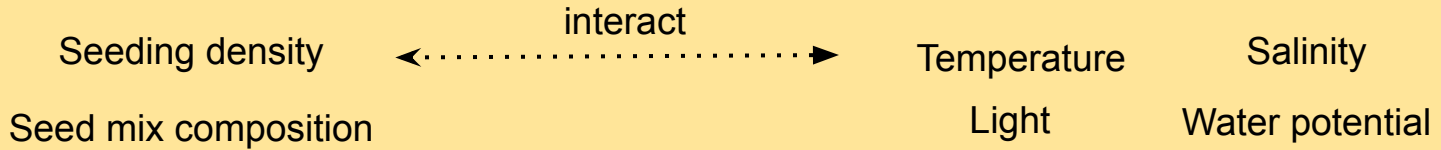
Poor outcomes after seeding

- High mortality
(Larson et al. 2015)
- Fail to meet goals
and very costly



Restoration manipulations

Environmental conditions



Native Plant Responses

Life stage transition probabilities Density Percent cover Biomass



Ecosystem Functions

Phragmites invasion resistance

Avian and macroinvertebrate habitat

Biogeochemical cycling

Productivity

Great Salt Lake Native Plant Species

Habitat-forming, slow-growing perennials

Threesquare bulrush
Schoenoplectus americanus



Photo: Ron Vanderhoff

Hardstem bulrush
Schoenoplectus acutus



Photo: Max Licher

Alkali bulrush
Bolboschoenus maritimus

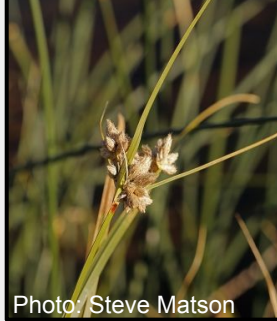


Photo: Steve Matson

Common spikerush
Eleocharis palustris



Nuttall's alkaligrass
Puccinellia nuttalliana



Photo: Steve Matson

Arctic rush
Juncus arcticus



Photo: Brent Miller

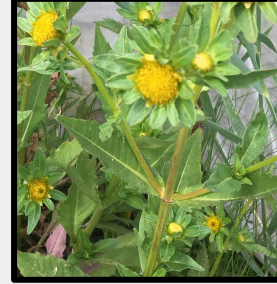
Saltgrass
Distichlis spicata



Photo: Peter Dziuk

+ Fast-growing "weedy" species

Nodding beggartick
Bidens cernua



Fringed willowherb
Epilobium ciliatum



Photo: Sheri Hagwood

Golden dock
Rumex maritimus



Pale smartweed
Polygonum lapathifolium



1. What are the effects of seed mix composition and density on native plant communities?
 - Single species field evaluation (pilot)
 - Seed mix density x composition greenhouse and field experiments
 - Seed mix density field experiment
2. How do environmental conditions impact survival across life stages?
 - Germination and emergence assessments in greenhouse and field



Q1. Single species field evaluation

Methods

- 100 pure live seed / 0.25 m²

**Threesquare
bulrush**
*Schoenoplectus
americanus*



Photo: Ron
Vanderhoff

**Hardstem
bulrush**
*Schoenoplectus
acutus*

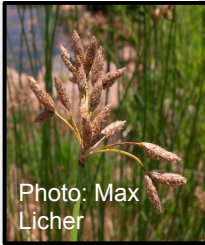


Photo: Max
Licher

Alkali bulrush
*Bolboschoenus
maritimus*

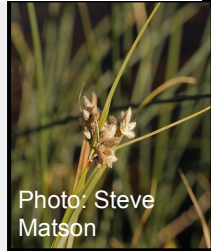


Photo: Steve
Matson

Saltgrass
Distichlis spicata



Photo: Peter Dziuk

Arctic rush
Juncus arcticus

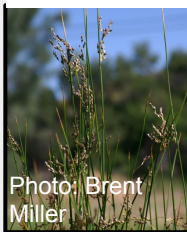
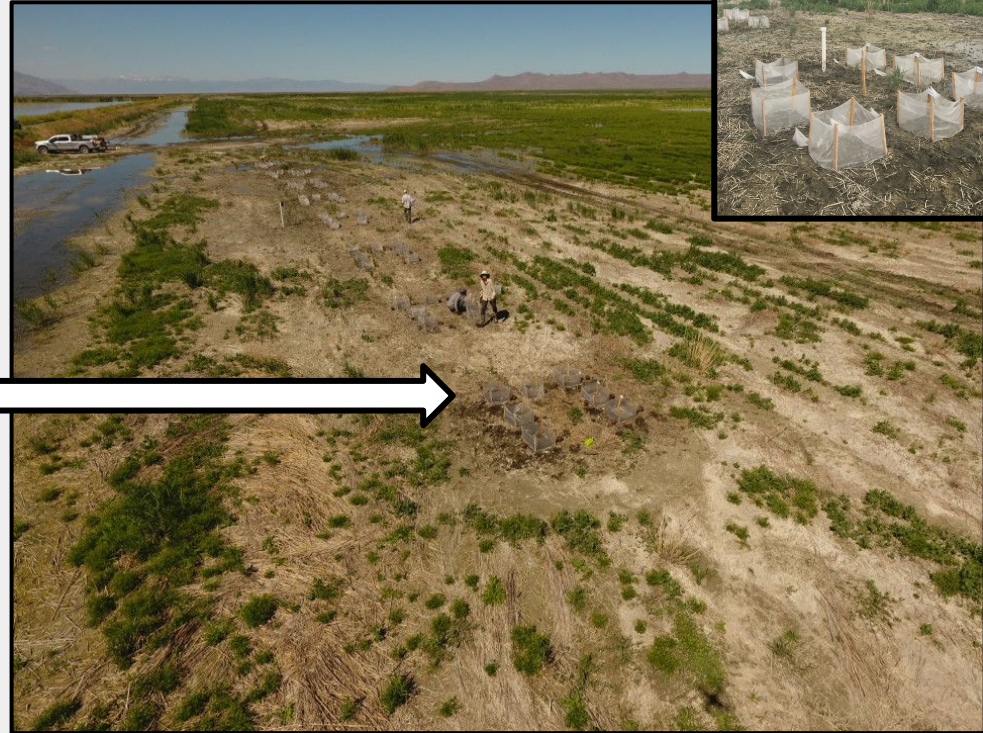


Photo: Brent
Miller

Common reed
*Phragmites
australis*



Q1. Single species field evaluation

Monitoring: some species perform better than others

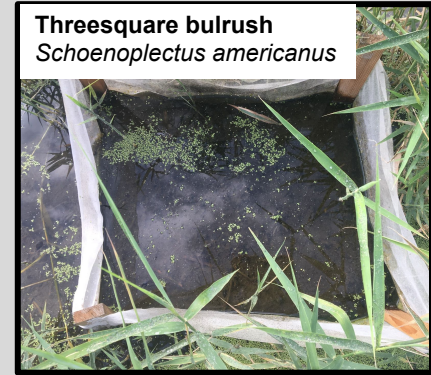
Saltgrass
Distichlis spicata



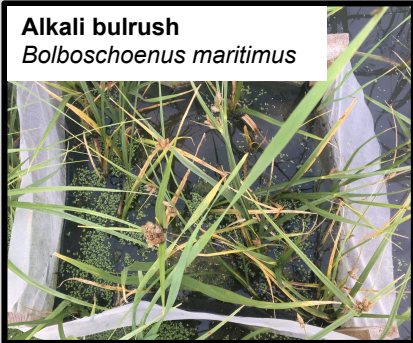
Hardstem bulrush
Schoenoplectus acutus



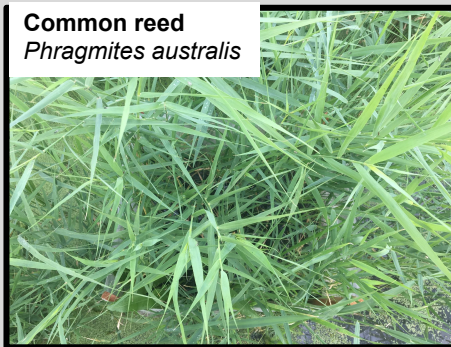
Threesquare bulrush
Schoenoplectus americanus



Alkali bulrush
Bolboschoenus maritimus



Common reed
Phragmites australis



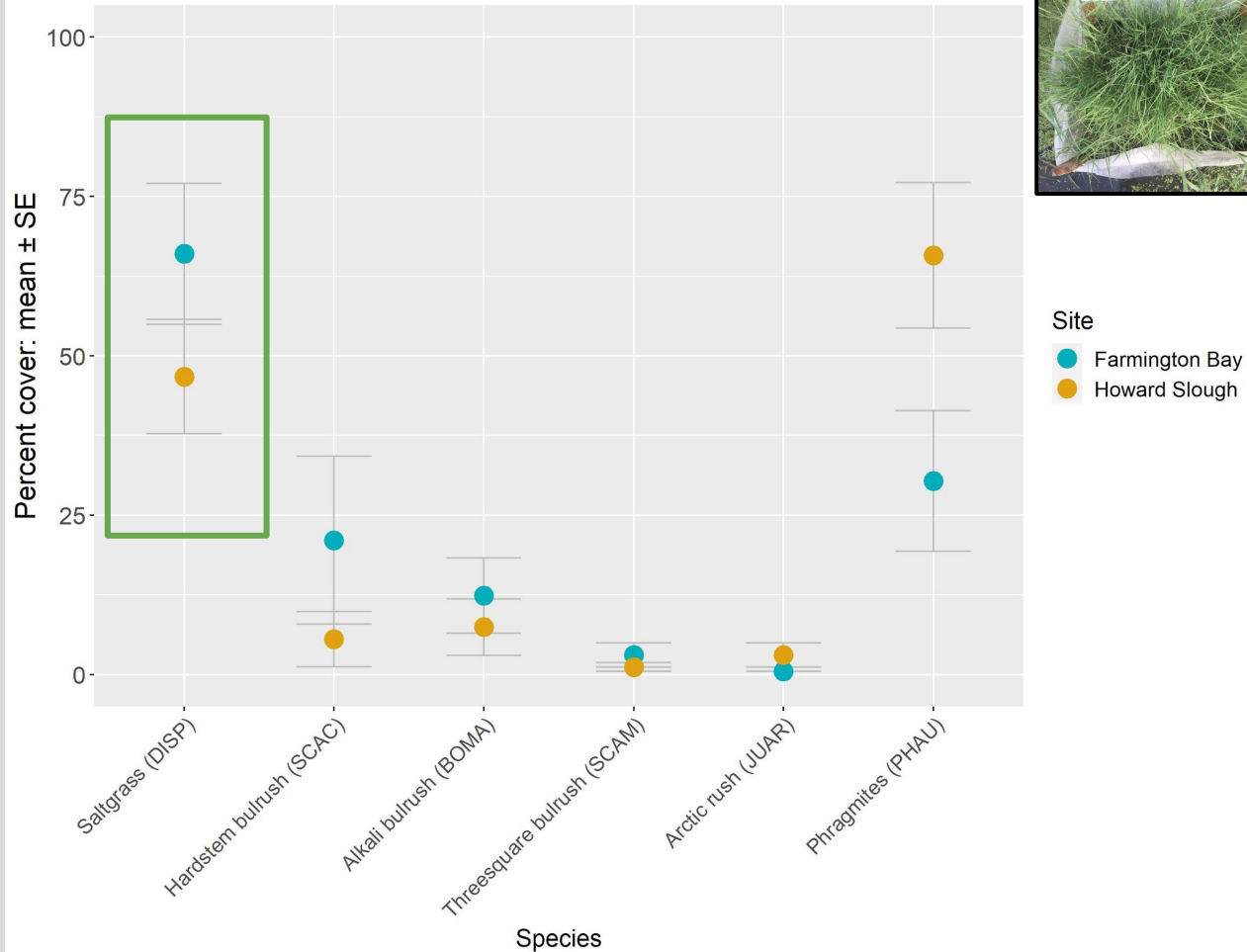
Arctic rush
Juncus arcticus



Control



End of season percent cover in single species plots



- Saltgrass
 - highest cover
 - broad tolerance for salinity and moisture
- Bulrushes
 - low cover
- What other species can we add to revegetation mixes?

Q.1 Seed mix density x composition greenhouse experiment

Methods: mixes and monocultures at 1x, 3x, and 5x densities

**Nodding
beggartick**
Bidens cernua



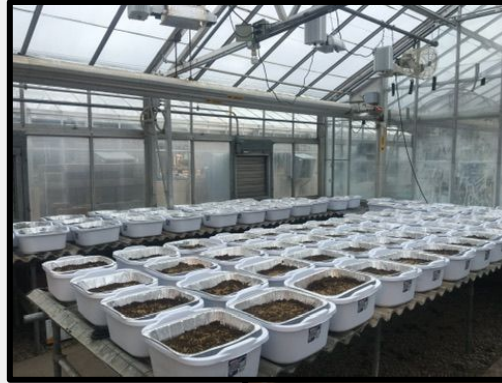
Fringed willowherb
Epilobium ciliatum



Golden dock
Rumex maritimus

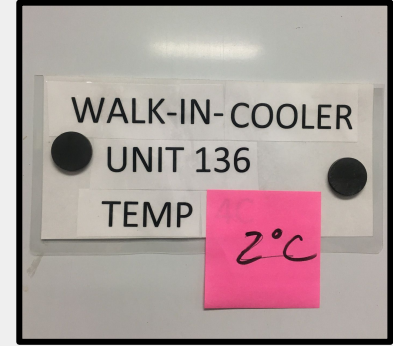


Pale smartweed
*Polygonum
lapathifolium*



Q.1 Seed mix density x composition greenhouse experiment

Methods: Seed collection and dormancy breaking



Q.1 Seed mix density x composition greenhouse experiment

Monitoring: day 15, weedy natives have higher cover

1x density
(125 PLS/tin)



Fringed willowherb
Epilobium ciliatum



Common spikerush
Eleocharis palustris

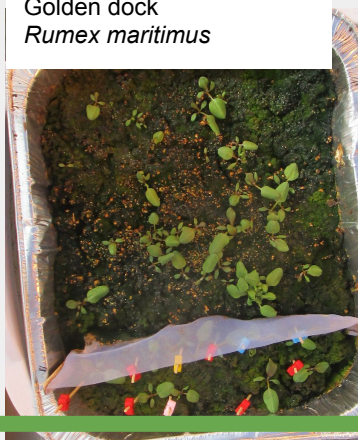


Nuttall's alkaligrass
Puccinellia nuttalliana

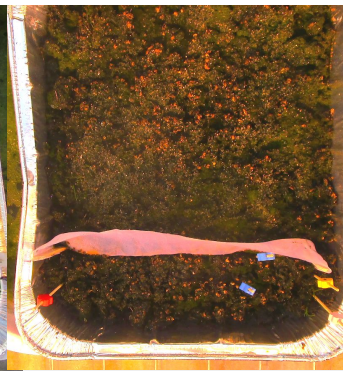


Nodding beggartick
Bidens cernua

Golden dock
Rumex maritimus



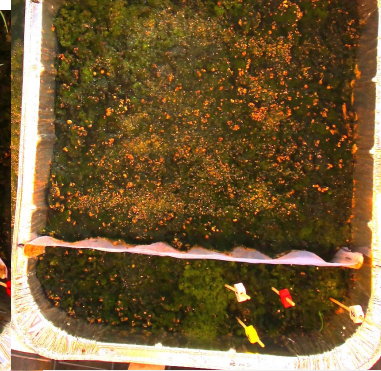
Hardstem bulrush
Schoenoplectus acutus



Saltgrass
Distichlis spicata



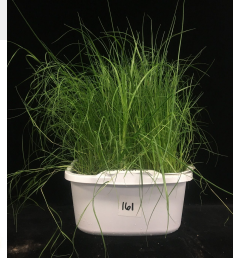
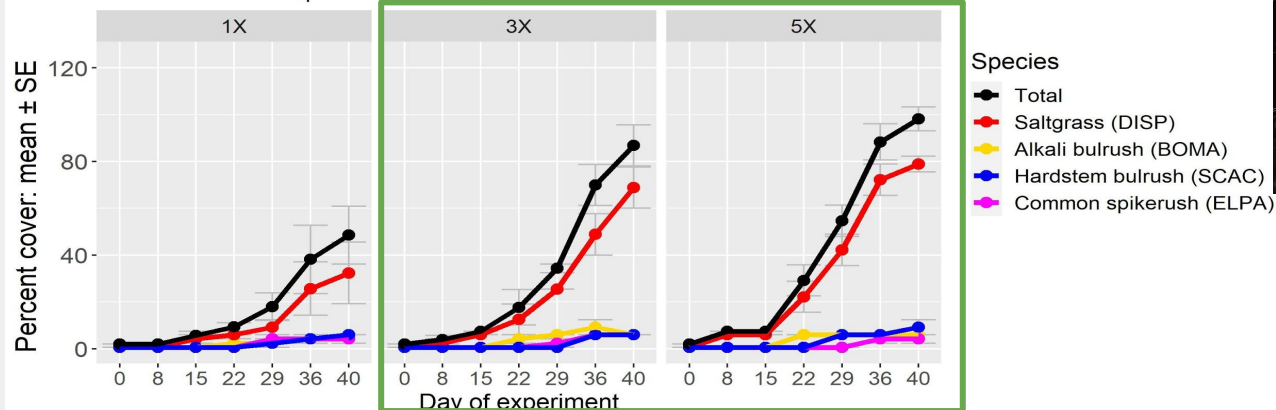
Alkali bulrush
Bolboschoenus maritimus



Pale smartweed
Polygonum lapathifolium

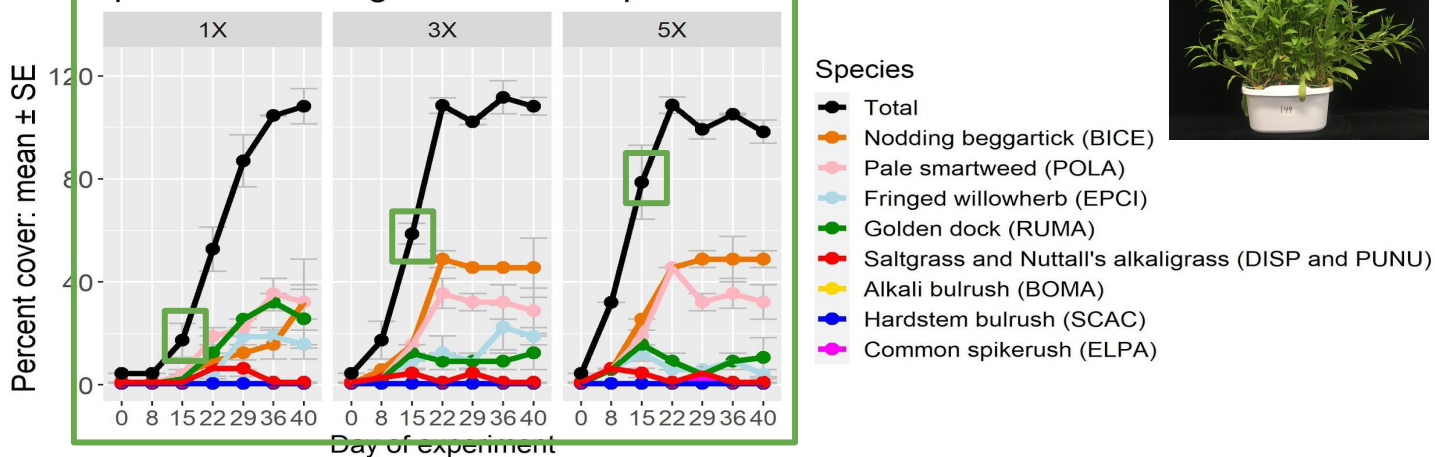


Species cover in greenhouse 4-species mix



- 3x and 5x have higher percent cover than 1x
- Cover driven by saltgrass

Species cover in greenhouse 9 species mix



- Reaches 100% cover much more quickly than 4-species mix.
- High density= high cover after 2 weeks
- Cover driven by weedy natives

Q.1 Seed mix density x composition greenhouse experiment

Take home message

- Competitive dominants are identified. We reduced proportion in field mixes to allow for better establishment of desirable perennial natives.
- 3x and 5x densities associated with higher final cover (4-species mix) and higher cover earlier on (9-species mix)

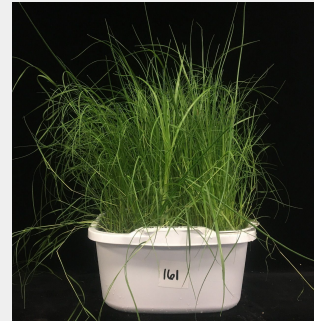
**Nodding
beggartick**
Bidens cernua



Fringed willowherb
Epilobium ciliatum



Golden dock
Rumex maritimus



End of experiment
4-species mix (5x)



Day 15
9-species mix (5x)

Q.1 Seed mix density x composition field experiment

Methods

Mix 1	Mix 2	Mix 3	Mix 4
0% weedy natives, 100% habitat-forming perennials	10% weedy natives, 90% habitat-forming perennials	25% weedy natives, 75% habitat-forming perennials,	100% weedy natives, 0% habitat-forming perennials

Weedy natives	Habitat-forming perennials
<i>Bidens cernua</i> <i>Epilobium ciliatum</i> <i>Rumex maritimus</i>	<i>Distichlis spicata</i> <i>Puccinellia nuttalliana</i> <i>Schoenoplectus acutus</i> <i>Bolboschoenus maritimus</i> <i>Eleocharis palustris</i>

- 2 densities (1x, 3x)
- 2 weeding treatments (weeded, unweeded)



Q.1 Seed mix density x composition field experiment

Monitoring: Native cover between ~30 - 100% in seeded plots

0% weedy natives mix, 3x



10% weedy natives mix, 3x



25% weedy natives mix, 3x



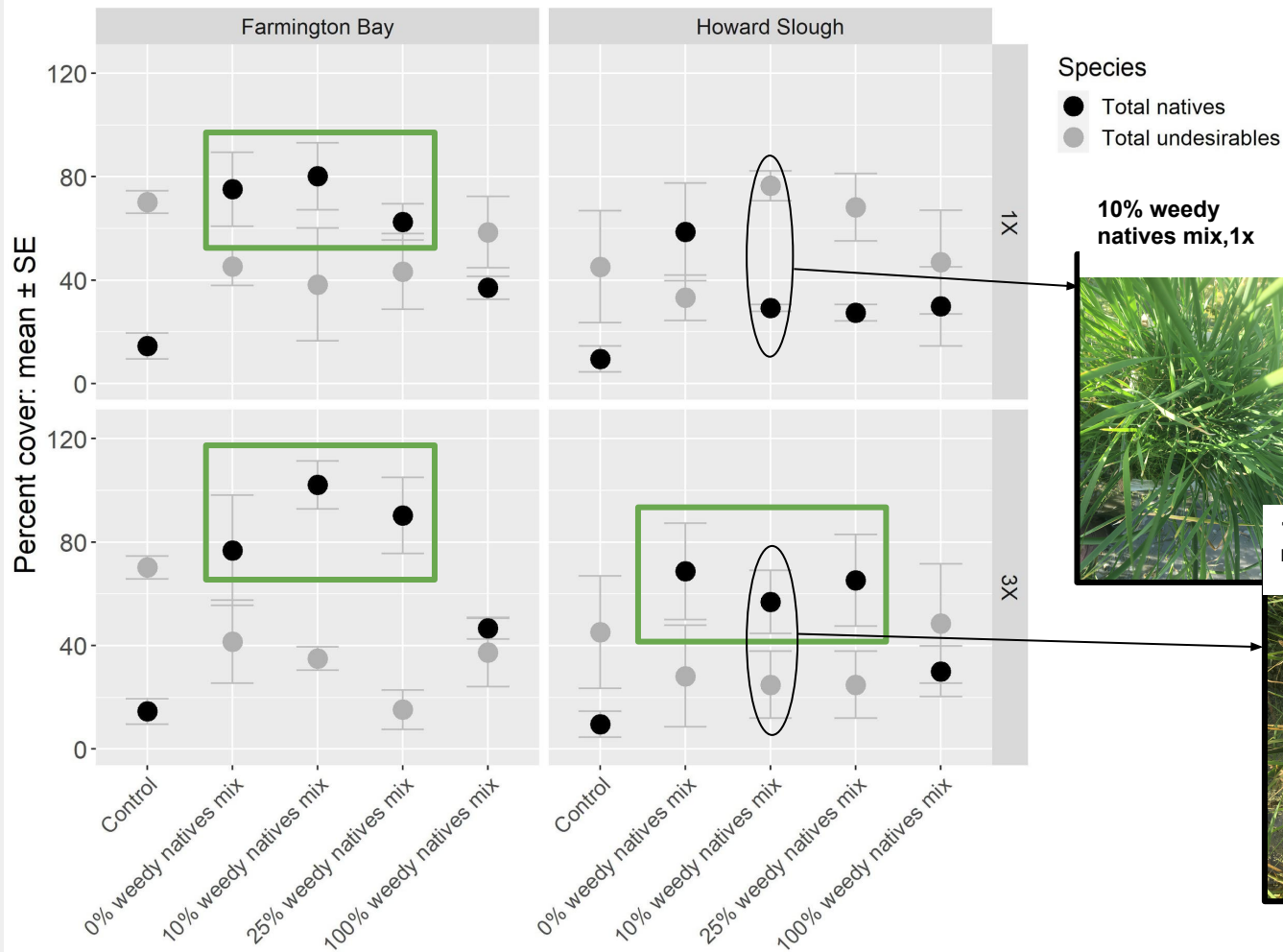
100% weedy natives mix, 3x



Control



End of season percent cover in unweeded plots



- At Howard Slough, 3x sowing density needed for natives > cover than undesirables

Q.1 Seed mix density x composition field experiment

Take home message

- Sowing seeds, even at 1x, results in ~2 - 4x higher cover of natives than in the control
- When undesirable cover is high, a 3x density may be needed for native cover to be > than undesirables
- Mixes with just habitat-forming perennials, 10%, or 25% percent weedy natives are all good options
 - For increasing native cover and decreasing undesirable cover
- What about *Rumex maritimus* and *Epilobium ciliatum*?

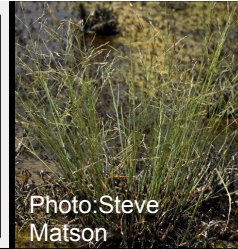


Q.1 Seed mix density field experiment *Methods*

Saltgrass
Distichlis spicata



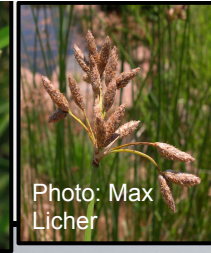
Nuttall's alkaligrass
Puccinellia nuttalliana



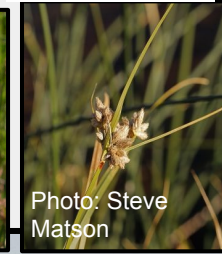
Threesquare bulrush
Schoenoplectus americanus



Hardstem bulrush
Schoenoplectus acutus



Alkali bulrush
Bolboschoenus maritimus



Common spikerush
Eleocharis palustris



August 2020



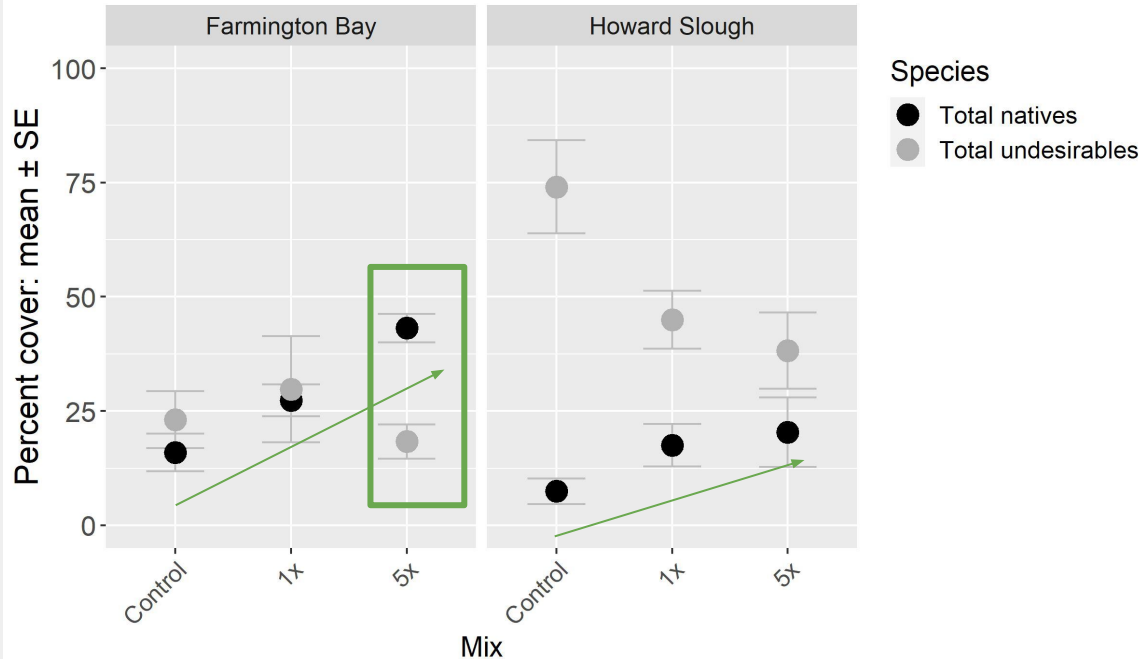
June 2020



Q.1 Seed mix density field experiment

5x density increases natives and decreases undesirables

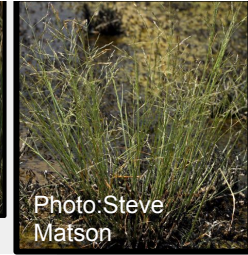
End of season percent cover in density experiment plots



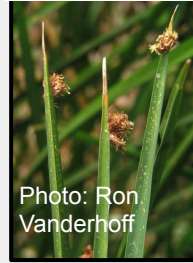
Saltgrass
Distichlis spicata



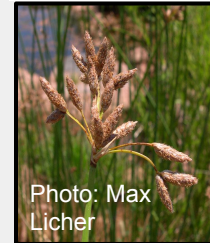
Nuttall's alkaligrass
Puccinellia nuttalliana



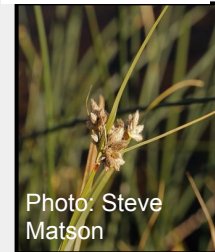
Threesquare bulrush
Schoenoplectus americanus



Hardstem bulrush
Schoenoplectus acutus



Alkali bulrush
Bolboschoenus maritimus

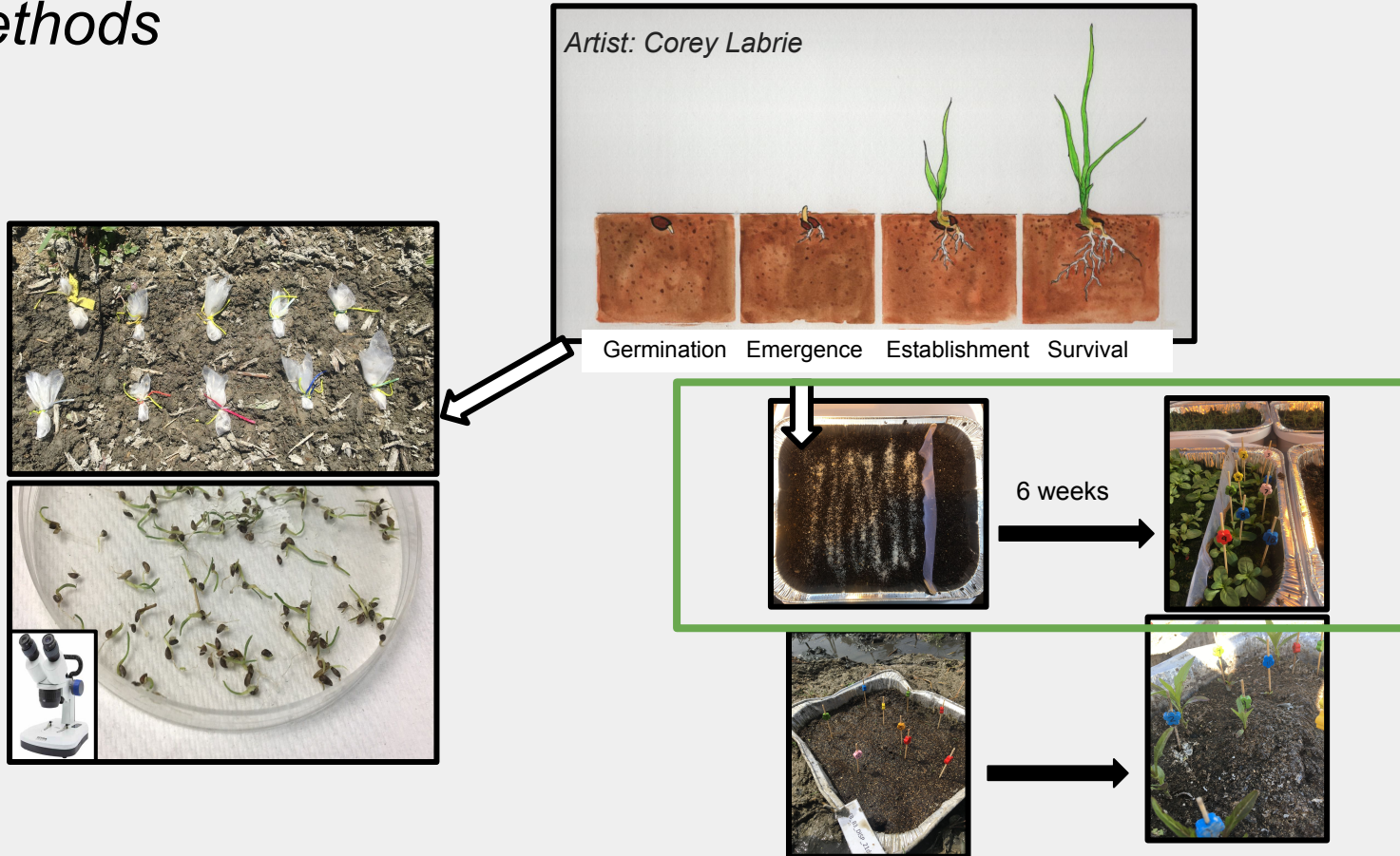


1. What are the effects of seed mix composition and density on native plant communities?
 - Single species field evaluation (pilot)
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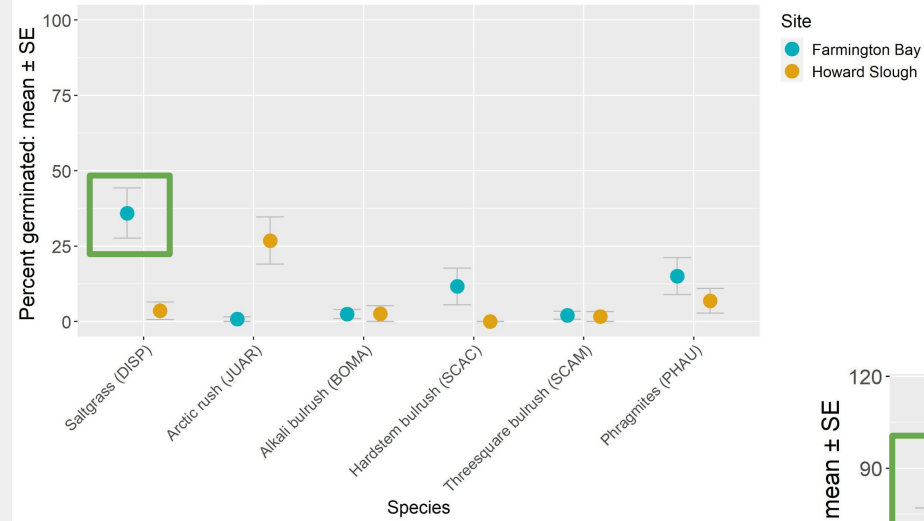


Q.2 Germination and emergence assessments

Methods

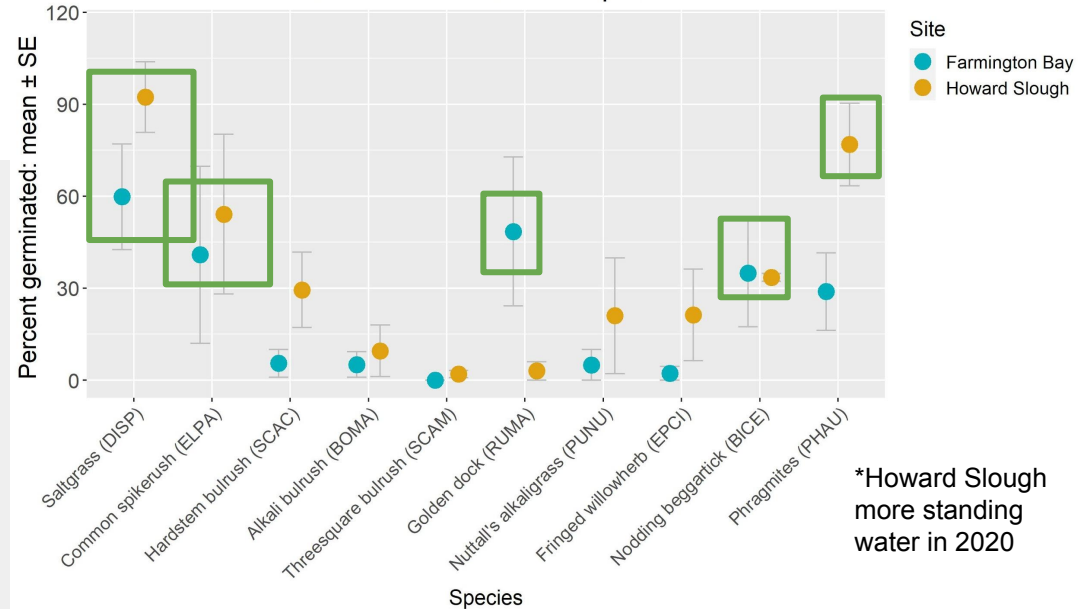


Germination in 2019 field experiment



- Germination variable across year, sites, species

Germination in 2020 field experiment

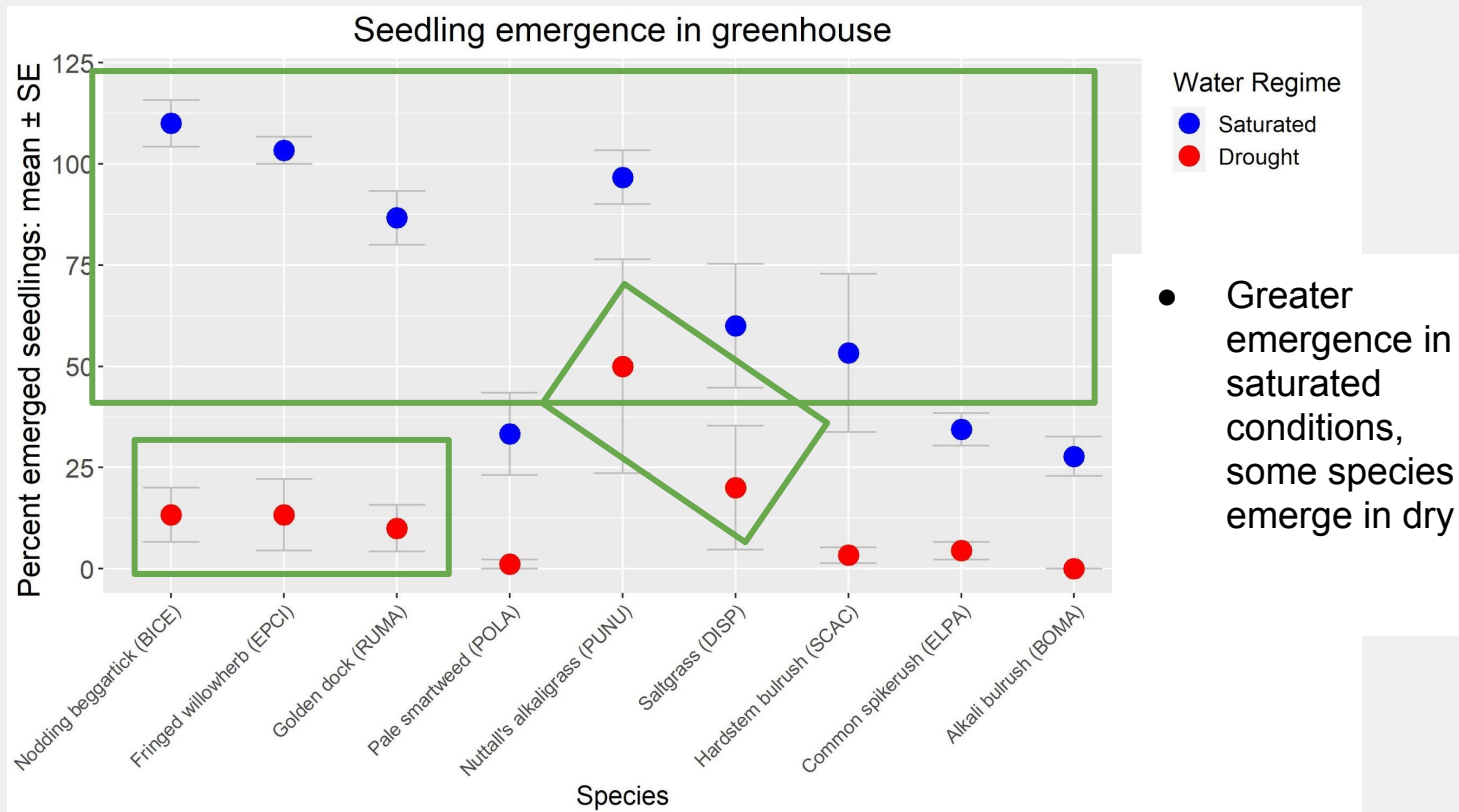


*Howard Slough more standing water in 2020





Q.2 Emergence assessments in greenhouse



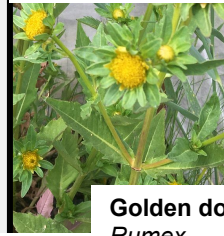
Q.2 Germination and emergence assessments

Take home message

- For germination, highly variable for year, site, and species, but highest germination ~30-90% for these species
- For emergence in greenhouse, saturated conditions = greater emergence (in some cases 100%) though some can emerge in drier conditions too
- Other interventions made be needed (improved dormancy-breaking, seed coating)



Nodding beggartick
Bidens cernua



Golden dock
Rumex maritimus



Common spikerush
Eleocharis palustris



Saltgrass
Distichlis spicata

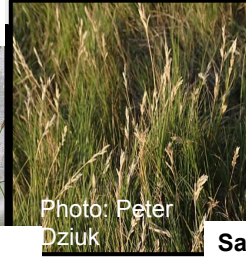


Photo: Peter Dziuk

Saltgrass
Distichlis spicata

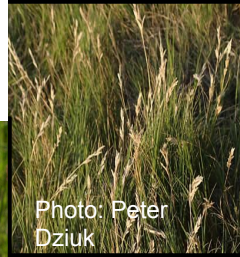


Photo: Peter Dziuk

Nodding beggartick
Bidens cernua



Golden dock
Rumex maritimus



Fringed willowherb
Epilobium ciliatum

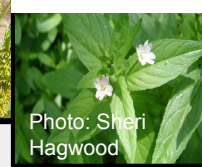


Photo: Sheri Hagwood

Nuttall's alkaligrass
Puccinellia nuttalliana

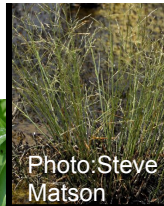


Photo: Steve Matson

Hardstem bulrush
Schoenoplectus acutus



Photo: Max Licher

Implications

- Contribute to knowledge of plant community reassembly
- My results suggest:
 - Seeding rates of 3x (540 PLS/ ft²) and 5x (900 PLS/ ft²) lead to greater native cover and lower undesirable cover
 - Inclusion of weedy native species into slow-growing perennial mix may increase native cover earlier on in season and increase native species richness

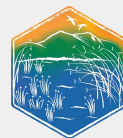


Potential species to include in revegetation mix	
Weedy natives	Desired habitat-forming perennials
<i>Bidens cernua</i> <i>Epilobium ciliatum</i> <i>Rumex maritimus</i>	<i>Distichlis spicata</i> <i>Puccinellia nuttalliana</i> <i>Schoenoplectus acutus</i> <i>Bolboschoenus maritimus</i> <i>Eleocharis palustris</i> <i>Schoenoplectus americanus</i>

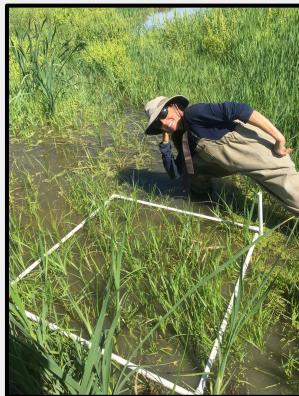
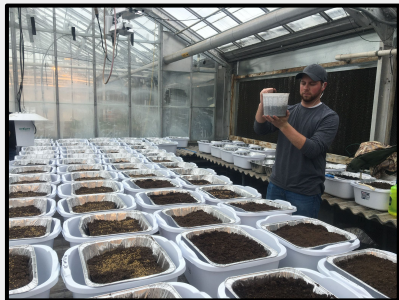
Acknowledgements

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- Amanda Mast
- Cole Patton
- Audree Provard
- Brandon Thomas
- Maggie Hallerud
- Coryna Hebert
- Emily Tarsa



USU Wetland Ecology
& Restoration Laboratory



Shane Sterner

Questions?

