



Reintroduction of the Ben Lomond Wallflower (*Erysimum teretifolium*, Brassicaceae)

Experimental Examination of the Roles of Soil Disturbance, Genetic Factors, and Habitat Conditions in Recovering an Endangered Plant Endemic to the Santa Cruz Sandhills

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PROBLEM

- Anthropogenic drivers are causing rare plant extirpations
- In some cases, introductions will be needed to ensure species persistence
- Successful reintroductions must address factors that will influence population persistence
- Some/all factors are often poorly understood
- Experimental approaches to introductions can fill data gaps

RARE PLANT INTRODUCTION CONSIDERATIONS

☐ Abiotic Factors

- ✓ Soils
- ✓ Climate
- ✓ Hydrology
- ✓ Etc.

☐ Biotic Factors

- ✓ Herbivores (e.g., safe sites for seedling establishment)
- ✓ Pollinators

☐ Disturbance regimes

☐ Population Factors

- ✓ Mating System
- ✓ Genetic considerations
- ✓ Minimum viable population size

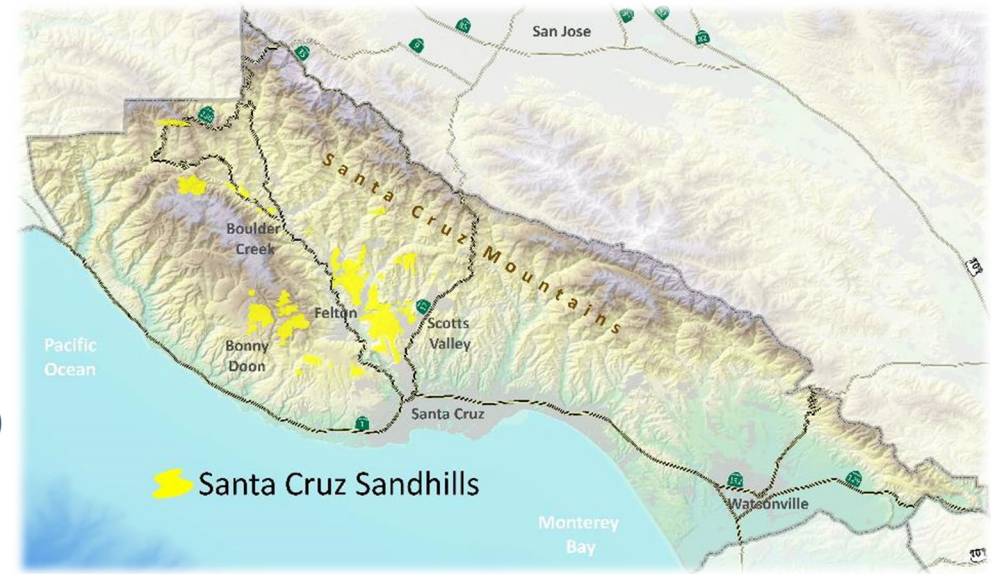


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SANTA CRUZ SANDHILLS

- Unique ecosystem on uplifted marine sediment in Santa Cruz Co.
- Two endemic plant communities
 - Silverleaf manzanita (*Arctostaphylos silvicola*) chaparral (sand chaparral)
 - Maritime coast range ponderosa pine (*P. ponderosa* var. *benthamiana*) forest (sand parkland)
- 6 endemic species (4 plants, 2 insects) and numerous undescribed taxa



Ben Lomond spineflower



Ben Lomond buckwheat



Silverleaf manzanita



Zayante band-winged grasshopper



Mount Hermon June Beetle



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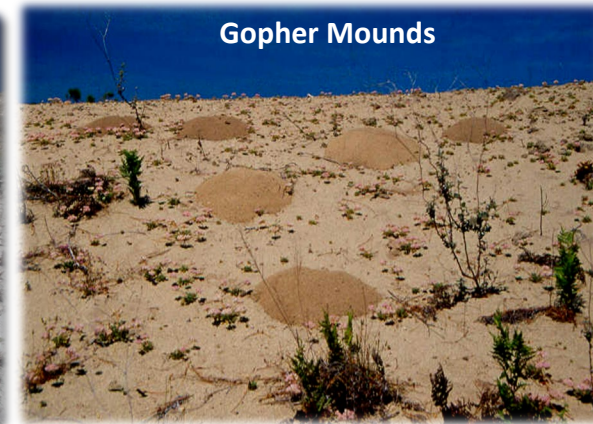


DISTURBANCE ECOLOGY

- Fire
 - Dominant species feature adaptation to fire
 - Precise aspects of 'natural' fire regime unknown
- Sandy soil → small-scale **soil disturbance**
 - Slides
 - Trails
 - Gopher mounds
- Disturbance promotes native plants
 - Reduces litter and competition
 - Reduces exotic plants
 - Stimulates seed germination



Small-Scale Soil Disturbances

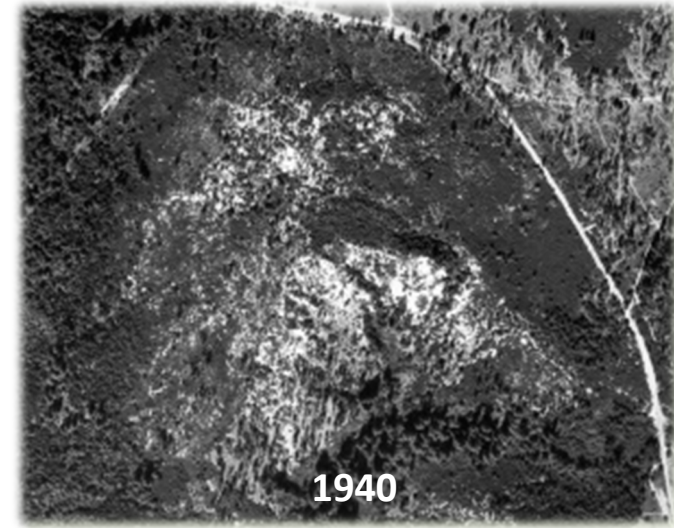


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THREATS

- ~6,265 ac. historically; ~3,960 ac. remain
- Habitat Loss
 - Sand quarrying
 - Development
 - Limited agriculture (vineyards)
- Habitat Degradation (loss of open sandy soil)
 - Fire exclusion
 - Exotic plants
 - Incompatible recreational use
- Climate Change: Increase in climatic water deficit
 - 'mega drought'
 - Increased temperatures



Fire Exclusion



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BEN LOMOND WALLFLOWER

- *Erysimum teretifolium* (Brassicaceae)
- Biennial to short-lived perennial, generally monocarpic
- Endemic to the Santa Cruz Sandhills, Central Santa Cruz County
- State endangered (1981), Federal Endangered (1994), CRPR 1B.1
- Weak self-incompatible mating system (limited self fertilization occurs)
- Late-acting inbreeding depression: self-pollinated offspring have lower survivorship and reproduction
- Preferentially occurs in open canopy, bare ground
 - Fire promotes performance by removing woody plants, dense (exotic) herbs, and litter
 - Soil disturbance promote germination, survivorship, and reproduction
- Outcompeted by exotic herbs, which compete for soil moisture
 - Most seedlings (95%) die before reaching juvenile (1+ years) stage
- 5 of 17 populations documented in the late 1970s have been extirpated

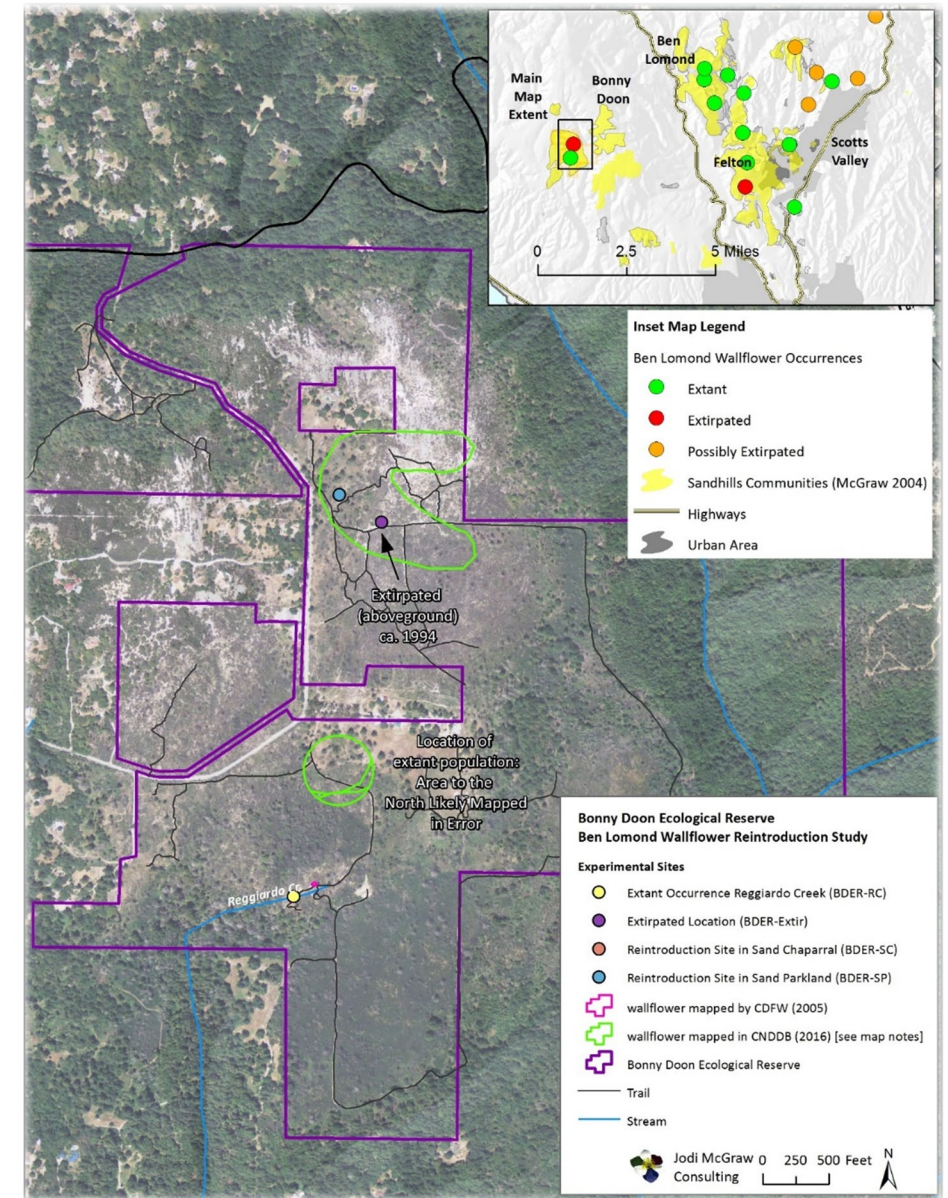


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BONNY DOON ECOLOGICAL RESERVE

- 552 acres
- Highly conservation value for sandhills: large size, high integrity
- Protected in 1989 by TNC, preventing proposed vineyard conversion
- Managed by California Department of Fish and Wildlife
- Two wallflower populations associated with prior unpaved roads
 - Northern: extirpated ~1994
 - Southern: <20 adults since 2013



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EXPERIMENTAL REINTRODUCTION

EXPERIMENTAL STUDY QUESTIONS

Disturbance Treatment: What are the effects of soil disturbance on wallflower?

Genetic Factors: What genetic aspects influence wallflower population introduction?

Habitat Conditions: What abiotic and biotic factors influence wallflower introduction?

INTRODUCTION PROJECT GOALS

1. Examine alternative soil disturbance treatments to enhance habitat
2. Evaluate whether the BDER population features locally adapted genetic complexes
3. Assess whether alleviating inbreeding depression caused by self-incompatibility alleles can promote plant fitness and population growth
4. Determine suitable habitat conditions
5. Establish wallflower in multiple locations within the BDER

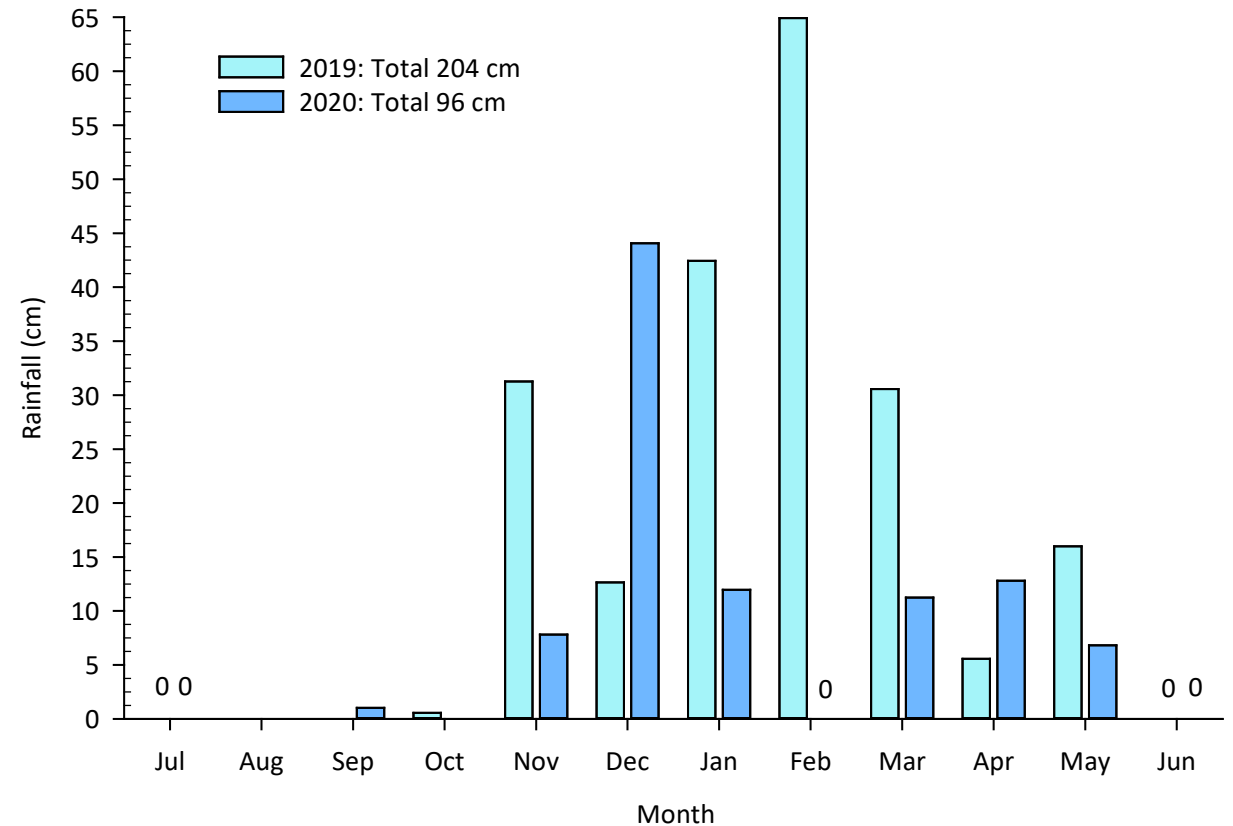


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STUDY APPROACH

- Small-scale manipulative experiment
- Replicated in two rainfall years (2019 and 2020), which differed greatly in precipitation
- Monitored for two years



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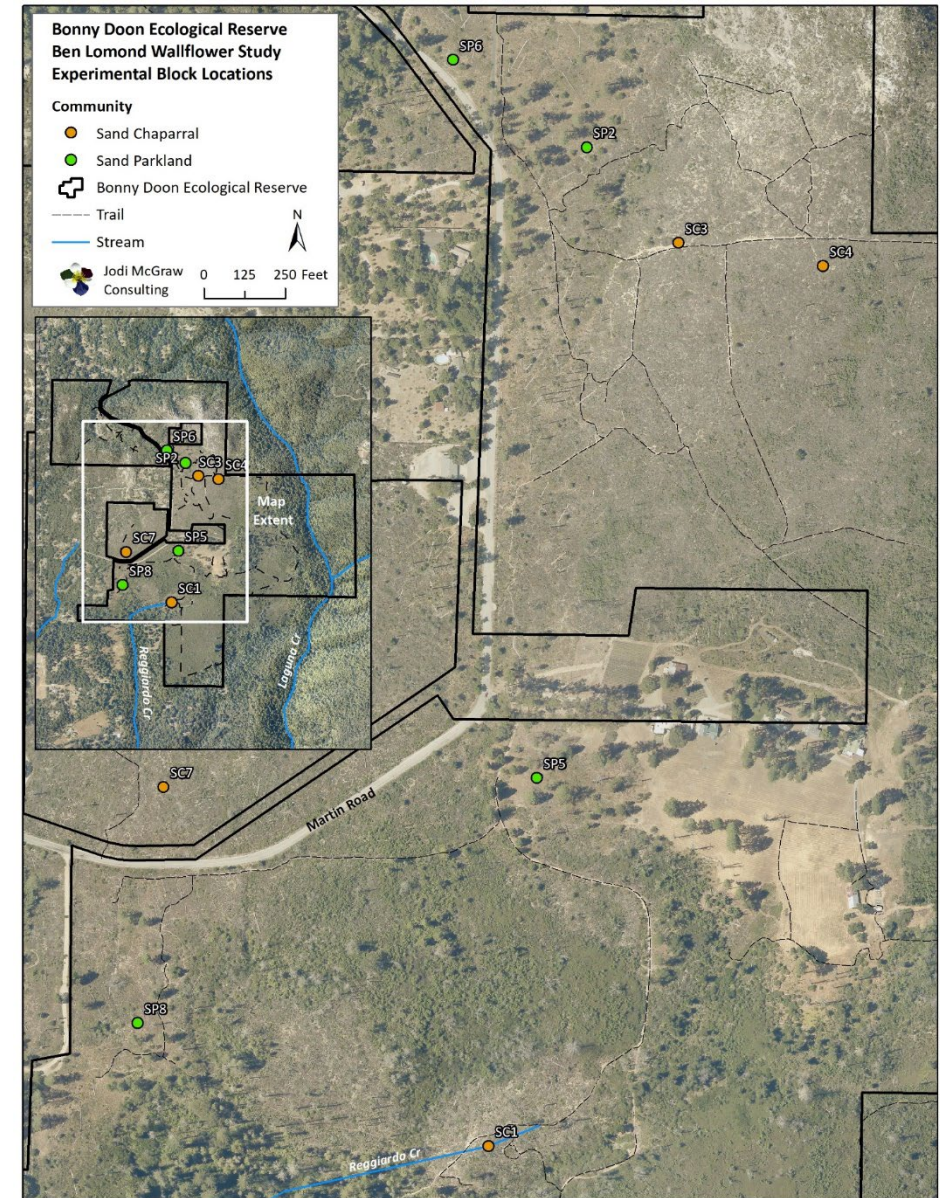


TWO COMMUNITY TYPES



**Maritime Chaparral
(aka Sand Chaparral)
(4 blocks)**

**Maritime Coast
Range Ponderosa
Pine Forest
(aka Sand
Parkland)
(4 blocks)**



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TWO DISTURBANCE TREATMENTS

Alternatives to mimic beneficial effects of natural soil disturbance

- Rake to remove litter and (most) established plants
- Till (after raking) to create loose sand soil characteristic of soil disturbance

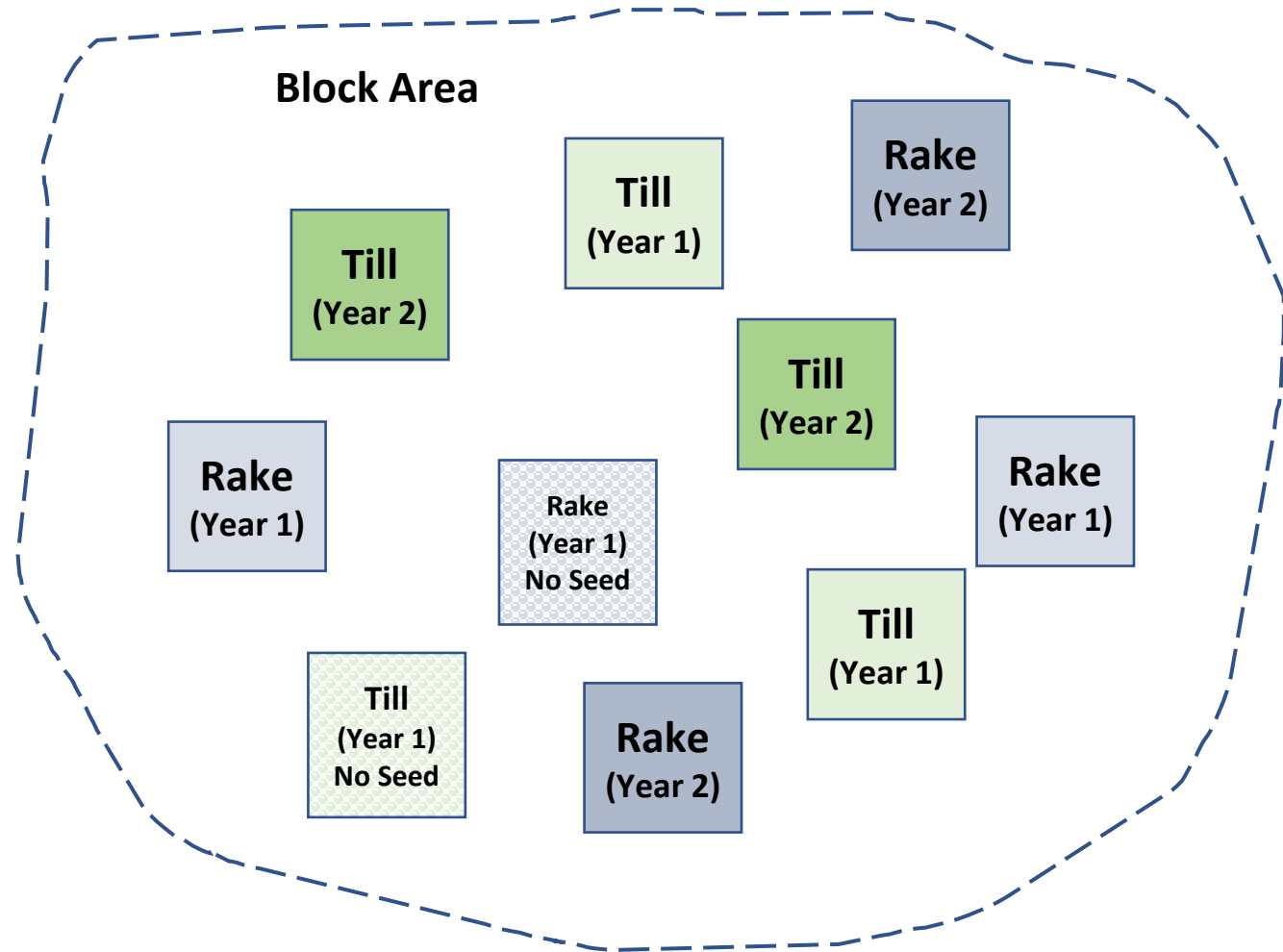


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BLOCK DESIGN

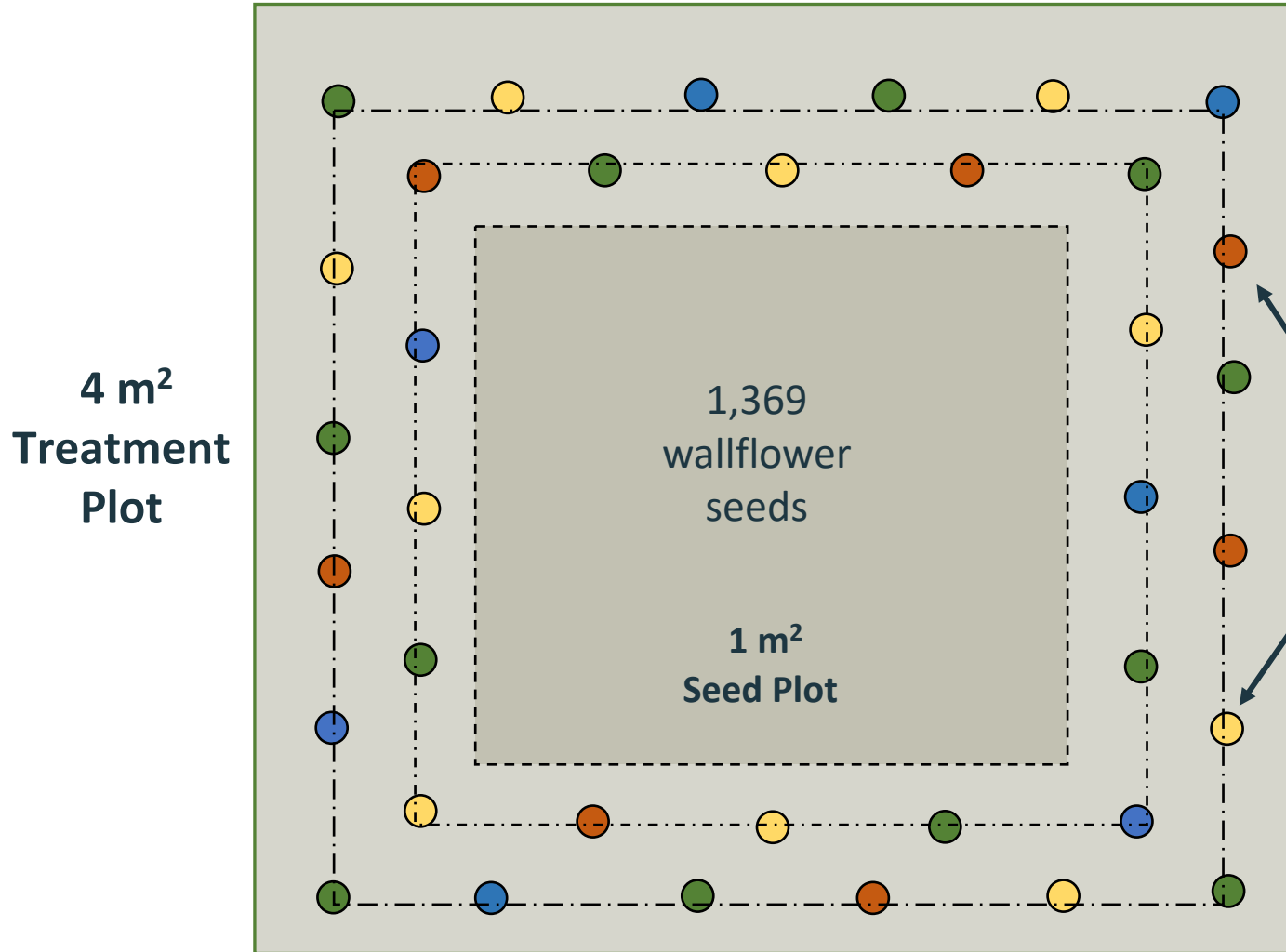
- 2 replicate seeded and planted plots for each habitat treatment
- One unseeded/unplanted control to check for seedbank (there was none)



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PLOT DESIGN



- Outer plot planted with genetic treatment seedlings
- Inner plot seeded with BDER Seed

Outplanted Seedlings (n = 36)
Four Genetic Treatments

Color	Genetic Treatment
Orange	Non-BDER X Non-BDER
Green	Non-BDER
Blue	BDER x Non-BDER
Yellow	BDER



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DATA COLLECTION: HABITAT

- ❑ 2019 and 2020
- ❑ Soil conditions
 - ✓ Depth
 - ✓ Texture
 - ✓ Chemistry (pH, CEC, OM, macronutrients)
- ❑ Plant Community Composition
 - ✓ Native and exotic plant cover and richness by species
 - ✓ Ben Lomond spineflower
 - ✓ Ben Lomond buckwheat



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WALLFLOWER DATA

Establishment



Reproduction



Survivorship



Seed Production



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Results



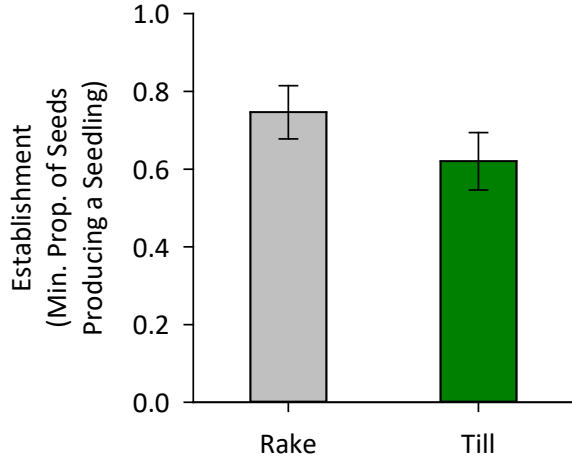
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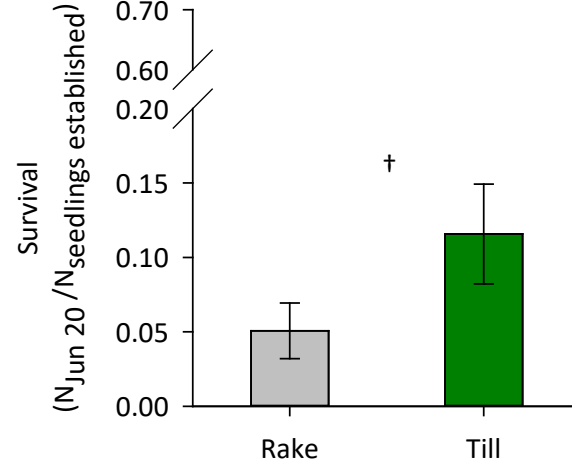
DISTURBANCE TREATMENT: SEEDING PLANTS

Year 1

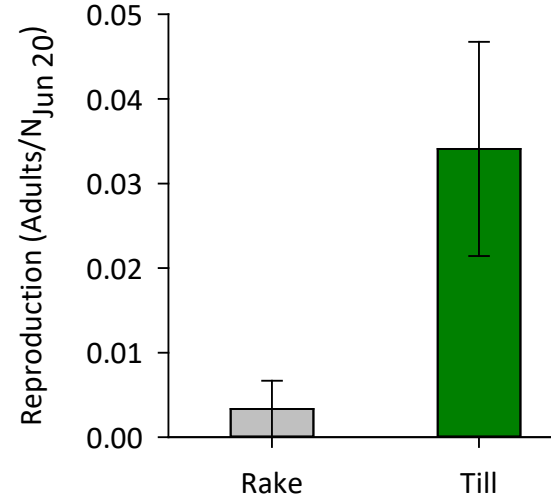
Establishment



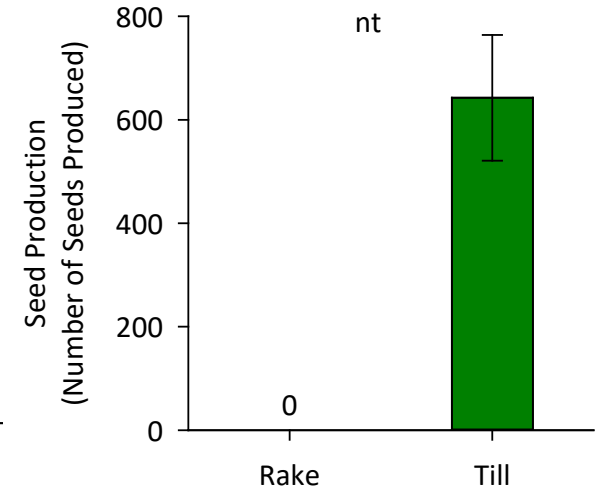
Survivorship



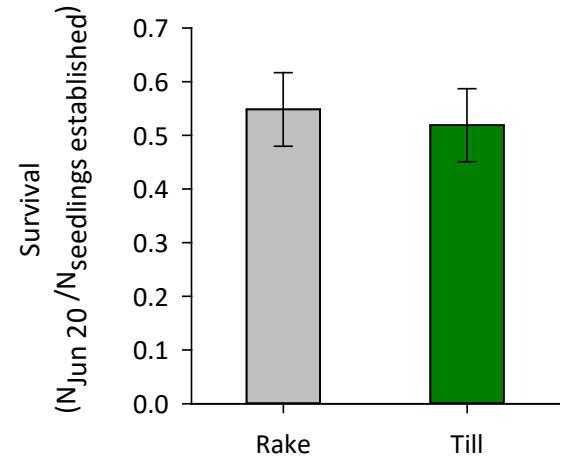
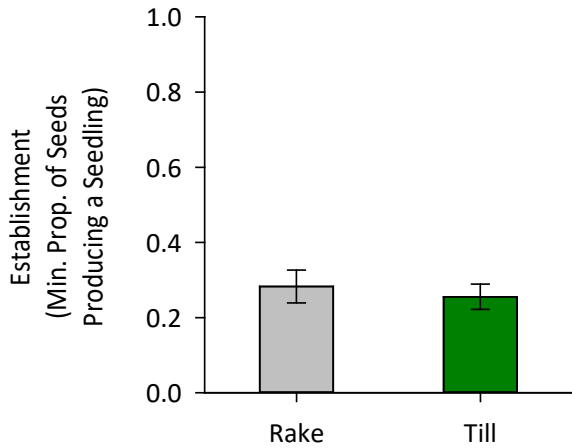
Reproduction



Seed Production



Year 2



Tilling the soil promoted

- Survivorship (Year 1 only)
- Reproduction
- Seed production

Tilling did not affect establishment in either year



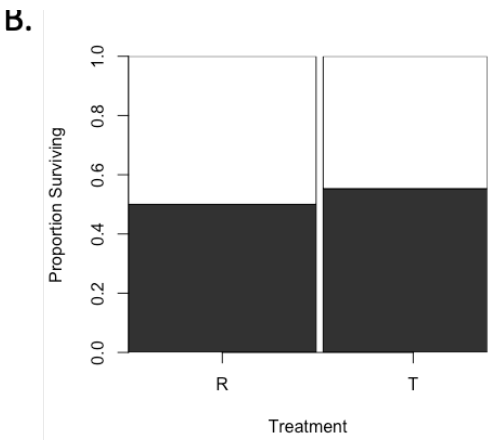
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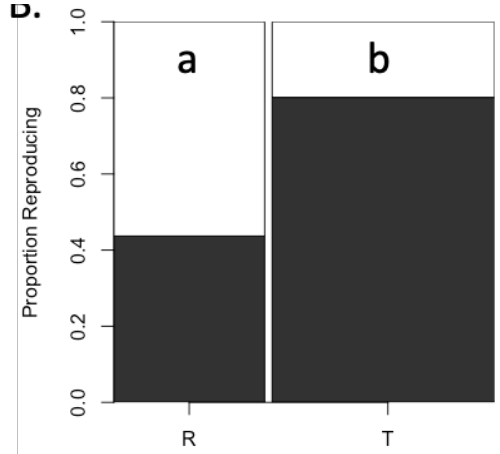
DISTURBANCE TREATMENT: TRANSPLANTED SEEDLINGS

Year 1

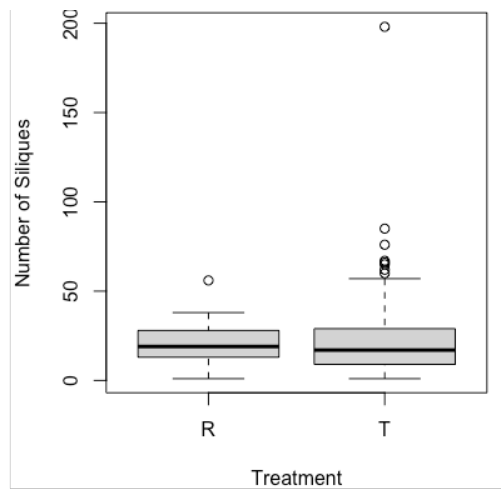
Survivorship



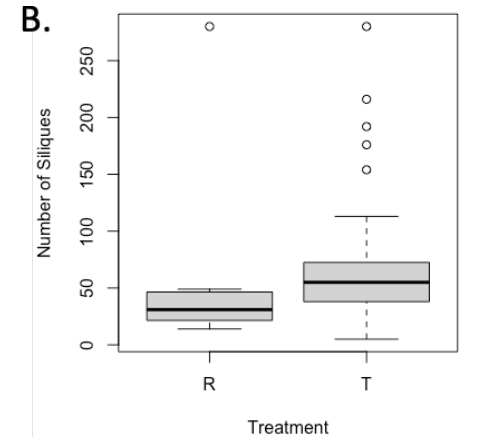
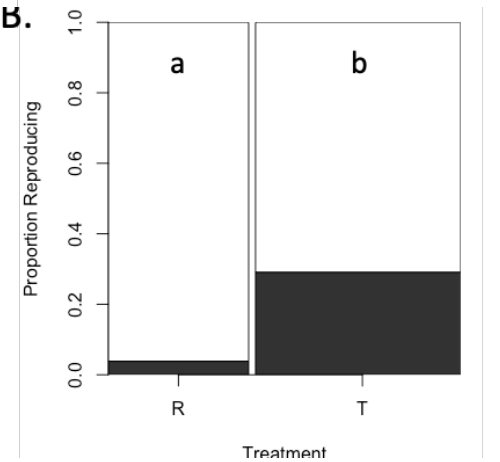
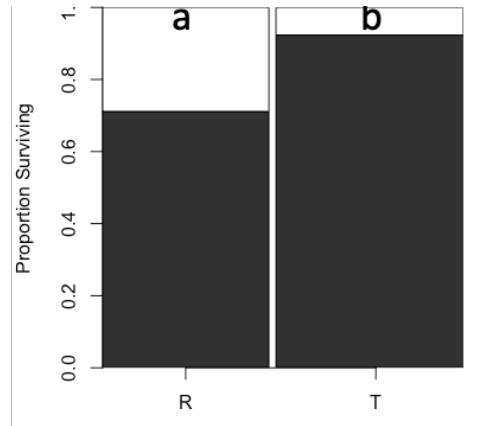
Reproduction



Seed Production



Year 2



Tilling promoted

- Survivorship in Year 2
- Reproduction in both years
- Seed production unaffected

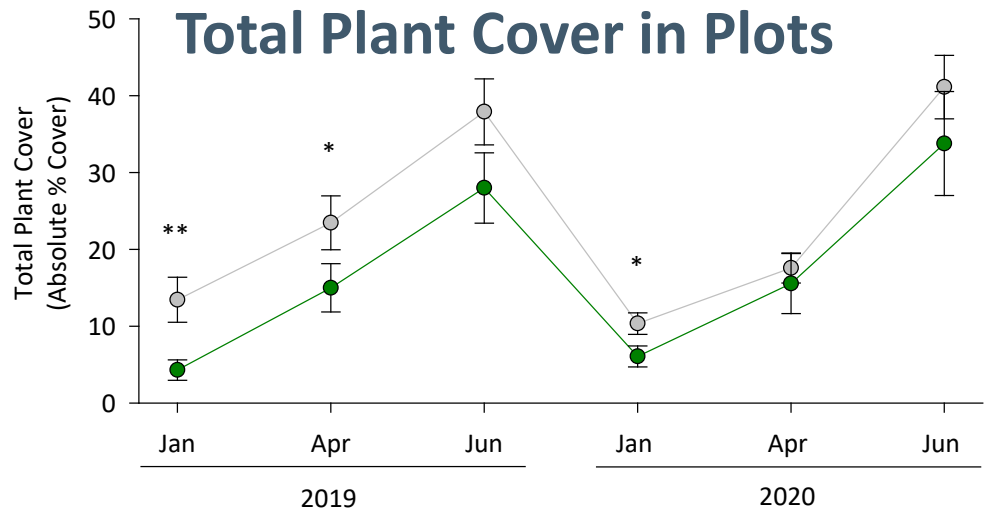
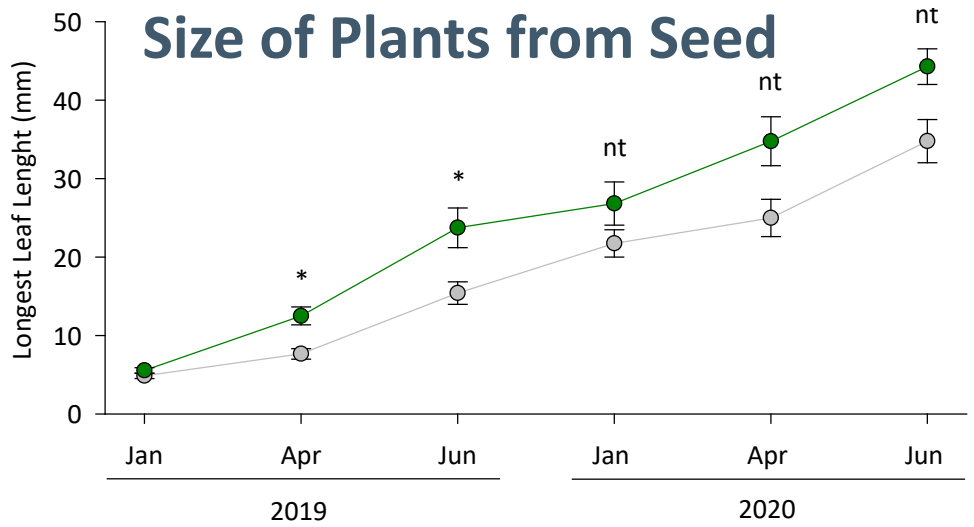


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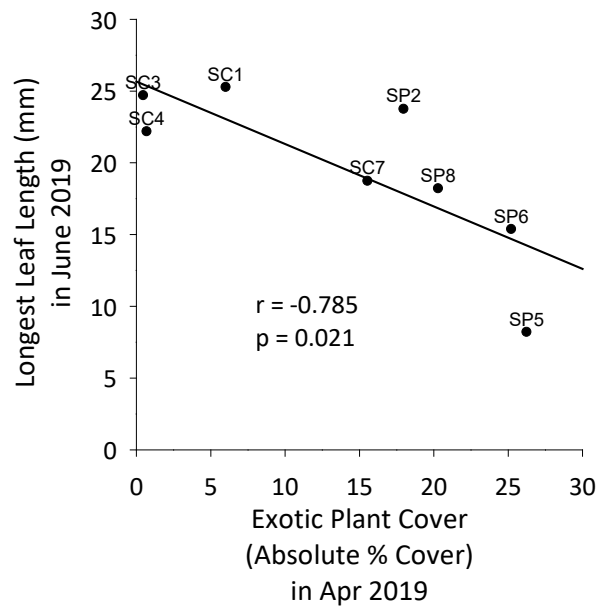


THE MECHANISM BEHIND TILLING

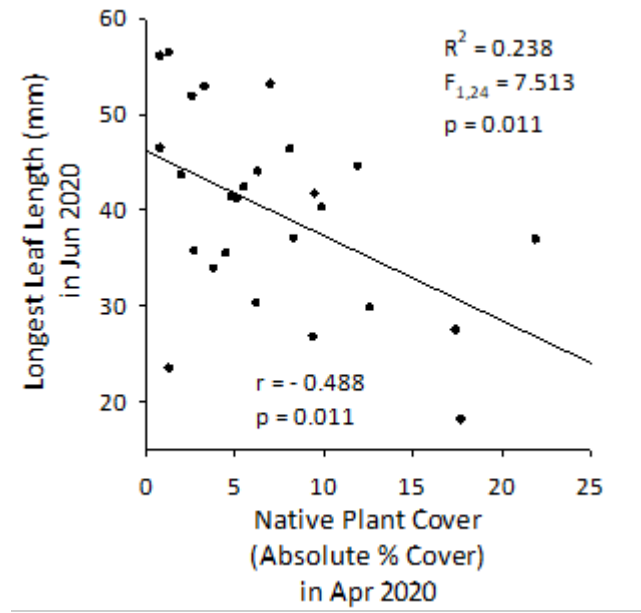
- Likely *partially* reduced competition
- No detected effects on soil nutrients
- Loose soil appears to benefit wallflower



Size vs. Exotic Cover



Size vs. Native Cover



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GENETIC TREATMENT

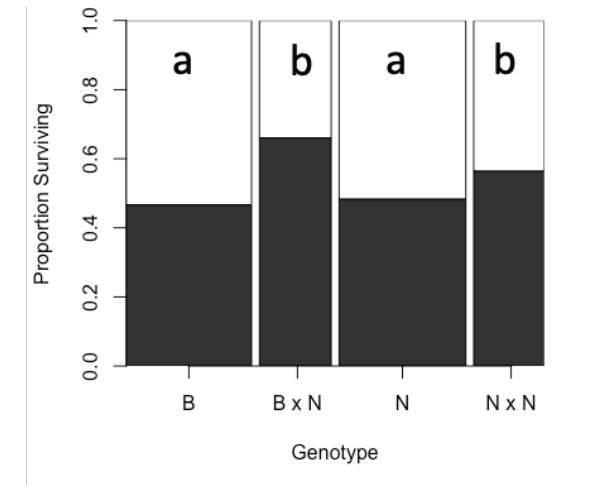
Performance varied by year and life stage

No consistent, significant evidence for either

- local adaptation (Bonny Doon genotype does better)
- outbreeding depression (crosses do better)

The hybrid genotype (B x N) had higher performance for 5 out of 7 measures including survivorship

- May reflect heterosis



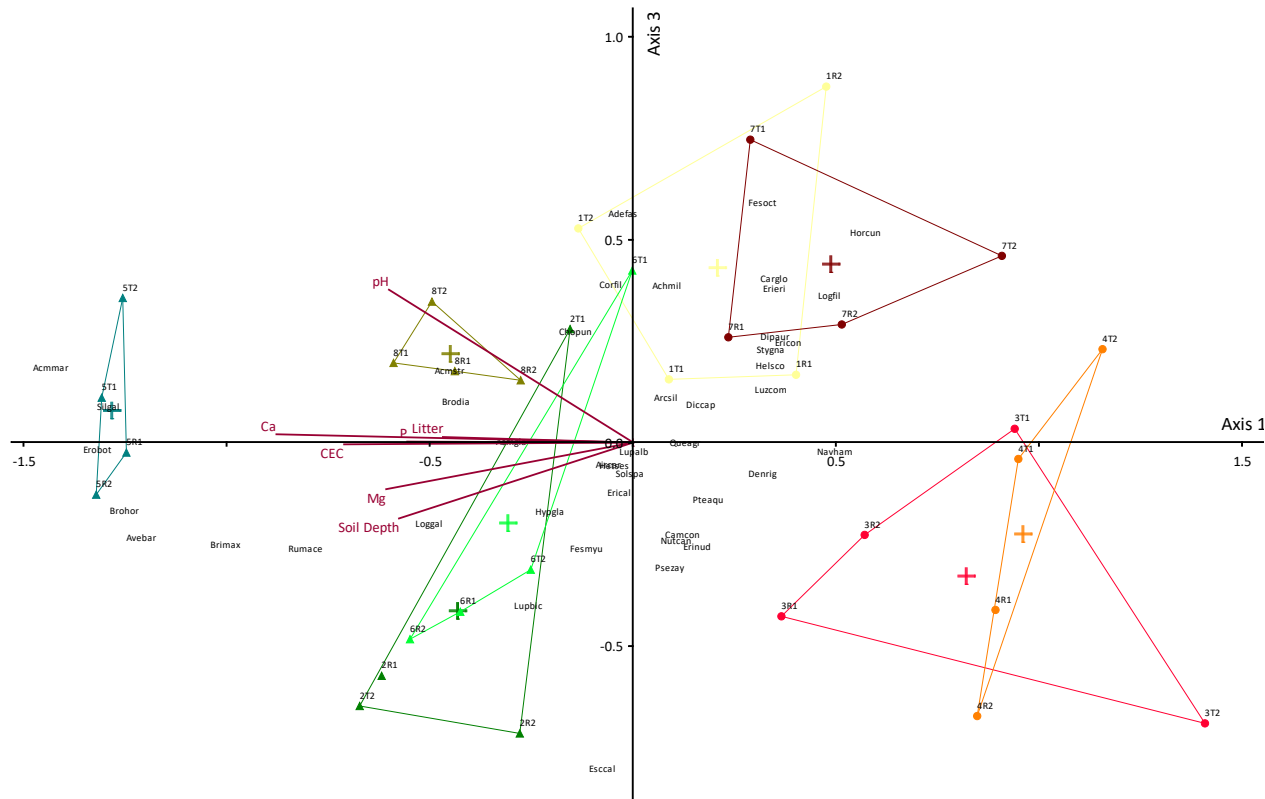
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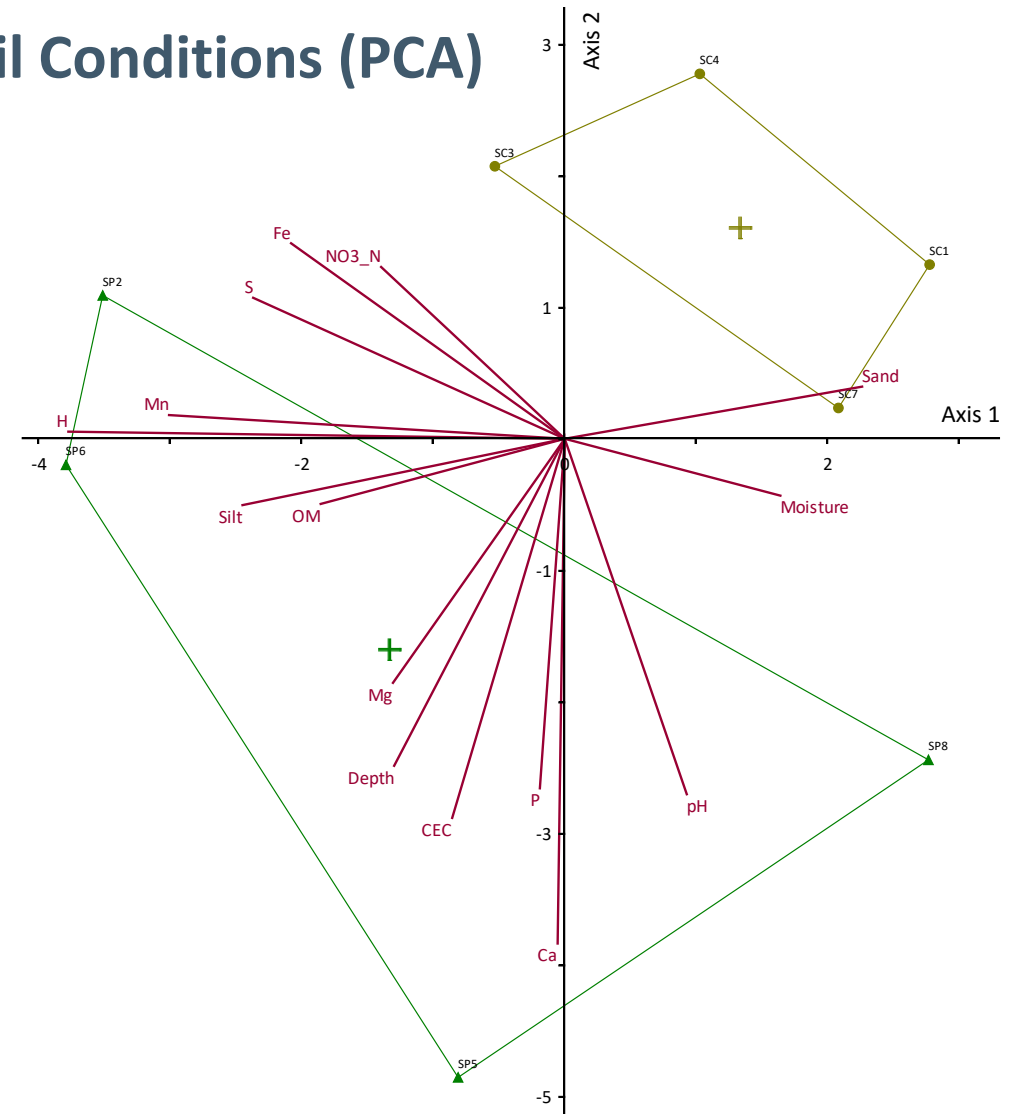
HABITAT CONDITIONS

8 blocks differed in soils and plant community composition

Plant Community Composition (NMDS)



Soil Conditions (PCA)



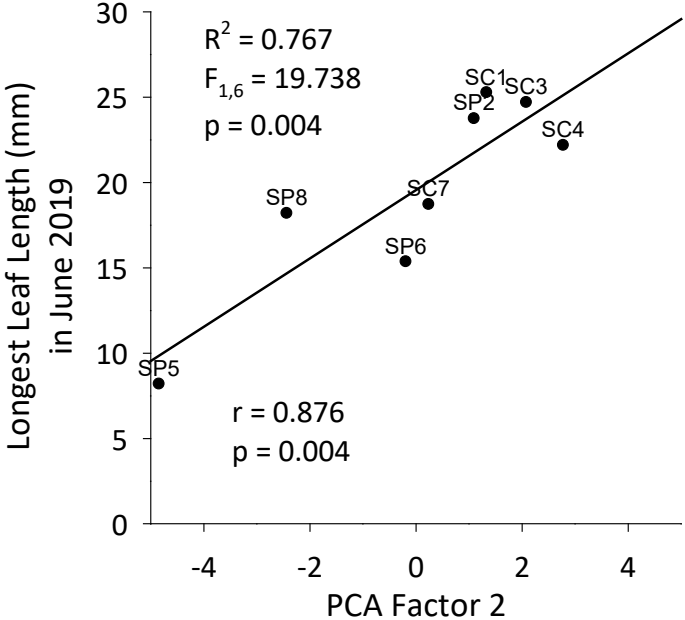
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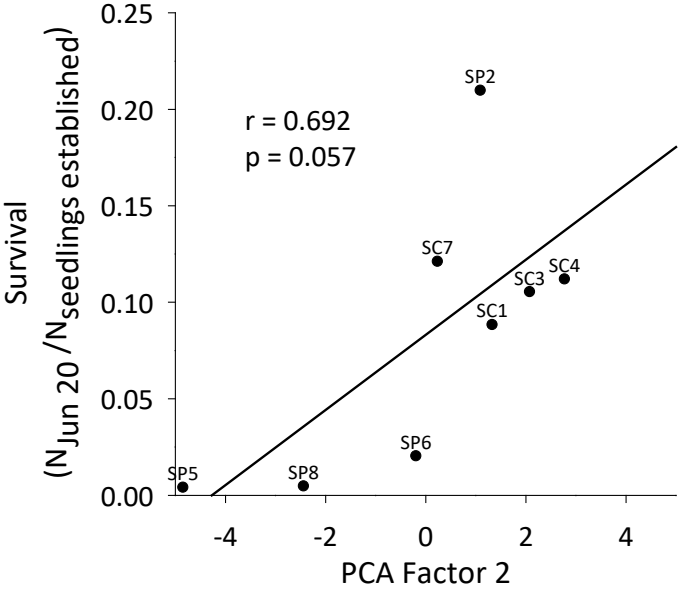
HABITAT CONDITIONS

Wallflower performed greater in lower fertility soils, which had lower exotic cover

Size vs. Soil Infertility



Survival vs. Soil Infertility



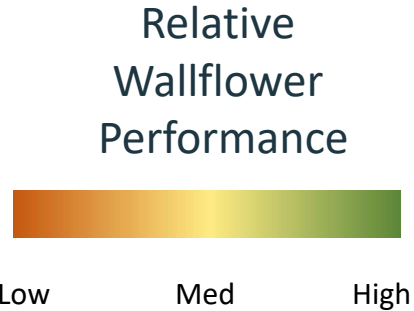
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HABITAT CONDITIONS

- Wallflower established in all 8 locations
- Wallflower performance varied among blocks, with the various measures uncorrelated

Variable	Sand Chaparral				Sand Parkland			
	SC1	SC3	SC4	SC7	SP2	SP5	SP6	SP8
Wallflower Demographic Performance								
Establishment (2019)	0.749	0.659	0.931	0.805	0.324	0.543	0.647	0.808
Survivorship (All plants)	0.088	0.105	0.112	0.121	0.210	0.004	0.020	0.005
Reproduction	0.003	0.049	0.006	0.011	0.030	0.000	0.031	0.000
Seed Production	5	740	780	0	865	.	504	.
Relative Fitness	0.00018	0.00402	0.00091	0.00018	0.00201	0	0.00146	0



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Summary and Management Implications



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Implications for Introduction

Disturbance Treatment

- ✓ Loosen soil through tilling or other means
- ✓ Use low intensity, low frequency disturbance to maintain open habitat and loose sand soil

Genetic Considerations

- ✓ Genetic mixing unlikely to disrupt locally adapted genetic complexes
- ✓ Using genetic material from multiple populations to promote crossing (heterosis) and reduce self-incompatibility and promote fitness

Habitat Conditions

- ✓ Introduce into a range of communities and microhabitats to maximize persistence given interannual variability in weather
- ✓ Preferentially select areas of low exotic plant cover or manage exotics



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Other Lessons Learned

- Outplanting seedlings can ‘jump start’ an introduction
 - Transplants often flowered in year 1, promoting survivorship to reproduction
 - Transplants had higher seed production than plants from seed
- Larger treatment areas will be more beneficial
 - Herbivory can be high adjacent to shrubs (small mammals)
 - Exotic plants recolonize plots from adjacent, untreated areas
- Ben Lomond spineflower and Ben Lomond buckwheat recruited at high rates in response to treatments, which also promoted other native species



Wallflower Transplants



Wallflower Herbivory



Ben Lomond Spineflower



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Status and Next Steps



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Current Status

- Wallflower has persisted in all blocks since 2018
 - Despite multi-year drought (2020-2022)
 - Despite impacts of CZU Lightning Fire Suppression (control line)
 - Despite 'borrowing' seed for next phase
- Plants have dispersed from treated plots



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Next Steps: 2022-2024

- Introduce in 2020 CZU Lightning Complex Fire areas
 - Area that was burned
 - Area where fuel break was created
- Scaled up introduction (4 m² plots → 16 m² plots)
- Route trails through introduction areas to create/maintain
 - Loose sand soil
 - Low litter and low competition



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ACKNOWLEDGEMENTS

Project Staff

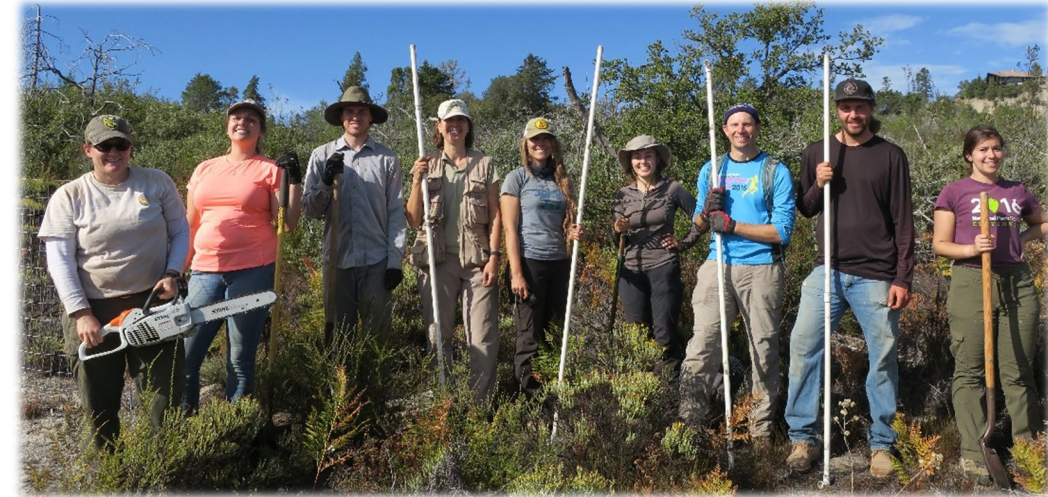
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Funding Provided under Section 6 Grant Agreement P1730601

- California Department of Fish and Wildlife
- United States Fish and Wildlife Service



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