The influence of drought, fire and invasion on coastal sage scrub ecosystems in San Diego

Mission Trails, 2022

Professor Elsa Cleland
School of Biological Sciences, UCSD

Goal: predict plant species responses to global change,

Inform conservation, restoration, and species management

Ellen Esch

Chandler Puritty

Liz Ryan

Karagan Smith

Claire Wainwright

Requires working across disciplines, features the work of many students & researchers

Scott Gressard

José Waterton

Much of this work has focused on one trait..

Lizzie Wolkovich

Julia Gaudio

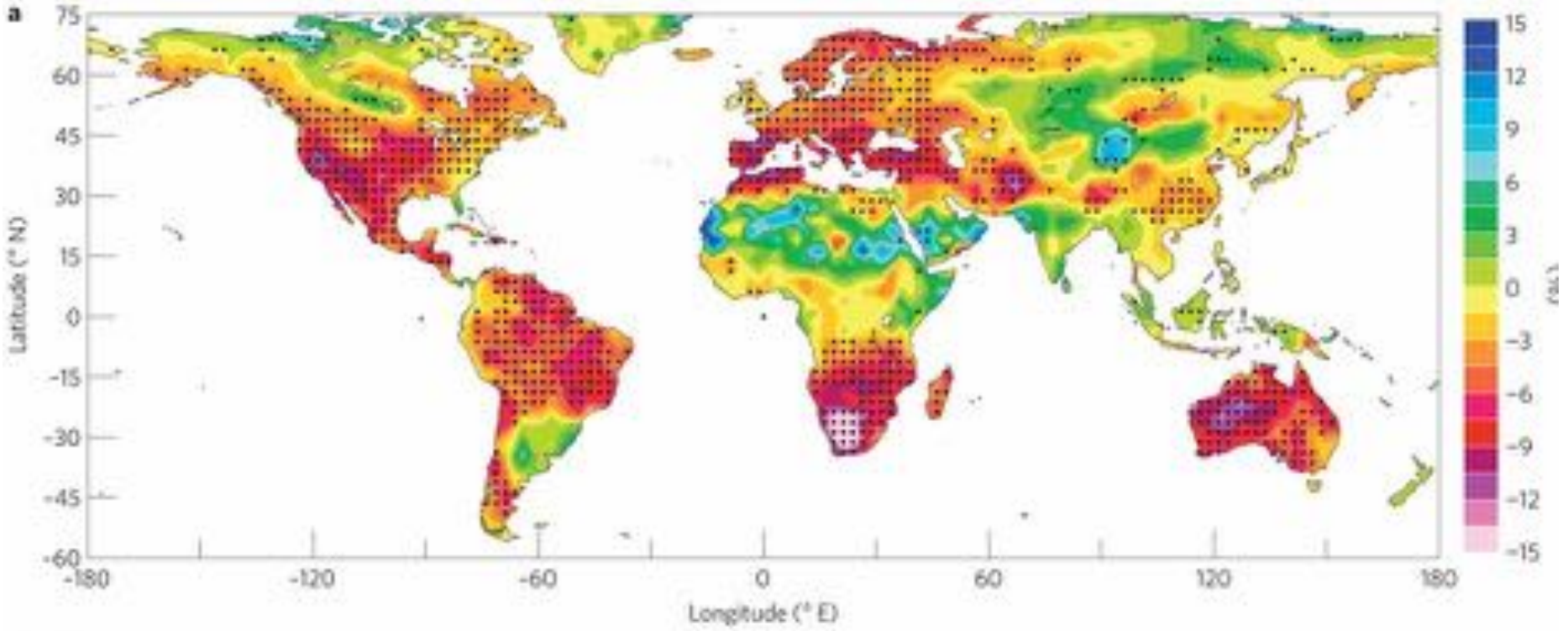
Phenology (timing)

- Seasonal timing of developmental events (germination, leafing, flowering)
- Determines the environmental conditions & biotic interactions experienced by individuals
- Highly sensitive to environmental cues
- Varies among species

Coastal sage scrub ecosystems responding to multiple, interacting global changes

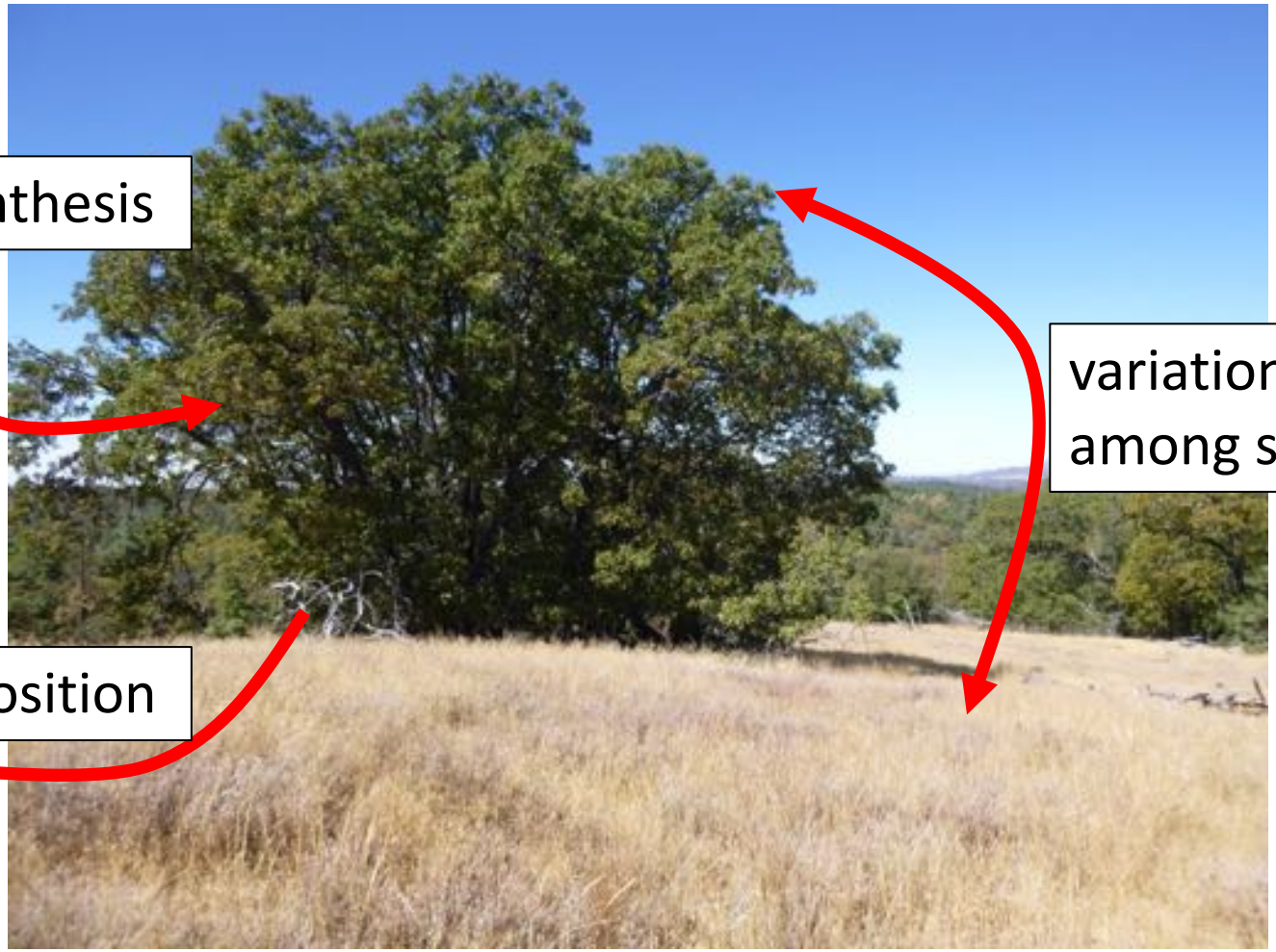
- Past work: Invasion alters ecosystem responses to drought
- Ongoing work: Factors that promote (or prevent) shrub recovery following wildfire
- New/future work: Assisted Gene Flow (AGF), experiments with California poppy

Ecosystems are projected to experience increasing drought in the coming decades

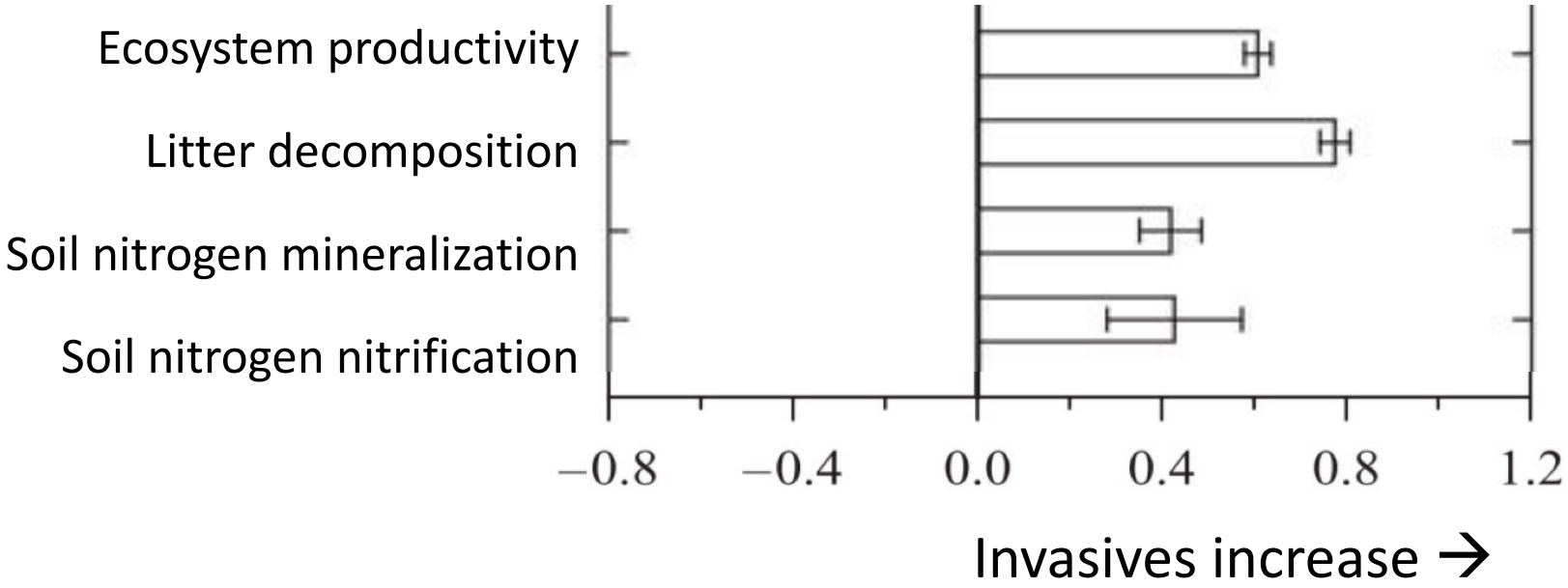


Dai 2013

Vegetation feedbacks to drought and climate change will influence ecosystem-level responses and global C cycles: species differ in carbon uptake/release



Invasive species accelerate C and N cycling; do they alter ecosystem responses to climate change?



adapted from Liao et al. 2008

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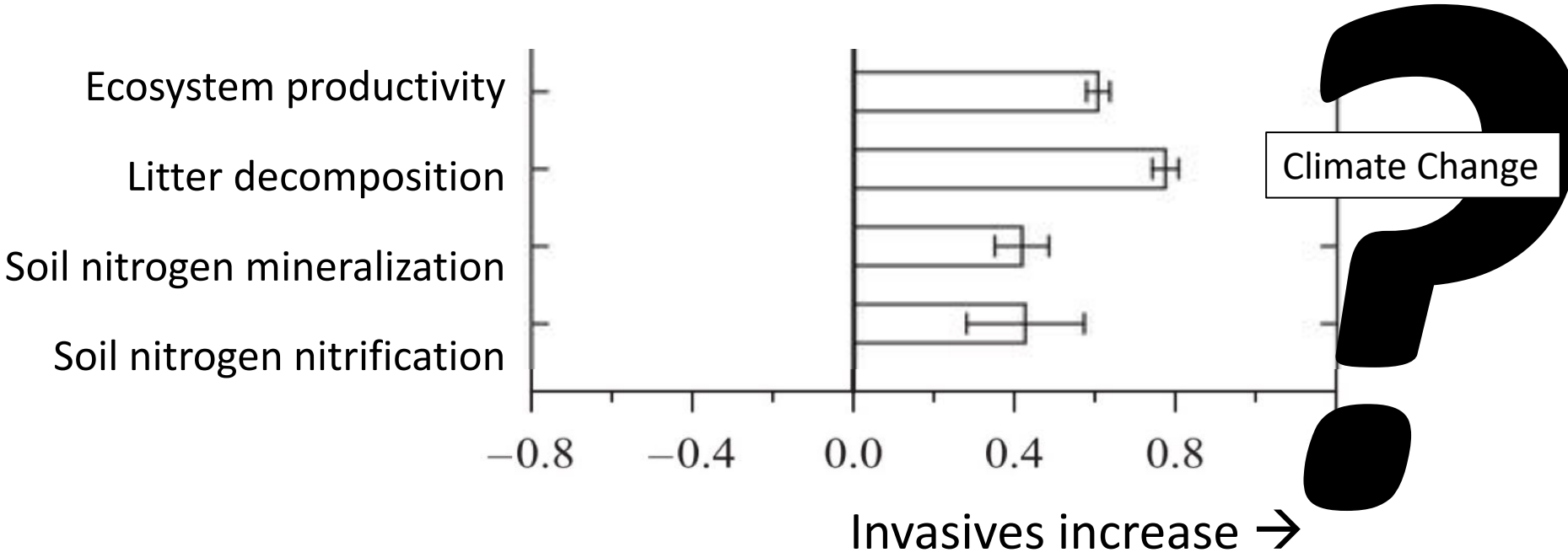


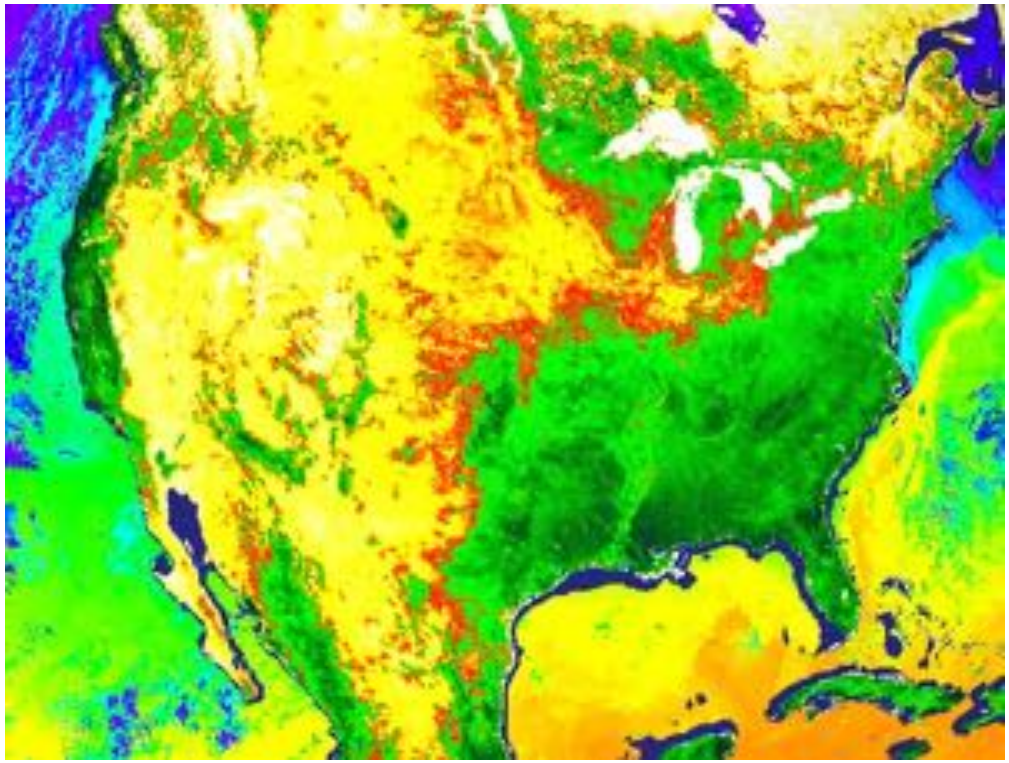
adapted from Liao et al. 2008

Exotic annual species are invading historically shrub-dominated Mediterranean-type ecosystems

Coastal sage scrub, Orange County California, Jen Funk

Ecosystems of the World, Vol. II, *Mediterranean-Type Shrublands*, DiCastri, et al. 1981

Invading species may be more phenologically sensitive to climate change than native species



http://modis.gsfc.nasa.gov/

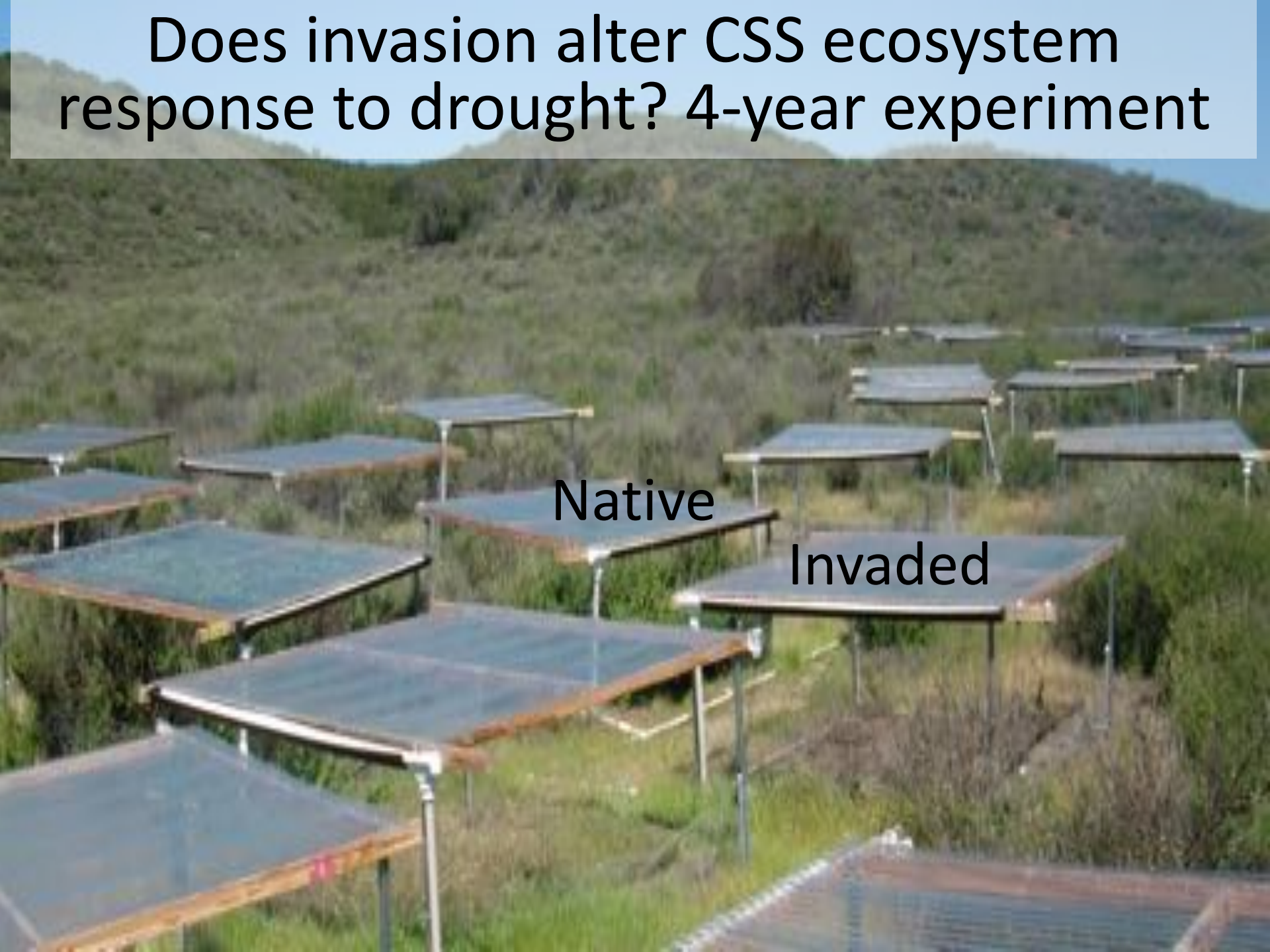
By AnRo0002 - https://commons.wikimedia.org

Invasive species can increase ecosystem productivity via a longer growing season: e.g. NE US

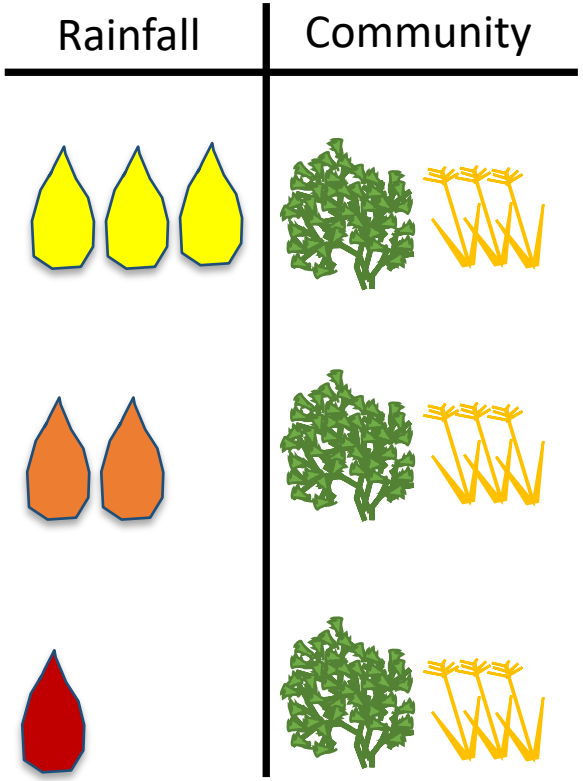
honeysuckle is greener in spring and fall than native species

Fridley 2012

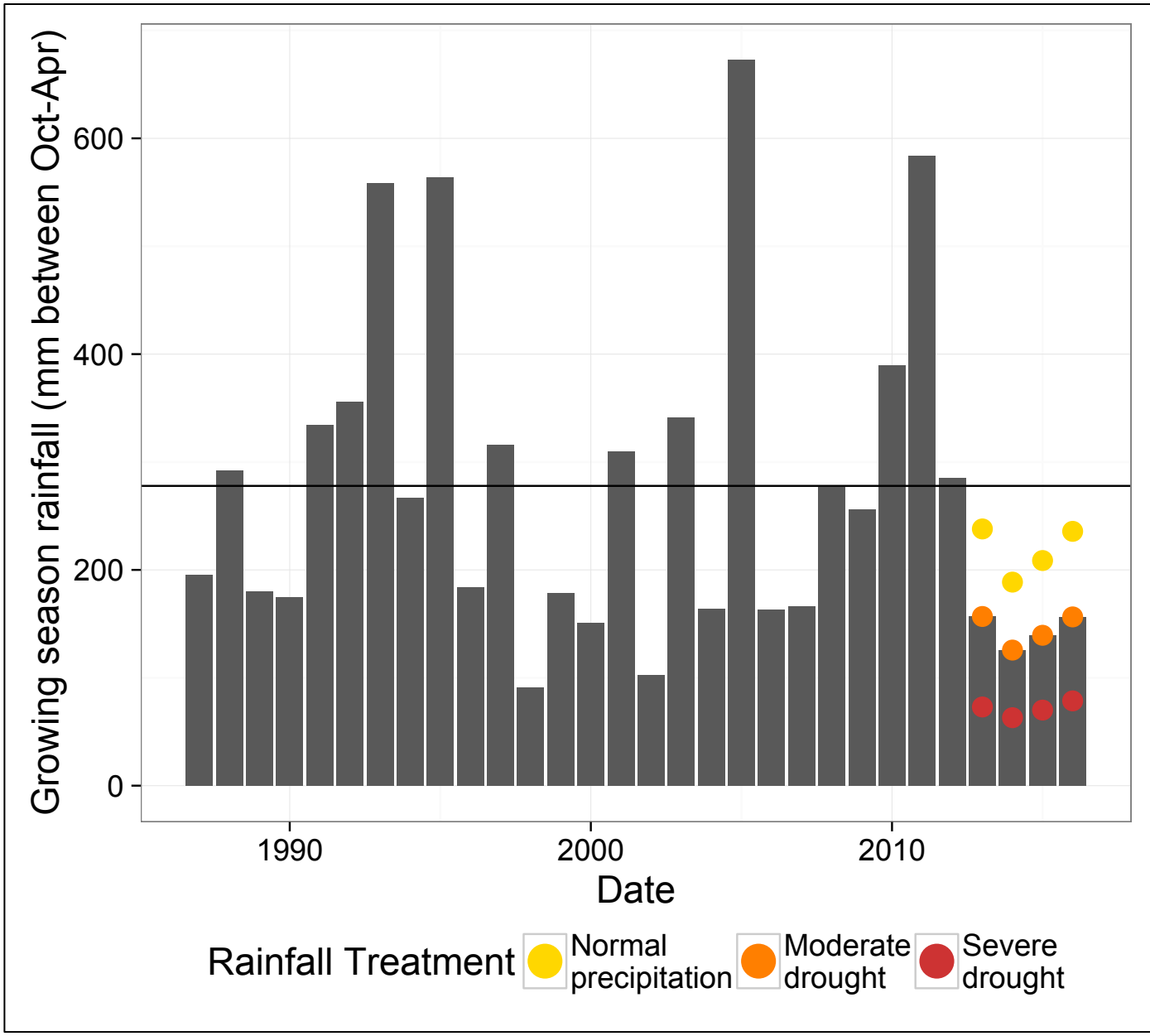
Does invasion alter CSS ecosystem response to drought? 4-year experiment



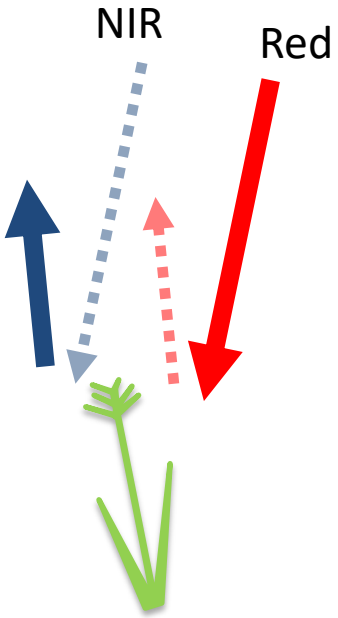
Plots dominated by native or invasive vegetation received three levels of rainfall



Treatments varied from near-average rainfall to severe drought



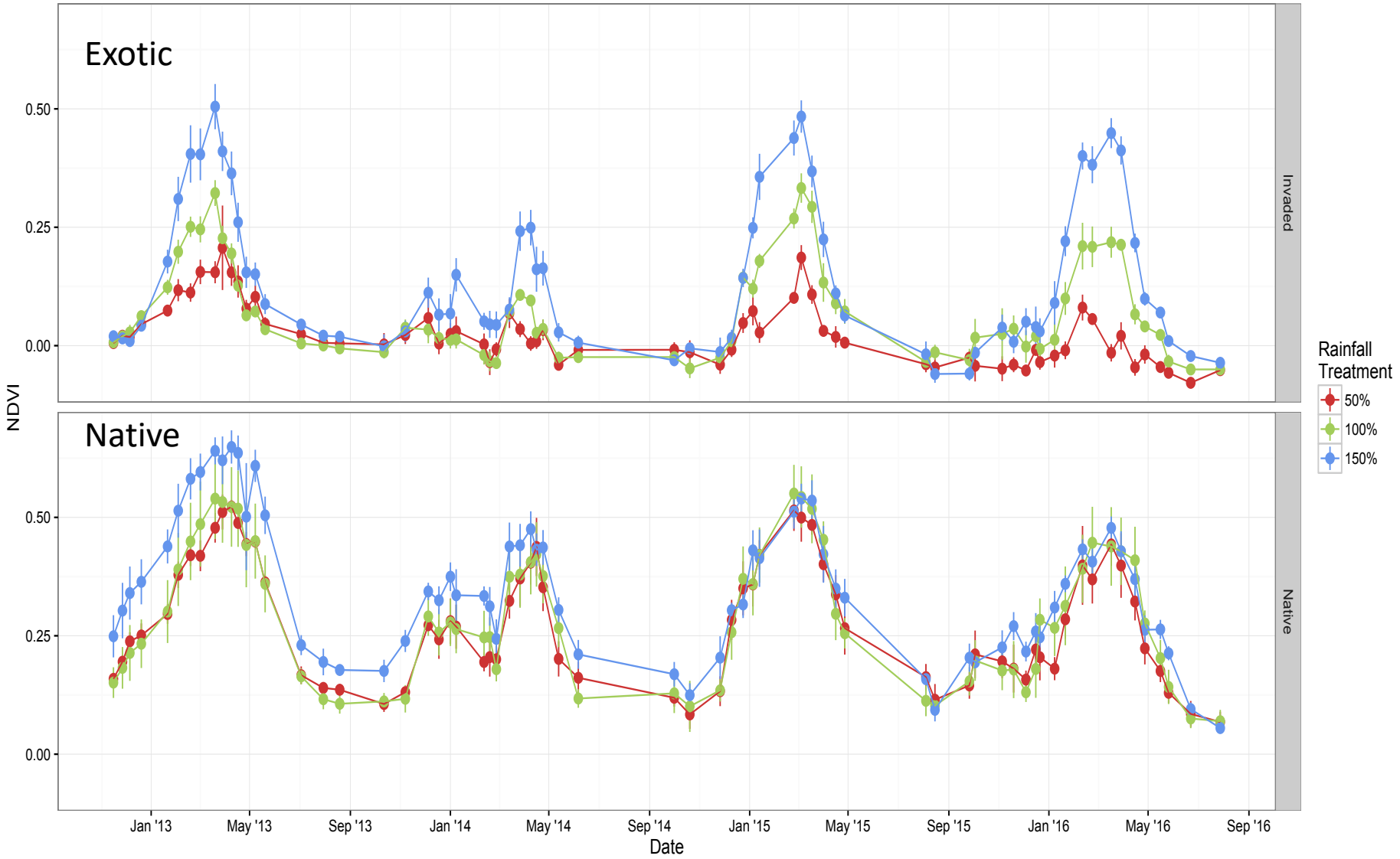
Estimated ecosystem productivity and phenology with NDVI (canopy “greenness”)



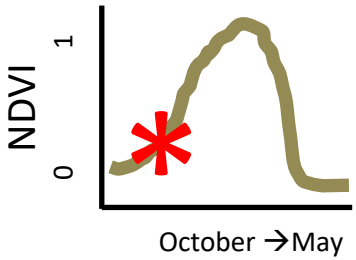
$$NDVI = \frac{NIR - Red}{NIR + Red}$$

Ellen Esch, PhD

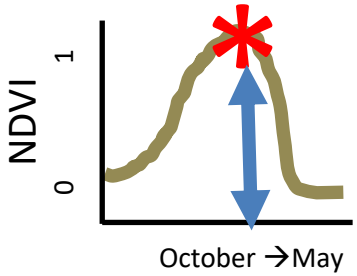
NDVI reflects growing season phenology at the ecosystem-scale



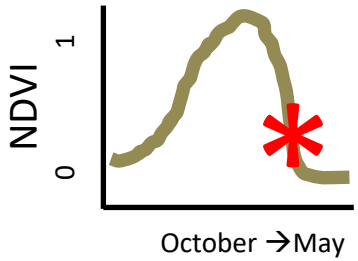
NDVI indicates productivity and phenology



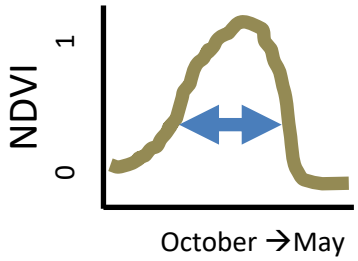
Green-up date



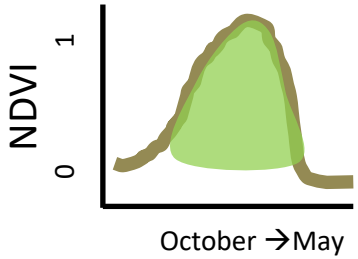
Peak greenness (Max NDVI)



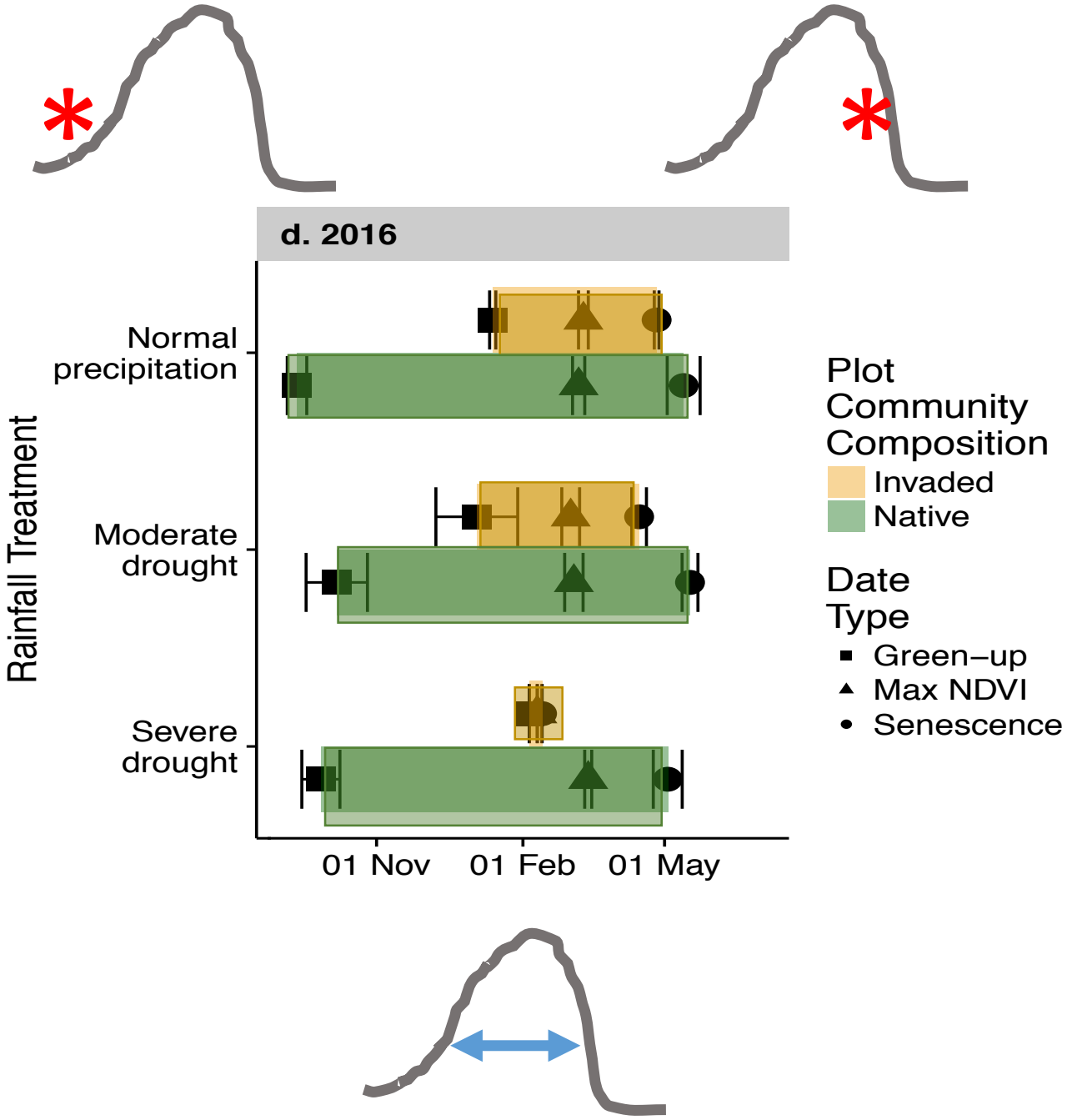
Senescence date



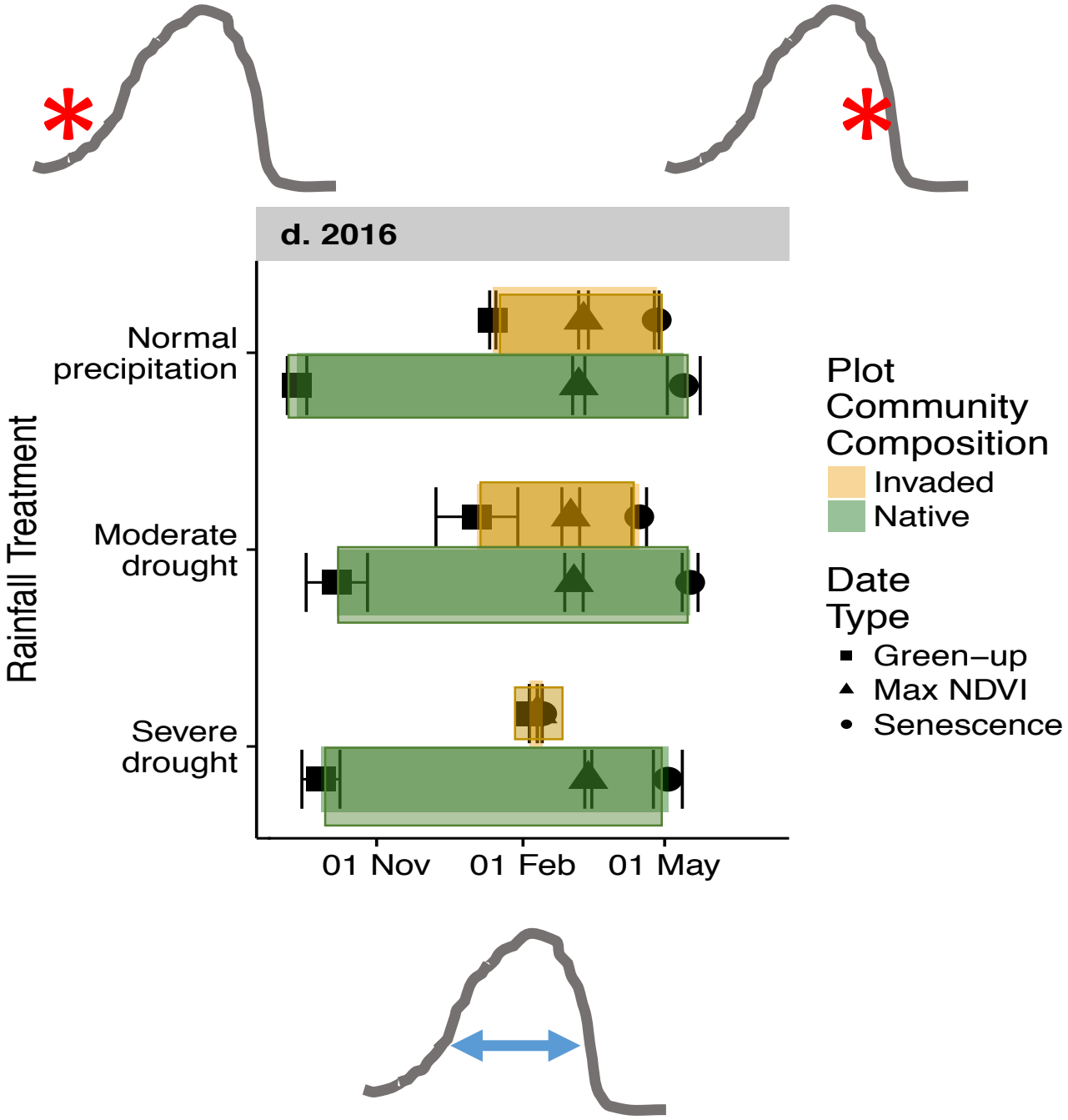
Growing season length



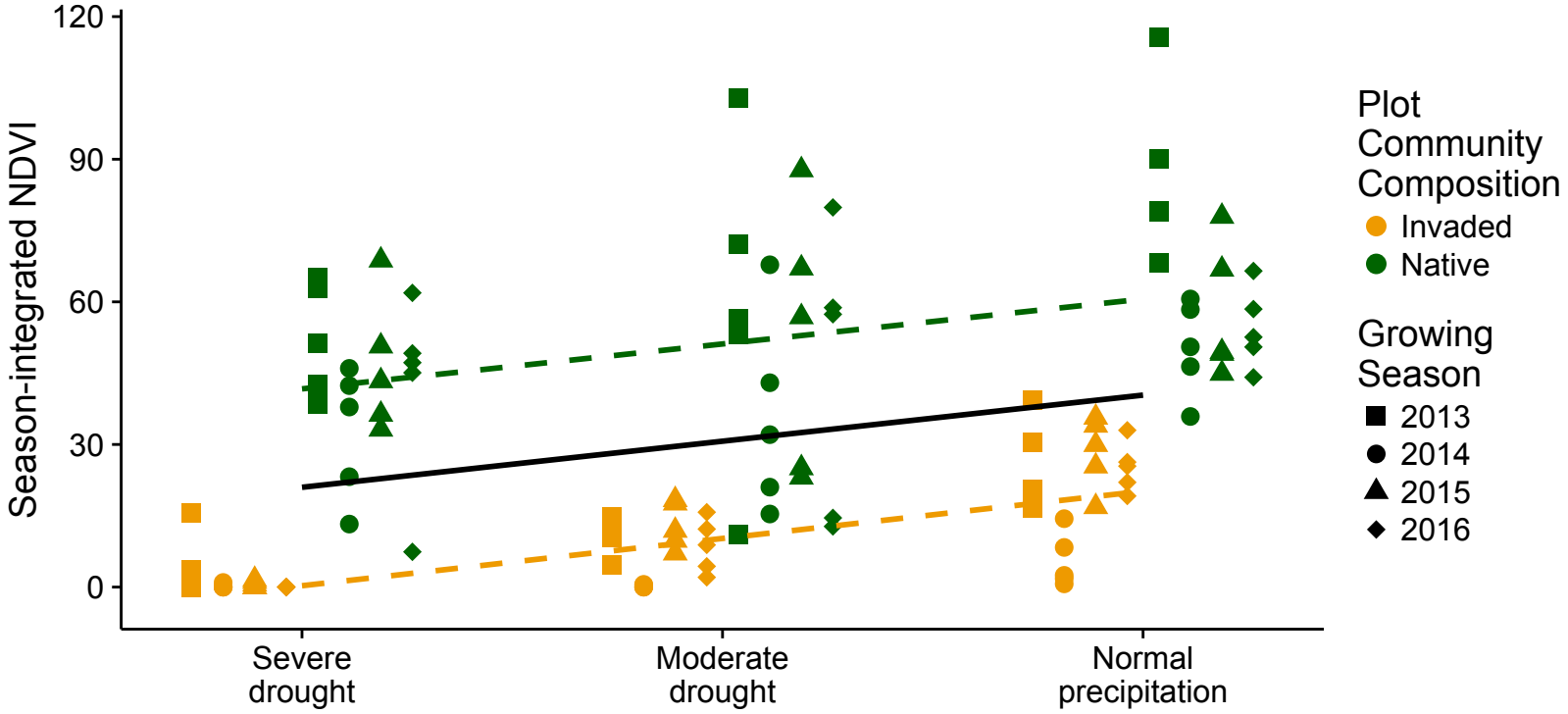
Seasonally integrated NDVI


d. 2016
Rainfall Treatment
Normal precipitation
Moderate drought
Severe drought
01 Nov
01 Feb
01 May
Plot Community Composition
Invaded
Native
Date Type
Green–up
Max NDVI
Senescence

Invaded areas have shorter growing seasons, especially with drought

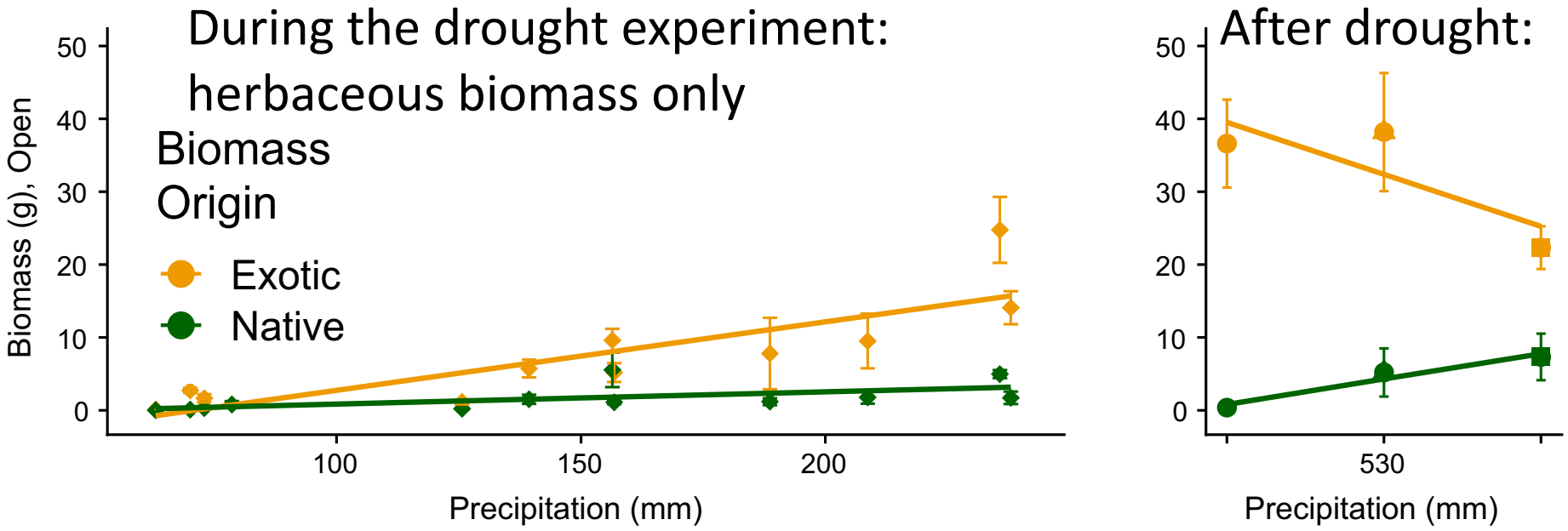


Invasion lowers productivity, especially in response to drought



Esch et al. 2019, Ecology

Exotic species are highly resilient following drought….



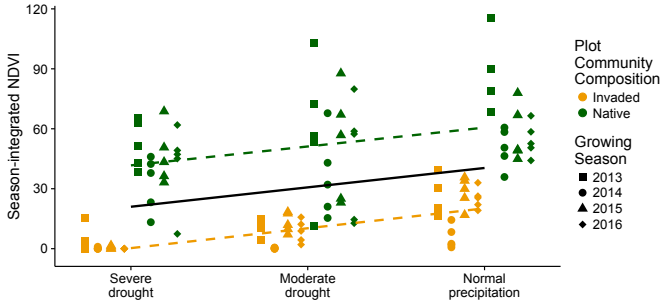
Puritty et al. 2019, Plant Ecology

- Exotic biomass declined under drought, but exploded in the high rainfall year following the drought experiment
- Drought won't save CA from invasion…

Chandler Puritty, PhD

Summary Part 1

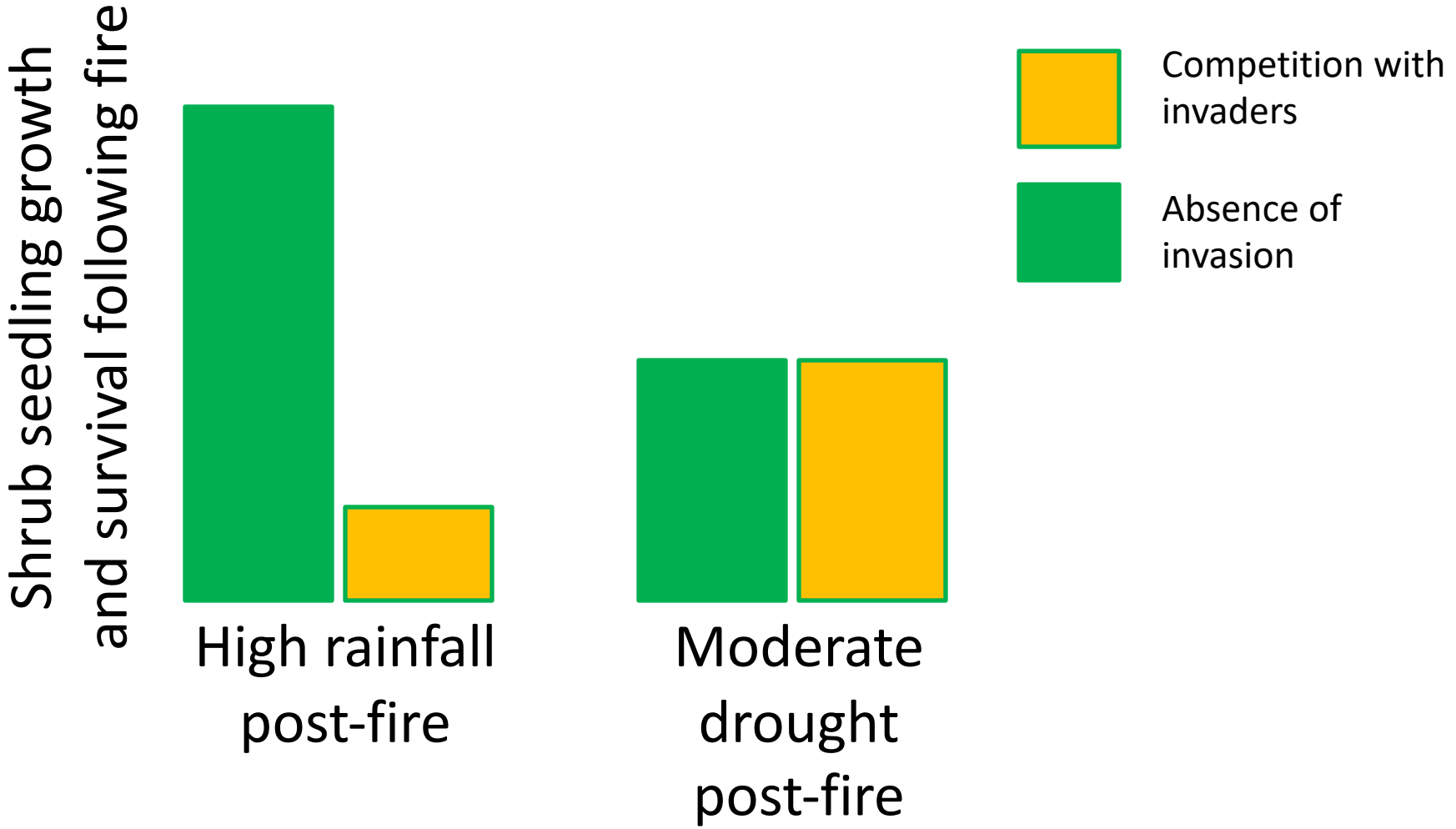
- The exotic species invading CSS are predominantly herbaceous and short-lived
- They have growing seasons that are shorter than the woody shrubs that dominate native biomass
- Invasion in CSS reduces ecosystem C stocks, especially when combined with drought



Coastal sage scrub ecosystems responding to multiple, interacting global changes

- Past work: Invasion alters ecosystem responses to drought
- Ongoing work: Factors that promote (or prevent) shrub recovery following wildfire
- New/future work: Assisted Gene Flow (AGF), experiments with California poppy

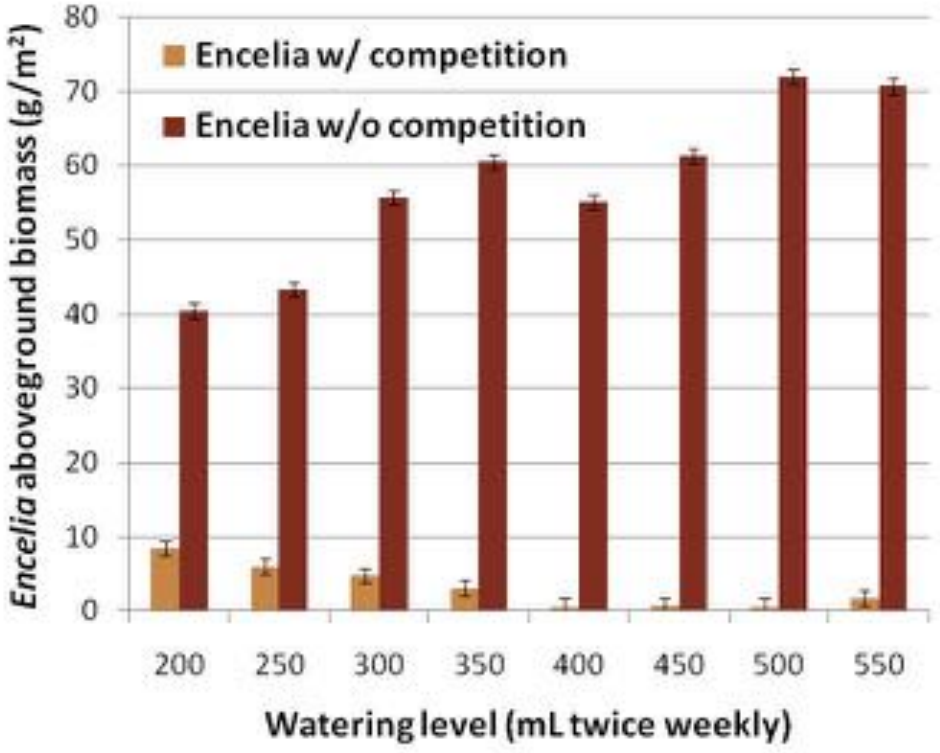
Hypotheses: Invasion will have a greater negative impact on shrub recovery under high rainfall than under drought



Greenhouse experiment: shrub seedlings planted w/ and w/o competition from invaders, at different levels of water supply

Shrub seedlings grow best with high soil moisture alone, but not in competition

- Competition with exotic grass strongly suppressed *Encelia californica* growth
- *Encelia* alone growth responded positively to water addition
- **When grown in competition, *Encelia* grew best under low water**



Esch et al. 2018, J.of Ecol

Comet Fire
Burned 40 acres
Palomar College
January 14, 2021

Escondido Times 2021

Image: Wayne Armstrong

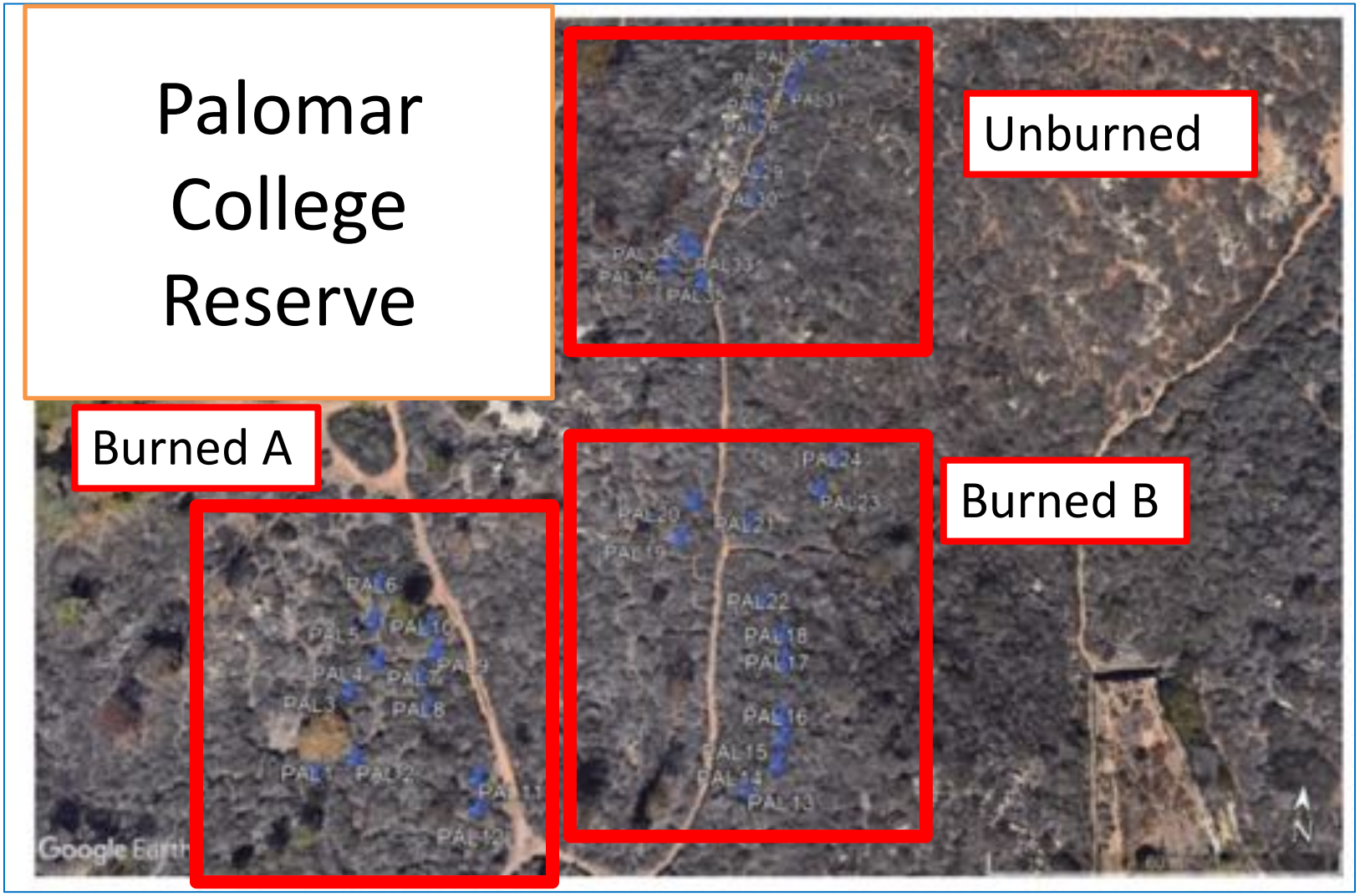
https://www2.palomar.edu/users/warmstrong/CometFireImages1.htm

- February 26, 2021 about 6 weeks after the fire

Burned Site A

Burned Site B

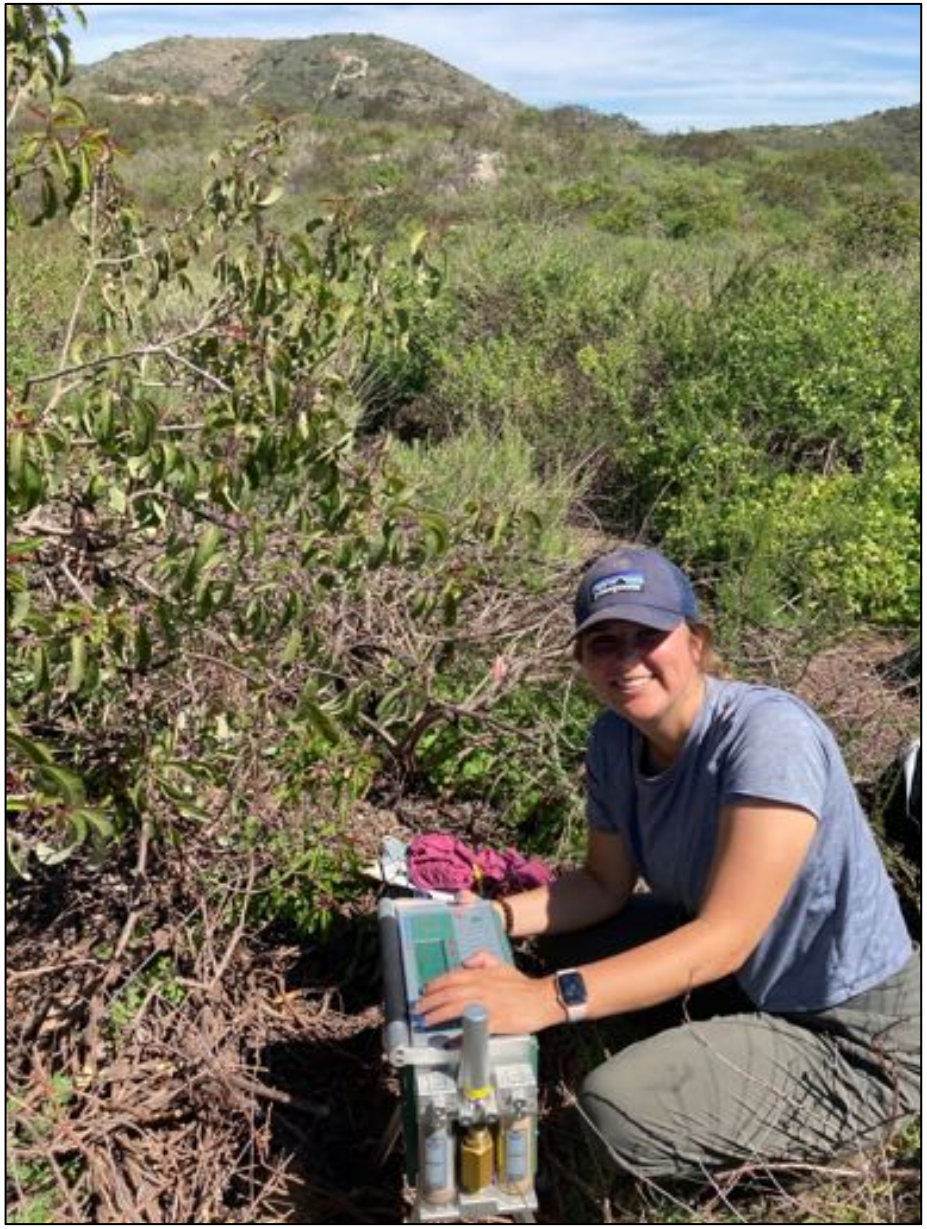
Experimental design: drought shelters vs controls in unburned CSS, burned invaded & burned native-dominated sites



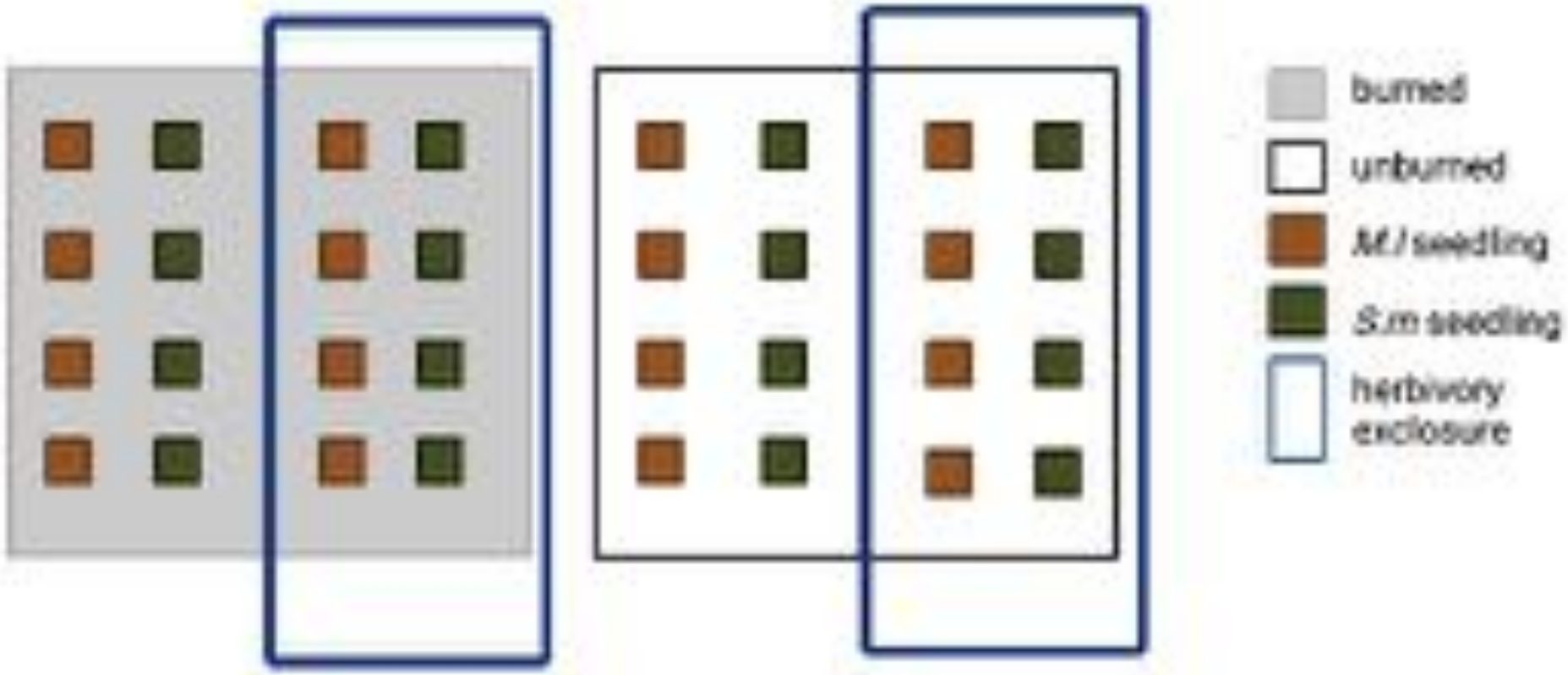
PhD research undertaken by Karagan Smith

Recovery by two shrub species:

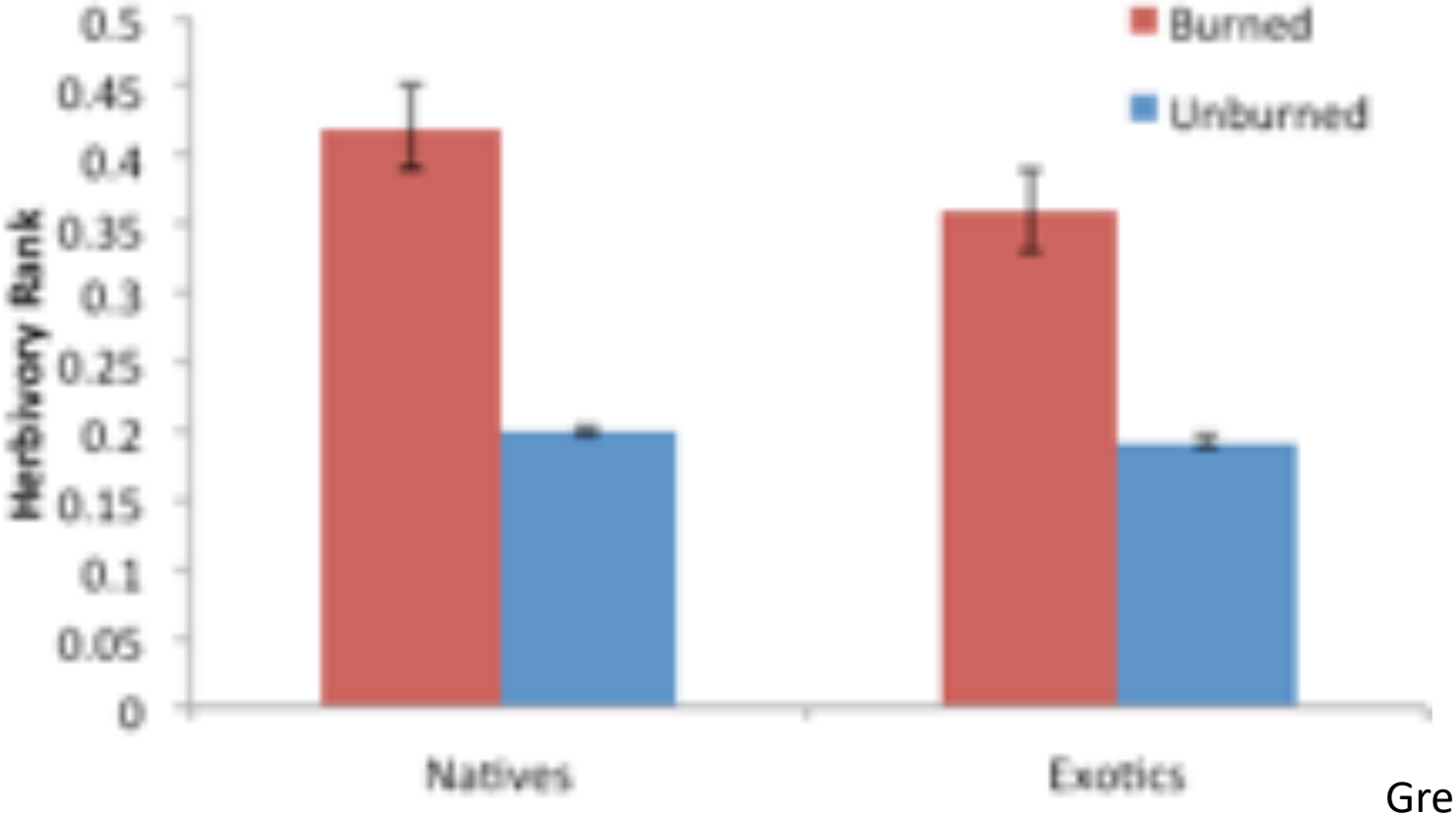
-*Salvia mellifera* (deciduous)
-*Malosma laurina* (evergreen)



Plant shrub seedlings in known locations in every plot, both accessible to herbivores and exclosed



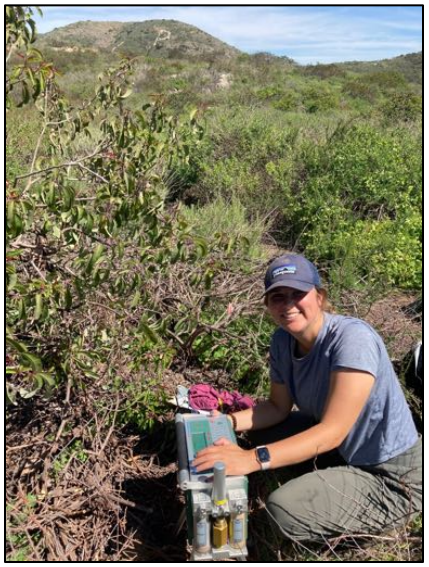
Planted native shrub seedings, and exotic competitors, had higher herbivory in a recently burned site, vs the adjacent unburned areas

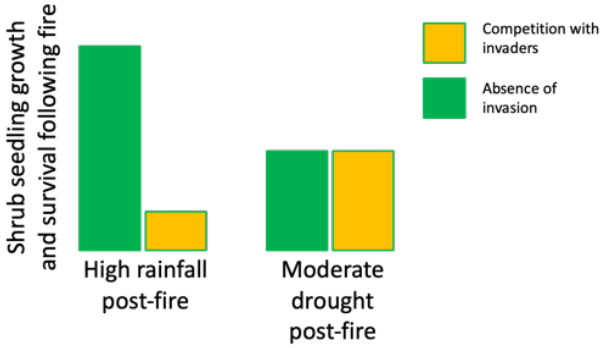


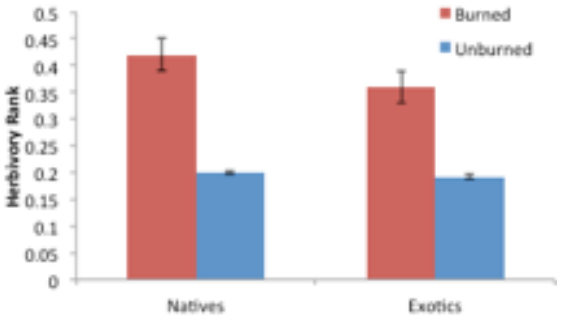
Gressard 2012

Summary part 2:

- Aim is to predict how drought, invasion and herbivory interact to predict CSS shrub recovery following wildfire
- We expect moderate drought may, surprisingly, increase shrub recovery by reducing competition from exotic species
- Herbivores likely slow shrub recovery via direct consumption, but could also aid in shrub recovery by removing exotic competitors







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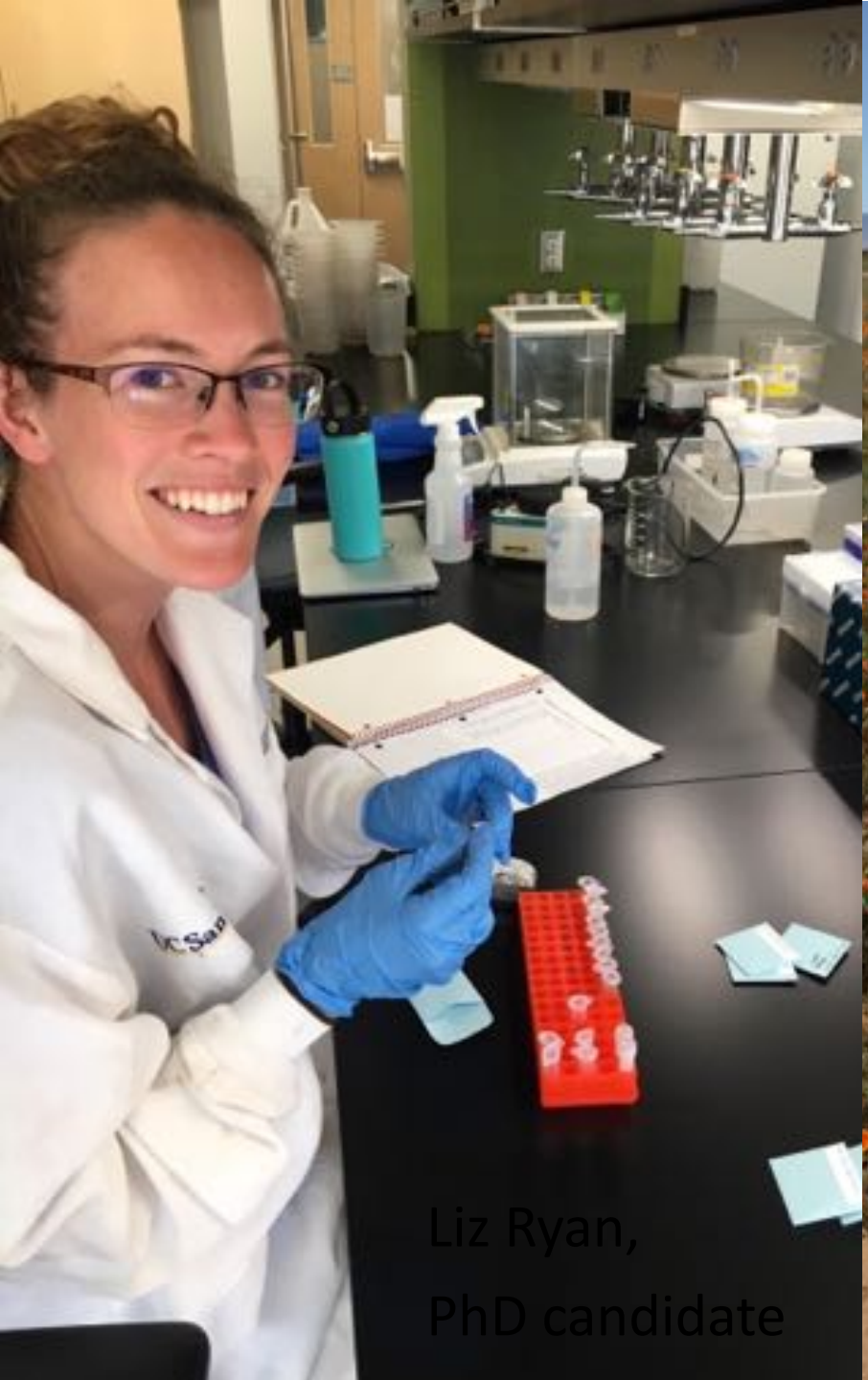
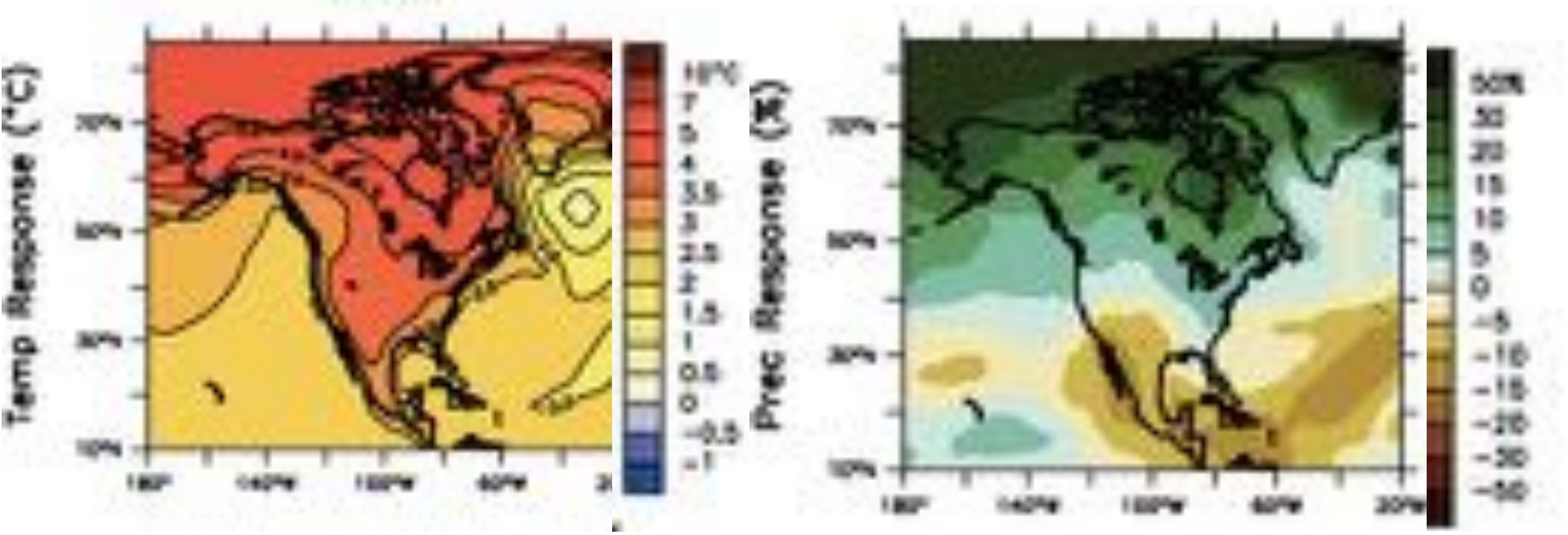


Liz Ryan,

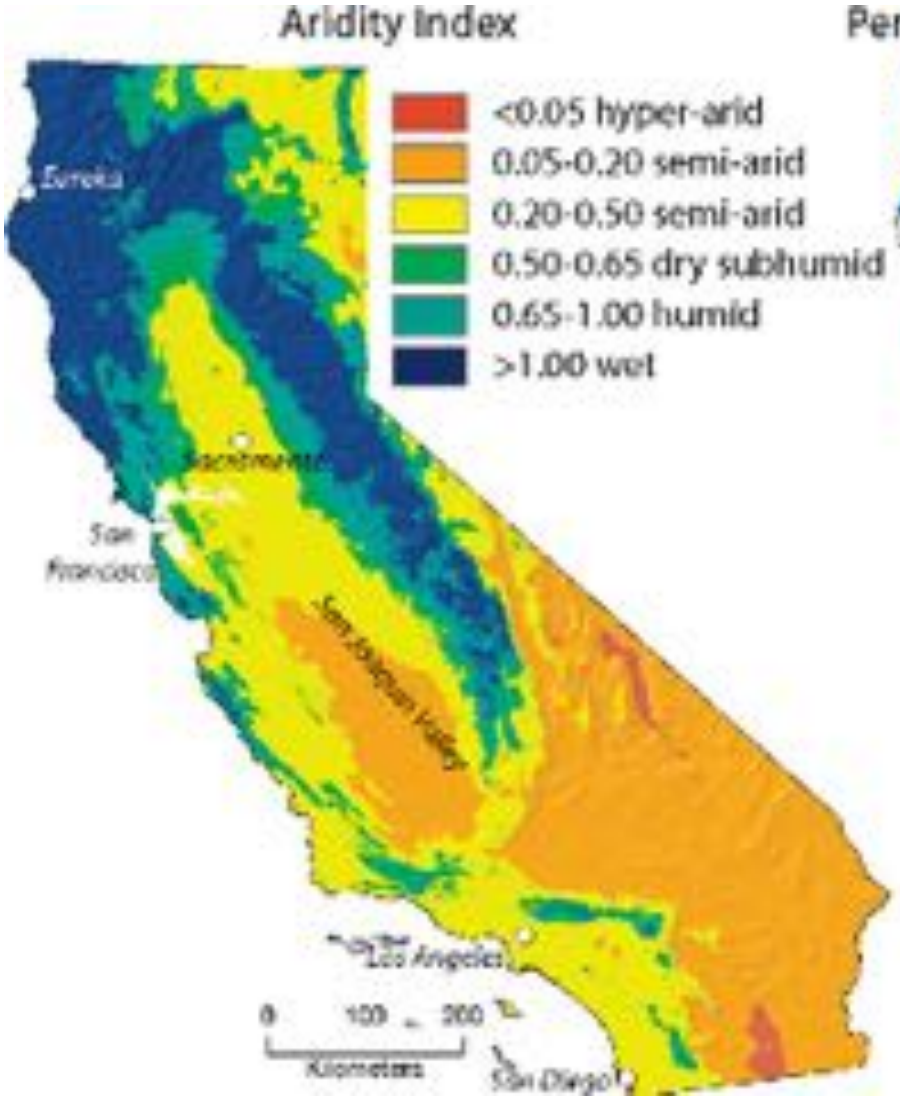
PhD candidate

In order to persist, species must tolerate climate change, adapt, or move



Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCCAR4 Ch. 11)

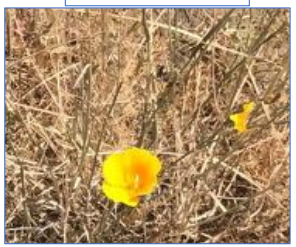
Genetic variation across a species range may predict potential to tolerate/adapt to climate change

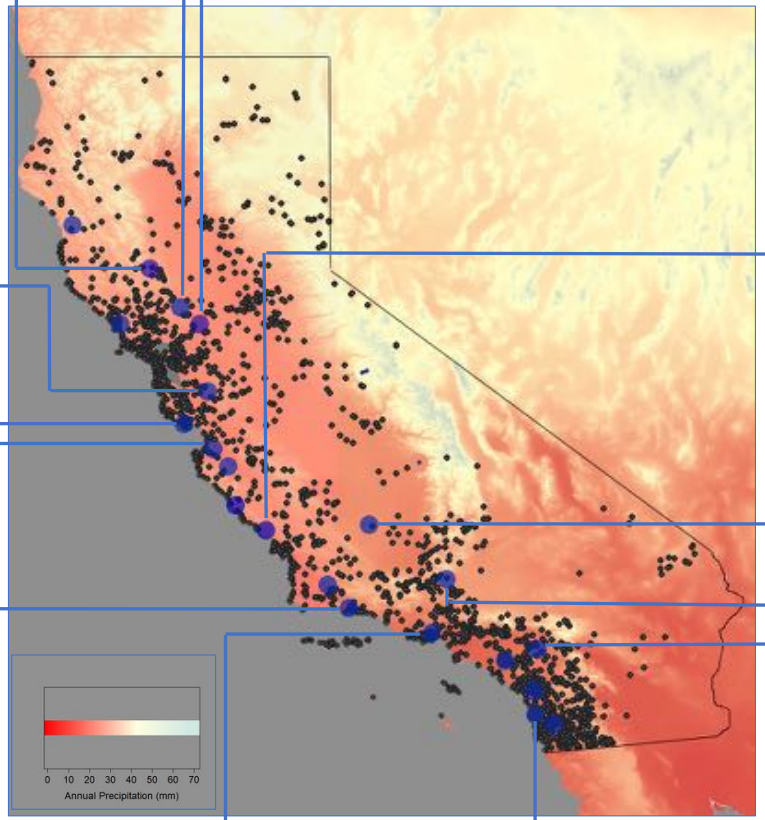


- Widespread species experience different climates across their range
- California has remarkable climatic gradients
- Hyp: populations from more arid sites should have higher drought tolerance than wet sites

Fram & Belitz 2011

California Poppy (*Eschscholzia californica*)





California poppy, *Eschscholzia californica*

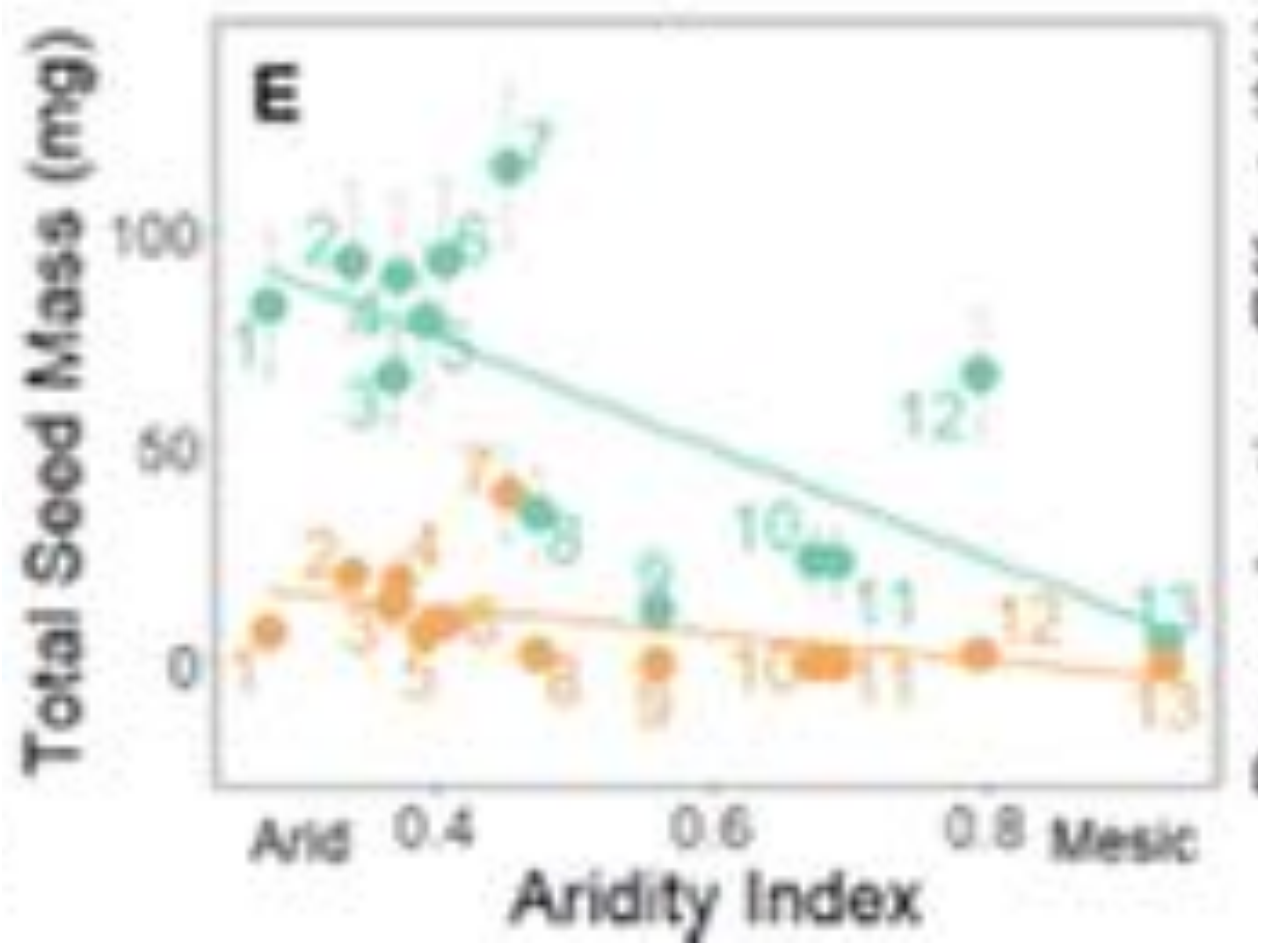
Widely distributed (black dots)

Spatial variation in flower color, seed dormancy, and longevity (Cook, 1961)

2017, seed collections from 25 sites

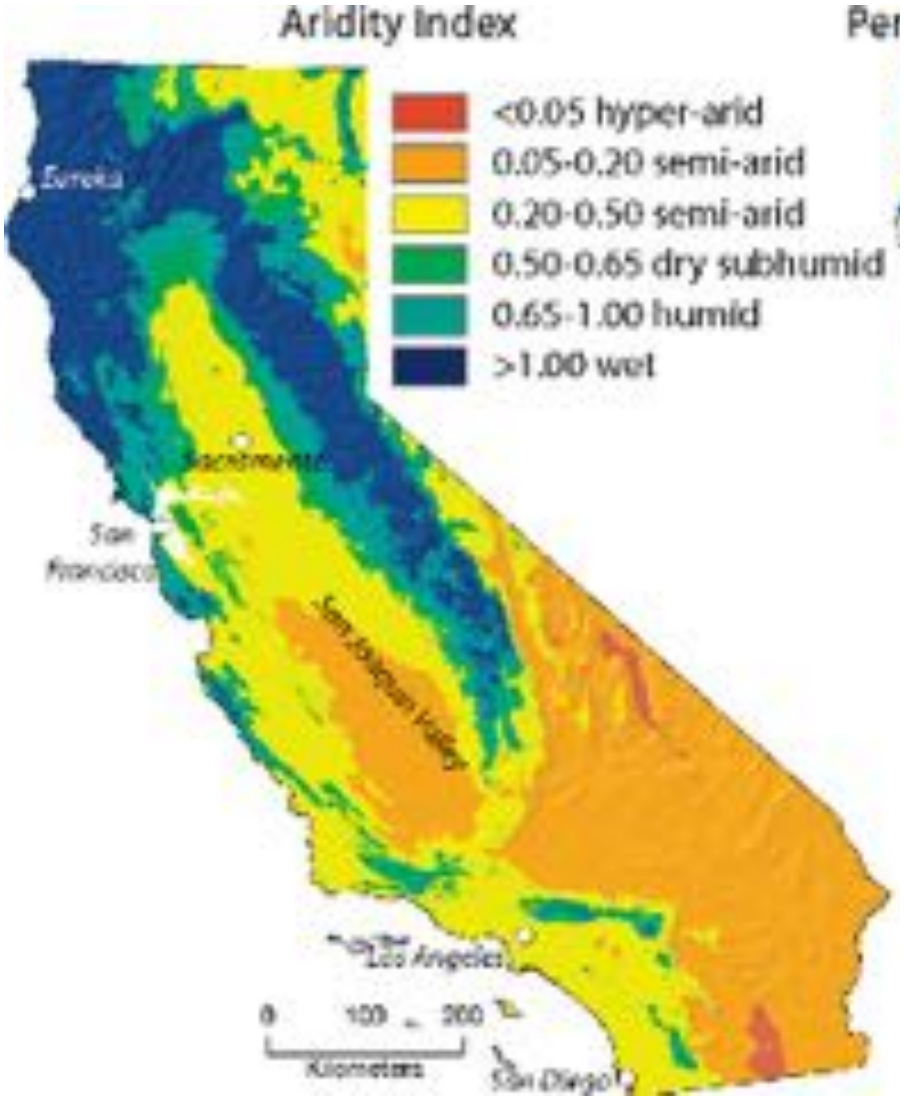
Greenhouse experiment: drought/high water

Populations from Southern, more arid sites are more drought-tolerant, and better able to capitalize on high rainfall



Ryan & Cleland 2021, Climate Change Ecology

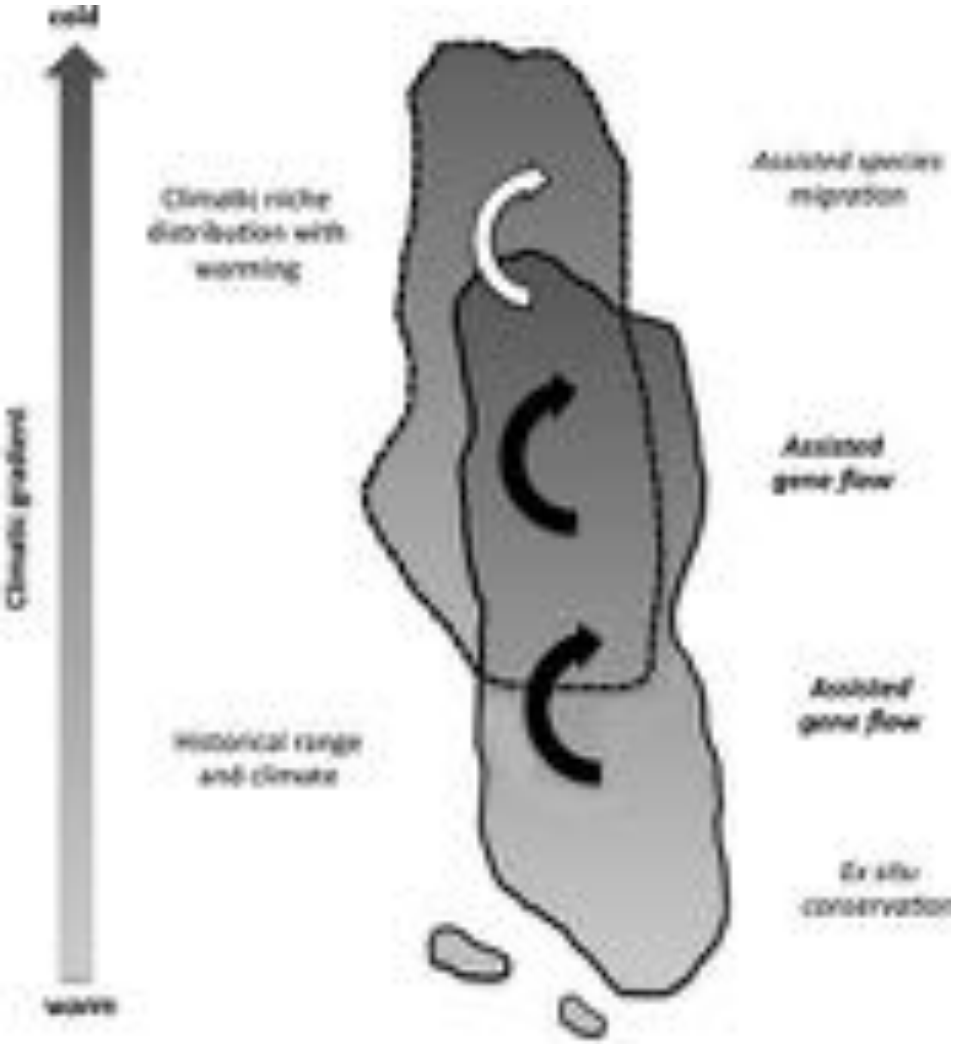
Does existing genetic variation across the range predict response to climate change?



- Yes - Populations from arid sites were more drought tolerant
- Significant genetic variation in traits is across populations (not within)

Fram & Belitz 2011

Implications: population level information can inform restoration



Aitken & Bemmels 2016

- Given likelihood of becoming increasingly arid, restorations may want to plant seeds from more arid sites (rather than nearby populations)
- "Assisted gene flow" could help speed adaptation to climate change

Can assisted gene flow enhance rate of adaptation to increasing aridity?

Does pollen transfer from arid to mesic populations enhance drought tolerance (test of assisted gene flow in the greenhouse)?

Conclusions: Coastal sage scrub ecosystems responding to multiple, interacting global changes

- Invasion lowers C capture by CSS, especially under drought
- Drought and herbivory interact to promote shrub recovery following wildfire?
- Assisted Gene Flow (AGF), is a potential tool to accelerate adaption to climate change

Thanks & acknowledgements

- David Lipson (SDSU)
- NSF Graduate Research Fellowships to Ellen Esch, Chandler Puritty, & Karagan Smith
- NSF DEB 1154082 supported the drought experiment
- NSF DEB 2154746 is supporting the fire recovery experiment
- Santa Margarita Ecological Reserve Staff (Pablo Bryant)
- Gordon Sato Jr. Faculty Fellowship
- UC Natural Reserve System
  - Mathias Graduate Research Grant to Liz Ryan
- Lab members, undergraduate researchers & volunteers who helped (and are helping) in the field

Questions?