An ecophysiological approach to restoration of California chaparral and sage scrub

Anna L. Jacobsen
California State University, Bakersfield, CA, USA

Photo credit: RB Pratt

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Students:

Antonio Mateiro, BS, MS in progress

Ernesto Chavez, BS in progress

Dorothy Tran, BS

Gonzalo Perez de Lis, post-doc

Collaborators:

Nicole Molinari, US Forest Service

Emma Underwood, UC Davis

Josie Lesage, Madison Hall, Neda Brehm, SBBG

Shane Dewees, Carla D'Antonio, UC Santa Barbara

Luke Hall, CSUB

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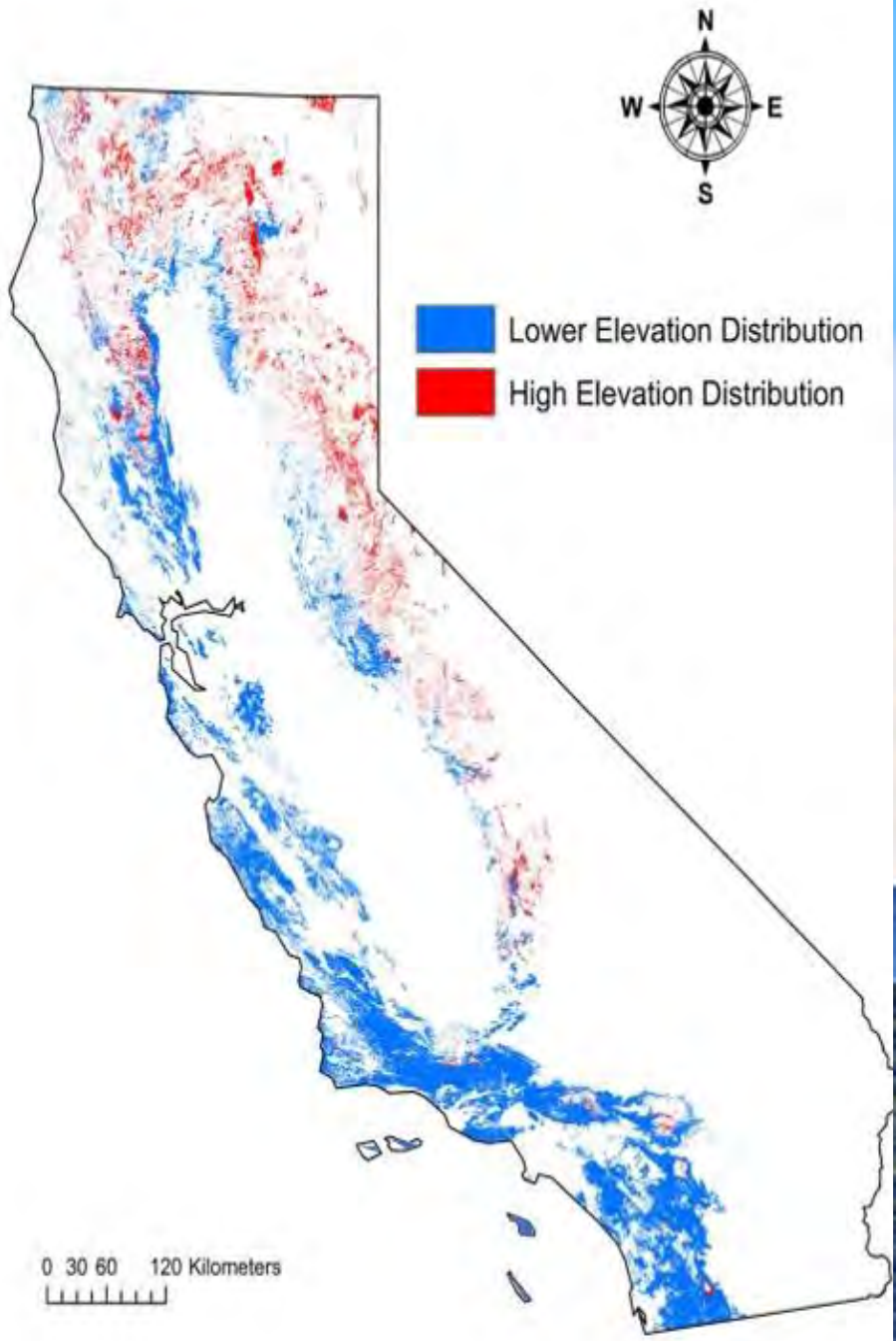
Chaparral

- A mediterranean-type climate region shrubland
- Evergreen leaves and thick hard leaves
- Fire-adapted (many species seed and resprout post-fire)
- Most-extensive vegetation type in California

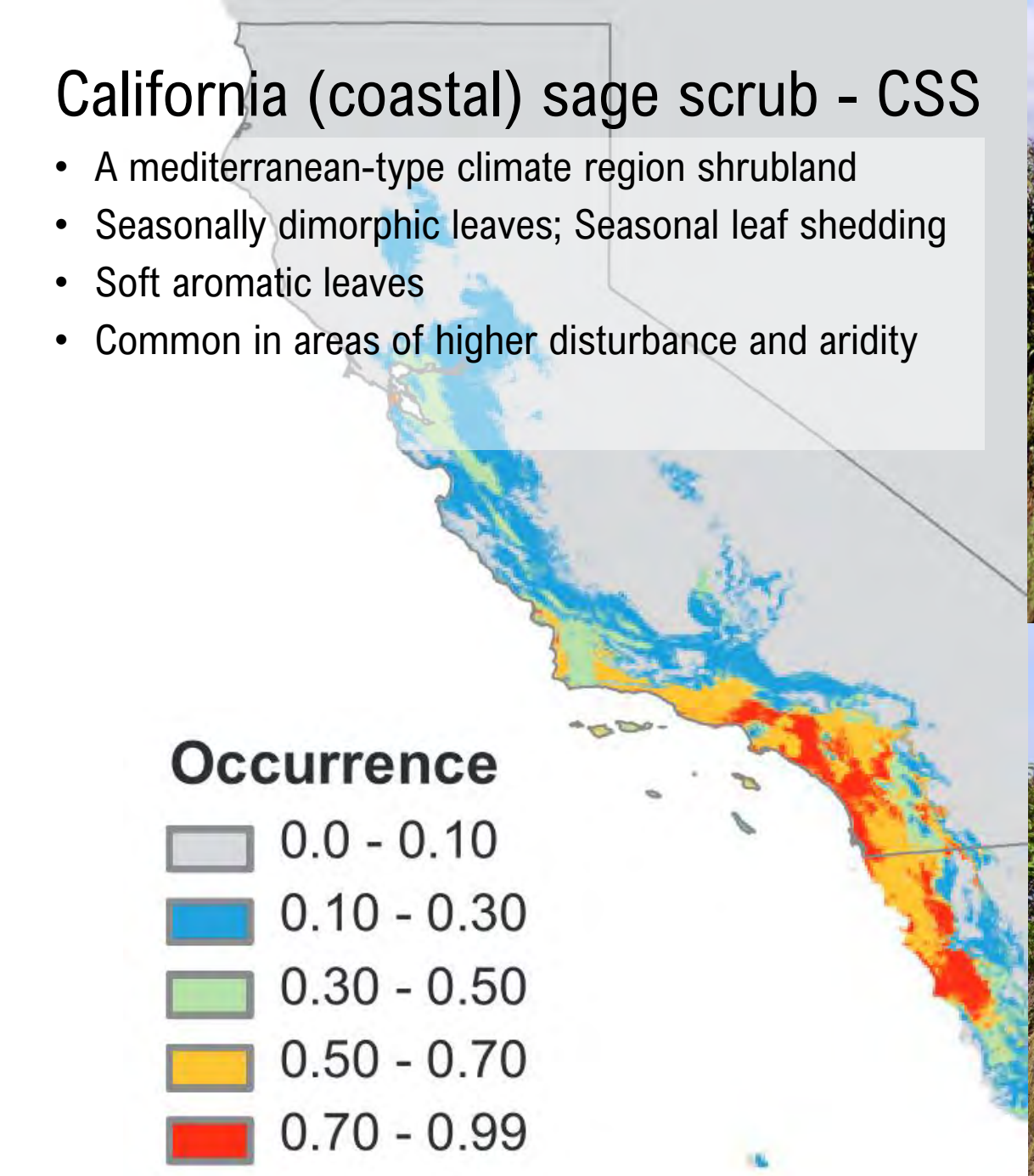
Photo Credit: Pratt



Map Credit: Parker, Pratt, and Keeley, 2016

California (coastal) sage scrub - CSS

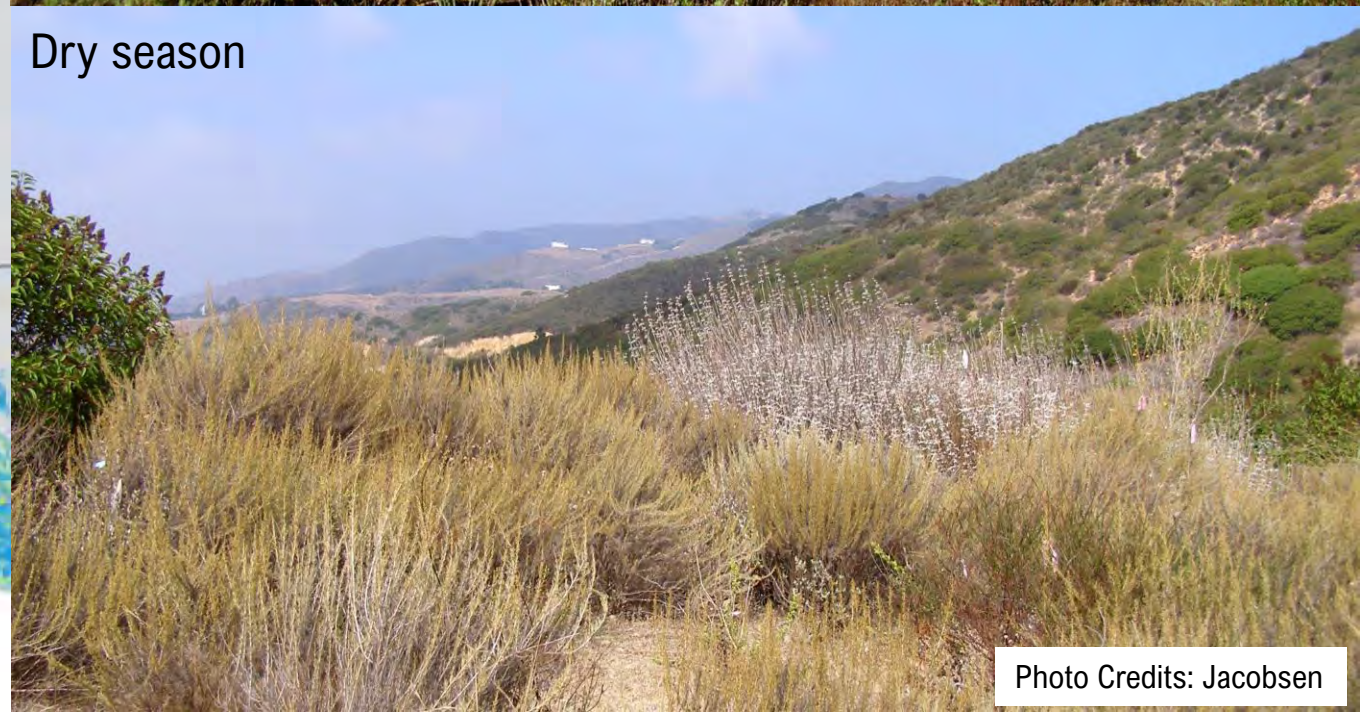
- A mediterranean-type climate region shrubland
- Seasonally dimorphic leaves; Seasonal leaf shedding
- Soft aromatic leaves
- Common in areas of higher disturbance and aridity



Riordan and Rundel 2009 Journal of Biogeography

Wet season

Dry season



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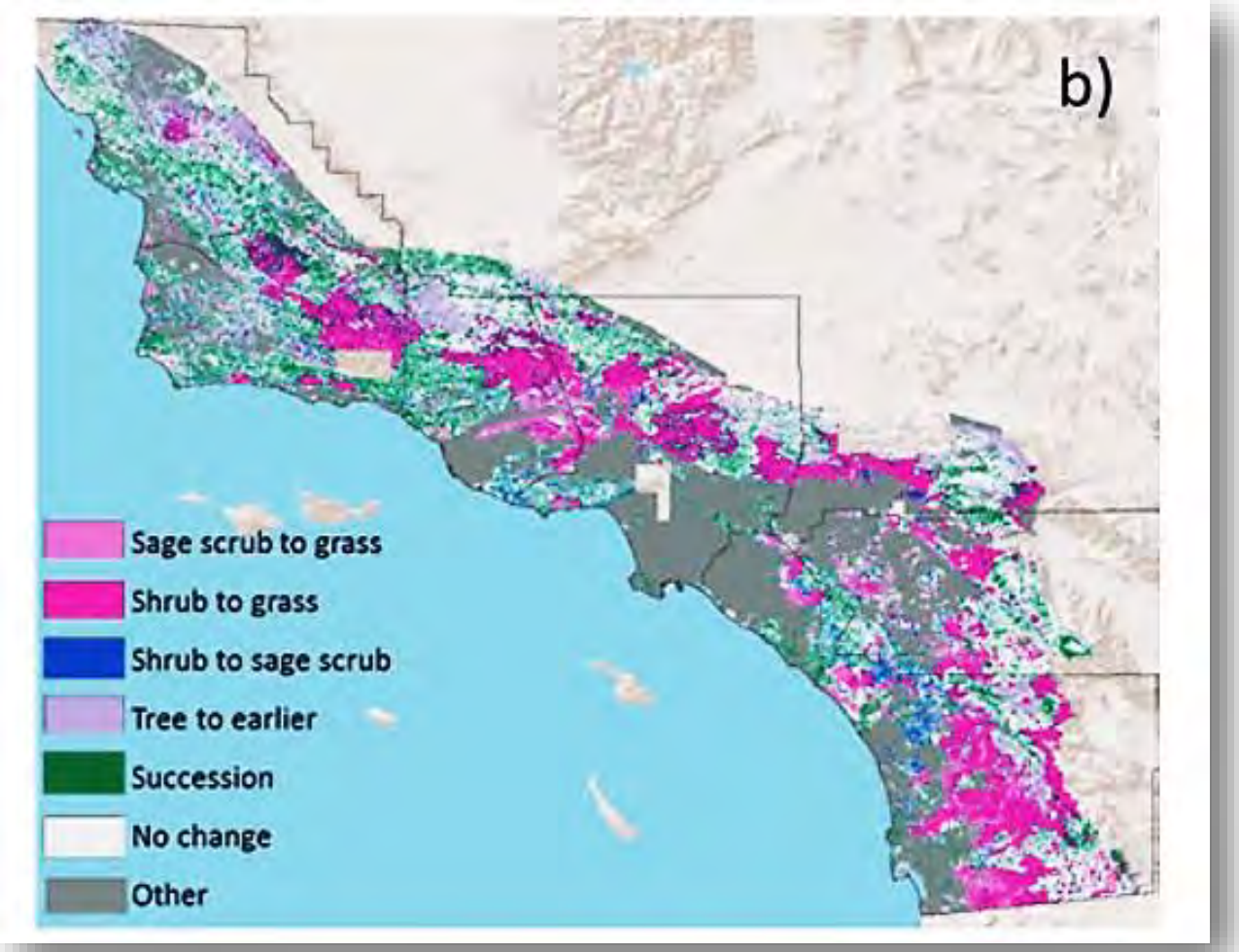
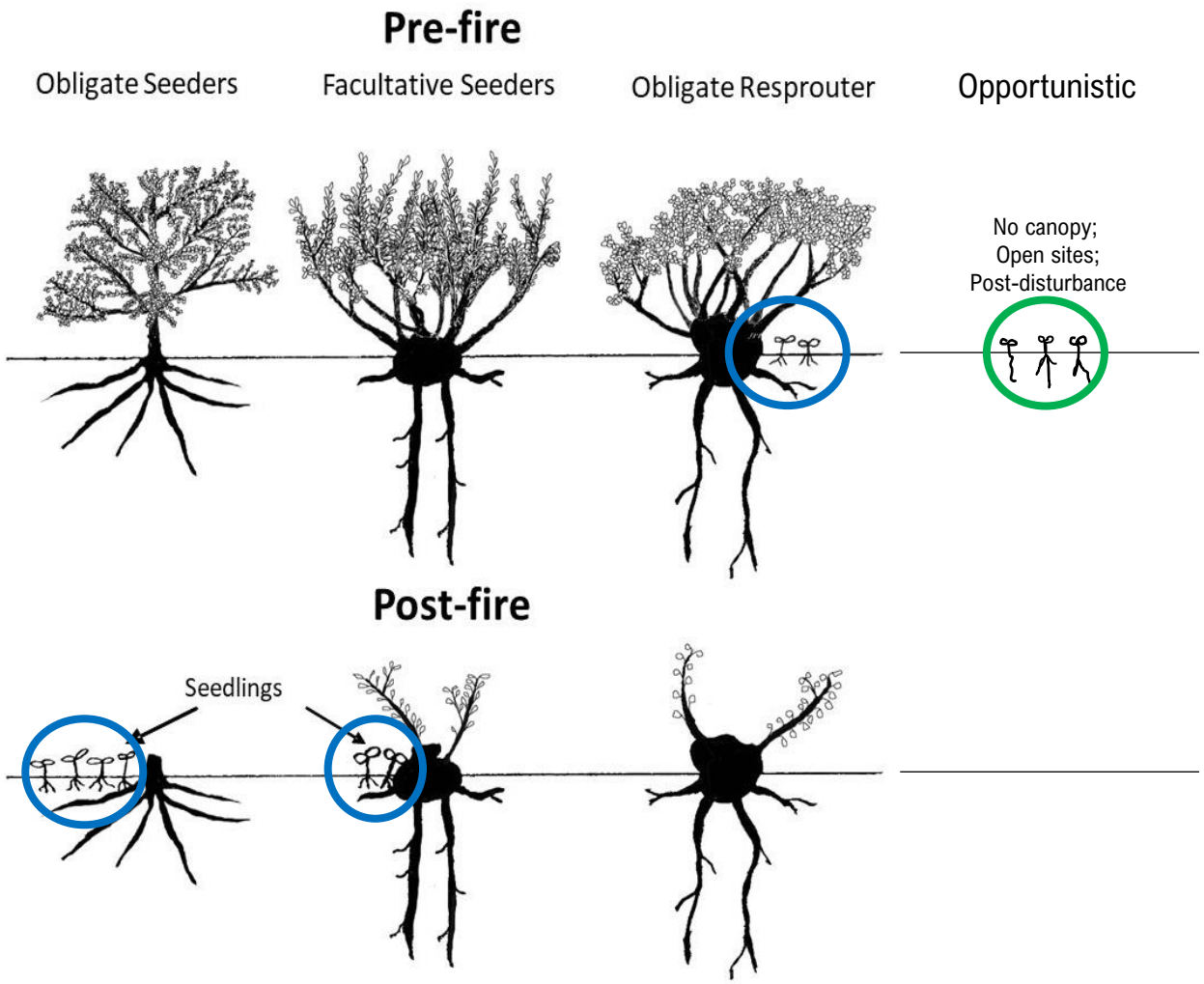


"Contemporary vegetation maps show consistent trends of increasing grass, tree, and other cover types and decreasing sage scrub and shrubs over time"

Syphard, A.D., Brennan, T.J. and Keeley, J.E., 2018. Chaparral landscape conversion in southern California. *Valuing chaparral: Ecological, socio-economic, and management perspectives*, pp.323-346.

Life History



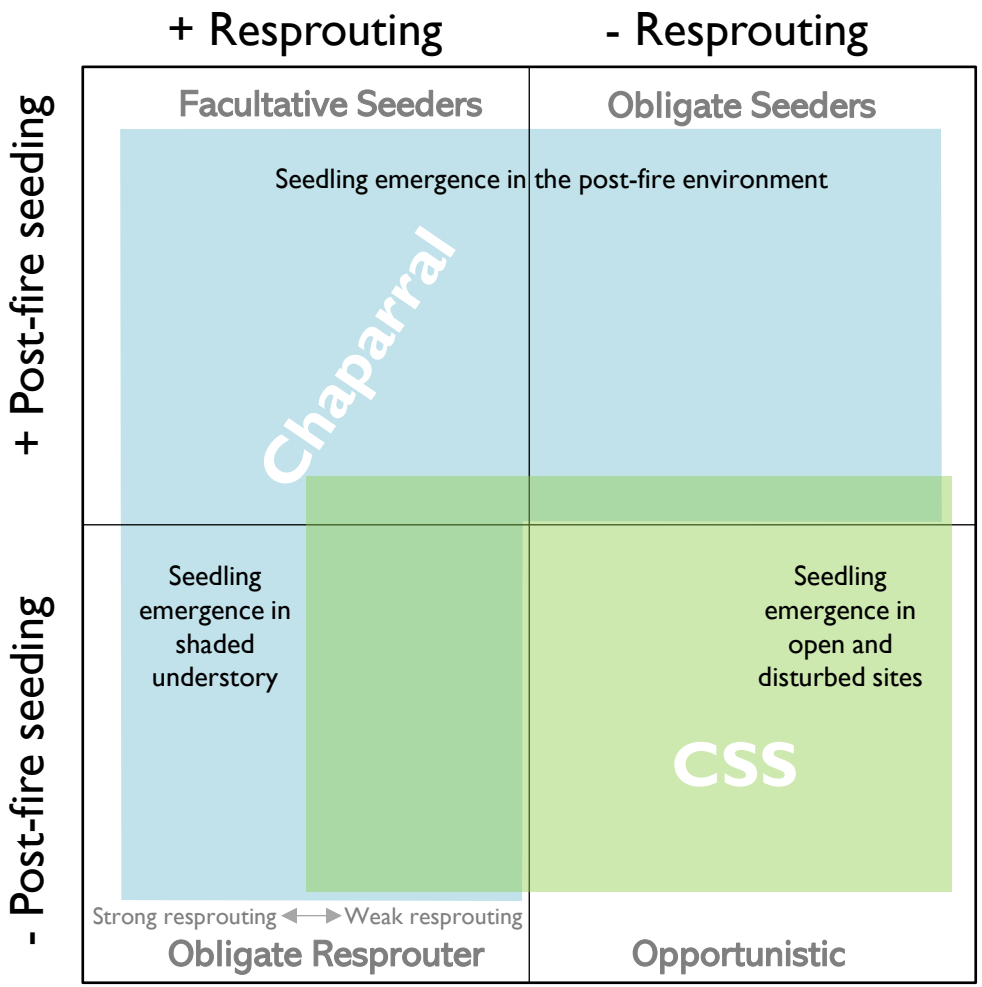
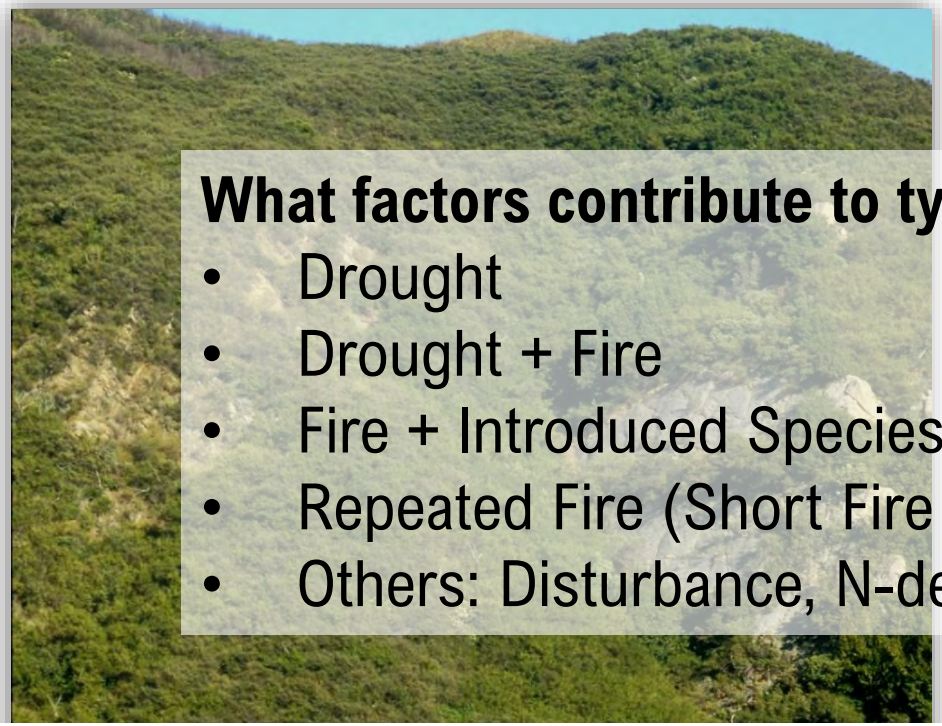
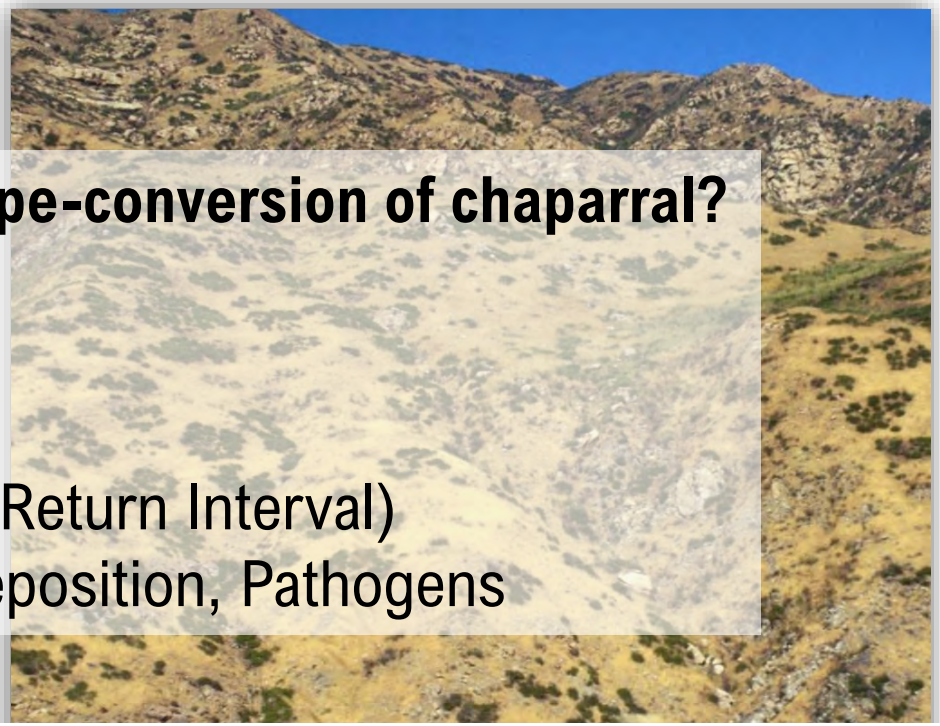


Image credit: modified from Pratt et al. 2008. Journal of Ecology

Vegetation-type conversion





What factors contribute to type-conversion of chaparral?

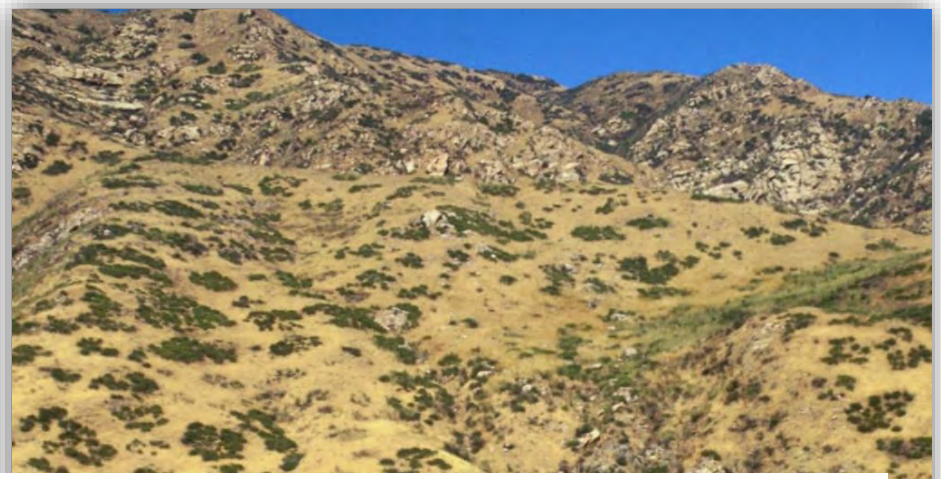
- Drought
- Drought + Fire
- Fire + Introduced Species
- Repeated Fire (Short Fire Return Interval)
- Others: Disturbance, N-deposition, Pathogens

Type-conversion results in:

- Loss or reduction of some species and life history types
- Conversion from closed-canopy to an open-canopy community
- Reduction/change in ecosystem function

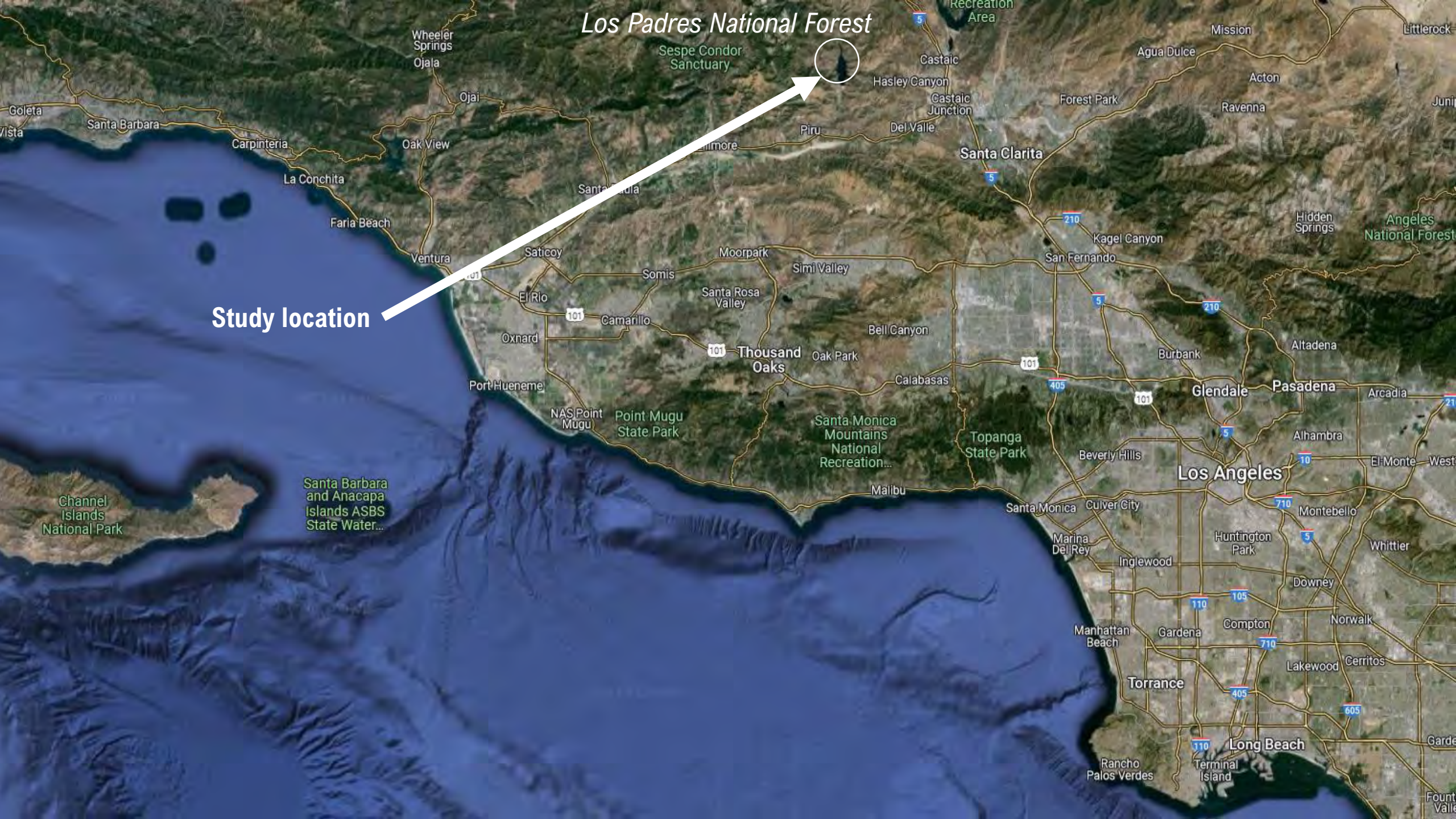
Photo credits: Stephen D Davis

Vegetation-type conversion

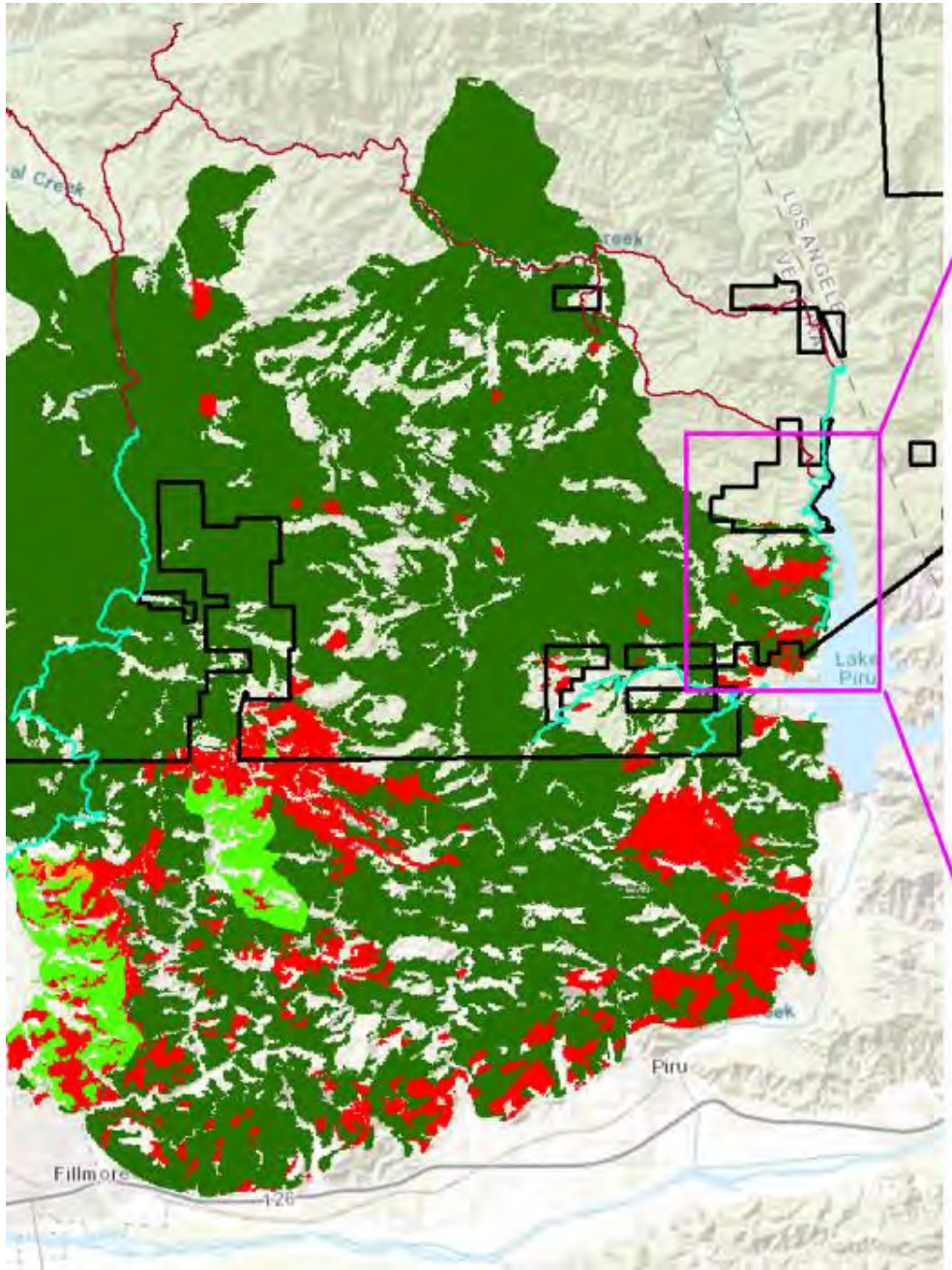


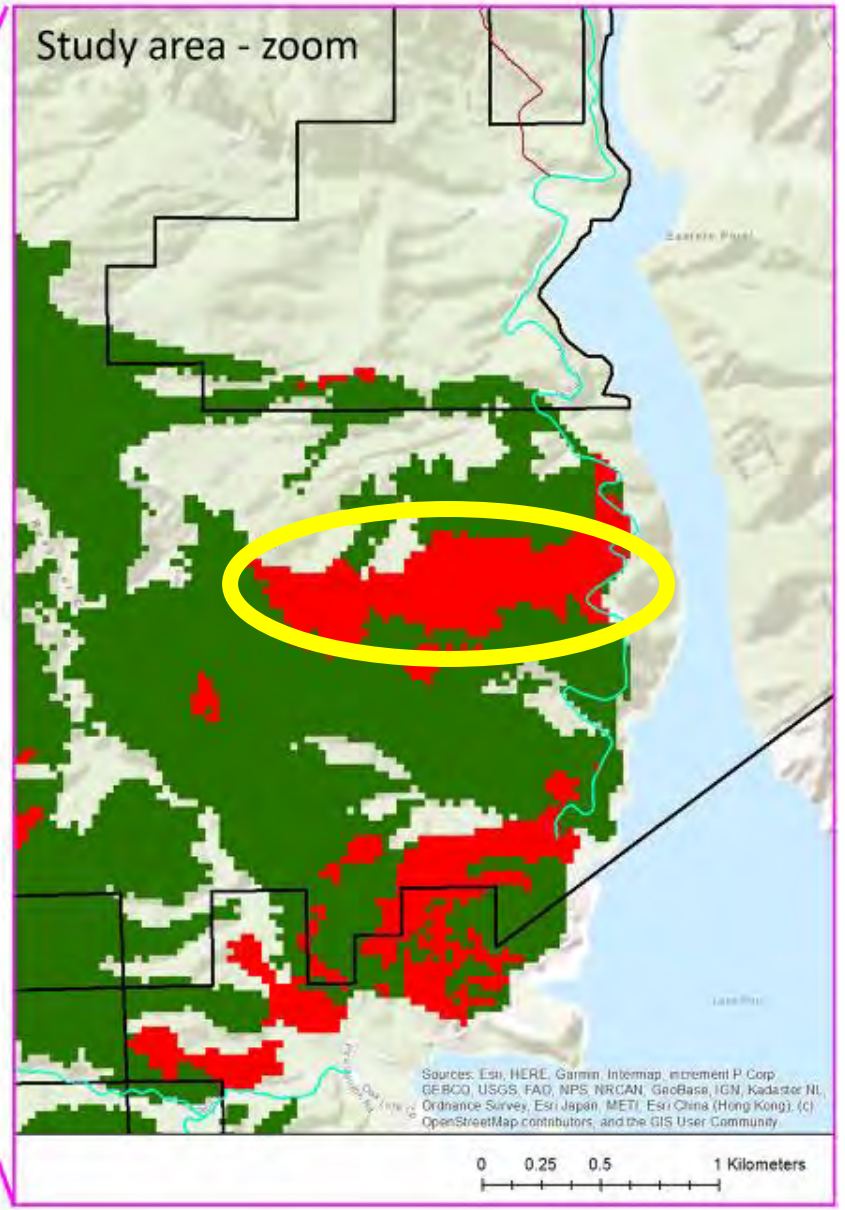
Can we restore shrubland to type-converted sites?

Photo credits: Stephen Davis


Los Padres National Forest
Study location
Wheeler Springs
Ojala
Sespe Condor Sanctuary
Ojai
Goleta
Santa Barbara
Carpinteria
Oak View
La Conchita
Faria Beach
Ventura
Saticoy
Somis
El Rio
Moorpark
Simi Valley
Santa Rosa Valley
Camarillo
Oxnard
Port Hueneme
NAS Point Mugu
Point Mugu State Park
Channel Islands National Park
Santa Barbara and Anacapa Islands ASBS State Water...
Thousand Oaks
Oak Park
Bell Canyon
Calabasas
Santa Monica Mountains National Recreation...
Topanga State Park
Malibu
Castaic
Hasley Canyon
Castaic Junction
Piru
Del Valle
Santa Clarita
Kagel Canyon
San Fernando
Mission
Agua Dulce
Acton
Forest Park
Ravenna
Hidden Springs
Angeles National Forest
Burbank
Altadena
Glendale
Pasadena
Arcadia
Alhambra
Beverly Hills
Los Angeles
El Monte
Santa Monica
Culver City
Montebello
Marina Del Rey
Inglewood
Huntington Park
Whittier
Downey
Manhattan Beach
Gardena
Compton
Norwalk
Lakewood
Cerritos
Torrance
Long Beach
Rancho Palos Verdes
Terminal Island

Postfire Restoration Prioritization Tool (PReP)





Molinari NA, Underwood EC, Sawyer SC, Butz RJ (2021) Chapter 5 California chaparral case study. Pages 99-122. In: Meyer MD, Long JW, Safford HD (eds). Postfire restoration framework for national forests in California. General Technical Report PSW-GTR-270. Albany: USDA Forest Service, Pacific Southwest Research Station.

Underwood EC, Hollander AD, Molinari NA, Larios L, Safford HD (2021) Identifying priorities for post-fire restoration in California chaparral shrublands. Restoration Ecology 30 (3): doi: 10.1111/rec.13513


1985
1997
2008
1954 (King Fire)
1997
2007 (Ranch Fire)

Photo Credit: Pratt

Photo credits: AL Jacobsen

58 plants per restoration plot
19 species (chaparral, CSS, monocots)
Dry season supplemental irrigation (18 species) and **non-irrigated (9 species)**

Goals and Research Questions

With minimal watering… (planted Jan-Mar, watering withheld after May)

- What species and traits are associated with high survival/success?
- Do chaparral and CSS species differ in their restoration success?

Sources of Variation (Mixed Model)

1. Species (4 chaparral; 5 CSS)
2. 16 plot pairs (16 restoration; 16 control)
3. Time (8 sampling dates)
4. Type (chaparral & CSS)

Responses

1. Survival
2. Height
3. Plant health (stress, leaf shedding, herbivory, flowers, fruit)
4. Dieback
5. Predawn water potential
6. Dark-adapted fluorescence

Species	Vegetation
Ceanothus oliganthus	Chaparral
Frangula californica	Chaparral
Heteromeles arbutifolia	Chaparral
Rhus ovata	Chaparral
Artemisia californica	CSS
Baccharis pilularis	CSS
Encelia californica	CSS
Eriogonum fasciculatum	CSS
Hazardia squarrosa	CSS


Restoration
Control
Photo credit RB Pratt

Additional Context:

Drought During Experiment

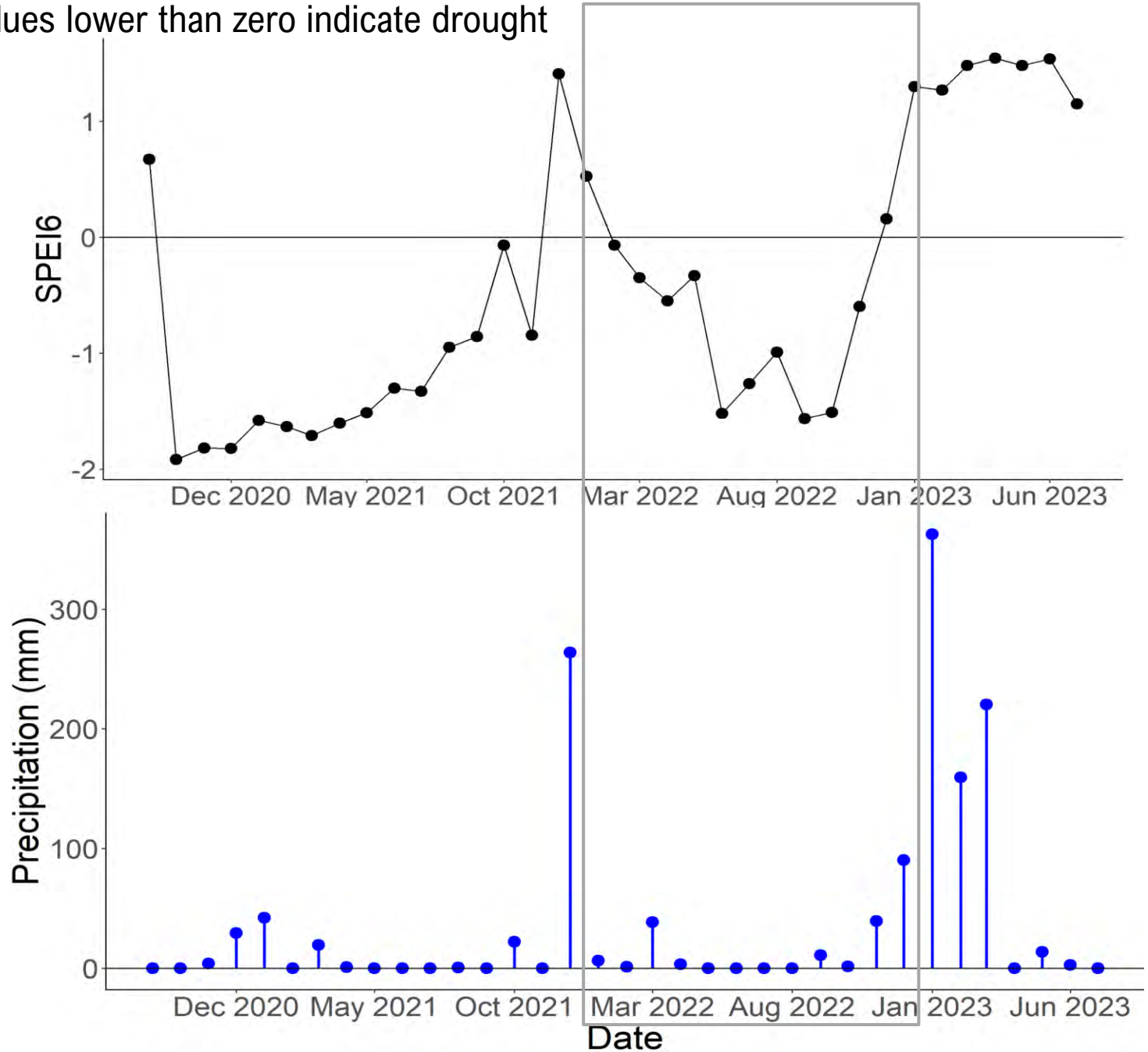
Precipitation

30-year average = 478 mm

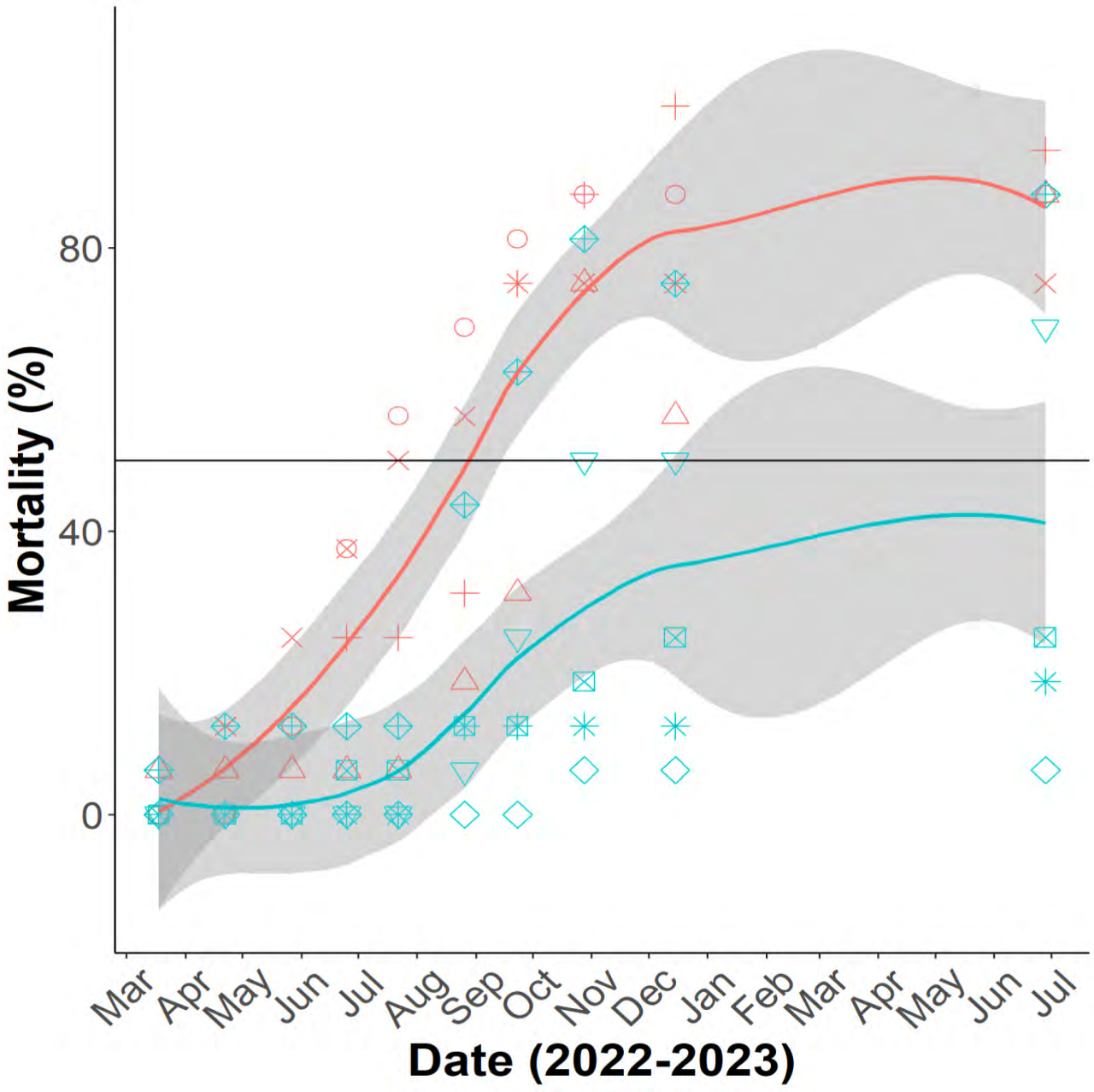
Study year (2022) = 335 mm

Standardized Precipitation-Evapotranspiration Index (SPEI) Drought Index

Values lower than zero indicate drought



Mortality: Chaparral > CSS



Species

- *Ceanothus oliganthus*
- *Frangula californica*
- *Heteromeles arbutifolia*
- *Rhus ovata*
- *Artemisia californica*
- *Baccharis pilularis*
- *Encelia californica*
- *Eriogonum fasciculatum*
- *Hazardia squarrosa*

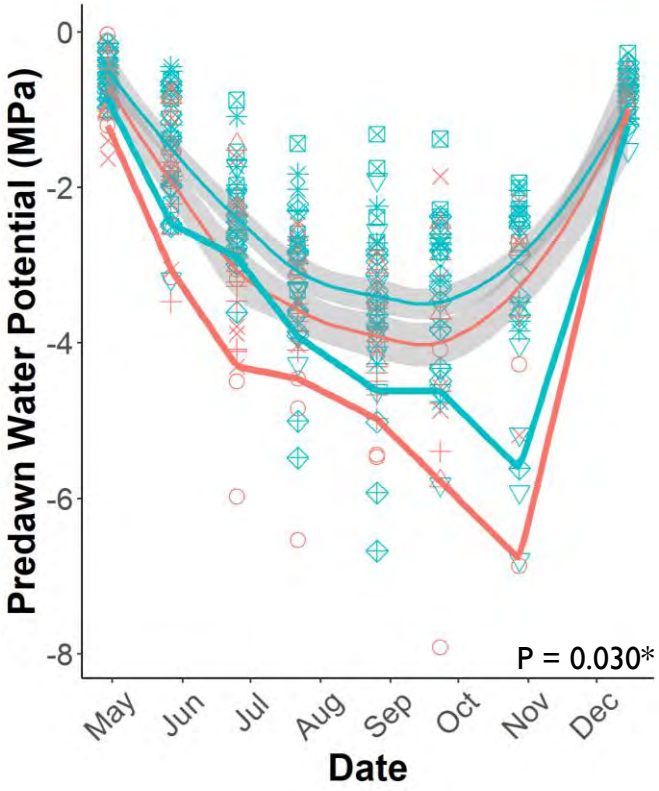
Type

- *Chaparral*
- *CSS*

$P < 0.001$***

Photo credits: AL Jacobsen and RB Pratt

Chaparral: Drier and more strained



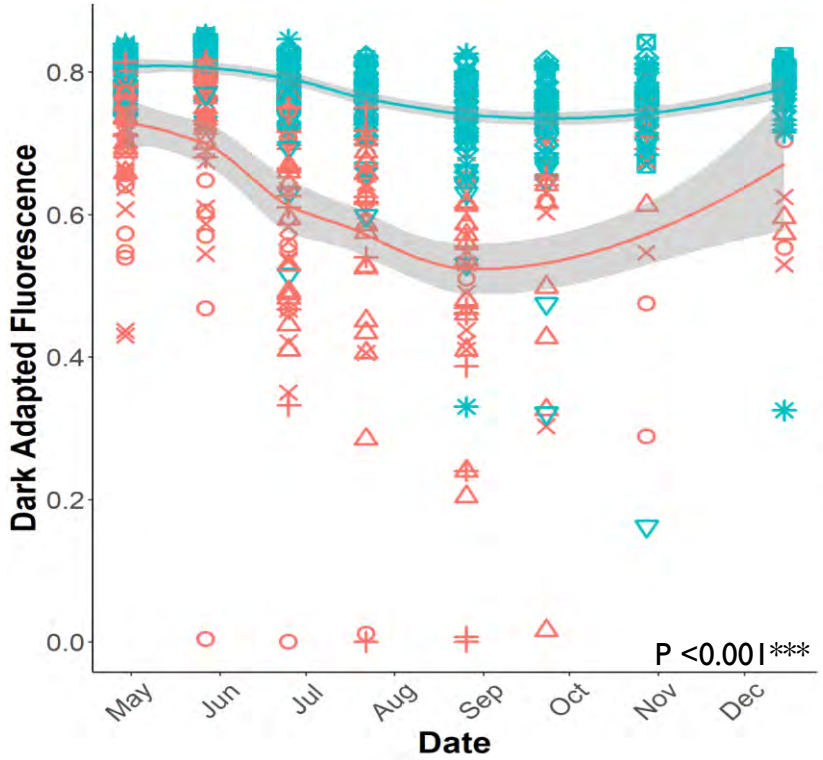
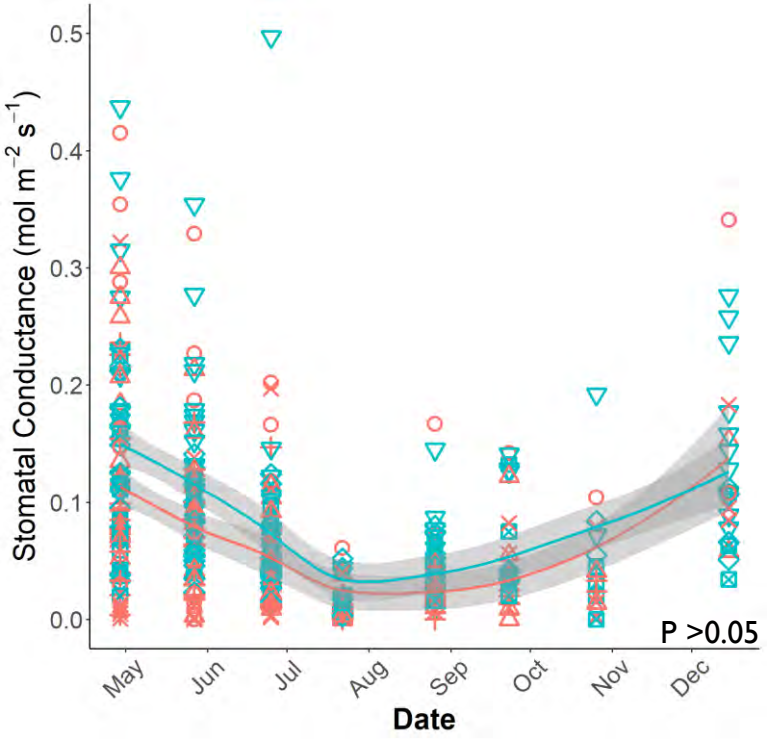


Photo credits: AL Jacobsen

Leaves displayed similar stomatal conductance seasonally, but fewer leaves were retained on dry-season CSS plants



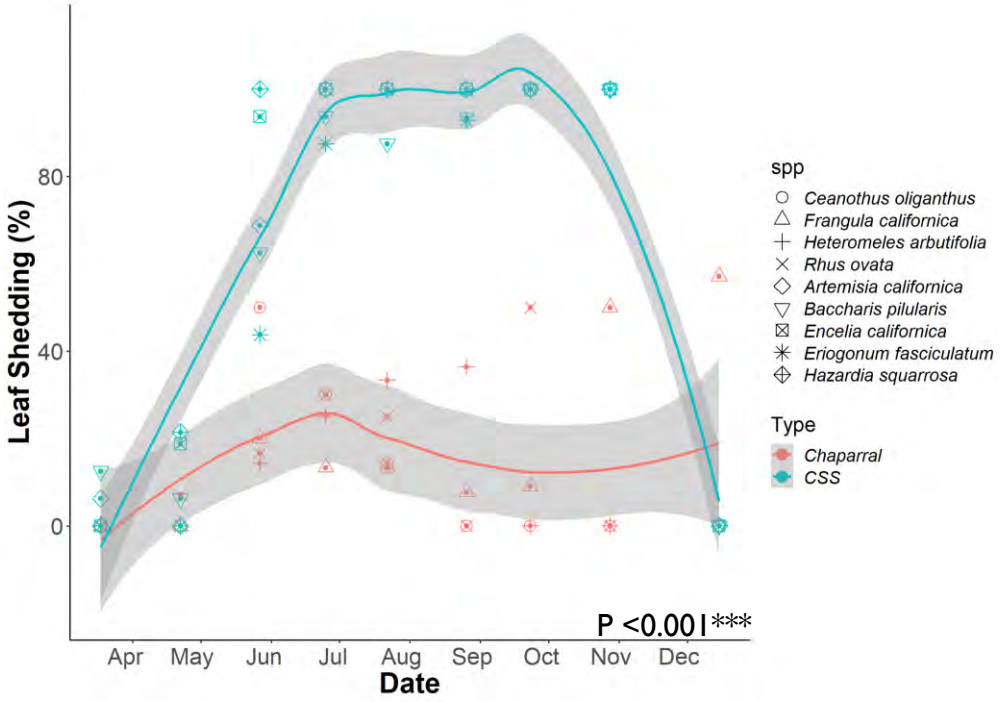
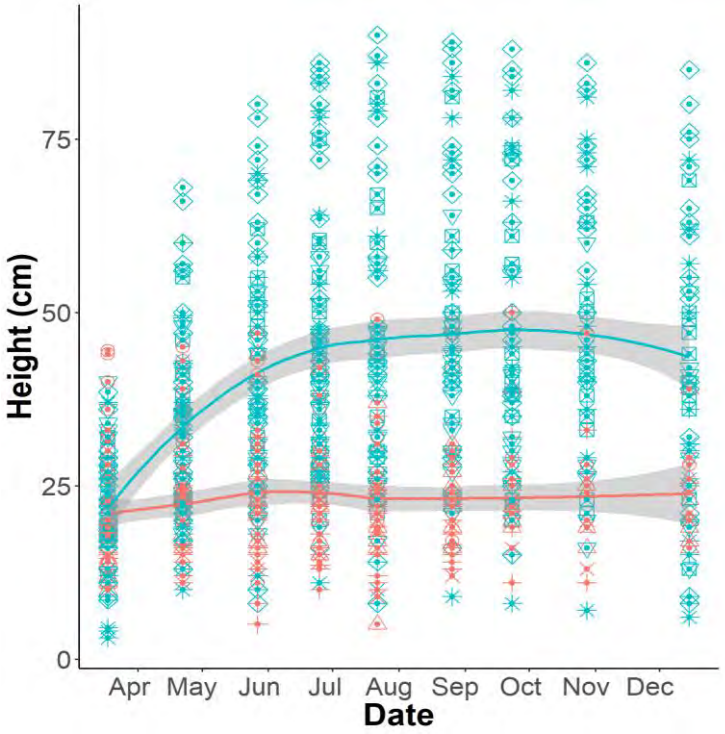


Photo credits: AL Jacobsen

CSS grew more and reached early reproductive maturity

(all CSS species except for *Baccharis* had some individuals set fruit)



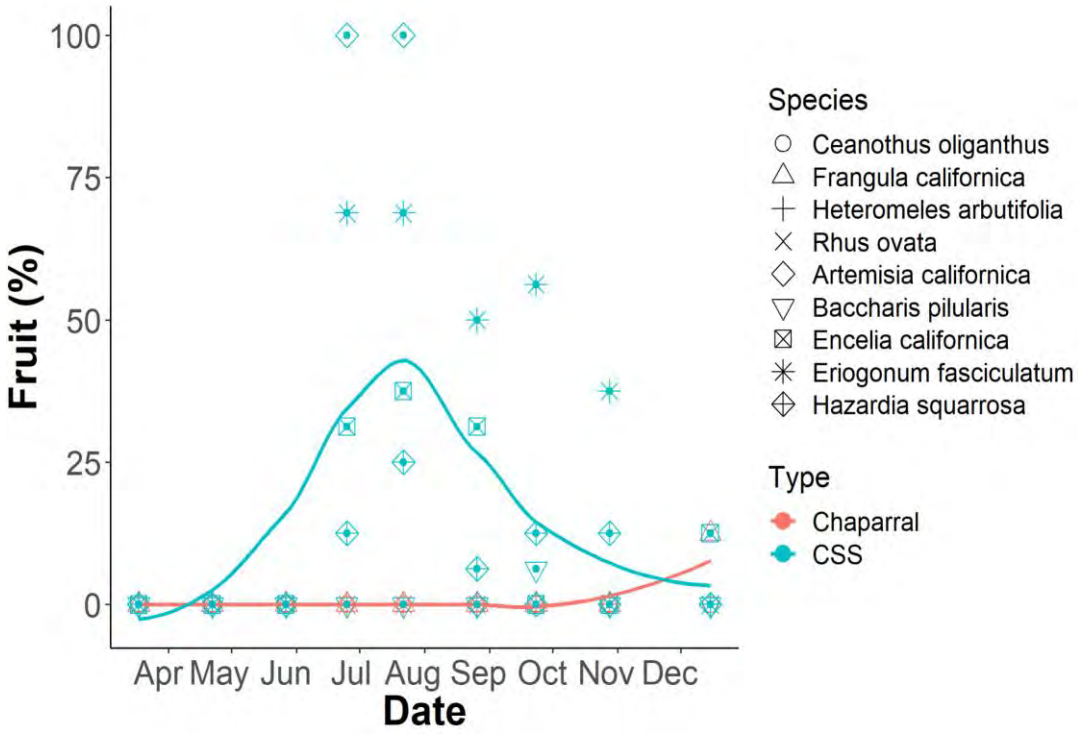
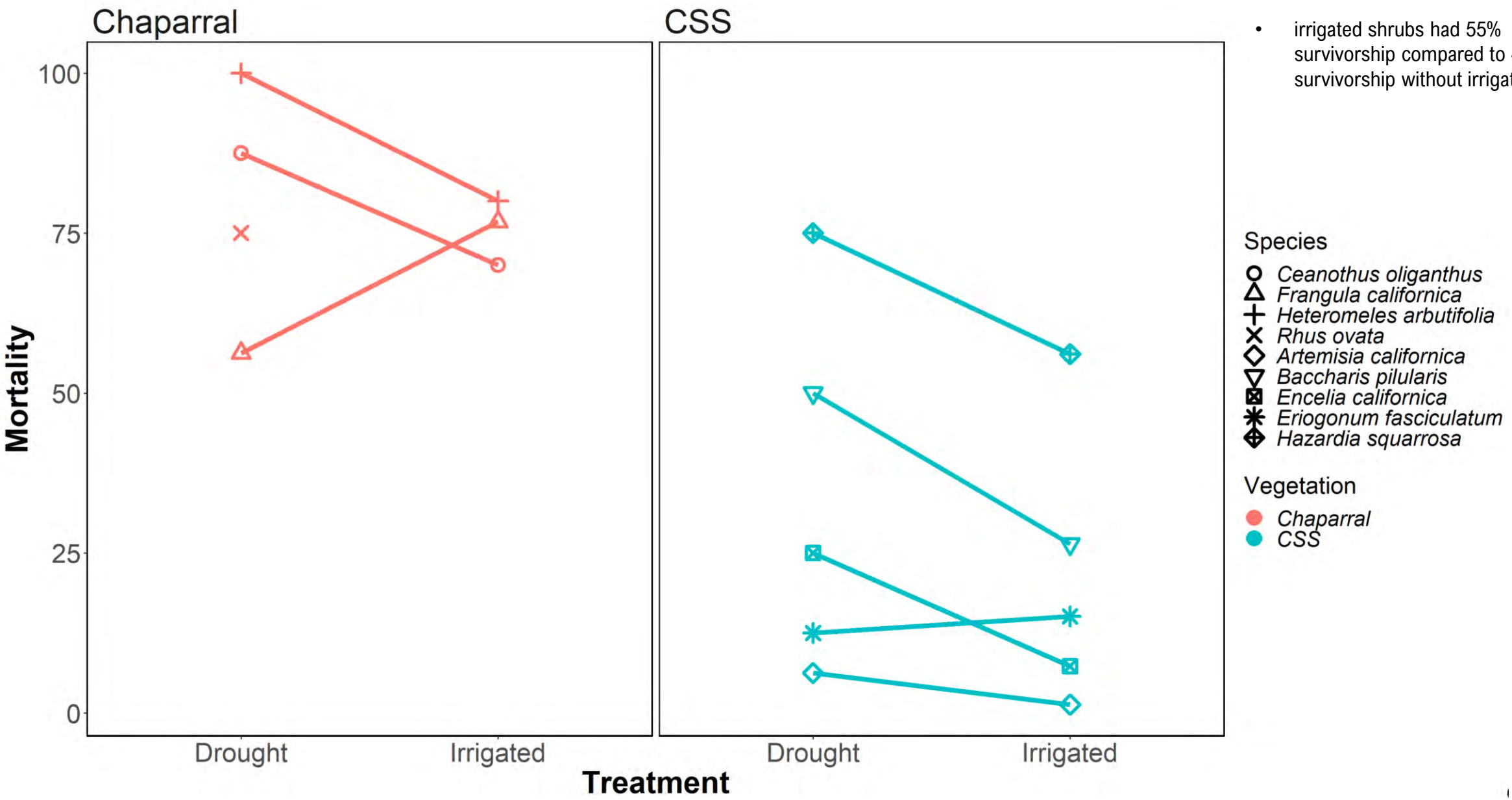


Photo credits: AL Jacobsen

The effect of drought on mortality

12% less mortality with irrigation



- % survivorship with and without irrigation was not significantly different (p=0.09)
- irrigated shrubs had 55% survivorship compared to 43% survivorship without irrigation

Malosma sapling

August-September 202

Jacobsen & Pratt


2022-07-03 7:38:19 PM M 1/2
68°F
CAM 56


1:42 PM M 2/2
68°F
CAM 34

Camera plot captures (June - Dec 2022)		
	RESTORATION PLOTS	**CONTROL PLOTS**
Bird		
Roadrunner	40	0
Quail	132	0
Mourning Dove	4	0
Other birds	40	0
Mammal		
Deer	6	0
Skunk	15	0
Rabbit	2	0
Pocketmouse	50	0
Bobcat	46	2
Fox	2	0
Cattle* (Dec only)	94	0

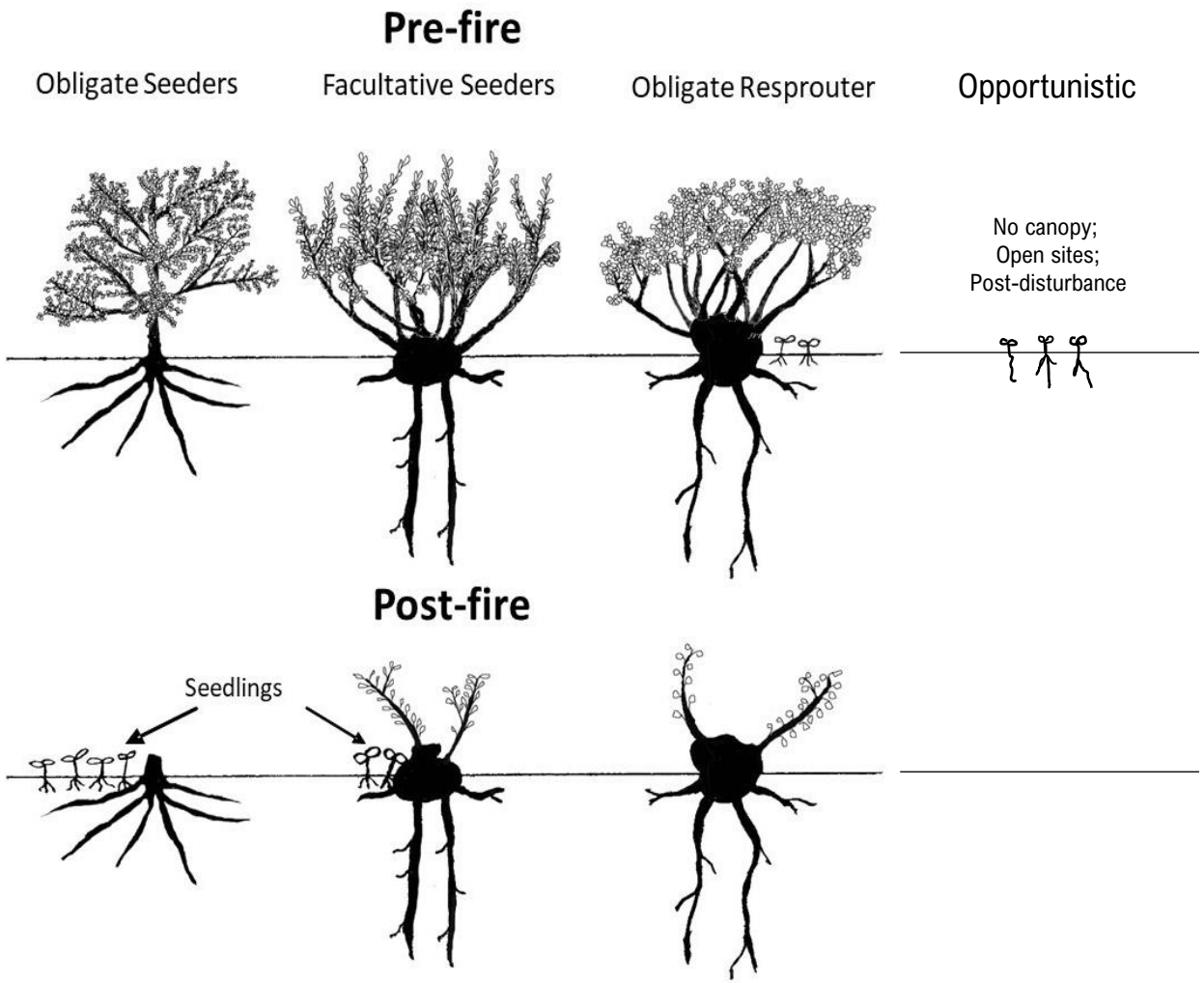


Image credit: modified from Pratt et al. 2008. Journal of Ecology

Chaparral restoration was unsuccessful relative to CSS.

The restoration environment is different from typical chaparral recruitment environments of…

a) Shaded understory (obligate resprouter LHT)
b) Post-fire (reduced competition and high nutrients) (Seeder LHT)

In contrast, CSS species are often able to recruit into disturbed and open environments (opportunistic LHT).

What are the critical factors limiting chaparral survival in type-converted sites?
-drought, heat waves, climate change, …

What plant traits predict successful restoration?
-can we use "CSS-like" chaparral?
-broader chaparral functional types (more resistant; Arctostaphylos, Ceanothus Cerastes)?

Framing of conservation	Key Ideas	Science underpinning
Nature for itself 	Species Wilderness Protected areas	Species, habitats and wildlife ecology
Nature despite people 	Extinction, threats and threatened species Habitat loss Pollution Overexploitation	Population biology, natural resource management
Nature for people 	Ecosystems Ecosystem approach Ecosystem services Economic values	Ecosystem functions, environmental economics
People and nature 	Environmental change Resilience Adaptability Socioecological systems	Interdisciplinary, social and ecological sciences

What is the goal of restoration?

- Specific/threatened species
- Species diversity
- Ecosystem function
- Habitat

Esler, Jacobsen, and Pratt. 2018. The biology of Mediterranean-type ecosystems. Oxford University Press.

SUMMARY & CONCLUSIONS

There are multiple threats to shrub species. Drought-associated mortality, fire, and other disturbances can drastically alter community composition leading to type-conversion.

Shrub restoration potential has, to date, been little studied. Many questions remain unanswered.

Chaparral species have low restoration success and active restoration and facilitation to increase survival are likely required. In contrast, CSS show higher success, but form a functionally different type of shrubland (drought deciduous; many opportunistic LHT).

Identification of species traits associated with restoration success could benefit species selection for shrub restoration projects for which facilitation is not possible.

Photo credit: AL Jacobsen

Photo credits: AL Jacobsen and RB Pratt

COMPLETE SPECIES LIST FOR RESTORATION PLOTS

Species	Common name	Shrub species type	Life history type	Drought avoidance traits	Number: irrigated	% Survival: irrigated	Number: drought row	% Survival: drought row
Artemisia californica	California sagebrush	CSS	FS	yes	64	98%	16	94%
Encelia californica	Bush sunflower	CSS	OR	yes	80	85%	16	75%
Eriogonum fasciculatum	California buckwheat	CSS	FS	yes	37	83%	16	69%
Salvia mellifera	Black sage	CSS	FS	yes	18	67%	--	--
Salvia leucophylla	Purple sage	CSS	FS	yes	37	62%	--	--
Acmispon glaber	Deerweed	CSS	OS	yes	50	61%	--	--
Baccharis pilularis	Coyote bush	CSS	OR	--	37	49%	16	31%
Malacothamnus fasciculatus	Chaparral mallow	CSS	OS	yes	54	39%	--	--
Hazardia squarrosa	Golden sawtooth	CSS	FS	--	41	32%	16	13%
Malosma laurina	Laurel sumac	chaparral	FS	--	17	67%	--	--
Heteromeles arbutifolia	Toyon	chaparral	OR	--	39	13%	16	6%
Ceanothus oliganthus	Hairy ceanothus	chaparral	OS	--	37	10% (23%*)	16	13%*
Frangula californica	Coffee berry	chaparral	OR	--	40	5%	16	13%
Cercocarpus betuloides	Mountain mahogony	chaparral	OR	--	56	4%	--	--
Quercus berberidifolia	Scrub oak	chaparral	OR	--	27	0%	--	--
Elymus condensatus	Giant wild rye	monocot	--	--	51	90%	--	--
Stipa pulchra	Purple needlegrass	monocot	--	yes	50	50%	--	--
Hesperoyucca whipplei	Chaparral yucca	monocot	FS	--	49	45%	--	--
Total					**784**		**128**	