Facilitative Effects of Nurse Shrubs on Growth and Survival of California Sage Scrub Native Plants

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Introduction

- **Facilitation by nurse plants is a common revegetation approach in restoration,** where neighboring plants benefit from shared resources. Nurse plants may also provide protection from UV radiation, temperature extremes, and herbivory in water-limited environments, where such pressures are amplified on recruiting seedlings *(5, 6).*
- **Herbivory pressures on recruiting seedlings under nurse plants is another factor that warrants further investigation** *(1, 2, 3).*
- **Prolonged drought in water-limited environments has left abundant dead shrubs in the landscape, whose effect on seedling establishment has received little study** *(1, 4, 7).*
- Dry and degraded inland California sage scrub is an ideal system for studying the effects of nurse plants due to its need for restoration.

Questions:

1. **Does native establishment and survival under nurse plants depend on abiotic factors or biotic factors?**
2. **Can dead nurse shrubs provide the same benefits as live nurse shrubs?**

Methods

Study Site

Experimental block with exposed, live nurse shrub, and dead nurse shrub treatments

Voorhis Ecological Reserve at Cal Poly Pomona, in Pomona, CA, 30 miles east of Los Angeles, CA.

Experimental Design:

- Five blocks, with a nurse shrub factor consisting of three treatments (exposed areas, live *Artemisia californica*, and dead *A. californica* nurse shrubs) and an herbivore exclusion factor of two levels (uncaged and caged) nested within each level of the nurse shrub factor.
- Soil moisture, soil temperature, and solar radiation sensors were installed in each nurse level in two blocks to measure abiotic factors.
- Motion sensor cameras were installed in each block to monitor herbivore activity.
- *A. californica* and *S. mellifera* seedlings were outplanted in January 2016. Native annuals were sown in February 2016 and in January 2017.

Study Species

Native Shrubs
- *Artemisia californica* (California sagebrush)
- *Salvia mellifera* (Black sage)

Native Annuals
- *Amsinckia intermedia* (Common fiddleneck)
- *Deinandra fasciculata* (Clustered tarweed)
- *Phacelia distans* (Common phacelia)
- *Pseudognaphalium californicum* (California everlasting)

Exposed nurse shrub level, with caged and un-caged levels nested within.

Data collection (January 2016- present)

- Biotic data collected: shrub height, seedling counts, seedling height, leaf water potential, chlorophyll fluorescence, herbivore activity, and plant biomass (2017).
- Abiotic data collected: soil moisture, soil temperature, solar radiation, PAR, and humidity.

Results

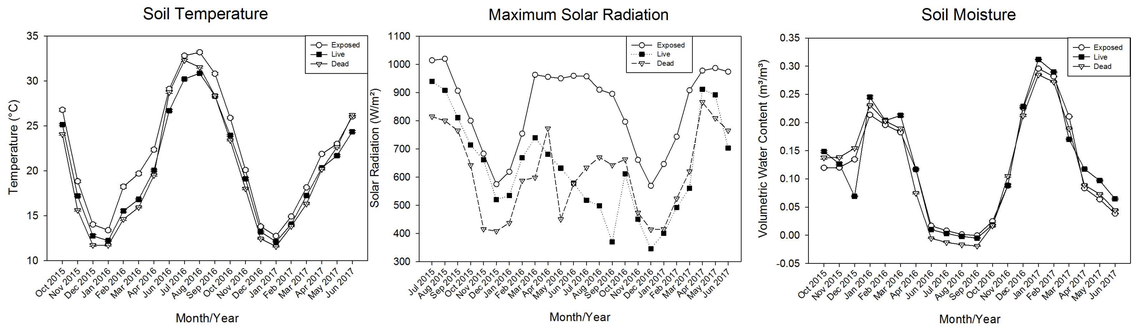

Figure 1. Abiotic conditions under live and dead shrubs were less stressful compared to exposed areas. Symbols show monthly means. During summer, abiotic conditions were most stressful in exposed areas. Soil moisture was greater during winter 2017 than winter 2016.

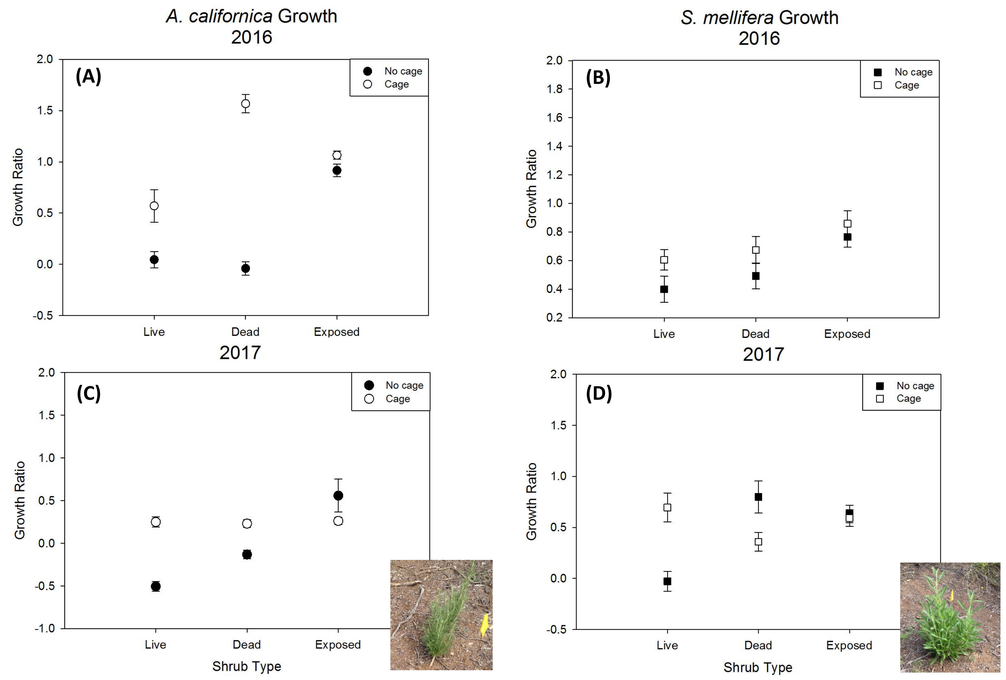

Figure 2. Herbivory had a significant impact on shrub growth, which was more pronounced in some nurse shrub types. Caged treatments and Shrub Type x Cage interaction term had significant effects on (A) *A.* californica growth in 2016 and (C) 2017 (Table 1). Caged treatments had a significant influence on (B) *S. mellifera* growth in 2016, while Shrub Type x Cage interaction term had a significant effect on growth in (D) 2017 (Table 1).

Table 1. Shrub growth and annual germination data were analyzed using Linear Mixed Effects Models, with a random Block term, fixed factors Shrub Type and Cage, and the interaction term (Shrub Type x Cage). Significant effects are shown below.

Shrub Growth

Year	Species	Factor	F	df	P
2016	*A. californica*	Cage	194.75	1, 584	2.2e -16
	A. californica	Shrub Type x Cage	65.405	2, 584	2.2e -16
	S. mellifera	Cage	12.82	1, 584	0.000371
2017	*A. californica*	Cage	20.7	1, 220	8.52e -6
	A. californica	Shrub Type x Cage	65.405	2, 220	5.97e -11
	S. mellifera	Shrub Type x Cage	20.18	2, 220	8.94e -9

Annual Germination in March

Year	Species	Factor	F	df	P
2016	*A. intermedia*	Cage	52.047	1, 102	9.76e -11
	A. intermedia	Shrub Type x Cage	6.348	2, 102	0.00252
	D. fasciculata	Cage	23.068	1, 102	5.38e -6
	D. fasciculata	Shrub Type x Cage	3.9663	2, 102	0.02193
2017	*A. intermedia*	Cage	75.75	1, 42	5.97e -11
	A. intermedia	Shrub Type x Cage	7.969	2, 42	0.001164
	D. fasciculata	Shrub Type x Cage	5.25	2, 42	0.009223
	P. distans	Cage	94.213	1, 42	2.711e -12

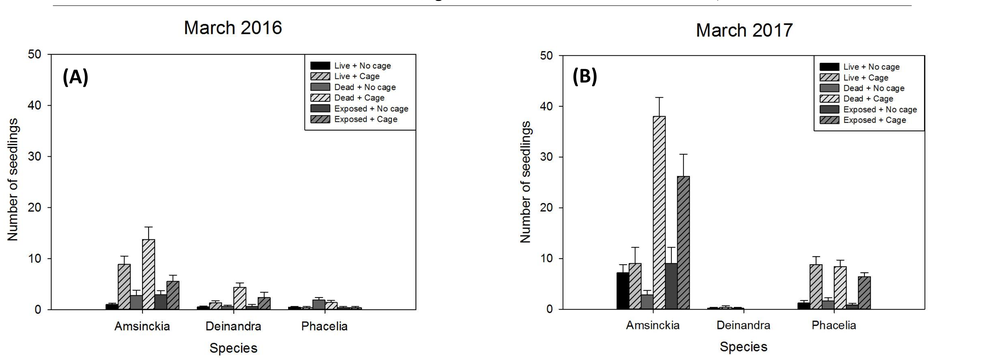

Figure 3. Herbivory had a significant impact on three annual species, which was more pronounced under dead shrubs. Cage and the interaction term, Shrub Type x Cage significantly affected *A. intermedia* and *D. fasciculata* germination in (A) March 2016 (Table 1). Cage had a significant influence on *A. intermedia* and *P. distans* germination, and the interaction of Shrub Type x Cage had a significant effect on *A. intermedia* and *D. fasciculata* germination in (B) March 2017 (Table 1).

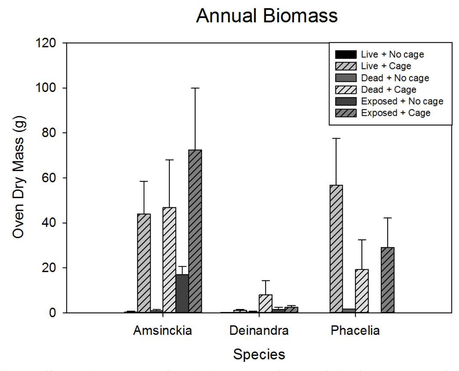

Figure 4. Overall, spring annuals, *A. intermedia* and *P. distans* produced the most biomass, while mid summer annual, *D. fasciculata* produced the least. Cage treatments had a significant effect on *A. intermedia* and *P. distans* biomass (Table 2).

Table 2. Linear Mixed Effects Models were used to analyze all biomass data from 2017.

Annual Biomass 2017

Species	Factor	F	df	P
A. intermedia	Cage	18.92	1, 20	0.0003109
P. distans	Cage	14.22	1, 12	0.002665

Discussion

- It appears that herbivory restricts uncaged *A. californica* growth under live and dead shrubs 2016 and 2017 (Question 1, Fig. 2A, Table 1). In 2016, caged *A. californica* seedlings under dead shrubs grew the most, being shaded and protected from herbivores (Question 2, Fig. 1A).
- It also appears that herbivory and nurse shrubs influenced *A. intermedia* and *D. fasciculata* germination in 2016 and 2017 (Question 1, Fig. 1 and 3, Table 1). Greater soil moisture during winter 2017 increased germination in caged *A. intermedia* and *P. distans* under dead shrubs (Fig. 3B).
- Cage treatments also significantly increased biomass production of *A. intermedia* and *P. distans*; however it seems that Shrub Type had no significant effect on biomass production of these annual natives (Question 1, Fig. 4, Table 2).
- These results suggest that herbivory is a significant barrier to native plant growth and establishment, and that facilitative effects of live and dead nurse shrubs vary for certain species excluded from herbivores.

A. californica seedling eaten by an herbivore.

Desert cottontails (*Sylvilagus audubonii*) under a live nurse shrub with *A. californica* seedlings.

Future Directions

- Herbivore occupancy and abundance analysis of each block may reveal a stronger relationship between seedling survival and increased herbivore activity.

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Acknowledgements

Thank you to J. Paolini, R. Fitch, J. Marfori, E. Hernandez, G. Morrison, S. Lauman , A. Ayyad, K. Chung, K. Fleurial, K. Moreno, A. Soto, and S. Sanchez for their help with data collection and project preparations. Cameras were generously loaned by Dr. W. Meyers (Pomona College). **Research reported in this publication was supported by the MENTORES (*Mentoring, Educating, Networking, and Thematic Opportunities for Research in Engineering and Science*) project, funded by a Title V grant, Promoting Post-baccalaureate Opportunities for Hispanic Americans (PPOHA) | U.S. Department of Education, Washington, D.C. PR/Award Number: P031M140025. This content is solely the responsibility of the authors and does not necessarily represent the official views of the Department of Education.**