Precipitation and nitrogen manipulations alter post-fire recovery of coastal sage scrub

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Introduction

California's coastal sage scrub ecosystem has decreased by nearly 60% directly due to the expansion of urban areas and the conversion of shrublands to agriculture, and indirectly through ecosystem type conversions. Although there now exist several preserves in southern California that contain coastal sage scrub habitat, the ecosystem remains threatened by the indirect effects of urbanization and by invasion by exotic Eurasian grasses. Shrublands may be particularly vulnerable to ecosystem type conversion during the fire recovery period.

- Drought severity and nitrogen deposition are two important factors that influence post-fire succession patterns of coastal sage scrub ecosystems.[1,2]
- Climate models project increased aridity and precipitation variability in southern California over the next century.[3]
- Urbanization near existing coastal sage scrub habitats has already increased the nitrogen deposition that many of these habitats receive to at or above the critical threshold for ecosystem type conversion (0.8 - 1 g N m^{-2} yr^{-1})[4]
- Fire frequency has increased dramatically over the past century,[5] particularly near large urban areas.[2]

The post-fire recovery period represents a window in which coastal sage scrub is particularly vulnerable to displacement. It is important to understand the effects increased aridity, precipitation variability, and nitrogen deposition may have on the coastal sage scrub ecosystem during the fire recovery period. We focused on the responses of *Acmispon glaber, Artemisia californica,* and *Salvia mellifera* to five years of precipitation and nitrogen manipulations.

Methods

Study site

- Loma Ridge, in foothills of the Santa Ana Mountains in Orange County at 117.704°W by 33.742°N
- Mediterranean-type climate
- 30cm mean annual precipitation, falling almost exclusively between November and April
- 6.2 - 21.0°C average winter (November through April) temperature range, 13.1 - 27.3°C average summer (May through October) temperature range
- Site rarely experiences freezing temperatures
- Site slopes gently to the southwest
- Soil classified as Myford Sandy Loam
- Vegetation is mosaic of annual grassland and deciduous shrubland (coastal sage scrub)
- Region receives ~1.5 g m^{-2} yr^{-1} nitrogen deposition
- Site burns frequently; recent burns in 1914, 1948, 1967, 1998, and 2007

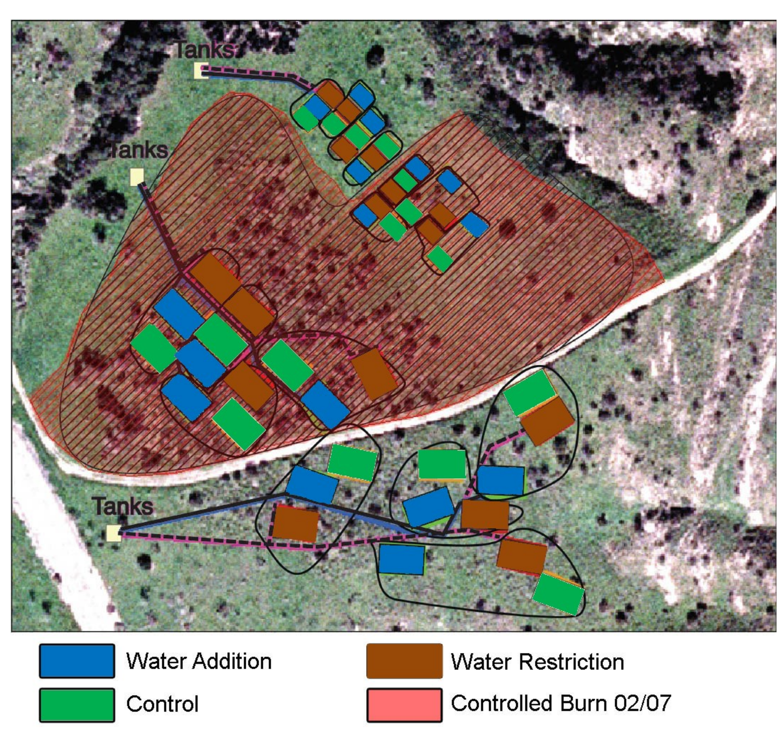
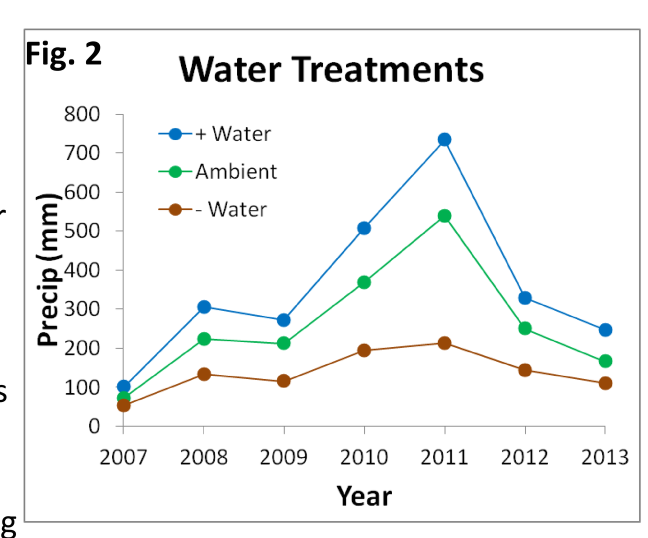


Fig. 1: Google Earth™ view of experimental site, water and fire treatments marked

Experimental design

- 24 plots (6.10x9.14m) were constructed in 2007 in a grassland portion of the study site and 24 plots (12.19x18.29m) were constructed in an adjacent coastal sage shrubland
- Shelters were constructed over 8 grassland and 8 coastal sage plots to intercept and collect rain; shelters remained uncovered ~95% of the year to minimize microclimate artifacts
- Irrigation manifolds were constructed on 8 grassland and 8 coastal sage plots to apply water collected off shelters
- Dry plots have cumulatively received ~51% less water than ambient plots and water addition plots have cumulatively received ~33% more than ambient plots to date
- Shelter closure was biased towards large storms with the goal of reducing storm intensity as well as frequency
- Remaining 8 grassland and coastal sage plots were left as control plots
- Half of each plot is treated with additional nitrogen to simulate additional nitrogen deposition of 6 g m^{-2} yr^{-1}
- 12 grassland and coastal sage plots were burned prior to construction in a controlled burn in February 2007. The entire site subsequently burned in the Santiago wildfire of October 2007, resulting in 24 plots that burned twice in short succession and 24 plots that burned much more intensely in October 2007

Fig. 2



Loma Ridge viewed from the west, shelters covered in preparation for rain. Grassland plots appear in the left side of the photo, larger coastal sage plots in the right side of the photo. Photo taken in November, prior to rain-induced germination of herbaceous plants and shrub regrowth.

Google Earth™ view of four coastal sage scrub shelters, showing the cumulative effect of 5 years of persistent drought. Note the relative absence of large shrubs growing within the shelters compared with surrounding terrain.

Results

Artemisia californica and *Salvia mellifera* were annually surveyed for survival and then measured and biomass determined allometrically.

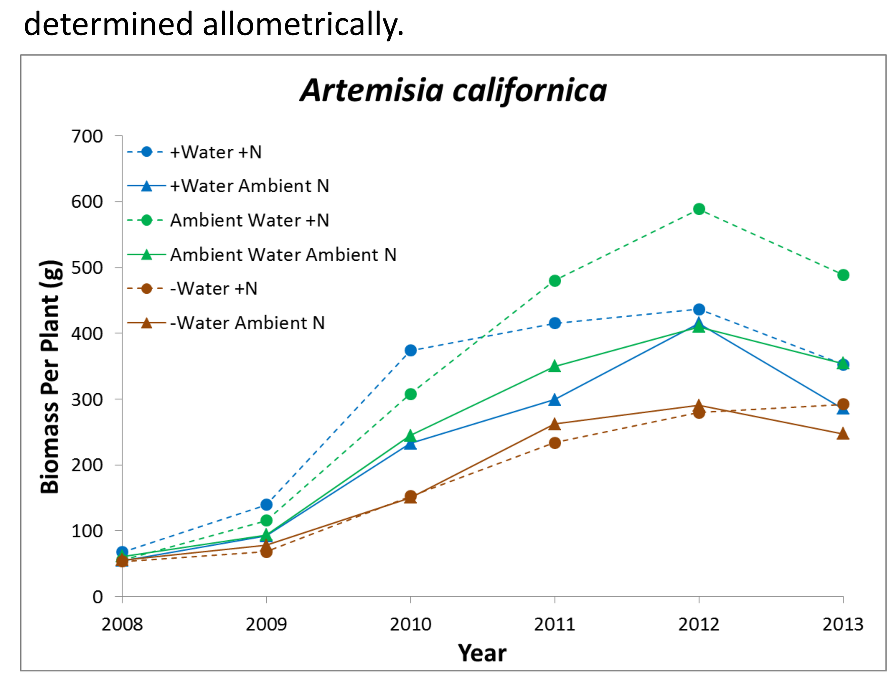


Fig. 3: *Artemisia californica* response to water and nitrogen treatments. Growth was affected by water treatments, and under ambient water conditions this species benefitted strongly from added nitrogen.

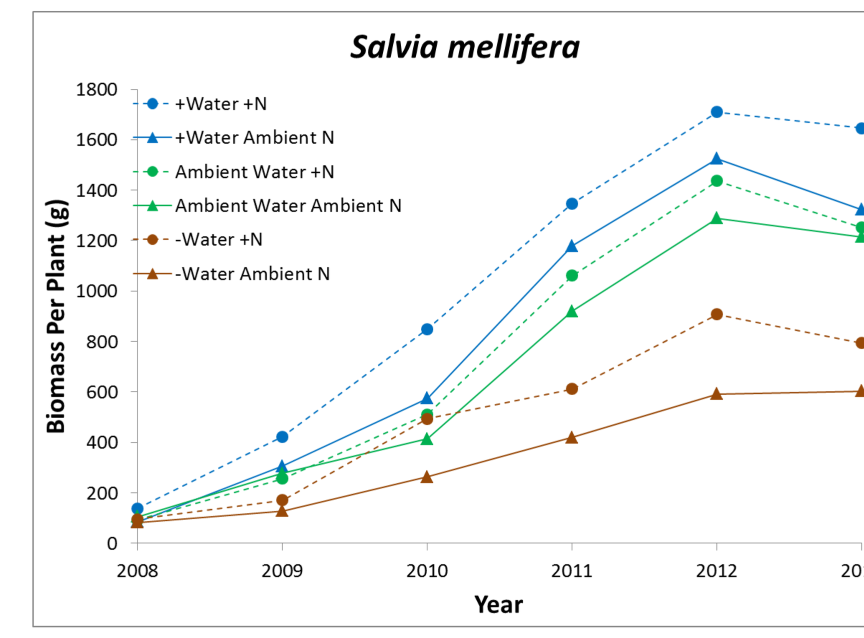


Fig. 4: *Salvia mellifera* response to water and nitrogen treatments. Shrub productivity was enhanced both by added nitrogen and added water, but added water provided the strongest response.

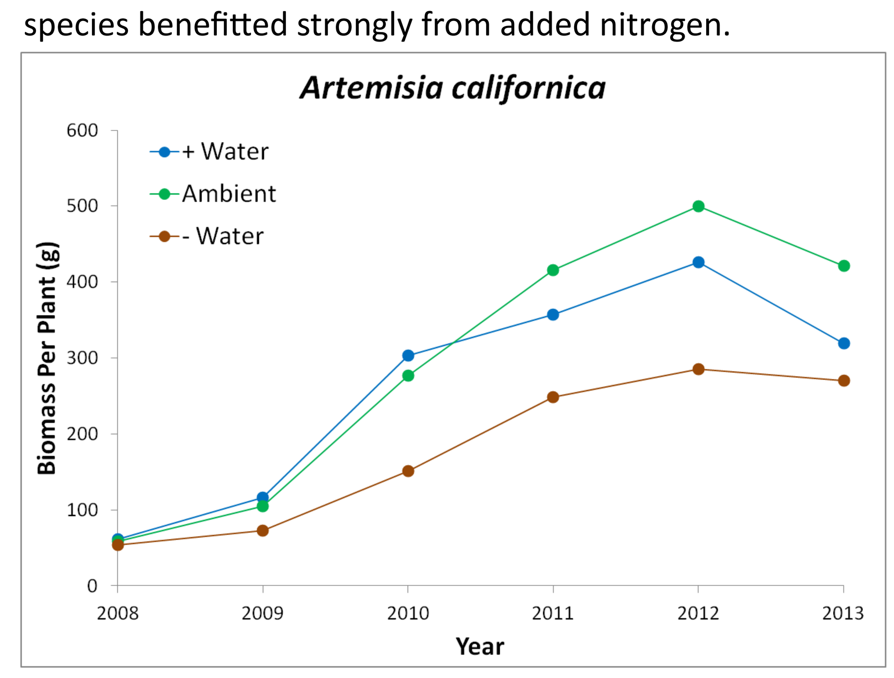


Fig. 5: *Artemisia californica* response to water treatments. Shrubs were most productive under ambient conditions. In the added water plots, shrubs were out-competed by herbaceous growth and by other shrub species.

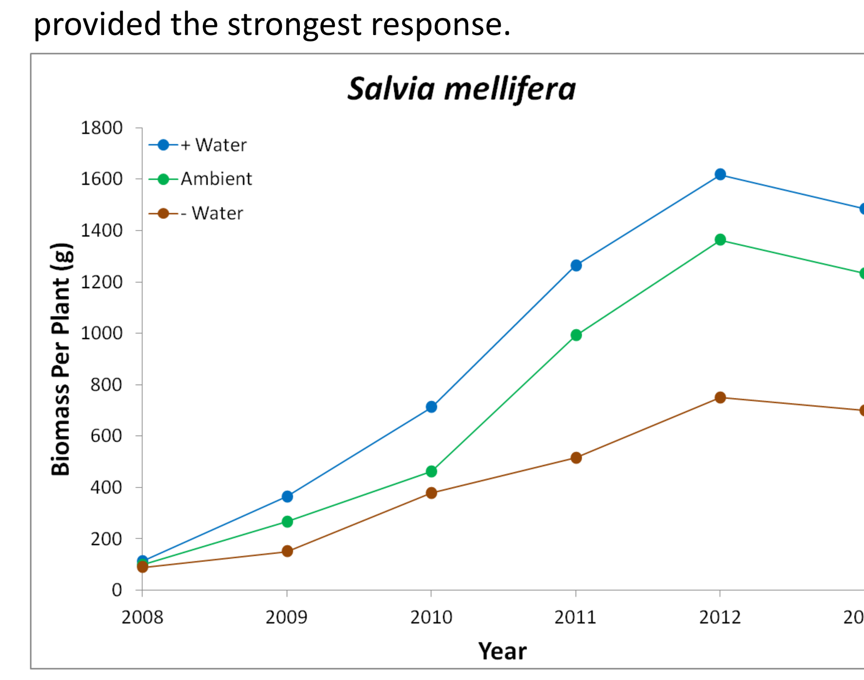


Fig. 6: *Salvia mellifera* response to water treatments. Both the productivity and mortality of this species responded strongly to water treatments, with lowest growth and highest mortality observed in restricted water treatments.

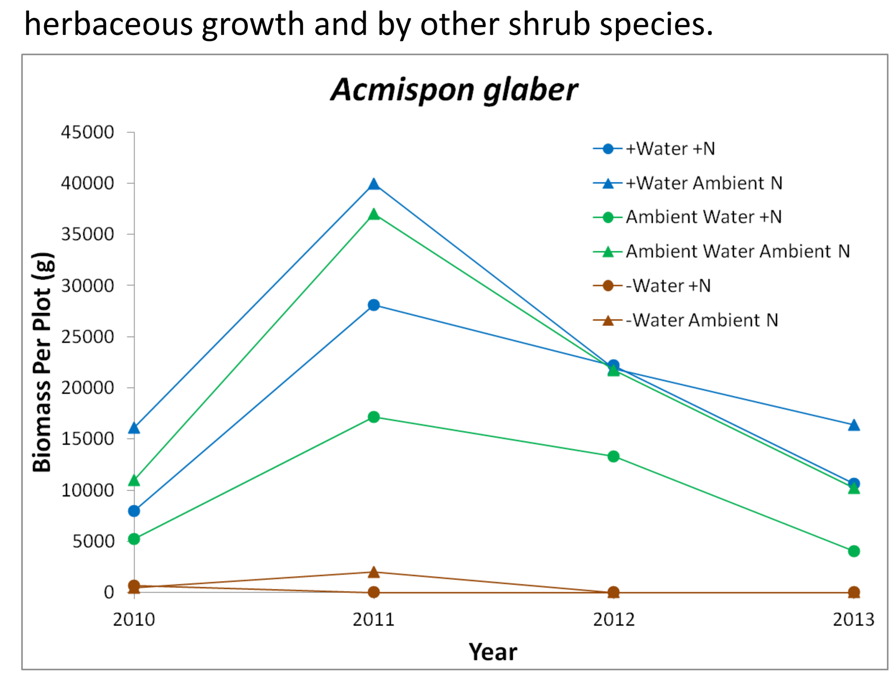


Fig. 7: *Acmispon glaber* response to treatments. Individual plants were randomly selected, harvested, and weighed, then combined with two measurements of *A. glaber* cover. Note strong positive response to added water and negative response to added nitrogen.

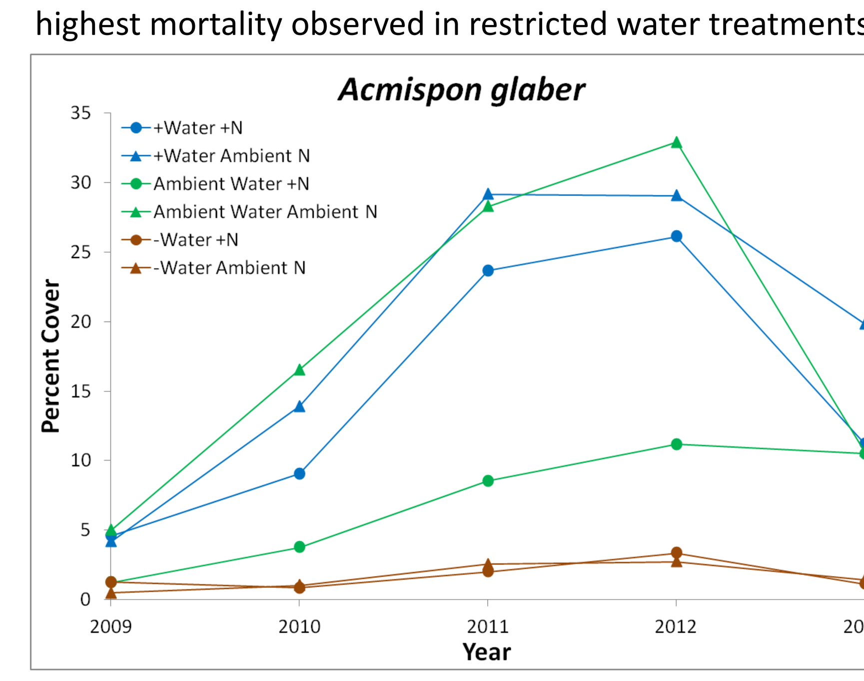


Fig. 8: Trends in *A. glaber* cover. Note strong positive response to added water and negative response to added nitrogen.

Discussion and Further Research

Reduced water and added nitrogen both significantly altered the fire succession patterns of *A. californica, S. mellifera,* and *A. glaber.* Wildfire combined with drought may provide a window in which invasive Eurasian grasses can become established in regions previously dominated by coastal sage scrub.

- *A. californica* and *S. mellifera* are both crown-resprouting shrubs that regrow rapidly following fire. As a result, their water requirements may be higher following fire.[6] The restricted water treatments greatly diminished their recovery capability.
- *A. glaber* is an obligate reseeder. Its decreased biomass and cover in the restricted water plots indicates that the restricted water treatments hindered the ability for *A. glaber* seedlings to establish.
- The striking difference in *A. glaber* biomass and cover between the nitrogen treatments in the ambient water plots indicates that *A. glaber*, a nitrogen fixer, may be at a competitive disadvantage under high nitrogen conditions.
- In restricted and ambient water plots, invasive Eurasian grasses accounted for greater than 50% cover through 2011. This declined in 2012 and 2013, possibly due to lower precipitation in all plots these two years.
- The decrease in reestablishment and growth of shrubs such as *A. glaber, A. californica,* and *S. mellifera* due to drought following a fire reduces competition for light and allows higher germination and productivity of herbaceous species, particularly invasive Eurasian grasses.
- The cover of non-native grasses in added nitrogen plots was significantly higher than the cover of native herbaceous plants. This supports the idea that invasive Mediterranean grasses are better able to make use of additional nitrogen than native coastal sage shrubs and thus gain a competitive advantage in regions with increased nitrogen deposition.

This experiment is ongoing. The water manipulations stopped after the 2013-2014 growing season, and the next phase involves tracking the recovery of the plots that experienced prolonged water restriction. We hypothesize that these plots may have converted from coastal sage scrub to Mediterranean annual grassland due to this prolonged drought.

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Acknowledgements

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