CLIMATIC SCALING EFFECTS OF FOUNDATION PLANT SPECIES & ARTIFICAL CANOPIES EXPLORED IN A CALIFORNIAN DRYLAND SYSTEM

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*“After all, only the desert remains.”*

- Zhu

**Abstract**

Shrub are known to be structural agents of facilitation, providing benefit to animals that take refuge under their canopy. The central theme of thesis is how shrubs compare to artificial canopies at reducing ambient temperature and incoming light. We tested the effects of UV permeable artificial shelters on how they influence ambient temperature and solar radiation using two shapes (square and triangle) at three different blockage intensities (15%, 50%, and 90%), and contrasted those against the dominant shrub *Ephedra californica* and the open using temperature-light sensor loggers. Shelters offered more stable temperatures and shade from direct sunlight compared to the open and functioned analogous to *E. californica*. The triangular shelter at 90% blockage was the best combination at lowering ambient temperature. Furthermore, I found that microsite level climate data are more ecologically-relevant than coarse-scale weather station data when examining species interactions.

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**General Introduction**

The study of interactions has fascinated the field of ecology for centuries. Competition, for the most part, dominated the field during the previous century; however, following the introduction of Bertness and Callaway’s Stress Gradient Hypothesis (SGH), the focus has been shifted to facilitation as a fundamental interaction in many communities (Bertness and Callaway 1994; Bruno, Stachowicz, and Bertness 2003). Facilitation is defined as a positive interaction where one interacting species benefits, whilst none are harmed (Bertness and Leonard 1997). The SGH in particular proposes a shift from competition to facilitation with increasing stressful environmental conditions (Bertness and Callaway 1994). Due to this, many studies of positive interactions have focused on harsh environments, including arid ecosystems (Lu et al. 2018; Synodinos, Tietjen, and Jeltsch 2015; Maestre et al. 2009). Thus, positive interactions are studied relatively well when discussing stress, though it’s almost paradoxical that many studies fail to report stress effectively. Climate in particular is a stressor not typically explored, not reported. Hence, to ideally advance the relative importance in stress with global change, we need to introduce climate into the equation when measuring interactions.

Foundational plant species are a vital component of facilitation research (Filazzola and Lortie 2014). Foundational plants can include shrubs, nurse plants, perennials, trees, and cushion plants (Gómez-Aparicio et al. 2004). These vegetation have the ability to facilitate other taxa through mechanistic pathways that include, but are not limited to, seed trapping, abiotic stress amelioration, herbivore protection, magnet pollination, facilitation-mediated secondary seed dispersal, and soil modification (Filazzola and Lortie 2014; Lortie, Filazzola, and Sotomayor 2016). Facilitation by shrubs is an established mechanism, able to repair and maintain semiarid ecosystems even post extensive damage (Lortie et al. 2018). Foundational plants have crucial impacts on the entire community dynamic, however much of the research has focused solely on plant-plant interactions (Gómez-Aparicio et al. 2004; Castro et al. 2004; Flores and Jurado 2003), while the interaction with other taxa such as vertebrates is less-explored. There are a total of 63,000 documented species of vertebrates worldwide (Brown 2018). The south-western region of the United States is home to a variety of vertebrate species, including some of the first to be listed as endangered (Tazik and Martin 2002). Shrubs fulfill a critical role as agents of structural facilitation by offering an environment where animals can thermoregulate, reproduce, and take refuge (Lortie, Filazzola, and Sotomayor 2016; Filazzola et al. 2017). In order to advance the theory of facilitation, an emphasis also needs to be placed on examining direct and indirect shrub-animal interactions, as they may be key to arid region management and restoration.

The state of California is home to a diverse array of vegetation including *Ephedra California. E. califronica* is an ecologically dominant or co-dominant foundational shrub, wide-spread in hot deserts (Sawyer, Keeler-Wolf, and Evens 2009). In recent years however, climate change and extensive land-use has imposed severe stress on arid ecosystems, resulting in rapid degradation that may be difficult to reverse (Verwijmeren et al. 2013). In the south-western region of the United States, anthropogenic disturbances and land-use have reduced the available terrestrial habitat, in turn decreasing biodiversity (Germano et al. 2011). The well-being and function of foundation plants species such as shrubs may depend on factors such as temperature, variability in precipitation, extended drought periods, and radiation (Tattini et al. 2006; Kogan and Guo 2015; MacDonald 2007). Shrubs can be expanding in cover in some arid system, whilst declining in others. Given that landscape recovery post disturbance can be slow, it is simply unrealistic to merely rely on management efforts to encourage the growth of new shrubs. Shrubs help augment structural diversity; thus, the availability of viable mimics as a temporary solution, alongside conservation efforts, can enhance management outcomes.

Arid region expansion and desertification are important global change challenges (Asner and Heidebrecht 2005). Anthropogenic climate change significantly modifies physical and biological systems in all continents (Rosenzweig et al. 2008). It’s important to understand that difference between macro and micro-climate. Micro-climate or weather can be defined as short-term (minutes to months) changes in atmospheric conditions in one small study site, while climate is the long-term weather pattern of a particular region (NASA 2005). By the year 2100, different micro-climatic parameters in California may vary; however, the overall temperature is predicted to increase by 5.6º-8.8º, which indirectly augments the frequency of extreme wildfires, and the average area burned statewide could increase by 77% (California’s Fourth Climate Change Assessment 2019). To examine the ecological and biological relevance of climate, it’s important to have data at both levels. Climate change can encourage shifts in species distributions and promote novel interactions between species (Parmesan and Yohe 2003). Climate envelope models are common tools to understand how species respond to change and environmental drivers, though one cannot ignore the interactions that buffer their tolerances.

The objective of this thesis is to examine the role shrubs as a form of structural facilitation and to tests the efficacy of artificial shelters at mimicking the micro-climatic effects of shrubs. In the following empirical chapter, I focus on the methodologies of UV Permeable Shade Cloth Shelters- a simple and cost-effective artificial canopy not examined previously. The goal of this chapter is not merely to describe how these shelters are built, or how they’re different from other prototypes discussed in the literature, but instead to understand the effects of shape and UV permeability on canopy microclimate, including temperature and light intensity, relative to the open and the foundational shrub *E. californica.* I hypothesized that:

1. The shape of the artificial canopy is an important characteristic that can influence abiotic parameters including temperature and solar radiation.
2. UV permeability influences the direct shade effects of a canopy on the thermal environment.
3. A combination of these factors can effectively emulate some of the impacts of *E. californica*.
4. Coarser-scale climate data is not an accurate measurement/representation of abiotic factors for microsite-level interactions.

I confirm that shelters act similar to vegetation in order to increase the thermal heterogeneity within a given environment, and are different from the paired, open microsites. I show that relationship between permeability and ambient temperature may be more complex than previously thought. Furthermore, I demonstrate that weather-station data is ecologically less-irrelevant. The concepts discussed in this thesis are valuable because globally no system is exempt from the impacts of climate change. The key ideas discussed can be used as tools for stakeholders in various restoration strategies, in conjunction with other conservation and management practices.

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**General Conclusion**

Facilitation has be the central theme of a large, growing body of literature, many of which have explored plant-plant and plan-animal interactions. Abiotic factors have the ability to directly and/or indirectly influence community dynamics. Despite this being a fairly well-known fact amongst ecologist, climate is often forgotten and not incorporated into the above dialogue. Furthermore, even when climate is included, most literature often use satellite or weather-station data for their contrast. In this thesis, we used an empirical approach to examine the impacts of canopy structure on microclimate. We used the microclimatic data collected via *in situ* loggersand contrasted those against data extracted from the nearby weather station. The mean daily temperatures recorded by the weather-station were consistently cooler than micro-site level data. Similar results were observed by other studies when contrasting coarser-scale climate against local climate (Lathlean, Ayre, and Minchinton 2011; Kollas et al. 2014). Climate can impact behaviour, habitat range shifts, as well as interaction dynamics. Knowing this, it is reasonable to conclude that finer-scale climate is in fact of greater importance ecologically and is a stronger predictor of community-level dynamics. This is not too say that focus should only remain on micro-site level data, but instead emphasizes the necessity for micro-macro level contrasts in relevant studies.

Anthropogenic climate change is perhaps one of the biggest ecological, sociological, and economical threats of the 21st century. Climate change is modifying habitats and living regimes, not just in the western arid regions of the United States, but also worldwide. Species in California face extensive habitat loss as a result of frequent forest fires and rising sea levels. These effects coupled with land-use for urbanization, livestock farming, and petroleum extraction can push many species beyond their range of tolerance and ultimately lead to species loss. Vegetation canopy plays a key role in how organisms cope with the effects of climate change, yet the re-growth and establishment of natural plants post-disturbance can be slow (Berry et al. 2016), and invasion by non-natives is amongst other confounding factors (Bishop et al. 2019). In this thesis we demonstrated that artificial shelters can function similarly to natural vegetation by altering the microclimate of their canopy. We showed that by experimenting with different shapes and permeabilities, stake-holders in the region can closely duplicate the effects of natural canopies. These shelters offer a cheap and quick alternative to natural vegetation and can be used as a restorative practice to mitigate some of the impacts of climate change.

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