**Effects of Natural and Artificial canopy on Microclimate in Arid and Semi-Arid Regions.**

Nargol Ghazian1\*, Mario Zuliani1, Michael Westphal2, and Christopher J. Lortie1, 3.

1Department of Biological Science, York University, 4700 Keele St, Toronto, ON M3J 1P3, Canada

2US Bureau of Land Management, Central Coast Field Office, 940 2nd Ave, Marina, CA 93933, United States

3National Centre for Ecological Analysis and Synthesis (NCEAS), 735 State St #300, Santa Barbara, CA 93101, United States

\*Corresponding Author: Department of Biological Science, York University, 4700 Keele St, Toronto, ON, M3J 1P3, Canada. Email: [nargolg1@my.yorku.ca](mailto:nargolg1@my.yorku.ca)

**Introduction**

As the rate of anthropogenic climate change increases, many arid and semi-arid regions in Western United States face extensive ecological shifts as a consequence (Abatzoglou and Kolden 2011). At the current rate, approximately 18% of all species worldwide are expected to become extinct (Urban 2015). Factors such as land-use changes including agriculture in drylands (Germano et al. 2011; Eliason and Allen 1997) can further decrease biodiversity by reducing the available terrestrial habitat for plants and animals (Nopper et al. 2018; Irwin et al. 2010; Elmqvist 2013). In deserts, animals will not only experience large scale changes such as drought, but also small scale changes such as relatively more extreme fluctuations abiotic factors such as temperature (Pugnaire and Luque 2001). This evidence suggests that not only do gross, large-scale changes in climate exert pressure on communities and sensitive species in drylands, but fine-scale changes can fluctuations can potentially further exacerbate loss.

The type of vegetation that covers a terrestrial habitat is an important characteristic that can influence: foraging site selection (Thiele, Jeltsch, and Blaum 2008), reproduction (Thyen and Exo 2005), predator-prey interaction (Barbosa and Castellanos 2005), and thermoregulation (Parmenter and MacMahon 1983). The state of California is home to many diverse landscapes, many which are dominated by a relatively high diversity of shrubs (Stuart and Sawyer 2001). Species such as *Ephedra Californica* (Mormon Tea) are known to be foundational plants, able to facilitate other taxa through various 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). An important agent of structural facilitation is shrub canopy (Filazzola et al. 2017). Canopy microclimates are generally cooler, more humid, and experience lower solar radiation compared to the open sites (Filazzola et al. 2017; Holzapfel and Mahall 1999). Shrubs fulfill a critical role; hence, more species are associated with shrubs than open spaces (Lortie, Filazzola, and Sotomayor 2016). Shrubs can be both expanding in cover in some grassland systems, yet declining in others. Given their incredible role as foundation species, it is both reasonable A) to test their role for simple functions such as thermal shelter for animals and B) directly test shelters through mimics as means to conserve heterogeneity in deserts for animals since conserving structural diversity in all ecosystems, in addition to species diversity is critical (Brooks 1999; Cowling et al. 1999; Morris 2000). Although shrubs can perform the above function, it would be ideal to have the capacity to mimic this to augment and enhance low shrub cover areas and serve as stopgap tools for conservation. Moreover, it’s important to direct and sample value of more shelter in some dryland systems as a form of thermal refuges and alternate modes of conservation whilst landscape recovery is made and new shrubs are grown.

Artificial canopies, such as rainout shelters and Open-Top-Chambers (OTC), have been used to study the change in a variety of abiotic parameters such as CO2, temperature, soil temperature, solar radiation, and humidity (Yahdjian and Sala 2002; Marion et al. 1997). Although these shelters are effective, they’re relatively expensive to build and may be difficult to assemble in a short period of time. Rainout shelters used in semi-desert grassland studies have proven to be effective in altering precipitation, yet they have minimal impact on changing other variables such as air and soil temperature, humidity, and light (English et al. 2005). On the other hand, OTCs have been experimentally used to increase temperature in plant studies in high-latitude ecosystems (Marion et al. 1997). Although these shelters are effective at manipulating different abiotic parameters, they’re relatively expensive to build and may be difficult to assemble in a short period of time. It is therefore key to take advantage of the variability in temperature and light in drylands to explore the effects of man-made shelters that are inexpensive and easily-built.

The concept of shade from higher and more variable temperatures in drylands is an important idea to explore experimentally for conservation and restoration. The landscape alongside the climate of southern California provides us with the opportunity to explore the effects of an inexpensive alternative pioneered in this study termed UV Permeable Shade Cloth Shelters (UPSS) made of PVC pipe skeleton and shade cloth cover. In this study, the following three goals were examined: 1) describing the methodology of constructing UPSS. 2) Exploring UPSS effects on canopy microclimate, including temperature and light intensity, relative to the open and natural vegetation. 3) Understanding how different light permeabilities and shelter shapes influence the above parameters. Artificial structures are not uncommon in drylands for energy and development (Pasqualetti 2001; Lovich and Ennen 2011); thus, a deeper understanding of physical structures impacts at fine-scales can also inform some of the ecology of these changes.

**Materials & Methods**

***Study Site***

This study was conducted in Panoche Hills Management Area located on the western edge of the San Joaquin Valley, California (Bureau of Land Management; 36°41.78′ N, 120°47.89′ W). The regional climate can be characterized as arid/semi-arid. The average annual precipitation is 25.5 cm with an annual low and high temperature of 10.4 °C (50.72 °F) and 24.6 °C (76.3 °F), respectively. Winter and fall are considered to be the wettest seasons. The mean temperature observed in May is 20.4 °C (68.72 °F) and 23.7 °C (74.66 °F) in June (Los Baños Weather Station, <http://www.usclimatedata.com/>). The region is heavily dominated by invasive grasses such as: *Bromus madritensis ssp. Rubens, Bromus hordeaceus, Erodium cicutarium* and *Schismus barbatus* (Filazzola et al. 2017)*.* The study took place between May 20th to June 12th, 2019.

***Shelter Construction***

Shelters were constructed using PVC piping and UV permeable shade cloths at three permeabilities including 15%, 50%, and 90%. The open (no structure) at 0% light blockage served as control. The cloths were attached to the PVC using zip ties. Table 1 describes the number of pieces at specific dimensions and diameter needed to build each triangle or square shelter (Supplementary Appendix). There were six replicates of each shape-two pertaining to each blockage percentage-for a total of 12 replicates. Pipes were slid onto metal stakes, which were hammered into ground for stability (Supplementary Appendix; Figure 1). Latitude and longitude coordinates of each shelter-open pair was also recorded (Table 2; Supplementary Appendix). Rectangular (referred to as square in stats) shelters consisted of two sides with two 61 cm ½ inch pipes facing the ground connected to a 61 cm ¾ inch pipe using a 90° elbow. Triangular shelters were built using a 75 cm ¾ inch top pipe connected to a ½ inch to ¾ inch adapter. The adapter was then attached to a ½ inch 3-way 90° elbow fitted with two 61 cm ½ pipes. Cloths were used to cover two side of the triangular shelters and three sides of the rectangular shelters. The cardinal direction or orientation of each shelter was decided using a random number table and recorded. Shelters were inspected weekly throughout deployment.

***Shelter Micro-climatic Measurements***

To measure the difference in light and temperature within shelters and between shelters and open microsites, Onset HOBO Temperature/Light Pendant (8K) loggers were placed inside and directly outside to the right of the shelters. A total of 24 pendants were used, where each pendant was tied to a plastic stake using a zip tie, recording data at 1 hour intervals. Stakes were hammered into the ground until stable with ~10 cm remaining above ground. This was done to ensure that logger data were not influence by ground cover and true ambient conditions both inside and outside were recorded. Air temperature (°F) and light intensity (lum/ft2) were recorded hourly. Loggers were placed out mid-May and collected in mid-June to account for spring-summer seasonal variation.

***Shrub Micro-climatic Measurements***

A set of Onset HOBO Temperature/Light Pendant (8K) (one soil and one ambient) were placed below the base of shrub canopy microsite to log temperature and light intensity data in 1 hour intervals. The ambient pendants were secured to pegs using the same protocol as above. Latitude and longitude coordinates of each shrub, as well as shrub height, length, and width (x, y, and z) dimensions were also recorded upon deployment of loggers. There were 7 shrub microsites resulting in a total of 14 loggers being used.

***Macro-climatic Measurements***

Hourly weather data were download for the study site for the total duration of the study (Los Baños Weather Station at 37°03.30′N, 120°51.00′W, http://www.usclimatedata.com/). Factors such as date, air and soil temperature (°F), and solar radiation (W/m2) were exported and saved as a Comma-Separated Values (CSV) file.

***Statistical Analyses***

All statistics were performed using R version 3.6.1 (R Core Team 2019).