Ghazian Progress Report

York University, Toronto, ON

Winter 2020

**Exploring the effects of artificial deploys on dryland communities in California.**

**Examination Committee:**

Dr. Suzanne MacDonald

Dr. Christopher Lortie

Dr. Laura McKinnon

Table 1. Ph.D. Research Timeline.

|  |  |  |
| --- | --- | --- |
| **Chapter** | **Title** | **Estimated Timeline** |
| **1** | **Effects of shelters on understory plant growth.** | Conduct research during the field season Winter-Spring of 2022. |
| **2** | **Mega chapter: Animal-shelter/artificial deploy Interactions.** | Conduct research possibly spring-summer of 2021 (COVID-19 dependent). |
| **Bonus Idea 1** | **International Shelter Protocol.** |  |
| **Bonus Idea 2** | **Wildlife Study in a different dryland system (Kenya or Israel).** |  |

**Background**

The frequency and intensity of anthropogenic disturbances are increasing in all systems globally. desertification is a growing issue in arid and semi-arid regions that compromise approximately 40% of the global land surface (Verón, Paruelo, and Oesterheld 2006). Deserts are not only becoming hotter (Nabhan 2013; Allen et al. 2014), but the duration and frequency of mega-droughts in these regions are also increasing (Guerreiro, Kilsby, and Fowler 2017; Kogan and Guo 2015). These changes decrease biodiversity by reducing the available terrestrial habitat for both plants and animals (Nopper et al. 2018; Irwin et al. 2010; Elmqvist 2013). If we extrapolate this current trends, it will not be long before resident animals can no longer behaviourally mitigate climate and land-use changes, such as urbanization and agriculture in drylands (Germano et al. 2011). Many organisms in drylands are not only sensitive to large-scale changes, but also small, fine-scale fluctuations (Shrode and Gerking 1977; Hadley 1970), which can further push species beyond the point of no return. At this current rate, it is simply unrealistic to rely on the ecosystem to restore itself to its original equilibrium. Hence, we must actively examine restoration strategies that function as a buffer to lower post-disturbance stress, including artificial refuges that lower the amplitude of micro-climatic variation.

Terrestrial vegetation is one of the most dominant forms of life on earth. In deserts, shrubs are the dominant vegetation (Miriti, Joseph Wright, and Howe 2001; Throop et al. 2012). Foundation shrubs can structurally facilitate other taxa through their canopy (Filazzola et al. 2017) by providing a cooler, more humid microhabitat that experiences less direct solar radiation (Filazzola et al. 2017; Holzapfel and Mahall 1999). Facilitation is defined as an interaction where one or more species (beneficiary) benefit from a benefactor, whilst none are harmed (+/0) (Bertness and Leonard 1997). With an increase in stress in a system, the direction of competitive interactions often switches to facilitation – Generally, the magnitude of this interaction also increases with increase in abiotic pressures. This is formally known as the Stress Gradient Hypothesis (SGH) first described by Bertness and Callaway (1994). *Ephedra Californica* (Mormon Tea) is a common foundation shrub, native to the Southwestern regions of California (Sawyer, Keeler-Wolf, and Evens 2009), able to benefits other plants (Lortie et al. 2018) and animals (Ivey et al. 2020). Foundation shrubs in dryland systems are typically slow-growing (Sawyer, Keeler-Wolf, and Evens 2009), difficult to establish in areas impacted by climate change (Meyer and Pendleton 2005), and frequently cleared by ranchers for livestock farming (Webb and Stielstra 1979). One way to replicate the ameliorating effects of shrubs canopies is through UV permeable artificial shelters (Ghazian, Zuliani, and Lortie 2020). Artificial shelters have been incorporated into ecological studies for a relatively long time (Yahdjian and Sala 2002; Marion et al. 1997; Lelièvre et al. 2010) and can provide micro-climatic heterogeneity at fine-scales, by offering more stable temperatures and less direct solar radiation compared to the open gaps (Ghazian, Zuliani, and Lortie 2020). Structural heterogeneity is important for biodiversity and community dynamics (Yang et al. 2015) because heterogeneity can increase the ability of organisms to colonize different microsites (Lundholm 2009). Shrubs, solar farm deploys, and artificial shelters can increase spatial heterogeneity of the landscape. Although UV permeable shelters can be used as a viable restoration strategy, associations with the resident fauna are not yet explored. Hence, to promote their widespread-use, non-trophic interactions with animals, alongside impacts on the understory vegetation, must also be examined. Moreover, studies such as one by (Arida and Bull 2008) have reported the tendency of wildlife to avoid artificial shelters made of plastic, such as those made of PVC, when wooden or brick alternatives were available. Likewise, it is vital that we continuously strive to improve shelter designs by replacing the plastic PVC frame with more eco-friendly, organic alternatives such as wood.

Foundation plants can facilitate other vegetation growing in their understory. Plant-plant facilitation research has favoured theme by ecologist with studies examining the topic receiving considerable attention in the last two decades (Brooker et al. 2007). Interactions among plants commonly encompass positive and negative effects functioning instantaneously and bidirectionally (Holzapfel and Mahall 1999), with shrubs enforcing strong positive and weak, or no negative effects on survival, biomass production, and seed production of the entire annual community. Similarly, artificial shelters can also increase plant production and Leaf Area Index (LAI) of understory plants (Sudmeyer et al. 2002), mainly due to their windbreak abilities. Knowing this, it would be interesting to experimentally manipulate annual growth by planting seeds under UV permeable shelter, natural shrubs, and the open gap to quantify similarities and differences in annual plant growth in both understories and the open.

Camera traps allow for the observation of wildlife with relatively little to no human interference. Previous studies have explored their use to estimate population size (Karanth 1995), examine wildlife and behaviour (Dupuis-Desormeaux et al. 2015), and explore activity patterns and habitat use (Bowkett, Rovero, and Marshall 2008); though, their use in animal-plant and animal-shelter interaction studies is less-explored. Furthermore, few studies explore photogenic rate as an index of animal density and diversity in different systems (Rovero and Marshall 2009; Si, Kays, and Ding 2014). Thus, it is crucial to A) extensively explore the literature to compile camera trap data for generating rarefaction curves based on sampling effort in different systems, and B) camera trap at shrub-open and shelter-open pairs to assess behavioural and associational differences at these microsites. Despite its versatile utility, camera trapping is proven to be an ineffective method for surveying smaller organisms such as arthropods and soil pathogens.

Studies focusing on arthropods in a community generally take advantage of other methods, including pan traps, malaise, and pitfall trapping (Missa et al. 2009). Coloured pitfall traps are widely used to attract a diverse group of insects, including herbivore pests and pollinators (Ernst, Loboda, and Buddle 2016). Additionally, some pollinators in deserts show a preference towards certain colours, closely-resembling the floral colour of their host plants (Wilson, Griswold, and Messinger 2008). Hence, it’s important to consider this factor when selecting pan-traps for plant-insect interaction studies in drylands. Furthermore, quantitative measurements of soil microbial communities can provide insight into the success of restoration strategies (Harris 2003) as they’re an integral part of terrestrial ecosystem well-being. Usually, the richness and abundance of microbial communities are analysed via soil core samples by examining ribosomal RNA (rRNA) (Buckley and Schmidt 2003). Measurements of soil microbes can be used to determine biodiversity, ecological processes, and structures (Harris 2003). Soil microbial communities are associated with aboveground plant communities through how plant communities control the soil moisture regime (Waldrop and Firestone 2006). Knowing that artificial shelters may impact relative humidity (RH) regimes under the canopy, it would be interesting to examine the diversity and richness of microbial communities under artificial shelters compared to those in the open gap, and under natural shrubs.

The aim of this proposal is thus to examine shrub-community and shelter-community dynamics through two central field experiments:

1. Examining the effects of shelters on understory annuals, in comparison to shrubs and the open gaps.
2. Investigating animal community (vertebrates, arthropods, and microbes) interactions with artificial shelters relative to foundation shrubs and the open.

Both proposed experiments are directly related to spatial heterogeneity in ecological systems that in turn impacts important functions, such as population structure through community composition to ecosystem processes (Cadenasso and Pickett 1995). Integrating compositional and configurational heterogeneity into conservation practices may be key in future management strategies. Additionally, they aim to test facilitation in conjunction with the theory of context-dependence that is variability in processes linked to changes in abiotic and/or biotic conditions (Pearson et al. 2018).

**Chapter 1: Effects of shelter on understory plant growth.**

**Purpose:** To quantify the extent to which shelters facilitate the understory annual community in comparison to natural *Ephedera califronica* shrubs and the open gap.

**Questions:** How do UV permeable artificial shelters modify microclimatic parameters such as RH? How does shape and UV permeability affect understory annual growth? Are all annuals facilitated to the same extend? How does growth compare to annuals planted underneath natural shrub canopies and in the open gap?

**Hypothesis:** Percent cover of annual plants does not differ between shrubs and artificial shelters, and both will be significantly higher than the open. Water is an important co-variate that significantly increases plant growth compared to un-watered microsites.

This advances the community assembly theory of context-dependence that is variability in processes linked to changes in abiotic and/or biotic conditions. In this case we focus on facilitation and its context-dependence.

**Predictions:**

* Artificial shelters increase humidity and create a windbreak environment, which in turn aids in understory plant growth.
* The microclimatic conditions create via shelters will be similar to those of shrubs; hence, understory plant growth (percent cover) will also be similar in both microsites.

**Methodology:** The study will take place in Carrizo Plain National Monument, California, U.S.A (35.1899° N, 119.8633° W) or another field site deemed fit for the project. UV permeable shade cloth shelters will be built using Ghazian et al. (2020) protocol, with a modified eco-friendly design. Seeds of two annual species (species to be selected) will be planted underneath shelters at the end of winter/beginning of spring growth period (~February-March). There will be a total of 12 shelters: 1 shape and permeability (1 shape X 3 permeabilities X 4 replicates). Half of the shelters (6) will also be watered regularly. There will be 12 shelter/microsites as well. All plants present underneath/around the shrub and artificial canopy will be removed before the experiment and the soils will be sieved. Annual seeds will also be planted in shrub-open pairs. All shelters and shrub-open pairs will be geo-references. RH and temperature data loggers will be attached to pegs via zip ties and placed ~10 cm above ground under each shelter and shrub-open pair and set to log in 1-hour intervals. Shrub dimensions will be measured in X, Y, and Z planes to allow for canopy volume calculations later on. Shelter and loggers will be left out in the field under the end of the growing period (~end of April/mid-March) at which point microsites will be visited and understory plant growth will be measured as percent cover of each species relative to total cover. Another way to do this is to not plant seeds manually and just observed what grows under shelters at the end of the growing season and compare the richness and abundance to those of shrubs.

**Chapter 2: Animal-shelter interactions.**

**Purpose:** To examine wildlife interactions with artificial shelters and to investigate how artificial shelters impact the soil microbial community.

**Questions:** How do UV permeable artificial shelters modify the soil microbial community richness and abundance? How often do vertebrates interact with artificial shelters? Which species interact with shelters the most often? What are they doing when interacting with shelters? Do arthropods interact with shelters? If yes, which species do most often? Does the richness and abundance of microbes differ between shelters, shrubs, and the open gap? Is the frequency and direction of vertebrate and arthropod interaction with shelters different from shrubs and the open?

**Hypothesis:** The magnitude and direction of association of vertebrates, arthropods, and soil microbes will be similar between natural shrubs and artificial shelters, and both will significantly differ from the open.

Herein, we test the theory of spatial heterogeneity and explored its application in a conservation and restoration framework.

**Predictions:**

* Artificial shelters can increase RH and thus soil moisture, which in turn increases the diversity and abundance of soil microbes compared to the open.
* Soil microbial community composition will be similar under natural shrubs and artificial shelters.
* Differences in microbial community between natural shrubs and shelters is will most-likely be due to that fact that shrubs provide different nutrients otherwise not provided by shelters.
* Vertebrates will positively associate with shelters as temperature and drought increase to take refuge from direct sunlight and extreme temperatures.
* The magnitude of the above interaction would be similar to those of shrubs.
* Similar arthropod communities would be associated with shelters and shrubs.

**Methodology:**

**Vertebrates:** The study will take place in Carrizo Plain National Monument, California, U.S.A (35.1899° N, 119.8633° W) or any other field site deemed fit. UV permeable shade cloth shelters will be built using Ghazian et al. (2020) protocol, with a modified eco-friendly design. The study will take place near medium shrub-cover areas from mid-May to mid-June to allow for seasonal variabilities. There will be a total of 12 shelters: 3 of each shape and permeability (1 shapes X 3 permeabilities X 4 replicates). We will select microsite triplets which will include a shelter, a shrub, and the equivalent open. Cameras will be mounted on pegs and set up facing the microsite at a 2-meter distance. All microsites will be georeferenced. There will be a 1-minute gap between when cameras are triggered until when they’re re-triggered to avoid repetitive images of the same individual. All images will be downloaded from SD cards and saved as Joint Photographic Expert Group (JPEG) files and data such as the presence and absence of animals will be recorded and compared across microsite. RH and temperature loggers will also be placed at microsite triplets and record data as described above.

**Arthropods:** Yellow-coloured pan-traps (As *E. califronica* flowers are yellow-orange) will be placed at microsite triplets and will contain soapy-water to trap insects. Insects will be collected every 3 days and will be preserved in ethanol and shipped back to Canada for expert identification.

**Microbial Community**: Soil core samples will be taken from all georeferenced microsites once at the beginning of the study and once following the completion of the study. Samples will be sent to an expert lab group at UC Davis, California for composition and abundance analysis.

**Mega Ideas:**

1. Explore food-web dynamics by measuring predator-prey interactions between the three groups above to advance the theory that shows shelters change trophic web structure.
2. Perform experiment in 3 very different sites: no shrubs ever, damaged shrubs, and healthy shrubs.
3. Do 2 different sites to be safe, and repeat protocol as is, but also test the same protocol under solar farm deploys to test for animal-shelter interaction in the context of another giant deploy and not just shade cloth shelters.

**Bonus Chapter Idea 1: International UV Shade Cloth Shelter Protocol.**

**Purpose:** To lead an international UV Shade Cloth Shelter project similar to the International Tundra Experiment (Molau and Molgaard 1996) that was used to examine global change with Open Top Chambers (OTC).

**Questions:** What is the impact of artificial shelters on microclimate in different systems worldwide? Do they always act similar to native shrubs in lowering the amplitude of variation for parameters such as temperature? Does regional wildlife interact with these shelters?

**Methods:** Write and revise a detailed protocol adapted from (Ghazian, Zuliani, and Lortie 2020) with more eco-friendly materials and ask international collaborators worldwide to repeat the same experiment in their home region. Perhaps set-up a website for the protocol and send the link to international collaborators.

**Bonus Chapter Idea 2: Construct shelters in a different dryland system such as Kenya or Israel.**

**Purpose:** To conduct the same exact field study as chapter 2 in a completely different region.

**Questions:** What is the impact of artificial shelters on microclimate in different systems worldwide? Do they always act similar to native shrubs in lowering the amplitude of variation for parameters such as temperature? Does regional wildlife interact with these shelters?

**Methods:** To physically fly to the region and re-conduct the experiment or ask collaborators in Kenya or Isreal to conduct the same experiment, to see if the effects of shelters on microclimate are the same in all dryland systems (scrubland, grassland, savannah, western desert verus the middle east, etc).

**Work Cited**

Allen, Michael F., C.W. Barrows, Michael D. Bell, G Darrel Jenerette, Robert F. Johnson, and Edith B. Allen. 2014. “Threats to California’s Desert Ecosystems.” 42 (2).

Arida, Evy Ayu, and C. Michael Bull. 2008. “Optimising the Design of Artificial Refuges for the Australian Skink, Egernia Stokesii.” *Applied Herpetology* 5 (2): 161–72. https://doi.org/10.1163/157075408784648826.

Bertness, Mark D., and Ragan Callaway. 1994. “Positive Interactions in Communities.” *Trends in Ecology & Evolution* 9 (5): 191–93. https://doi.org/10.1016/0169-5347(94)90088-4.

Bertness, Mark D., and George H. Leonard. 1997. “The Role of Positive Interactions in Communities: Lessons from Intertidal Habitats.” *Ecology* 78 (7): 1976–89. https://doi.org/10.1890/0012-9658(1997)078[1976:TROPII]2.0.CO;2.

Bowkett, Andrew E., Francesco Rovero, and Andrew R. Marshall. 2008. “The Use of Camera-Trap Data to Model Habitat Use by Antelope Species in the Udzungwa Mountain Forests, Tanzania.” *African Journal of Ecology* 46 (4): 479–87. https://doi.org/10.1111/j.1365-2028.2007.00881.x.

Brooker, Rob W., Fernando T. Maestre, Ragan M. Callaway, Christopher L. Lortie, Lohengrin A. Cavieres, Georges Kunstler, Pierre Liancourt, et al. 2007. “Facilitation in Plant Communities: The Past, the Present, and the Future.” *Journal of Ecology* 0 (0): 070908024102002-??? https://doi.org/10.1111/j.1365-2745.2007.01295.x.

Buckley, Daniel H., and Thomas M. Schmidt. 2003. “Diversity and Dynamics of Microbial Communities in Soils from Agro-Ecosystems.” *Environmental Microbiology* 5 (6): 441–52. https://doi.org/10.1046/j.1462-2920.2003.00404.x.

Cadenasso, M.L, and S.T.A Pickett. 1995. “Landscape Ecology: Spatial Heterogeneity in Ecological Systems” 269 (5222). https://doi.org/10.1126/science.269.5222.331.

Dupuis-Desormeaux, Marc, Zeke Davidson, Mary Mwololo, Edwin Kisio, Sam Taylor, and Suzanne E. MacDonald. 2015. “Testing the Prey-Trap Hypothesis at Two Wildlife Conservancies in Kenya.” Edited by Stephanie S. Romanach. *PLOS ONE* 10 (10): e0139537. https://doi.org/10.1371/journal.pone.0139537.

Elmqvist, Thomas, ed. 2013. *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment ; a Part of the Cities and Biodiversity Outlook Project*. Springer Open. Dordrecht: Springer.

Ernst, Crystal M., Sarah Loboda, and Christopher M. Buddle. 2016. “Capturing Northern Biodiversity: Diversity of Arctic, Subarctic and North Boreal Beetles and Spiders Are Affected by Trap Type and Habitat.” Edited by Calvin Dytham and Thomas Bolger. *Insect Conservation and Diversity* 9 (1): 63–73. https://doi.org/10.1111/icad.12143.

Filazzola, Alessandro, Michael Westphal, Michael Powers, Amanda Rae Liczner, Deborah A. (Smith) Woollett, Brent Johnson, and Christopher J. Lortie. 2017. “Non-Trophic Interactions in Deserts: Facilitation, Interference, and an Endangered Lizard Species.” *Basic and Applied Ecology* 20 (May): 51–61. https://doi.org/10.1016/j.baae.2017.01.002.

Germano, David J., Galen B. Rathbun, Lawrence R. Saslaw, Brian L. Cypher, Ellen A. Cypher, and Larry M. Vredenburgh. 2011. “The San Joaquin Desert of California: Ecologically Misunderstood and Overlooked.” *Natural Areas Journal* 31 (2): 138–47. https://doi.org/10.3375/043.031.0206.

Ghazian, Nargol, Mario Zuliani, and Christopher J. Lortie. 2020. “Micro-Macro Climate Data for Shrubs and Artificial Shelters in Panoche Hills, California, USA, 2019.” Environmental Data Initiative. https://doi.org/10.6073/PASTA/A97A2785A17AFBA922CCB9E2229E0F83.

Guerreiro, Selma B., Chris Kilsby, and Hayley J. Fowler. 2017. “Assessing the Threat of Future Megadrought in Iberia: ASSESSING THE THREAT OF FUTURE MEGADROUGHT IN IBERIA.” *International Journal of Climatology* 37 (15): 5024–34. https://doi.org/10.1002/joc.5140.

Hadley, Neil F. 1970. “Micrometeorology and Energy Exchange in Two Desert Arthropods.” *Ecology* 51 (3): 434–44. https://doi.org/10.2307/1935378.

Harris, J. A. 2003. “Measurements of the Soil Microbial Community for Estimating the Success of Restoration: Microorganisms and Restoration Success.” *European Journal of Soil Science* 54 (4): 801–8. https://doi.org/10.1046/j.1351-0754.2003.0559.x.

Holzapfel, Claus, and Bruce E. Mahall. 1999. “BIDIRECTIONAL FACILITATION AND INTERFERENCE BETWEEN SHRUBS AND ANNUALS IN THE MOJAVE DESERT.” *Ecology* 80 (5): 1747–61. https://doi.org/10.1890/0012-9658(1999)080[1747:BFAIBS]2.0.CO;2.

Irwin, Mitchell T., Patricia C. Wright, Christopher Birkinshaw, Brian L. Fisher, Charlie J. Gardner, Julian Glos, Steven M. Goodman, et al. 2010. “Patterns of Species Change in Anthropogenically Disturbed Forests of Madagascar.” *Biological Conservation* 143 (10): 2351–62. https://doi.org/10.1016/j.biocon.2010.01.023.

Ivey, Kathleen N, Margaret Cornwall, Hayley Crowell, Nargol Ghazian, Emmeleia Nix, Malory Owen, Mario Zuliani, Christopher J Lortie, Michael Westphal, and Emily Taylor. 2020. “Thermal Ecology of the Federally Endangered Blunt-Nosed Leopard Lizard (Gambelia Sila).” Edited by Steven Cooke. *Conservation Physiology* 8 (1): coaa014. https://doi.org/10.1093/conphys/coaa014.

Karanth, K. Ullas. 1995. “Estimating Tiger Panthera Tigris Populations from Camera-Trap Data Using Capture—Recapture Models.” *Biological Conservation* 71 (3): 333–38. https://doi.org/10.1016/0006-3207(94)00057-W.

Kogan, Felix, and Wei Guo. 2015. “2006–2015 Mega-Drought in the Western USA and Its Monitoring from Space Data.” *Geomatics, Natural Hazards and Risk* 6 (8): 651–68. https://doi.org/10.1080/19475705.2015.1079265.

Lelièvre, Hervé, Gabriel Blouin-Demers, Xavier Bonnet, and Olivier Lourdais. 2010. “Thermal Benefits of Artificial Shelters in Snakes: A Radiotelemetric Study of Two Sympatric Colubrids.” *Journal of Thermal Biology* 35 (7): 324–31. https://doi.org/10.1016/j.jtherbio.2010.06.011.

Lortie, Christopher J., Eva Gruber, Alex Filazzola, Taylor Noble, and Michael Westphal. 2018. “The Groot Effect: Plant Facilitation and Desert Shrub Regrowth Following Extensive Damage.” *Ecology and Evolution* 8 (1): 706–15. https://doi.org/10.1002/ece3.3671.

Lundholm, Jeremy T. 2009. “Plant Species Diversity and Environmental Heterogeneity: Spatial Scale and Competing Hypotheses.” *Journal of Vegetation Science* 20 (3): 377–91. https://doi.org/10.1111/j.1654-1103.2009.05577.x.

Marion, G.M., G.H.R. Henry, D.W. Freckman, J. Johnstone, G. Jones, M.H. Jones, E. Lévesque, et al. 1997. “Open-Top Designs for Manipulating Field Temperature in High-Latitude Ecosystems.” *Global Change Biology* 3 (S1): 20–32. https://doi.org/10.1111/j.1365-2486.1997.gcb136.x.

Meyer, Susan E., and Burton K. Pendleton. 2005. “Factors Affecting Seed Germination and Seedling Establishment of a Long-Lived Desert Shrub (Coleogyne Ramosissima: Rosaceae).” *Plant Ecology* 178 (2): 171–87. https://doi.org/10.1007/s11258-004-3038-x.

Miriti, Maria N., S. Joseph Wright, and Henry F. Howe. 2001. “THE EFFECTS OF NEIGHBORS ON THE DEMOGRAPHY OF A DOMINANT DESERT SHRUB ( *AMBROSIA DUMOSA* ).” *Ecological Monographs* 71 (4): 491–509. https://doi.org/10.1890/0012-9615(2001)071[0491:TEONOT]2.0.CO;2.

Missa, Olivier, Yves Basset, Alfonso Alonso, Scott E. Miller, Gianfranco Curletti, Marc De Meyer, Connal Eardley, Mervyn W. Mansell, and Thomas Wagner. 2009. “Monitoring Arthropods in a Tropical Landscape: Relative Effects of Sampling Methods and Habitat Types on Trap Catches.” *Journal of Insect Conservation* 13 (1): 103–18. https://doi.org/10.1007/s10841-007-9130-5.

Moher, David, Alessandro Liberati, Jennifer Tetzlaff, Douglas G. Altman, and The PRISMA Group. 2009. “Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement.” *PLoS Medicine* 6 (7): e1000097. https://doi.org/10.1371/journal.pmed.1000097.

Molau, Ulf, and Per Molgaard. 1996. “International Tundra Experiment.” Danish Polar Center. https://www.gvsu.edu/cms4/asset/3A8AF24B-DDCC-71FD-83D796AFC483CEEF/itexmanualfull.pdf.

Nabhan, Gary Paul. 2013. *Growing Food in a Hotter, Drier Land: Lessons from Desert Farmers on Adapting to Climate Uncertainty*. White River Junction, Vt: Chelsea Green Pub.

Nopper, Joachim, Jana C. Riemann, Katja Brinkmann, Mark-Oliver Rödel, and Jörg U. Ganzhorn. 2018. “Differences in Land Cover – Biodiversity Relationships Complicate the Assignment of Conservation Values in Human-Used Landscapes.” *Ecological Indicators* 90 (July): 112–19. https://doi.org/10.1016/j.ecolind.2018.02.004.

Pearson, Dean E., Yvette K. Ortega, Özkan Eren, and José L. Hierro. 2018. “Community Assembly Theory as a Framework for Biological Invasions.” *Trends in Ecology & Evolution* 33 (5): 313–25. https://doi.org/10.1016/j.tree.2018.03.002.

Rovero, Francesco, and Andrew R. Marshall. 2009. “Camera Trapping Photographic Rate as an Index of Density in Forest Ungulates.” *Journal of Applied Ecology* 46 (5): 1011–17. https://doi.org/10.1111/j.1365-2664.2009.01705.x.

Sawyer, John O, Todd Keeler-Wolf, and Julie Evens. 2009. *A Manual of California Vegetation*. Sacramento, Calif.: California Native Plant Society Press. http://books.google.com/books?id=y40lAQAAMAAJ.

Shrode, Joy B., and Shelby D. Gerking. 1977. “Effects of Constant and Fluctuating Temperatures on Reproductive Performance of a Desert Pupfish, Cyprinodon n. Nevadensis.” *Physiological Zoology* 50 (1): 1–10. https://doi.org/10.1086/physzool.50.1.30155710.

Si, Xingfeng, Roland Kays, and Ping Ding. 2014. “How Long Is Enough to Detect Terrestrial Animals? Estimating the Minimum Trapping Effort on Camera Traps.” *PeerJ* 2 (May): e374. https://doi.org/10.7717/peerj.374.

Sudmeyer, R. A., M. C. Crawford, H. Meinke, P. L. Poulton, and M. J. Robertson. 2002. “Effect of Artificial Wind Shelters on the Growth and Yield of Rainfed Crops.” *Australian Journal of Experimental Agriculture* 42 (6): 841. https://doi.org/10.1071/EA02018.

Throop, Heather L., Lara G. Reichmann, Osvaldo E. Sala, and Steven R. Archer. 2012. “Response of Dominant Grass and Shrub Species to Water Manipulation: An Ecophysiological Basis for Shrub Invasion in a Chihuahuan Desert Grassland.” *Oecologia* 169 (2): 373–83. https://doi.org/10.1007/s00442-011-2217-4.

Verón, S.R., J.M. Paruelo, and M. Oesterheld. 2006. “Assessing Desertification.” *Journal of Arid Environments* 66 (4): 751–63. https://doi.org/10.1016/j.jaridenv.2006.01.021.

Waldrop, M. P., and M. K. Firestone. 2006. “Response of Microbial Community Composition and Function to Soil Climate Change.” *Microbial Ecology* 52 (4): 716–24. https://doi.org/10.1007/s00248-006-9103-3.

Webb, Robert H., and Steven S. Stielstra. 1979. “Sheep Grazing Effects on Mojave Desert Vegetation and Soils.” *Environmental Management* 3 (6): 517–29. https://doi.org/10.1007/BF01866321.

Wilson, Joseph S., Terry Griswold, and Olivia J. Messinger. 2008. “Sampling Bee Communities (Hymenoptera: Apiformes) in a Desert Landscape: Are Pan Traps Sufficient?” *Journal of the Kansas Entomological Society* 81 (3): 288–300. https://doi.org/10.2317/JKES-802.06.1.

Yahdjian, Laura, and Osvaldo E. Sala. 2002. “A Rainout Shelter Design for Intercepting Different Amounts of Rainfall.” *Oecologia* 133 (2): 95–101. https://doi.org/10.1007/s00442-002-1024-3.

Yang, Zhiyong, Xueqi Liu, Mohua Zhou, Dexiecuo Ai, Gang Wang, Youshi Wang, Chengjin Chu, and Jeremy T. Lundholm. 2015. “The Effect of Environmental Heterogeneity on Species Richness Depends on Community Position along the Environmental Gradient.” *Scientific Reports* 5 (1): 15723. https://doi.org/10.1038/srep15723.