**An examination of shrub and animal density-dependent interactions in desert ecosystems.**

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**Committee:**

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Table 1: Timeline for MSc Research

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| --- | --- | --- | --- | --- |
| **Chapter** | **Title** | **Progress** | **ST Goals** | **LT Goals** |
| 1 | Making a deal with the Devil | Literature review started September 2018 | Collect preliminary data and have reviewed/analyzed by December 2018/January 2019 | Analyses complete by July/August 2019. Draft by September 2019? |
| 2 | revise | Field Season to start May 2019 | Data analysis by September/October 2019 | Second field season May 2020? |

**Background**

Positive interactions between plant and animal species have been reported in most ecosystems globally. Positive interactions are defined as non-trophic interactions between species where at least one of the interacting species has a positive benefit towards their overall fitness, while the other remains unaffected (Bertness & Callaway 1994, Molina-Montenegro et al. 2016). While there are documentations of many types of interactions that are negative towards one species and positive towards the other, such as predation, a significant number of studies have arisen where only positive interactions are analyzed (Bertness & Callaway 1994, Kéfi et al. 2016). The term used to describe these positive interactions is facilitation where species interactions are usually beneficial to at least one of the species (Kikvidze & Callaway 2006, Kéfi et al. 2016). These positive interactions are also considered to be beneficial if only one of the species of the interaction is benefiting as long as the other is not experiencing any adverse negative effects that could hinder its survival (Bertness & Callawat 1994, Bruno et al. 2003, Grinath et al. 2012). In semi-arid/arid environments, it is proposed that these types of positive interactions, between plant-plant, plant-animal and animal-animal, often occur more frequently and are more prevalent (Holzaphel & Bruce 1999, Stachowicz 2001). In many of the cases where facilitation occurs in these arid/semi-arid environments, it has been proposed that without this interaction many species are dependent on this interaction for their survival (Holzaphel & Bruce 1999). Shrubs are able to facilitate these positive interactions either directly through shrub-animal-plant interactions or through a more indirect pathway being, shrub-plant-animal (Lortie et al. 2016). Shrubs can provide a variety of positive interactions for animals including; acting as a resource, protecting from predators and being a refuge for different species (Vázquez et al. 2009, Lortie et al. 2018). The shrubs can also indirectly benefit plant and animal species that take refuge under the canopy cover, by creating a microhabitat for these species (Noble et al. 2016). Species such as the blunt nosed leopard lizard depend on this type of interaction to cool during the warmer seasons (cite new Westphal paper that came out Friday instead). Animals interacting with the shrub can also act benefit the shrub by dispersing the shrubs seeds, pollinating the shrub, and by consuming herbivorous species or competitor species near the shrub (Vázquez et al. 2009, Lortie et al. 2016). This is term mutualism (cite Bronstein paper - Bronstein, J. L. 2009. The evolution of facilitation and mutualism. - Journal of Ecology 97: 1160-1170.

) then end with implication… so, are you planning on studying mutulism? The intro implies yes here but I am not sure you are…

Shrubs are able to provide these benefits to various animal species through different means (Bertness et al. 1997, Bortolus et al. 2002). Environments that display extreme conditions are excellent areas to display these types of positive interactions between shrubs and animal species (Bortolus et al. 2002, Hughes 2012, Filazzola et al. 2018). The resources, such as shelter and food, have a critical influence on the survival of a species and could impact the presence of the species and its total population (Hughes 2012, Rey et al. 2018). Shrubs act as keystone species in these types of arid environments allowing for facilitation with other shrub species (Filazzola & Lortie, 2014, Lortie et al. 2018). These types of positive interactions can be seen either having a direct interaction on animal species or by having an indirect interaction (Grinath et al. 2012, Lortie et al. 2016, Lortie et al. 2018). Not many indirect interactions, such as providing a microclimate, have been focused on, though they are considered to be very important for these types of beneficial interactions (Hughes 2012). Looking at the different ways in which shrubs are associated with this type of positive interaction could provide information necessary for proper restoration of these areas (Suding et al. 2004). Since facilitation can be seen through both direct and indirect effects between shrubs and animals, then is it possible that there could be a connection to shrub density and this type of interaction? revise

Shrub population densities could have a large impact on the interactions experienced by various different species both plant and animal (Springer et al. 2003, Tietje et al. 2008). Density is defined as the total number of individuals in a given area, or per unit area (Lyon 1968). From this we can define shrub density to be the total number of individual shrubs per unit area (Lyon 1968). Since these shrubs show interactions with other plants and animals (Hughes 2012), it is possible that the total density of these shrubs has an effect on the population densities of other species in the area. Some studies have shown that some species prefer shrub cover as opposed to open areas as they provide better microhabitats and movement trails (Stapp and Van Horne 1997). With this in mind, could the total shrub density, be seen as favorable for species? Cut out these Qs – sounds rhetorical and instead state research gap directly..Shrubs consist of a microclimate underneath their canopy cover, this cover proves to be favorable to many species, both plant and animal, which usually results in a larger animal density being noted (Hanley 1978, Koyama et al. 2015). In areas that are considered arid or semi-arid, shrubs that are found at low densities areas have a trend of increasing in overall density, which is especially seen after the cessation of disturbances (Musick et al. 1998). Animal density could be seen to alter as the shrub density fluctuates (Skarpe 1990). Populations of herbivores could potentially fluctuate with changes to woody shrub abundance, thus suggesting that there may be some connection between the two densities (Skarpe 1990).

OK – so I think intro could be tidied up a lot and reorganized.

Para 1 – positive interactions are…

Para 2 – positive interactions can be mutualistic with animals and also include indirect –put all together.

Then you need Para 3 – density dependence in ecology is… it is important because.. and we need to study plant-animal density interactions bc… etc..

The purpose of this experiment is to explore the relationship between the density of *Ephedra Californica* and the population densities of animal species with the local community. Interactions between these species will be analyzed as well as the correlation between shrub density and population density. better implication – NEED to know OPTIMAL shrub densities for restoration and management bc not cheap to do , need to know what to restore to, and need to know how much to protect. Also, need to know is there are ‘density hotspots’ within the region where foundation plant species and animal populations overlap – critical to know for landscape-level decisions.

**Chapter 1: Making a Deal with the Devil: A Systematic Review of the plant-animal interactions**

**Purpose:**

The purpose of the systematic review is to gain insight on relationship between shrub and animal densities that have been recorded in literature. The main focus will be to look at these papers where facilitation occurs and see if shrub density is recorded.

**Research Questions**:

What types of activities are occurring around shrubs? If there are interactions between species, then are there only beneficial interactions? Are the interactions having direct or indirect effects? Are the shrub densities measured in these studies?

**Predictions:**

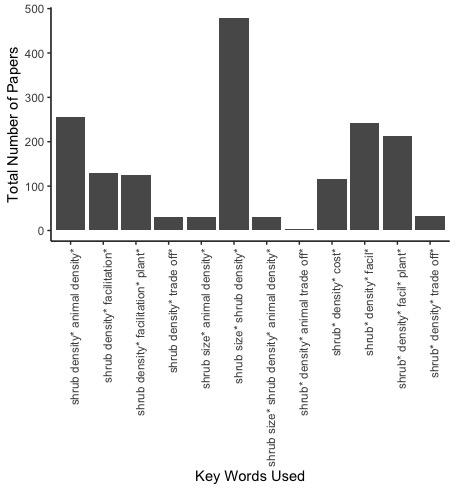
1. Many studies will primarily focus on benefits of benefactor interaction.
2. Costs to helper species replace with benefactor and protégé throughout please will be overlooked in most papers.
3. Shrub densities will not be focused on or recorded in many papers.

**Methods:**

Web of Science was used to acquire peer-reviewed articles that may have been relevant to the topic at hand. Key terms including; plant\*, facilitation\*, shrub\*, animal\*, and density\* will be used, in varying combinations, to find relevant articles. A bar graph was generated to display the number of papers corresponding to the variety of key words searched. In addition, a PRISMA diagram was generated to show the flow of filtering out papers that would be relevent to the synthesis of the chapter and those that would not be relevant for this particular study.

The papers acquired are loaded onto a digital library (Zotero) with other articles that may prove to be relevant. These articles will undergo a personal review and any that contain relevant content that may prove useful in answering the research questions will be saved and further analysis will be done. The papers must include interactions (direct, indirect or both), provide information on the population of the species in the area and must include coordinates and a biome relevant to the study.

**Progress to Date:**

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**Figure 1:** Bar plot displaying the key words used while searching Web of Science, and the resulting total number of papers.

Figure 1 displays the results of searching various key words, on the Web of Science data base, and the corresponding number of papers associated with each set. At a very large range, there are over 400 different types of papers, but once key words such as density\*, shrub density\*, animal density\* and trade off\* are added to the search, the total number of papers reduces to around 30 and less.

**Identification**

Papers obtained through searching Web of Science database.

Key Words:

density\* facilitation\* shrub

shrub\* density\* facilitate\*

density\* shrub\* animal\* facilitate\*

(n = 375)

Papers obtained from other sources, such as books and other databases

Records after duplicates removed

(n = 375

Items screened based on relevance to field of Ecology

(n = 278)

**Screening and Eligibility**

Items Excluded

(n = 97)

Items screened based on Abstract

(n = )

Items Excluded

(n = )

Items screened based on work mentioning shrub density with facilitation.

(n = )

Items Excluded

(n = )

**Included**

Items Included in final Synthesis

(n = )

Figure 2: PRISMA diagram (Moher et al, 2009) of workflow for plant-animal density systematic review.

**Chapter 2: Shrub and Animal Density Correlation in Desert Ecosystems**

**Site Location**

The Carrizo Plain is located in California’s San Joaquin Valley and is about a 190km drive south to Santa Barbara. Its coordinates are 35.1899° N, 119.8633° W. The area receives a very low amount of precipitation, just below 15cm. The total size of the site is approximately 820km2. The main area that will be focus on in the site is the Elkhorn Plains, which are located at the southeastern portion of the monument. The most dominant shrub in the area, and the one that is being focused on, is *Ephedra Californica*.

**Shrub Species**

*Ephedra Californica* is the dominant plant species in the Elkhorn plain. The species is seen as a foundation species important for the possible restoration of deserts in California (Lortie et al. 2017, Filazzola et al. 2018). The species has been seen to interact with other animal species within the Elkhorn plain including Blunt-nosed Leopard lizards (Noble et al. 2016), and Kangaroo rats (Prugh & Brashares, 2010). The Ephedra have positive interactions with many of the species in the Carrizo plain, primarily with the formation of burrows under its canopy cover, which are used as used for refuge from predators and as home burrows (Hawbecker 1951). After mechanical damage is inflicted on the *Ephedra Californica* species, it recovered even in periods of drought (Lortie et al. 2018). The interactions that are associated with this plant species, along with the population densities of the species that it interacts with, will be the major focus of the study.

**Purpose:**

The purpose of the experiment is to discover possible trends in shrub and animal population densities and to see if there is a correlation between the two densities. revise

**Research Questions:**

Is there a relationship between shrub density and animal population density in the Carrizo Plain? Do animal populations respond to shrub density? How are the varying populations of species interacting near the shrubs?

**Hypothesis**

There should be a correlation between shrub density and population density of other species, possibly due to beneficial interactions between the two groups. There may also be a relationship between varying species abundance. Weak – revise – hypothesis is statement of how a system works.

**Predictions:**

1. Higher Shrub density should correlates with a higher animal? species density.
2. High shrub density areas should have a larger number of animal visitations than the lower density shrub areas. Is this not the same as #1?
3. Camera will have more hits in the high shrub density areas nope same.

Revise

Need independent predictions.

Shrub and animal densities within a site are positively density dependent.

Higher shrub densities also increase animal species richness.

Then a third one? Annual plants? Or something about the measurement protocol? Or the importance of shrub size etc

**Treatments:**

* 2 Sites (On the Elkhorn Plains)
* Shrub vs Open
* Shrub Density (Low, Medium, high)
* 10 Replicates

**Methods:**

**Camera Traps and Density Mapping:**

The study site for this experiment will be the Carrizo Plain National Monument/Elkhorn Plains. I will examine species presence within the research site while taking into account the density of shrubs (mainly *Ephedra Californica*). Shrub densities will be determined via remote sensing analyses and field-based sampling of shrub densities. While determining shrub densities and site locations, presence and total number of burrows under the shrub canopy will be noted. The study site will be subdivided into smaller microsites where they will be classified depending on the total shrub density. This will range from High, Medium and low.

After searching through web of science for works that could potentially act as a guideline to establish gradient for high, medium and low density, it was found that none specifically create a set amount for this. There is limited reporting in the lit of shrub densities (Web of Science searchers). However, a paper Musick et al. (1998), looked at arid? woody shrub coverage and classified the percent coverage into 4 classes (1, 2, 3, 4). These classes went in increasing increments starting with <1% coverage of what?, representing class 1, and ending at > 25% coverage, representing class 4 (Musick et. Al 1998).Once the shrub densities have been determined and a corresponding gradient for Low, Medium and High density is established, camera traps will be deployed in the field. The Camera traps will be distributed at 2 separate study sites on the Elkhorn. The total number of cameras is as follows:

2 Sites x 3 density gradient (Low, Medium, High) X 2 (Shrub vs Open) x 10 Reps = 120 Sets of data

2 cameras will be placed at each study site, one looking towards the shrubs and the other away from the shrub, towards an “open” area. These traps will remain at the site untouched for a “Week” which will be classified as a 3 day cycle. Cameras will be set to the video function and will have a 5 second run time when triggered by movement. Once cameras have been removed and the corresponding SD cards are labeled and downloaded onto a hard drive, an excel sheet will be generated and used for data analysis. The sheet will consist of: date, rep, day, week, microsite (O/S), animal.hit, RTU, time.block, actual.time, start, stop, behavior, and observations. From there the total number of “hits” and “false hits” will be organized. From there an analysis will be conducted to show the total number of hits in the areas that are classified as High, Medium and Low shrub densities.

**Transect:**

In addition to camera traps, transects will be set up along the sites (High medium and low shrub density) to gather more measurements on shrub densities in the area, as well as observing any animal activity or presence along the transects. The total number of transects will be dependent upon the total number of microsites located/established which will be determined after the first visit in February. A 100m transect will be set up randomly along the site. From there, every 2 meters along the transect, the total shrub density will be recorded in a 10m radius. This will continue from 0m to 100m on the transect. GPS locations for the beginning and end of the transects will be taken and recorded. While continuing on the transect any animal observations will be noted on the corresponding section of the transect. Any animal activity must take place within the 10m Radius from the transect. Revise be more direct in language – state what you will do.

**Focal Observations:**

The Final portion of the study is to include several hours of focal observations. A few hours will be dedicate to each site where any observed animal will be recorded. Recordings including GPS location, which site the animal is found and activity will be noted. This will be conducted at the same time as the Camera traps are deployed in the field. Recordings will be taken whenever an animal is found during the observations. When found time will be noted as well as the type of animal, its behavior, its corresponding location, distance to shrub, and if possible how dense the shrubs are in the area.

**Progress to Date:**

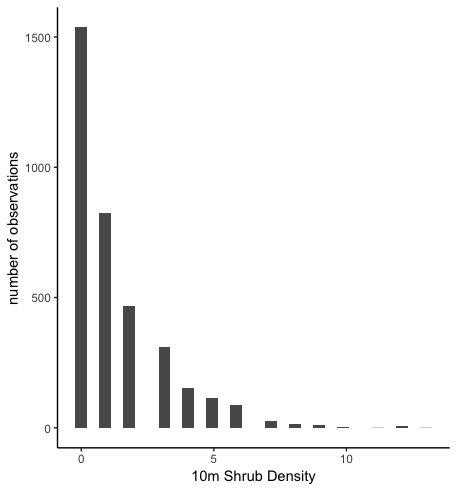


Figure 2: Total *Ephedra Californica* density in a 10m radius at site 4 in the Carrizo plain in 2016, 2017 and 2018.

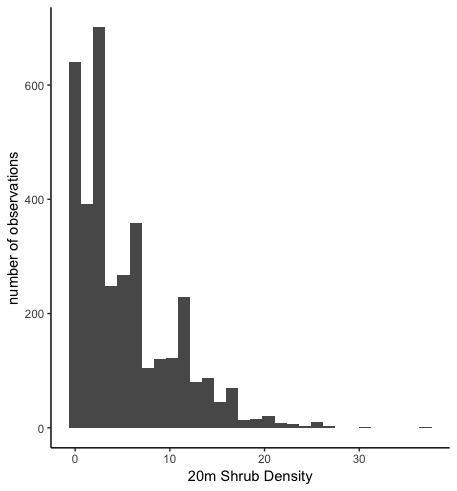
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Figure 4: Total *Ephedra Californica* density in a 20m radius at site 4 in the Carrizo Plain in 2016, 2017 and 2018.

The data for Figure 3 and Figure 4 were taken from shrub density measurements using ArcGIS imagery at the Carrizo National Monument. The total number of *Ephedra Californica* at varying sites, in a 10m radius (fig 3) shows that the mean number of shrubs found within a 10m radius is around 1. When the observation increases from 10m to 20m, we notice an increase in the number of shrubs that would be found in this radius. Figure 4 shows that this increase from observing density at 10m to 20m, increases the total density of the area. The average density when observing in this 20m radius was around 5 shrubs.

**Timeline:**

Table 2: Timeline for Chapter 2 Research.

|  |  |
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| **Timeline** | **Goals** |
| February 2019 | Travel to Carrizo study site to get preliminary data on potential sites. Pick potential sites. |
| March 2019 | Work with data collected from February trip. |
| April 2019 | Continue working with data collected from February trip, work on write up for Chapter 1 |
| May 2019 | Travel to Carrizo site, acquire camera traps and SD cards. Deploy cameras at sites (Chosen in February). Conduct focal observations and transects |
| June 2019 | Return from field site. Begin analyzing data from camera traps, transects and focal observations. Continue work on Chapter 1 if not yet completed |
| July 2019 | Continue working with dataset from May field month. Continue work on Chapter 1. |

Good.

**References:**

Bertness, Mark D., and Ragan Callaway. 1994. “Positive Interactions in Communities.” Trends in Ecology & Evolution 9 (5): 191–93.

Bertness, Mark D., and George H. Leonard. 1997. “The Role of Positive Interactions in Communities: Lessons from Intertidal Habitats.” Ecology 78 (7): 1976.

Bortolus, Alejandro, Evangelina Schwindt, and Oscar Iribarne. 2002. “Positive Plant-Animal Interactions in the High Marsh of an Argentinean Coastal Lagoon,” 11.

Bruno, J. F., Stachowicz, J. J., & Bertness, M. D. (2003). “Inclusion of facilitation into ecological theory.” Trends in Ecology & Evolution, 18(3), 119-125.

Filazzola, Alessandro, Amanda Rae Liczner, Michael Westphal, and Christopher J. Lortie. 2018. “The Effect of Consumer Pressure and Abiotic Stress on Positive Plant Interactions Are Mediated by Extreme Climatic Events.” New Phytologist 217 (1): 140–50.

Filazzola, Alessandro, and Christopher J. Lortie. 2014. “A Systematic Review and Conceptual Framework for the Mechanistic Pathways of Nurse Plants: A Systematic Review of Nurse-Plant Mechanisms.” Global Ecology and Biogeography 23 (12): 1335–45.

Grinath, Joshua B., Brian D. Inouye, Nora Underwood, and Ian Billick. 2012. “The Indirect Consequences of a Mutualism: Comparing Positive and Negative Components of the Net Interaction between Honeydew-Tending Ants and Host Plants: Decomposing a Net Indirect Interaction.” Journal of Animal Ecology 81 (2): 494–502.

Hanley, Thomas A. 1978. “A Comparison of the Line-Interception and Quadrat Estimation Methods of Determining Shrub Canopy Coverage.” Journal of Range Management 31 (1): 60.

Hawbecker, Albert C. 1951. “Small Mammal Relationships in an Ephedra Community.” Journal of Mammalogy 32 (1): 50.

Holzapfel, Claus, and Bruce E Mahall. 1999 “Bidirectional Facilitation and Interference between Shrubs and Annuals in the Mojave Desert,” 16.

Hughes, A. Randall. 2012. “A Neighboring Plant Species Creates Associational Refuge for Consumer and Host.” Ecology 93 (6): 1411–20.

Kéfi, Sonia, Milena Holmgren, and Marten Scheffer. 2016. “When Can Positive Interactions Cause Alternative Stable States in Ecosystems?” Edited by Francisco Pugnaire. Functional Ecology 30 (1): 88–97.

Kikvidze, Zaal, and Ragan M. Callaway. 2009. “Ecological Facilitation May Drive Major Evolutionary Transitions.” BioScience 59 (5): 399–404.

Koyama, A., T. Sasaki, U. Jamsran, and T. Okuro. 2015. “Shrub Cover Regulates Population Dynamics of Herbaceous Plants at Individual Shrub Scale on the Mongolian Steppe.” Edited by Francisco Pugnaire. Journal of Vegetation Science 26 (3): 441–51.

Lortie, Christopher J., Alessandro Filazzola, and Diego A. Sotomayor. 2016. “Functional Assessment of Animal Interactions with Shrub-Facilitation Complexes: A Formal Synthesis and Conceptual Framework.” Edited by Richard Michalet. Functional Ecology 30 (1): 41–51

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

Lyon, L. Jack. 1968. “An Evaluation of Density Sampling Methods in a Shrub Community.” Journal of Range Management 21 (1): 16.

Moher, David, Alessandro Liberati, Jennifer Tetzlaff, and Douglas G. Altman. 2010. “Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement.” International Journal of Surgery 8 (5): 336–41.

Molina-Montenegro, Marco A., Rómulo Oses, Ian S. Acuña-Rodríguez, Cristian Fardella, Ernesto I. Badano, Patricio Torres-Morales, Jorge Gallardo-Cerda, and Cristian Torres-Díaz. 2016. “Positive Interactions by Cushion Plants in High Mountains: Fact or Artifact?” Journal of Plant Ecology 9 (2): 117–23. https://doi.org/10.1093/jpe/rtv044.

Musick, H Brad, Gerald S Schaber, and Carol S Breed. 1998. “AIRSAR Studies of Woody Shrub Density in Semiarid Rangeland: Jornada Del Muerto, New Mexico,” 12.

Noble, Taylor J., Christopher J. Lortie, Michael Westphal, and H. Scott Butterfield. 2016. “A Picture Is Worth a Thousand Data Points: An Imagery Dataset of Paired Shrub-Open Microsites within the Carrizo Plain National Monument.” GigaScience 5 (1).

Prugh, Laura, and Justin Brashares. 2010. “Basking in the Moonlight? Effect of Illumination on Capture Success of the Endangered Giant Kangaroo Rat.” Journal of Mammalogy 91 (5): 1205–12.

Rey, P. J., I. Cancio, A. J. Manzaneda, A. González-Robles, F. Valera, T. Salido, and J. M. Alcántara. 2018. “Regeneration of a Keystone Semiarid Shrub over Its Range in Spain: Habitat Degradation Overrides the Positive Effects of Plant-Animal Mutualisms.” Edited by D. Byers. Plant Biology 20 (6): 1083–92.

Rowcliffe, J. Marcus, Juliet Field, Samuel T. Turvey, and Chris Carbone. 2008. “Estimating Animal Density Using Camera Traps without the Need for Individual Recognition.” Journal of Applied Ecology 45 (4): 1228–36.

Skarpe, Christina. 1990. “Shrub Layer Dynamics Under Different Herbivore Densities in an Arid Savanna, Botswana.” The Journal of Applied Ecology 27 (3): 873.

Springer, T. L., C. L. Dewald, P. L. Sims, and R. L. Gillen. 2003. “How Does Plant Population Density Affect the Forage Yield of Eastern Gamagrass?” Crop Science 43 (6): 2206.

Stachowicz, John J. 2001. “Mutualism, Facilitation, and the Structure of Ecological Communities.” BioScience 51 (3): 235.

Stapp, P., and B. Van Horne. 1997. “Response of Deer Mice (Peromyscus Maniculatus) to Shrubs in Shortgrass Prairie: Linking Small-Scale Movements and the Spatial Distribution of Individuals.” Functional Ecology 11 (5): 644–51

Suding, Katharine N., Katherine L. Gross, and Gregory R. Houseman. 2004. “Alternative States and Positive Feedbacks in Restoration Ecology.” Trends in Ecology & Evolution 19 (1): 46–53

Tietje, William D., Derek E. Lee, and Justin K. Vreeland. 2008. “Survival and Abundance Of Three Species Of Mice In Relation to Density Of Shrubs and Prescribed Fire In Understory Of An Oak Woodland In California.” The Southwestern Naturalist 53 (3): 357–69.

Vázquez, Diego P., Nico Blüthgen, Luciano Cagnolo, and Natacha P. Chacoff. 2009. “Uniting Pattern and Process in Plant–Animal Mutualistic Networks: A Review.” Annals of Botany 103 (9): 1445–57.