

2023

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Espinoza, Xavier O. (2023) "Understanding the Effect of Ranching on *Quercus Brandegeei* Recruitment in the Sierra La Laguna Biosphere Reserve," *DePaul Discoveries: Volume 12*, Article 11.

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Acknowledgements

The author acknowledges the financial support of an Undergraduate Summer Research Program (USRP) grant from DePaul University's College of Science and Health. The author also acknowledges the Morton Arboretum, its staff, and their collaborators who worked under the "Integrated Conservation of the Arroyo Oak in the Cabo Region, Mexico" conservation project for providing the data utilized in this study. The author acknowledges the community of San Dionisio for allowing us to observe their animals and for assisting in the regular maintenance of camera trap and fences.

Understanding the Effect of Ranching on *Quercus brandegeei* Recruitment in the Sierra La Laguna Biosphere Reserve

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ABSTRACT In this study, we attempt to deepen our understanding of the mechanisms responsible for *Quercus brandegeei*'s observed lack of regeneration by identifying which animal species (wild and domesticated) most frequently were observed eating, passing by, or searching for seeds and seedlings. We established 10 paired plots (10 enclosed and 10 immediately outside enclosures) and positioned one motion-activated camera in each plot to observe animal visitations to *Quercus brandegeei* individuals over the course of several months (October 2019 – March 2020). No seeds and seedlings survived outside of enclosed areas at the end of the study based on their absence. Very few seedlings survived within enclosures. We did not make any comparisons between enclosure and unenclosed plots because the enclosures were being used by another study to test the effect of shade on seedling development. We present data on animals with the most frequent visits, greatest time spent in the plots, and who were observed eating and searching for seedlings. We found that pigs had the highest absolute number of visits (2058) and total time spent in the plots (>1436 hours). Their activity was split equally between type of activity observed (33.3% eating, 33.3% searching, 33.3% passing). Sheep had the next highest visitation (1489) and time spent in the plots (>173 hours). They spent 75% of time eating and 25% passing. Our results indicated that seed predation/destruction from livestock affected *Q. brandegeei* regeneration more than seed predation/destruction from wild animal species. However, even if seedling mortality is disproportionately caused by livestock, the total absence of live seeds outside of the fenced areas may suggest a compounding effect with climatic factors like drying or human collection of seeds.

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Research Completed in Summer 2022

INTRODUCTION

Quercus brandegeei is an endangered oak tree endemic to Baja California Sur, Mexico. Despite one third of *Q. brandegeei*'s range falling within the protected sandy streambeds of the Sierra La Laguna Biosphere Reserve (SLLBR), fewer than 1,000 individuals remain and no regeneration has been observed in the past 100 years (Denvir et al., 2018). Since 2017, Dr. Silvia Álvarez-Clare and colleagues have collected genetic, phenological, and ecological data on *Q. brandegeei* to identify specific threats and guide conservation actions (Álvarez-Clare & M. Westwood, n.d.). Data indicates overgrazing of seeds and seedlings by livestock and wildlife may be preventing regeneration of this endangered species within the SLLBR (Álvarez-Clare & M. Westwood, n.d.). Overgrazing of *Q. brandegeei* seeds and seedlings will likely continue as the area has several ranching communities established long before the Biosphere became a protected territory in 1994 (Pío-León et al., 2017). According to the Comisión Nacional de Areas Naturales Protegidas in 2003, there are three times as many heads of cattle in the Biosphere than they would recommend for a protected natural area (Denvir & Westwood, 2016). The purpose of this study is to determine if and how the introduction of exotic livestock species has had an impact on the regeneration of *Q. brandegeei* populations by comparing the interactions of animal species introduced by ranching and wild animal species with *Q. brandegeei* seeds and seedlings. I hypothesize that predation of fallen acorns and developing seedlings is the mechanism responsible for restricting regeneration of *Quercus brandegeei* populations. I also hypothesize that domesticated animal species prey on acorns and seedlings at higher rates than wildlife, including endemic animal species.

METHODS

Study Area

The Sierra La Laguna Biosphere Reserve (SLLBR), established in 1994, is located on a mountain range with two recognized zones. The core zone encapsulates the areas with the highest altitude. This area features a temperate climate

and abundance of pine-oak forests. Mule deer, an ungulate endemic to the Biosphere, prefer the conditions of the core zone and mostly reside here. The buffer zone refers to the lower altitude parts of the Biosphere. This zone features an arid and warm climate. *Q. brandegeei* grows in tropical dry forests of the buffer zone. Populations of *Q. brandegeei* tend to grow in sandy soils of the Baja California Peninsula near ephemeral rivers. The ranching communities of the Biosphere Reserve represent the legacy of Jesuit missionaries who arrived at the peninsula in the 16th century (Pío-León et al., 2017). Geospatial information indicates that these communities are concentrated in the buffer zone, often near a permanent source of water (Galina-Tessaro et al., 2019). A ranching community by the name of San Dionisio is located near an ephemeral river where several *Q. brandegeei* have established on its banks. We conducted this study in the San Dionisio community because it represents the ranching tradition of the region and its interactions with *Q. brandegeei* would be typical of the Biosphere Reserve (Figure 1).

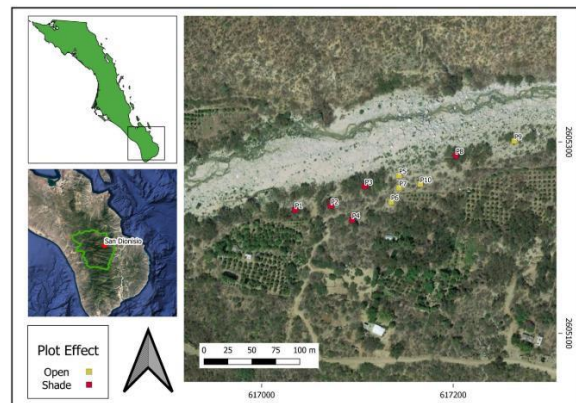


Figure 1. Map of the Sierra de la Laguna Biosphere Reserve. The map shows “plot effects” but no distinctions were made between open and shaded plots for this study. Map courtesy of Daniel Perez Morales.

Data Collection

We monitored activity patterns of several animals, domestic and wild, within the San Dionisio community in the SLLBR. This location is important because it represents a ranching-based system that is representative of family and community livelihoods in the reserve (Galina-Tessaro et al., 2019; Pío-León et al., 2017). We

installed ten paired plots with motion-activated cameras in each plot at the San Dionisio site to observe and record animal visitation to fallen *Quercus brandegeei* seeds and developing seedlings. One plot in each pair was enclosed to prevent the entrance of large and small animals. The cameras remained active throughout every hour of every day of the observation period (October 2019 – March 2020), but only photographs taken on Mondays, Thursdays, and Saturdays from 12:00 AM to 11:59 were used for analysis. We limited our data to these days and timings because of time and labor constraints brought on by the COVID-19 pandemic in Mexico. However, we believe that these photographs provide sufficient insight regarding the visitation patterns of local wildlife to *Q. brandegeei* and the effect that it has on their regeneration. Records of visitation include plot number, date, day, start time of visit, end time of visit, total time spent during a visit, an initial photo reference number, a range of photo reference numbers for the multiple photographs taken during a single visit, the common name of the species, the scientific name of the species, the number of individuals present during the visit, and type of activity this species was engaging in. The photographs had a timestamp which allowed us to determine when an individual or group arrived and when the individual or group left. Animal activity was determined through visually observable behavior from the photographs. For example, we considered an animal to be “eating” if their head was down near the ground for more than thirty seconds. Some of the animal activity could not be determined due to limited field of view or obstructions at the time the photograph was taken. In such cases, an animal is recorded as present, but their activity is not included in the data. The size of the animal had no effect on our ability to identify an animal and determine its activity.

Data Analysis

The total number of visits to *Q. brandegeei* across all plots for a particular species was determined by taking the sum of all sightings of that species in every plot from October 2019 to March 2020. Groups were counted based on the number of individuals observed at the time of visit; repeat

visitation for any individual is likely. Therefore, this number does not represent the total number of livestock present in San Dionisio. For any instance, the total time spent visiting *Q. brandegeei* was calculated using the difference between the time of entry and the time of exit. The total time spent visiting *Q. brandegeei* across all plots for a particular species was determined by adding up the total time spent of every instance of that species in every plot. For instances where we observed a group, the total time spent is shared by the group as a single instance. Once the totals for visitation and total time spent were obtained, we were able to determine how much time each animal species spent engaging in a specific activity. The most common activities were eating, searching, or passing so only those activities were listed. No distinction was made between enclosed and unenclosed plots.

RESULTS

A total of eleven animal species were observed during the study (Table 1). However, since many of the species were infrequent visitors and spent little time in the plots (Figures 2 & 3), we present our results for the five species that spent the most time in the plots: the Pig (*Sus scrofa domestica*), the Sheep (*Ovis aries*), the Cow (*Bos taurus*), the Baja California Grey Fox (*Urocyon cinereoargenteus peninsularis*), and the White-winged Dove (*Zenaida asiatica*). Pigs were the top visitor by frequency and time spent in the study area (Table 1). Pigs spent their time equally split between eating, passing, or searching (Figure 4). Sheep were the next top visitor by frequency and time spent in the study area (Table 1 & Figure 4). Cows were the third most frequent visitor and fifth in terms of time spent near *Q. brandegeei* (Table 1 & Figure 4). Grey foxes were our fourth most frequent visitor and were third in terms of overall time spent just above cows (Table 1). Grey foxes spent their time evenly between searching and passing (Figure 4). White-winged doves were our fifth most frequent visitor fourth in terms of absolute time spent near *Q. brandegeei* (Table 1). Out of their total time spent in the study area, 90% of their observed activity was eating while the rest of the time was passing (Figure 4). Census data for transplanted seedlings in enclosed areas (Maddie Fernandez-

Laris, 2021) showed that 21% of all *Q. brandegeei* seedlings in enclosed plots had evidence of herbivory around the same time we observed visitation by white-winged doves. However, since dove visitations occurred some

time between census data collections, we could not determine whether seedling mortality inside the enclosures can be attributed solely to white-winged doves.

Data

Animals	Total Visits	Time Spent in Plots (Hours:Minutes:Seconds)
Pig	2058	1436:44:18
Sheep	1489	173:03:51
Cow	208	46:13:50
Grey Fox	142	109:58:52
Dove	83	68:03:13
Chicken	23	2:24:03
Dog	12	0:40:50
Horse	11	1:23:33
Donkey	7	0:16:26
Cat	7	0:00:06
Mule	2	0:00:01
Grand Total	4042	1838:49:03

Table 1. Eleven animal species observed visiting *Q. brandegeei* from October 2019 through March 2020. The first column shows the total number of individuals from each species that were observed during visits. The second column shows the total time each species spent during their visits in hours, minutes, and seconds.

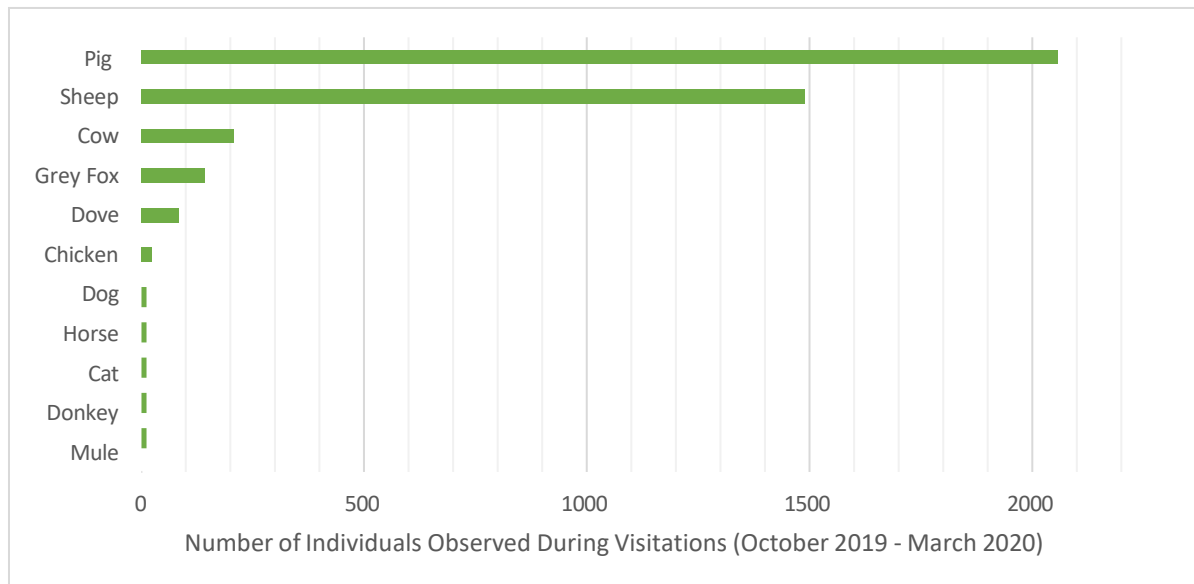


Figure 2. Number of individuals from each animal species observed visiting *Q. brandegeei* sites from October 2019 through March 2020.

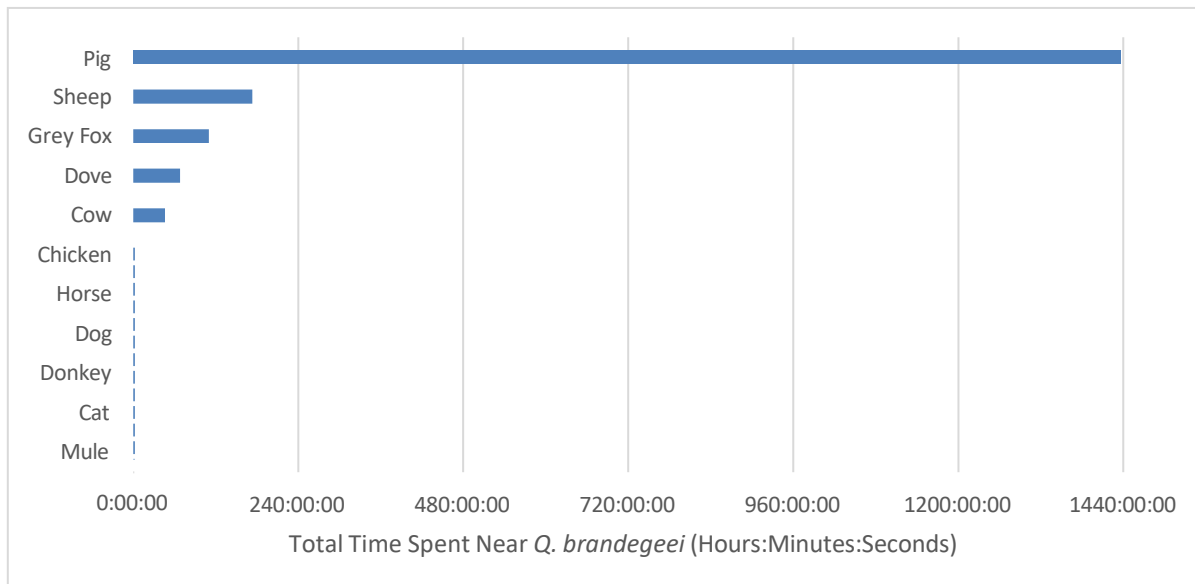


Figure 3. Total amount of time each animal species spent visiting *Q. brandegeei* sites from October 2019 through March 2020.

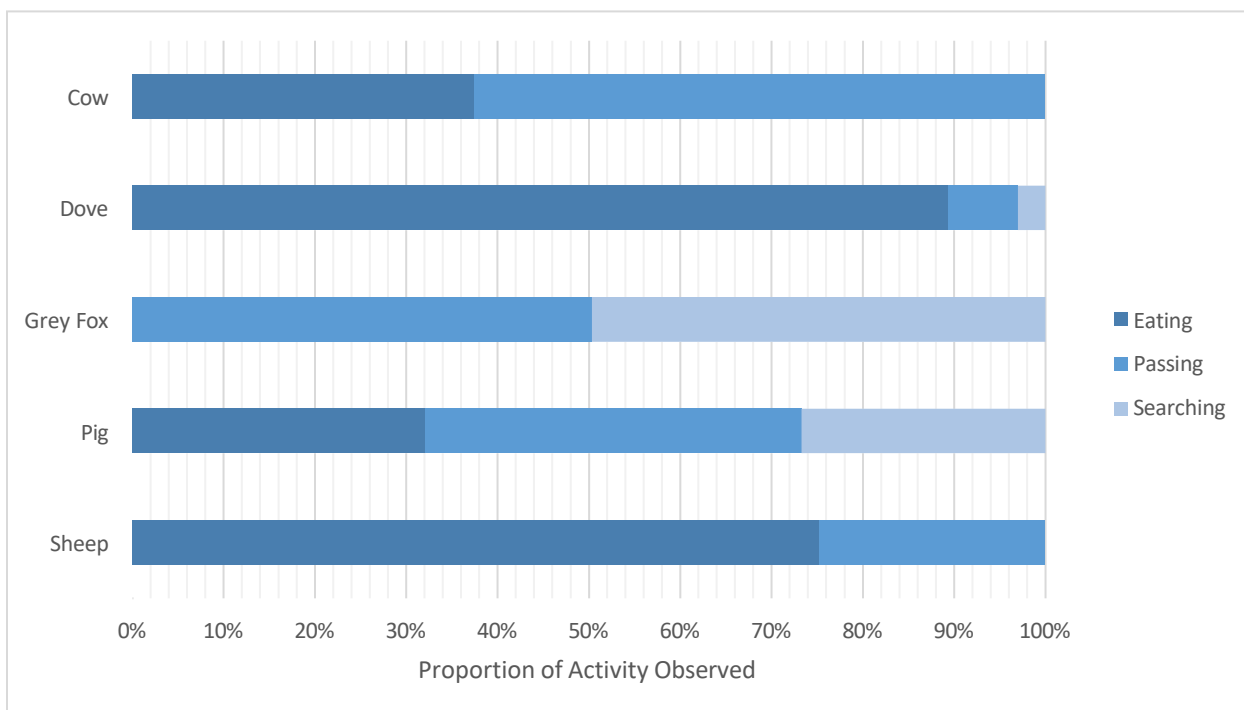


Figure 4. Proportion of total time each animal species spent engaging in one of three activities: eating, passing, and searching.

DISCUSSION

Pigs and sheep were frequent visitors who spent most of their time engaging in activities that pose the most risk to *Q. brandegeei* populations: eating and searching. Both activities are related to the

causes of seedling mortality in *Quercus pyrenaica* and *Quercus suber* L., two species of Mediterranean oak under conditions similar to those experienced by *Quercus brandegeei* (Galina-Tessaro et al., 2019; Gómez et al., 2003). In the studies of *Q. pyrenaica* and *Q. suber* L,

vertebrate animals such as feral pigs and bovines contributed to the removal and/or consumption of oak acorns. The visitation behaviors we observed in our study align with the patterns leading to seed mortality in the studies of the two Mediterranean oaks. Pigs and sheep contribute the most to seed mortality in *Quercus brandegeei* populations through the removal and/or consumption of the species' acorns. A description of a pig's diet from the Sierra La Laguna Biosphere Reserve confirms the presence of oak seeds in the stomachs of these animals (Galina-Tessaro et al., 2019). A subsequent analysis of pig stomach contents described in the same article suggests that oak acorns were the fourth highest percentage in diet volume at 10% between 2010 and 2011 when they were tested (Galina-Tessaro et al., 2019). Our study indicates that pigs are of concern for their consumption of both oak seeds and developing oak seedlings. Despite spending more time passing than eating at *Q. brandegeei* locations, cows remain an important contributor of seed/seedling mortality because of their potential to trample plants while they pass or search in areas where *Quercus brandegeei* reside

(Galina-Tessaro et al., 2019; Gómez et al., 2003; Herrera, 1995). Based on our observations and observations made by Maddie Fernandez-Laris, white-winged doves may be consuming seedlings in enclosed areas where larger animals are not able to reach. Grey foxes were never observed eating during their visits. Given their size it is unlikely that they are capable of trampling *Quercus brandegeei*. Studies of similar design and focus, along with our results, point towards seed predation/destruction from livestock affecting *Q. brandegeei* regeneration more than seed predation/destruction from wild animal species. We found a similar result with seedling mortality. However, even if seed and seedling mortality is disproportionately caused by livestock, the total absence of live seeds outside of the fenced areas may suggest a compounding effect with climatic factors like drying or human collection of seeds. Indeed, a study on the phylogeny of American live oaks by Cavender-Bares et al (2015) referenced climatic factors to explain the absence of seedling recruitment and juvenile regeneration in populations of *Quercus brandegeei* in the Sierra La Laguna Biosphere.

ACKNOWLEDGEMENTS

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