Analysis of the Seasonal Activity Rate of Sympatric Carnivores and their Prey in Saguaro National Park

Mary Beth Benton
Saguaro National Park, Tucson, Arizona

Siria A. Cerda-Navarro, Katie R. Keck, and Brittany N. McKnight
University of Arizona, Tucson, Arizona

Abstract—*We investigated the monthly activity rates of bobcats (Lynx rufus), gray foxes (Urocyon cinereoargenteus) and four of their potential prey species, antelope jackrabbits (Lepus alleni), black-tailed jackrabbits (Lepus californicus), desert cottontails (Sylvilagus audubonii) and eastern cottontails (Sylvilagus floridanus), in Saguaro National Park using remote camera trap data. We analyzed images taken over an 11-month period and over 10,000 camera nights and compared the time of day, month, and location of photographs of bobcats, gray foxes and four lagomorph species. Our findings suggest that bobcats and gray foxes are successful sympatric species for much of the year, but during the autumn and winter seasons gray fox activity increased as a result of reduced food availability. Lagomorph activity also changed in the winter, when both jackrabbit species and desert cottontail rabbit activity decreased, while eastern cottontail activity increased, in a manner that was quite similar to that of gray foxes. Lagomorph activity may be influenced by the activity of their predators. Knowledge of how mammals utilize the landscape of Saguaro National Park will enable wildlife managers to implement more effective conservation and management strategies.*

Introduction

Sympatry among animals has become more prevalent due to habitat loss, urbanization, and expansion of natural distributions (Chamberlain and Leopold 2005). Sympatry often results in competition among animals due to the use of shared resources. Niche segregation of resources can occur in areas where sympatry is pronounced. Fedriani and others (1999) found that three sympatric carnivores—Iberian lynx (*Lynx pardinus*), Eurasian badger (*Meles meles*), and red fox (*Vulpes vulpes*)—altered their activity patterns to avoid overlap in resource utilization. The potential for competition among species that overlap in geographic range is increased when species are comparable in body size and engage in similar feeding habits (Barrientos and Virgós 2006). In the Sky Island region of southern Arizona, two sympatric carnivore species—bobcat (*Lynx rufus*) and gray fox (*Urocyon cinereoargenteus*)—consume similar prey species such as lagomorphs and ground dwelling rodents (Fritzell and Haroldson 1982; Larivière and Walton 1997). Bobcats and gray foxes inhabit relatively similar environments. In Arizona, these two species can be found in mixed forests, rocky outcrops, and brush areas from elevations up to 3,000 m or more (Tekiela 2008).

One such area in the desert southwest where bobcats and gray foxes co-occur is Saguaro National Park in Tucson, Arizona. Both species are prevalent within the park, where Benton and others (unpublished data) found that their temporal and spatial distributions overlap extensively. Riley (2006) argues that bobcats are more affected by proximity to urbanization than gray foxes. Gray foxes have often been documented entering developed areas and their home ranges typically occupy urban locations whereas bobcats rarely enter developed areas and have been shown to avoid crossing paved roads (Riley 2006). These patterns are likely caused by differences in diet and the social system of the species. Although gray foxes and bobcats tend to prey on small rodents, bobcats are strictly carnivorous whereas gray foxes are omnivorous (Riley 2006). Riley (2006) states that this more flexible use of the landscape allows gray foxes easier access to increased resources and habitat whereas bobcats' sensitivity has put them at risk to decreased viability in urban-protected zone interfaces. The trend described by Riley (2006) does not apply in Tucson, Arizona, where bobcats are found not only in the wilderness areas of Saguaro National Park but also in adjacent neighborhoods and deeper into the suburban sprawl of the community (Haynes and others 2010). The large population of mountain lions in Saguaro National Park may be influencing the movement of bobcats into urban areas and could be one indication as to why so few bobcats are seen on wildlife cameras. While coyotes have been shown to kill gray foxes (Neale and Sacks 2001), the interactions between these canid species may not be as severe as the interactions between felid species in Saguaro National Park. The interspecific relationships of apex predators and mesopredators impact the behavior of animals at every trophic level; therefore, it is important to understand these patterns in order to appropriately manage and conserve mammalian wildlife.

Antelope jackrabbits (*Lepus alleni*), black-tailed jackrabbits (*Lepus californicus*), desert cottontails (*Sylvilagus audubonii*), and eastern cottontails (*Sylvilagus floridanus*) are commonly occurring lagomorphs found in Saguaro National Park. Although the park has not collected a

In: Gottfried, Gerald J.; Ffolliott, Peter F.; Gebow, Brooke S.; Eskew, Lane G.; Collins, Loa C., comps. 2013. Merging science and management in a rapidly changing world: Biodiversity and management of the Madrean Archipelago III; 2012 May 1-5; Tucson, AZ. Proceedings. RMRS-P-67. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

specimen to confirm the identity of the eastern cottontail, this species is most likely to be the cottontail that is often observed at higher elevations in the park (Swann 2011). The temporal and spatial distributions of these species demonstrate their sympatry and overlaps in activity with bobcats and gray foxes (Benton and others, unpublished data). The lagomorphs of Saguaro National Park are herbivorous species whose diet consists of green plants and some cactus fruits in spring and summer and other woody plants and berries in winter (Tekiela 2008). These lagomorphs inhabit similar areas ranging from deserts and grasslands to woodland thickets (Tekiela 2008).

The Sonoran desert experiences five seasons every year. Foresummer in May and June, when this study began, brings high temperatures, low humidity, and typically no rain. Most plants and animals are dormant during this time, due to the lack of available surface water (Phillips and Comus 2000). The summer monsoon season—early-July through mid-September—is distinguished by high temperature, high humidity, and frequent thunderstorms and corresponds with the second and main growing and flowering season for much of the plant community (Phillips and Comus 2000). Autumn—October and November—is typically warm, with low humidity and very little rain and triggers the growing season of the annual plant community (Phillips and Comus 2000). Winter—December and January—is characterized by mild temperatures and sunny days and gentle rains (Phillips and Comus 2000). Spring—early February through April—when this study was completed, is characterized by mild temperatures and little rainfall, and accounts for the first flowering season of the year (Phillips and Comus 2000). The differences in the availability of flowers, grasses, and fruits to gray foxes and lagomorphs during each season in the Sonoran desert may influence the rate of activity of these species as well as the rate of activity of their conspecifics and predators.

The goal of this study was to determine whether bobcat and gray fox activity in Saguaro National Park differs during certain periods of the year based on dietary differences. Additionally, we were interested in how bobcat and gray fox activity affects the seasonal activity of lagomorphs. We tested several hypotheses using images from wildlife cameras that were captured by a Saguaro National Park wildlife camera program conducted from May 2011 through March 2012. We predicted that the activity patterns of bobcats and gray foxes would be similar during the foresummer, summer monsoon, and autumn seasons due to their sympatric nature. However, during the winter we predicted that gray fox activity would shift when supplementary food resources, such as fruits, were not available. In addition, we predicted that lagomorph activity would increase during the foresummer, summer monsoon, and autumn when gray foxes have supplementary food sources, and decrease in late autumn and winter when fox predation intensifies.

Methods

Study Area

Saguaro National Park is approximately 37,000 ha and is divided into two districts: Rincon Mountain District and Tucson Mountain District (fig. 1). Rincon Mountain District (RMD) lies 32 km east of the center of Tucson and is the larger of the two districts. Elevation ranges from 664 m to 2,641 m and the dominant plant communities include thorn-scrub, chaparral, grasslands, and temperate coniferous forests. Tucson Mountain District (TMD) lies 24 km west of the center of Tucson and ranges in elevation from 668 m to 1,498 m. Dominant

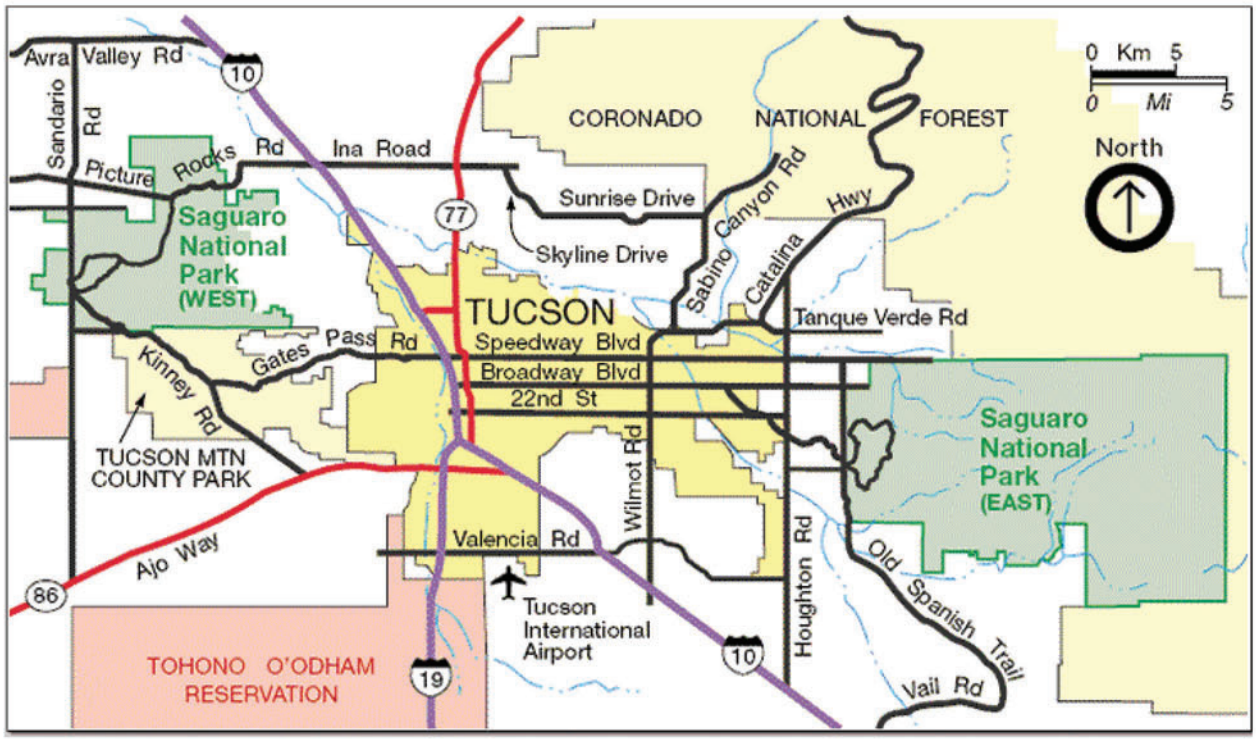

Figure 1— Map of Saguaro National Park in Tucson, Arizona. The distance between the Rincon Mountain District (east) and the Tucson Mountain District (west) is 24 km.

plant communities include those that are characteristic of the Sonoran desert ecosystem.

Data Collection

Saguaro National Park began a year-long study in May 2011 using wildlife cameras to determine species richness and species occupancy within the park. Saguaro National Park made these data available to us for use in better understanding the monthly activity rates of bobcats, gray foxes, and lagomorphs. The park used *Cuddeback Capture* units, white flash heat, and motion sensor digital wildlife cameras under a study design where both districts of the park were divided into 1-km^2 plots using a grid feature in the Hawths tool set of ArcMap, a geospatial processing program. Plots were randomly located and distributed among four elevation gradients: 0-914 m, 914-1,524 m, 1,524-2,134 m, and greater than 2,134 m. Any plot containing more than 50% land outside the park boundary was removed from the data set. The steeper Rincon Mountain District (RMD) was divided into four strata, while the Tucson Mountain District (TMD) was divided into two strata. Fifteen plots were chosen in each stratum using a random selection tool in Hawths tools. Camera locations were randomly selected using ArcMap as well. On a rotational basis, two plots in each stratum had four cameras set, no less than 200 m apart, for periods of 6 weeks. The strategy to keep the camera points random, without human bias, was to place them within 20 m of the randomly selected coordinate. The study resulted in a total of 10,338 camera nights throughout Saguaro National Park, including 3,527 nights in strata 1; 3,361 nights in strata 2; 1,652 nights in strata 3; and 1,798 nights in strata 4 (66.4% of these nights were in the Rincon Mountain District and 33.6% in the Tucson Mountain District). For personnel and camera safety, we occasionally used alternative random points (e.g. if the point fell on the side of a cliff). Cameras were set using metal stakes and nylon straps, and were placed as close to the random points as possible in an open area in hopes of increasing the probability of detection of an animal if it was present. The cameras were programmed to sense heat and motion at a 14° angle from the IR sensor, up to a distance of 10 m. The date and time were programmed on each camera and a 30-second timer was engaged, meaning that when the camera detected movement and a difference in heat gradient, a photograph would be captured every 30 seconds.

Approximately every 2 weeks, resource management staff and volunteers checked each camera to collect images, solve trouble-shooting issues, replace batteries, and assure camera placement was still intact. Photos were extracted from SD cards and downloaded to an MP3 player for backup. These data were then brought back to the office to save images and ensure data security, enter data, and analyze photos. The date, time, location, species, and number of individuals associated with each photo were recorded into the park's wildlife camera database. The captured images were analyzed using graphs to observe patterns and trends.

This study was solely descriptive as we searched for patterns in activity between bobcats, gray foxes, and their potential prey animals. First, we summarized monthly numbers of photographs of bobcats, gray foxes, and lagomorphs. Total capture numbers for each species were not equivalent; therefore, we standardized monthly activity rates using proportions of photographs. Figure 2 illustrates a total of 257 gray fox images, compared to 67 bobcat images. Figure 3 demonstrates a total of 959 desert cottontail images; compared to 62 eastern cottontail images, 342 antelope jackrabbit images, and 495 black-tailed jackrabbit images. Each month's number of captures was divided into the total number of captures for that species to create the y-axis proportion of photographs. This method allowed for efficient visual representation of patterns between our focal species. Graphing the monthly activity of bobcats, gray foxes, and lagomorphs allowed us to explore potential explanations for differences in mesopredator activity during specific seasons or months.

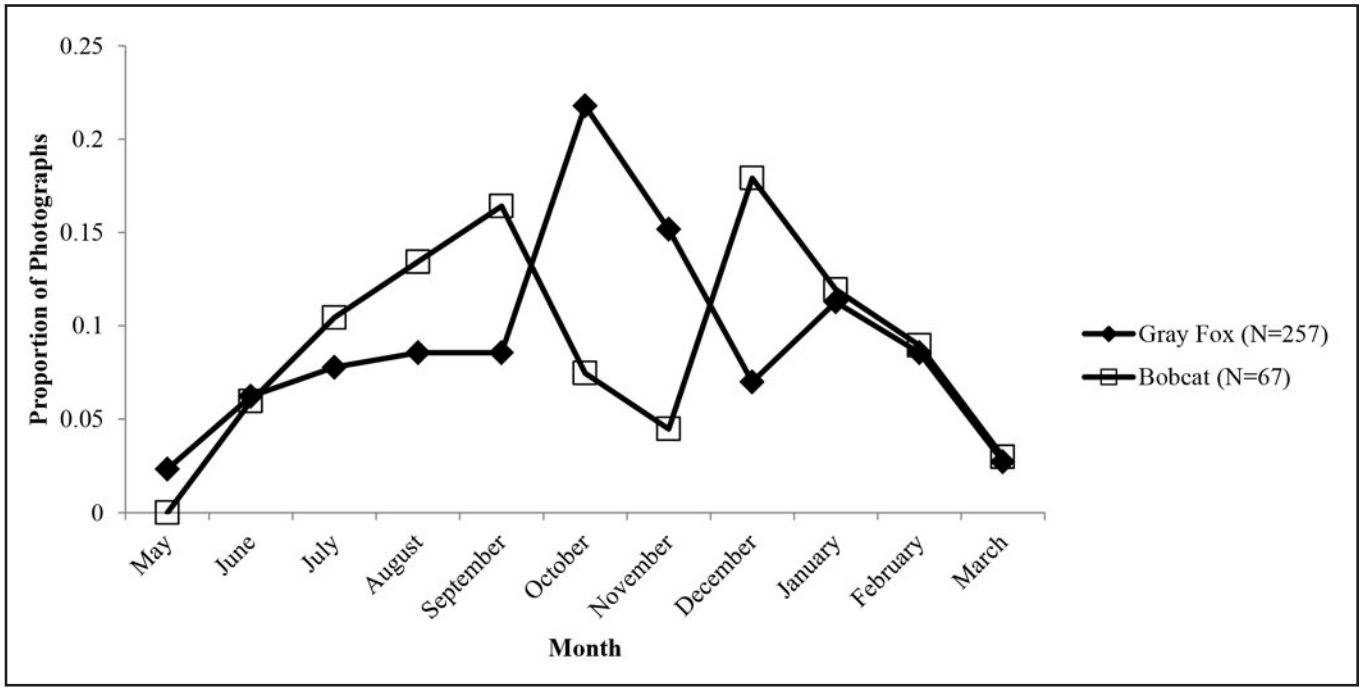

Figure 2— Monthly activity rate of bobcats and gray foxes in Saguaro National Park as determined by proportion of photographs.

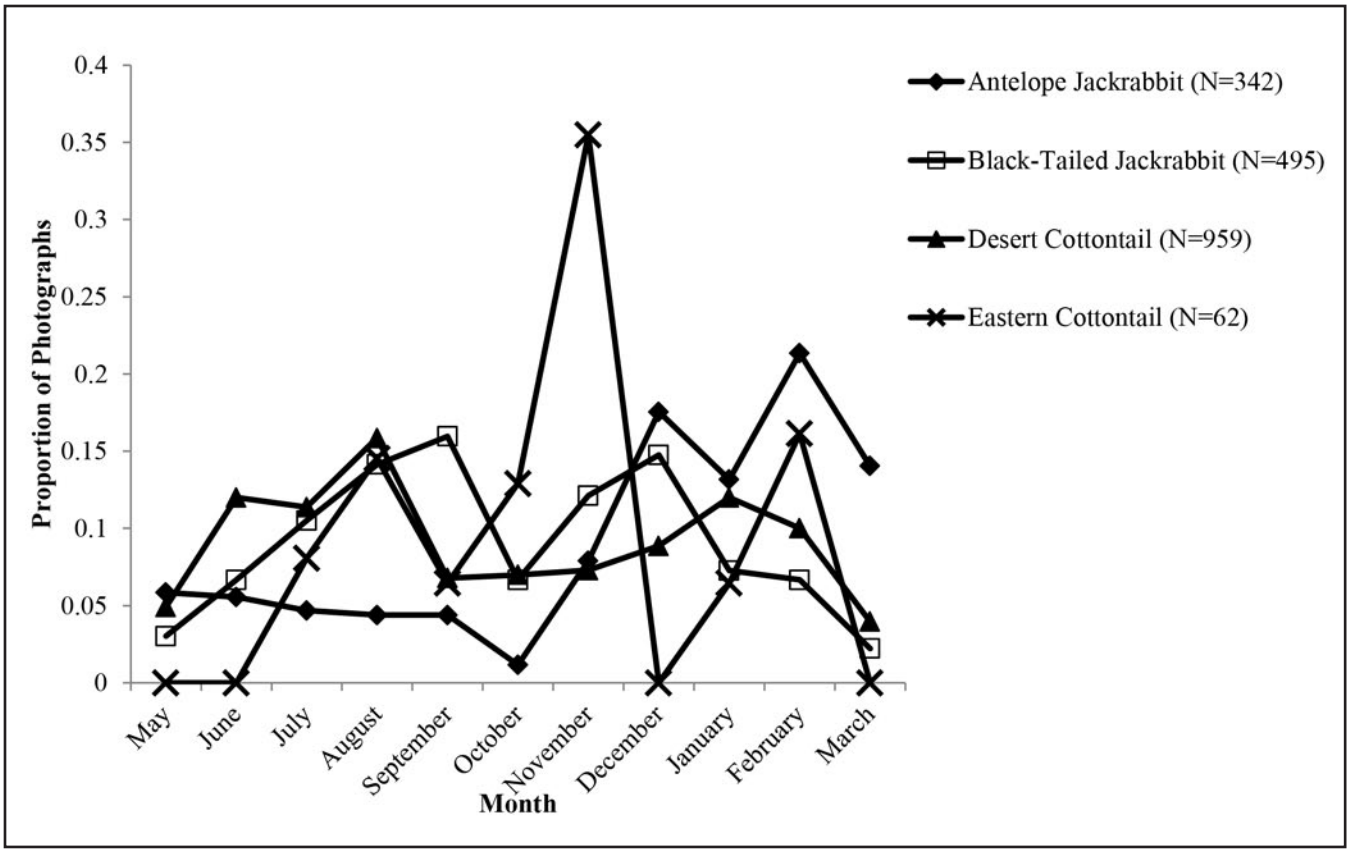

Figure 3—Monthly activity rate of lagomorphs in Saguaro National Park as determined by proportion of photographs.

Results

The total number of images of bobcats, gray foxes, and four lagomorph species captured over an 11-month period in Saguaro National Park were organized in table 1. As demonstrated in figure 2, activity of gray foxes was relatively low beginning in the foresummer when the study began and remained low throughout the summer monsoon season. Activity rates of gray foxes increased dramatically in the month of October, but decreased from November through March. Figure 2 also illustrates that bobcat activity was high from May through September, but decreased dramatically in October and November, before peaking again in January and decreasing between January and March. Figure 3 shows that black-tailed jackrabbit activity patterns mimic those of bobcats very closely. Black-tailed jackrabbit activity was high from May through September, before decreasing dramatically in October, then peaking again in December and decreasing from December through March. Desert cottontail rabbit activity was also high during the foresummer and part of the summer monsoon

Table 1—Monthly activity rates of bobcats, gray foxes, desert cottontails, eastern cottontails, antelope jackrabbits, and black-tailed jackrabbits in Saguaro National Park as determined by proportion of photographs taken between May 2011 and March 2012

Month	Bobcat	Gray Fox	Desert Cottontail	Eastern Cottontail	Antelope Jackrabbit	Black-tailed Jackrabbit
May	0	6	47	0	20	15
June	4	16	115	0	19	33
July	7	20	109	5	16	52
August	9	22	152	9	15	70
September	11	22	65	4	15	79
October	5	56	67	8	4	33
November	3	39	70	22	27	60
December	12	18	85	0	60	73
January	8	29	115	4	45	36
February	6	22	96	10	73	33
March	2	7	38	0	48	11
Total	**67**	**257**	**959**	**62**	**342**	**495**

season, before decreasing in September. Unlike black-tailed jackrabbit activity, desert cottontail activity did not increase again in the winter, but rather it remained relatively low throughout the autumn, winter, and spring seasons. Antelope jackrabbit activity was low and constant throughout the foresummer and summer monsoon and their activity was nearly undetectable in October before increasing between the months of October and March. During the foresummer, eastern cottontail activity was undetectable. In July and August eastern cottontail activity increased, before going down in September and spiking substantially in November. Immediately following the spike in activity in November, eastern cottontail activity was undetectable in December. From January to February eastern cottontail activity increased before it was undetected again in March.

Discussion

By capturing images of bobcats and gray foxes in the same areas at approximately the same times, our results indicate that bobcats and gray foxes are sympatric carnivores in Saguaro National Park for a large portion of the year; however, as seen in figure 2, gray fox activity increased dramatically from September to November before dropping off in December. We predicted this shift in activity was the result of the differences in the dietary constraints of bobcats and gray foxes. These results support our hypothesis that gray foxes alter their activity when utilizing alternate food sources such as grasses and fruits to supplement their diet of prey animals. Gray fox activity is lower in warmer months of the year because they have additional food sources such as manzanita fruit (Neale and Sacks 2001). Scat analyses suggest that fruit comprises 45-60% of gray fox diet in the foresummer, summer monsoon, and autumn months of the year and only about 15% of their diet in the winter and spring (Neale and Sacks 2001). Rodents and lagomorphs make up 15-30% of gray fox diet in the warmer months of the year and 45-50% of their diet in the winter and spring. Bobcat activity remains relatively constant throughout the year because their diet is limited to the consumption of meat; 50-60% of bobcat diet consists of rodents and lagomorphs in the summer monsoon and autumn, but during the winter the percentage of rodents in the diet decreases and lagomorphs increases from around 5% in the autumn to 15% in the winter (Neale and Sacks 2001). Prey selection in bobcats may shift as temperatures decrease due to a reduced amount of desert squirrel and rodent activity during colder months when they store food and remain in their burrows throughout the winter (Phillips and Comus 2000).

We found some support for our hypothesis that lagomorph activity would decrease in late autumn and winter (fig. 3) when gray fox activity increased. Although black-tailed jackrabbits and desert cottontails exhibited generally similar patterns of behavior across the 11-month study, desert cottontail activity was high in the summer monsoon, low during October-December, and then increased slightly in January before decreasing in the spring. Black-tailed jackrabbit activity was high in the foresummer and summer monsoon, but dropped in the autumn and increased during the winter, before it decreased again in the spring. Antelope jackrabbit activity was low and constant through foresummer and summer. Beginning in October, antelope jackrabbit activity began to increase and between October and December 2011, the amount of activity doubled. This increase was short-lived, before it dropped to a more stable amount in the spring. We hypothesized that the change in lagomorph activity during the autumn months may be the result of an increase in gray fox predation (fig 4). The desert cottontail may have been more impacted by the change in gray fox activity during autumn compared to antelope and black-tailed jackrabbits. The desert cottontail was the only lagomorph species found at low elevation that did not return to the same high activity rate seen in the warmer months of the year following its drop in activity in the autumn. Unlike the antelope and black-tailed jackrabbits, desert cottontail activity remained relatively constant at a low rate from October through March. Eastern cottontail activity was undetected in the spring, a pattern that was unique among the lagomorphs analyzed. A gradual increase in activity was then seen from late summer through the fall. A marked increase in eastern cottontail activity was seen only in November 2011. Later in the winter, activity remained relatively high but was more constant. The difference in detection among lagomorphs may be the result of decreased food availability in the forest due to cold temperatures and snow cover. Lagomorph activity in Saguaro National Park changes seasonally, which may be due to surface water availability and food supply. The bimodal periodicity of rain in the Sonoran desert often influences mammalian behavior because water is a limiting resource in this arid environment (Phillips and Comus 2000). It is important to consider this variable when analyzing detection rates of gray foxes, bobcats, and lagomorphs in Saguaro National Park.

In order to ensure that our data analysis was not overly simplistic, we investigated alternative hypotheses for the increase in activity seen in gray foxes between September and December. One alternative explanation is simply sample size: in October 2011 Saguaro National Park hosted the 2011 National Geographic BioBlitz event. This event drew thousands of visitors to both districts of the park, including the back country areas, and many of the wildlife cameras were deployed for educational purposes; resulting in a smaller number of camera nights. This decrease in the number of camera nights overall may have created spurious proportional relationships in the data. The abundances of bobcats and gray foxes differ between the two districts of the park due to differences in habitat type and overall available area. Because this study analyzed the activity of species in both districts of the park, we must account for these differences. TMD has half the elevation gradient as RMD, and as a result, TMD has fewer strata. Each month TMD had fewer camera nights than RMD and in some months there were half as many at TMD compared to RMD. The difference in the number of camera nights is the result of the reduced amount of area available to survey in TMD. The amount of gray fox activity at TMD is higher than RMD even though we had fewer camera nights in TMD. Approximately 53.3% of gray fox images were captured in TMD. The distribution may be influenced by

Figure 4— Gray fox with a desert cottontail in its mouth.

the difference in the amount of sampling conducted in each district, and gray fox activity could potentially be much higher each month than previously thought. Future studies using camera data at Saguaro National Park should account for the differences between districts by analyzing them as separate entities or by standardizing the number of camera nights in each district

Not only did the BioBlitz alter the October 2011 data collection, it may have altered wildlife behavior. The increased human activity of the BioBlitz event may have influenced the behavior of gray foxes within the park and forced them to relocate to more isolated areas where cameras were more likely placed. Based on our photographic results, October 2011 saw the highest amount of gray fox activity and it may have been human influenced. The mere presence of a wildlife camera may also cause gray foxes to alter their behavior. Remote camera trapping did not allow us to identify individuals. Because we can only count activity at a camera, we do not know if the camera is recording the activity of one or 100 individuals. For example, a single animal could be utilizing the same portion of a wash due to its proximity to the animal's den. Park employees have noticed over the years that gray foxes appear to be more curious about wildlife cameras than many other species. One example of this is on a plot in TMD where two gray foxes loitered extensively near a specific camera location, which resulted in numerous photographs of the same individuals.

Conclusions

Our study contributed to the understanding of the coexistence of two sympatric carnivores and some of their prey sources in a Sky Island ecosystem. More data collection and analysis would be possible by marking individuals or analyzing bobcat patterns in order to identify individuals to better understand the population dynamics of each species. Due to the delicate and ever-changing composition of the ecosystem at Saguaro National Park, this study should be continued over many years. An annual study would help to determine if gray fox activity does in fact change in response to differences in food availability at different times of the year or if the activity is more greatly influenced by external factors like annual precipitation. In addition to an annual study, a more comprehensive analysis of the rodents and lagomorphs should be conducted in order to understand their ecology directly and not just through their predators. Park biologists and technicians can utilize this data to study the interspecific interactions of mammals in Saguaro National Park and make informed decisions about the management of wildlife species within the park.

Acknowledgments

We would like to thank the staff and volunteers of Saguaro National Park, specifically the Resource Management Department and Don Swann, Nicholas Perkins, and Kristina Ratzlaff. We would also like to thank Sergio Avila and the staff and volunteers at Sky Island Alliance for their assistance with this project. Without their countless hours of advice and support this project would not have been possible.

References

Barrientos, R. and E. Virgós. 2006. Reduction of potential food interference in two sympatric carnivores by sequential use of shared resources. Acta Oecologica. 30:107-116.

Chamberlain, M. J. and B. D. Leopold. 2005. Overlap in space use among bobcats (*Lynx rufus*), coyotes (*Canis latrans*) and gray foxes (*Urocyon cinereoargenteus*). The American Midland Naturalist. 153:171-179.

Fedriani, J. M., F. Palomares, and M. Delibes. 1999. Relations among three sympatric Mediterranean carnivores. Oecologia. 121:138-148.

Fedriani, J. M. and T. K. Fueller. 2000. Competition and intraguild predation among three sympatric carnivores. Oecologia. 125:258-270.

Fritzell, E. K. and K. J. Haroldson. 1982. *Urocyon cinereoargenteu*s. Mammalian Species. 189:1-8.

Haynes, L., J. Lamberton, C. Craddock, [and others]. 2010. Mountain lions and bobcats of the Tucson Mountains: Monitoring population status and landscape connectivity. Pima County Final Report.

Lariviére, S. and L. R. Walton. 1997. *Lynx rufus*. Mammalian Species. 563:1-8.

Neale, J. C.C. and B. N. Sacks. 2001. Food habits and space use of gray foxes in relation to sympatric coyotes and bobcats. Canadian Journal of Zoology. 79:1794-1800.

Phillips, S. J. and P. W. Comus. 2000. A natural history of the Sonoran Desert. Tucson: Arizona-Sonora Desert Museum. 628 p.

Riley, S. P. D. 2006. Spatial ecology of bobcats and gray foxes in urban and rural zones of a national park. Journal of Wildlife Management. 70:1425-1435.

Swann, D. E. 2011. Mammals of Rincon Mountain District, Saguaro National Park. Natural Resource Report NPS/SODN/NRR—2011/437. National Park Service, Fort Collins, CO.

Tekiela, S. 2008. Mammals of Arizona field guide. Adventure Publications Inc., Cambridge, MN.

The content of this paper reflects the views of the authors, who are responsible for the facts and accuracy of the information presented herein.