



ARTICLE

Wildlife Monitoring at Organ Pipe Cactus National Monument

[Organ Pipe Cactus National Monument](#)



Black-tailed jackrabbit (*Lepus californicus*). NPS photo.

Overview

At National Park Service units across the Sonoran Desert and Apache Highlands, the [Sonoran Desert Network](#) (SODN) is monitoring medium- and large-sized mammals. The goal of this project, started in 2016, is to detect biologically significant changes in mammal community and population parameters through time. The intent is to provide park managers with reliable, useful information on mammal species at various spatial and temporal scales. To do this, we use passively triggered remote wildlife cameras in concert with methods of sampling and analysis that address management needs.

In 2022, SODN field crews deployed 61 wildlife cameras at Organ Pipe Cactus National Monument (NM). The cameras recorded 689 total detections (animal photographs) from March 11 until April 26. Upon analysis, the photos revealed 16 mammal species, plus an additional five mammalian orders, families, or

Key points

- In 2022, field crews deployed 61 wildlife cameras that recorded 16 different mammal species at Organ Pipe Cactus National Monument.

genera that could not be identified to species due to insufficient visual evidence. Two bird species were also detected, along with three birds that could not be identified to species.

Investigating how wildlife populations change through time, and how different variables impact them, gives us valuable insight into how best to

manage and protect species now and into the future. While this report only summarizes findings from 2022, those findings will be combined with data collected from past and future years for use in occupancy modeling. Occupancy modeling provides SODN and park managers with multi-year information on the status and trends of mammal species, including their population distribution and stability.

- Knowing how wildlife populations change through time, and how different variables impact them, helps managers decide how best to protect species now and into the future.
- Single-year data provide species-specific insights.

At least five years of pooled data are needed to establish reliable multi-year occupancy models. The methods for multi-year trend analysis are currently in development, as we have just obtained enough data to begin. However, to provide a sense of what can be learned from this modeling, an example of an occupancy model for a single species using only the 2022 data appears below. Single-year data are also useful for other species-specific insights, such as new detections within the monument and potential drivers of species distributions.

Background

Motivation for wildlife monitoring

The need for wide-scale environmental monitoring to meet conservation needs is increasing. In response to anthropogenic disturbances, such as habitat loss and climate change, many species face pressures that force shifts in their distribution. Expansive tracts of suitable habitat to allow for such shifts are a conservation necessity (Parmesan and Yohe 2003, Thomas et al. 2004). Large protected areas, such as national parks, can provide critical wildlife habitat—but even they are not immune to anthropogenic disturbances (Brashares 2010, Carroll 2010, Chen et al. 2022). Knowing how species respond to various pressures requires an understanding of abiotic and multi-species interactions at broad spatial scales. Occupancy modeling of data from remote cameras can help meet this challenge (Post et al. 2009).

Use of cameras



Wildlife camera deployed at Saguaro National Park, Tucson Mountain District.

Remote wildlife cameras are powerful research tools. They are non-invasive and allow researchers to collect data on multiple species simultaneously over large spatial scales. Scientists worldwide have demonstrated the ability of remote cameras to provide robust trend-monitoring data for terrestrial mammals. Remote cameras can capture data on individual animals that are uniquely identifiable, such as jaguars, which enables trend estimations of their broader population through mark-recapture modeling (Steenweg et al. 2015). However, many animals without unique pelage (fur markings and patterns) can only be recognized to the species level, rendering mark-recapture modeling impossible. Instead, occupancy modeling provides a means to monitor distribution (occupancy) trends of numerous species concurrently.

What is occupancy modeling?

In SODN's monitoring, occupancy is the proportion of an area that is inhabited (occupied) by a species. When a species is detected by a camera, it is classified as present. If a species is not detected by a camera, it may be either truly absent, or present but undetected. This issue of imperfect surveys (i.e., when the probability of detecting a species is less than 1) can be statistically accounted for with occupancy modeling. A rigorous framework for occupancy modeling has existed since 2002 (MacKenzie et al. 2002) and is in strong subsequent development (MacKenzie et al. 2006, 2018). Therefore, we utilize occupancy modeling for the data collected by wildlife cameras at Organ Pipe Cactus NM and other parks.

While the data tell us where a species occurs, they do not tell us why a species does or does not occur at a particular location. We can assess the driving contributors to a species' distribution by evaluating the effects of covariates on occupancy and detection probability. Some environmental influences, such as elevation, do not change during a sampling window and likely influence occupancy probability. Other environmental variables, such as temperature or precipitation, change day-to-day and may influence detection probability (e.g., species may be harder to see and less active in excessive heat). By including covariates, we can evaluate their influence on wildlife occupancy and detection probability and begin to understand why a species is detected at one place and/or time but not another.

Methods

Effort

In March 2022, SODN field crews deployed 61 Cuddeback G Series wildlife cameras at non-baited, pre-established monitoring locations throughout Organ Pipe Cactus NM. The cameras have been deployed during the same time period and in the same locations annually since 2016 (except for 2019 due to the government shutdown). We chose to pair our camera locations with SODN's long-term vegetation and soil monitoring plots, which were allocated mostly through a Reversed Randomized Quadrant-Recursive Raster (RRQRR) spatially balanced design (Theobald et al. 2007, Hubbard et al. 2012). This pairing will allow us to apply detailed covariate data on vegetation species composition and structural characteristics to our wildlife data—useful because vegetation covariates are potentially important drivers of habitat conditions impacting wildlife.

Technicians followed standard operating procedures to ensure the cameras were deployed consistently (Hubbard et al. in prep). For example, the cameras were placed in the same locations and employed the same settings as in prior years. The cameras were either mounted on a stake in the ground or strapped to a secure structure, such as a tree.

Relying on infrared and motion-trigger technology, the cameras took a photo whenever they detected motion or a sudden temperature change in their detection zone. They collected data from March 11 until April 26, 2022, and were then retrieved. Technicians again followed standard operating procedures to ensure the cameras were retrieved consistently (Hubbard et al. in prep), including documenting each camera's functionality and properly removing and storing their memory cards.

Back at the office, technicians analyzed the contents of the cameras' memory cards. This process begins by downloading the photos and sorting them to remove "false triggers," which are photos that do not contain an animal. A photo that does contain an animal is classified as a "detection." From there, the dataset is further sorted using the Colorado Parks and Wildlife Photo Warehouse Database, which enables us to categorize the photos and attribute spatial, temporal, and species metadata to them (Ivan and Newkirk 2016). Finally, a metadata export is produced for use in occupancy analysis.

Single-species single-season occupancy models

Many large-scale wildlife occupancy trend models require data from consecutive years, which renders data from a single sampling period inadequate for trend analysis. However, the terrestrial mammal data we collect from a single field season can still be informative and incorporated into different occupancy models that provide information on specific species or covariates of interest.

As an example, we modeled occupancy using a single-season, single-species approach (MacKenzie et al. 2002, 2006) with package “unmarked” in R (Fiske and Chandler 2011). To minimize heterogeneity caused by short periods of high activity in front of the cameras, we grouped our 2022 detection data into seven-day sampling periods (Bowler et al. 2017, MacKenzie et al. 2018, Kays et al. 2020). We then selected nine target species for analysis based on two criteria: rarity and body size. We deemed terrestrial mammal species reliably detectable and identifiable by cameras if they were at least 43 centimeters long, which is equivalent to the size of a rock squirrel (*Spermophilus variegatus*). Smaller animals can be difficult to identify correctly through photographs, especially nocturnal animals with similar characteristics. For this reason, we excluded smaller rodents, such as chipmunks, rats, and mice from analysis. Furthermore, we only included species for analysis that were detected at least once on >30% of sampled sites to minimize statistical modeling errors. This excluded rarer species, such as bighorn sheep (*Ovis canadensis*).

Because we had limited initial information about which covariates might influence occupancy and detection probabilities, we chose backwards elimination over an information-theoretic approach (Steidl 2006, 2007) to identify covariates with explanatory power (Ramsey and Schafer 2013). We first identified covariates that influenced detection probability with an intercept-only model, then used those in models for occupancy, retaining only those covariates with some explanatory power ($p < 0.10$).

Results for 2022

Detections

During the 2022 sampling window (March 11–April 26), 61 wildlife cameras recorded 689 total detections (i.e., animal photographs) at Organ Pipe Cactus NM, including 416 detections of mammals identified to 16 species and an additional 267 detections identified to order, family, or genus ([see table](#)). Several animals, detected 35 times, exhibited clear mammalian characteristics but could not be classified further due to insufficient visual evidence. Two bird species were also detected, along with three birds that could not be identified to species.

Notable detections included [antelope jackrabbit](#) (*Lepus alleni*), [bighorn sheep](#) (*Ovis canadensis*), [mountain lion](#) (*Puma concolor*), [Sonoran pronghorn](#) (*Antilocapra americana sonoriensis*), [western spotted skunk](#) (*Spilogale gracilis*), and [white-tailed deer](#) (*Odocoileus virginianus*). Some of these species were detected at new locations during the 2022 sampling window. It is encouraging that these species are active, because they all play an important

role ecologically but are generally uncommon or even rare to observe within the monument. The mountain-lion detection in 2022 was only our second ever at Organ Pipe Cactus NM (a mountain lion was previously detected in 2020). It's rare that these elusive predators are captured on wildlife cameras at the monument, because their home ranges are large and very few of them live within monument boundaries. They are more common in higher-elevation, mountainous regions with more-abundant food and cover, but can also be found in the lower-elevation areas of the Sonoran Desert.

The number of statistically significant wildlife photos (i.e., photos containing an animal) collected from sampling at Organ Pipe Cactus NM has ranged from 575 to 3,738 annually. It is hard to know exactly why this range has varied throughout the years. We are hoping to gain insight into this question and others by assessing the impacts of environmental factors on mammal distribution and detectability via occupancy modeling. We currently have six years of data (2016–2022, excluding 2019 due to the government shutdown).

Citizen scientists typically assist with the fieldwork associated with camera deployments and retrievals. In 2022, three volunteers and four interns from various parks and partner organizations helped deploy and retrieve cameras in Organ Pipe Cactus NM. We are grateful for their support.



Field crews deployed 61 wildlife cameras at the monument in 2022.





Selected from remotely triggered wildlife camera monitoring done by the Sonoran Desert Network at Organ Pipe Cactus National Monument in 2022.

Wildlife detections (photographs) collected from 61 remote cameras at Organ Pipe Cactus National Monument, March 11–April 26, 2022.

Class	Common name	Scientific name	Number of detections
Mammal	Mule deer	<i>Odocoileus hemionus</i>	106
Mammal	Javelina	<i>Pecari tajacu</i>	65
Mammal	Black-tailed jackrabbit	<i>Lepus californicus</i>	59
Mammal	Coyote	<i>Canis latrans</i>	41
Mammal	Kit fox	<i>Vulpes macrotis</i>	37
Mammal	Sonoran pronghorn	<i>Antilocapra americana sonoriensis</i>	34
Mammal	Gray fox	<i>Urocyon cinereoargenteus</i>	27
Mammal	Desert cottontail	<i>Sylvilagus audubonii</i>	18
Mammal	Bobcat	<i>Lynx rufus</i>	12
Mammal	Antelope jackrabbit	<i>Lepus alleni</i>	5
Mammal	Bighorn sheep	<i>Ovis canadensis</i>	4
Mammal	American badger	<i>Taxidea taxus</i>	2
Mammal	Rock squirrel	<i>Spermophilus variegatus</i>	2
Mammal	White-tailed deer	<i>Odocoileus virginianus</i>	2
Mammal	Mountain lion	<i>Puma concolor</i>	1
Mammal	Western spotted skunk	<i>Spilogale gracilis</i>	1
Mammal	Unknown jackrabbit	<i>Lepus</i> sp.	179
Mammal	Unknown fox	<i>Urocyon</i> or <i>Vulpes</i> sp.	45

Mammal	Unknown deer	<i>Odocoileus</i> sp.	4
Mammal	Unknown rodent	Rodentia	3
Mammal	Unknown canid	Canidae	1
Mammal	Unknown mammal	Mammalia	35
Total mammals	--	--	683
Bird	Gambel's quail	<i>Callipepla gambelii</i>	2
Bird	common raven	<i>Corvus corax</i>	1
Bird	unknown bird	Aves	3
Total non-mammals	--	--	6
Total	--	--	689

Why is this Information Useful?

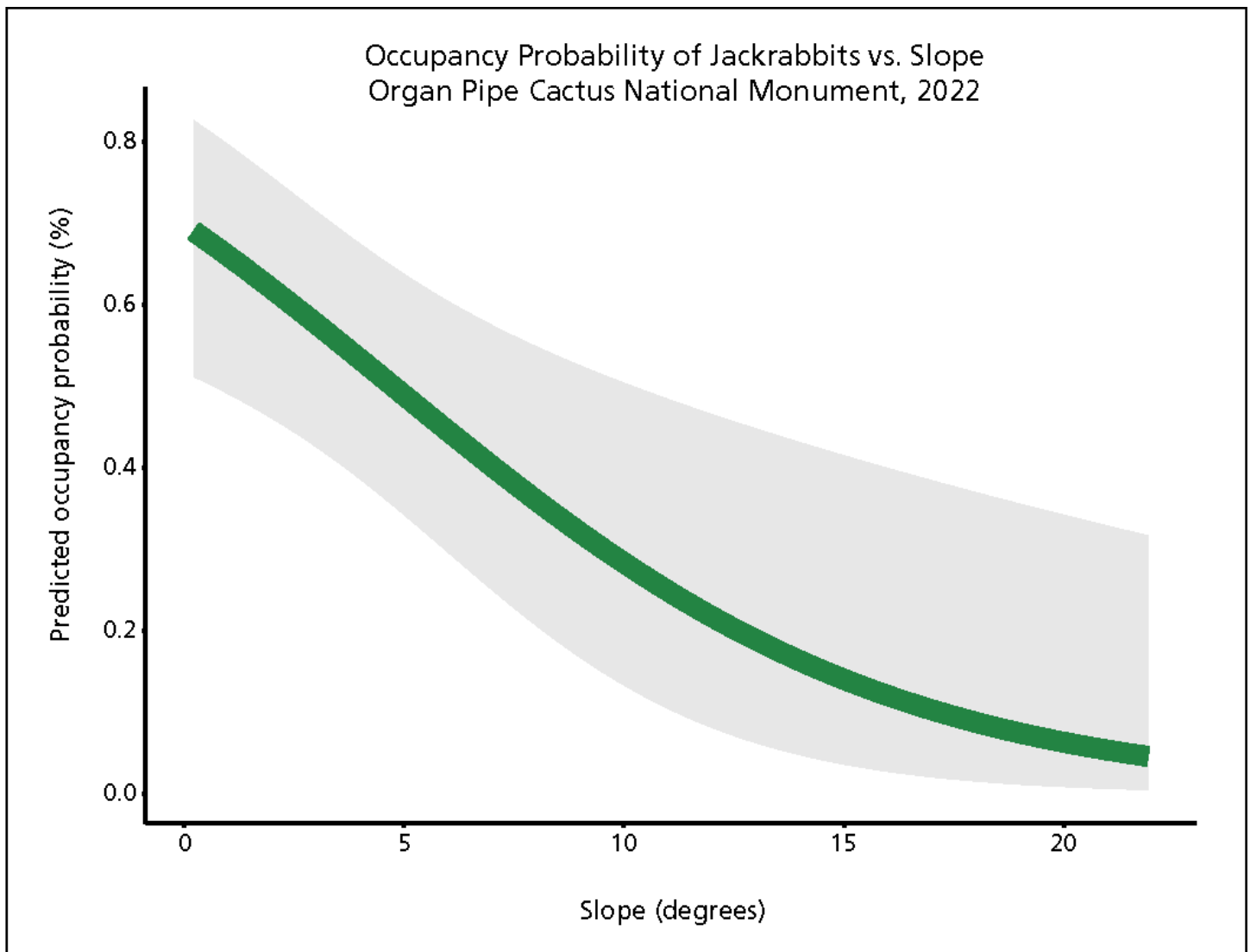
Long-term monitoring allows us to evaluate trends in parameters of management interest. Modeling occupancy over several years provides SODN and park managers with information on the status and trends of mammal species, including their population distribution and stability. Occupancy is often used as a surrogate for abundance (MacKenzie et al. 2018), so pooling annual occupancy estimates can help us determine how stable or unstable a wildlife population is. When analyzed with occupancy models, SODN's photographic dataset enables us to monitor trends of numerous terrestrial mammal species, including whether they are potentially increasing, stable, or decreasing.

Depending on the covariates used in the modeling process, we can also plot trends of covariate influence on wildlife occupancy and detection probabilities. For example, assessing the influence of temperature and precipitation on wildlife occupancy and detection is helpful when we want to understand the potential impacts of climate change on species or populations of interest.

Single-season, single species analysis example

Below is the output for a single-season, single-species occupancy model for jackrabbit species found in Organ Pipe Cactus NM, based on data collected in 2022. We combined black-tailed jackrabbit, antelope jackrabbit, and unknown jackrabbit detections to maximize data input and minimize statistical error. This model illustrates the significant influence of slope on the occupancy probability of jackrabbits. More specifically, the model shows a negative relationship between these two parameters, with the occupancy of jackrabbits decreasing as slope increases. In the flatter areas of Organ Pipe Cactus NM, occupancy probability of jackrabbits is high (60–80% occupied). However, the occupancy probability of jackrabbits drops significantly (less than 20%) in steep areas (above 12 degrees incline) within the monument.

The model suggests jackrabbits prefer to inhabit flatter areas over steeper areas in Organ Pipe Cactus NM. This is likely because the flatter areas provide easier access to food, water, and cover compared to the monument's steeper areas, which are more barren, rugged, and harder to traverse. This outcome provides park managers with insight into how jackrabbits use different areas of the monument. The model also illustrates how data from a single sampling period can provide valuable information.



Occupancy probability of jackrabbits (*Lepus californicus* and *Lepus alleni*) in response to slope at Organ Pipe Cactus National Monument in 2022. Occupancy probability decreased with increasing slope within the monument. The average is illustrated in green and the standard error is illustrated in grey.

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