Examining Wildlife Responses to Phenology and Wildfire Using a Landscape-Scale Camera Trap Network

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Abstract—*Between 2001 and 2009, the Borderlands Jaguar Detection Project deployed 174 camera traps in the mountains of southern Arizona to record jaguar activity. In addition to jaguars, the motion-activated cameras, placed along known wildlife travel routes, recorded occurrences of ~ 20 other animal species. We examined temporal relationships of white-tailed deer (*Odocoileus virginianus*) and javelina (*Pecari tajacu*) to landscape phenology (as measured by monthly Normalized Difference Vegetation Index data) and the timing of wildfire (Alambre Fire of 2007). Mixed model analyses suggest that temporal dynamics of these two species were related to vegetation phenology and natural disturbance in the Sky Island region, information important for wildlife managers faced with uncertainty regarding changing climate and disturbance regimes.*

Introduction

The Madrean Archipelago is known to have exceptional wildlife diversity, related in part to the wide variety of available habitat in the area as well as its location at the confluence of ranges of subtropical and northern species (Felger and Wilson 1994). Monitoring wildlife populations in this area has become increasingly important as human-caused and natural disturbances (e.g. United States/Mexico Border fence, drought and climate change) affect wildlife movement corridors and the quality and quantity of available habitat. Populations of terrestrial vertebrates, both herbivores and predators, are dependent on primary productivity of vegetation for their survival, and fluctuate according to resource availability (White 2008). This dynamic is often amplified in arid and semi-arid ecosystems where populations respond to resource pulses, in particular growth of vegetation, driven by both local and global climatic patterns (Marshal and others 2002). Vegetation dynamics, which include plant phenology, are captured and quantified by satellite imagery and have been used to model wildlife habitat, vegetation cover, and species abundance (Wallace 2008; Sesnie and others 2011). In addition to climate-induced variability in plant productivity, resource availability for mammals can also be limited or enhanced by natural disturbances like wildfire (Smith 2000). For example, ungulates are responsive to changes in vegetation structure, feeding in areas with increased plant growth after high-intensity fires, and carnivores and omnivores are believed to be opportunistic and will often feed near areas of recent burns where prey abundance has increased (Smith 2000).

Monitoring wildlife populations is traditionally accomplished using labor-intensive human observation (e.g. avian surveys) or expensive trapping methods (e.g. capture-recapture). An alternative to human observation and trapping are remote, motion-triggered camera "traps." Camera traps are typically set up to capture information on rare and secretive species of conservation concern (McCain and Childs 2008), but are increasingly being used to monitor general wildlife population dynamics (Rowcliffe and Carbone 2008). Motion-triggered cameras offer several benefits over traditional methods of wildlife observation (see Cutler and Swann 1999); they are noninvasive, can be set up in rugged and remote locations, and provide continuous monitoring while the camera remains operational. This last point is an important distinction in that repeat, long-term camera monitoring provides a photographic time series that can be analyzed with continually collected satellite and climate data allowing us to examine connections between wildlife abundance and vegetation phenology.

In this project, we used an existing, landscape-scale camera trap network to examine the relationship between wildlife dynamics, vegetation phenology, and fire. We chose two example species, white-tailed deer (*Odocoileus virginianus*) and javelina *(Pecari tajacu)*, which are the primary prey of the jaguar and other felids as well as economically important game species in Arizona. It was anticipated that the multi-species information gathered from the photographic database might provide insight into decadal and annual population dynamics, by capturing a measure of wildlife abundance at the camera locations as well as activity in the movement corridors on which the cameras were located. In addition, this study was conceived to help

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guide future trap efforts and study design by demonstrating the value of incidental, non-targeted species data for understanding wildlife dynamics related to climate and vegetation, and illustrating some of the challenges of data analysis at a landscape scale.

Study Area

The study area is located at the western portion of the Madrean Archipelago north of the United States/Mexico border stretching from the Altar Valley to the San Rafael Valley (McCain and Childs 2008). Wildlife monitoring sites were located at the Baboquivari, Sierrita, Tumacácori, Atascosa, Patagonia, and Santa Rita Mountains. Vegetation of the study sites consists of Madrean evergreen woodland and semidesert scrub grassland (Brown 1994) and elevations range from 934-1944 m. The average maximum temperature recorded at Tumacácori National Historical Park (1948-2005) was 36 °C, (July), the average minimum was 0 °C (January), and average annual precipitation was 40 cm.

Data and Methods

Primary data for this project were (1) animal detections collected by the Borderlands Jaguar Detection Project (McCain and Childs 2008) using a series of remote cameras and (2) 250-meter resolution Normalized Difference Vegetation Index (NDVI) data. The following sections provide details of the camera and vegetation data sets.

Camera Trap Data

A total of 8 (174 total cameras) different camera sites were monitored between 2001 and 2009 using passive infrared camera systems that detect heat-in-motion. Cameras were intentionally located in areas with high probability of detecting jaguar movement (i.e. game trails, washes, and canyon bottoms). Cameras were typically left in the original location for the entire length of the study in order to detect variations in movement over time; however, some cameras were moved to more strategic nearby sites if higher animal activity was found in the area.

Moderate Resolution NDVI

We used Normalized Difference Vegetation Index (NDVI) calculated from Moderate Resolution Imaging Spectroradiometer (MODIS) data. Composites of MODIS NDVI data were acquired from the University of Arizona Remote Sensing Center for 2000-2009. NDVI is calculated using a ratio of the spectral properties of vegetation reflectance in the red and near-infrared wavelengths of the electromagnetic spectrum; green vegetation typically has low reflectance in red wavelengths and high reflectance in the near-infrared wavelengths. NDVI values are positively correlated with the relative abundance of green, growing vegetation.

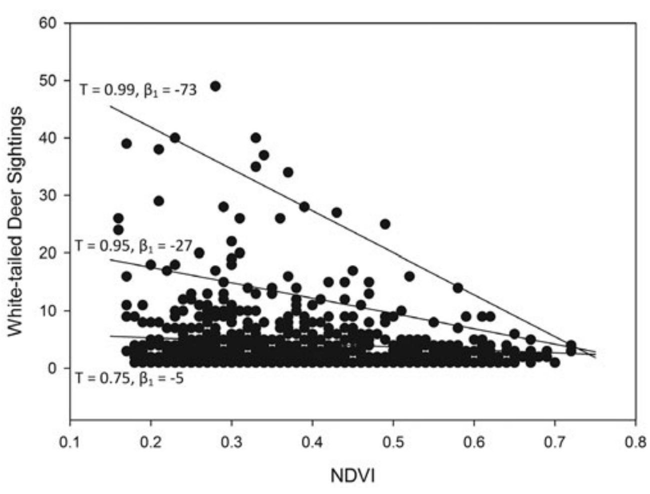
Analysis

Detection photographs were compiled into a digital database with each camera location attributed with the number of animal sightings per month by species, monthly NDVI, and time-since-fire values (months) for cameras that were in or near the Alambre burn perimeter (July 7, 2007 in the Baboquivari Mountains).

Counts of animal sightings per month were analyzed and histograms of whitetail sightings were constructed by mountain range (8 total). The relationship of whitetail sightings with NDVI among mountain ranges was evaluated with quantile regression. Additionally, a mixed model analysis was performed with whitetail sightings as the response, mountain range, month, and NDVI as fixed effects, and year and camera as random effects. The relationship of javelina sightings with NDVI near the Alambre burn perimeter was evaluated using a mixed model analysis with NDVI as a fixed effect and year and camera as random effects. The relationship of javelina sightings with months since fire was similarly evaluated with the time variable as a fixed effect and year and camera as random effects.

Results and Discussion

Monthly sightings of whitetail ranged from very low to as large as 50 in the different mountain ranges. Two-tailed Student's t-tests show that camera locations with whitetail sightings have significantly lower NDVI values than camera locations with no sightings (fig. 1).



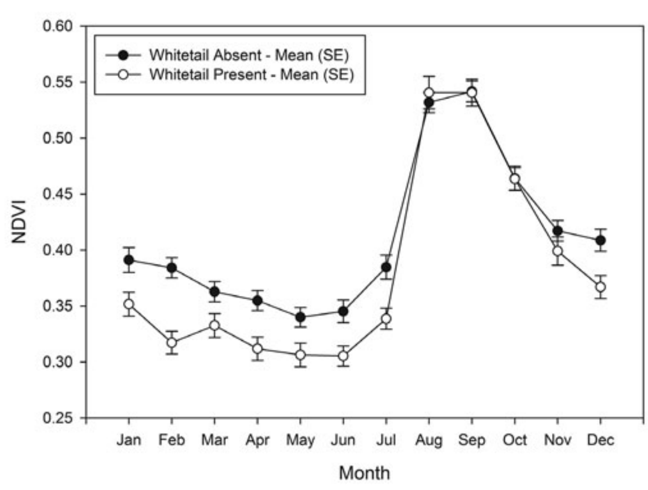


Figure 1—Quantile regression results for monthly white-tailed deer sightings as a function of NDVI. Tau (T) refers to the quantile of whitetail sightings conditional to NDVI, and B_1 values are the slopes of the regression lines, which were significant with $p < 0.05$ (left). Mean (standard error) monthly NDVI for camera locations with Whitetail deer sightings during the study period (right).

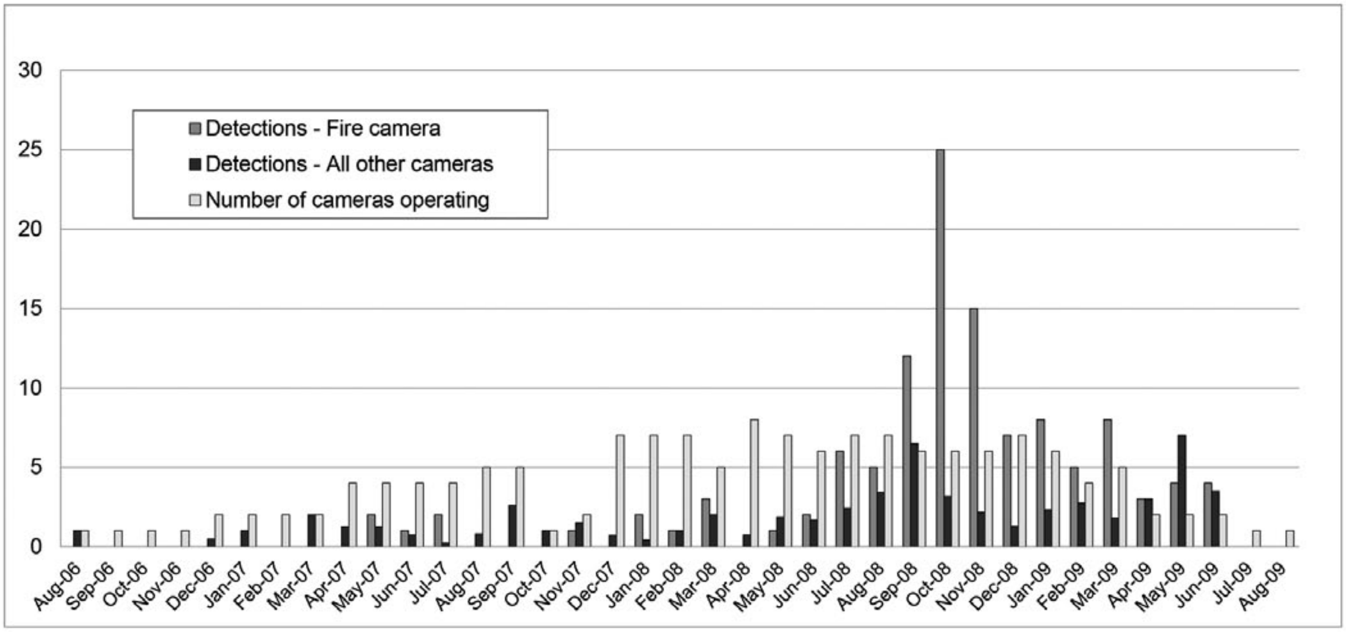


Figure 2—Distribution of javelina sightings at the Coyote Mountain study site before and after the Alambre Fire of July 7, 2007. One camera located inside the burn perimeter showed a marked increase in javelina sightings in 2008 when compared to cameras outside the burn area.

Mixed model analysis indicated that mountain range ($p = 0.1$) and NDVI ($p = 0.06$) had a weakly moderately significant correlation with whitetail sightings, whereas month did not appear to be significant ($p = 0.27$). Quantile regression analysis showed a significant negative relationship for the largest values of whitetail sightings conditional to NDVI (fig. 1). This suggests that low abundance of whitetail sightings occurred for a wide range of NDVI; however, the largest monthly sightings occurred during periods of relatively low NDVI. On average, large values of NDVI occurred during the summer monsoon and post-monsoon months of August, September, and October (fig. 2) and NDVI was comparably lower during the other months of the year when sightings were greater. This observed pattern may be related to greater whitetail activity during the breeding season (winter months).

Mixed model analyses indicated that NDVI and time since fire were significant for javelina sightings ($p = 0.02$, respectively). Javelina sightings increased with time (1-24 months) since burning. The relationship of javelina sightings to NDVI was also positive. NDVI often decreases immediately after fire, then increases with time as vegetation recovers, and therefore might be expected to covary with time since burning; however, histograms depicting observations from a camera in the fire perimeter compared to those outside suggest that the increase of javelina was related to post-fire effects (fig. 2).

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