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A Preliminary Assessment on the Habitat Use of Carnivores in Al Mujib Biosphere Reserve Using Camera Trapping

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Abstract

Carnivore populations in Jordan are on the decline due to continuous habitat loss, fragmentation, and human persecution. Monitoring movement patterns and habitat preferences through noninvasive methods is important to plan effective conservation programs within protected areas. We conducted a camera trap survey of carnivores in Al Mujib Biosphere Reserve, an arid sandstone habitat in southwestern Jordan. Six species were detected: the red fox, caracal, Afghan fox, striped hyena, grey wolf, and the wild cat. Detection of carnivores was higher at night, yet several were active during the day. Captures were also highest within the wilderness zone of the reserve. Most species showed higher preference for wadi systems which provided corridors for movement across their wide ranges and for stalking prey. This is the first study to monitor carnivore distribution and habitat use within protected areas in Jordan using noninvasive survey methods. It provides crucial data through relatively rapid means to assess reserve effectiveness and guide management efforts such as a land use planning within the reserve.

Keywords: camera trapping, carnivores, habitat use, Al Mujib Biosphere Reserve, Jordan, protected area.

1. Introduction

With the current advances in measuring and monitoring mammalian diversity, noninvasive techniques have been developed to reduce disturbance and document the presence of trap-shy and rare species (Kelly *et al.,* 2012; Kays and Slauson, 2008; Long *et al*., 2008; Saleh *et al.*, 2018). Remote camera trapping is considered an excellent tool for estimating species richness and abundance, habitat use, activity pattern, behavioral ecology and population dynamics (Trolle and Kery, 2005; Lyra-Jorge *et al*., 2008; Rowcliff and Carbone, 2008; Rowcliffe *et al.,* 2008). It can also provide valuable information for evaluating conservation efforts (Tobler *et al*., 2008; Balme *et al*., 2009). The method proved to be useful for studying mammals within protected areas in the Middle East (Cunningham and Wronski, 2009; Abi-Said and Amr, 2012; Ahmed *et al.,* 2016) and provided an exciting transition in wildlife survey methods (Burton *et al.,* 2015).

The carnivores of Jordan were studied extensively over the past three decades using conventional observational and capture methods (Qumsiyeh *et al.,* 1993, Amr *et al.,* 1996; Bunaian *et al.,* 2001; Abu Baker *et al.,* 2004; Qarqaz *et al.,* 2004). Yet, no studies were conducted to monitor the distribution and habitat use of carnivores within protected areas using noninvasive methods. The present study provides crucial preliminary data on the distribution and habitat use of carnivores in Al Mujib Biosphere Reserve in the context of the reserve zoning plan. The study aims to address the relationship between the degree of protection and the diversity of carnivores in protected areas.

2. Material and Methods

2.1. Site Description

The study site covered an area of approximately 85 km^2 from the western lower part of Al Mujib Biosphere Reserve. The Reserve is located at the shoreline of the Dead Sea covering an area of 212 km^2. The highest elevation of the study site starts at 260 m at the eastern site and continues west to reach -420 m below sea level at the western border of the reserve. The reserve is located at the lowest elevation on earth within the Sudanian Penetration biogeograpical zone and is characterized by hot summer and warm winter. Three vegetation types dominate the study site including the saline vegetation, the semitropical vegetation, and the water vegetation in the wadis (Al-Eisawi, 2014). The site is dominated by sandstone escarpments characterized by deep slopes and hard terrain especially at the eastern parts, intermixed toward the north-west with large amount of sedimentary hells of Tethys origin locally known as Sab'e Al-Wedyeh (the seven wadis). Nine wadis cross the study area from east to west: Wadi Al-Mujib is one of the oldest wadis at the eastern site of the Rift Valley (Barberi *et al.,* 1979; Abed, 2000). Other wadis include Zarga Maine, Zara, Zgara, Atoun, Abu Irtimeh, Um Ghreiba, Hidan, Um Zghaib, and Shgaig.

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The biosphere reserve is governed by a zoning plan that fits with the biosphere designation. Three different zones were identified according the their accessibility and use: Intensive use zone at the outer edge of the reserve, semi-intensive use zone that acts as transitional zone between the semi intensive and the core wilderness zone, and the core wilderness zone where minimum use is practiced except for conservation of wildlife (Figure 2).

2.2. Camera Trapping

Thirty-one Browning Trail Cameras (BTC-6hd) were used during the study period between September 2015 and May 2016. Camera setting mode was set for three photos at each trigger, with five seconds delay between events day and night. Cameras were installed in rock crevices about one meter above ground. Cameras were placed within three designated land use zones in the reserve: 13 in the wilderness, seven semi-intensive use, eight in the intensive use area, and 3 between the wilderness and the semi intensive use zones as shown in Table 1. Animal diversity was calculated using the number of camera trap photos as an estimate for its abundance and the total number of species captured by each camera as an estimate for species richness in the camera site. Species diversity was calculated using Simpson's Diversity Index (SDI). The number of trap nights in each site was used to control for the variation in the effort between the sites.

Table 1. Description of sites and number of cameras used in Al Mujib Biosphere Reserve.

Site	No. of cameras	Description
Wadi Abu Nkhalah	1	Wadi with dense vegetation wide about 4-8 m wide
Al Addadeh	1	Mountain ridge, with steep cliffs facing west, hard terrain intermix with rich vegetation
Al Menqat'ah	2	Mountain ridge overlooking the Mujib wadi system
Marah	4	Open area
Qanani al Hirbah	1	Cliffs with erosion
Qullat Awad	2	Highest peaks on the western side sand stone
Raddas vicinity	4	Open rocky area
Seba'a Wedyeh	1	Sedimentary hills extending from east to west
Um Skhaib	5	Sand stone out crops, deepest wadis with sharp mountain ridges

3. Results

3.1. Species Diversity and Spatial Distribution

The results of camera trapping lasted for 5202 trapping nights, with a total of about 40,000 photos. They were filtered to 2947 informative photos, with only 67 photos for wild carnivores.

A total of six species of wild carnivores were documented in Al Mujib Biosphere Reserve (Figure 1, Table 2), including three canids, two felines and one hyena. During the study period, a total of 67 photos were captured. By far, the red fox, *Vulpes vulpes*, was the most captured species with 49 observations (73.13%), while the wild cat, *Felis silvestris*, was the least species with a single observation (1.5%).

Table 2. Frequency of carnivores photo-trapped in Al Mujib Nature Reserve.

Species	No. of photos	%
Vulpes vulpes	49	73.13
Vulpes cana	5	7.47
Canis lupus	2	2.98
Caracal caracal	6	8.95
Felis silvestris	1	1.50
Hyaena hyaena	4	5.97

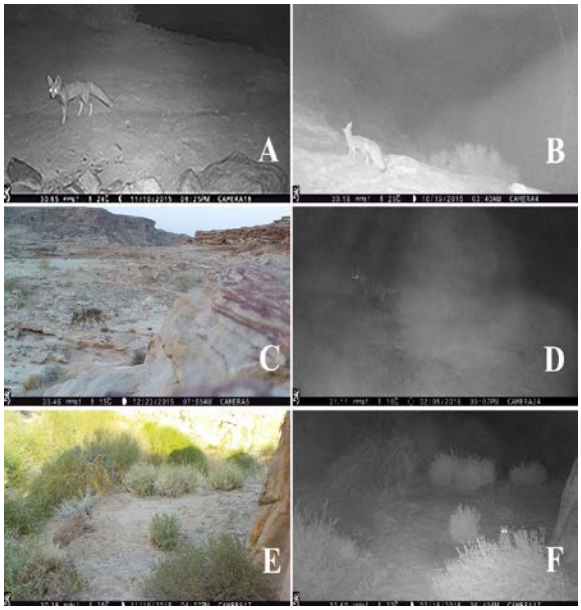

Figure 1. Carnivores captured by camera traps in Al Mujib Biosphere Reserve. **A.** *Vulpes vulpes* in Al Menqat'ah. **B.** *Vulpes cana* in Um Skhaib. **C.** *Canis lupus* in Um Skhaib. **D.** *Hyaena hyaena* in Al Menqat'ah. E. *Caracal caracal* in Wadi Abu Nkhalah. **F.** *Felis silvestris* in Wadi Abu Nkhalah.

Detection of carnivores was higher at night, yet several were active during the day. *Vulpes vulpes* was encountered in all types of habitats including open areas and wadi systems. It was found in photo-trapped in 18 locations representing all zones of land use (intensive and semi-intensive, wilderness use). *Vulpes cana* was photographed in four locations around sandstone mountains and cliffs, three and one in the wilderness and intensive zones respectively. The wolf, *Canis lupus*, was found in two locations in the wilderness zone. *Caracal caracal* was located in only one site at the edge of both wilderness and intensive zones. It was photographed along wadi systems that are used by the ibex with relatively rich vegetation cover. *Hyaena hyaena* was spotted in three sites; two within the wilderness zone and one in semi-intensive zone.

Species diversity was highest (SDI 0.24-0.5) in the wilderness zone (Al Mrah, Qanani al Hirbah), and the least in the intensive use zone (SDI 0-0.095). Fourteen cameras recorded only one species; seven in the wilderness, two in the semi intensive, three intensive and two at the edge of both wilderness and semi intensive zones. Six cameras photographed two species; three in the wilderness, two in the semi intensive and one in the intensive zones. Variation in species diversity among the different land use zones is expressed in Figure 2.

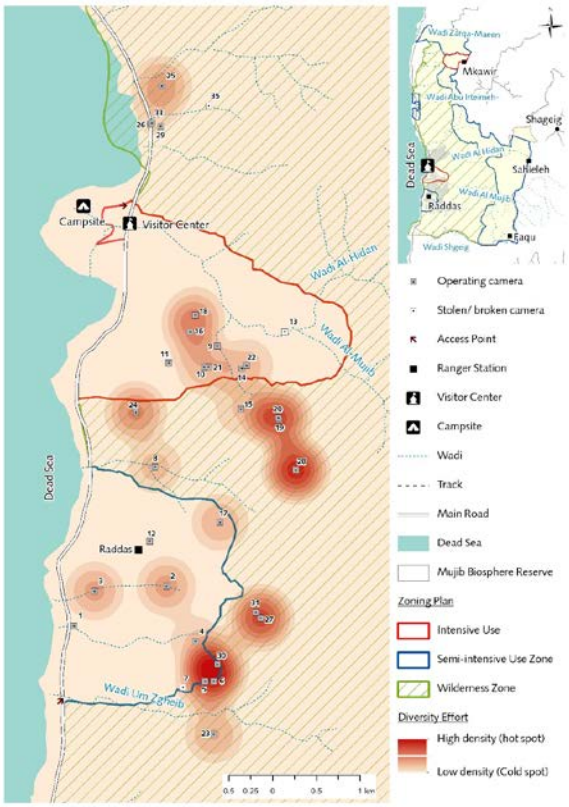

Figure 2. Heat map showing carnivores species diversity in Al Mujib Biosphere Reserve according to zones.

3.2. Seasonal activity patterns

Seasonal activity patterns and diversity of carnivores throughout the study period was highest during the cold winter months (Table 3). Between December and March, 3-5 species were detected, whereas only two were trapped between September and November. The red fox, *V. vulpes*, was recorded throughout the study period. The caracal was observed in the coldest months of the year, with highest number (3) of observations in March.

Table 3. Seasonal activity patterns of carnivores at Al Mujib Biosphere Reserve though out the study period.

Month	*C. caracal*	*C. lupus*	*F. silvestris*	*H. hyaena*	*V. vulpes*	*V. cana*
January	1	0	0	1	5	0
February	1	0	1	1	1	1
March	3	1	0	0	3	0
September	0	0	0	1	3	0
October	0	0	0	0	16	4
November	1	0	0	0	11	0
December	0	1	0	1	10	0

4. Discussion

The present study documents the presence and distribution of carnivores in Al Mujib Biosphere Reserve. Evidently, the red fox, *V. vulpes* was the most common species. This species has a wide spectrum of diet and can survive in all types of habitats in Jordan. Similar results were obtained in the eastern desert and Dana Biosphere reserve (Amr *et al*., 1996; Bunaian *et al*., 2001). *Vulpes cana* is associated with sand stone habitat, and was previously reported from around sharp edges and cliffs of different altitudes of Paleozoic sandstone mountains in Al Mujib Biosphere Reserve, whereas only six individuals were captured during 461 trap nights (Abu Baker *et al*., 2004). Detection by camera traps suggests that most species showed higher preference for the wadi systems and secluded canyons which provided corridors for movement across their wide ranges and for stalking prey. It seems that the reserve is used by both *C. lupus* and *C. caracal* as feeding grounds, as they ascend from the rocky areas to the west, where they seek large mammals as the Nubian ibex, *Capra nubiana.* The ibex population in Al Mujib Biosphere Reserve is one of the healthiest and most protected in Jordan. Both predators have a wide home range; 34.6 ± 19.5 km^2 for *C. lupus* (Hefner and Geffen, 1999) and 270-1116 km^2 for *C. caracal* (van Heezik and Seddon, 1998).

Habitat use and distribution of carnivores can be used to measure management effectiveness within protected areas due to their important role in terrestrial ecosystems and sensitivity to man-made threats such as poaching and habitat loss (Li *et al.*, 2012). Spatial patterns in species diversity drawn from camera trap photos can be used to guide conservation efforts and reserve effectiveness when quantified on spatially explicit maps. The zoning and the degrees of protection have advantages for conserving carnivores by reducing the costs of intensive conservation measures to limited areas, and can provide simple managements procedures in areas of conflicts (Linnell *et al*., 2005). The current zoning of Al Mujib Biosphere Reserve reflects the effect of conservation on the diversity of carnivores, where the highest diversity was found within the wilderness zones, and the least in the intensive use areas (Fig. 2). In the wilderness zone, no human activities are allowed except for patrolling and research, thus more conservation efforts are implemented, while in the intensive zone, tourism and grazing are allowed. The semi intensive zone is open for eco-tourism only with low patrolling efforts. Conflicts with humans should be minimized in order to protect some of the endangered species of carnivores such as the caracal. This was also observed by Johnson *et al.* (2006) and Carter *et al.* (2012), where they reported that abundance of *Panthera tigris* was related human population and disturbance.

Long-term use of camera-traps proved to be an excellent tool for wildlife monitoring as it can provide quantitative data on spatial patterns of habitat use. This approach can effectively quantify species diversity and habitat use on spatially explicit maps to develop recommendations for managers to improve the degree of protection and land use within protected areas. Noninvasive studies are especially useful in arid environments where animals are rare and disperse over wide ranges. Camera-trapping surveys may be the most effective method in detecting carnivore species (Gecchele *et al*., 2017). Comparative studies in other protected areas in Jordan should be carried out to relate the effect of conservation and zoning on wildlife.

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