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SPATIAL CHARACTERISTICS OF NEST SITES OF CRITICALLY ENDANGERED INDIAN VULTURES (*GYPS INDICUS*) IN RAJASTHAN, INDIA

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ABSTRACT

Vultures in India have experienced catastrophic declines over the past fifteen years. The cause of declines is well studied, but fundamental knowledge of vulture ecology within the context of India's human-dominated landscape is lacking. Here we report on landscape-level habitat associations of 54 nests of Indian vultures (*Gyps indicus*) across Rajasthan, India. Our data show that on average, vulture nests were 4.4 km from a water source (range: 0 –25km) and 1.3 km from human settlement (range: 0 –11km). The majority of Indian vulture nest sites we observed were in trees, an apparently atypical nest substrate for this species. Drivers of Indian vulture nest site selection are currently unknown yet understanding them is likely key for the success of vulture conservation, particularly the reintroduction of captive bred populations. This study provides the first observational data on Indian vulture nest sites from which causal hypotheses can be generated and tested.

Key words: Indian vulture, Human-dominated landscape, Rajasthan, Spatial characteristics, Nest site.

Introduction

Indian vultures (*Gyps indicus*) are part of a non-migratory scavenging raptor complex that was once widely distributed across most of northern India and Pakistan (Houston, 1985; Prakash, 1999; Gilbert *et al*., 2002). Recent declines in Indian vulture populations were first documented in 1999 (Prakash, 1999) and have since been attributed to the widespread use of the veterinary drug diclofenac (Green *et al*., 2004; Oaks *et al*., 2004). Climate change is also considered a contributing factor to vulture declines, with La Niña induced drought causing thermal and water stress while likely increasing vulture exposure to livestock inoculated with diclofenac (Hall *et al*., 2012).

Vultures are particularly important for the ecology of India because most human populations do not consume the livestock they own. Dead animals are often left in fields or taken to municipal dumping grounds to be disposed of by vultures (Naoroji, 2006). The reduction or complete loss of vultures has facilitated a rapid increase in feral dog populations leading to increased incidence of dog attacks and rabies cases among humans (Markandya *et al*., 2008).

Most recently there is evidence to suggest that vulture population declines may have slowed or even stopped since the 2006 ban on diclofenac (Prakash *et al*., 2012). Despite these positive gains, several threats to wild and captive bred vultures (Vulture Rescue, 2014) across India remain, namely habitat destruction, collisions with cars and trains, continued illegal use of veterinary diclofenac, use of human diclofenac in livestock, climate change, and increased competition for food resources (Chhangani and Mohnot, 2004; Markandya *et al*., 2008; Chhangani 2009; Hall *et al.,* 2012; Prakash *et al*., 2012). Many of these threats may be more significant because current populations are so small (Caughley, 1994).

At present there is a gap in knowledge of landscape-level habitat associations of Indian vulture nests. It is well documented that municipal dumping grounds of major cities attract large numbers of vultures likely due to the abundance of food (Houston, 1985; Ferguson-Lees *et al*., 2001; Naoroji, 2006). Likewise vultures use large water bodies for drinking and bathing after meals (Houston, 1985; Fergusons-Lees *et al*., 2001; Chhangani, 2005; Naoroji, 2006). This trend has been observed in areas of both high and low human population density (Chhangani, 2005; Hall *et al*., 2012). Despite the known association between vultures and human settlements, patterns of proximity of vulture nest sites to food, water, human settlements or even other vulture nests have never been reported. A better understanding of the relationship between the changing landscape (Government of India, 2010), human populations, and endangered vultures will be key to pinpoint areas where wild and reintroduced vultures (Vulture Rescue, 2013) have the highest probability of survival. Here we analyze characteristics of Indian vulture

Vultures nest across Rajasthan and their nest are found 4.4 Km from water source (range: 0- 25Km) and 1.3 Km from human settlement (range: 0-11 Km).

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nest sites in order to describe their relationship with four landscape characteristics, proximity to water bodies, human settlements, major cities, and nearest neighboring nest.

Methods

Fifty-four Indian vulture nest sites across the northwest state of Rajasthan from May 2008 to June 2008 during road transect surveys were located. Nests were spotted using binoculars or the naked eye and all were within 1km of the road. Location of each nest site were marked using a handheld GPS unit and recorded the substrate (tree, cliff, or other) the nest was located on.

Visual interpretation of satellite imagery from Landsat 5 and Google Earth to identify the landscape characteristics associated with each nest site were used. Twenty-four Landsat 5 images were downloaded from the USGS EROS website and the images were chosen to be cloud-free and acquired within one month of the fieldwork. Following landsat metadata and the cost method (Chavez, 1996) each image was converted to ground reflectance. Next, we mosaicked the separate images to create one single image of the study area. We then overlaid vulture nest site GPS data onto the mosaicked image (Fig. 1) and individually measured distances from each nest site to each landscape feature of interest (defined in Table 1). We chose our landscape features of interest based on previous research on Indian vulture populations (Prakash, 1999; Chhangani, 2005;, Naoroji, 2006; Hall *et al.,* 2012). The distance of nest sites to landscape features were taken from nest site to the nearest edge of the landscape feature of interest. Finally, we repeated each landscape measurement for each nest site to landscape features using the high-resolution images in Google Earth (Google, 2014) in order to provide a check on the Landsat measurements. The Landsat imagery has the advantage of consistency of spatial scale (30 m pixels) and timing acquisition. The Google Earth

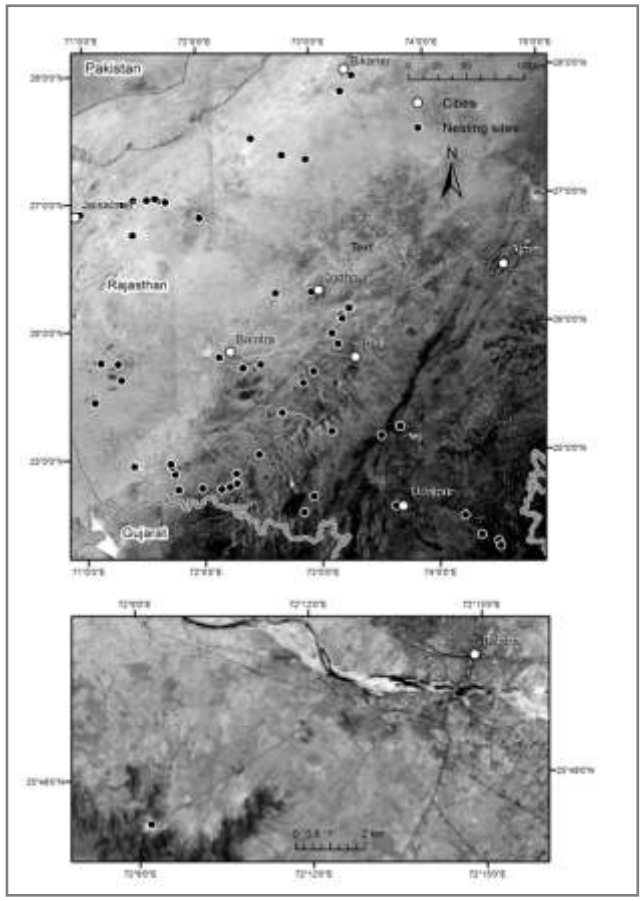

Fig. 1 : Map of nest sites in study area in Rajasthan, India

imagery includes high spatial resolution (1-5 m) commercial satellite imagery, but the nature of the image coverage is not consistent over large areas. Thus, by combining analyses from the two sources we were able to ensure consistency, but also have the benefit of potential for verification from Google Earth data.

Nest site data were analyzed by first calculating the percentage of nest sites on trees, cliffs, or other substrate. In order to describe the landscape-level habitat associations of nest sites we then calculated

Table 1 : Description of landscape characteristics of interest.

Landscape feature	Definition
Water Body	Any discernable enclosure/area filled with water.
Human Settlement	Any discernable housing structure not part of a major city.
Major City	Closest city with a reported population of 2 million in 2008.
Nearest Neighboring Nest	Closest nest site to the nest site of interest.

Table 2 : Summary statistics of nest site proximity to landscape characteristics.

Landscape Characteristic	Distance (km)				
	Mean	Median	Standard deviation	Minimum	Maximum
Water Body	4.39	3.92	4.16	0.04	25.00
Human Settlement	1.34	0.58	2.08	0.00	11.13
Major City	63.73	68.16	38.77	1.12	136.09
Nearest Neighboring Nest	15.70	14.67	12.55	1.39	61.16

summary statistics of nest site distances to each of the four landscape characteristics and lastly constructed boxplots of the summary statistics to visually represent our observations. All calculations and plots were done using R (R 2013).

Results

Of the 54 Indian vulture nests observed the majority were found in trees (67%) (Fig. 2). The remaining 33% of nest sites we observed were on cliffs.

On average nest sites were 4.4 km from water (Table 2). Seventy-five percent of observed nest sites were within 6.5 km of a water body and all but one nest site was within 12 km of this landscape feature (Fig. 3). The average distance between a given nest site and it's closest neighbor was 15.7 km. With the exception of one nest all sites were within 45 km of each other (Fig. 3).

Nest sites averaged a distance of 1.4 km from human settlements (Table 2) and all sites were within 11 km. Ninety three percent of nest sites were less than 4 km away from a human settlement. Average nest site distance to a major city was considerably longer at 63.7 km (Table 2) with all nests within 140 km of a city (Fig. 3). The majority of nest sites were less than 100 km from a major city and all were at least of 1.1 km outside large urban areas (Table 2).

Discussion

Historically Indian vultures gathered in large numbers at municipal dumping grounds to feed on the abundant dead livestock (Houston, 1985; Prakash *et al*., 2003; Chhangani, 2005). However, it is not known how far these municipal feedings sites were from nesting sites. In fact, these historical data may not be especially useful to modern conservation because the remarkably high density that once existed of vultures in India.

The only study on vulture home range in the Indian subcontinent was conducted in Pakistan and suggested white-backed vultures (*Gyps bengalensis*) could cover an area of 60,000+km^2 to find food (Gilbert *et al*., 2007). A similar study on breeding site selection of Eurasian griffon (*Gyps fulvus*) in the Caucus region shows that nest sites were within 20 km of feeding areas (Gavashelishvili and McGrady, 2006). Our data suggest that on average Indian vultures nest within 64 km of major cities, sites where food is consistently available. Presumably the Indian vultures we observed in our study would not have to travel more than ~140 km to find food and return to a nest. This observation has important implications for conservation of nest sites in areas surrounding major cities given historical evidence that vultures regularly feed within city limits.

No data exists on vulture nest proximity to water bodies despite the importance of water for vulture survival (Fergusons-Lees *et al*., 2001; Naoroji, 2006). Our observations show that nests are generally close to water, which suggests water may be an important factor for Indian vulture nest site selection. Many of the water

Fig. 2 : Two Indian vultures nesting in a tree; an atypical nesting substrate for this species

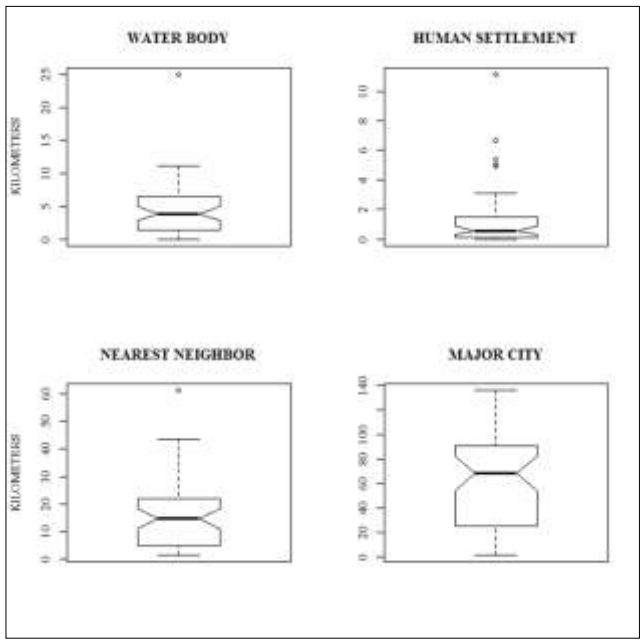

Fig. 3 : Boxplots of nest site distances from landscape characteristics

bodies across Rajasthan, particularly village ponds, are rain fed by the monsoon rains that last from July to September. Because Indian vultures begin nesting and breeding in October (Fergusons-Lees *et al*., 2001; Naoroji, 2006) it is likely they would chose to be near a water source (in the case of our observations within 25 km). Increased variability in monsoon rain patterns brought about by global climate change is expected to affect the amount of water available from seasonal rainfall (Holmgren *et al*., 2006; Francis, 2009). The relationship between vulture nest site selection and available water bodies may become particularly important for vulture conservation within the context of a changing climate.

Indian vultures are known to nest colonially, primarily on cliffs while white-backed vultures (*Gypsbengalensis*) have frequently been observed nesting in trees (Fergusons-Lees *et al*., 2001; Naoroji, 2006). A large proportion of the Indian vulture nests we observed were in trees (Fig. 2), a phenomenon only recently documented in Bikaner and Jodhpur, Rajasthan (Naoroji, 2006; Chhangani, 2011). Although our sampling was non-random (from roads), our data suggest that Indian vultures may nest in trees more frequently than previously recognized. This observation has important implications for the reintroduction of captive bred Indian vultures that would be less constrained than a population that exclusively nests on cliffs.

Two years after the ban on diclofenac our observations suggest that Indian vulture and human populations remain closely associated on a relatively fine spatial scale. The next steps for Indian vulture research include determining the causal relationship between vulture nest site selection, human settlements, and human land use change ultimately leading to the construction of models that can predict optimal nest sites human dominated landscapes. These data form the foundation of such models. The success of vulture recovery will depend on how well conservationists and managers understand the spatial dynamics of vulture nest sites and whether or not the observational patterns we've observed here are in fact important drivers of vulture survival.

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राजस्थान, भारत में नाजुक रूप में संकटापन्न भारतीय गिद्धों (*जीप्स इन्डिकस*) के घोंसला स्थलों का स्थानिक अभिलक्षण

जॉनेथन सी. हाल, अनिल कुमार छंगानी एवं टिमोथी ए. वारनर

सारांश

भारत में गिद्धों ने गत पन्द्रह सालों में भयंकर अवनति का अनुभव किया है। अवनति के कारणों का अच्छी तरह अध्ययन किया गया है, किन्तु भारत के मानव-प्रभुत्व वाले भूदृश्य के संदर्भ के बीच गिद्ध पारिस्थितिकी के विषय में बुनियादी ज्ञान का अभाव है। यहाँ हम राजस्थान, भारत के आर-पार भारतीय गिद्धों (*जीप्स इंडिकस*) के 54 घोंसलों के भूदृश्य स्तर आवास संबंधों पर सूचना दे रहे हैं। हमारे आँकड़े दर्शाते हैं कि औसतन गिद्धों के घोंसले जल स्रोत से 4.4 कि.मी. (रेंज 0-25 कि.मी.) तथा मानव स्थापना से 1.3 कि.मी.(रेंज 0-11 कि.मी.) पर थे। हमारे द्वारा प्रेक्षित अधिकांश भारतीय गिद्ध घोंसला स्थल वृक्षों में थे, जो इस प्रजाति के लिए स्पष्टतया असामान्य घोंसला अध:स्तर है। भारतीय गिद्ध घोंसला स्थल चयन केच ालकव र्तमानम ेंअ ज्ञातह ैं िफरभ ीइ न्हेंस मझनाि गद्धघ ोंसलास् थलोंप रप हलाप ेक्षणीयअ ाँकड़ाउ पलब्धक राताह ै,ि जससेक ारणात्मक परिकल्पना सृजित एवं परीक्षित की जा सकती है।

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