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Source: Folia Zoologica, 64(1) : 32-39

Published By: Institute of Vertebrate Biology, Czech Academy of Sciences

URL: https://doi.org/10.25225/fozo.v64.i1.a4.2015

Folia Zool. – 64 (1): 32–39 (2015)

Striped hyena (*Hyaena hyaena*) status and factors affecting its distribution in the Gir National Park and Sanctuary, India

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Received 14 July 2014; Accepted 19 January 2015

Abstract. The striped hyena (*Hyaena hyaena* Linnaeus, 1758) is a near threatened large carnivore having a wider distribution range than other hyenas. However, very little information is available about its status and ecology. In the present study, we assessed the current status and population density of striped hyenas in the semi-arid tropical forests of the Gir National Park and Sanctuary, India. The density of striped hyenas was estimated through individual identification using a photographic capture-recapture framework. With an effort of 600 trap nights, 24 individual hyenas were identified with an average trapping effort of 17.6 per hyena photograph. The estimated density (individual/km² ± SE) for central zone was 0.04 ± 0.01, for eastern zone 0.12 ± 0.03, for National Park 0.08 ± 0.05, and for western zone 0.02 ± 0.01, while the estimated mean density was 0.07 ± 0.03. We discuss the results of this study in relation to the distribution of hyenas in the Gir National Park and Sanctuary, which provides them a safe denning refugia and dietary requirements. Striped hyenas are under continuous pressure of various threats that directly or indirectly affect its occurrence and abundance, and lack of reliable status of their populations makes it extremely difficult to develop and implement an effective conservation plan to arrest the inferred decline. Very few studies have been conducted so far on this species and our findings may provide some useful information for its conservation in India and elsewhere.

Key words: carnivore, distribution pattern, photographic capture-recapture, status survey

Introduction

Several hyena species are scavenger by habit (Prater 1971, Kruuk 1976, Macdonald 1984, Boitani & Bartoli 1986, Hofer 1998). They seek their food by scent and usually feed on prey killed by other animals. Some hyena species are considered as proficient hunters (Prater 1971, Kruuk 1976). General appearance of hyenas suggest their relation with the dog family, but the structure of skull, teeth and other anatomical features place them in the Feliformia suborder of the Carnivora. Due to these considerations they have been placed in separate family Hyaenidae (Prater 1971). Family Hyaenidae has four species belonging to three genera; spotted hyena *Crocuta crocuta* Erxleben, 1777, brown hyena *Hyaena brunnea* Thunberg, 1820, striped hyena *Hyaena hyaena* Linnaeus, 1758 and aardwolf *Proteles cristatus* Geoffroy Saint-Hilaire, 1824.

The striped hyena is categorized as Near Threatened by the IUCN (Arumugam et al. 2008), while in India it is placed in schedule-III and hunting is prohibited (The Wildlife Protection Act 1972). In some parts of its global distribution range, striped hyenas are considered as critically endangered (Can & Lise 2004, Kasparek et al. 2004). The scanning of literatures reveals that the striped hyena is already extinct in many localities (Kruuk 1976, Hofer & Mills 1998, Wagner 2006, Khorozyan et al. 2011), and that populations are generally declining throughout their geographical range due to persecution, poisoning, and hunting for meat or medicinal purposes. The striped hyena is considered as data deficient and ecological information is needed for its conservation in many parts of its distribution range (Kruuk 1976, Hofer & Mills 1998, Qarqaz et al. 2004). Total Indian population estimate is around 1000 to 3000 individuals representing around 18 percent to 20 percent of the total world population estimate of 5285 to 14670 individuals. The total African population estimates 2450 to 7850 individuals represent roughly half of the world wide estimated population (Hofer

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& Mills 1998). Other ecological factors such as scarcity of food and shelter may also be contributing to the decline, including diminishing food stocks and competition with other carnivores over shelter (Wagner 2006, Alam 2011).

Of the four extant hyena species, only the striped hyena is found in India. Despite its larger distribution range compared to other hyenas, very few studies have been reported from this species; from Africa (Kruuk 1976, Leakey et al. 1999, Wagner 2006), Israel (Skinner & Ilani 1979, Bouskila 1984, Macdonald 1984, Kerbis-Peterhans & Horwitz 1992), Jordan (Qarqaz et al. 2004), Turkey (Kasparek et al. 2004), Armenia (Khorozyan et al. 2011), India (Davidar 1990, Gupta et al. 2009, Harihar et al. 2010, Singh et al. 2010), and in captivity by Rieger (1978). However, most of data are based on anecdotal information and were brief or relatively informal. Only a few detailed studies on its behavioural aspects and ecology have been conducted in Kenya (Wagner 2006), and in India (Alam 2011, Bopanna 2013).

It is important to assess the status and distribution of animals to monitor population trends, especially in the case of rare or endangered species. This is one of the key ecological parameters for understanding the ecology and conservation status of a species (Williams et al. 2002). The assessment of the current status and population trends of the striped hyena is complicated by a number of problems, such as its nocturnal habit, solitary behaviour and occurrence in low densities. Sightings are infrequent and surveys difficult to carry out in most of its distribution range. Accordingly, some special techniques have been developed or established methods modified to accommodate particular situations. For striped hyena methods like questionnaire surveys, extrapolation, Lincoln index, identification of individuals and tracks, signs and vocalizations (Mills 1998) and capture-recapture method using photo camera trap (Karanth 1995) may be used. Photographic capture-recapture estimates of the abundance of a large cat was successfully obtained for tigers *Panthera tigris* Linnaeus, 1758 (Karanth 1995, Karanth & Nichols 1998, Azlan & Sharma 2003, Karanth et al. 2004), jaguars *Panthera onca* Linnaeus, 1758 (Silver et al. 2004), and leopards *Panthera pardus* Linnaeus, 1758 (Henschel & Ray 2003). Further developing this technique for estimating densities of naturally marked species has led most researchers to conclude that this method holds the best promise for estimating abundance of large elusive carnivores. Carnivores normally use game trails and roads for their movements (Henschel & Ray 2003), and placing camera traps in strategic positions along these travel routes may deliver photographic captures of individual using the study area.

Owing to a long history of its management, the Gir National Park and Sanctuary (GNPS) in India has given a significant result in term of Asiatic lion *Panthera leo persica* Meyer, 1826 conservation as well as an umbrella protection to many other endangered and rare species (Meena & Kumar 2012). The GNPS supports high densities of several carnivore species, such as the Asiatic lion and common leopard. It also supports a relatively important striped hyena population in India (Singh & Kamboj 1996, Menon 2003). However, no investigation of the local population of striped hyenas was done. Information on factors influencing the hyena populations across their distribution ranges is also limited. Effective management and conservation of protected area requires monitoring population trend of all wildlife species to provide better management and conservation efforts. Hence the present study was initiated to ascertain current status and distribution of striped hyenas in the GNPS.

Material and Methods

Study area

The study was carried out in the Gir National Park and Sanctuary, located in Gujarat State of India (20°40′-21°50′ N to 70°50′-71°15′ E) (Fig. 1). The total area of the GNPS is 1412.13 km² of which the National Park comprises of 258.71 km² surrounded by 1153.41 km² of Sanctuary. The GNPS is well-known for the only wild population of Asiatic lion in the world. However, it also supports a rich biodiversity viz., 606 recorded flowering plant species, 39 mammal species, 37 reptiles, 300 species of birds and more than 2000 species of insects (Singh & Kamboj 1996, Alam 2011, Meena & Kumar 2012). The GNPS falls under the type 5A/Cla, i.e. Very Dry Teak Forest (Champion & Seth 1968). The area is comprised of low hills of volcanic origin with an altitudinal range of 83-524 m. The GNPS lies around 40 km away from the coast in the Kathiawar or Saurashtra peninsula of Gujarat state. It stretches over a length of about 70 km from west to east and 40 km from north to south. The Sanctuary is narrowest in the east and west. Gir forest falls within the Junagadh, Gir Somnath and Amreli districts. The climatic condition of Gir is generally hot with an erratic monsoon. Seasons in Gir are fairly distinct. June through September is monsoon, followed by a post monsoon season. Late November to early March is winter season. It is followed by a hot dry season from mid March to mid June. The

maximum and minimum temperature is 45 °C in summer and 7 °C in winter. Rainfall is erratic and unevenly distributed. Maximum and minimum annual rainfall varies between 1866 mm and 199 mm, with an average of 980 mm. There are 45 small settlements known as nesses occupied by Maldharies (pastoral grazers) in some part of the Gir sanctuary (Meena & Kumar 2012, Alam et al. 2014a).

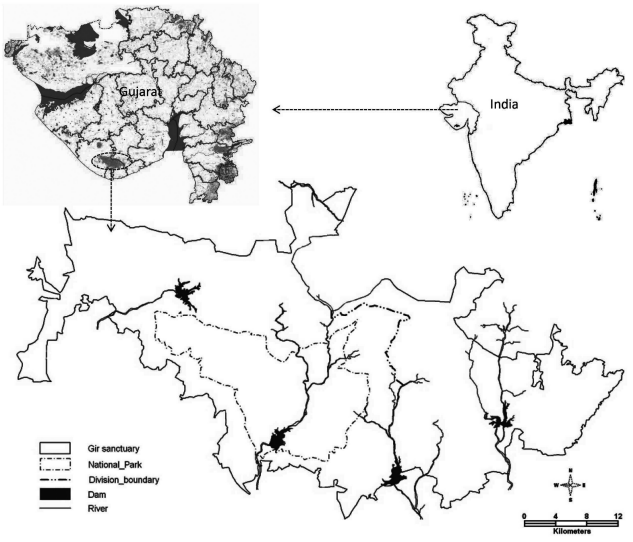

Fig. 1. Location of the Gir National Park and sanctuary in Gujarat, India. Gir is divided into three management units namely Gir East Division, Gir West Division and Gir National Park.

Fig. 2. Location of camera traps in different sampling zones and effectively sampled area.

Methodology

Photographic capture-recapture sampling technique using remotely triggered camera traps was used to obtain an estimate of the striped hyena density through individual identification of their striped pattern (Karanth 1995, Karanth & Nichols 1998, Azlan & Sharma 2003).

There is often little choice in defining a study area, as it may be dictated by jurisdictional boundaries, habitat divisions or by logistics (Henschel & Ray 2003). The accuracy of the density estimate increases with population size, as the larger the area, the smaller the "edge effect". Like all large carnivores, striped hyenas maintain home ranges which must be large enough to provide them with sufficient food year round. The minimum known home ranges of two radio-collared striped hyena females were 44 km² (Kruuk 1976) and 36 km² (Wagner 2006). The study area should ideally be large enough to contain at least parts of the home ranges of several individuals (Henschel & Ray 2003). For most camera trap studies, the number of units available is usually the limiting factor. It is, however, crucial to the sampling design that the whole study area is evenly covered with traps, and that none of the individuals present has a zero chance of being captured (Karanth & Nichols 1998, 2002). If fewer camera units are available, the solution is to subdivide the area into smaller subsections and sample them one by one (Karanth & Nichols 2002).

The GNPS have three different management units named Gir West, Gir East and National Park, and all these management units differ in terms of topography, vegetation cover, prey base availability, rainfall and anthropogenic activities (Khan et al. 1996, Meena & Kumar 2012). With limited time frame, available camera traps and logistic support we identified four zones in the GNPS; East, Central, NP and West. The central zone was overlapping with the east and west management units, which had a mosaic of different vegetation cover. We overlaid a grid of 2.5 × 2.5 km on the study area, and selected 15 grids in the respective four zones to cover all the habitat types and management units. Grids of each zone were searched on foot and using a motorcycle, and the most appropriate sites in each grid were selected as camera trap stations. This approach resulted in a total of 15 stations per zone (Fig. 2). Each zone was further divided into three sub-zones of five grids. At the time one sub-zone was sampled, camera traps were mounted for 10 continuous days or 10 trapping occasions. Thus each zone was covered in 30 days with a total effort of 150 trap nights. A total sampling effort of 600 trap-nights for all the four zones (150 trap-nights per zone) was conducted for six months (December 2007 to May 2008). The trapping efforts were continuous except when climatic and logistical constrains occurred. In the west zone (part of this area is also open for ecotourism) of camera trap survey, all the units were daily mounted and removed from the station to avoid depiction by people and vandalism. In the other three zones camera trap units were kept mounted for 10 continuous days using a night activation mode, and were checked at least

each alternate day. All the camera trap stations were marked on a map using a Global Positioning System (GPS).

Ten units of the Camtrakker brand passive camera traps (Manufactured by Camtrakker South, Watkinville, Georgia, supplied by Forestry Suppliers), were used. The Camtrakker units come with a heat-in-motion detector, which operates on a horizontal plane. When something moves and gives off heat, a silent electronic switch engages the camera, which takes a photograph. A unique identification number was given to each camera trap unit and each film roll before loading to avoid any mix-up.

All the camera traps were mounted as described by Karanth et al. (2004). The Camtrakker units are equipped with a delay selector mechanism that precludes the camera from taking a photograph for a set period of time. The time delay between photographs was set to a minimum of 20 seconds. Considering the extremely nocturnal behaviour of striped hyenas (Prater 1971, Kruuk 1976, Macdonald 1984, Boitani & Bartoli 1986, Hofer 1998), all camera traps were kept active in night mode. For the complete identification of a striped hyena it was necessary to acquire photographs of both sides of its body (Karanth 1995). Therefore two camera traps were set up on each side of the trail at each station. Camera units were mounted on tree in such a way that both flanks of an individual hyena would get clearly photographed. Wherever suitable trees were not found self-designed locally made iron pole with camera trap adjustment screw were used. To avoid flaring of photo from mutual flash interference, two cameras were not positioned directly facing each other. All camera trap stations were identified by giving them a code referring to the name of the area, as well as with their Global Positioning System (GPS) location. Care was taken to match the code of camera trap stations with the corresponding film roll, date and camera trap unit.

Striped hyenas were identified and separated as individuals on the basis of their asymmetrical stripe pattern (Karanth 1995, Karanth & Nichols 1998). We used striped patterns and pelage markings on the limbs to identify individuals. Besides this, in some cases natural markings like notches on the ear pinnae were also used. Both side photographs were used for identification of an individual. Because there is no significant sexual dimorphism in body size in this species, individuals could not be sexed based on photographs. Individuals were coded as HYE when a hyena was observed in the East Zone, HYC when observed in the Central Zone, HYN when observed in the National Park Zone and HYW when observed in the West Zone. For example, the first hyena observed in West Zone was coded as HYW1.

The program CAPTURE (White et al. 1982, Rexstad & Burnham 1991) was used to analyze the capture and recaptured photograph data of striped hyenas. The survey duration was 30 days at each zone, and thus kept short in relation to expected demographic

Fig. 3. The asymmetry of striped pattern on two flanks of the same striped hyena HYC-4 (a, b), and example of unambiguous identification of the same striped hyena HYC-5 (c, d).

turnover rates to provide reasonable assurance that the assumption of "demographic closure population" was achieved. Closure test (Z) was performed to test the null hypothesis of population closure, and the goodness-of-fit tests and overall discriminate function to compare the models (Karanth & Nichols 2002, Williams et al. 2002). CAPTURE tests seven different models, which differ in capture probability variation. The Null Model (M_0), which is simplest, assumes no variation between individuals or over time. Other complex models are the Heterogeneity Model (M_h) in which individuals differ due to sex, age, activity and ranging patterns, etc. the Time Variation Model (M_t) with capture probabilities changing over time; the Behavior Model (Mb) with capture probabilities varying with the behavior, e.g. the boldness of animals; and three combinations of these complex models i.e. time and behaviour (M_{tb}); behavior and heterogeneity (M_{bh}); time, behaviour, and heterogeneity (M_{tbh}). The program identifies which model best fits the data set in subject and then generates capture statistics for all adequately fitted models (Rexstad & Burnham 1991, Karanth & Nichols 1998, Henschel & Ray 2003).

Density estimates were generated by dividing striped hyena abundance by the effectively sampled area (Karanth 1995, Karanth & Nichols 1998). The effective sample area includes a buffer around minimum convex polygon formed by the camera traps stations. Buffer width was estimated at half of the home range diameter. The home range diameter was derived from the mean maximum distance moved by the striped hyena captured more than once (Wilson & Anderson 1985, Karanth & Nichols 1998). The population density of striped hyena was estimated as:

$$D = \frac{N}{A\,(W)}$$

Where D is the resulting hyena density, N the population size computed by CAPTURE, and A (W) the resulting effectively sampled area.

Results

Altogether, 34 usable striped hyena photographs were obtained with an average trapping effort of 17.6 trap nights per striped hyena photograph. The photographs obtained were of good quality and useful. Out of 60 grids, striped hyena photographs were captured from 25 grids (41.6 percent). Different individual hyenas were identified with the asymmetrical striped pattern of both flanks (Fig. 3). From 34 striped hyena photographs, 24 individual hyenas were identified. Among these, 17 individuals were captured once, four individuals were caught twice, and three were caught three times during the sampling period. Total number of individuals identified at each zone varied from 3 to 11, and the number of total capture and recaptures varied from 3 to 16.

The test for behaviour response, test for time specific variation in trapping probabilities and goodness-of-fit test of models of programme CAPTURE were performed. Test for heterogeneity of trapping probability in population of null hypothesis of model M_0 *vs.* alternative hypothesis of model M_h was not performed due to small expected values. The CAPTURE test for closure supported the assumption of population closure i.e. no immigration, emigration, births, or deaths in all the sampling zones during survey period. The model selection criteria of Program CAPTURE identified M_0 as the most appropriate model for three zones; central, east, and NP. This model assumes no differences in capture probability between different individuals and sampling occasions. CAPTURE did not select any model for west zone due to insufficient recapture of identified individuals, thus we selected heterogeneity model (M_h) for west zone, which assumes heterogeneous capture probability of individual (Karanth & Nichols 1998).

The Minimum Convex Polygon (MCP) formed by the most outer camera trap stations was measured with a buffer of half of the home range diameter was added as described in methodology (Wilson & Anderson 1985, Karanth & Nichols 1998). The buffer width (W (SE)) was estimated as 1.99 (0.59) km. For the central zone camera trap polygon was 61.06 km² and with buffer the effectively sampled area (A) was 132.37 km², for the east zone 69.58 km² and with buffer 145.44 km², for the National Park 78.55 km² and with buffer 159.03 km², and for the west zone 61.56 km² and with buffer 132.29 km². The average capture probability (P) per sample for central was 0.17 and corresponding population size estimate N with standard error (SEN) was 5 ± 1.32, for east P was 0.09 and corresponding population size estimate was 17 ± 5.14, for NP P was 0.05 and corresponding population size estimate was 12 ± 8.81 and the P per sample for west was 0.10 and corresponding population size estimate was 3 ± 2.46. The striped hyena density was obtained by dividing estimated population size N by the effectively sampled area (A). The estimated density (D ± SE striped hyena/km²) for the central zone was 0.04 ± 0.01, for the east zone 0.12 ± 0.03, for the National Park 0.08 ± 0.05, and for the west zone 0.02 ± 0.01. The mean density of striped hyena was estimated as 0.07 ± 0.03 for the whole GNPS.

Discussion

We attempted to estimate abundance of the striped hyena population in a semi-arid forest ecosystem in western India. Unlike spotted hyenas, striped hyenas live solitarily and occur at relatively low population densities throughout their distribution range (Kruuk 1976, Holekamp & Smale 1993, Wagner 2006, Singh et al. 2010, Alam 2011). The quantitative estimation of striped hyena density in Africa, based on the observation of a limited number of individuals, was greater than 0.02 striped hyena per km² in the Serengeti National Park (Kruuk 1976), and 0.03 adult striped hyena per km² in Laikipia District, Central Kenya (Wagner 2006). Heptner & Sludskij (1980) reported a density of 0.01 striped hyena per km² in Tadzhikistan. Recently, a few population estimations were also obtained in India. A density of 0.15 striped hyena per km² was measured in the Sariska tiger reserve (Gupta et al. 2009), 0.03 to 0.05 in the Rajaji National Park (Harihar et al. 2010), and 0.03 and 0.06 in Kumbhalgarh and Esrana sites of Rajasthan, respectively (Singh et al. 2010), which are both located outside protected areas. The mean density estimate of striped hyenas of 0.07/km² in the GNPS is similar but slightly higher than the population estimates in other areas (Kruuk 1976, Heptner & Sludskij 1980, van Aarde et al. 1988, Wagner 2006, Harihar et al. 2010, Singh et al. 2010), except in Sariska Tiger Reserve in Rajasthan (Gupta et al. 2009). The abundance of prey species is a determining factor for the abundance of large predators (Karanth & Nichols 1998, Karanth et al. 2004) that also could determine the population of natural scavengers. The reason for the relatively higher density estimation in the GNPS, as compared to other studies, may be related to the higher availability of herbivores and natural predators resulting in higher incidence of carcasses (Khan et al. 1996, Meena & Kumar 2012). Studies on striped hyenas seem to indicate that populations occur at lower densities in Africa than in Asia (Kruuk 1976, Heptner & Sludskij 1980, van Aarde et al. 1988, Wagner 2006, Harihar et al. 2010, Singh et al. 2010, Alam 2011).

We expect that striped hyenas are relatively equally distributed in GNPS, but variation in their density in the different zones was observed. The variation in the striped hyena density in different zones could be related to habitat and availability of resources (Alam 2011). In the GNPS habitat changes from teak (*Tectona grandis*) dominated dense forest in western parts to more arid and open type scrub land in eastern parts (Alam et al. 2014a). The other factor governing low population could be operation of ecotourism which is restricted to the west zone area; however, there is no validation done on impact of ecotourism on wildlife. Generally striped hyenas favour open or thorn bush country in arid to semi-arid environments (Prater 1971, Rosevear 1974, Kruuk 1976, Rieger 1978, Leakey et al. 1999, Wagner 2006, Alam et al. 2014b). The eastern part of the GNPS is more open with thorn bushy and less vegetation density and high grass cover, where we found high striped hyena density, compare to west sanctuary which has a relatively dense vegetation cover. Results of a striped hyena-habitat relationship study in the GNPS suggests that the striped hyena population density was positively correlated with the grass availability and negatively correlated with the tree density (Alam 2011). The other reason for the observed higher density in the eastern part could be related to the higher presence of nessess, human settlements and livestock availability. Striped hyena may remain active in areas frequented by humans, while avoiding them on a temporal scale (Rosevear 1974, Kruuk 1976, Wagner 2006, Singh et al. 2010, Alam et al. 2014b). The availability of safe refuge with human and livestock presence (alternative food from the carcass by natural causes and by predators) may govern the population of striped hyena.

Our study is the first to assess the status and distribution of striped hyena in the GNPS. Confirming the previous research (Karanth 1995, Karanth & Nichols 1998, Azlan & Sharma 2003, Karanth et al. 2004, Silver et al. 2004, Trolle & Kery 2005), this study demonstrates the viability of the method for estimating densities of individually recognizable species that have been usually difficult to study because of cryptic habitats, large home range, and low population densities. Despite of some methodological shortcomings of this study, largely due to time, recourse constraints and lower number of camera trap units, photographic capture-recapture method was successfully applied to assess the status of striped hyena more rigorously than had been possible earlier. Further refinement to the methodology and its application would make this method even more useful for monitoring the status of elusive species. Density estimates of the striped hyena can be generated using this method from protected areas across the distribution range which can serve as critical baseline data for future monitoring. Our findings for its population status in the GNPS have foremost potential value for global range conservation of this species. These estimates are critical for filling the gap in information on status

and ecology of this wide-ranging but less-studied species, which is essential for conservation not only in India but also in other part of its geographical distribution.

Striped hyenas are under the continuous pressure of several threats that directly or indirectly affect their occurrence and abundance (Arumugam et al. 2008, Alam 2011, Khorozyan et al. 2011). Based on the studies (Mills & Hofer 1998, Wagner 2006, Alam 2011, Akay et al. 2011, Khorozyan et al. 2011) striped hyenas are declining in many places owing to persecution (poisoning, killing and hunting), habitat alteration and destruction and as a result of decreasing natural sources of food. This could also happen because other sympatric carnivores are facing population decline. However, lack of reliable status of its population makes it extremely difficult to develop and implement an effective conservation plan to arrest the inferred decline. Such status assessments would be extremely useful to deduct changes in status of sympatric carnivores. Based on the population trends observed through regular monitoring, reappraisal of the status of these species could be done and appropriate conservation strategies could be developed throughout the distribution range.

Acknowledgements

We are grateful to Ministry of Environment and Forest, Government of India for financial support and Gujarat Forest Department for granting permission for conducting fieldwork. Special thanks to S.M. Raja, DCF, Wildlife Division, Sasan-Gir for his help and support during the study. We are thankful to Department of Wildlife Sciences, Aligarh Muslim University for logistic and institutional support. We are also very much thankful to two anonymous reviewers for their valuable comments helped in improving the quality of this paper. We are also thankful to field assistances and forest staffs of GNPS for their help and support in field.

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