International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133, Print ISSN: 2664-7125
Received: 24-07-2021, Accepted: 10-08-2021, Published: 25-08-2021
Volume 3, Issue 3, 2021, Page No. 135-139

Habitat suitability of striped hyena (*Hyena hyena*) in Sariska tiger reserve, Rajasthan India

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Abstract
The present study was conducted to understand the habitat features governing distribution of striped hyena in Sariska Tiger Reserve, Rajasthan, India, based on habitat suitability approach. Binary logistic regression method was used to model habitat suitability for striped hyena in the study area between November 2007 to June 2009. In total, 100 trapping stations were sampled for 25 days resulting into total effort of 2500 trapping nights. The 100 trapping stations covered an area of 95.99 km^2 (MCP). Binary logistic regression analysis revealed overall prediction accuracy for depicting the striped hyena presence in the intensive study area was 72%**.** It was found that striped hyena was using the area presence of *Boswellia*, scrubland and area close to villages in study area. Comparatively, very less area was found as medium and high suitable areas for this species in the study area. Validation based on independent variables predicted probability of occurrence through logistic models was true for intensive study area.

Keywords: striped hyena, logistic regression, camera trapping, sariska tiger reserve

Introduction

The striped hyena *Hyaena hyaena* is one of the most important large scavengers they are widely distributed in an area extending from east and northeast Africa, through the Middle East, the Caucasus region, and central Asia, to the Indian subcontinent (Mills and Hofer 1998) [15]. In Indian subcontinent, they occupy habitats located in arid and semi-arid regions to the wet zone of the south-western coast (Prater 1971; Karanth 1986) [17, 13] except the moist forests of the north-eastern region (Prater 1971) [17]. This nocturnal carnivore is a long-ranging and solitary forager, living in small groups with unknown compositions (Mills and Hofer 1998) [15].

Striped hyena feed on variety of vertebrates, invertebrates and vegetation and play an important role in consuming dead and decaying bodies and also recycling dead organic matter (Kruuk 1976; Gupta 2011) [14, 10].

Evaluation of population status and their habitat attributes at the local and regional level is crucial for planning a conservation strategy to maintain viable population of a species (Gupta et. al 2009, Singh *et al* 2014) [24, 20]. Despite the important role of the striped hyenas in ecosystems, disproportionately little effort has been expended in studying them. Habitat alteration across their range is a likely cause of declining populations (Ripple *et al*. 2014) [21]. In recent past, widely accepted camera trapping technique was used to estimate the population of striped hyena in few pockets of its distribution (Gupta *et al* 2009, Harihar *et al* 2010, Alam et. al 2014, Singh et.al 2014) [24, 2, 20] and a few studies were conducted to study the suitable habitats for striped hyena (Alam et. al 2009, Singh et.al 2010, Singh *et al* 2014, Alam *et al* 2014) [1, 25, 20, 2] based on different statistical approaches. The International Union for the Conservation of Nature (IUCN) has classified the striped hyenas as near threatened (Arumugam *et al*. 2008 Athreya et. al 2013) [5, 4]. Evaluation of the population status and their habitat attributes at the local and regional level is crucial for planning a conservation strategy to maintain viable populations. Unfortunately, few studies have looked into the ecology of striped hyenas (Singh *et al*. 2014) [20].

Previously, the authors studied population of striped hyena in Sariska Tiger Reserve (STR), Rajasthan (Gupta *et al*. 2009) [24] and found that STR holds high density of striped hyena (15 individuals/ 100 km^2) comparing with the other studies conducted in semi-arid landscapes in India and Africa (Kruuk 1976; Wagner 2006; Singh 2008; Wagner *et al.* 2008) [14, 28, 20, 27] and it was assumed that high density of striped hyena could be attributed to the availability of high wild prey base and domestic livestock in the study area (Gupta *et al*. 2009, Gupta S 2011) [24, 10]. Another study in the same study area revealed that the proportion of nilgai (*Boselaphus tragocamelus*) and cattle (*Bos indicus*) was more than 25% and proportion of other wild ungulates (chital *Axis axis* and sambar *Rusa unicolor*) was nearly 35% in the diet of striped hyena (Gupta. S 2011, Chourasia *et al*. 2011) [10, 16].The proportions of large ungulates (chital, sambar and nilgai) were observed more in scat samples as compared to the proportion of other livestock, birds, rodent and hare (*Lepus nigricollis ruficaudatus*) (Gupta, S 2011, Chourasia *et al*. 2012) [10, 16]. Hence, believing in the complex matrix between a medium sized scavenger carnivore and occurrence of different wild prey base in different habitat types, it was imperative for authors to study the habitat suitability of striped hyena in the study area. In the present study, authors predicted habitat suitability model for striped hyena in STR using logistic regression approach.

Study Area

The present study was conducted in Sariska Tiger Reserve (STR), 27.3104° N, 76.4389° E situated in the Aravalli Hill range and lies in the semi-arid part of Rajasthan (Rodgers and Panwar 1988) [22]. The total area of the Tiger Reserve is 881 km^2, including 273.8 km^2 as a notified National Park. The intensive sampling for presence-absence data was conducted in an area of 144 km^2 inside the notified National Park area. The vegetation of Sariska corresponds to Tropical dry deciduous forests and Northern Tropical thorn forests (Champion and Seth 1968) [6]. Open areas in the Park are occupied with scrub forests dominated by *Zizyphus nammularia, Capparis sepiaria, Capparis decidua, Adathoda vasica, Prosopis juliflora* and *Acacia sp*. The valley areas in STR are dominated by *Zizyphus mauritiana* mixed forests, gentle slopes are dominated by *Anogeissus pendula* forests and the steep slopes are occupied with *Boswellia serrata* forests.

Other than striped hyena, STR supports various carnivore species such as tiger, leopard, jackal (*Canis aureus*), jungle cat (*Felischaus)* and herbivore species like chital, sambar, nilgai, common langur (*Semnopithecus entellus)*, wild pig (*Sus scrofa)*, porcupine (*Hystrix indica)*, rufous-tailed hare and indianpeafowl (*Pavo cristatus)* (Sankar 1994). There are 30 villages within STR and a large number (N ~ 18000) of buffaloes (*Bubalus bubalis*), goats (*Capra hircus*), sheep (*Ovis aries*) and cattle are kept by people living in villages.

Materials and Methods

A block of 144 km^2 (12 km X 12 km) was selected as intensive study area inside STR and the entire block was divided into 1 km X 1 km grid-cells (resulting into 144 grid-cells). Camera trapping method was adopted to collect presence and absence information of striped hyena in intensive study area (144 km^2) from November 2007 to June 2009. A total of 100 locations were selected for the placement of camera traps in the intensive study area. Each camera trap location was considered as the representative of that particular grid-cell determining the presence or absence of striped hyena. If striped hyena was detected at least once at a site over the entire sampling duration, were recorded as present '1' or '0' otherwise. These binary records of presence/ absence of striped hyena were converted into digital data in GIS using Arc Map Program, and plotted as presence and absence information on each grid-cell.

Spatial data, which were generated for STR (Sankar et.al 2009) [8], was used for preparing spatial layers on habitat features relevant for striped hyena. Total of 12 macro habitat variables, considered for the preliminary analysis were characterized under four environmental descriptor classes as given in Table 1 and Table 2. Topographical variable (Digital Elevation Model - DEM), anthropogenic variables (Euclidean distance from the centre point of a grid-cell to nearest village and road), habitat variables including vegetation types (7 macro vegetation types) and Normalized Differential Vegetation Index (NDVI), hydrological variable (Euclidean distance from the centre point of a grid-cell to the nearest water source were considered to build the model for habitat suitability of striped hyena in the study area. These variables were chosen on the basis of field knowledge and information on species biology provided by Prater (1971) [17] and Schaller (1967) [18].

Mapping of vegetation types was done based on remotely sensed data of Landsat -7 – ETM+ imagery for the month of September. Geocoded False Color Composite (FCC) on 1:50,000 scales for entire study area were procured, and the different colour tones for 30 classes were prepared. The colour classes were merged depending on the similarity in vegetation types. The map was further improved using supervised maximum likelihood classifier to incorporate unclassified and misclassified data. Seven major vegetation and land cover classes were delineated and mapped with 80% accuracy (Sankar et. al 2009) [8]. Area occupied by each vegetation type in each grid-cell (1 km x 1 km) was extracted from vegetation map. A separate layer was prepared computing area of each vegetation type in each grid-cell for the final analysis. Digital data on contour and drainage were used to create Digital Elevation Model (DEM) on the basis of interpolation. All village locations and water points were recorded using GPS and all roads were mapped in the study area. The locations were further downloaded and Euclidean distance was calculated from the centre of each grid-cell to the nearest water sources, roads and villages. The information of major food items (as described by Chourasia *et al* 2012) [16] were estimated with the encounter rates of each species photo-captured in each camera locations (i.e. in each grid-cells) and colour-gradient layers were prepared for each species based on their encounter rates in the intensive study area. Based on the camera trap photographs and extensive sign survey in the intensive study area, a probabilistic surface of distribution was created for striped hyena. All the other variables were then equalized and extracted to 1 km x 1 km grid-cells using Arc Map program (ESRI 1996) [7] and then were taken to SPSS/PC software for further analysis and construction of equation to generate probability surface of distribution.

For binary logistic regression all grid data including eleven candidate variables (that are closely related to each other like vegetation classes) and six categorical variables were used for the study species. These variables were selected for model building and further validation of model. A cross-correlation matrix was produced initially to see if the variables were highly correlated to one another. Inclusion of highly correlated variables can lead to over fitting of the model and lead to overestimating the performance of the model. Variables with correlation coefficients > 0.60 were removed from the models. Enter elimination processes were applied to identify and remove redundant variables and those variables that did not contribute significantly in segregating presence of any species in the study area. Enter method was more useful as it enables better control over explanatory variables and consequently, allows inclusion of desired variables that have biological significance, but could have been compromised over better model fit by different elimination processes. Overall prediction efficiency of the variables was assessed based on Nagelkerke-R^2. Influence of individual variables including categorical variables was assessed using Wald statistics. Hosmer and Lemeshow goodness-of-fit test (chi square test) and concordance analysis (classification tables) were done to understand the fit of the model (Hosmer and Lemeshow 1989) [12]. Sensitivity (percentage true positive or presence correctly predicted) and specificity (percentage true negative or absence correctly predicted) were calculated for each cut-off point (0.1 to 0.9) and best cut-off point was chosen on the basis of optimum sensitivity and specificity. The cut-off level would allow categorization of the probability values to represent either 0 if it is below the cut-off point or 1 if it is above the cut-off point.

Logistic regression was done using the selected variables and at an appropriate cut-off level and the probability of occurrence was estimated for each of the variables using the following formula.

Probability of event (or presence) = 1 / (1 – EXP–z)

Where,
Z = a + (b1 ´ X1) + (b2 ´ X2) + (b3 ´ X3) + …….. (bk ´ Xk),
a =constant, b = coefficients and X = predictor variable.
The equation was then taken to GIS and probability of occurrence of striped hyena was predicted for the intensive study area and habitat suitability map was generated using ArcMap. The transformed output was then classified into least, low, suitable and high suitability areas for striped hyena. Due to lack of information from the other areas of STR and adjoining areas the model was not used to predict or extrapolate for entire STR.

Results and Discussion
Logistic regression analysis revealed clear pattern of presence grids for each explanatory variable involved in model building for striped hyena. It was found that striped hyena largely used Boswellia forest, scrubland and areas near villages (Figure 2). Enter method was initially applied for all eleven variables and six categorical variables, the variables which were strongly correlated (P>0.6), were then discarded to avoid redundancy in the predictors. Based on quality of 100 information, final eight variables were retained to develop a better model fit and also for development of final equation for striped hyena (Table 2). The -2 Log Likelihood value and Nagelkerke R2 were 78.399 and 0.319 respectively, indicating improvement of model fit with inclusion of the above variables and a combined effect of the variables in predicting probability of occurrence. Hosmer and Lemeshow goodness-of-fit test indicated that the obtained model did not differ significantly from null model or expected fit ($\chi 2$ = 9.511, p = 0.30). Overall correct prediction rate of the model was 71.8%. Prediction rate for true positives (presence - 1) was 79.5 and it was 62.5% for true negatives (not present -0). The best cut-off level that optimized sensitivity and specificity was at 0.5 (Figure 1). Final analysis at this cut-off point had six explanatory variables (with three land cover variables) and two categorical variables (prey) were used to develop final equation (Table 2).
Distribution maps obtained for striped hyena in this study represents probability values (0-1) in 144 km^2 (1 x 1 km grid-cells) indicating chance of encountering the particular species in intensive study area in STR. The entire approach was based on the premise that species distribution is related to vegetation, food species and topographic features. Spatial mapping of probability of occurrence using logistic regression method has been found to be effective in predicting occurrence of striped hyena in STR. In the present study, logistic regression technique provided a basis for constructing probabilistic model and enabled to remove redundant variables from the equation. Besides DEM and water, seven variables (including vegetation classes) were found insignificant with the model building were removed from the final equation for this species. These variables collectively accounted for 72% for explained variable which was used in equation for striped hyena (R^2=0.319). Scrub and canopy cover indicated by NDVI, distance to nearest village, *Boswellia* dominated forest and scrubland) and encounter rate of chital were found to be negatively correlated with the occurrence of striped hyena and other variables like distance to road, *Zizyphus* mixed forest and encounter rate hare were found to be positively correlated with species occurrence.
Although above explanation indicate the role of individual variables in the equation, it could not be substantiated due to observed multicollinearity in the explanatory variables, as indicated by large p-values. Multicollinearity is known to exist when explanatory variables are highly correlated with each other and is an intractable problem in all regression analysis as it undermines statistical significance of individual explanatory variables (Allen 1997 and Ramesh 2003) [19, 3]. However, since the objective was to come up with an overall prediction of species distribution regardless of which variable is contributing in relative magnitude, multicollinearity was taken into account. Moreover, it was found that these variables together predicted the distribution well and removal of any of the covariates from the model resulted in reduction of prediction rates.
Out of total intensive area 144 km^2, 36 km^2 and 82 km^2 were found very low and low suitable areas respectively for striped hyena which represented 82% of total study area while 25 km^2 and 1 km^2 was considered as medium and high suitable areas respectively and these areas represented for 18% of study area (Figure 2). The present result on distribution of striped hyena was consistent with the information available on this species from other areas where it typically inhabits the scrubland, woodland and rocky terrain (Kruuk, 1976; Wagner, 2006) [14, 28].
The presence of the hyena may have been associated with such habitats because they provide concealed daytime resting sites. During our field surveys and camera trapping captures, we flushed hyenas during the daytime in dense shrub. These observations support our findings regarding the positive effect of scrubland as hiding or resting places during the daytime for hyenas. Earlier studies all support they are commonly found near human habitation in India (Prater, 1971, Singh et.al 2014) [17, 20]. In East Africa they are mostly observed in Acacia savannah with little shrub and trees (Kruuk, 1976) [14]. Suitable sites for striped hyena in STR were largely dependent upon areas near to road and villages and some vegetatio0 classes like Boswellia and Zizyphus (Figure 2). Among the prey species, distribution of hare highly affected the distribution and suitable sites for striped hyena in the intensive study area. The present study also forms baseline information of habitat preferences of striped hyena in semiarid landscape. It is crucial to evaluate the habitat of striped hyena to ensure the continuity of distribution whose population is tend to decrease in many parts of its natural distribution areas.

Table 1: List of the variables used in Logistic regression analysis to model habitat suitability of striped hyena in Sariska Tiger Reserve, Rajasthan, India

Variables	Variables type	Source
1. Habitat	Anogessius dominated forest	Land use and land cover map from Landsat -7 – ETM+ data (source: Sankar et. al 2008)
	Boswellia dominated forest	
	Butea dominated forest	
	Zizyphus mixed forest	
	Acacia mixed forest	

	Scrubland	
	NDVI	Field data (camera trapping)
	Prey information	Field data (camera trapping)
2. Anthropogenic	Distance from village (mean)	Village and road map, WII
2. Anthropogenic	Distance from roads (mean)	Village and road map, WII
3. Topographical	DEM	Contour map, WII
4. Hydrological	Distance from water (mean)	Water source map, WII

Table 2: Coefficient and variables used in logistic regression to model habitat suitability of striped hyena in Sariska Tiger Reserve, Rajasthan, India

Variables	Coefficient	S.E.	Wald	df	Sig.	Exp(B)
NDVI	-7.141	10.089	.501	1	.479	.001
ROAD	.006	.006	.954	1	.329	1.006
VILLAGE	-.004	.003	1.276	1	.259	.996
BOSWELLIA	-38.200	19.960	3.663	1	.056	.000
ZIZYPHUS	10.133	9.200	1.213	1	.271	2.515
SCRUBLAND	-45.959	30.185	2.318	1	.128	.000
CHITAL	-2.504	.969	6.680	1	.010	.082
HARE	1.535	.883	3.024	1	.082	4.642
Constant	3.589	4.244	.715	1	.398	36.187

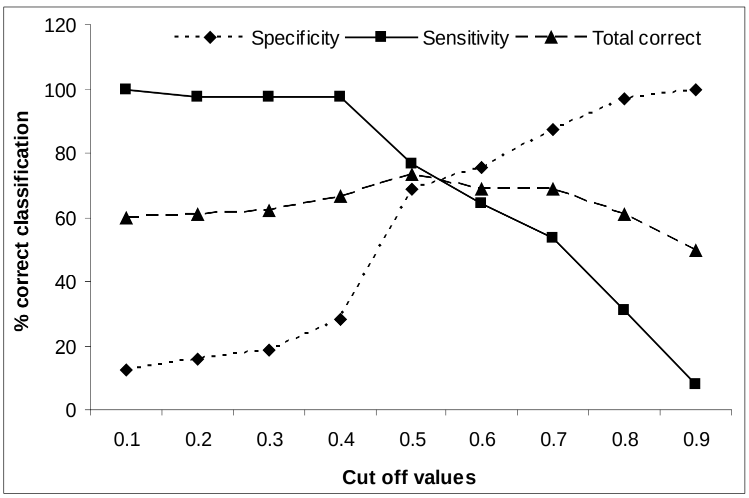

Fig 1: Concordance analysis depicting sensitivity and specificity in different cut-off of values for striped hyena in STR, Rajasthan.

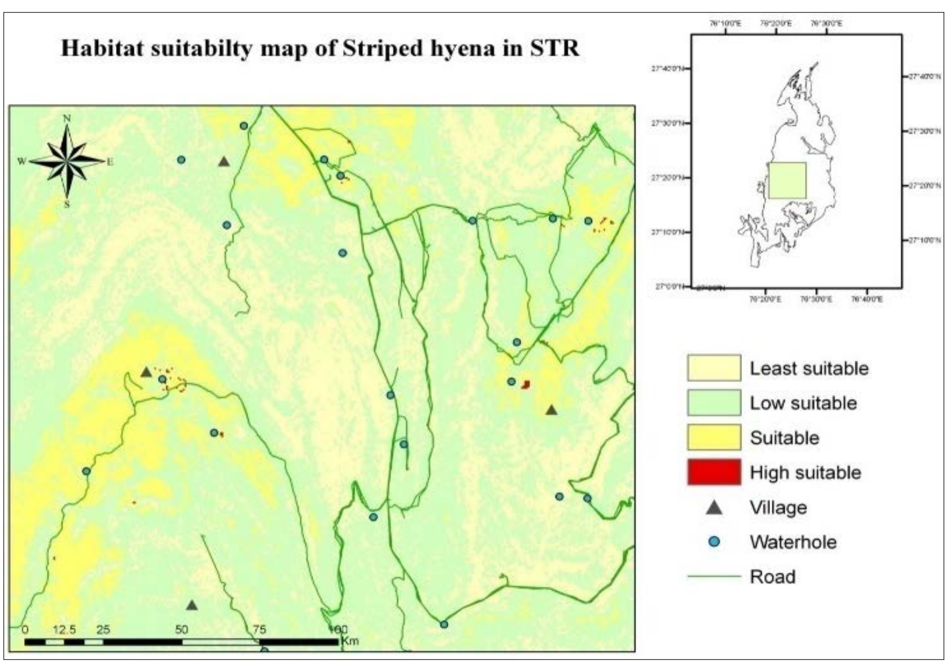

Fig 2: Habitat suitability map predicting occurrence of striped hyena in intensive study area in STR, Rajasthan, India

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