

**HABITAT USE, RANGING PATTERN AND FOOD  
HABITS OF STRIPED HYAENA (*Hyaena hyaena*) IN  
KUTCH, GUJARAT**

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**Certificate**

This is to certify that the thesis titled '*Habitat use, ranging pattern and food habits of Striped Hyaena (Hyaena hyaena) in Kutch, Gujarat.*' submitted for the award of degree of **Doctor of Philosophy in Wildlife Science** to Saurashtra University, Rajkot (Gujarat) is a record of original and independent work carried out by **Mr. I. P. Bopanna** under my guidance. No part of this thesis has been submitted in part or full to any other University/Institution for the award of any other degree and it fulfils all the requirements laid down by Saurashtra University.

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## **Executive Summary**

Most of the wildlife in Kutch has survived outside the Protected Area network in the agro-pastoral landscape system, owing to the traditional lifestyle and land use practices. This makes Kutch a unique ecosystem within the semi-arid biome of India, where large numbers and an interesting assemblage of wildlife are harboured. Among the diverse carnivores found in Kutch, the striped hyaena is the one of the largest and the region is also a stronghold for the species. Hence this study was developed for a better understanding of the ecology and behaviour of the species. It aims at providing a better understanding of density, food availability and sociability in hyaenas, at the interface of human land uses. The study was carried out mostly in Abdasa and parts of Lakhpat, Nakhatrana and Mandvi talukas in Kutch district of Gujarat state, for five years from January 2006 to January 2011. During the course of the study, the sudden influx of industrialization in the region changed the dynamics drastically, undermining traditional way of life and value system. This change in dynamics resulted in rapid change in land use patterns and illegal encroachment of prime wildlife areas, directly affecting the wildlife in the region. This study will directly contribute for the conservation of the species in the region and elsewhere.

Among hyaenids, the striped hyaena is relatively data deficient very few studies have been carried out on ecological aspects of species. Most of the intensive study has been conducted in African continent and few in the Middle East. Since, in Indian sub-continent most of the studies were brief, there is very little information available on the species ecology, behaviour and social organization from this region. Ecological information is not easily obtained for cryptic species like hyaenas due to its elusive behaviour, poorly accessible habitats and also due to their inconsistent activity patterns. Therefore, our use of Radio telemetry was an important and an indispensable tool to understand the ecology of the species. A total of 24 clans were identified in the study area from surveys, out of which 5 clans in the intensive study area were studied by telemetry, where multiple individuals from each clan were equipped with radio collars. Along with home range estimates for hyaenas, other ecological information like movement, denning ecology and social behaviour would be inferred from the radio tracked locations.

## Diet

Since the study area is an agro-pastoral dominated landscape, it supports a large population of livestock and people being largely vegetarians, large quantity of food is available in form of carcasses, to scavengers. I determined the food habits and foraging patterns of the species in the region and its dependence on anthropogenic food sources. The baseline data on striped hyaenas diet was evaluated through analysis of adult scats (n=1460), cub scat (n=500) and regurgitated pellets (n=466) collected seasonally from all known dens in the study area and intensive study area. Adult scats comprised of 46.23% of single prey (SP), 53.77% of multiple prey (MP), 16.44% were of single food item (SFI) and 83.56% were of multiple food item (MFI). In regurgitated pellets 29.83% were of single prey (SP), 70.17% were of multiple prey (MP), 16.31% were of single food item (SFI) and 83.69% were of multiple food item (MFI). The overall diet components in scats and regurgitated pellets were grouped into a) Vertebrates (21 species found in scat and oral cast) b) Major plant derived c) Others d) Garbage and e) Unidentified. It was found that vertebrates contribute to more than 50% volume intake in both scats (54.50%) and regurgitated pellets (56.01%). The sample size estimation quantified for scats show that the cumulative frequencies of prey items stabilize at around 160 scats and at around 290 samples for regurgitated pellets. No significant differences in diets were seen in scats across seasons among major diet components. Birds were represented more in winter; reptile and cutiba (*Cucumis sp.*) intake was higher in winter and monsoon. Similarly no significant seasonal differences among major food item were found in regurgitated pellets. Rodent and cutiba were represented more in monsoon; jackal (*Canis aureus*), melons (*Cucurbitaceae*), others were more frequent in summer samples. *Zyzyphus* (*Zyzyphus spp.*) intake was higher in winter; while reptiles and groundnut (*Arachis hypogea*) were represented more in winter and monsoon. Significant differences in mean proportions among major food items were observed between scat and regurgitated pellets. Cattle (*Bos spp.*), dogs (*Canis lupus familiaris*) and cutiba were represented more in scat; while sheep (*Ovis aries*), goat (*Capra aegagrus*), wild pig (*Sus scrofa*), other mammals, jackal and grass (*Poacea spp.*) were more in regurgitated pellets. But, the frequency of occurrence is biased towards mammals with long hair, coarse hair and quills. The grass presence is very high in regurgitated pellets as compared to scats, this act as roughage bundling undigested food material into a compact ball,

these grass dominated oral cast samples have short mammalian hair embedded in them. The results of scat and regurgitated samples show a very varied food habit. Along with plant derived food items, garbage/refuse; the diet is represented by 21 vertebrates (19 mammals), only the Indian wolf (*Canis lupus pallipes*) and Indian fox (*Vulpes bengalensis*) is not represented in either scat or regurgitated samples (but, they have been identified from bone accumulations around den). These two species represented in bone accumulations, complete the representation of a high trophic diversity; with all mammalian species in the study area identified from both sample types. Cattle and medium livestock (goats and sheep) are heavily represented; indicating the species dependency on anthropogenic provided food source as major vertebrate contribution in diet, followed by dogs and jackals. Wild pig and porcupine (*Hystrix indica*) were found only in 'multiple prey (MP)' and 'multiple food item (MFI) type samples, indicating that these prey item carcass elements were scavenged. While, Birds, Black naped hare (*Lepus nigricollis*) and rodents are found in 'single food item' (SFI) in the diet, and are likely to be the result of predation. The presence of prosopis (*Prosopis spp.*) pods and grass in samples are likely to perform the function of roughage. I also found striped hyaena in 20 samples (oral: n=7, scat: n=13), indicative of cannibalism. Where most of the food is opportunistically obtained from carcass elemental scavenging (presence of maggot case in samples, is evident of scavenging), scavenging on human generated refuse (evident from the 'garbage' presence in samples) and incorporating plant-derived food reveals that the striped hyaena is an opportunistic feeder with a generalized diet. In this study, with a good sample size of regurgitated pellets, the possibility of using only regurgitated pellets for hyaena diet analysis was explored. Using only regurgitated pellet samples would be an over estimate of certain species and under estimate of others.

### **Home range and Movement patterns**

As hyaenas derive their energy requirements from anthropogenic induced food sources, it is important to know how hyaenas balance the potential benefits and costs of movement in a human dominated landscape. The home range and movement pattern of hyaenas in Kutch were studied between 2007 and 2011. A total of 8 hyaenas were trapped in 69 trap-nights from 4 different clans (groups). Out of the 8 hyaenas trapped, 7 were fitted with radio collars. The animals were observed and followed on foot and four-wheel drive at dawn (0600 to 0900 hrs) and dusk (1730 to

1945 hrs). Their nocturnal activity (2000 to 0600 hrs) and locations were inferred from radio tracking. For continuous tracking (24 hr), the maximum times allotted between locations were 15 minutes. Two non-parametric methods, the minimum convex polygon (MCP) and the fixed kernel, were used to estimate home range size. In this study, for choosing the smoothing parameter, several curves were plotted and the estimate found in most accordance with the density of locations was chosen. Thus, the reference bandwidth was reduced to a fixed proportion of 0.80. The total number of 'fixes' of each individual was sorted into 'fixes' at every 2 hour interval, to reduce autocorrelation, and only data from collared individuals were considered. 'Home range' is defined as ranging pattern of individual hyaenas computed using only 'fixes with 2hr interval' in order to use uniform number of locations for both MCP and FD kernel estimators. 'Space use' is defined as the absolute size of the area covered by individual hyaenas, where 'Total numbers of fixes' were used and only 100% MCP were estimated. To estimate daily movement patterns, I used speed between successive locations as a measure of movement rate. Only continuous tracking (24 hr tracking) data was used to compute the movement rate of hyaenas. The average distance covered by hyaena in one night is 14.0 ( $\pm$  0.6) km with average speed of 1.2 ( $\pm$  0.05) km/hr. The distance travelled every two hours was computed to determine the peak travel time (time of the day where the animal moves covers larger distances). It was found that the hyaenas covered majority of their travel distance between 11pm and 5 am. It was also determined that average home range size of hyaena in Kutch was 100% MCP home range of 82.4( $\pm$  12.0 SE) km<sup>2</sup>, 95% MCP home range of 48.5 ( $\pm$  10.5) km<sup>2</sup> and 95% kernel home range of 61.9 ( $\pm$  14.8) km<sup>2</sup>. I found significant difference between the average home range size of the male hyaena in Kutch (125.25 km<sup>2</sup>) and the average female home range size (66.1 km<sup>2</sup>). Members of a clan inhabit essentially the same area, with highly overlapping home ranges. Total continuous (24 hr) monitoring (n=104) accounted for 2496 hours of tracking seven collared hyaenas, out of which 1200 hrs (48%) of the time was spent resting and for 1300 hrs (52%) hyaenas were active. Activity allocation in a day is 30% in a day used for movements (from den site to food source, between food source and back), 10% of time was spent in the vicinity of villages, 2% in foraging (only active foraging observations included here) and 10% of time spent around den centres of activity. Ten percent (250 hrs) of the total activity time spent around villages indicates its dependence on these 'known food sites', and village realms contribute to the major (vertebrate intake) portion of

the overall diet. This suggests that possibly striped hyaenas have adapted to co-exist with humans. The fact that only 30% (750 out of 2496 hours) was spent in movement, indicates that most of the search efforts were around 'known food sites' (villages) and majority of the movement is between meals. Since food resources sites are known and hyaenas have high dependence on these sites, the search efforts are reduced facilitating time to be spent at center of activity (10% -750 out of 2496 hours) promoting healthy socializing with clan members. To understand the movement pattern with the home ranges for each individual, 'Home range loop' (HRL), the possible number of times a hyaena uses its home range in a night trip, with the assumption that the distance covered in a night by a hyaena is linear, is used for this study. Striped hyaena movements within home ranges indicated that their movements are affected by 2 factors, mainly the distribution of their food and the location of their dens. Mortality factor and dispersal has immense influence on sampling regimes; in the course of the study, out of 7 collared hyaenas (F07, F08-1, F08-2, F09-1, F09-2, F09-3 and M10), 71% succumbed to human induced mortality, and 14% were lost and only 14% survived the study period. To establish their dispersal pattern (in terms of extensive movements), the number of traversed home ranges were computed; where average 100% MCP home range of hyaena was converted to represent an equivalently sized circular home range:  $2(\sqrt{(\text{home range area})/\pi})$ . Linear dispersal distances were then divided by this diameter to determine number of average home ranges traversed. Long distance dispersal was observed during the study and while a few hyaenas (both males and females) dispersed, most of their fate remains unknown, except for a female hyaena (F08-2). F08-2 was a victim of dispersal mortality, but the final dispersal location was known. It was found that F08-2 traversed 5 home ranges as dispersal distance (400 km<sup>2</sup>); indicating female hyaena dispersers are capable of extensive movements from the natal den area.

### **Modelling distribution and movement pattern**

To understand environmental factors affecting hyaena occurrence and to predict potential distributions for hyaena den sites in the landscape, MaxEnt (a species distribution modelling method, using a maximum entropy approach) for modelling presence-only data was used. Presence of hyaenas was determined by field surveys (spoor, tracks, sighting), camera trapping, radio-telemetry data and presence of den sites. Habitat variables related to terrain, human disturbance, and land cover were

considered. All variables were derived from the classified imagery of Kutch (LISS III) at 30 m<sup>2</sup> resolution and digitized Google earth image (Google Earth (Version 5.1)). Land cover was classified into seven broad classes of: Annual crop, Seasonal crop, sparse grass type vegetation, savannah type vegetation, grassland type vegetation, rocky vegetation, and bare patch-no vegetation. The data for water bodies, dams and check dam (surrogate for water bodies), human habitation (villages, towns and cities), drainage (rivers, stream, ravines), large scale human disturbances (mines, industries and quarries) and tar roads (considering more traffic and speeding vehicles) were digitized using Google earth and these data were then converted into distance maps in ArcView v.3.2. The model covering a geographic extent of 6570 km<sup>2</sup>, was considered to be adequate to predict a realistic probability of occupancy for Kutch. From 23 environmental, geographical variables, after accounting for auto-correlation, I used 16 variables in the final model. The 16 variables were: Drainage distance, Village distance, Village count, Water body distance, Dam/check dam distance, Road distance, Road density, Annual crop, Seasonal crop, Scrub forest, Grassland vegetation, Savannah vegetation, Sparse vegetation, Bare patch, Rocky vegetation and mines/industries. Using the habitat variables measured at presence locations, four alternative MaxEnt models were derived for hyaena distribution using substitutable subsets of presence-only data: 1) Composite: radio telemetry locations and all other direct and indirect evidence 2) Combined shelter: only den and refuge sites were used 3) Refuge: used only refuge site (day resting/rendezvous site) data used and 4) Den sites: only den site (breeding site/centre of activity) data were used. Linear, quadratic, threshold and hinge features were used to generate the MaxEnt model with 10,000 background points, 100 iterations and Area under Curve (AUC) more than 85%. The different models performed adequately in predicting hyaena presence when evaluated for model fit with a Receiver Operating characteristic (ROC) plot (Composite model: AUC mean=0.79, SD=0.062; Combined shelter model: AUC mean=0.85, SD=0.151; Refuge site model: AUC mean=0.91, SD=0.121; Den site model: AUC mean=0.79, SD=0.036). Refuge site model was developed using only telemetry based presence data (refuge site) restricted to intensive study area (ISA). The four Maxent models were hierarchical, where composite models predicted general hyaena distribution and combined shelter model predicts distribution of den and refuge sites within the composite model. And, within combined shelter model, den site model predicts the distribution of den sites. Ecologically den site selection is crucial to fulfil the species

life-history objectives and this model based inferences is important for management and conservation of the species.

### **Sociability**

In an effort to describe sociability in striped hyaena, a naturalistic observation approach was used to gather data on hyaena social behaviour at den sites. Out of the 6 clans in the ISA, BND clan was intensively monitored for social behaviour, as successive years had collared individuals, making it easier to track active den sites for observation. All possible memberships to the clan were individually identified with the help of photographs obtained from hand held and remotely operated cameras, so as to focus on the individual in a group and quantify the differences in behaviour of known individuals. Every identified individual was sexed if possible and aged, hyenas were assigned to certain age class based continuous data (cub: 6 months to 1 year, sub-adult: 1 to 3 yrs, adult: 3+ yrs). Preliminary observations, to develop a limited ethogram for striped hyaena, were carried out. Scan sampling and focal animal sampling and ad libitum sampling was used to record interactions within family unit for a specific amount of observable time (between 06:00 hours to 07:30 hours, and 17:30 hours to 19:45 hours). I used a descriptive approach along with simple quantitative indices to provide an understanding of hyaena sociology. All observed behaviour units were grouped by functional type into two broad categories 1) Social and 2) Non-social and I only describe social interactions. In the BND clan, 'Megamass' was the breeding female for all the litters, but the male that fathered each litter could not be identified and was never observed. From preliminary observations and during the course of the study, I defined social interactions into 50 unique social interaction behaviour types, under 8 broad behaviour categories: Agonistic, Social play, Social grooming, Attention soliciting, Affiliative-greeting, Vocalization, Group movement and Miscellaneous. From 472 hours of observation of the BND clan I identified 320 instances of social interaction, lasting 46.4 hours. Out of the 472 hours of observations on den site, only 46.4 hours (9.7%) of time was spent in social events, 90.3% of the time they were non social. It is evident that there is a negative correlation between the number of group members using den and the age of the cubs. A stable group composition was found to be important for steady socializing, which might affect the fitness of the cubs. Den sites are important as active centres of socializing and cubs are an important part of group cohesion. Out of 320 unique social

interaction events, affiliative greetings were the most frequent (n = 79, 24.69%), followed closely by social play (n = 70, 21.88%). Between the different age classes of the clan members, the cubs interacted longest with other cubs (45.89%), followed by their interaction with sub-adults (28.11%). While I found that the Adult-Adult interaction is minimal (4.96%), this is attributed to the low frequency of presence of more than one adult at the den. Similarly, the frequency of the number of interaction events was highest amongst cubs (38.72%), followed by sub-adult-cub interactions (25.05%) and Adult-cub interactions (0.73%). The number of times a sub-adult interacts with a cub is more than the number of times it interacts socially with another sub-adult (11.18%). The longest amount of time spent was in group movement (42.58% per unit time), while the shortest was spent on attention soliciting (0.96% per unit time). The total number of social interactions, 34.05% of the times, they were involved in an affiliative greeting (the most among all the interactions) and the least in attention soliciting and vocalization (2.13%). In Adult-sub-adult interactions, the most amount of time and also the longest time was spent on miscellaneous activity (25.93% and 52.04% per unit time respectively). In the Sub-adult – Cub interactions, there was no attention soliciting behaviour, but the most frequent category of social interaction was affiliative greeting (32.23%) and the longest was spent under the miscellaneous category (51.10% per unit time). The cubs interacted with each other most frequently by social play (26.2%), while the longest interactions were during miscellaneous activity (41.23% per unit time). Interestingly, the adult-cub interaction was most frequently and longest during social grooming (43.06% and 54.24% per unit time). The adults were most frequently involved in social grooming (46.09% and 38.24% per unit time), while the sub-adults spent the longest duration in interactions involving miscellaneous behaviour (48.8% per unit time) and most frequently in affiliative greeting interactions (34.08%). Social play was observed as the most important social interactions that cubs were involved in (24.03% and 20.7% per unit time). Cubs were also frequently involved along with social play, in affiliative greeting interactions (22.09%), while they spent the longest duration in interactions involving miscellaneous behaviour (39.73% per unit time). Despite spatial grouping in striped hyenas, group members are behaviourally solitary; they forage and feed alone. Hence, the den is a focal point of social activity for all group members, not just mothers and cubs, but most clan members visit it regularly. Even at the socially active centre, the levels of association are low and group members remain physically

isolated more than 90% of the time. The social system is governed by the presence of cubs and their growth period as the role of clan members in maintaining contact with cubs and other clan members steadily declines at den sites as cubs get older. The clan members provision food to the cubs at den sites, by bringing bones and carcass to den. Striped hyaenas were observed to be more social than reported earlier exhibiting helping behaviour..

### **Attitudes of local people and conservation prospects**

It is important to determine the attitude and perspective of local people towards wildlife and hyaenas, for a deeper understanding of hyaena survival in a human dominated landscape. Generally the region is culturally tolerant and has a positive attitude towards wildlife. The objective was achieved by assessing the attitude and knowledge of local people regarding hyaena, with respect to various backgrounds like gender, age class and occupation. Simultaneously, a broad suite of variables likely to influence the perception of local people of hyaenas was examined and determinants of conflict in the area were identified. The results of the study can also be used to provide a framework to mitigate the threats endangering the species in the study area, and can be extended broadly to understand the complexities of hyaena persecution in other regions where hyaena populations are declining. A total of 267 respondents from 124 villages were interviewed using a semi-structured questionnaire, covering aspects on their background information, awareness and knowledge regarding wildlife and hyaenas, perception of hyaenas, threats to hyaena survival and attitude towards hyaenas. Education qualification or size of land holding didn't prove useful, as the responses were biased towards occupation of the respondent. The study area supports a heterogeneous mix of ethnic groups and lifestyles that are generally intermixed in villages, In the context of this study these social conditions of the respondents did not prove to be useful, and also defining and describing ethnic groups can be confusing and problematic; hence respondents were categorized based on occupation. All respondents were grouped into one of the five occupation 'sectors', based on the defining traits of their occupation and considering their level of exposure to wildlife associated: Husbandry, Agriculture, PIWL (Occupation with possible interaction with wildlife), Academics, NPIWL (occupation with no possible interaction with wildlife) and they were divided into three age classes. Respondents were randomly selected across the landscape representing all occupation sectors. Out of the 267 respondents,

22% (n=58) were females and 78% (n=209) were males. A large number of the respondents were more likely to encounter wildlife in their occupation (63%, n=168), while, 37% (n=99) respondents had little or no chance of interaction with wildlife in their occupation. Quantifying the response to the questionnaire, I found that among the causes listed for loss of livestock, predation was listed as the last (15%, n=12), while disease was listed as the major factor (40%, n=31). Respondents also reported a visible decline in wildlife numbers in the area (70%, n=186) and attributed this decline to hunting, lack of forage, human population growth, expansion of agriculture and lack of shelter. In the survey, the knowledge of wildlife in the region was also tested. A total of 13 species of wild animals were listed collectively by respondents (n=267), and this list was almost a complete representation of all important mammalian fauna in the region, but conspicuously absent from this list are the small Indian civet (*Viverricula indica*), the mongoose (*Herpestes spp.*) and some important bird species like great Indian bustard (*Ardeotis nigricaps*) and vultures (*Gyps spp.*). To test if the 'occupation sector' influences knowledge of wildlife, I applied a logistic regression model and the result from odd's ratio indicates that respondents from 'husbandry sector' are 8.11 times more aware to the presence of hyaena around their village than 'NPIWL sector'; similarly 'PIWL sector' was 5.25 times more aware and 'agriculture sector' are 4.83 times more aware than 'NPIWL sector'. When the respondents were tested on their knowledge of hyaena in particular, a large number of respondents (78%, n=209) were able to describe hyaena with traits that are actual representation of the animal's morphology, habits and diet. The results from odd's ratio indicate that, males described 1.38 times more accurately than females, consecutively increasing age class category described 1.58 times more accurately than the other; and respondents from 'husbandry sector' described 3.07 times more accurately than 'NPIWL sector', while accuracy in description in 'PIWL sector' was 2.26 times, 'agriculture sector' 1.98 times and academic sector 1.63 times more higher than NPIWL sector. Considering the bulk of respondent and large number (n=27) of actual traits described, it can be concluded that there is an exceptional level of awareness among local people in the region regarding hyaena. Occupation appears to be an important factor governing the level of awareness about hyaena. It is also important to appreciate; that there is considerable exchange of information among different occupation groups, eventually influencing the awareness and attitude of a larger section of people in the landscape. Out of 51 respondents who gathered

information on hyaenas, the largest proportion of information was gathered from shepherds (75%, n=38), the rest were from elders and hunters. While a total of 11 different hyaena parts were used in traditional medicines, according to the respondents (n =77), out of which the tongue was mentioned by most (75%, n =58), they had no knowledge regarding mention of hyaenas in folklores, myths, folk songs, art or culture. Even though the awareness of wildlife in the region is high, majority of the respondents (75%, n = 200) alleged that some wildlife in the region can be problematic, but only a very small fraction felt that the presence of hyaenas near their villages could be problematic (3%, n =9). For crop raiding, nilgai (*Boselaphus tragocamelus*) headed the list as being most problematic (90%, n = 179), whereas hyaenas were considered the least troublesome. For predation, hyaenas along with wolves were held accountable for most of the medium livestock predation (41%, n =82). When questioned on hyaenas alone, while majority believed that they did not cause crop damage (34%, n=91) and they did not predate on livestock (55%, n =146), there were also substantial amount of people who were unsure regarding crop damage (50% n=133) and predation (35%, n =94). While most people supposed that hyaenas could attack humans (57%, n = 153), it was mainly attributed to rabid hyaenas (71%). Only 18 incidents of hyaena attacks (all rabid) could be recollected by respondents (31%, n = 34), and all these hyaenas were violently killed. In the study area, the most important mortality factor explained for all the dead hyaenas (n=32), was mortality caused by road traffic accidents (50%, n=16); followed by snaring (16%, n=5). A general positive trend regarding hyaenas was experienced from the survey, most respondents acknowledged that hyaenas are important part of the ecosystem (55%, n =147) and that they are beneficial to the ecosystem (78%, n =209), as they clean the villages and keep them disease free. They also recognized that hyaenas mortality by anthropogenic factors are in fact people's loss (66%, n =176), and were supportive of idea that the government should spend money on hyaena conservation. The results of the present study establish that there is overall positive level of awareness among local people regarding hyaenas, and the conflict levels were considerably low, which compares favourably to most locations in its wide range. In spite of widespread awareness level and tolerant approach to its presence, considerable numbers are eliminated directly or indirectly by anthropogenic induced causes. Traffic accident and non-target snaring emerge as important mortality factor. In actuality, of all collared hyaenas (n=7) in the present study, 57% (n=4) died in snares and 14% (n=1)

was killed in road accidents. Surprisingly, it was established from the study that use of body parts in traditional medicines and other purposes were as prevalent as in most parts of its range and use of hyaena body parts are more wide spread than previously thought. A major issue of concern is, if the use of hyaena body parts is rampant in the landscape, it needs further probing as poaching for trading purpose can have a negative impact on populations.

It can be concluded that striped hyaenas in Kutch are opportunistic generalist foragers with wide omnivorous diet, with heavily dependency on human induced food sources and villages. Hyaenas in Kutch have large home ranges, with significant difference in home range sizes among sexes, where males have much larger home ranges. Members of a clan inhabit essentially the same area, with highly overlapped home ranges. Each clan area is largely exclusive and no overlap exists in area of use among adjacent clans. Their movement patterns are governed by two factors, location of food sources and location of den sites. Large part of their activity budget is spent resting, followed by movement between villages and in search efforts around villages. The den sites are the critical habitat need for hyaena presence and survival in the region, the den site are highly correlated with the presence of drain network. The hyaenas in Kutch have a strong kin based “cub-centric” social system, where adult males did not show any role. In this kind of social system (kin based “cub-centric”), relies mainly on group size and presence of sub-adults for the stability and functioning of the hyaena clan. The general attitude towards wildlife and hyaenas are positive, in spite of widespread awareness level and tolerant approach to its presence, considerable numbers are eliminated directly or indirectly by anthropogenic induced causes. Traditional approaches of biodiversity conservation and sustainable use should be recognized by the policy makers. The grazing lands protection should be prioritized and wasteland conversion resolution should be reconsidered; as these lands not only support large herds of livestock in the region, but also majority of wildlife in the region inhabit these areas. Proactive education and awareness program should be prioritized; for it is unstated that awareness has a profound influence on perception and behaviour of people towards wildlife. All these may increase the capacity of these local communities to cohabit with carnivores.



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# 1 General Introduction

## 1.1 The striped hyaena

The four extant species of hyenas (Hyaenidae; Carnivora) includes the aardwolf (*Proteles cristatus*), a termite-feeding specialist, and three species with a craniodental morphology adapted to cracking the bones of prey and/or carcasses, the spotted hyena (*Crocuta crocuta*), brown hyena (*Parahyaena brunnea*), and striped hyaena (*Hyaena hyaena*) (Figure 1-1). They form a morphologically and ecologically heterogeneous group of feliform carnivorans that are remnants of a formerly diverse group of mammalian predators (Koepfli et al. 2006).



Figure 1-1: Striped hyaena in Kutch.

### 1.1.1 Evolution of hyaenids

Hyaenids have existed for over 23 million years (Werdelin and Solounias 1991) and at the peak of hyaenid diversity in the late Miocene, at least 70 (Werdelin and Solounias 1991) different hyena species concurrently roamed Eurasia and Africa. (Mills 1983, Werdelin and Solounias 1996). The history of the family Hyaenidae unfolded in Eurasia and Africa, during the Miocene epoch, which began 23 MYA, and spanned roughly for 18 million years. Only one hyaenid (*Chasmaporthetes*) ever made it to North America, and no hyenas ever occurred in South America or Australia (Werdelin and Solounias 1991).

From their origins as civet- and mongoose-like creatures in Eurasia, the Hyaenidae diversified throughout the Middle Miocene. This first great radiation of the Hyaenidae produced a wide array of dog-like forms. Many of the hyaenids appearing during this first radiation were animals with body proportions, skulls and teeth much like those of modern canids (Werdelin and Solounias 1991, 1996). No species appeared in these first hyaenid radiations that were specialized for bone cracking. The Hyaenidae continued to diversify throughout the Late Miocene, achieving peak species diversity 11-7 MYA (Werdelin and Solounias 1991). A second group of dog-like hyenas appeared in the Late Miocene as the first great hyaenid radiation continued from the Middle Miocene. These new dog-like hyenas are referred to by many palaeontologists as the “hunting hyenas.” Near the end of the Miocene, a wave of extinctions occurred among the Hyaenidae. Hardest-hit here were the civet- and dog-like hyenas. The first bone-cracking hyena, *Adcrocuta eximia*, does not appear in the fossil record until the late Miocene. The skull of *Adcrocuta* bears a remarkably close resemblance to that of modern spotted, brown and striped hyenas. However, *Adcrocuta* had a very stocky build, with short, robust limbs, and it showed none of the cursorial adaptations seen in the extant bone-cracking hyenas (Werdelin and Solounias 1996). The appearance of *Adcrocuta* was followed by the second great hyena radiation, involving the appearance of several other hyaenid genera that were morphologically specialized for bone cracking, including the lion-sized *Pacyhcrocuta brevirostus*. Weighing roughly 150 kg, *Pacyhcrocuta* was the largest hyaenid ever known. Most of the bone-cracking hyenas became extinct before the Pleistocene (Werdelin and Solounias 1996).

Many hyaenid fossils have been recovered and described from the Indo-Pakistan region. *Percrocuta grandis*, *Progenetta sp*, *Palhyaena sivalensis* from Siwaliks of the Potwar Plateau, northern Pakistan (Badgley 1986). A Pleistocene hyaena-*Pachycrocuta brevirostris* was described from several Siwalik locations in Pakistan (Turner and Antón 1996, Saunders and Dawson 1998, Dennell et al. 2005, Dennell 2007) and *Crocuta crocuta* from upper siwalik, Pakistan (Dennell et al. 2005, Dennell 2007).

In India, the first fossil hyaenidae skull was described by Baker (1835). Subsequently, few other skulls were collected and described (*H(C). sivalensis*, Falconer 1868; *H(C). felina*, Bose 1880; *H(C). colvini*, Lydekker 1884 and *H(C). bossi*, Matthew 1929, all skulls are believed to have been collected from upper Siwaliks. The authors had wrongly designated the skulls into different genera of extinct hyaenas, later Pilgrim (1932) re-evaluated these skulls and were designated to sub species of *Crocuta*. More fossil hyaenids have been reported from India, *Crocuta spp.* have been described from Siwalik beds, Pinjor, Punjab (Khan 1972, Nanda 2002), *Hyaenictis bosei*, *Crocuta felina*, *C. colvini*, *C. sivalensis*, from the Pinjor Formation (Nanda 2008). Few Siwalik-Pinjor fauna migrated outside the Siwaliks into Indo-Gangetic plain and peninsular India, Fossils of *Crocuta cf. C. sivalensis* are described from Indo-Gangetic plain (Nanda 2008) and a *Crocuta spp* described from Kurnool caves, Andhra Pradesh (Prasad 1996).

The early Pleistocene hyaena from India *Crocuta Sivalensis*, is the ancestral species (Kurtén 1958, Turner 1990) which evolved into four subspecies of *crocuta crocuta*-*C. crocuta* (extant *spp*-Africa, spotted hyaena), *C. ultra* (extinct-Africa), *C. spelaea* (extinct-Europe, also called cave hyaena) and *C. ultima* (extinct-China) (Kurtén 1958).

The *H. hyaena* is known from fossil evidences from Africa only (Turner 1990, Werdelin and Solounias 1991). The earliest striped hyaenas are seen in the East African deposits of Omo Valley at around 3.0 Ma (Howell and Petter 1976) and in Makapansgat at a similar date (Randall 1981). It is common in deposits from East and West Turkana and Olduvai (Petter 1973, Howell and Petter 1980). In South Africa it is also known from the undated deposit at Kromdraai (Turner 1986) and from the deposits at Swartkrans at about 1.7 Ma (Turner 1988).

All four extant species of hyenas (*Proteles cristatus*, *Crocuta crocuta*, *Hyaena hyaena* and *Hyaena brunnea*) originated in Africa, their ancestors having arrived earlier from Eurasia via the Gomphothere land bridge at what is now Saudi Arabia. The genera *Hyaena*, *Parahyaena* and *Crocuta* all first appear in the fossil record in the Late Pliocene, so these three genera are among the most recently evolved within the clade of bone-cracking hyaenids (Koepfli et al. 2006). After originating in Africa and finding refuge there during the glacial periods of the Pleistocene, striped hyenas (*Hyaena*) dispersed out of Africa sometime within the last 130,000 years (Rohland et al. 2005). Striped hyaena and brown hyaenas are sister taxa (Koepfli et al. 2006, Sakai et al. 2011). *Crocuta crocuta* is basal sister species to this clade, along with striped and brown hyaenas form a clade specialized for bone cracking (Koepfli et al. 2006). Aardwolf is the basal taxon in extant hyaenidae and close sister species to the three bone cracking species, is the sole surviving member of a once-large clade of dog-like hyenas (Werdelin and Solounias 1991, Koepfli et al. 2006) that diverged from other hyaenas roughly 10.6 million years ago (Koepfli et al. 2006).

Primitive hyaenids lack bone-cracking modifications as compared to the generalized carnivore morphotype, in agreement with their insectivorous-omnivorous diet. A key innovation in hyaenid evolution was the acquisition of enamel dominated by zig-zag Hunter-Schreger bands (HSB) (Ferretti 2007) in the Middle Miocene, marking the transition of the group to the bone-eating niche (Ferretti 2007). Viranta (2003) categorized hyaenidae from middle and late Miocene Eurasia based on dietary and size into omnivores (9 spp), mesocarnivores (14 spp), hypercarnivores (1 spp) and bone breakers (18 spp). The observed morphological changes in hyaenids suggest an increasing degree of specialization towards bone-consumption. Extant bone-cracking hyaenas (*Crocuta*, *Hyaena* and *Parahyaena*) are characterized by the same HSB morphology as described for *Pachycrocuta brevirostris* -the largest known hyaena. Modern bone-cracking hyaenas clades, possess a more robust mandible, with a steeply inclined anterior symphyseal margin and greatly reduced post-carnassial dentition (Ferretti 2007). The extensiveness of zigzag HSB increased within the dentition during the evolution of hyaenids. The occurrence of the zigzag pattern in association with bone-eating habits in living taxa suggests that this structure strengthens the enamel to resist the high stresses accompanying the fracturing of hard, tough objects such as bones. Initial evolution of the hyaenid bone cracking

ecomorphology involved skull shape changes that increased stress dissipation, permitting incorporation of more hard food into the diet. Subsequent evolution of larger bite forces was then required to increase the size limit of bones that can be cracked and consumed. This mode of evolution would have allowed transitional hyaenid ecomorphologies to continuously increase the carcass processing ability both during competitive feeding and scavenging throughout their evolution (Tseng and Stynder 2011). Bone-cracking hyenas of modern type were already differentiated in the early Late Miocene; they became widespread only in the Pliocene (Werdelin and Solounias 1991). All extant members of the family have a complete dental formula of  $i\ 3/3, C\ 1/1, P4/3, M1/1=34$ . In aardwolf cheek teeth are reduced to small peg like structure; spaced widely apart and often lost in adults, leaving as few as 24 teeth (Anderson 2004).

Hyaena and *Crocuta* are characterized by a long neck and long forelimbs. The humerus is relatively short and the radius and metacarpal bones are long. In the hind limb the os femoris is long and the tibia short. The proportions are adapted to carry large and heavy prey and provide maximum static stability. *Proteles cristatus* which mainly feeds on termites and insects the long neck and forelimb in common with the other hyaenidae, but its hind limbs are longer and the length of limb segments reveal more canid proportions. *H. hyaena* differs from *C. crocuta* by having longer limbs due to a longer radius, tibia and metapodial bones, their intermediate index however, is not different. The proportion of *H. brunnea* have an intermediate position between those of *H. hyaena* and *C. crocuta* (Spoor 1985).

The extant species span a spectrum of social complexity: the aardwolf (*Proteles cristatus*) is solitary during the nonbreeding season, and forms monogamous pairs during the breeding season (Richardson and Coetzee 1988) the striped hyena (*Hyaena hyaena*) lives solitarily or in small groups (Wagner et al. 2008a) the brown hyena (*Hyaena brunnea*) lives in groups of up to 14 individuals (Mills 1983) and the spotted hyena (*Crocuta crocuta*) lives in complex hierarchically organized groups containing up to 90 animals (Kruuk 1972a). Driven by the demands of processing cognitive information associated with complex social lives, large brain volume relative to body size is found in the spotted hyena compared to striped and brown hyenas. Other factors may drive the evolution of large brains in hyaenids. The relative brain volume variation is not found among striped hyenas, brown hyenas

and aardwolf. The aardwolf has the smallest brain size in the family. The spotted hyena also possesses a larger anterior cerebrum volume relative to total brain volume than is found in the other hyena species; this region is composed primarily of frontal cortex (Sakai et al. 2011). There is no difference in nasal and frontal sinus design between the extinct *Crocuta crocuta spelaea* and the recent populations of *Crocuta crocuta crocuta* and *Hyaena hyaena*. Potentially different habitat and ecology have no major influence on sinus development (Dockner 2006).

### **1.1.2 Habitat requirement**

The habitat of the striped hyena has expanded from Africa probably in very recent times because of the missing fossil record (Werdelin and Solounias 1991). The small genetic variation worldwide indicates a very recent expansion possibly down to Neolithic time. The recent emigration of striped hyenas from Africa to Eurasia resulted in a dramatic expansion of the geographical range of striped hyenas (Rohland et al. 2005). While the other three extant members are restricted to African continent; spotted hyaena inhabits desert to fringes of tropical rain forest in Sub-Saharan region except Congo rainforest and far south; brown hyaena inhabits arid region of western South-Africa and south Angola; two subspecies of aardwolf inhabit two open savannah plains *P.c.cristatus* (S.Africa) and *P.c.septentrionalis* (E.Africa) (Macdonald 2009). The striped hyaena has an extensive range from parts of Northern and eastern Africa; Arabian Peninsula; Asia Minor up to the Mediterranean coast and in the Caucasus Mountains; southern Afghanistan; Pakistan, and much of India. Hyaenas did not reach Assam, Bhutan, Sri Lanka, and Myanmar (Mills and Hofer 1998). Wide distribution and local adaptations have resulted in several variations in hyena morphology. Such morphological variations resulted in the striped hyena having been classified into 28 subspecies. Pocock (1934) definitively reclassified them into five subspecies based on pelage characteristics and cranial structure (Jenks and Werdelin 1998, Wagner 2006, Macdonald 2009). These include *H. h. Barbara* from northwest Africa, *H.h. dubbah* from northeast Africa, *H. h. syriaca* from Syria, Asia Minor and the Caucasus, *H. h. Hyaena* from India, and *H. h. sultana* from Arabia.

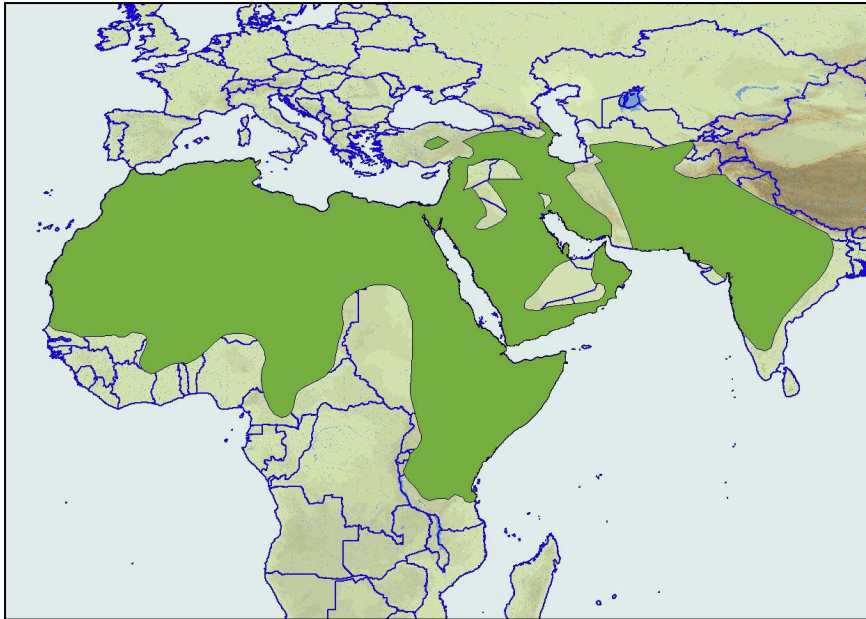


Figure 1-2: Global distribution of the striped hyena adapted from Wagner (2006).

Generally striped hyaena favours open or thorn bush country in arid to semi-arid environments (Rosevear et al. 1974, Kruuk 1976, Rieger and Ruppert 1978, Leakey et al. 1999a) where water is available within 10 km (Rieger and Ruppert 1978). Striped hyaenas have been found to altitudes of 3,300 m in Pakistan (Rieger and Ruppert 1978) and at least to 2,300 m in the Ethiopian Highlands (Yalden et al. 1996). Striped hyenas seek out relatively heavy vegetative cover or rocky depressions, particularly large caves, for resting (Kruuk 1976, Rieger and Ruppert 1978, Leakey et al. 1999a, Wagner et al. 2008a). Striped hyenas may remain active in areas frequented by humans, while avoiding them on a temporal scale (Kruuk 1976, Yom-Tov and Mendelsohn 1988, Wagner 2006).

Throughout its range (Figure 1-2), the striped hyena occurs at low densities, but is distributed broadly across the landscape. There have been only two estimates of striped hyena density in Africa: in Serengeti National Park, Tanzania, an estimate based on observations of a limited number of individuals was given as greater than 0.02 per km<sup>2</sup> (Kruuk 1976), while from a larger study in Laikipia District, central Kenya, estimated the minimum regional density at 0.03 adults per km<sup>2</sup> (Wagner 2006). In India the estimates were 6.2 per 100 per km<sup>2</sup> in Sariska Tiger reserve, Rajasthan (Gupta et al. 2009), 6.5 per 100 km<sup>2</sup> in Kumbhalgarh, Rajasthan (Singh et al. 2010) and 5.67 per 100 km<sup>2</sup> in Rajaji National park, Uttaranchal (Harihar et al. 2010).

### 1.1.3 Sociality

Almost invariably described as solitary, research in Kenya has shown that striped hyenas routinely rest in pairs and occasionally in groups of up to four individuals (Wagner 2006, Wagner et al. 2008a). While group-living males appear to father the majority of cubs, multiple paternities of litters by those males have been detected through parentage analysis of genotype data. Home range sizes in Serengeti were reported for one male and one female at 44 and 72 km<sup>2</sup>, respectively (Kruuk 1976). In Kenya, mean home range size for four males and six females was 68.9 km<sup>2</sup> (SE=7.8) with no significant difference in home range size between sexes. No two adult females were found to have significant home range overlaps, although groups of up to three males and one adult female had almost complete overlap in home ranges (Wagner 2006).

### 1.1.4 Ecology

The striped hyaena is the second largest of the living hyenas in the world. It is built much like the spotted hyaena (*Crocuta crocuta*) and brown hyaena (*Hyaena brunnea*), with broad heads with large eyes, thick set muzzles, and large, pointed ears. Back slopes downward from the head to the tail. Powerful jaws and strong carnassial teeth indicate their primarily carnivorous diet (Ilani 1975, Kingdon 1977, Rieger and Ruppert 1978). The striped hyaena Male and female hyenas look alike, but males are slightly larger. The striped hyaena's coat colour varies from grey to light brown with vertical black stripes along the length of the body and dark, striped legs. Along their backs are darker, erectile crests Coat hair is long, and develops a woolly undercoat in colder climates (Ilani 1975).

Striped hyenas have a well-developed anal pouch, a slit-like glandular orifice over-arching the anus from either side. The anal pouch may be inverted and thus be apparent while pasting or presenting during social encounters (Fox 1971, Rieger and Weihe 1975, Kruuk 1976, Rieger and Ruppert 1978). In juveniles, there is an unusual convergence in genital appearance between sexes. Juvenile females have well defined labia-like folds anterior to the vagina. These ridges are hairless and darker than the surrounding tissue. Juvenile males have smaller, smooth, hairless pre-scrotal skin folds along the middle septum close to, but anterior to, the scrotum (Wagner 2006, Wagner et al. 2007b, Wagner et al. 2008a).

Deliberate exposure of its black or brown throat by one striped hyena to another has been construed as a conciliatory gesture or signal of trust (Kingdon 1977). The exposure of dark and light areas during elaborate behaviour rituals has been interpreted as components of a signal code that might help regulate social interactions. Thus, during ritual or play-fights the pale cheeks and upper sides of the neck become targets for nipping with half-open mouth (Fox 1971, Kingdon 1977). In contradiction to these suggestions, the dark throat patch has been proposed as a mechanism to orient bites during agonistic interactions (Rieger and Ruppert 1978).

Striped hyaena female sexually mature at 2-3 years, 1-4 cubs (usually 3) cubs are born after 90 days of gestation and the cubs are weaned at 10-12 months (Rieger and Ruppert 1978, Skinner and Ilani 1979, Macdonald 2009). Cubs are raised in dens, which may be either holes dug by the mother, holes formed and abandoned by other species, deep, natural, and sometimes complex, caves (Kerbis-Peterhans and Horwitz 1992, Leakey et al. 1999a), or simple rock depressions less than a meter deep (Wagner et al. 2008a).

Hyaenas are able to consume and digest parts of prey that would remain untouched by other animals. They completely digest organic matter such as bones, while indigestible items such as hooves, horns, ligaments and hair are regurgitated in pellets (Estes 1991). It is thought striped hyenas are mainly scavengers rather than hunters, the powerful jaws, large teeth and skull are adapted to bone crushing. The shape of the skull has been changed to provide good attachment for the powerful muscles, which work the jaws and teeth. In striped hyaena the premolar are smaller than spotted hyaena and carnassials are used for crushing, chopping and shearing, whereas in spotted hyaena carnassials teeth are used almost solely for slicing or shearing. These differences relate to striped hyaena dependence on a wider range of food, including insects, small mammals, eggs, fruits as well as carrion and prey (Macdonald 2009).

#### **1.1.5 Scope of the study**

Among hyaenids, the striped hyaena is relatively data deficient. In spite of such wide distribution and being a large carnivore with ecological and evolutionary significances. Very few studies have been carried out on ecological aspects of species. Most of the intensive study has been conducted in African continent on *H. h. Dubbah*

(Kruuk 1976, Leakey et al. 1999a, Wagner 2006) and *H. h. syriaca* in Israel (Yom-Tov and Mendelsohn 1988). Other studies conducted in Middle East were on *H. h. syriaca* in Jordon (Qarqaz et al. 2004), Turkey (Kasperek et al. 2004), Jordan (Kuhn 2005), Lebanon (Abi-Said and Abi-Said 2007) and Turkey (Akay et al. 2011). Most literature from the Indian sub-continent on the species are results of short studies/observations or in form of popular articles (Davidar 1985, 1990, Jhala 2002, Sankar and Jethwa 2002, Gajera et al. 2009, Gupta et al. 2009, Harihar et al. 2010, Singh et al. 2010). In addition to field based studies literature, literatures from studies on captive striped hyaena are available (Rieger and Weihe 1975, Spoor and Badoux 1986). Because all studies from Indian sub-continent were brief, there is very little information available on the species ecology, behaviour and social organization from India.

This study was developed for a better understanding of the ecology and behaviour of the species and also; provides a better understanding of the correlation between density, food availability and sociability. The study was carried out, in Kutch district of Gujarat state, for five years from January 2006 to January 2011. The semi-arid landscapes of Kutch, in North-western India appears to be the stronghold of the species (Jhala 2002), providing a scope for better understanding of the ecology and behaviour of the hyena in Indian subcontinent. This will add crucial information to the already existing information on striped hyaenas, helping in drawing meaningful conclusions on their ecology and evolution and also in conservation planning and management in the region. In consequence of unanticipated technical issue (faulty camera traps) in the course of the project, the methodological approach had to be altered with the original plan.

To achieve the objectives of determining the habitat needs, land tenure systems of the hyenas, their movement patterns within their territories and determining their home ranges, radio telemetry was the preferred methodology. Seven individuals (6 F and 1 M) were live trapped and fitted with radio collars, during the course of the study. Both triangulation and homing technique (White and Garrot 1990) was utilized in locating the collared individual. To comprehend the food habits, food availability, its distribution and foraging Patterns, baseline data on diet is recorded from analysis of scats (Korschgen 1980, Maddock 1993, Mukherjee et al. 1994) and also by analysing

occasional regurgitated hair pellets (Estes 1991). Since direct observations on actual feeding are difficult because of undulating terrain and nocturnal habits of the animals. In addition to scat analysis food-habits is supplemented by examination of food remains at dens (Kerbis-Peterhans and Horwitz 1992) and questionnaire survey. While following the collared individuals and also from large-scale surveys, the habitat needs of the species (habitat usage pattern, den site quality and usage pattern) were quantified. Consequently breeding dens were identified following the collared study animals; and observations were carried from June 2008 onwards, to determine the family group (clan) composition, understand role of individual in the clan and cub rearing and social behaviour (Wagner 2006, Wagner et al. 2008a). One family group (clan) with three collared individuals of varied age class was intensively monitored, three other clans were additionally monitored to co relate behaviour and pattern across landscape.

## 2 STUDY AREA

### 2.1 Location

The study was conducted in SW Kutch (Gujarat), situated at the extremes of western India (23.13°–24.68°N and 68.10°–71.80°E). Kutch district is located in the crescent shaped peninsula in the state of Gujarat. It is the largest district in Gujarat and has an area of 45,612 sq. Km, constituting 23% of the state. The Tropic of Cancer passes through the district of Kutch, which is 320 kms long and 170 km wide (Mehta 2001). Kutch is bordered by the Great Rann of Kutch on the North with Pakistan beyond it, by the Little Rann of Kutch on the East, on the South it is surrounded by the Gulf of Kutch and on the West by the Arabian Sea (All 1945). It has nine talukas or administrative sub districts: Bhuj and Nakhatrana in the north; Lakhpat and Abdasa in the west; Mandavi, Mundra and Anjar in the south and Bachau & Rapar in the east. Kutch is a district of highly variable topography and climate, though largely barren and rocky, the physical feature of the district is mottled by ranges of hills and low peaks, rugged and deeply cut river beds, valleys and large tracts of rich pasture lands, shrub lands, agricultural fields, forested lands, and a number of dry rivers (Williams 1958a).

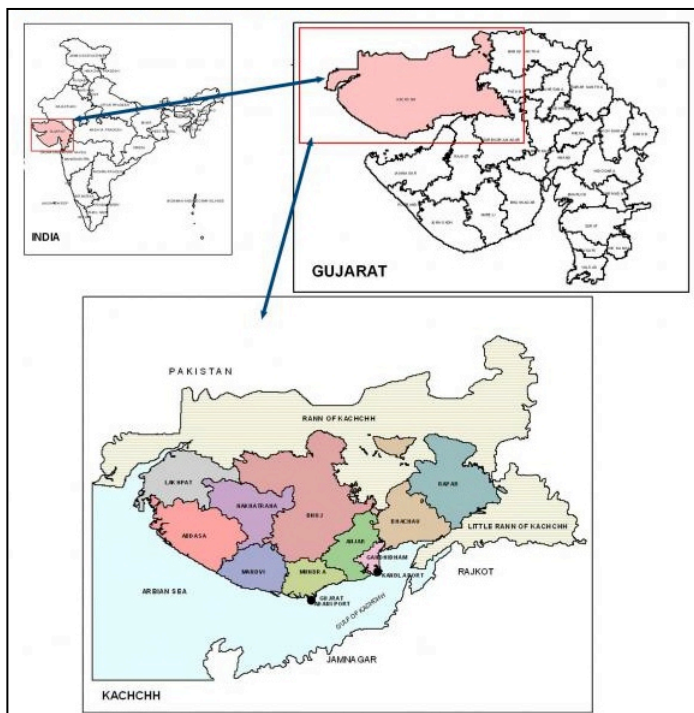


Figure 2-1: Location of Kutch and talukas (administrative divisions) of Kutch.

## 2.2 Geology

Kutch can be categorized into four geomorphic zones delimited by east to west trending faults. These are the a) Coastal plains (southern portion), b) Mainland (central portion comprising of rocky upland and northern hills), c) Banni Plains (raised fluviomarine sediments, mud flats and salt pans), and d) Ranns (the Great Rann and little Rann) (Biswas 1980a). The coastline of Kutch along the Arabian Sea is an amalgamation of widely varying coastal landforms and can be broadly divided into the following five segments: 1) The deltaic coast to the west of Kori Creek, 2) The irregular drowned prograded coast between Kori Creek and Jakhau, 3) The straightened coast between Jakhau and Bhada, 4) The spits and cusped foreland complex between Bhada, Mandvi and Mundra, and 5) The wide mud flat coast to the east of Mundra up to the Little Rann (Kar 1993). Along the 410 km long coastline of Kutch, mangroves are distributed in the form of narrow discontinuous patches and cover approximately an area of 727 sq. kms and account for more than 75% of the total mangrove area of Gujarat. In Kutch, dense and sparse mangroves cover about 344 km<sup>2</sup> and 383 km<sup>2</sup> areas respectively. While the best mangrove patches are found in Kori creek and area around Jakhau coast, there are few remnant patches in the coastal areas of Mundra, Anjar and Bhachau talukas (Stanley 2004).

Kutch is poorly endowed in terms of its land quality, as ~23310 sq. km (51%) of the area is covered by saline deserts (Greater and Little Ranns) (Joshi et al. 2009). Rann, now a saline wasteland in the northeast, played significant role in the evolution of various aspects of this region. In ancient times, Rann was an arm of the Arabian Sea and Kutch was an island, forming an Adam's Bridge between Sind and Kathiawad. This condition, island surrounded by gulfs of sea and coastal towns, continued till historical times. The gulf gradually silted up and led to a slow elevation of the land (Williams 1958b). Legend has it that much of Kutch was a navigable lake during the time of Alexander's conquest of Sind (Thakker 1988). In the vernacular lingo of the region, this area is divided according to the type of vegetation and land surface: The first, known as **Rann**, lends its name to the whole tract; the second, known as **Dhoi** or **Bet**, is a sandy soil, free from salt. bearing a growth of grass, and occasionally stunted trees and bushes, is found round the margins of the Rann and rising, as islands of

various size, from the surrounding tract of rann; the third, known as **Kalar** may be regarded as a transition between the rann and dhoi, it is less impregnated with salt than the rann and bears some scattered vegetation. The Little Rann of Kutch (LRK) has an area of approximately 3000 sq. km, bordering Rajkot and Surendranagar districts on the southern side and Kutch district on the northern side of Gujarat. The LRK is dry during October – June, however, with the onset of monsoon in July, the rivers Banas, Saraswati and Machchu discharge into the LRK. By the end of July and beginning of August, the monsoon gains momentum and the Little Rann gets flooded. The LRK gets connected to the Gulf of Kutch, facilitating entry of post-larvae of *Metapenaeus kutchensis* into the Rann. The juveniles of ginger prawn, *M.kutchensis*, form a significant seasonal fishery in shallow estuarine waters of the LRK during the monsoon months (Ghosh et al. 2012). Kutch accounts for 60% of total salt production in India. Along the edges of the Rann, several small and large salts manufactures lease out land to the Agarias (salt worker) who produce land, pump out salt water using diesel pumps and prepare salt (Lamba and Kapoor 2006). The Ranns have a unique ecosystem of their own, with the only site for flamingo breeding and the Wild Ass in the country.

Banni is a huge mudflat that lies in the arid western part of India. It is also a vast degraded rangeland that was traditionally dependable grassland (India's largest grassland) for cattle rearers in the Kutch region. Over 2525 sq. km in area, it is circumscribed to the north by the marshy salt flat of the Great Rann of Kutch and the rocky Pachham island, while the southern boundary is defined by the Kutch mainland (Singh and Kar 2001). Banni was derived from the Kutchi word "Bani", which means "Bannihui" in Gujarati, meaning "made up". This signifies that detritus has formed the land. The Banni grassland, once known to be Asia's finest grassland, accounts for approximately 45% of the permanent pasture and 10% of the grazing ground. Banni has an area of 3847 km<sup>2</sup>, consisting of 48 villages (Parikh and Reddy 1997, Joshi et al. 2009). There are many depressions in Banni, known as Dhand, Jhil or talav. Shallow wetlands are developed in low-lying parts of Banni after monsoons. In total 34 such seasonal and permanent wetlands exist in the Banni area including Chhari – Dhand, Khirjog-Dhand, Abdha-Jheel and Luna Jheel. Chhari – Dhand has the maximum water spread area of 80sq.km and falls under the category of seasonally flooded wetland type(Stanley 2004).



Figure 2-2: The geomorphologic zones of Kutch (Biswas 1980b). P.Is: Pachatam island, K.Is: Kadir island, B.Is: Bela island (all these island (bets) are part of the Kutch mainland).



southern and southeastern parts of the area. Trappean rocks, however, cover a major part of the southern portion. The extreme east and south-east portions comprise Quaternary sediments with a few occurrences of Tertiary rocks (Sohoni and Karanth 2003). The Kutch region of Peninsular India displays an excellent development of Jurassic rocks ranging in age from Bajocian to Tithonian (Biswas 1993, Fürsich et al. 2001). These sediments are filled in an E–W oriented rift basin located on the western margin of the Indian Plate (Biswas 1991) and attain an estimated thickness of about 1625 m (Krishna et al. 1983). Jurassic rocks occupy nearly half of the area in the Kutch region, lying nonconformably on a Precambrian basement (Mitra et al. 1979, Biswas 1993). The Jurassic rocks of Kutch are classified into the Patcham, Chari, Katrol and Umia formations, in ascending order (Sastry and Mamgain 1971, Kumar 1985).

**Patcham Formation** marks the beginning of Jurassic marine transgression in Kutch. It consists of 300 m thick succession of limestone, marl and shale and has yielded pelecypods, corals and ammonites.

**Chari Formation** consists of 400 m thick succession of limestone, marl and shale. It contains fossil remains of ammonites and gastropods.

**Katrol Formation** is a 750 m thick succession of shale, limestone and sandstone deposited during Late Jurassic. The Katrol Formation has yielded fossils.

**Umia Formation** is about 550 m thick succession of sandstone, sandy shale and marl. This formation is characterized by presence of ammonite fossils.

Much of the geological and geographical changes in the history of Kutch are believed to be a result of the upheaval and submergence of the landmass and the tectonic movements since time immemorial. Tectonics of Kutch Rift Basin dates back to early Mesozoic era and presents a complete sequence from Triassic to Recent period (Biswas 1992). The Kutch Peninsula falls in the high seismic zone of India, which has a long history of strong earthquakes, is bordered from the north and to the south by ancient rift systems (Krishna 1992, Bendick et al. 2001). The mainland within these rift systems is subjected to compression stress and reverses faulting resulting from India's collision with Asia (Chandra 1977). The first reported historical Kutch earthquake was the 1819 Allah Bund earthquake. Damaging earthquakes also

occurred in 1845, 1856, 1857, 1864, 1903, 1927, 1940, 1956, and 1970 with magnitudes ranging from 5.0 to 6.0 (Bapat et al. 1983) and a disastrous earthquake struck in 2001 popularly known as “Bhuj” earthquake, of 7.6 magnitude (Srivastava and Babu 2010). Kutch region has been a site for successive deformational events since the advent of Mesozoic leading to a considerable amount of structural deformation of the rocks. Faulting forms as one of the most conspicuous groups of structures that developed in Central Kutch Mainland. Normal faults in particular are very well exposed throughout the region (Sohoni and Karanth 2003).

The Mesozoic sequence of Kutch known for its fossil treasures has intermittently been a favourite hunt for paleontologists (Singh et al. 1982). Terrestrial mammals comprising eight taxa (*Deinotheriums indiense*, *Gomphotheres idaeindet.*, *Brachypotherium spp.*, *Parabrachyodus hyopotamoides*, *Sivameryx palaeindicus*, *Conohyuss indiensis* or *Tetraconodonmalensis*, *Giraffokeryx punjabiensis*, and *Dorcatherium minus*) occur at Pasuda in the KhariNadi Formation of central Kutch (Bhandari et al. 2010). The Indian subcontinent is widely considered to be the birthplace of whales (Cetaceans), and the middle Eocene Harudi Formation of Kutch has long been known to be a major source of early whales. The Kutch cetaceans are of critical importance in understanding the evolutionary transition of whales from land to sea (Ravikant and Bajpai 2010).

### **2.3 Climate**

Kutch falls in the semiarid–arid zone, semiarid zone (aridity index 0.2–0.5) covers 17.7% of earth’s land surface and is characterized by scanty rainfall with high inter–annual variability (White et al. 2000). Kutch with semi arid type climate, accounts for 60% of the semi arid tract in Gujarat (Mehta 2001). This region experiences extreme temperature with large diurnal and seasonal temperature ranges may be variation. The three prominent seasons are winter (November–February), summer (March–June), and monsoon (July–October). The temperature is high most of the time, and it reaches a maximum of 48°C–49°C during May and June (the hottest months). The winter temperature goes down to 5°C– 10°C, with January and February being the coldest months. Rainfall occurs only once in a year, when the south–west monsoons reach the coastal regions (mid–June) thereafter spreading to the other parts (early July). Rainfall is erratic and variable, and long term records indicate that rainfall arrives before

July 15 in 65% of the years, whereas late onset occurs in 35% of the years (Sinha et al. 1972). The average rainfall is about 380 mm ranging from 440 mm in southern Kutch to 338 mm in western Kutch (Raju 1995). The rainfall ranged between 78–888 mm during 2000–2010. It only rains a few days per year in Kutch (15 days on average) and is considered to be a drought prone district as droughts are a recurring phenomenon (Mehta 2001, Lamba and Kapoor 2006, Joshi et al. 2009). In a period of 13 years, Kutch saw 9 droughts, and the Government spent more than 640 crores during droughts (Lamba and Kapoor 2006). As a result of high evapo–transpiration rate, natural water sources dry up during lean periods leaving behind a few man–made water sources to exist. Kutch has 97 non-perennial rivers with sharp gradient and high runoff rates. The region also has 177 watersheds (Mehta 2001), and most of the dry rivers and watershed areas have been recently dammed, resulting in extensive water reservoirs created in past 2-3 years. Water has been the central theme that has dominated the development directions in Kutch. Post independence, the country's preoccupation with irrigated models of agriculture and animal husbandry diverted attention of Kutch from developing its rain fed areas to external ways of bringing water into Kutch - first from the Sindhu, (Indus, Pakistan) then from the Indira canal (in Rajasthan) and now from the Narmada (Lamba and Kapoor 2006).

## **2.4 Habitat and Wildlife**

This region falls in Biogeographic Zone 3B Kutch Desert (Rodgers et al. 2002). Thar, the world's smallest hot desert covering 10% of India's geographical area, extends here. The vegetation in this area has been classified as “Northern tropical thorn forest” (6B/C1) and sub classified as “Desert thorn forest”, as per the classification of forest types by Champion and Seth (1968). The area has an undulating terrain with the low hillocks being dominated by species such as *Acacia nilotica*, *Acacia senegal*, *Prosopis juliflora*, *Salvadora persica*, *Salvadora oleoides* and *Euphorbia nudiflora*. Other species of flora interspersed are *Capparis decidua*, *Balanitesa egyptica*, *Commiphora wightii* and *Zizyphu nummularia*. There are also grassland areas dominated by *Cymbopogon spp.*, *Chrysopogon spp.*, *Aristida spp.* and *Dicanthium spp.* The broad habitat types are: a) sparse cover to short grasslands dominated by *Cymbopogon*, *Aristida*, *Dicanthium* and *Chrysopogon* grasses; b) savanna to scrubland dominated by *Zizyphus*, *Acacia*, *Capparis*, *Salvadora*, *Euphorbia* and invasive introduced *Prosopis juliflora* shrubs; and c) agricultural matrix including

seasonal and annual crops, fallows and ploughed fields (Figure 2-4). While Kutch has the maximum mangrove cover in the State, it displays very low diversity with 8 mangrove species. The area has only one dominating mangrove species—*Avicennia marina*. Other species like *Rhizophoram ucronata*, *Ceriopstagal*, *Avicennia officinalis*, *A alba*, *Bruguiera gymnorhiza*, *Sonnera tiaapetala*, *Aegicero scorniculatum* are found in very small proportion (Stanley 2004).

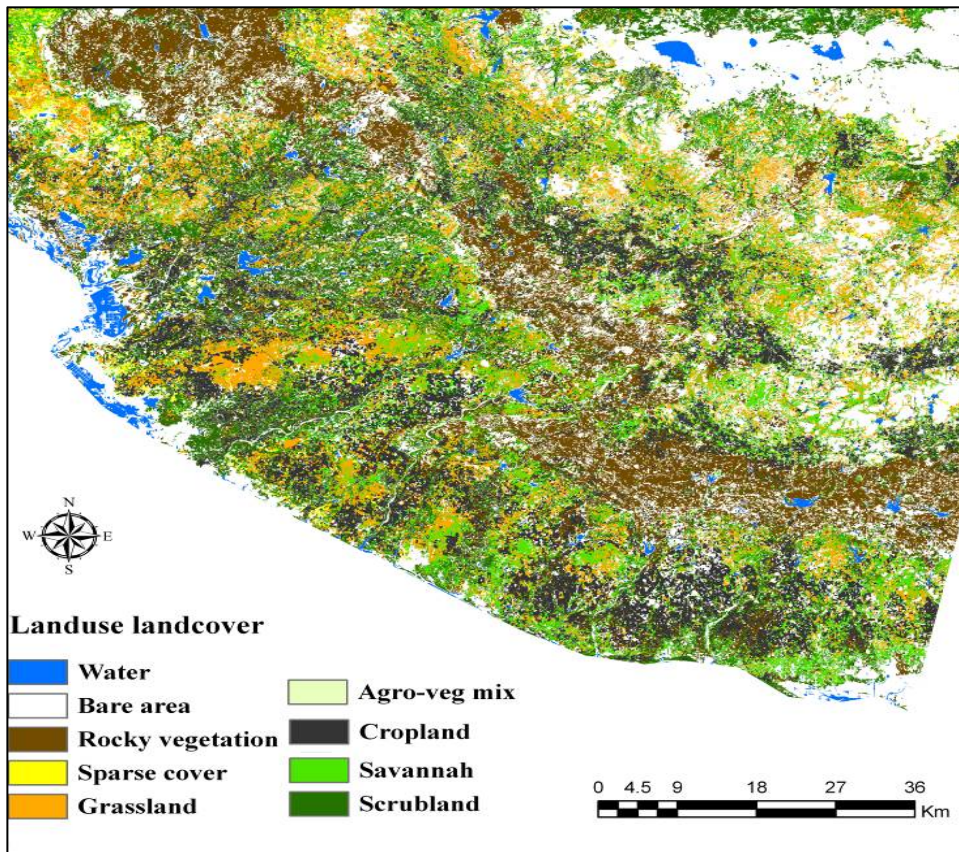


Figure 2-4: Land cover maps of the study area (Kutch, India) during 2007–11

Kutch harbours a plethora of wildlife, which are important both from the ecological and conservation perspectives. Some of the notable mammals are the rodent Indian desert jird (*Meriones hurrianae*), Indian fox (*Vulpes bengalensis*), desert cat (*Felis silvestris ornata*), jungle cat (*Felis chaus*), golden jackal (*Canis aureus*), striped hyaena (*Hyaena hyaena*), Indian porcupine (*Hystrix indica*), Ratel (*Mellivora capensis*) and Bengal monitor (*Varanus bengalensis*). Apart from a rich and diverse array of wildlife, Kutch supports six critically endangered species of wild fauna, listed as schedule-I species according to the wildlife protection act of India (1972). These

are the Indian wolf (*Canis lupus pallipes*), caracal (*Caracal caracal*), chinkara (*Gazella bennettii*), Indian wild ass (*Equus hemionus khur*), Great Indian bustards (*Ardeotis nigriceps*), Lesser florican (*Sypheotides indica*), spiny tail lizard (*Uromastix hardwii*). Houbara bustard (*Chalamydotis undulate*) is another endangered bird migrating to Kutch in winters. Chinkara and nilgai (*Bocelaphus tragocamelus*) and wild boar (*Sus scrofa*) are the only wild ungulates found in the region. Kutch falls in the cross-road of bird migratory routes, and is represented by about 300 Palearctic and Oriental species (Pandey et al. 2008).

## 2.5 History and People

Historically and geographically, Kutch has remained relatively peripheral to the subcontinent's mainstream. Once an island surrounded by inlets of the Arabian Sea, and an independent princely kingdom until 1948, it was only joined administratively and then by rail and road networks, to the western Indian state of Gujarat in the 1960s (Ibrahim 2008). The entire district lies along India's border with Pakistan. This border has been a politically sensitive one since its creation in 1947. It remains heavily surveyed and policed; border crossing is strictly prohibited along this entire section. Kutch has been at the confluence of two regions and religions-Vagad, the eastern part of Kutch has largely been influenced by the Saurashtra Hindus; and 'Kutch', in the west and northwest, traced its practices to the Persian and Islamic influences

Kutch has a population of 1,526,321 people inhabiting 949 villages in nine administrative units or *tehsils*, at a density of 33 human per sq. km (Census of Housing, Govt. India, 2001). The Bhuj Ridge which is habited by the thorn forests, straddles the district from east to west and has the most dense population in the district (Lamba and Kapoor 2006). The important towns in this region are Gandhidham, Bhuj, Anjar, Mandvi and Mundra. From the traces of Indus Valley civilization (~3000–1500 BCE) found here, it appears that Harappan people are the first documented inhabitants of this region. More than five dozen Harappan settlements have been discovered in this region and about thirty are reported as urban settlements such as Dholavira, Surkotada, Junikuran and Kanmer, to name a few (Kharakwal et al.). Much later, a series of migrations took place from Sindh to Kutch, during which, the Sama Rajputs (later called Jadejas) arrived and ruled this land till India's independence (Williams 1958a). Kutch was a Rajput State, which was united

in 1540 by Maharao (or king) Khengarji I, a Rajput of the Jadeja clan (McLeod 1999). During the princely time, Kutch was under feudal or *Zamindari* governance. Based on the beneficiary of the sovereign's land offerings, the feudal type was either *Girasdari* (offering to relatives) or *Inamdari* (for showing valor in battles) or *Barkhalidari* (to Bramhins for their service). Land reforms of 1956 abolished this system but these feudal values had pervaded the populist Kutchi culture (Joshi 2002).

In modern times, Kutch is ethnically and culturally very diverse, belonging to various communities including the traditional pastoralist communities like Rabari, the Bharvad, Muslim maldaris (Jat, Halaypotra, Hingora, Mutwa, Royma, Bamba, Samma), scheduled tribes (Kholi, Paradhi, Nath), scheduled castes (Meghwal, Maheswari, Marwada, Charan, Magwar, Banjara), Muslims (Thuriya, Sangar, Samma, Pinjara, Mandra, Lodra, Saati, Kerifakir, Katri, Machiyar, Wagher, Kumbhar), Hindus (Ahir, Bhanushali, Bawaji, Maharaj, Thakker, Lohana, Sangar, Kanbi, Patel, Bhatia, Govar, Rajput (Jadeja and Soda), Kharva, Machar, Rathore, Brahman), Vaniya (Jains), and the recent immigrants (from states of Punjab and Haryana are settled farmers, while from states of Kerala, Bihar and West Bengal are skilled workers). In Kutch, each ethnic group has its own distinctive tradition of embroidering its clothing.

## **2.6 Economy**

Gujarat is one of the most urbanized states of India but Kutch continues to be predominantly rural (Hirway et al. 2002). Only Fifteen percent of the area of Kutch is cultivable and rain fed agriculture and animal husbandry are the chief occupations in Kutch (Mehta 2001). In the district as a whole- and more so in northern and western Kutch-livelihoods have traditionally been constituted through pastoral activity. Agrarian production in these areas is low; a season of failed or low rainfall has a dire impact on the capacity of local populations to maintain livestock, adversely affecting their economic activity for the entire year. The dominant livelihood strategies in the region are Animal Husbandry, Agriculture (Dryland, Canal irrigated, Well irrigated), Fisheries, Collection of Minor Forest Produce, Crafts, service, and self-employment. Animal husbandry involves cattle (cow), buffalo, sheep and goat or camel; because of good breed characteristics and availability of open grazing spaces. The famous cattle breeds are 'Kankrej', a popular farm animal in the region and also the

‘Banni’/’Kundi’ breed of buffalo, a famous milch breed. Sheep and goat are sold for meat purpose and sometimes are also exported to the gulf countries. Agricultural land is privately owned, but draws water from common pool resource domain, when it is dependent on canal irrigation. Livestock in animal husbandry is privately owned but draws on a common pool resource of grasslands. For minor forest produce, the community owns the land on which this occupation is dependent and fisheries are dependent on the sea resource.

Gujarat is one of the most developed states of India with the fastest growing state per capita. Much of its development is due to the rapid industrial growth marked by 175,000 crores INR investment for industries in 1999–2000. This development has been costly in terms of rapid degradation of natural resources and social disparities (Hirway et al. 2002). The post–green revolution phase (1967–68 onwards) has seen fast growth and reduced inter–annual variability in crop production. In Kutch, major crop (jowar, bajra, maize, wheat, groundnut, sugarcane and cotton) production has increased from 590 (1961–63) to 1088 (1971–73), 1426 (1981–83) and 1641 (1991–93) million INR. This translates into 2.2–3.6% annual rate of increase, which is faster than many other districts. Land productivity has grown from 1637 (1961–63) to 6538 (1991–93) INR per ha but has stagnated since then. Agricultural development has been achieved mostly through growth in yield and not through increase in arable area, but this is not true for Kutch. Such agricultural growth has been spearheaded by technological advancements and accompanied by shift to cash crops. For example, number of tractors/1000 ha increased from 0.12 (1961–63) to 3.19 (1991–93) and that of pump sets/1000 ha increased from 8.03 (1961–63) to 30.50 (1991–93) in Kutch (Mathur and Kashyap 2002).

Kutch harbors various economic minerals, the most important being bentonite and lateritic bauxites (Valeton 1983). Both lateritic bauxite and bentonite constitute what is popularly known as an "alteration blanket", where bauxite occurs in a narrow belt of laterite cover. This is situated 20 to 40 km away from the Gujarat coast with a parallel alignment, extending over a length of 200 km from Ramania in Mundrataluka in the southeastern extremity to very near to Lakhpat in Northern West part of the district. It has an average thickness of 10-20 m and runs parallel to the Lower Tertiary shoreline in Kutch. The bauxite mines of Kutch are owned by Gujarat Mineral Development Corporation and a gross reserve of 42.41 million tonnes of bauxite is

explored in Kutch District(Jadhav et al. 2012). Kutch is now poised at the beginning of another major change, that of Industrialization.

## **2.7 Area of Interest**

Fieldwork was conducted mostly in Abdasa and parts of Lakhat, Nakhatrana and Mandvi talukas. Abdasa taluka is bordered by Arabian Sea in western side where as by Lakhat, Nakhatrana and Mandvi taluka at other sides. It is spread over 2,300 sq. km and 165 villages and hamlets are part of the taluka (Lamba and Kapoor 2006). It is very sparsely dotted with villages (0.075 per sq. km) and inhabited by 50 humans per sq.km (Figure 2-5). Naliya being the taluka head quarter is the biggest town in taluka, while Kothara, Mothala, Vayor and Jakhau are other major villages. Major traditional occupations in the taluka are animal husbandry and agriculture, with the fisheries restricted to coastal villages. Due to industrial development, influx of labour has increased in the area in last several years. Cattle (*Bostaurus indicus*), goat (*Capra aegagrushircus*), sheep (*Ovis aries*), buffalo (*Bubalus bubalis*) and camel (*Camelus dromedaries*) constitute the major livestock and their grazing action has historically modified the vegetation structure to its current form. The land is under mixed ownership: 1) reserved grasslands/forest lands owned by the Forest Department, 2) Revenue Department lands, 3) community lands owned by village Panchayats, and 4) private agricultural lands. The study area supports a heterogeneous mix of ethnic groups and lifestyles that are generally intermixed in villages, although informal 'vaas (clusters)' where members of same ethnic group live close together, do exist. But these different ethnic groups have strong economic, social, structural and linguistic links with each other, attaining a unique regional identity.

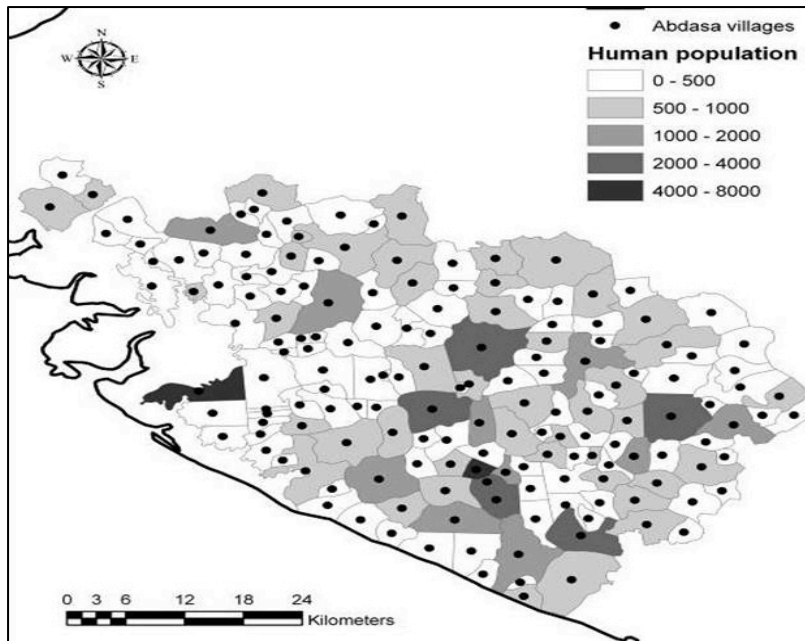


Figure 2-5: Human population at villages in Abdasa taluka

Most of the rock formations in Abdasa are marine deposited formation, while some area represents igneous rock and its altered deposited rock. Oldest formation in the study area is the Deccan trap basalt, which is formed by volcanic activity. This formation occurs in the east part of the study area. Adjoining to this formation, laterite rock, a secondary deposited rock by chemical weathering of basalt, occurs in northeast portion. There is also the limestone and clay formation deposited, which are marine formations. The marine formations, known as Berwali and Bermoti series, are located at northwest part of the taluka. Berwali series consist of different coloured shale, while Bermoti series consist of Nummilitic limestone. This formation is overlain by Khari series, which has two stages - one is Vinjhan and other is Aida stage. In vinjhan stage, shale and siltstone occurs, while Aida stage formed of khakhi coloured clay. A formation with sandstone deposited is known as Kankavati formation. This formation ranges from Naliya to Mothala in central part and between Dumara-Kothara villages. These all are marine deposited formation except basalt and laterite. In recent period, fluvial action formed alluvium formation, which is youngest formation. This formation occurs near coastal area in south to west part of the study area (Technologies 2008).

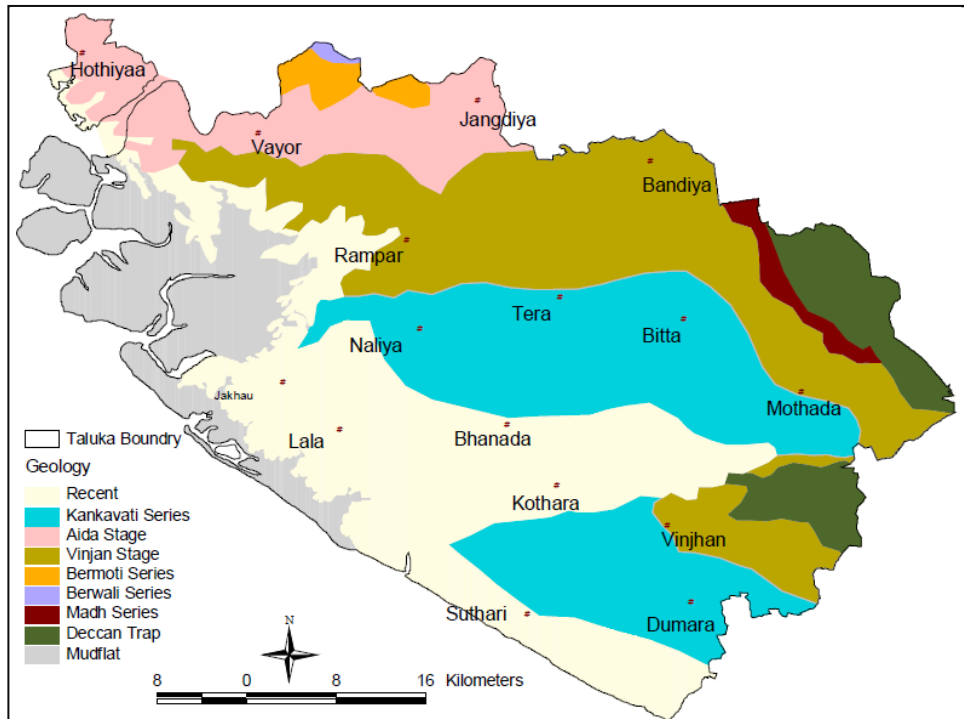


Figure 2-6: The geological map of Abdasa taluka (Technologies 2008)

However in the last five years, Abdasa has experienced increased anthropogenic pressures in several concurrent ways. Infrastructure has developed in the form of electricity and road network. This has made irrigation accessible to the remotest corners, in turn intensifying and altering cropping patterns, replacing traditional dry land crops with water intensive cash crops. Introduction of bore wells has ensured permanent mechanized cultivation, at the same time depleting ground water and increasing salinity by seepage of sea water. An emerging boom of industrial development and wind power generation has raised the real estate values ensuing in local villagers illegally encroaching and cultivating prime wildlife habitats. Along with the important wildlife habitats being utilized as cultivable land, the ‘gauchar lands’ (grazing lands), which provide habitat to large number of wildlife and were community commons are also being destroyed to be converted to arable lands. Such socio-ecological changes necessitate a comprehensive assessment of the conservation status of local fauna and strategies to safeguard their viabilities.

The semi-arid landscape of Kutch, in Northwestern India appears to be the stronghold of the striped hyaena (Jhala 2002, 2003, Jhala 2006). Therefore, this landscapes provides a scope for better understanding of the ecology and behavior of the hyena in Indian subcontinent. Based on this prior information, I conducted a reconnaissance survey in the region and identified potential study hyaena clans/dens around Tera village in Abdasa taluka. The reconnaissance survey involved active search for hyaena dens and interview with locals. This helped in delineating the **study area** for modeling striped hyaena distribution and habitat requirements, and **intensive study area** for studying home range, diet patterns and social behaviour using radio telemetry method. The study was carried out for five years from January 2006 to January 2011.

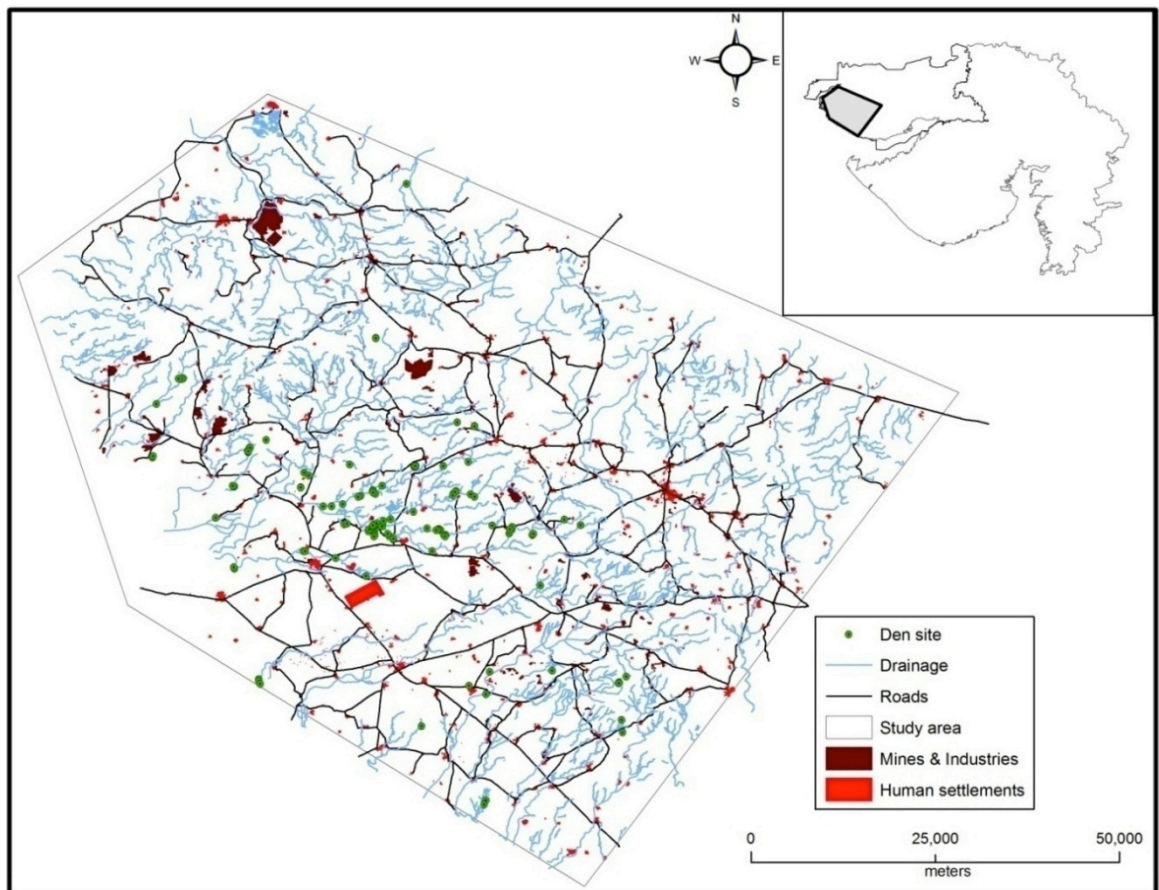


Figure 2-7: Location of Study area in Kutch. Human habitations, mines, industries and hyaena den sites in the study area.

The study area landscape encompassed  $\sim 6570 \text{ km}^2$ , between hill ranges of Bhuj (Roha) to Great Rann of Kutch (west to east) and from Banni grasslands to Arabian

Sea (north to south). The intensive study area encompassed ~300 km<sup>2</sup> of agro–grass–scrub mosaic habitats, in and around 22 villages (*Tera, Bara, Gurther, Ustiya, Hiraper, Sujaper, Nagia, Sukhper, Ramper, Baraper, Patt, Karaiya, Kuvapader, Narayan nagar, Hamirper, NaniDufi, MotiDufi, Jaatvan, Lakaniya, Sudodro, Kalatalav and Kaunatiya*) in central Abdasa.

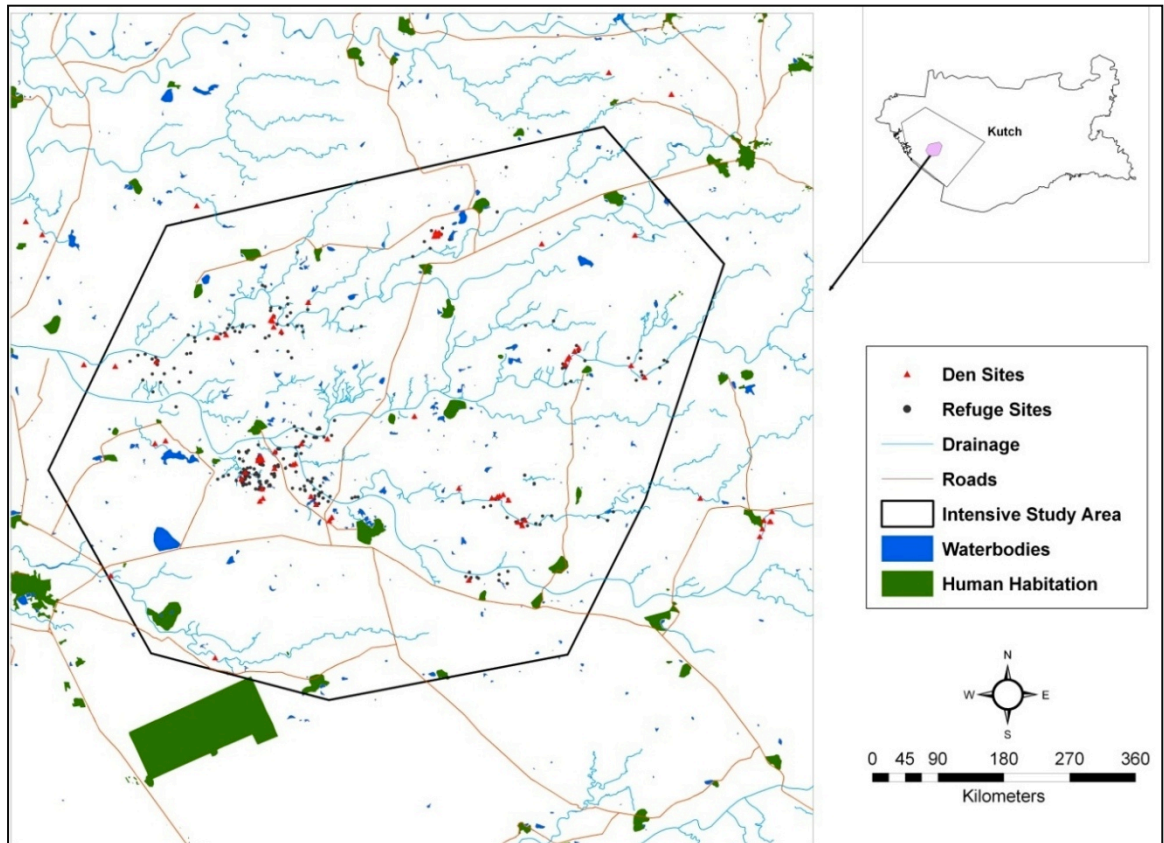


Figure 2-8: Location of Intensive study area (ISA) within the study area. Human habitation, water bodies, roads, and drainage, refuge and den sites of study hyaenas clans in the ISA.

The ISA landscape (Figure 2-8), dotted with villages is a mosaic of agricultural lands, scrublands, patches of grasslands and intermixing rocky outcrops dotted. Few seasonal rivers flow through and networks of dry drainages are frequently encountered. The lifestyles of the locals are typical of the region, with animal husbandry, agriculture and craftsmanship important form of livelihood. Livestock grazing is dependent on ‘gauchar bhoomi’ (designated grazing lands around each

village), with medium livestock (goats and sheep) and cattle constituting the major livestock population. These grazing lands (gauchar bhoomi) are prime wildlife habitats providing refuge and breeding grounds to an array of wildlife. Like most parts in Abdasa, in the past five years the ISA has lost large prime wildlife habitats to intensified commercial agriculture, wind farms and industrial developments.

### **3 Diet and foraging pattern of hyaenas**

#### **3.1 Introduction**

Food habit studies are an important prerequisite to understanding animal ecology, conservation and management (Korschgen 1980, Mills 1992, Litvaitis 2000). In human-dominated landscape, the most vulnerable species are the largest and most specialized species, often top predators (Crooks and Soulé 1999, Cardillo 2003, Swihart et al. 2003). However, predator densities may increase with additional food resource (anthropogenic food: livestock: garbage) (Yom-Tov and Mendelsohn 1988). The predator diet varies depending on both the level of anthropogenic activity and anthropogenic food abundance (Tremblay et al. 1998).

The study area is agro-pastoral dominated landscape, supporting a large population of livestock and people. As the majority of the human communities in this landscape are vegetarian, large quantity of food is available in form of carcasses to scavengers. Striped Hyaenas are thought to be abundant in the region and being the largest carnivore, they are positioned in the higher of the carnivore guild composition in Kutch. No study has been carried out in this region to determine the diet of the species and its dependence on anthropogenic food sources. As a result, the information on diets on hyaena from the region is speculative. Given this proviso; the results of the study will be able to determine the food habits and foraging patterns in the region, correlating with prey availability.

Striped hyenas have been reported to consume a wide variety of vertebrates, invertebrates, vegetables, fruit, and human originated organic wastes (Flower 1932, Novikov and Novikov 1962, Harrison 1968) (Ilani 1975) and this limited data has led to the interpretation that striped hyenas are essentially omnivorous scavenger. In Israel, groups of hyenas converge at feeding sites (Kruuk 1976, Bouskila 1984), but relatedness of observed groups has not been investigated. Foraging activity in Tanzania was restricted entirely to night-time (Kruuk 1976). Striped hyenas have also been described as raiding human grave sites and carrying away bones (Horwitz and Smith 1988). Also raiding of fruit and vegetable crop is considered a serious problem in Israel (Kruuk 1976).

## 3.2 Methods

The identification of food remains found in faeces is the most common method for analyzing carnivore food habits; it is found to be useful for constructing a basic description of a carnivore's diet, where other types of observation are not possible (Mills 1992).

Direct observations on actual feeding in the study area are difficult, because of undulating terrain and nocturnal habits of the animals. Therefore baseline data on striped hyaena diet was evaluated through analysis of scats and regurgitated pellets collected from January 2005 to February 2011. Hyaenas leave prominent white scats at latrines and dens; an adequate sample can be collected to determine the basic food habits. Scats were collected systematically from all dens of four clans in the intensive study area. The den designations to clans were established by radio telemetry and from previous studies. The four clans intensively surveyed were- H.ridge clan/location.1 (2005-2011), Patt clan/location.2 (2005-2011), BND clan/location.3 (2008-2011) and Moriya clan/location.4 (2008-2011). Most scats were collected from latrine sites used regularly and around den sites. Scats were also collected opportunistically from 30 different dens/sites (2005-2011) (referred as random locations in this study) outside the intensive study area.

Hyaena scats were identified by the patterns of shape, size and colour, mostly oval to cylindrical shaped with white or off-white colouration. The white colouration is results of high content of calcium, corresponding to their bone consumption habits. They can also be black in colour, resulting from high consumption of tissue and blood (Bearder and Randall 1978). The shape of black coloured scats differ from the typical white coloured hyaena scats; shaped mostly cylindrical with pointed or round extremities. Along with adult scats, cub scats were also collected from the intensive study area and random locations. Almost all cub scats were black in colouration and cylindrical in shape with tapering ends resembling felid scats. Care was taken to collect cub scats from active hyaena dens only, and to avoid misidentification only typical white coloured hyaena scats were collected from outside active den and latrine sites. Within the den and latrine sites, any scats of unsure origin were discarded. All scats from active den and latrine sites were collected at a given time to estimate scat deposition rates.

The collection of regurgitated casts (hair pellets/balls) followed the same protocol as scat collection, where they were collected opportunistically from around den, resting, feeding and refuge sites in intensive study area and from random sites. Regurgitated casts are dense mass of only prey hair, lacking faecal matter component as in scats and are embedded with undigested skeleton and plant elements. Since the binding material is mostly mucus, regurgitated casts are of varying shapes and sizes and disintegrate rapidly in field conditions. The cast shapes diverge into rounded lump, cylindrical (segmented at times) with rounded or pointed extremities, square shaped with rounded edges, flattened or rounded oval, mixed and irregular. Since hyaena is the only large carnivore in the landscape known to produce regurgitated pellets, all samples collected during the study period were diagnosed as hyaena regurgitated pellets with confidence. Only possible misidentification would be the occasional Hyaena and wolf scats exposed to prolonged field conditions; where the faecal matter component is lost and only prey hair and other residues remaining in the scat, resembling a regurgitated pellet. Such doubtful samples were examined for compactness and traces of faecal matter, if they didn't satisfy the general description of regurgitated pellets the samples were discarded.

Each sample collected was stored in zip lock bags, labelled with date; GPS coordinates and associated habitat types. Most of the scats collected in the field were dry; however, if scats were collected fresh, they were sun dried and stored. Each scat was washed manually in hot water through 1 mm sieves to separate the undigested components (i.e., hairs, fruit seeds, hairs, claws, scales, feathers, hooves, claws, teeth and bones and insect chitin). The washed samples were sun dried and components were separated into hair, bones, teeth, claws, hooves and plant matter, and then stored in individual zip lock bags. Prey identification was accomplished by analyzing hair macro- and microscopically, and comparing skeletal material recovered from the scats (i.e., teeth, claws and bones).

The mammal species were identified by comparing the physical appearance of hairs combined with medullar characteristics and cuticle scale patterns to the reference collections (Korschgen 1980, Maddock 1993, Mukherjee et al. 1994). Reference slides for cuticle and medullar patterns were prepared for all the mammals in the study area. The hairs separated were washed in xylene and slides were prepared for microscopic analysis. Whole mounts of hairs were prepared in DPX for examining

medullar characteristics. Cuticle imprints of the hairs separated were made on a gelatin layer and alternate medium (agar and glossy nail polish) prepared on slides and observed under 10X and 45X magnifications.

Samples were grouped seasonally, considering summer (March-June), monsoon (July- October), winter (November-February). To determine the minimum number of scats that needs to be analyzed to have an accurate estimate of the food habits, the cumulative percent frequencies of the occurrences of the different prey species were calculated for each increment of ten scats and this was plotted against the total number of scats. It is seen that as the number of scats increase the proportion of prey items stabilize at a point giving an approximate number of scats required to analyze the annual food habits. Sample size estimation was done individually for both scats and regurgitated pellets as well as for all seasons analyzed (Jethva and Jhala 2003). The frequency of occurrence of a prey item was calculated as the number of times a specific prey item was found to occur in the fox scats expressed as a percentage. Frequency of occurrences of prey items was calculated for the scats and regurgitated pellets collected from all locations spanning all seasons.

Chi-squared test was used to compare diet of the species across different seasons in two sample types (scats and regurgitated pellets) and between the two sample types. Traditional chi-squared tests used in diet analysis of animals use Pearson's chi-square test using relative frequency of occurrence (RFO) method. Wright (2010) argues that this violates the assumptions of independence and also has the problem of pseudo replication, hence will lead to deflated or inflated chi-square statistics (Kramer and Schmidhammer 1992, Garson and Moser 1995) and presents a solution in the form of the Absolute frequency of occurrence method (AFO).

For example, if our scat data (number  $k= 1, \dots, n$ ) can be represented in a matrix, the rows represent individual scats examined ( $i = 1, \dots, l_0$ ) and the columns represent the prey items detected ( $j= 1, \dots, m$ ) across the entire collection and the cells for each prey type and scat examined indicate the presence or absence by a binary vector(1,0). In the RFO method, the scat samples are classified in an  $r \times c$  contingency table, where the rows represent the classification to be contrasted (seasons, years, etc,) and the columns contain the frequency of the different prey types found in the scats for each

of the classifications. The proportion of occurrence for a given prey species under RFO is given by Equation 3-1,

$$\hat{p}_{ij}^{RFO} = \frac{\sum_{k=1}^{n_i} I_{ijk}}{\sum_{j=1}^m \sum_{k=1}^{n_i} I_{ijk}},$$

Equation 3-1: The proportion of occurrence under RFO

For example, if we are comparing diet across three seasons and there are 6 different prey types found, there would be 3 rows and 6 columns in the contingency table. Under this method, each scat can appear more than once in each row (i.e., as many as there are prey types) and therefore the true number of scats is over estimated. This violates the assumption of independence and also resulting in pseudo replication. These two violations would result in incorrectly estimating the chi-squared value.

In the AFO approach, we correct for this over estimation of the true number of scats by adding another row for each prey item in the contingency table, the number of scats in which the prey item was absent from the total number of scats examined. The proportion of prey occurrence in this method is given by Equation 3-1,

$$\hat{p}_{ij}^{AFO} = \frac{\sum_{k=1}^{n_i} I_{ijk}}{n_j}.$$

Equation 3-2: The proportion of occurrence under AFO

That is, if we are comparing the diet across three seasons and there are six prey items found in the diet, there would be two rows (presence, absence) for each prey item for each season. Here the true number of scats is represented for each prey item and therefore corrects for independence and also for pseudo replication. As represented in the analyses by Wright (2010), the re-analyses of data by AFO method from studies using the RFO approach showed over-estimation and under-estimation chi-squared

values resulting in wrong assumptions about the diet pattern. Therefore, in this analysis we chose to use the AFO method, which accounts for the assumptions of a chi-square test.

On the frequency of occurrences obtained, 95% confidence intervals were generated by 1000 bootstrap simulations (Efron and Tibshirani 1997, Andheria et al. 2007). All bootstrap simulations to generate confidence intervals on the frequency of occurrences were done using the statistical software SIMSTAT (Version 2.5.8). (<http://www.provalisresearch.com/simstat/simstatv.html>).

We calculated percentage occurrence of each prey category in the total number of scats for each species as an indication of how often each species fed on each dietary component (Loveridge and Macdonald 2003). The relative percentage occurrence (number of times a food item was encountered as a percentage of the total occurrence of all species) indicates the importance of each food item to the overall diet (Loveridge and Macdonald 2003).

### 3.3 Result

A total of 3000 confirmative adult hyaena scats, 466 regurgitated pellets and 1800 cub scats were collected in the span of the project. Out of which (n=1460) adult scats (H.ridge clan/location.1: n=380, winter: n=140, summer: n=120, monsoon: n=120), (Patt clan/location.2: n=380, winter: n=140, summer: n=120, monsoon: n=120), (BND clan/location.3: n=200, winter: n=80, summer: n=60, monsoon: n=60), (Moriya/location.4 : n=200, winter: n=80, summer: n=60, monsoon: n=60) , ( random locations n=300, winter: n=140, summer: n=120, monsoon=40; regurgitated pellets (n=466) location.1,2,3,4 and random location, winter: n=217, summer: n=122, monsoon: n=127 and cub scats (n=500) location.1,2,3,4, winter: n=140, summer: n=240, monsoon: n=120 were analyzed.

Food Categories	Kutch, India (1), n=1926 *	Serengeti NP, Kenya (2), n=50	Laikipia, Kenya (3), n=28	Lothagam, N.Kenya(4), n=120	Sariska TR, India (5), n=26	Gir NP, India (6), n=94 *	N.Gujarat, India (7), n=unknown
Very large livestock	Y						
Large livestock	Y				Y	Y	Y
Medium livestock	Y		Y	Y	Y		Y
Domestic dog	Y					Y	Y
Very large wild ungulate			Y				
Large wild ungulate	Y	Y	Y		Y	Y	
Medium wild ungulate	Y	Y	Y	Y	Y	Y	
Wildboar/warthog	Y					Y	
Porcupine	Y						
Small mammals	Y	Y			Y	Y	Y
Large carnivore	Y		Y				
Medium carnivore	Y						
Small carnivore	Y			Y		Y	
Primate			Y			Y	
Rodents/insectivore	Y	Y	Y	Y	Y	Y	Y
Birds	Y	Y	Y	Y	Y	Y	
Reptile	Y	Y		Y			
Bats			Y				
Fish	Y						
Invertebrates	Y					Y	
Fruit/vegetable/crop	Y	Y		Y	Y	Y	
Garbage	Y						

Table 3.1: Food habits of striped hyaena from different landscape, identified by scat analysis. The number in each study area corresponds to the source; (1) from present study, (2) from Kruuk (1976), (3) from Wagner (2006), (4) from Leakey et al. (1999b), (5) from Sankar and Jethwa (2002), (6) from Alam et al. (2009) and (7) from Gajera et al. (2009). \* indicates the inclusion of scats and regurgitated pellets.

Since most hyaena scats had vegetation matter along with major food items, I considered the overall diet of striped hyaena classified as prey types considering only the vertebrate presence, into ‘single prey (SP)’ where only one vertebrate was present in the scat/regurgitated pellet and ‘multiple prey (MP)’ where more than one vertebrate was present in scat/regurgitated pellet. The overall diet was reclassified as diet types considering all food items, into ‘Single Food Item (SFI)’ where the scat/regurgitated pellet has presence of only one food item and ‘multiple food item (MFI)’ where the scat/regurgitated pellet has the presence of more than one food item. In adult scats (n=1460) it was found that 46.23 % were of single prey (SP), 53.77 % were of multiple prey (MP), 16.44 % were of single food item (SFI) and 83.56 % were of multiple food item (MFI). In regurgitated pellets/regurgitated pellets (n=466) it was found that 29.83 % were of single prey (SP), 70.17 % were of multiple prey (MP), 16.31 % were of single food item (SFI) and 83.69 % were of multiple food item (MFI) (Figure 3-1).

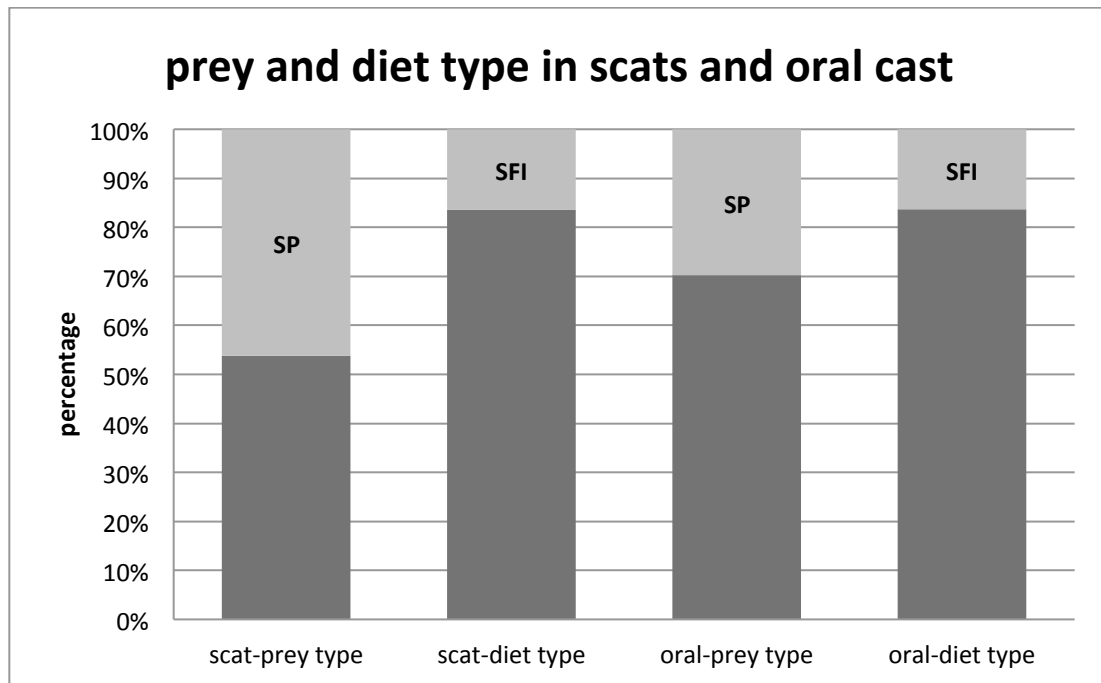


Figure 3-1: Prey (single and multiple vertebrate items) and diet (only vertebrate and vertebrate combined with non vertebrate items) in scats and regurgitated pellets/regurgitated pellets. Scats (n=1460) regurgitated pellets (n=466). MP: multiple prey, SP: single prey, MFI: multiple food items, SFI: single food item

The diet diversity (Shannon index  $H'$ ) of scats and regurgitated pellets were similar, scats (3.08) and regurgitated pellets (3.14) with 32 food items (Table 3.2). Food item category of 'others' includes infrequently occurring animal and plant derived items [scat: fish, crab, snail, scorpion, maggot case, snake gourd (*Trichosanthes cucumerina*), papaya (*Carica papaya*), cucumber (*Cucurbitaceae*), green chillies (*Capsicum spp.*), tomato (*Solanum lycopersicum*), sapodilla (*Manilkara zapota*), dates (*Phoenix spp.*), coriander seeds (*Coriandrum sativa*), mustard (*Brassica spp.*), coconut (*Cocos nucifera*), paddy (*Oryza spp.*), wheat (*Triticum spp.*), pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum spp.*), cluster beans (*Cyamopsis tetragonoloba*), green gram (*Vigna radiata*), wild fruits (*Cordia gharaf*, *Cordia dichotoma*, *Balanites aegyptiaca*, *Physalis spp.*) and charcoal. Regurgitated pellets: fish, snail, scorpion, maggot case, bitter gourd (*Momordica charantia*), bottle gourd (*Lagenaria siceraria*), papaya, cucumber, green chillies, tomato, brinjal (*Solanum melongena*), sapodilla, dates, mango (*Mangifera indica*), coconut, pearl millet, sorghum, cluster beans, green gram, wild fruits (*Cordia gharaf*, *Cordia dichotoma*, *Balanites aegyptiaca*, *Capparis spp.*) and charcoal.

<b>Food item</b>	<b>scat-all (n=1460)</b>	<b>oral-all (n=466)</b>	<b>scat-summer (n=480)</b>	<b>scat-winter (n=580)</b>	<b>scat- monsoon (n=400)</b>	<b>oral-summer (n=127)</b>	<b>oral- winter (n=217)</b>	<b>oral-monsoon (n=122)</b>
Cattle	34.86	18.67	35.42	28.62	43.25	18.90	17.97	19.67
Sheep	27.53	36.27	28.54	30.17	22.50	32.28	38.25	36.89
Goat	25.75	33.91	28.75	26.72	20.75	25.98	34.56	40.98
Dog	20.62	9.66	19.58	20.17	22.50	14.17	8.29	7.38
Buffalo	4.32	4.29	2.92	4.14	6.25	5.51	4.15	3.28
Porcupine	4.32	9.01	3.75	4.48	4.75	9.45	6.45	13.11
Wild pig	7.67	17.81	5.83	7.93	9.50	18.11	18.89	15.57
Jackal	9.45	14.81	9.79	9.66	8.75	20.47	10.14	17.21
Camel	2.26	4.72	2.29	1.55	3.25	5.51	4.61	4.10
Hare	4.73	4.51	5.42	5.34	3.00	3.94	6.45	1.64
Rodent	8.29	12.23	9.58	7.59	7.75	11.81	9.22	18.03
Nilgai	6.03	10.94	5.00	7.41	5.25	7.87	10.60	14.75
Chinkara	4.52	5.36	4.17	5.86	3.00	5.51	5.53	4.92
Cat	2.81	1.50	3.33	2.59	2.50	0.00	2.76	0.82
Civet	3.29	3.00	2.71	3.79	3.25	4.72	1.84	3.28
Badger	0.55	0.21	0.63	0.17	1.00	0.00	0.00	0.82
Mongoose	4.04	6.87	3.33	5.17	3.25	5.51	6.45	9.02
Hedgehog	1.16	6.44	0.83	1.03	1.75	4.72	7.83	5.74
Hyaena	0.89	1.50	0.42	0.86	1.50	1.57	2.30	0.00
Bird	18.36	20.39	14.58	23.62	15.25	14.96	23.96	19.67
Cutiba spp.	36.99	26.39	28.75	43.10	38.00	13.39	26.73	39.34
Prosopis spp.	29.38	28.11	31.67	29.83	26.00	24.41	29.95	28.69
Muskmelon	9.86	9.01	9.79	9.66	10.25	25.20	0.92	6.56
Zizyphus spp.	11.78	9.66	11.88	10.34	13.75	3.15	14.75	7.38
Grass	6.51	42.27	8.13	6.03	5.25	36.22	42.40	48.36

Watermelon	0.55	0.21	0.63	0.34	0.75	0.79	0.00	0.00
Reptile	13.97	11.59	9.17	16.21	16.50	6.30	13.82	13.11
Groundnut	31.03	25.97	27.50	34.48	30.25	15.75	30.41	28.69
Insects	10.34	9.01	9.79	11.03	10.00	9.45	6.91	12.30
Garbage	12.05	10.94	13.75	11.03	11.50	7.09	12.90	11.48
Others	16.85	14.16	15.42	17.59	17.50	21.26	13.36	8.20
Unidentified	6.10	7.73	6.67	7.93	2.75	7.87	8.29	6.56

Table 3.2 : The food items recorded as per frequency of occurrence in scats and regurgitated pellets, also for three seasons respectively

Food item	scat- season		oral- season		scat-oral overall	
	$\chi^2$	df=2 p-value	$\chi^2$	df=2 p-value	$\chi^2$	df=1 p-value
Cattle	6.604	0.037	0.155	0.92562012	43.349	4.58E-11
Sheep	4.303	0.116	1.103	0.576156673	16.926	0.000039
Goat	7.546	0.023	6.325	0.042316346	11.715	0.00062
Nilgai	3.198	0.202	3.072	0.215272032	12.753	0.000355
Wild pig	4.225	0.121	0.599	0.741273845	39.915	2.65E-10
Chinkara	3.056	0.217	0.065	0.968008672	0.310	0.577381
Other Herbivore	7.839	0.02	0.594	0.150960996	3.155	0.075678
Dog	1.338	0.512	8.233	0.016303224	14.711	0.000125
Jackal	0.265	0.876	11.598	0.003031065	2.841	0.091906
Mongoose	3.106	0.212	1.305	0.520860524	6.266	0.012305

Other						
Carnivores	0.383	0.826	0.534	0.765669033	0.658	0.417285
Hare	0.164	0.2236	4.334	0.114515847	0.038	0.844965
Rodent	1.635	0.441	5.683	0.058344216	6.551	0.010481
Other mammals	1.201	0.548	1.462	0.481417315	38.868	4.53E-10
Bird	18.097	0.000118	4.052	0.131838593	0.952	0.329251
Cutiba spp.	23.864	0.000000658	21.605	0.00002	17.555	2.79E-05
Prosopis spp.	3.516	0.712	1.246	0.536366534	0.277	0.598576
Melon	0.223	0.895	61.485	4.45E-14	0.485	0.486241
Zizyphus spp.	2.745	0.254	13.334	0.001271904	1.594	0.206712
Grass	3.354	0.187	3.761	0.152547427	351.354	2.15E-78
Reptile	13.930	0.000944	4.805	0.090503815	1.731	0.188222
Groundnut	6.791	0.034	9.602	0.008220955	4.326	0.03753
Insects	0.611	0.737	2.800	0.246651667	0.693	0.405286

Garbage	2.058	0.357	2.829	0.243067361	0.419	0.517404
Others	0.841	0.657	8.948	0.011404264	1.878	0.170598
Unidentified	11.508	0.003169653	0.336	0.845285039	1.545	0.213815

Table 3.3: Chi-square and P value calculated for scats across season (1<sup>st</sup> and 2<sup>nd</sup> column), for oral cast across season (3<sup>rd</sup> and 4<sup>th</sup> column) and for comparison between scats and oral cast (5<sup>th</sup> and 6<sup>th</sup> column). The presence- absence of each variable was used for the calculation (Wright 2010). The marked P values show a significant difference

Food item category of 'unidentified' includes unidentified fruits, seeds and mammalian hair for both scats and regurgitated pellets. Food item category 'garbage' includes human generated refuse like polythene bags, plastic, cloth, rubber, gunny bag, foam, thermacol, threads, electrical wires, nylon rope pieces, paper, glass pieces and fiber glass pieces for both scats and regurgitated pellets.

The overall diet components in scats (n=1460) and regurgitated pellets (n=466) were grouped into the following categories to determine the proportional contribution of each food type (Table 3.2). It was found that vertebrates contribute to more than 50% volume intake in both scats (54.50 %) and regurgitated pellets (56.01 %).

- Vertebrates: cattle (*Bos spp*), sheep (*Ovis aries*), goat (*Capra aegagrus*), dog (*Canis lupus familiaris*), porcupine (*Hystrix indica*), wild pig (*Sus scrofa*), jackal (*Canis aureus*), camel (Camelus dromedaries), black nape hare (*Lepus nigricollis*), rodent, nilgai (*Boselaphus tragocamelus*), chinkara (*Gazella bennettii*), cat (domestic and wild species grouped together) (*Felis spp*), civet (*Viverricula indica*), badger (*Mellivora capensis*), mongoose (*Herpestes javanicus*), hedgehog (*Hemiechinus collaris*), hyaena (*Hyaena hyaena*), bird and reptile)
- Major plant derived: Cutiba, *Prosopis spp.*, musk melon (*Cumis melo*), water melon (*Citrullus lanatus*), *Zizyphus spp.*, grass and groundnut.
- Others: Others and insects
- Garbage
- Unidentified

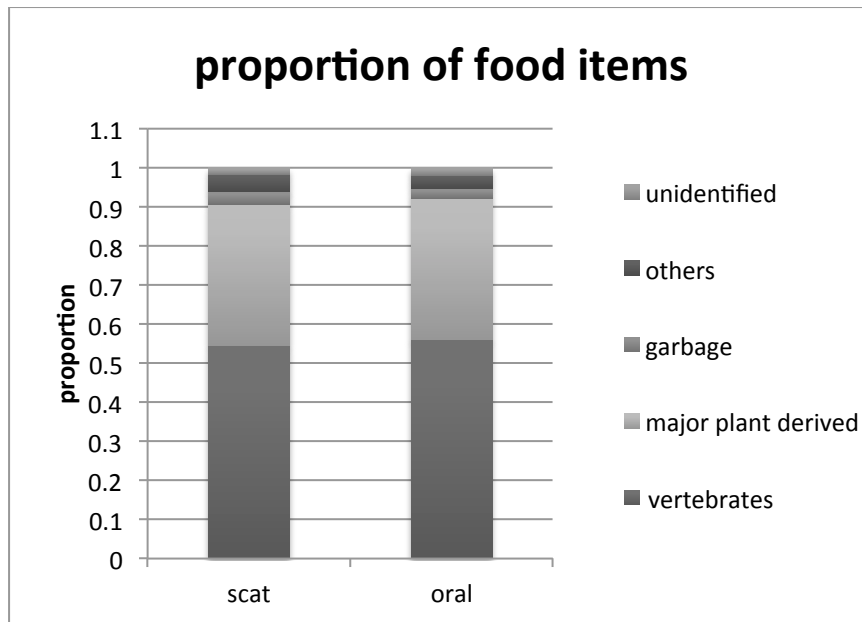


Figure 3-2: Proportion of food items in scat (n = 1460) and regurgitated pellets (n = 466) of hyaenas, quantified from the study in Kutch

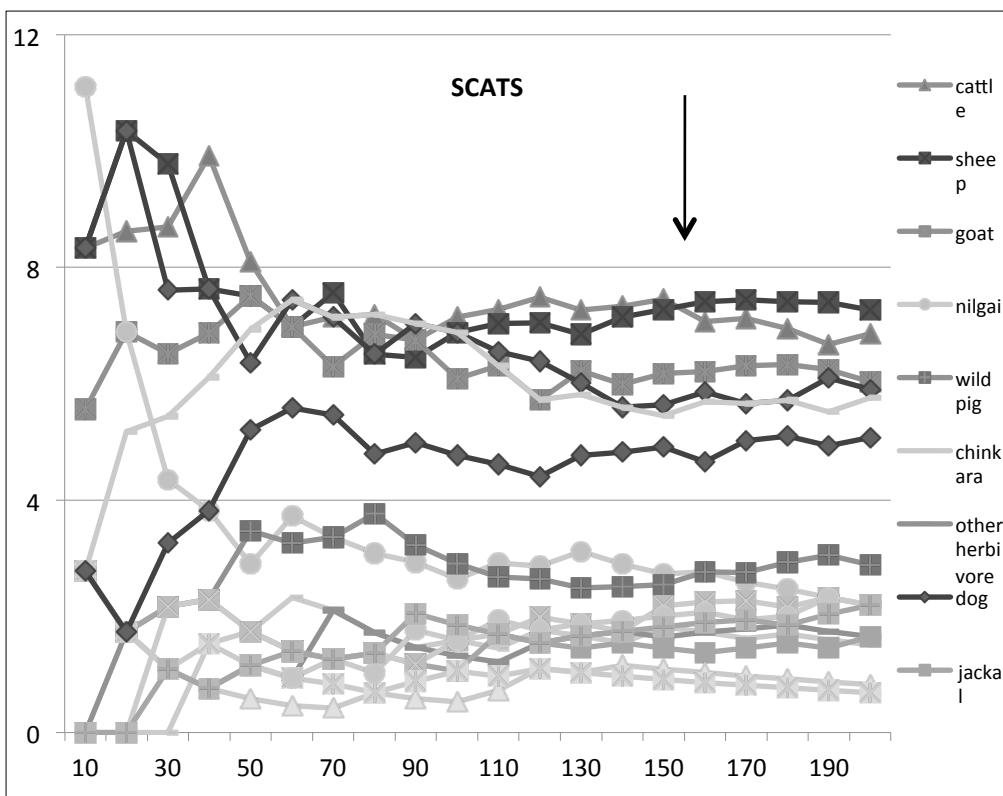


Figure 3-3: Estimation of the minimum number of regurgitated pellets to study the annual food habits of the striped hyaena (n= 1470). The number of scats stabilizes to about 160 samples

Since vertebrates prey items contribute the major portion of the overall diet, only vertebrate prey items were considered in sample size estimation. The vertebrate prey items with less than 5% frequency occurrences were grouped into order level- other herbivore (buffalo, camel and donkey), other carnivores (hyaena, cat, civet, badger, wolf and fox) and other mammals (porcupine and hedgehog). In this study domestic cat and wild species of small cats (jungle cat, desert cat and caracal) were grouped into food item-‘cat’ and musk melon and water melon were grouped into food item ‘melon’. The sample size estimation done for scats (n=1460) shows that the cumulative frequencies of prey items stabilize at around 160 scats (Figure 3-3) and at around 290 sample size for regurgitated pellets (n=46)

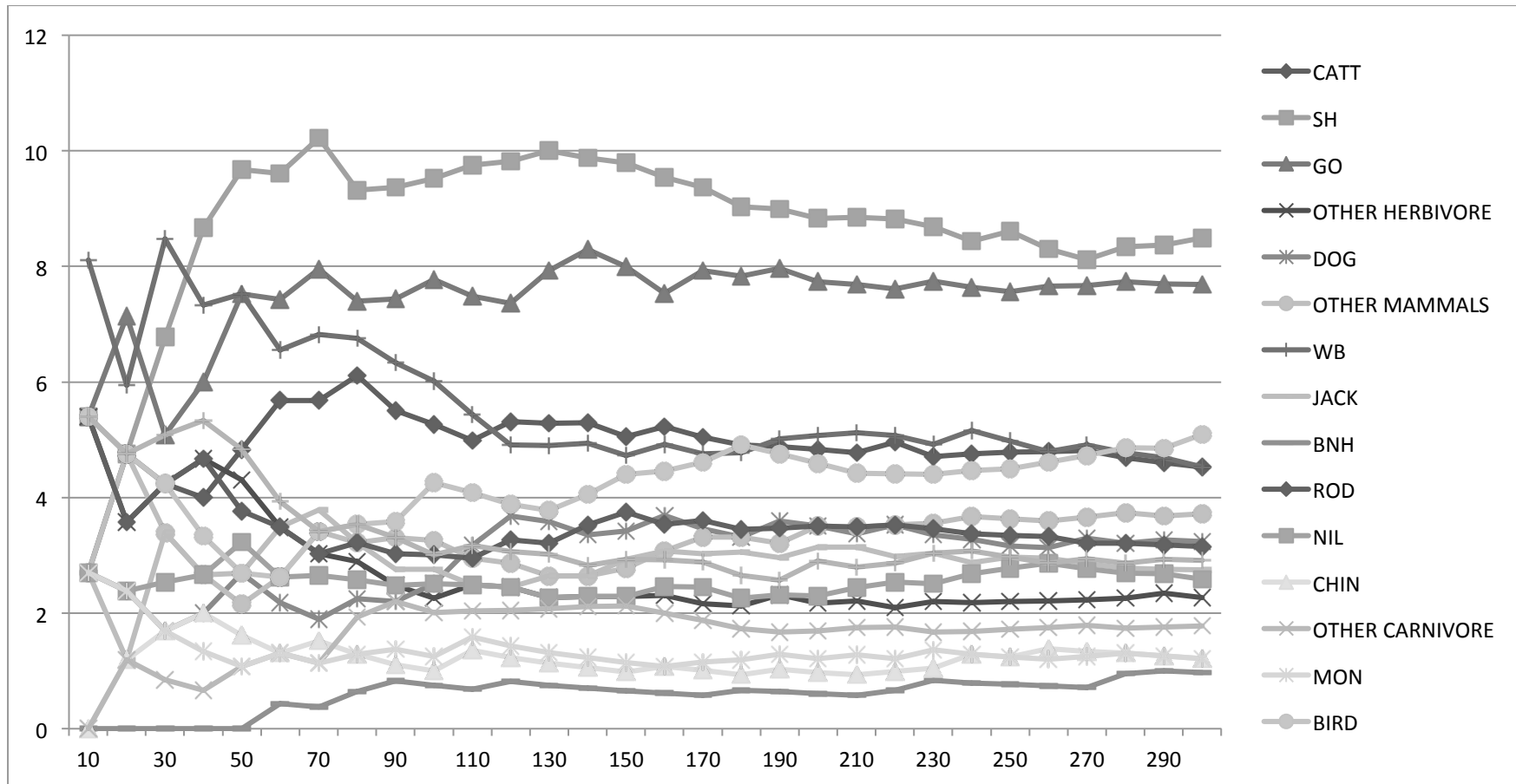


Figure 3-4: Estimation of the minimum number of regurgitated pellets to study the annual food habits of the striped hyaena (n= 1470). The number of scats stabilizes to about 290 samples

No significant differences in diets were seen in scats (n=1460) across seasons among major diet components (MFI)(Table 3.3). For only three food items, we found significant differences across seasons: Birds (Figure 3-6) was represented more in winter, while reptiles (Figure 3-6) & cutiba (Figure 3-8) intake was higher in winter and monsoons.

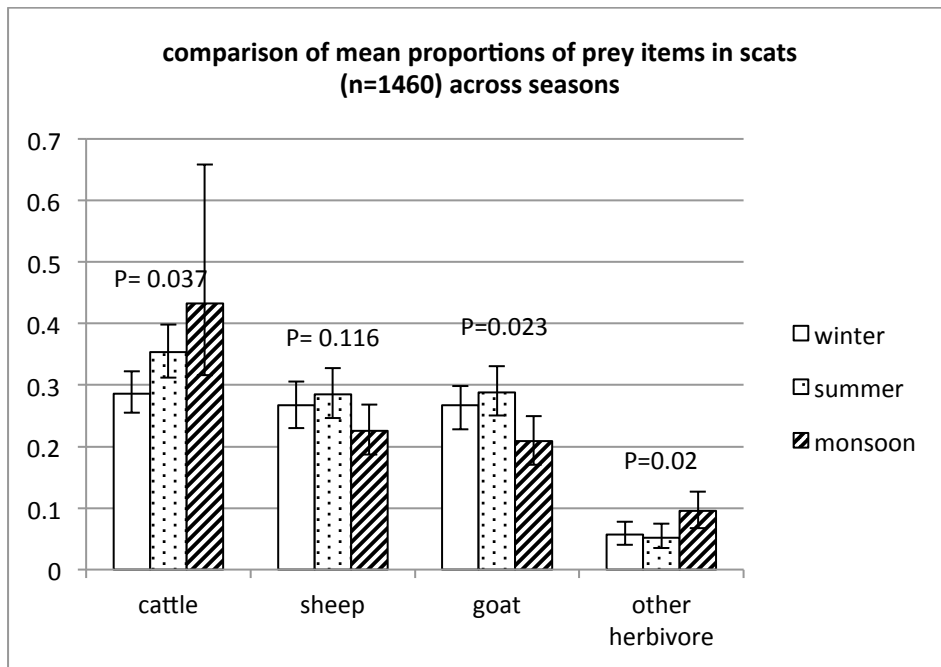


Figure 3-5: Comparison of mean proportion of prey items in scats of hyaenas (n=1460) collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

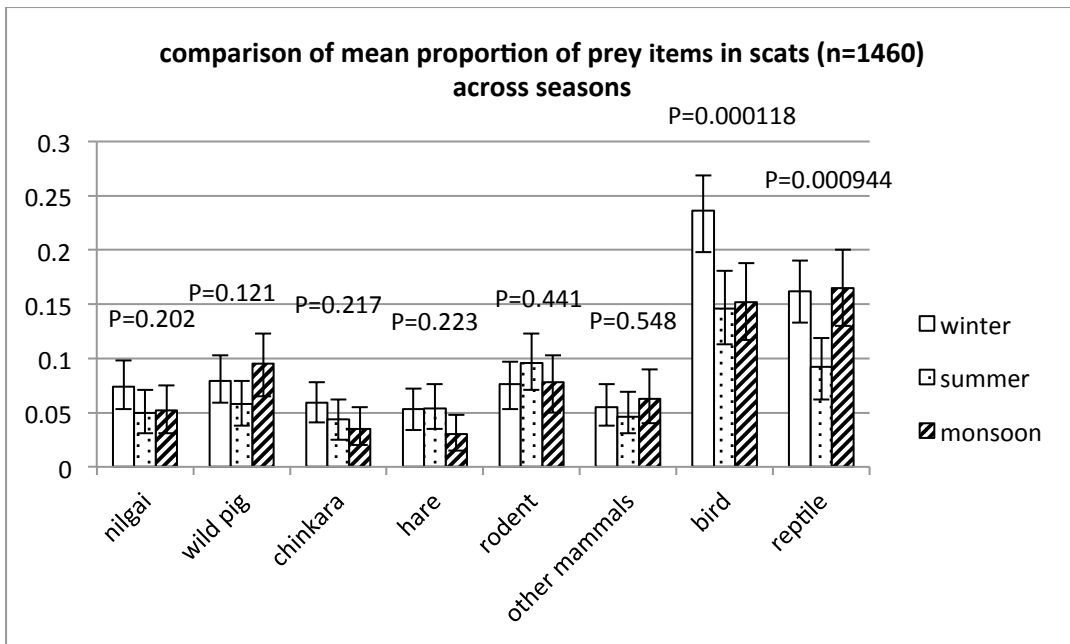


Figure 3-6: Comparison of mean proportion of prey items in scats of hyaenas (n=1460) collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

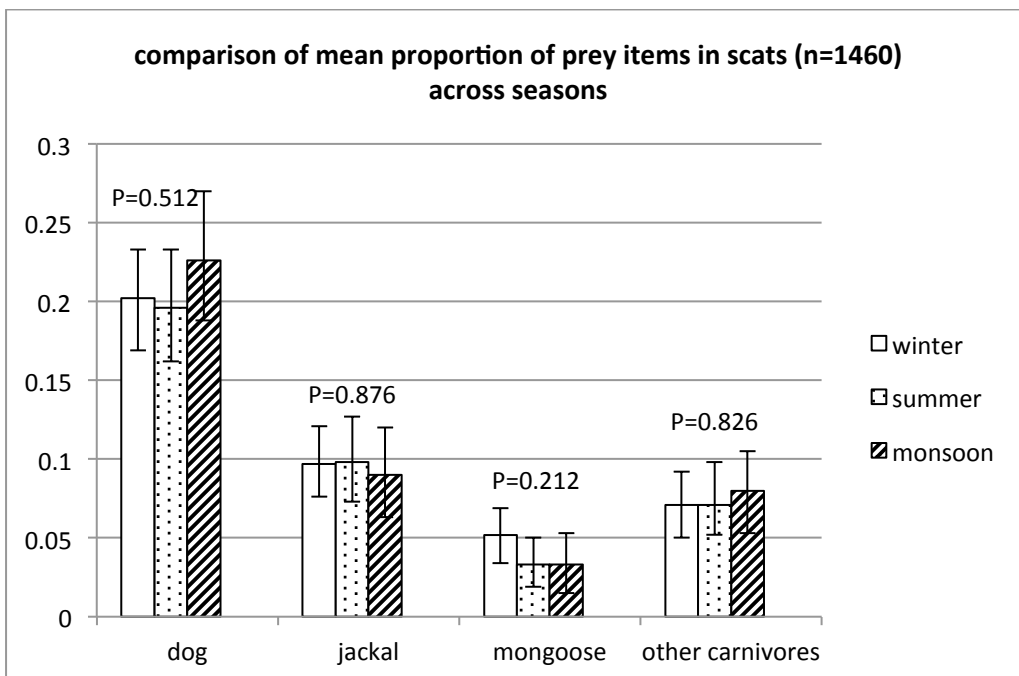


Figure 3-7: Comparison of mean proportion of prey items in scats of hyaenas (n=1460) collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

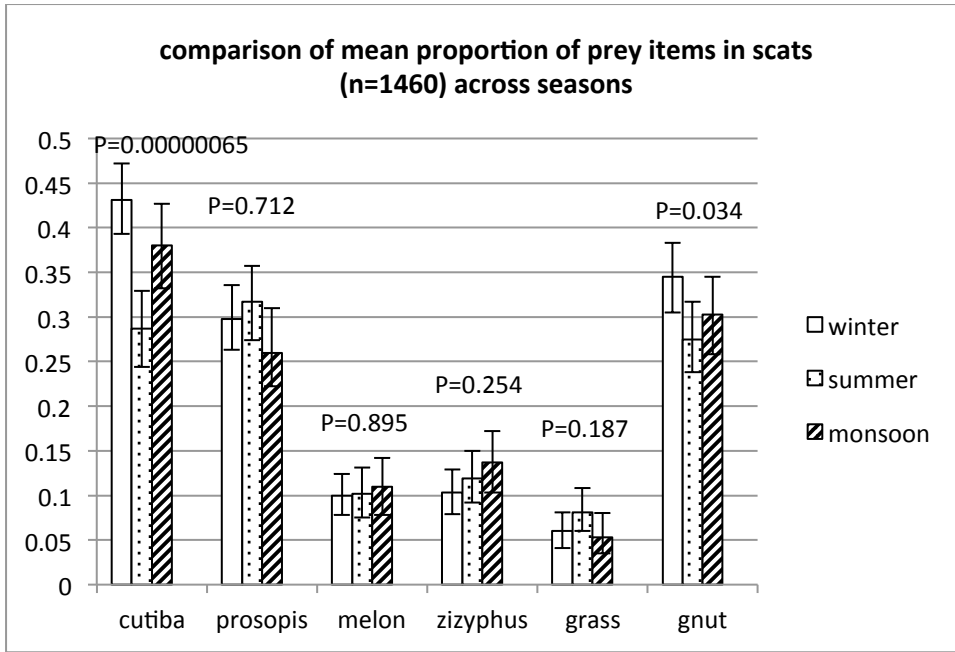


Figure 3-8: Comparison of mean proportion of prey items in scats of hyaenas (n=1460) collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

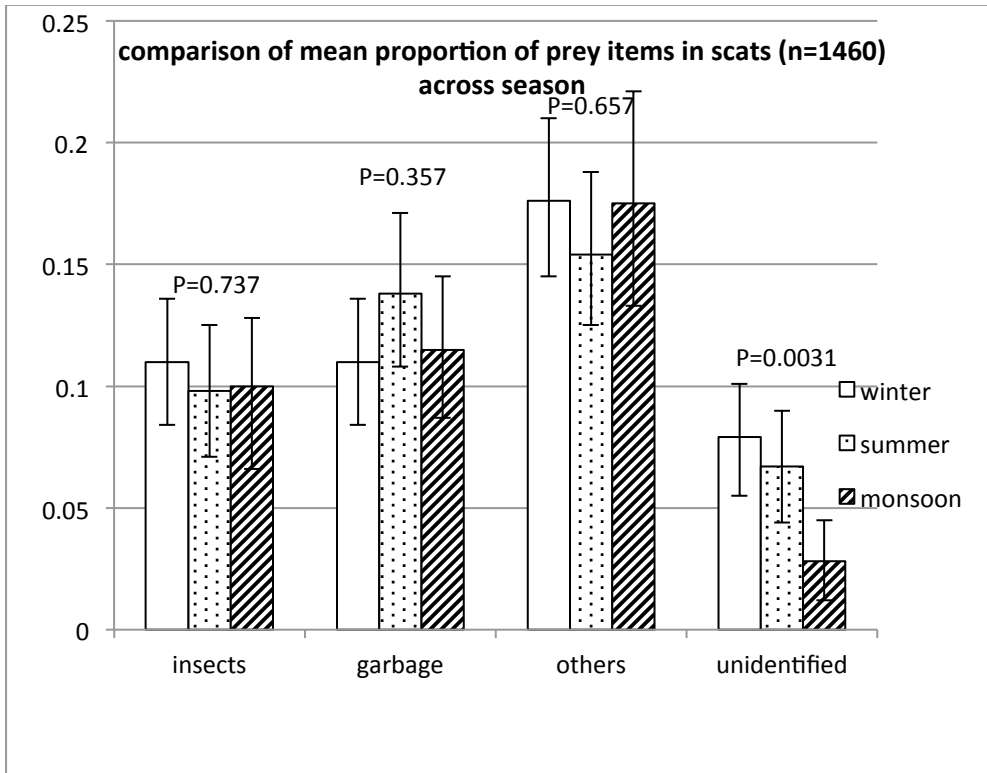


Figure 3-9: Comparison of mean proportion of prey items in scats of hyaenas (n=1460) collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

No significant seasonal differences among major food item (MFI) were found in regurgitated pellets (n=466)(Table 3.3). But as with scats, in regurgitated pellets, we found some significant seasonal variation in some of the prey items. Rodent (Figure 3-11) and Cutiba (Figure 3-13) were represented more in monsoon; jackal (Figure 3-12), melons (Figure 3-13), others (Figure 3-14) were more frequent in summer samples. *Zizyphus spp.* (Figure 3-13) intake was higher in winter, while reptile (Figure 3-11) and groundnut (Figure 3-13) were represented more in winter and monsoon.

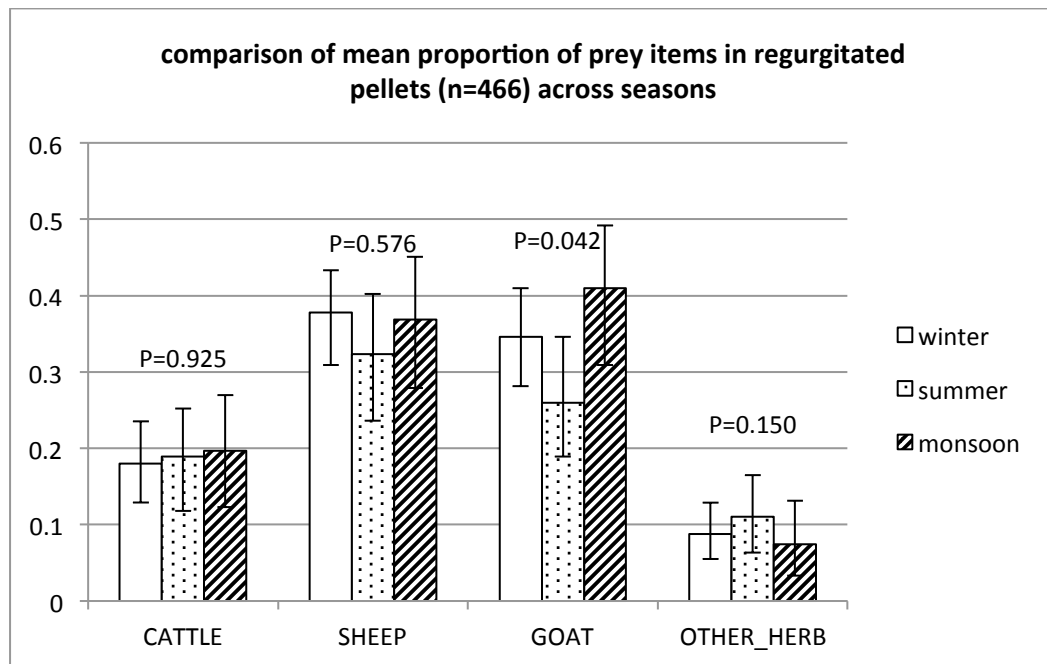


Figure 3-10: Comparison of mean proportion of prey items in regurgitated pellets of hyaenas (n=466) collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

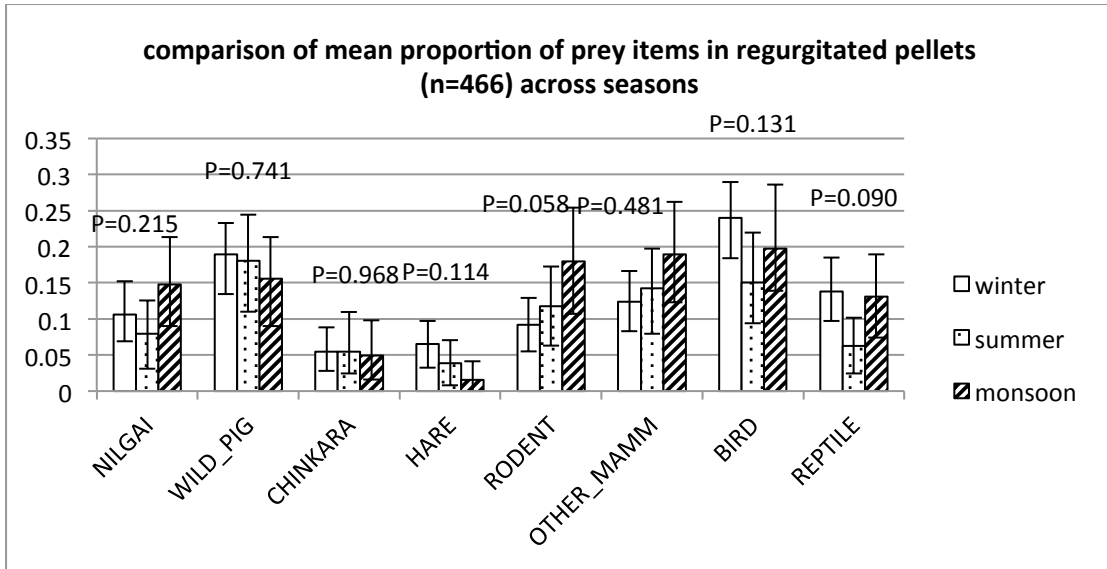


Figure 3-11: Comparison of mean proportion of prey items in regurgitated pellets of hyaenas (n=466) collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

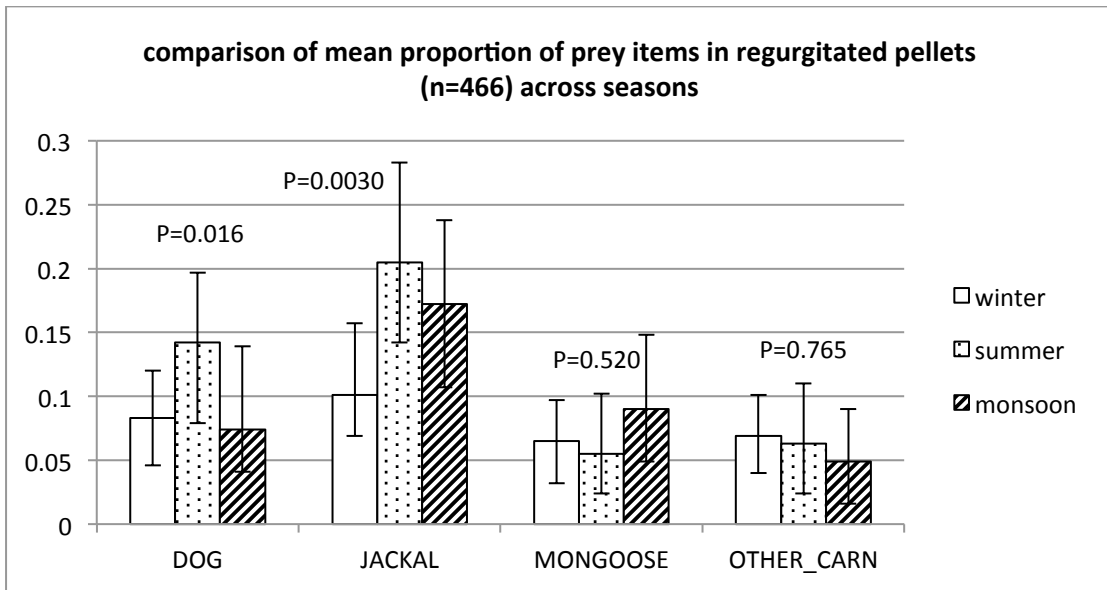


Figure 3-12: Comparison of mean proportion of prey items in regurgitated pellets of hyaenas (n=466) collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

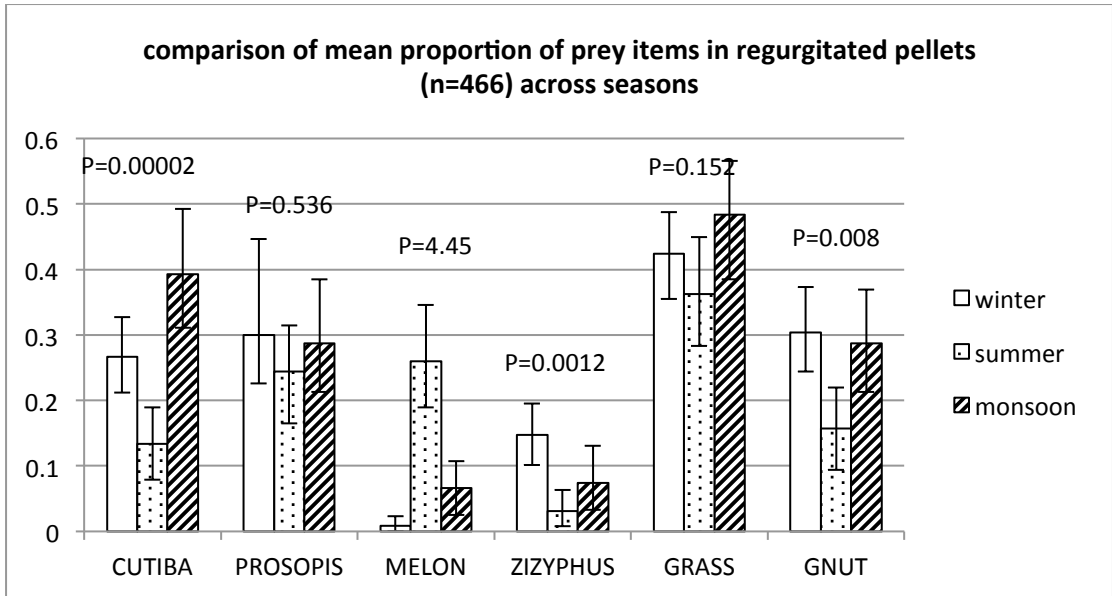


Figure 3-13: Comparison of mean proportion of prey items in regurgitated pellets of hyaenas (n=466) collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

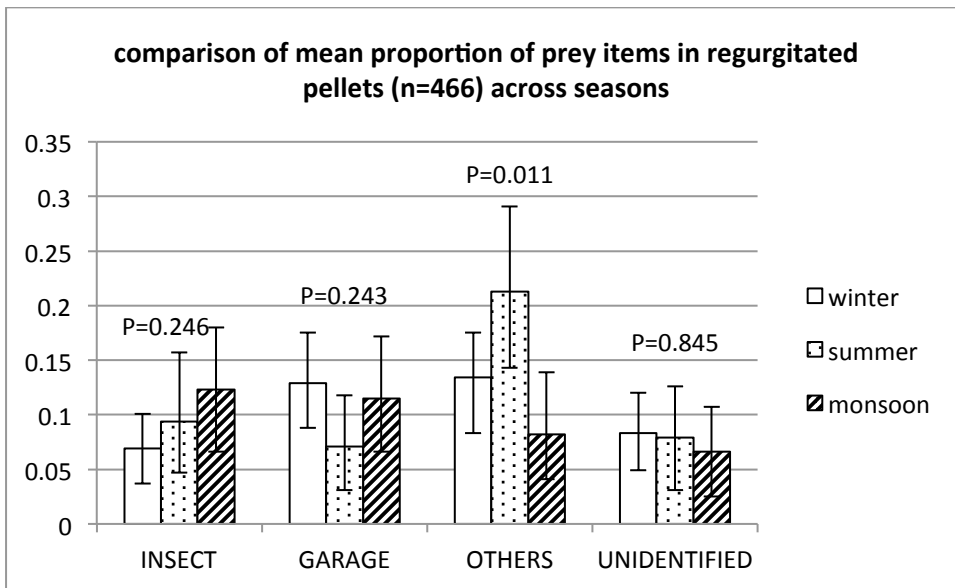


Figure 3-14: Comparison of mean proportion of prey items in regurgitated pellets of hyaenas (n=466) collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

Significant differences in mean proportions among major food items were observed between scat (n=1460) and regurgitated pellets (n=466). Cattle (Figure 3-15), dogs (Figure 3-17) and cutiba (Figure 3-18) were represented more in scat; while sheep (Figure 3-15), goat (Figure 3-15), wild pig (Figure 3-16), other mammals (Figure 3-16), jackal (Figure 3-17) and grass (Figure 3-18) were more in regurgitated pellets.

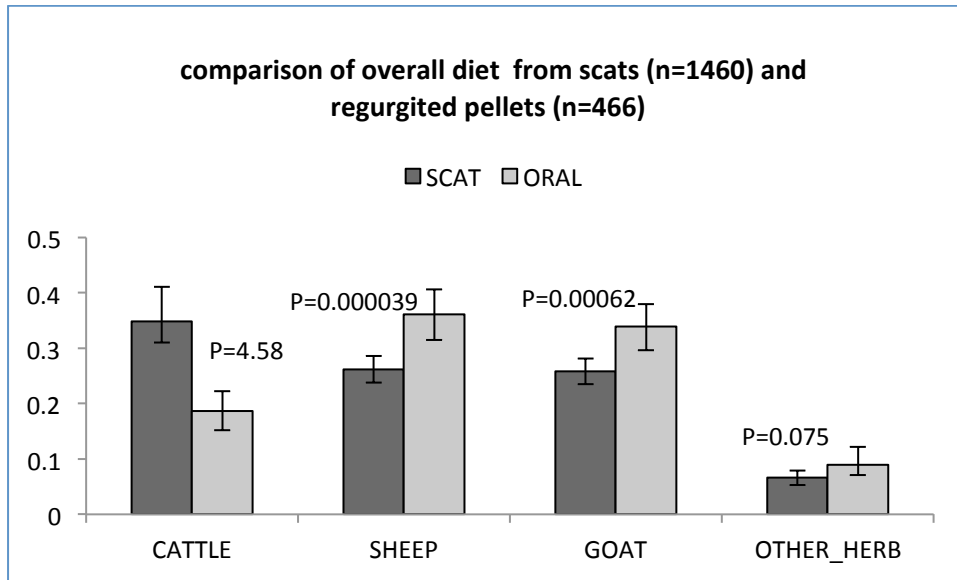


Figure 3-15: Comparison of overall diet from scats (n=1460) and regurgitated pellets (n=466), collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

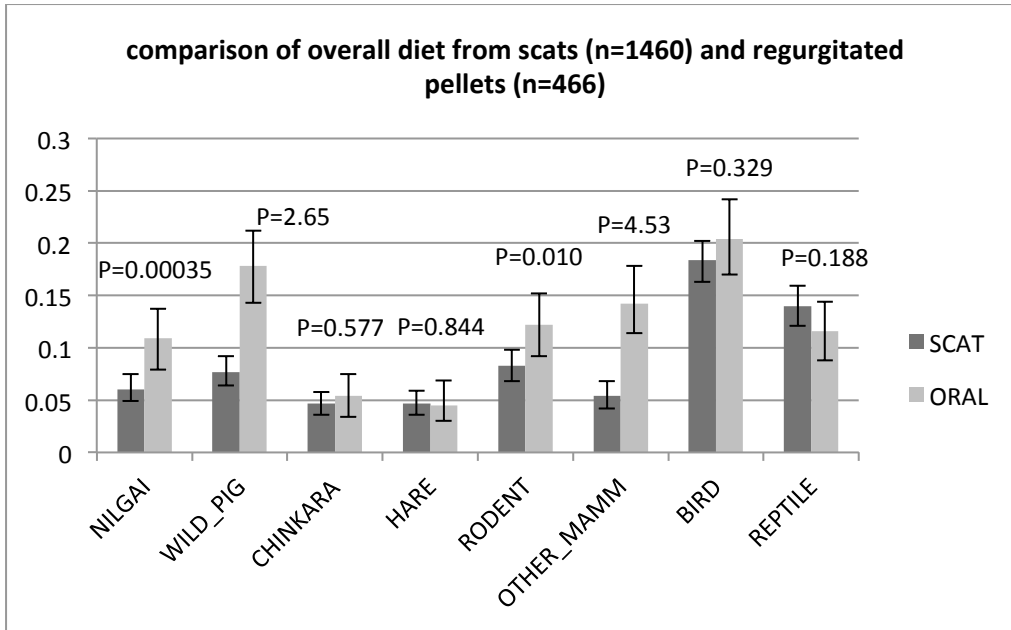


Figure 3-16: Comparison of overall diet from scats (n=1460) and regurgitated pellets (n=466), collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

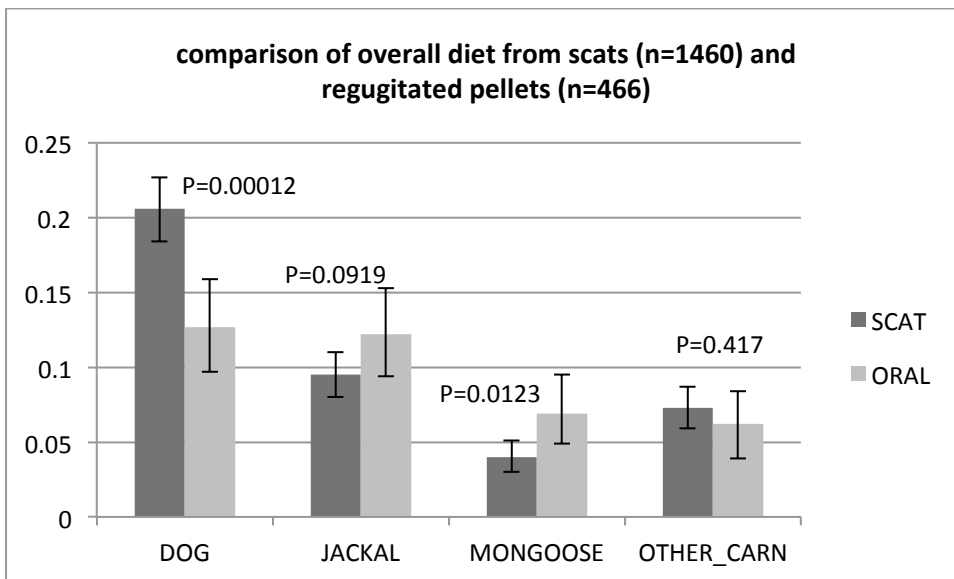


Figure 3-17: Comparison of overall diet from scats (n=1460) and regurgitated pellets (n=466), collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

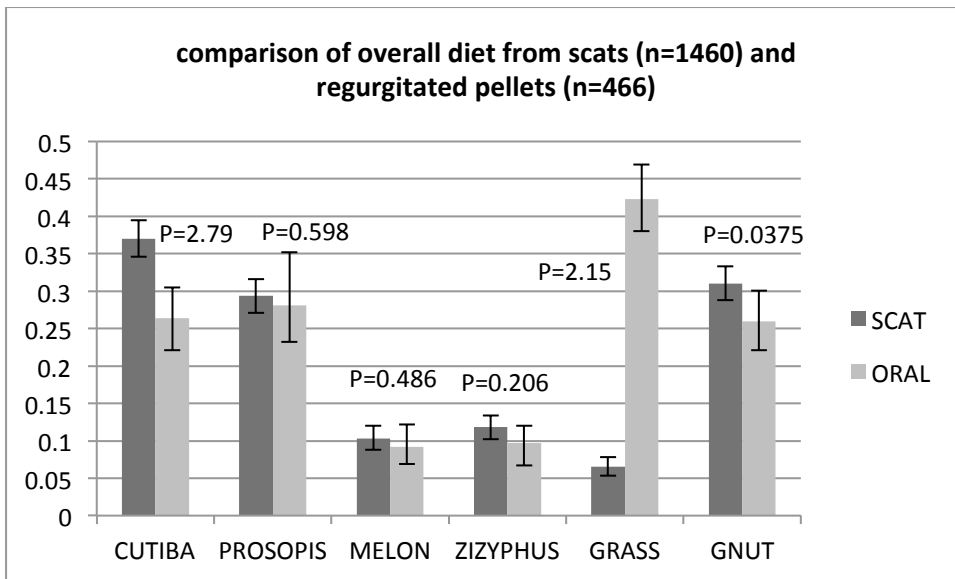


Figure 3-18: Comparison of overall diet from scats (n=1460) and regurgitated pellets (n=466), collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

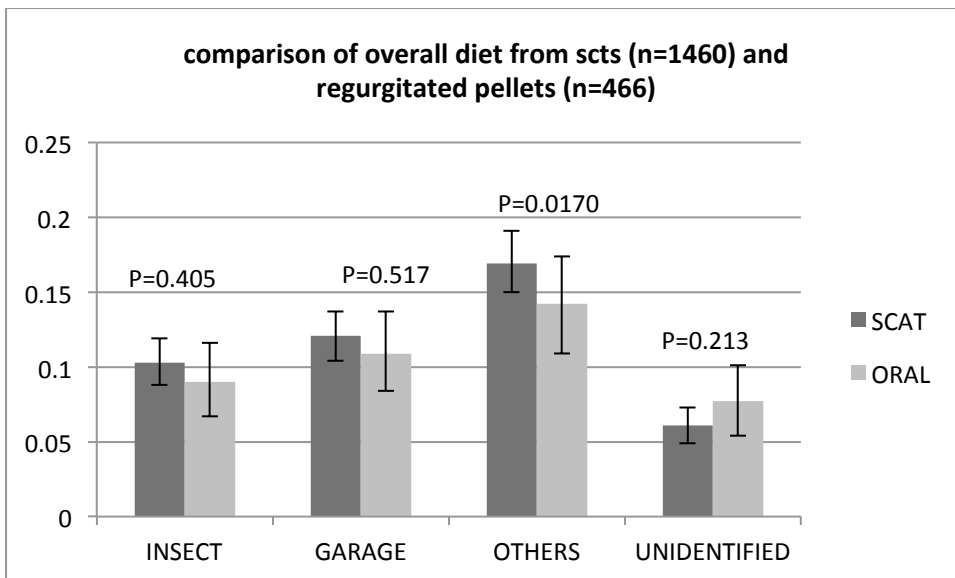


Figure 3-19: Comparison of overall diet from scats (n=1460) and regurgitated pellets (n=466), collected across the three seasons (winter, summer and monsoon) during the study in Abdasa, Kutch from 2007 – 2011. Error bars represent 95% bootstrap confidence intervals (n=195).

### 3.4 Discussion

The sample size estimation done for scats shows that the cumulative frequencies of prey items stabilize at around 160 samples (Figure 3-3) and at around 290 sample size for regurgitated pellets (n=466) (Figure 3-4). Since, in the study the number of scats (n=1460) and regurgitated pellets (n=466) exceeded the required sample sizes; the results can be considered to be an accurate representation of the diet of the hyaenas in Kutch.

The results of scat (n=1460) and regurgitated (n=466) samples show a very varied food habit. Along with plant derived food items, garbage/refuse; the diet is represented by 21 vertebrates (19 mammals) reflecting high faunal diversity of the immediate area (Table 3.2). Only the Indian wolf and Indian fox is not represented in either scat or regurgitated samples (but, they have been identified from bone accumulations around den). These two species represented in bone accumulations, complete the representation of a high trophic diversity; with all mammalian species in the study area identified from both sample types. Among livestock, donkeys are underrepresented (with occurrence only in one sample). While, cattle and medium livestock (goats and sheep) are heavily represented; indicating the species dependency on anthropogenic provided food source as major vertebrate contribution in diet, followed by dogs and jackals.

Wild pig and porcupine were found only in 'multiple prey (MP)' and 'multiple food item (MFI)' type samples, indicating that these prey item carcass elements were scavenged (which are mostly available as refuse from bush meat poaching-indicating the degree of poaching in the area).

Birds, Black nape hare and rodents represented in the diet are likely to be the result of predation as several scats with these species were Single Prey Type. The presence of *prosopis spp.* pods and grass in samples are likely to perform the function of roughage. The presence of hyaena in diet is interesting; cannibalism is mostly evident through infanticide. Similar observations were made by Wagner (2006) in Kenya. Mills (1990b) observed cannibalism in brown hyaenas and Henschel and Skinner (1991) recorded cannibalism twice in *Crocuta spp* on members of the same clan. The striped hyaena occurred in 20 samples (oral: n=7, scat: n=13) across years in different locations; points to mortality among hyaenas in the study area and scavenging habits

of hyaena possibly from road kills of other hyaenas or even possibly intra species predation/killing.

The large percentage of ‘multiple prey (MP)’ and ‘multiple food item (MFI)’ type samples are indicative of the food habits. Where most of the food is opportunistically obtained from carcass elemental scavenging (presence of maggot case in samples, is evident of scavenging), scavenging on human generated refuse (evident from the ‘garbage’ presence in samples) and incorporating plant derived food.

Comparison with other studies (Table 3.1) in different geographical regions reveals that the striped hyaena is opportunistic predator with a generalized diet. Wide omnivores diet can be attributed to striped hyaena’s moderately developed crushing molars and premolars (Werdelin 1996). A mixed diet that includes significant proportions (more than 25% of total volumetric intake on an annual basis) of vertebrates is associated with an intermediate basal rate (varying from 75 to 96% of the carnivore curve; mean 91%), whereas a mixed diet that includes few vertebrates (less than 25% of total intake), is associated with low basal rate (varying from 54 to 82%; mean 68%) (McNab 1989). Striped hyaena have intermediate basal rate of metabolism in relative to mass standard (McNab 1989). The results show that more than 50% of the diet contribution, as determined by frequency of occurrence, is by vertebrates in the study area (Figure 3-2).

The contributions in terms of biomass of various food items were not estimated, as the study species is primarily a scavenger, foraging on carcass elements. The amount of hair and other indigestible matter ingested per kilogram of food item varies with each meal, species and parts eaten, since it depends on the state of the carcass, making quantitative assessment of data unreliable (Kruuk 1972a, Bearder 1977, Mills and Mills 1978). The data can be analyzed only on presence-or-absence basis. Accordingly, food items such as rodents, insect and reptiles may be over represented.

The composition of a predator’s diet often exhibits seasonal changes, however in the study area there is little seasonal variation in dietary composition; as it is dominated by human-induced food available year around.

In this study, with a good sample size of regurgitated pellets (n=466. Summer: n=127, winter: n=217, monsoon: n=122); the possibility of using only regurgitated pellets for

In this study, with a good sample size of regurgitated pellets (n=466. Summer: n=127, winter: n=217, monsoon: n=122); the possibility of using only regurgitated pellets for hyaena diet analysis was explored. As one of the major advantage is that these oral samples are free of faecal matter, entirely composed of mammalian hair with other food items embedded in them. It is easier to handle (as no washing is required) and mammalian hair and other undigested material are easily available for analysis. But, the disadvantages associated with regurgitated pellets are; low persistence in field conditions and collecting adequate samples in a short duration might be difficult. The analysis shows that the diet diversity (Shannon index  $H'$ ) of scats and regurgitated pellets were similar-scats (3.08) and regurgitated pellets (3.14) with 32 food items (Table 3.3). But, the frequency of occurrence is biased towards mammals with long hair, coarse hair and quills (wild pig, jackal, sheep, goat, camel, porcupine and hedgehog). The grass presence is very high in regurgitated pellets as compared to scats, this act as roughage bundling undigested food material into a compact ball; these grass dominated regurgitated pellets samples have short mammalian hair embedded in them.

Only using regurgitated pellet samples would be an over estimate of certain species and under estimate of others. The best is to combine the results from regurgitated pellets, carcass accumulation at den sites and scats for robustness.

## **4 HOME RANGE AND MOVEMENT PATTERNS**

### **4.1 Introduction**

The dynamics of a population are directly linked to the spatial arrangement and movements of individuals caused by internal or external pressures on the population; hence, Understanding the organization of animals in space and time is a vital necessitate of ecology (Kernohan et al. 2001). Home range is an important concept associated with habitat selection, where habitat-selection scales are often assumed to be a function of home-range sizes (Rettie and Messier 2000, McLoughlin et al. 2002, Chamberlain et al. 2003, McLoughlin et al. 2004). Home range of an animal is defined as the limited area within which it can be found during a specified time period (Harris et al. 1990, Kernohan et al. 2001). According to this definition, a home range can be flexible, varying with season and overlapping with conspecifics (Harris et al. 1990), making the concept of home range particular useful for habitat selection studies. In contrast, a territory, a term commonly used interchangeably with home range, is defined as an area that is occupied by an individual or group to the exclusion of other animals of the same species (Mech 1970, Börger et al. 2008). Animals may or may not be territorial, but will still have a home range. A home range is defined and estimated without reference to defense or advertisement or reaction to intrusion by neighboring individuals; only the presence of the individual is required (Brown and Orians 1970). Territoriality arises when individuals exhibit spatially oriented aggressive behavior (aggressive defense of a space containing limiting resources) (Brown and Orians 1970, Davies and Houston 1983, Maher and Lott 1995). The term 'core area' refers to those areas within the home range where individuals are found with greater probability (Kaufmann 1962, White and Garrott 1990, Börger et al. 2008). Locations of concentrated use within home ranges are the core areas of any given species (Kaufmann 1962) encompassing den sites, quality foraging area and other important resources for survival (Ewer 1968).

Quantifying the space use of a species or group is of great importance because it provides valuable information on its survival, growth and reproduction and inter- and intraspecific interactions within the restrictions imposed by their physiology and environment (Harris et al. 1990, Kernohan et al. 2001, Aarts et al. 2008). Home range

sizes are a concern for carnivore conservation and management; like carnivores use large individual home ranges, indicating that they need large tracts of land for their survival (Linnell et al. 2001a, Linnell et al. 2001b). Reflecting that the size of protected area is correlated with risk of extinction in carnivores and the home-range size of a species is a good predictor of its extinction probability within protected areas (Woodroffe and Ginsberg 1998, Woodroffe 2000). Unfortunately, home-range sizes vary between carnivore species by several orders of magnitude. Much of this variation is evidently to differences in body size, feeding habits, and habitat (Harestad and Bunnell 1979, Kelt and Van Vuren 2001). Home-range size variation is also often reported to be due to prey population density (Carbone and Gittleman 2002). However, even within a species there can be differences in home-range size by two orders of magnitude (McCloughlin et al. 2000). This variation at both the inter- and intraspecific levels makes it very difficult to transfer results from one study area to another (Nilsen et al. 2005).

Among hyaenids, the home range sizes are highly variable between the four extant species (aardwolf, spotted hyaena, brown hyaena and striped hyaena) and also within species. Aardwolves occupy home ranges that vary from 1 to 6 km<sup>2</sup> (Kruuk and Sands 1972, Bothma and Nel 1980, Richardson 1985). Home range size in the spotted hyaena is extremely variable, from less than 40 km<sup>2</sup> in the Ngorongoro Crater (Kruuk 1972b), 62 km<sup>2</sup> in Masai Mara National Reserve, Kenya (Boydston et al. 2001), 240-366 km<sup>2</sup> in Ongava game reserve and Etosha National Park Namibia (Stratford and Stratford 2011), to 552-1,776 km<sup>2</sup> in the Kalahari (Mills 1990a). Brown hyaenas homeranges are also varied. In the Kalahari, home ranges varied in size from 170 to 461 km<sup>2</sup> (Owens and Owens 1979, Mills 1990a, Owens and Owens 1996), and along the Namib Desert coast group home ranges may cover 220 – 980 km<sup>2</sup> (Goss 1986, Wiesel 2007). In the Transvaal agricultural area, the range of a translocated adult male was only 49 km<sup>2</sup> (Skinner and Aarde 1987).

In spite of its wide distribution range; the striped hyaena is relatively data deficient, little is known about its habitat utilization and virtually no information is available on this aspect from India. Home range sizes in Tanzania (Serengeti national park) were estimated for one male at 72km<sup>2</sup> and a female at 44km<sup>2</sup> (Kruuk 1976). In the Negev desert region (Syrian-African Rift Valley near Hazeva) of Israel, a female hyaena used an area of 60.9 km<sup>2</sup> as home range (Van Aarde et al. 1988). In Kenya (ranch

land in Laikipia District), mean home range size for four males and six females was estimated to be 68.9 km<sup>2</sup> (SE=7.8) with no significant difference in home range size between sexes (Wagner 2006).

Most ecological and evolutionary process involves individual movements. In heterogeneous landscapes, animal movements reveal the strategies that individuals have adopted to meet their requirements (Bergman et al. 2000, Austin et al. 2004), such as choices concerning the type of resources to use, the location of resources, and how they distribute the use of resources among time periods (Schoener 1971, Stephens and Krebs 1986, Bell 1991). In theory, animals should balance the potential benefits (e.g. resource access) and costs (e.g. energetic costs, risk of predation) of movement (Bell 1991). Several factors may influence these individual movements including both internal state (e.g. reproductive status, body condition, seasonal requirements) and external factors (e.g. food distribution, climatic conditions, and disturbance) (Stephens and Krebs 1986). Survival and reproduction are therefore linked intimately to movement strategies, which should be driven by natural selection (Fahrig 2007). Activity patterns should optimize energy intake while minimizing costs associated with foraging (Charnov 1976). Foraging time should therefore be optimized to exploit resources efficiently (Schoener 1971, Stephens and Krebs 1986).

Most animals show a rhythmic behaviour called the “circadian rhythm”, which depends mostly on physiological states (Sollberger 1965), but also can be affected by environmental variables (Aschoff 1966). In addition to this expected great variability in daily movement patterns, animal movement rates may vary according to individual requirements (which vary for example during the year and with reproductive status) and the environment in which they move (e.g. habitat types, terrain ruggedness, risky habitat). Because of the hyaena’s elusive behavior and wide ranging habits, its movement, and factors that govern these movement patterns are poorly understood. As hyaenas derive their energy requirements from anthropogenic induced food sources, it is important to know how hyaenas balance the potential benefits and costs of movement in a human dominated landscape. In this chapter, I try to understand the basic movement strategies of hyaenas and to determine their movement and activity patterns.

## **4.2 Methods:**

### **4.2.1 Trapping and radio tracking:**

Telemetry is without any doubt the most common method to quantify either habitat selection or home range patterns, especially in mammalian carnivore species. Telemetry is a tool or technique used to research wild animal species in the field in order to gain a thorough understanding of that population and its dynamics as well as to identify any potential threats to its survival(White and Garrott 1990).

Individual hyaenas from target clans were trapped using soft pad leg hold traps. The trapped animals were anesthetized using a dose of combination of Ketamine (2.5 ml (100mg/ml) and xylazine (0.5 ml (100mg/ml) and delivered intra muscular (IM). Immobilized animals were removed from the trap and treated for any injuries or skin ailments. At each capture we collected hair samples, blood samples and copro-parasite (for further study on disease profiling and genetics). Along with morphometric and tooth measurements for each captured individual, reproductive and lactation conditions were recorded. For each captured hyena, sides of the body profile (for stripe pattern), dentations and genitals were photographically recorded. Based on above data, each animal was assigned to age class based on estimates from body measurements, weight, and tooth wear (cub: < 6 months, juvenile: 6months to 1year, young adult: 1 to 3 yrs, adult: 3+ yrs) (adapted from Wagner (2006)).

All hyaenas captured in the study area were fitted with VHF radio collars (Telonics, Inc., Mesa, AZ, U.S.A.). The collared animals were only released after complete recovery from tranquilization; in any case all released collared animals were monitored for safeguarding them from any possible dangers (domestic dogs, humans). Since striped hyaenas are nocturnal in habits, with limited movements during day. The animals were observed and followed on foot at dawn (0600 to 0900 hrs) and dusk (1730 to 1945 hrs). Their nocturnal activity (2000 to 0600 hrs) and locations were inferred from radio tracking. Most of study area is navigable using a four wheel drive vehicle, hence most of the GPS coordinates were collected by homing-in technique and where ever the terrain were not negotiable GPS coordinates were obtained by

triangulation technique. The possible path taken by the animal was retraced the next day for confirmation of coordinates, additional information like presence of food resources, resting sites, and preferred pathways and also to assess the possible threats (snares around fields, roads crossed) it might encounter in the agriculture mosaic landscape. For continuous tracking (24 hr), the maximum times allotted between locations were 15 minutes. In additions to recording the location of the hyena being tracked, we scanned for the frequencies of all other hyenas to determine if any were in the area. We determined whether a hyena was active or inactive based on activity sensors in the radio collars and changes in the direction and clarity of signals. For every location, we recorded the time, whether the hyena was active or inactive, and the presence or proximity of other hyenas or other animals. We located all collared hyaenas at least once in a week, some animals were located daily. At least one continuous monitoring (24 hr tracking) was carried out on each collared hyaena. We used ArcGIS 9.8 and ArcView 3.2a (ESRI, Redlands, California, USA) to plot and analyze spatial data.

#### **4.2.2 Analysis of spatial data:**

Two non-parametric methods, the minimum convex polygon (MCP) (Mohr 1947) and the fixed kernel (Worton 1989) were used to estimate home range size. The 100% MCP method is most widely used historically (Harris et al. 1990) and is presented for comparison with past studies. To remove the effect of exploratory movements and outlying fixes we computed the 95% MCP and 95% fixed kernel (White and Garrott 1990, Kernohan et al. 2001).

The MCP (a polygon containing all location estimates, where all vertices are convex) has the advantage of being simple to construct and, because its use has a long history, it often enables comparisons to be made with previous work (Harris et al. 1990). In recent years, kernel estimators have become increasingly popular (Worton 1989, Seaman and Powell 1996). Kernel analysis produces home range estimates in the form of probability distributions (known as 'utilization distributions') calculated from the fixes within a home range. The kernel method is useful for identifying areas on the landscape that are of great importance to the individual. Kernel density estimators provide a utilization distribution of a specified probability that the animal will be located within a certain area (Powell 2000). The density of the kernel at any location

in the home range is a function of how much time the animal spent in that location (Seaman and Powell 1996).

The kernel estimator, computed most often as the fixed kernel (Seaman and Powell 1996), includes inherent statistical restrictions, such as the need for independent locations and the choice of smoothing parameters. For organisms that return to a specific location repeatedly throughout the year (e.g., burrows or dens), autocorrelation or non-independent locations are unavoidable. Focusing on the avoidance of autocorrelated data may detract from the main goal of home range estimation, namely understanding the space use of a species. Hence in this study, in order to reduce the autocorrelations; only locations (fixes) recorded every two hours were considered for home range computation for each collared hyaena. In addition to autocorrelation, estimation using the kernel method is complicated by a number of parameters set by the user, such as the smoothing factor  $h$ , which can have a drastic impact on estimates of home range area (Worton 1987, Worton 1995, Seaman and Powell 1996). Choosing the appropriate smoothing parameter (or bandwidth) is the single most important issue in a kernel analysis (Wand and Jones 1995). No single best method of choosing a bandwidth a priori exists (Worton 1989). Common approaches to selecting a fixed value of  $h$  are to use the reference bandwidth  $h_{ref}$  (derived from variance in the coordinates of fixes), or least squares cross validated (LSCV) multiplier of  $h_{ref}$  (Worton 1995). However, further investigation has provided only limited support for either of these methods and has produced some contradictory findings. One study (Seaman and Powell 1996) found that LSCV smoothing provided the most accurate estimates, except with small sample sizes ( $N < 50$  fixes) where it performed poorly. By contrast, Blundell et al. (2001) found that  $h_{ref}$  performed better than LSCV at estimating the 95% home ranges of river otters *Lontra Canadensis*. Least squares cross-validation, however, tends to be especially sensitive to sample size. Animal locations numbering in the thousands, such as those derived from GPS devices, often result in under-smoothing and a utilization distribution consisting of small perimeters around individual data points (Kie et al. 2002). A compromise is to reduce the reference bandwidth to a fixed proportion, thereby reducing over-smoothing. If the objective is to estimate a contiguous home-range boundary, it is possible to reduce the reference bandwidth just prior to the point where that estimate starts to fragment into multiple polygons (Berger and Gese 2007,

Jacques et al. 2009). In this study, for choosing the smoothing parameter; several curves were plotted and the estimate found in agreement with the idea density was chosen (subjectivity by eye). Thus, the reference bandwidth was reduced to a fixed proportion of 0.80. To reduce autocorrelation, the total time required for a hyaena to cover its home range was determined (intention was to use the measured time in subsampling i.e. obtain locations every 'total time measured').

Minimum Convex Polygon (MCP) home ranges obtained by ten cumulative sequential samples were plotted versus number of locations to determine the adequacy of sample size of radio locations for home range estimation (Harris et al. 1990, White and Garrott 1990, Phillips and Catling 1991, Kernohan et al. 2001).

To estimate daily movement patterns, we used speed between successive locations as a measure of movement rate. For each collared animal, movements were characterized independently by discrete segments connecting successive relocations. Speed between relocations was estimated by dividing segment lengths with time.

### **4.3 Results**

A total of 8 hyaenas were trapped in 69 trap-nights (the number of individual traps set multiplied by the number of nights each trap was active) over 3-year study period (2007-2010) from 4 different clans (groups). The clans were distributed spatially and temporally in the landscape, assigned based on their center of activity (active den sites) at a given time (Figure.1). Proximity to the field camp and terrain determined the target clan; out of the 8 hyaenas trapped 7 were fitted with radio collars, one individual was found too young for the purpose (Table 4-1).

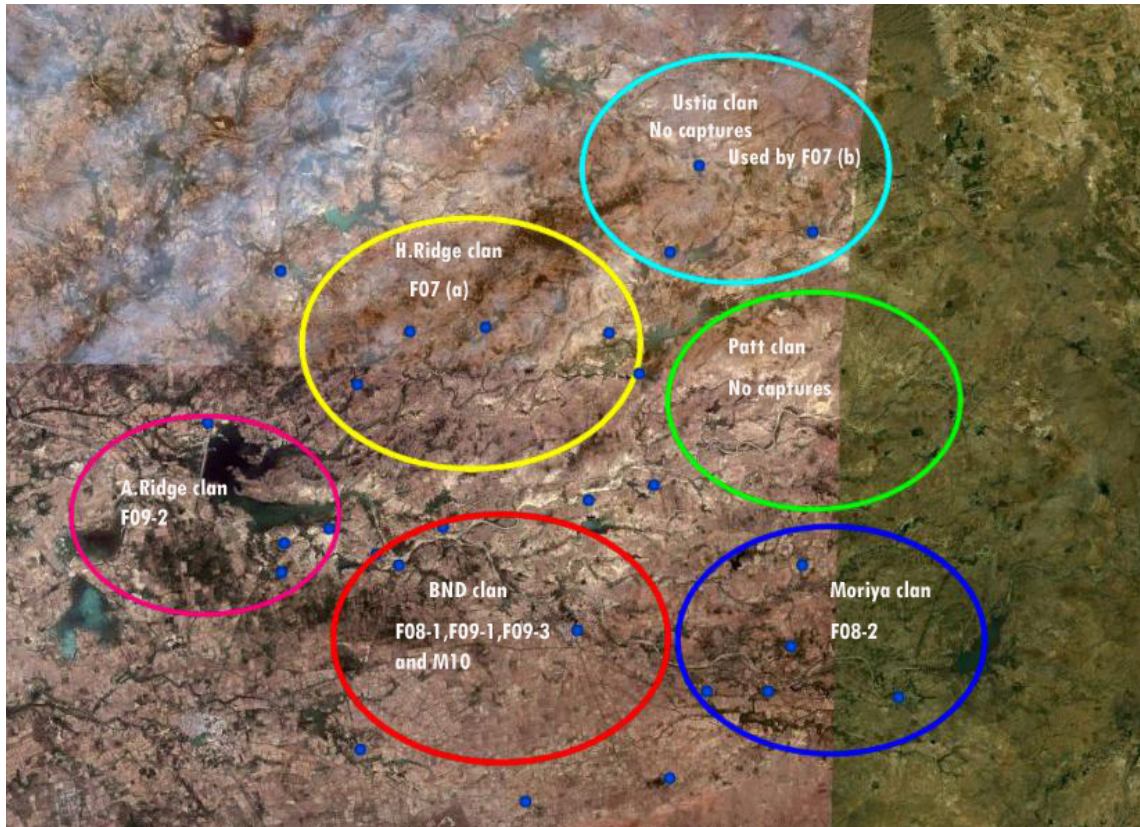


Figure 4-1: A simplified representation of clan orientations and collared individuals from each clan. The point locations represent the villages around target clans. The captured and uncollared young individual was associated with ‘H.Ridge’ clan.

Hyaena ID	Clan association	Gender	Status	Age (Years)	Tracking period (months)
F07	H.Ridge and Ustia	F	Breeding adult	4	48
F08-1	BND	F	Young adult	2	17
F08-2	Moriya	F	Young adult	1.5	11
F09-1	BND	F	Young adult	1.5	10
F09-2	A.Ridge	F	Juvenile	1	3
F09-3	BND	F	Juvenile	1	20
M10	BND and H.Ridge	M	Young adult	2	7

Table 4-1: Details of collared hyaenas monitored in the study during 2007 – 2011 in Abdasa, Kutch.

The home range and habitat preference of hyaenas in Kutch were studied between 2007 and 2011. Some hyaenas were not located as frequently as dictated by the sampling regime due to the terrain and long distance movements of the animals. During the study period, few animals were lost because of emigration and few were

short lived, as a consequence there is no uniformity in locations collected (Table 4-2). The total number of ‘fixes’ of each individual was sorted into ‘fixes’ at every 2-hour interval, to reduce autocorrelation (Table 4-2). During the course of the study one individual hyaena (F07) was long lived and had used two different area in different calendar years respectively; hence to reduce error, these two areas were computed as two different area of use and assigned as F07<sup>a</sup> (original area of use) and F07<sup>b</sup> (displaced area of use) (Figure 4-1 and Table 4-2).

<b>Hyaena ID</b>	<b>Total number of 'fixes'</b>	<b>Number of 'fixes' at 2hr interval</b>
<b>F09-1</b>	1089	256
<b>F08-1</b>	2505	478
<b>F09-2</b>	250	83
<b>F08-2</b>	627	135
<b>F07<sup>a</sup></b>	598	261
<b>F07<sup>b</sup></b>	155	69
<b>M10</b>	546	122
<b>F09-3</b>	2848	685

Table 4-2: Location details of collared individuals monitored in the study during 2007 – 2011 in Abdasa, Kutch.

Wagner 2008 in his study on striped hyaenas in Kenya used the terms ‘home ranges’ and ‘space used’ as separate entities; where ‘home ranges’ were computed for individuals with 80 locations and ‘space use’ broad ranging pattern of any individual (both collared and uncollared). In this study, the terms have been borrowed and redefined to suit the aim of the study. In this study only data from collared individuals were considered. Where ‘home ranges’ is defined as ranging pattern of individual hyaenas computed using only ‘fixes with 2hr interval’ (Table 4-2), in order to use uniform number of locations for both MCP and FD kernel estimators. ‘Space use’ is defined as the absolute size of the area covered by individual hyaenas; where ‘Total numbers of fixes’ (Table 4-2) were used and 100% MCP were computed. I also computed 95% MCP and 95% kernel with all locations. Composite space use and home ranges were calculated for all collared animals. Hyaenas in Kutch had an average 100% MCP space use of 80.7 ( $\pm$  13.8 SE) km<sup>2</sup> (Table 4-3 and Figure 4-2).

Hyaena ID	Space use 100% MCP (km <sup>2</sup> )	95% Fixed kernel (km <sup>2</sup> )	Number of location (space use)	Number of location (Fixed Kernel)	Monitoring period (months)
<b>F07<sup>a</sup></b>	90.1	88.2	598	261	24
<b>F07<sup>b</sup></b>	91.7	118.5	155	69	24
<b>F08-1</b>	120.6	47.8	2505	478	17
<b>F08-2</b>	61.6	48.9	627	135	11
<b>F09-1</b>	72.6	26.4	1089	256	10
<b>F09-2</b>	8.9	7.1	250	83	3
<b>F09-3</b>	64.4	26.2	2848	685	20
<b>M10</b>	136.2	134.4	546	122	7
<b>Average (SE)</b>	80.7 (13.8)	62.2 (16.4)	1077 (364)	261 (76)	14.5 (2.8)

Table 4-3: Space use estimates of collared individuals in the study monitored during 2007- 2011 in Abdasa, Kutch and comparison with 95% Fixed Kernel estimates.

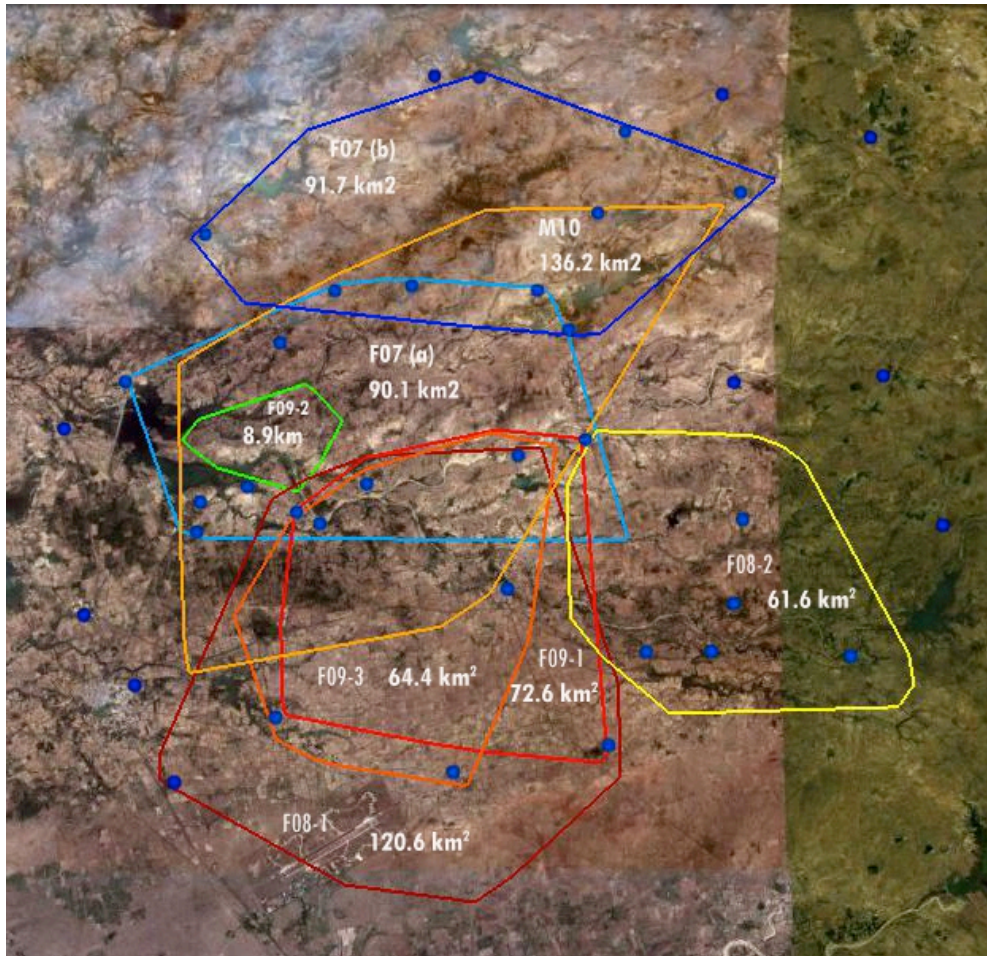


Figure 4-2: Space use polygons for all collared hyaenas and point location for villages in the study area. Calculated by 100% MCP, these polygons are not the actual home ranges, but extend of space used during the course of the study. It appears that many individuals with spatial overlap, because this map does not account for time. Spatial and temporal overlap do not correspond here (no collared individuals from different clans had area of overlap in both time and space); with exception of F08-1, F09-3 and F09-1, who were related individuals and belong to the same clan (BND) had significant area over lap spatially and temporally

The Plots of 95%, 90% and 50% fixed kernel range verses sample sizes stabilized at around 70 locations showing adequacy of sample size (Figure.3, Table.2). The 95%, 90% and 50% MCP range sizes versus sample sizes stabilized for all hyaenas at around showing the inadequacy of sample sizes for home range estimates for few animals (F09-2 and F07<sup>b</sup>) (Figure 4-4, Table 4-2). The home ranges of F09-2 and F07<sup>b</sup> were excluded from computing the average values of home range sizes of hyaenas.

When the average home ranges were computed for all hyaenas (including F09-2 and F07<sup>b</sup>), it was had an average 100% MCP home range of  $73.5(\pm 12.9 \text{ SE}) \text{ km}^2$ , 95%

MCP home range of 45.9 ( $\pm 10.2$ ) km<sup>2</sup> and 95% kernel home range of 62.2( $\pm 16.4$ ) km<sup>2</sup> (Table 4-4).

The average home range size of hyaena (excluding F09-2 and F07<sup>b</sup>) was 100% MCP home range of 82.4( $\pm 12.0$  SE) km<sup>2</sup>, 95% MCP home range of 48.5 ( $\pm 10.5$ ) km<sup>2</sup> and 95% kernel home range of 61.9 ( $\pm 14.8$ ) km<sup>2</sup>.

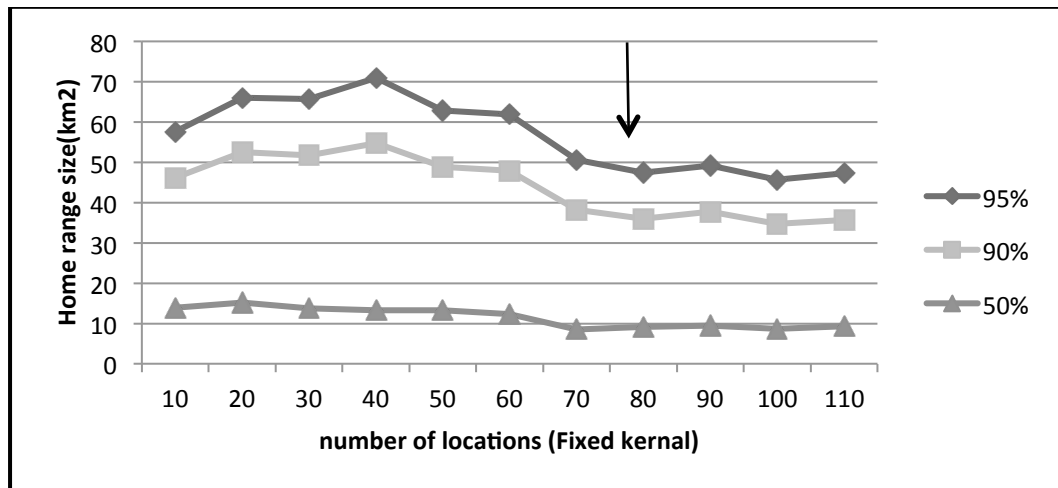


Figure 4-3: Mean minimum number of locations for Fixed kernel estimator, estimated for the collared hyaenas in the study, monitored during 2007 – 2011 in Abdasa, Kutch.

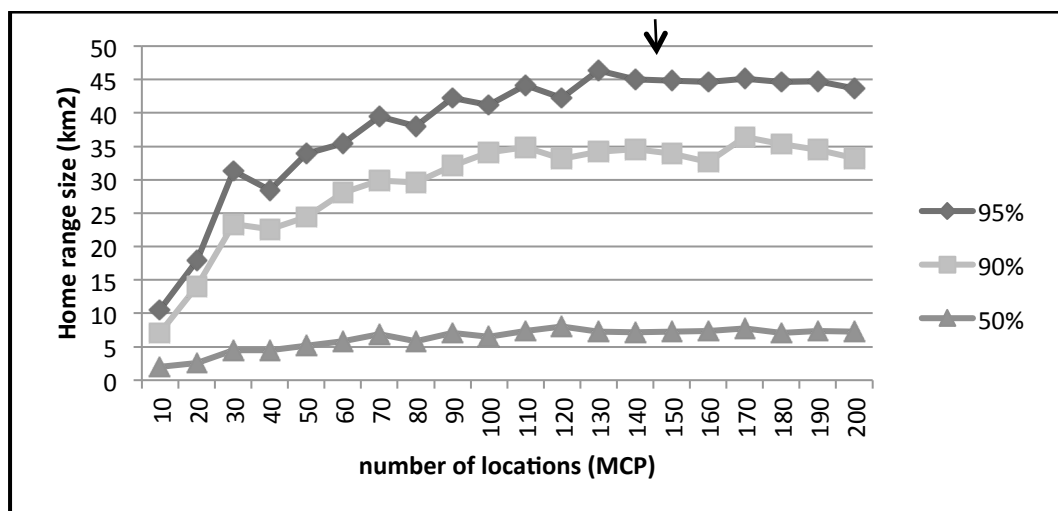


Figure 4-4: Mean minimum number of locations for MCP estimate, quantified for the collared hyaenas in the study, monitored during 2007 – 2011 in Abdasa, Kutch.

Hyaena ID	100% MCP (km <sup>2</sup> )	95% MCP (km <sup>2</sup> )	95% Fixed kernel (km <sup>2</sup> )	Number of location	Monitoring period (months)
<b>F07a</b>	88	68.5	88.2	261	24
<b>F07b</b>	85.4	70.1	118.5	69	24
<b>F08-1</b>	107.7	50.4	47.8	478	17
<b>F08-2</b>	54.2	32.9	48.9	135	11
<b>F09-1</b>	61.5	25.1	26.4	256	10
<b>F09-2</b>	7.6	5.2	7.1	83	3
<b>F09-3</b>	58.2	23.9	26.2	685	20
<b>M10</b>	125.3	90.7	134.4	122	7
<b>Average (SE)</b>	73.5 (12.9)	45.9 (10.2)	62.2 (16.4)	261 (76)	14.5 (2.8)

Table 4-4: Home range estimates of hyaenas collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch.

Isopleths of 95% Fixed kernels were plotted against mean home range sizes to determine the core area (center of activity) (Figure 4-5).

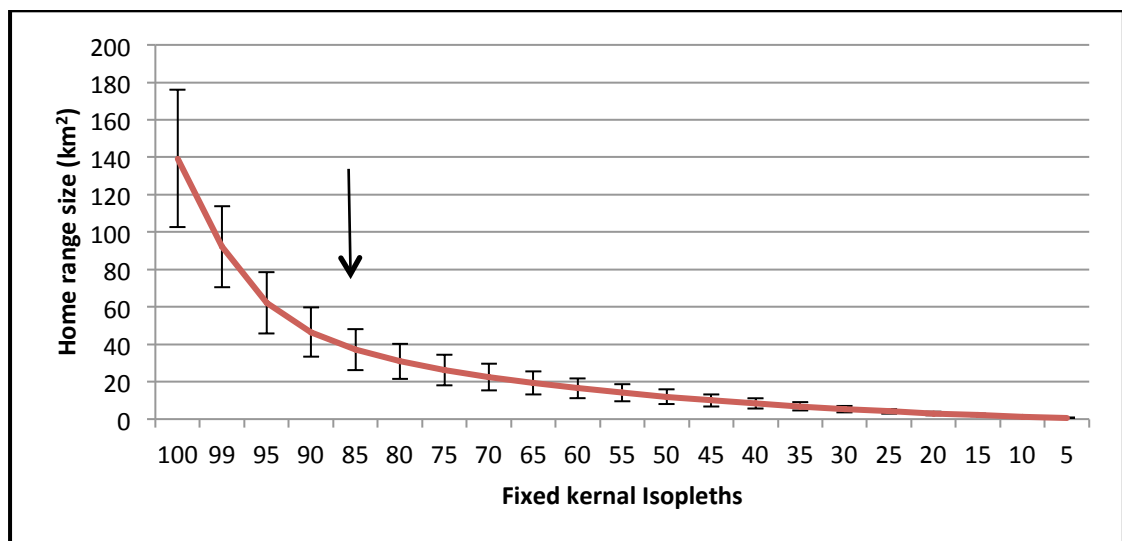


Figure 4-5: Mean core area estimation using Fixed kernel isopleths, estimated for the collared hyaenas monitored in the study during 2007 – 2011 in Abdasa, Kutch. The error bars are due to variation between different hyaenas.

85 % fixed-kernel method was used to estimate size and shape of the core areas or centers of activity within home ranges of hyaenas in Kutch (Figure 4-6, Figure 4-7, Figure 4-8, Figure 4-9, Figure 4-10, Figure 4-11, Figure 4-12, &Figure 4-13).

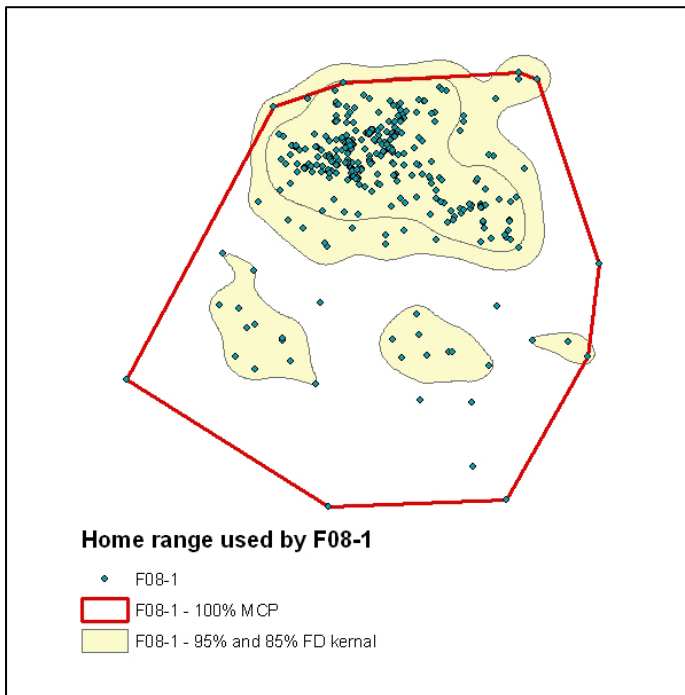


Figure 4-6: Home range and core area used by F08 -1 (Sub-Adult, Female) collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch. 100% MCP home range (107.7 km<sup>2</sup>) and 95% FD kernel home range (50.4 km<sup>2</sup>), core area used-85% FD kernel (20.6km<sup>2</sup>).

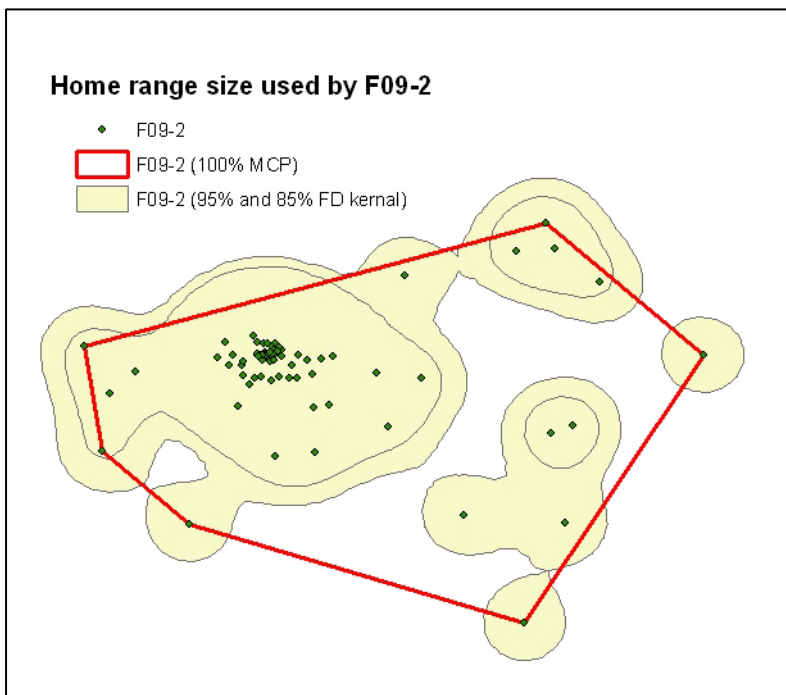


Figure 4-7: Home range and core area used by F09-2 (Female, cub), collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch. 100% MCP home range

(7.6 km<sup>2</sup>) and 95% FD kernalthome range (7.1 km<sup>2</sup>), core area used-85% FD kernalthome range (3.3 km<sup>2</sup>).

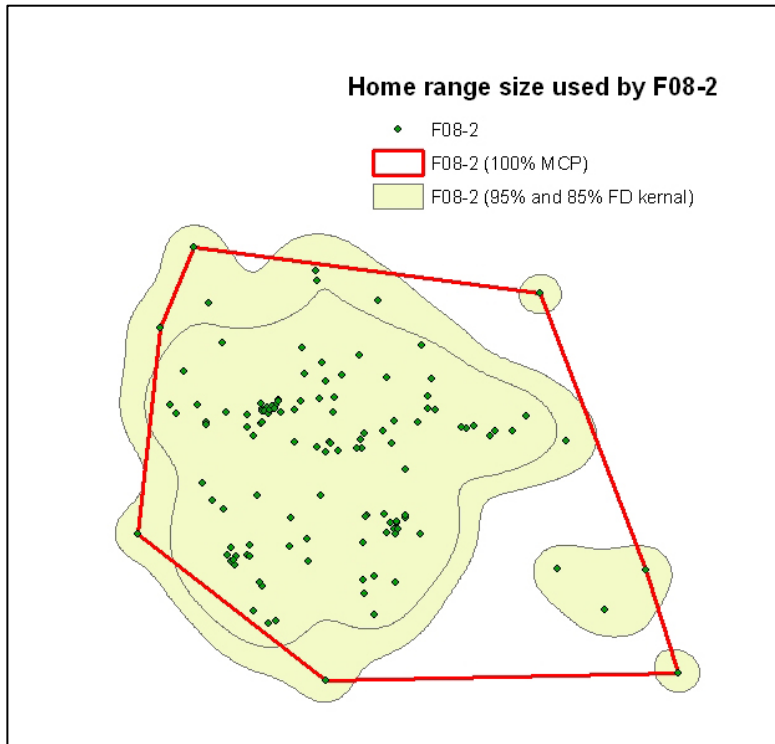


Figure 4-8: Home range and core area used by F08-2(Female, Sub-Adult), collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch. 100% MCP home range (7.6 km<sup>2</sup>) and 95% FD kernalthome range (7.1 km<sup>2</sup>), core area used-85% FD kernalthome range (3.3 km<sup>2</sup>).

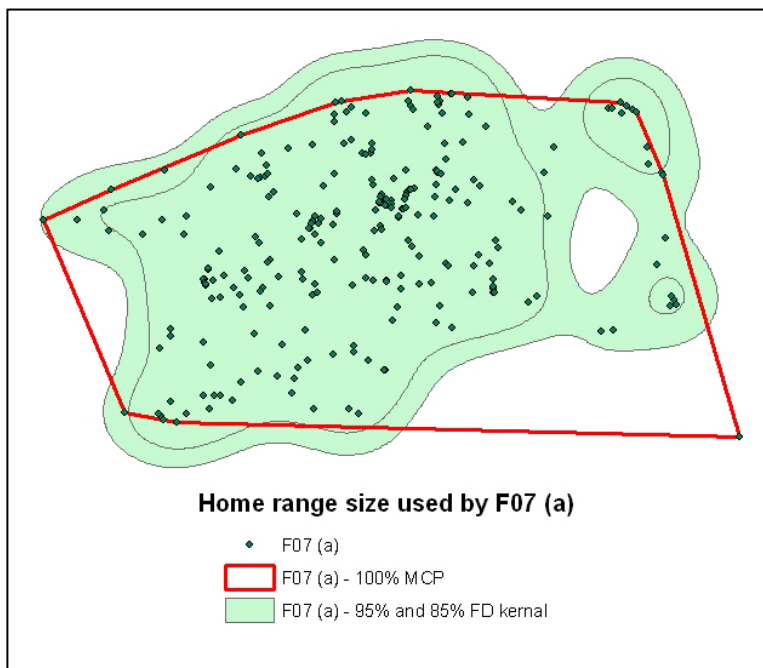


Figure 4-9: Home range and core area used by F07<sup>a</sup> (Female, Breeding Adult), collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch. 100% MCP

home range (88.0 km<sup>2</sup>) and 95% FD kernalthome range (88.2 km<sup>2</sup>), core area used-85% FD kernalthome range (59.4 km<sup>2</sup>).

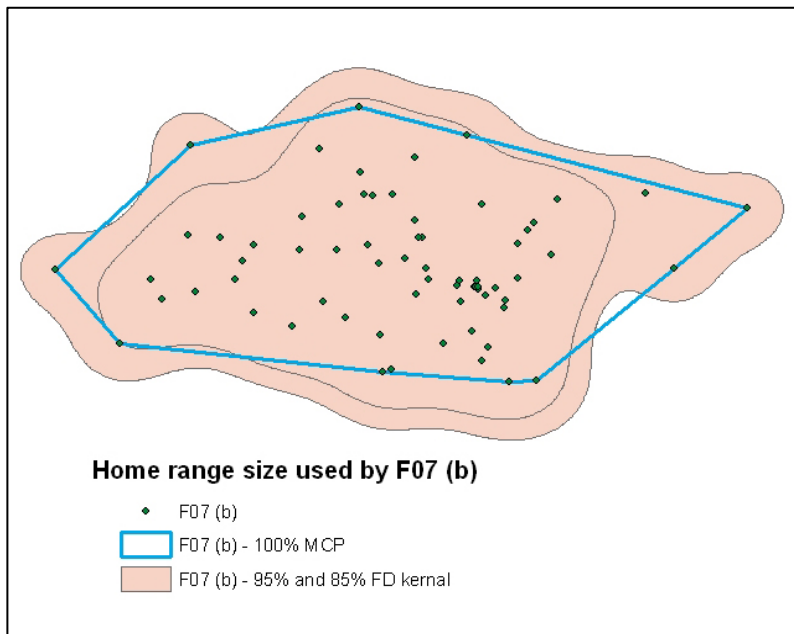


Figure 4-10: Home range and core area used by F07<sup>b</sup>(Female, Breeding Adult), collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch. 100% MCP home range (85.4 km<sup>2</sup>) and 95% FD kernalthome range (118.5 km<sup>2</sup>), core area used-85% FD kernalthome range (76.2 km<sup>2</sup>).

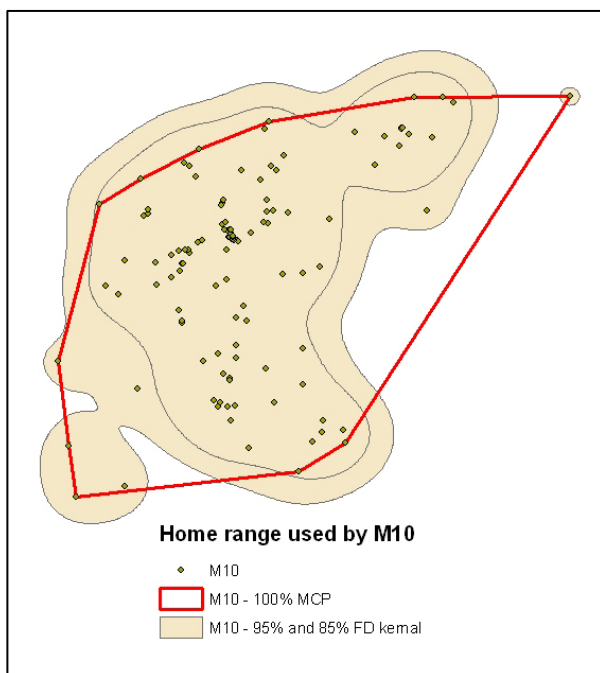


Figure 4-11: Home range and core area used by M10(Male, Sub-Adult), collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch. 100% MCP home range

(125.3 km<sup>2</sup>) and 95% FD kernalthome range (134.4 km<sup>2</sup>), core area used-85% FD kernal (83.0 km<sup>2</sup>).

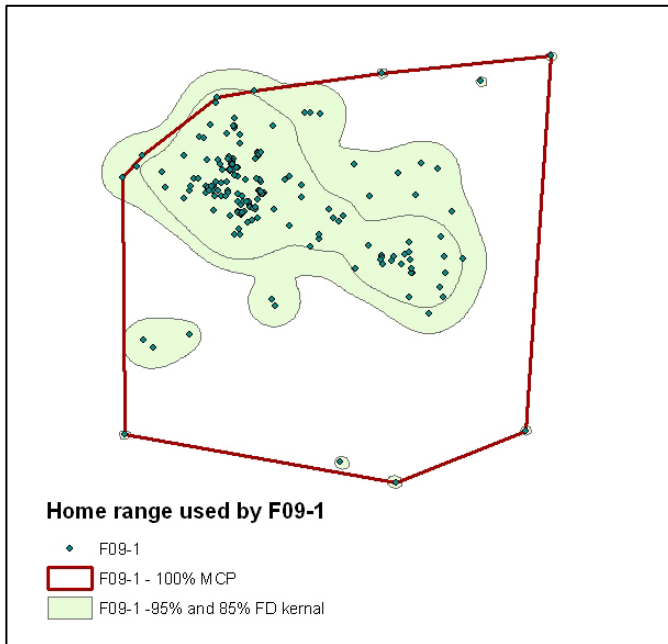


Figure 4-12: Home range and core area used by F09-1 (Female, Sub-Adult), collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch. 100% MCP home range (61.5 km<sup>2</sup>) and 95% FD kernalthome range (26.4 km<sup>2</sup>), core area used-85% FD kernal (12.5 km<sup>2</sup>).

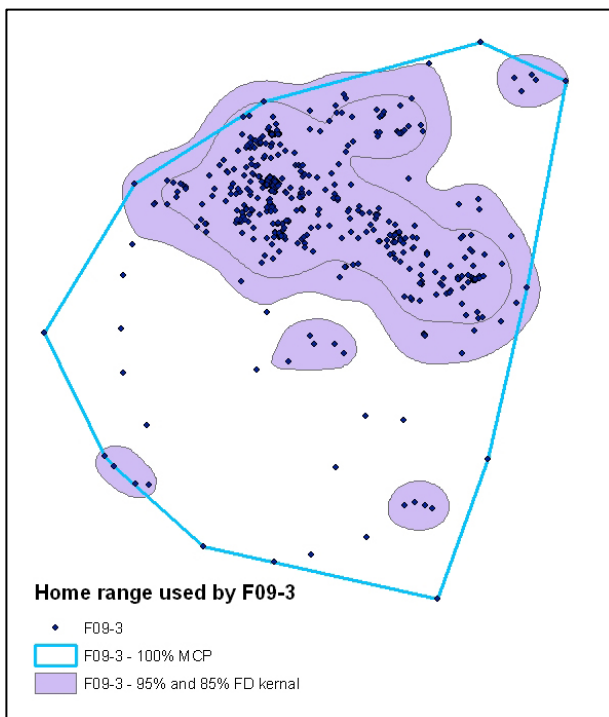


Figure 4-13: Home range and core area used by F09-3 (Female, Cub), collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch. 100% MCP home range

(58.2 km<sup>2</sup>) and 95% FD kernel home range (26.2 km<sup>2</sup>), core area used-85% FD kernel (12.8 km<sup>2</sup>).

Only continuous tracking (24 hr tracking) (Table.5) data was used to compute the movement rate of hyaenas. The average distance covered by hyaena in one night is 14.0 ( $\pm$  0.6) km with average speed of 1.2 ( $\pm$  0.05) km/hr (Table.5). F07<sup>b</sup> covered the largest distance (21.3 ( $\pm$  6.4) km with a speed of 2.2 ( $\pm$  0.5) km/hr, while F09-2 covered the smallest distance (8.9 ( $\pm$  0.9) with a speed of 0.8 ( $\pm$  0.1) km/hr (Table 4-5). The distance travelled every two hours was computed to determine the peak travel time (time of the day where the animal moves covers larger distances). It was found that the hyaenas covered majority of their travel distance between 11pm and 5 am (Figure 4-14). Among individuals, F07<sup>b</sup> covered large distances (6.5 km) around 3-5 am with greater speed and; M10 covered distances above 3 km between 11 and 5 am, indicating constant speed (faster than the other hyaenas) in movement (Figure 4-15).

Hyaena ID	Number of continuous monitoring (days)	Total activity (hrs)	Total time at rest (hr)	Average distance moved - km (SE)	Average speed- km/hr (SE)
F09-3	32	398.85	369.15	13.2 (1.0)	1.1 (0.09)
F08-1	21	272.55	231.45	15.3 (1.7)	1.1 (0.1)
F08-2	12	138.73	149.27	11.0 (1.0)	0.9 (0.08)
F07 <sup>a</sup>	10	112.50	127.50	13.3 (1.5)	1.1 (0.1)
F07 <sup>b</sup>	3	28.17	43.84	21.3 (6.4)	2.2 (0.5)
M10	11	117.17	146.84	17.0 (2.5)	1.6 (0.2)
F09-1	9	115.45	100.45	15.5 (1.6)	1.2 (0.1)
F09-2	6	66.58	77.42	8.9 (0.9)	0.8 (0.1)

<b>Average (pooled) (SE)</b>	13.1 (3.3)	156.25 (42.72)	155.74(36.32)	14.0 (0.6)	1.2 (0.05)
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Table 4-5: Daily distance covered in a night and travel speed of hyaena, as quantified from hyaenas collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch.

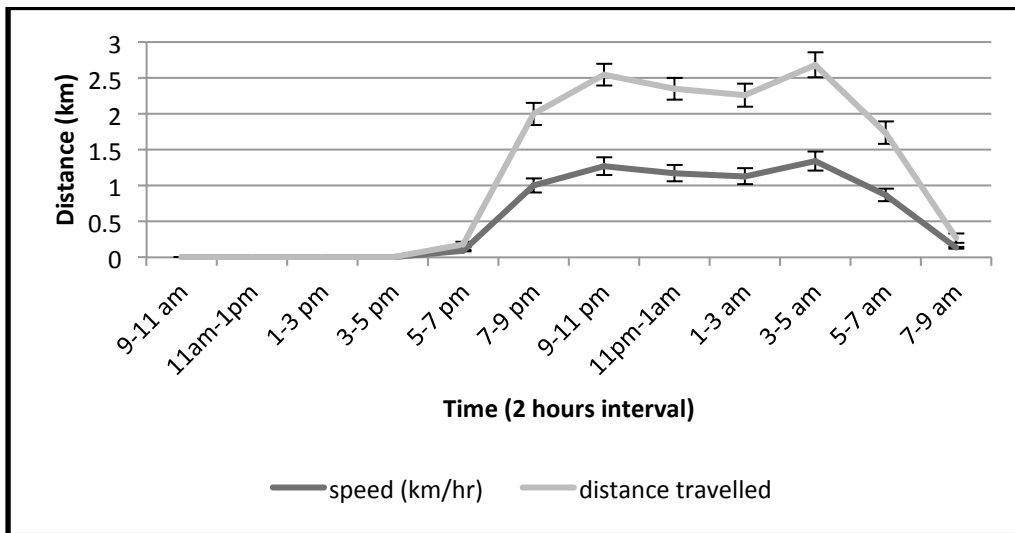


Figure 4-14: Net distance travelled and net travel speed at 2 hr interval in Kutch by hyaenas, collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch.

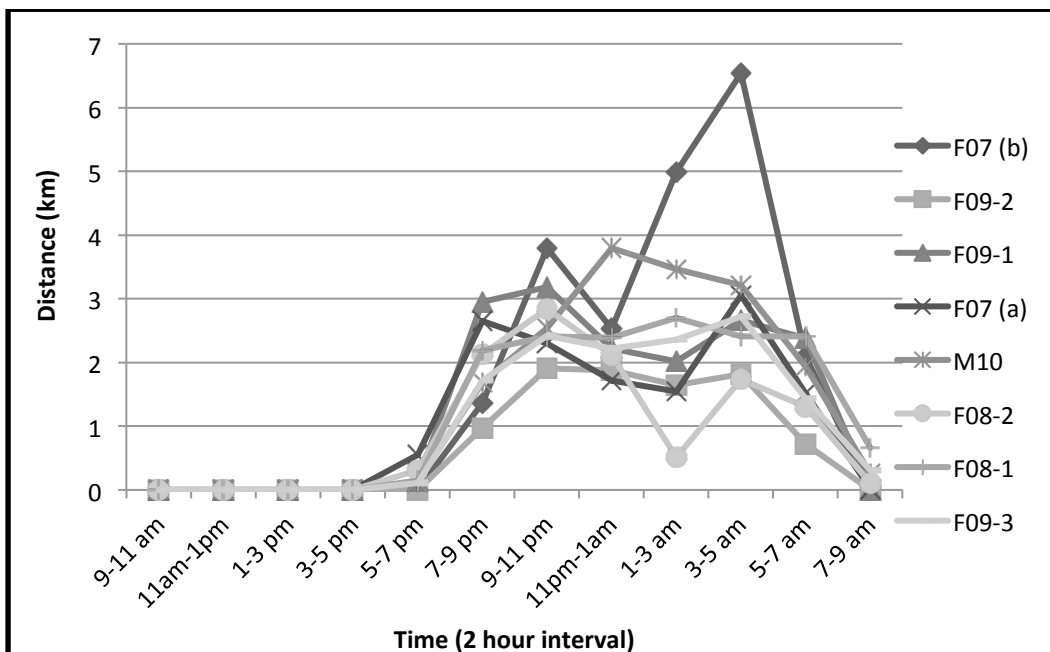


Figure 4-15: Average distance travelled every 2 hr interval by individual hyaenas collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch. F07<sup>b</sup>

(breeding female covered maximum distance (6.5 km) in a 2hr interval time. M10 (male hyaena) covered around (3.5 km) and the rest covered distances less than 3 km in 2 hr interval

As expected, striped hyaenas showed a circadian movement pattern (and thus activity pattern) with a peak from dusk to dawn and the main resting period during the day (Figure 4-16 & Figure 4-17). The study animals spent 48 % of their day resting (8 am to 6 pm), 30 % in movement, 10 % around villages, 2% foraging (where only active foraging observations included) and 10 % around center of activity (den sites) (Figure 4-16&Figure 4-17).

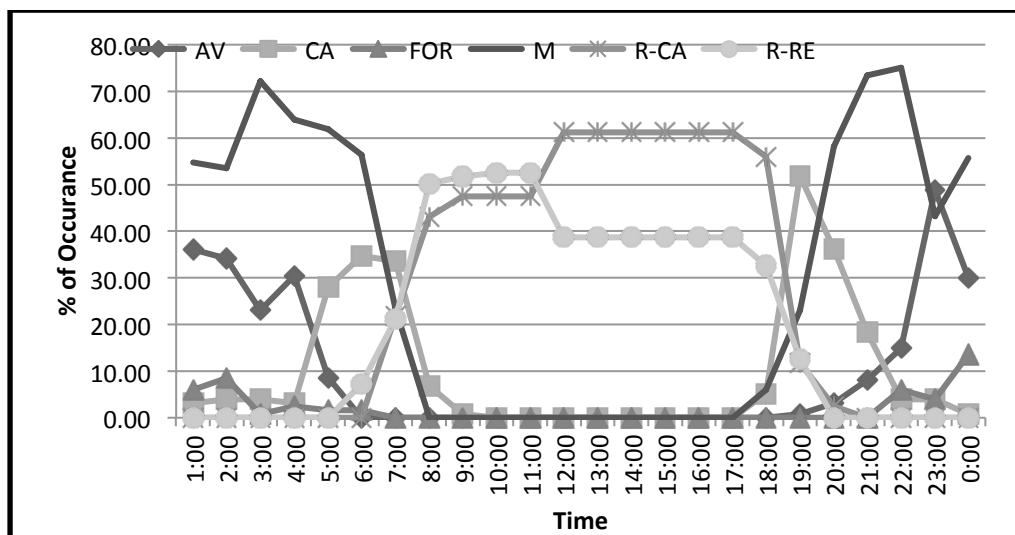


Figure 4-16: Activity pattern of hyaenas collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch (n=104 continuous (24 hr) tracking. AV: around villages, CA: center of activity (dens with cubs), FOR: foraging-where active foraging have been observed: movement, R-CA: resting in center of activity (dens), R-RE: resting in refuge sites (most of them close to center of activity).

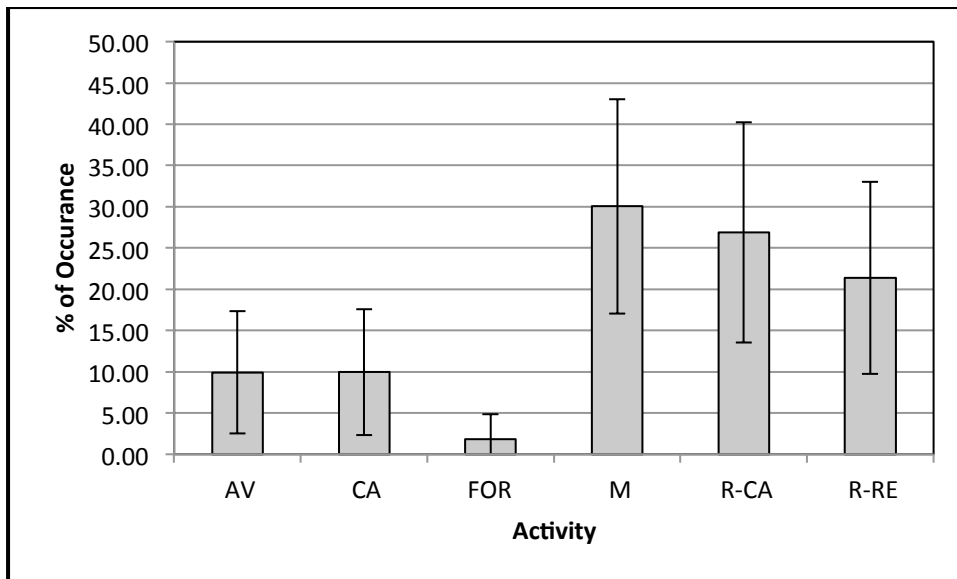


Figure 4-17: Activity pattern of hyaenas collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch (n=104 continuous (24 hr) tracking). AV: around villages, CA: center of activity (dens with cubs), FOR: foraging-where active foraging have been observed: movement, R-CA: resting in center of activity (dens), R-RE: resting in refuge sites (most of them close to center of activity).

Hyaena ID	Location count	Schoener Index	Swihart-Slade Index
<b>F08-1</b>	2505	0.08166	2.08173
<b>F09-2</b>	250	0.12651	2.24058
<b>F08-2</b>	627	0.01101	2.18108
<b>F07 a</b>	598	0.58993	1.65898
<b>F07 b</b>	155	0.58861	2.04969
<b>M10</b>	546	0.08849	2.91427
<b>F09-1</b>	1089	0.10914	2.50334
<b>F09-3</b>	2848	0.13943	2.10178

Table 4-6: Schoener index and Swihart-Slade index values for ‘Total number of fixes’, generated by ArcGIS 9.8 (ESRI, Redlands, California, USA) for hyaenas collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch.

Hyaena ID	Location count	Schoener Index	Swihart-Slade Index
<b>F08-1</b>	478	0.79211	1.27532
<b>F09-2</b>	83	1.1502	1.21178
<b>F08-2</b>	135	0.7508	1.49254
<b>F07 a</b>	261	1.36242	0.8353
<b>F07 b</b>	69	1.16623	1.30556
<b>M10</b>	122	0.56608	2.17765
<b>F09-1</b>	256	0.9099	1.49722
<b>F09-3</b>	685	0.92078	1.28549

Table 4-7: Schoener index and Swihart-Slade index values for ‘number of fixes at 2hr interval), generated by ArcGIS 9.8 (ESRI, Redlands, California, USA) of hyaenas collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch. If Schoener index value is less than 1.6 or more than 2.4 indicates significant autocorrelation. If Swihart and Slade index value is more than indicates significant autocorrelation.

Hyaena ID	Monitoring period (months)	Fate	Remark
<b>F07</b>	48	alive	alive
<b>F08-1</b>	17	lost	dispersal- never seen in natal clan ever since
<b>F08-2</b>	11	mortality	dispersal mortality-human induced
<b>F09-1</b>	10	mortality	natal area mortality- human induced
<b>F09-2</b>	3	mortality	natal area (center of activity shift) mortality- human induced
<b>F09-3</b>	20	mortality	natal area mortality- human induced
<b>M10</b>	7	mortality	natal area (clan shift) mortality- human induced

Table 4-8: Details of fate of the study hyaenas, as last recorded in Feb. 2011, collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch.

Hyaena ID	Gender	Age (collar)	Age (study)	Duration (months)	100% MCP (km <sup>2</sup> )	95% MCP (km <sup>2</sup> )	95 % Fixed kernel (km <sup>2</sup> )
F07 a	F	4	6	24	88	68.5	88.2
F07 b	F	4	8	24	85.4	70.1	118.5
F08-1	F	2	3.7	17	107.7	50.4	47.8
F08-2	F	1.5	2.5	11	54.2	32.9	48.9
F09-1	F	1.5	2.5	10	61.5	25.1	26.4
F09-2	F	1	1.5	3	7.6	5.2	7.1
F09-3	F	1	3	20	58.2	23.9	26.2
M10	M	2	3	7	125.3	90.7	134.4

Table 4-9: Details of home ranges for all individual hyaenas collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch. Age (collar): refers to the approximate age (in years) of the individual when it was trapped and collared. Age (study): refers to the approximate increment in age (in years) of the individuals along the course of the study (in most cases age at which the individual was lost).

Hyaena ID	100% MCP HR (km <sup>2</sup> )	Average night trip distance (km)	Average speed (km/hr)	Diameter of HR (km)	Total time required to navigate HR (hours)	Number of HR loop
<b>F07a</b>	88	13.3 (1.5)	1.1 (0.1)	10.5	9.6	<b>1</b>
<b>F07b</b>	85.4	21.3 (6.4)	2.2 (0.5)	10.4	4.7	<b>2</b>
<b>F08-1</b>	107.7	15.3 (1.7)	1.1 (0.1)	11.7	10.6	<b>1</b>
<b>F08-2</b>	54.2	11.0 (1.0)	0.9 (0.08)	8.3	9.2	<b>1</b>
<b>F09-1</b>	61.5	15.5 (1.6)	1.2 (0.1)	8.8	7.3	<b>2</b>
<b>F09-2</b>	7.6	8.9 (0.9)	0.8 (0.1)	3.1	3.8	<b>3</b>
<b>F09-3</b>	58.2	13.2 (1.0)	1.1 (0.09)	8.6	7.8	<b>2</b>
<b>M10</b>	125.3	17.0 (2.5)	1.6 (0.2)	12.6	7.8	<b>1</b>
<b>Average (SE)</b>	73.5 (12.9)	14.0 (0.6)	1.2 (0.05)	9.6	8	<b>1</b>

Table 4-10: Movement rate of individual hyaenas collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch. 100% MCP home ranges of individuals converted to represent an equivalently sized circular home range:  $2(\sqrt{(\text{home range area})/\pi})$ . HR: home ranges, Number of HR loop: refers to the number of times the individual can cover its home range in a night-calculated by dividing average night trip distance by diameter of home range.

The space use pattern of 3 individuals (F08-1, F09-1 and F09-3) from the same clan (BND clan) (Figure.17) demonstrates that members of a clan inhabit essentially the same area, with significant area over lap spatially and temporally.

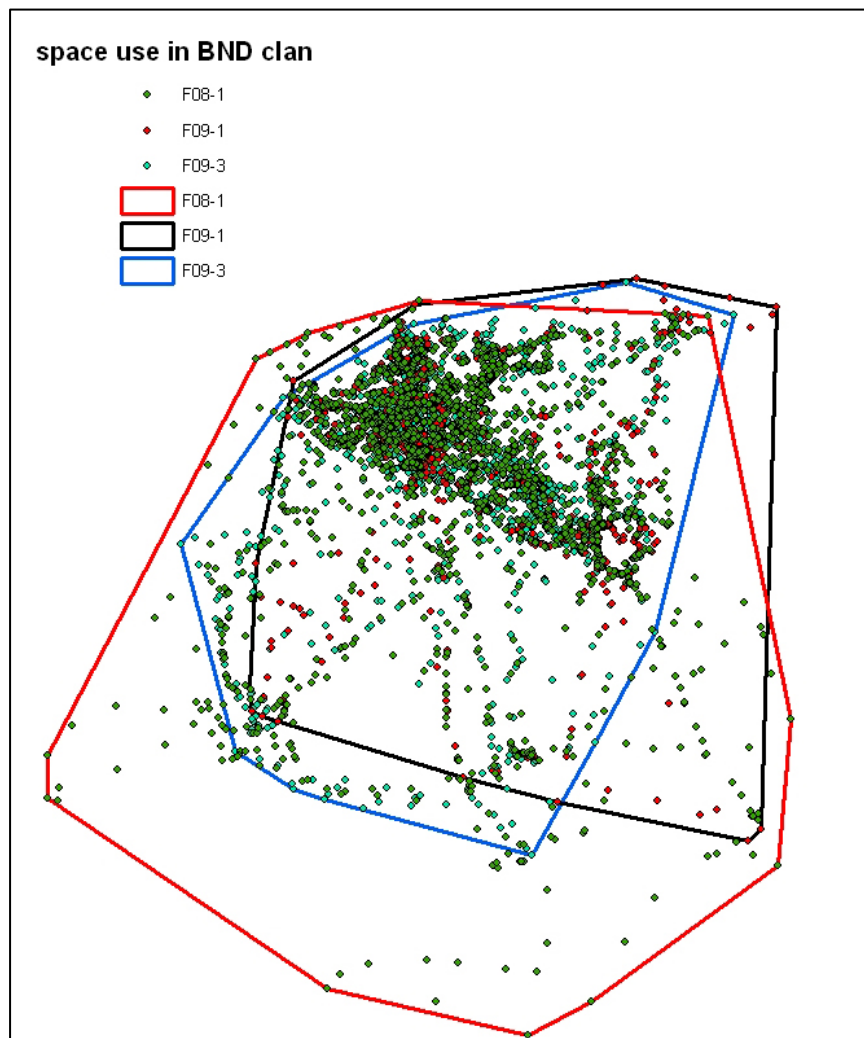


Figure 4-18: Space use overlap (both spatial and temporal) in F08-1, F09-1 and F09-3, collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch. Most locations for all three individuals were clustered around the center of activity (around 14 den sites used by the clan).

M10 space use and clan shift (Figure.18). M10 was captured in BND clan area (in fact M10 and F09-3 siblings); initially M10 used its natal clan area (spatially and temporally overlapped with F09-3) later it shifted to H.Ridge clan (nearest neighboring clan) area and didn't frequent in BND clan area.

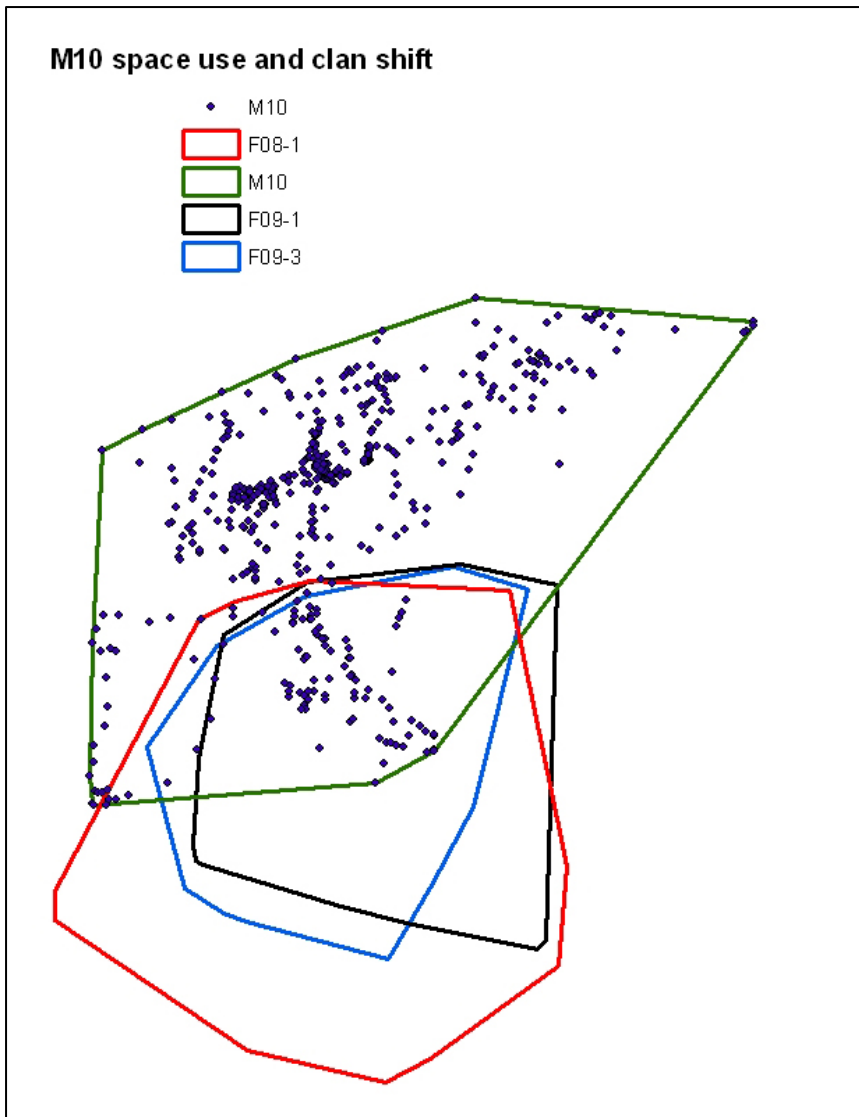


Figure 4-19: Hyaena M10 space use and clan shift., collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch

Space use by F07 and its displacement. The mature individual (F07) was captured in H.Ridge clan and monitored for the longest duration (4 years). The initial two years she occupied H.ridge clan area (F07a) considered as natal clan based on capture site orientation. After 2 years of use of natal clan she (F07b) was displaced to adjoining area (Ustia clan area), where she established a clan (based on the fact that she was the breeding female in the clan). The term 'displacement' is used, as from field observations it is known that H.Ridge clan still supported a breeding female and H.Ridge clan had exclusive area.

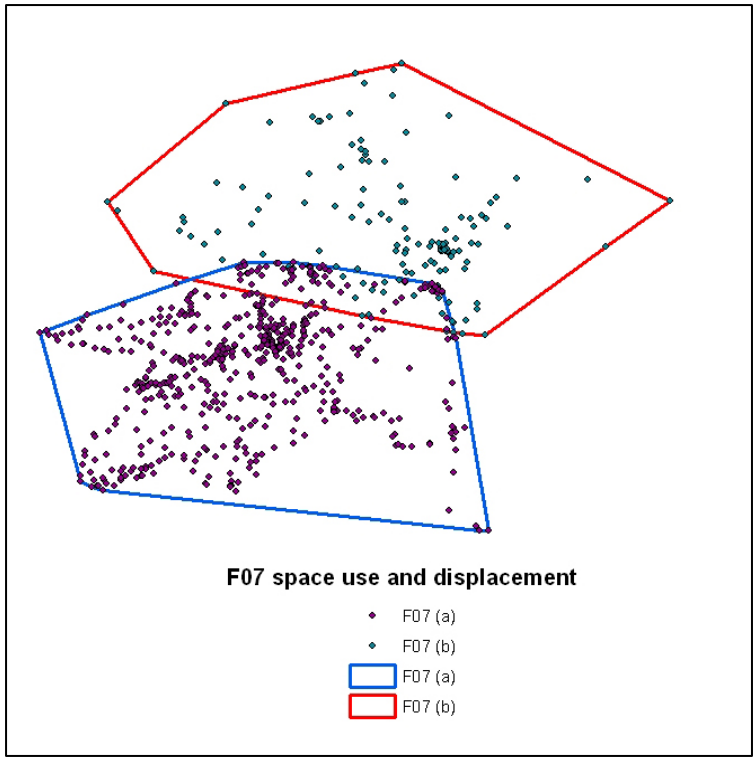


Figure 4-20: Hyaena F07 collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch - space use and displacement

Space use of M10, F09-2 and F07 (F07a and F07b). Figure.20 displays space use of the individuals (with no temporal overlap).

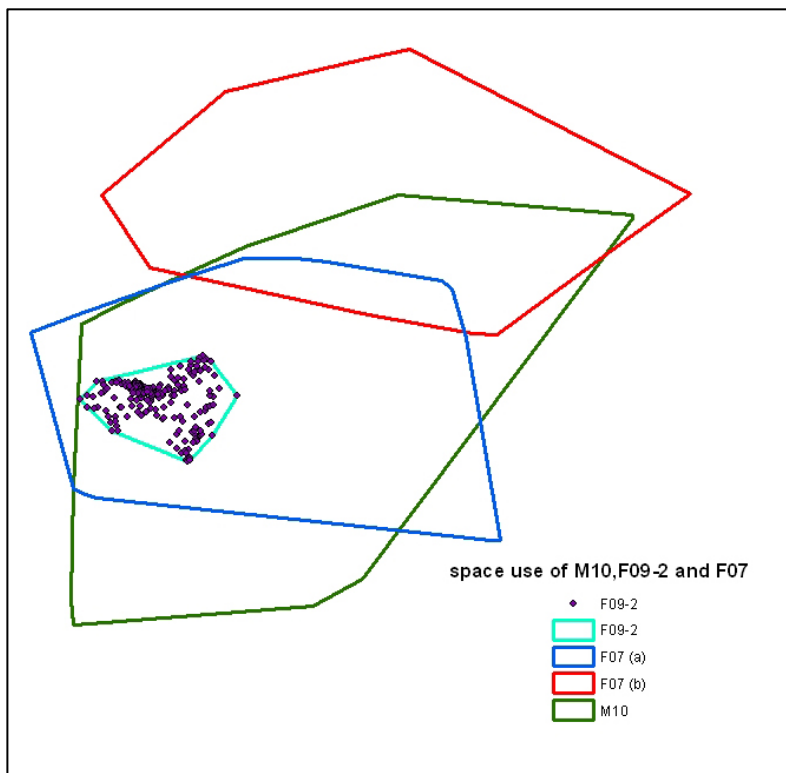


Figure 4-21: Hyaenas M10, F09 – 2 and F07 collared and monitored in the study during 2007 – 2011 in Abdasa, Kutch – Space use.

To establish their dispersal pattern (in terms of extensive movements), the number of traversed home ranges were computed for each female; where average 100% MCP home range of hyaena was converted to represent an equivalently sized circular home range:  $2(\sqrt{\text{(home range area)}/\pi})$ . Linear dispersal distances were then divided by this diameter to determine number of average home ranges traversed (Table.12).

Hyaena ID	Average HR (100% MCP) km <sup>2</sup>	Average diameter of HR (km)	Linear Distance (km)	Number of traversed HR
F08-2	82.4	10.2	50	4.9
F09-2	82.4	10.2	8	0.8

Table 4-11: Number of traversed home ranges by dispersing study hyaenas collared and monitored during 2007 – 2011 in Abdasa, Kutch.



Figure 4-22: Space use and Dispersal of F09-2, collared and monitored during 2007 – 2011 in the study. The point location with polygon indicates the capture site and space use (8.9 km<sup>2</sup>) of F09-2. The ‘unmarked point locations’ represent the villages around the clan (A.Ridge) area (figure.1).

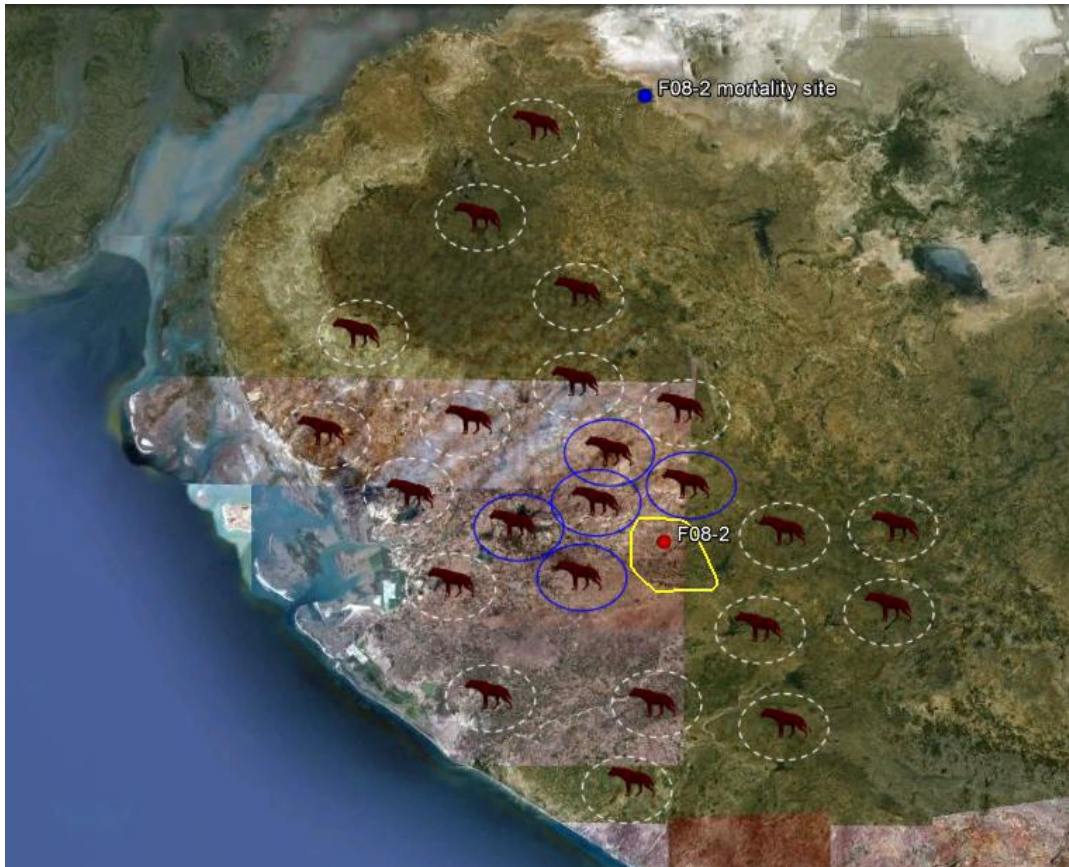


Figure 4-23: Space use and dispersal of F08-2. The point location with a polygon indicates the capture site and space use (61.6 km<sup>2</sup>) and the point location represents the mortality site of F08-2. The ‘solid circles’ indicates the orientation of the intensively studied hyaena clans (figure.1). The ‘dashed circles’ indicates the orientation of lesser studied hyaena clans around Moriya clan (F08-2’s natal clan) and enroute to dispersal mortality site location.

#### 4.4 Discussion:

In this study we considered the use of the terms ‘space use’ and ‘home ranges’ with distinction to suit the broader objectives of the study. ‘Space use’ (as defined in 4.3) comprises extend of area use by an individual hyaena, which will prove useful to derive information on habitat preference, resource distribution and utilization and to define ‘clan’ boundaries and understand clan dynamics. Only 100% MCP was used to estimate space use, as MCPs may better reflect the area required by animals to ensure that the range contains sufficient resources, which is a significant consideration in the management of species. ‘Home range’ (as defined in 4.3) aims at the uniformity of sample sizes and sampling regimes, and computes the estimates as close as possible in scale with accepted scientific methods for comparison purposes. Both MCP (100% and 95%) and Fixed kernel (95%) estimators were used to compute home ranges. Percent overlap between adjacent home ranges was not calculated, as the study animals were temporally distributed (Figure 4-2).

Since most locations obtained for almost all individuals were clustered, there were issues with autocorrelation and choosing a bandwidth for 95% fixed kernel. Because of the clustered nature of locations, they are highly non-significantly auto correlated (Table 4-7).

To reduce autocorrelation, the total time required for a hyaena to cover its home range was determined (intention was to use the measured time in subsampling i.e. obtain locations every ‘total time measured’). The net home range was converted to represent an equivalently sized circular home range:  $2(\sqrt{(\text{home range area})/\pi})$  and the diameter and time taken to cover the diameter were calculated. The net home range 82.4km<sup>2</sup>(Table 4-4) had a diameter of 10.2 km, travelling with a net speed of 1.2 km/hr (Table 4-5) it will take 8.5 hours to navigate the home range from end to end. Considering locations at 8.5-hour interval was impractical; as majority of the study animals would have had deficient number of locations compelling their exclusion from the analysis, resulting in unrealistic values and loss of information. Sub-sampling data to eliminate it often reduces the value of the resulting estimate (Solla et al. 1999, Fieberg 2007).

Sub-sampling was done for cumulative time of an hour (i.e. every 1 hr, 2 hr, 3 hr, 4 hr locations were taken for each hyaena). The time interval of 2 hour between locations were suited best; as majority of the study animals had the minimum number of locations needed for the estimation (Figure 4-3, Table 4-2), but still the values were non-significantly auto correlated. It is argued that autocorrelation conveys useful biological information, and that home-range size; time partitioning and total distance travelled are therefore better represented by auto-correlated observations (Otis and White 1999, Solla et al. 1999, Blundell et al. 2001).

For understanding the space use of a species, random sampling in a stratified pattern over a long period of time is more important than constructing model-designed data sets that avoid auto correlated data (Otis and White 1999, Solla et al. 1999).

When choosing the appropriate smoothing parameter (bandwidth) for the kernel estimator, the Least squares cross-validation (LSCV) was found to be sensitive to the clumped of locations and displayed error in performance. Few studies have negotiated the problem by reducing the reference bandwidth to a fixed proportion such as 0.70 (Bertrand et al. 1996) or 0.80 (Kie and Boroski 1996, Kie et al. 2002). Since not all regions of an animal's distribution are necessarily characterized by the same degree of spatial autocorrelation (Osborne and Suárez-Seoane 2002) using a single smoothing parameter may over-smooth in some regions and under-smooth in others (Hemson et al. 2005). For the present study the appropriate reduced reference bandwidth was fixed to 0.80 proportion, by reducing the reference bandwidth just prior to the point where that estimate starts to fragment into multiple polygons (Berger and Gese 2007, Jacques et al. 2009).

Home range estimates may vary based on a number of factors, including choice of estimator, number of locations, sampling frequency, study duration, distribution of locations, autocorrelation and software (Lawson and Rodgers 1997, Seaman et al. 1999, Laver and Kelly 2008).

Radio-telemetry studies often must compromise the allocation of resources between the number of locations and relative independence of those locations. A statistically relevant number of locations may be impossible to achieve within a given activity season for sufficient home range analysis (Powell 2000). Also mortality factor and

dispersal has immense influence on sampling regimes; in the course of the study, out of 7 collared hyaenas (F07, F08-1, F08-2, F09-1, F09-2, F09-3 and M10) 71% (succumbed to human induced mortality), 14 % was lost and only 14% survived the study period (Table.9). With high rates of unnatural mortality among study animals coupled with spatial and temporal drawbacks of VHF collars; the sampling regimes could not be followed for all collared hyaenas, hence no uniformity in sampling frequency. Along with home range estimates for hyaenas, other ecological information like movement, denning ecology and social behavior would be inferred from the radio tracked locations; for which locations were taken whenever the study animals were encountered (maintaining time allotted between locations at 15 minutes), hence most locations are clustered.

In Kutch had an average 100% MCP space use of 80.7 ( $\pm$  13.8) km<sup>2</sup> (Table.3 and Figure.2) and 95% MCP space use of 53.8 ( $\pm$  10.6) km<sup>2</sup>.

When the average home ranges were computed for all hyaenas (including F09-2 and F07<sup>b</sup>), it was had an average 100% MCP home range of 73.5( $\pm$  12.9 SE) km<sup>2</sup>, 95% MCP home range of 45.9 ( $\pm$  10.2) km<sup>2</sup> and 95% kernel home range of 62.2( $\pm$  16.4) km<sup>2</sup> (Table 4).

The actual average home range size of hyaena (excluding F09-2 and F07<sup>b</sup>) was 100% MCP home range of 82.4( $\pm$  12.0 SE) km<sup>2</sup>, 95% MCP home range of 48.5 ( $\pm$  10.5) km<sup>2</sup> and 95% kernel home range of 61.9 ( $\pm$  14.8) km<sup>2</sup>. As shown in the analysis, the sampling frequency does not have large effect on home ranges and the values are not drastically different from 'space use' (absolute area usage) values; also Fixed kernel estimates were not affected by sample size (from n=8 to n=6), hence it would be factual to conclude that the sub-sampling protocol and bandwidth selection was suitable for the data set from this study.

Apart from sampling regimes age, duration of tracking period and gender has an influence on home ranges (Table.10). M10 –the only male collared during the study, had the largest home range size (shifted clan) was estimated in spite of short duration of tracking period. It is evident that male striped hyaenas have larger home ranges than females in Kutch. While, the mature female (F07) had a home range of similar sizes in natal area (F07<sup>a</sup>) and displaced area (F07<sup>b</sup>), evident that she established a stable home range in the displaced area. F08-1 had larger 100% MCP home range

when compared to the mature female (F07) but 95% MCP home ranges are smaller, suggesting that exploratory long distance dispersal movement outliers were captured by 100% MCP estimators (eventually this individual dispersed). Rest of the individual were short lived (killed before reaching the age of maturity), hence a gap in dispersal pattern information.

The home range size of male hyaena in Kutch ( $125.25 \text{ km}^2$ ) is larger than in Africa, where one male had  $72 \text{ km}^2$  home range sizes in Tanzania (Serengeti national park) (Kruuk 1976) and  $68.9 \text{ km}^2$  in Kenya (Wagner 2006). The average female home range in Kutch was  $73.9 \text{ km}^2$  (includes all collared females), when F07b and F09-2 are excluded the average female home range size is  $66.1 \text{ km}^2$ ; more than home ranges of a female in Serengeti national park at  $44 \text{ km}^2$  (Kruuk 1976) and a female from Negev desert region at  $60.9 \text{ km}^2$  (Van Aarde et al. 1988), and close to the home range size in Kenya at  $68.9 \text{ km}^2$  (Wagner 2006).

There is a significant difference in home range size between males and females in Kutch and Serengeti national park (Kruuk 1976), while Wagner (2006) reported no significant difference between sexes.

The biological rhythm of hyaenas followed the time of sunrise and sunset. Activity is initiated after sunset till few hours after sunrise. Total continuous (24 hr) monitoring (n=104) accounted for 2496 hours of tracking seven collared hyaenas, out of which on 1200 hrs (48 %) of the time was spent resting and for 1300 hrs (52%) hyaenas were active (Table.5). Activity allocation is 30% of time in day used for movements (from den site to food source, between food source and back), 10% of time was spent in the vicinity of villages, 2% in foraging (only active foraging observations included here) and 10% of time spent around center of activity (Figure.16, Figure.17). 10% (250 hrs) of the total activity time spent around villages indicates its dependence on these 'known food sites', as shown in Chapter 3 (diet and foraging pattern) village realms contribute to the major and important (vertebrate intake) portion of the overall diet ( Figure 2-2)

This is in agreement with the suggestion of Skinner and Ilani (1979) that striped hyaenas have adapted to co-exist with man

The fact that only 30% (750 out of 2496 hours) was spent in movement, indicates that most of the search efforts were around ‘known food sites’ (villages) and majority of the movement is between meals. Since food resources sites are known and hyaenas have high dependence on these sites, the search efforts are reduced facilitating time to be spent at center of activity (10 % -750 out of 2496 hours) promoting healthy socializing with clan members.

Hyaena movement seemed to differ with age of individuals (Table.12). On an average the mature female (F07) covered large distance (21.3 ( $\pm$  6.4) km in a night foraging trip, while F09-2 covered smaller distance (8.9 ( $\pm$  0.9) km. To understand the movement pattern with the home ranges for each individual, a term ‘Home range loop’ is framed and used for this study. Which is defined, as the possible number of times a hyaena uses its home range in a night trip, with the assumption that the distance covered in a night by a hyaena is linear. ‘Home range loop’ is calculated by using 100% MCP estimates and converting it to represent an equivalently sized circular home range:  $2(\sqrt{(\text{home range area})/\pi})$  and by division of distance covered in a night by an individual by its home range diameter (Table.9); the resulting value will be the possible number of times a hyaena uses its home range in a night, where value of 1 or less than 1 is considered ‘constructive use’ and value more than 1 as ‘compelling use’.

From Table.12, it is clear that of the individual (F07a, F08-1, F08-2, and M10) seem to use extent of home ranges as ‘constructive use’ (covered the extent of home range only once in a night trip); while F07b, F09-1 and F09-3 (covered the extent of home range twice in a night trip) and F09-2 (covered the extent of its home range 3 times in a night trip) seem to use extent of home ranges as ‘compelling use’. The ‘home range loop’ value might reflect distribution and availability of food resources and the search effort by individual hyaenas. In case of F09-2 it was collared as a young animal and monitored for a short duration, during which the individual ranged close to center of activity (avoided long distance travel-constrained by age) and has smallest home range (7.6 km<sup>2</sup>); the ‘home range loop’ value of 3 makes sense here as there were no villages at proximity (Figure.21) and all the search efforts were concentrated in the home range. It is evident that the home range is poor in food resource distribution, by the fact that the animal was

‘compelled’ to cover the extent of home range 3 times in a night trip to increase search effort.

The variation of home range use in F07 is of significance, the home range in its natal area F07<sup>a</sup> (88.0 km<sup>2</sup>) and displaced area F07<sup>b</sup> (85.4 km<sup>2</sup>) are very close in size; but the range use for the same hyaena is different in different area (Table.11). F07<sup>a</sup> used the home range in a ‘constructive use’ regimes (covered the extent of home range only once in a night trip), while F07<sup>b</sup> used the home range in a ‘compelling use’ regime (covered the extent of home ranges twice in a night trip); indicating possible difference in patch quality.

It is interesting to note that why would mature and long distance travelling individuals (F07<sup>b</sup>, F09-1 and F09-3) restrict themselves to ‘compelling use’ home ranges. It would be more beneficial in terms of search effort and energy consumption, if the night foraging trips were transformed into linear paths (as no territoriality is observed in study area) and move beyond their restricted home ranges. But they don’t, this explains that there are factors other than food resources that govern the home range size and use. Center of activity (den location) might be a very important determinant, as from field observations it is known that F07b was a breeding female and F09-1 and F09-3 actively participated in rearing of cubs. Females will establish a minimum territory with enough resources to provide food for herself and her offspring (Jarman 1974).

In contrast the male study animal (M10) had ‘home range loop’ value of 1, indicating that the animal covered the extent of its home range only once in night trip (indicating quality of home range in terms of food resources). We hypothesis that since the male was immature and home range had good distribution and availability of food resources the ‘home range loop’ value was 1 (‘constructive use’ regime), but as the individual (M10) matures the ‘home range loop’ value will increase many folds (shift from ‘constructive use’ regime to ‘compelling use’ regime) in this case to ensure breeding success (to roam and compete with other males for mating).

The average activity pattern shows that 30% (750 out of 2496 hours) was spent in movement, indicates that most of the search efforts were around ‘known food sites’ (villages) and majority of the movement is between meals. The ‘home range loop’ values

indicate the accessibility of a meal in a home range, which depends on distribution (in this case it is number of livestock in villages incorporated in the home ranges) and availability (in this case mortality of livestock and hunting success). When resources are patchily distributed, movements should be slower and more convoluted in high-quality patches, to keep individuals in these good habitats (Zollner and Lima 1999, Mårell et al. 2002, Fahrig 2007, Snider and Gilliam 2008).

Resource dispersal hypothesis states that territory size is determined by the dispersal of transient food patches, and a group size is positively correlated with the patch quality (Macdonald 1983). Studies in Kalahari on brown and spotted hyaena movements within territories indicated that both species are affected by 2 factors, mainly the distribution of their food, but also the location of their dens (Mills 1990a). ‘Home range loop’ is an attempt at viewing night trip distance (daily travel distance) from a different perspective and to explore the relationship between home range and distance moved on a rapid assessment basis. Many interesting aspects of clan dynamics and home ranges were observed and understood in the course of the study.

#### **4.4.1 Observation.1**

Similar pattern was noted in striped hyaenas studied in Kenya, where individual home ranges show spatial grouping, with high spatial overlap within groups and low overlap between groups, but these patterns do not reveal whether individuals interacted with one another within the shared range (Wagner et al. 2008a). In the current study, these individual interacted with each other in center of activity, but temporally exploited ‘known food sites’ in the home ranges. Some species form ‘spatial groups’ within which group members have highly congruent and overlapping home ranges but remain behaviorally solitary within the shared range (Macdonald 1983).

#### **4.4.2 Observation.2**

Clan shift (emigration) was the most important determinant of brown hyaena and spotted hyaena group size, both sexes; particularly males emigrated from natal clans (Mills 1990). Like in brown and spotted hyaenas, emigration and immigration play an important role in clan dynamics

#### **4.4.3 Observation.3**

It is evident that the conditions in H.Ridge clan area were favorable for breeding and had clan membership, and F07 didn't abandon the clan area as unfavorable. We hypothesize that F07 was displaced by one of her offspring who survived till maturity and stayed back in the natal area. If this hypothesis holds well, then the question arises 'how many breeding females can a striped hyaena clan support at a breeding season.

#### **4.4.4 Observation.4**

When F07a used H.Ridge clan area, the clan F09-2 is associated with (A.Ridge clan) was not functional; in fact the area was used by F07a. And by time M10 was collared and monitored, A.Ridge clan has shifted its center of activity. It is quite possible that, like in observation.3 some individual was displaced from nearby clans (nearest neighboring clan being H.Ridge and established this clan. Observation2, 3 and 4 gives an impression that hyaenas from adjoining clans are closely related, but since we didn't use genetics as a tool for the study relatedness information across clans is lacking.

#### **4.4.5 Observation.5**

During the course of study, 3 female hyaenas (F08-1, F08-2 and F09-2) dispersed from their clan area and were lost. F08-1 was never contacted again so the fate remains unknown. In most vertebrates, individuals are usually difficult to follow once they have left their natal group or range and those that settle close to their group of origin are more likely to be detected than those that move further (Koenig et al. 1996, Sharp et al. 2008). But F08-2 and F09-2 were victims of dispersal mortality and their final dispersal location was known (Figure.21, Figure.22).

It was found that F09-2 didn't traverse home ranges, indicating that it was not a dispersal but movement within the home range. But then the individual (F09-2) was too young for dispersal and shift within the clan area (as its range was very less). The shift in center of activity is associated not only with F09-2 but the entire clan (A.Ridge clan); backwaters

from a huge dam (Figure.16) hindered the access of clan members to ‘known food sites’, hence the clan abandoned this center of activity to a better-suited one. Temporal changes in space-use patterns may result from age- or stage-dependent behavioral responses, environmental variability or other factors affecting the distribution or importance of resources (Börger et al. 2006).

In case of F08-2, it was found that she traversed 5 home ranges as dispersal distance, indicating that the individual moved far from the natal den area. A total of 24 clans (including 5 intensively used clans) were spatially distributed around F08-2 clan area, not joining any of the clans.

In most social mammals, some females disperse from their natal group while others remain and breed there throughout their lives and female group members are close relatives but, in a few, females typically disperse after adolescence from their natal groups to join established breeding groups or found new breeding units; and few individuals remain and breed in their natal group. These contrasts in philopatry and dispersal have an important consequence on the kinship structure of groups which, in turn, affects forms of social relationships between females (Lukas and Clutton-Brock 2011)

Females may benefit from dispersal from their natal group because it allows them to gain access to unrelated males and to avoid inbreeding with close relatives (Bengtsson 1978, Greenwood et al. 1978, Pusey 1987, Koenig and Haydock 2004).

It is likely that the variation in female dispersal patterns have important consequences for the dynamics of groups and the regulation of population density; the demographic consequences of variation in female dispersal remain almost totally unexplored (Clutton-Brock 2009).

## 4.5 Conclusion

It was determined that average home range size of hyaena in Kutch was 100% MCP home range of  $82.4(\pm 12.0 \text{ SE}) \text{ km}^2$ , 95% MCP home range of  $48.5 (\pm 10.5) \text{ km}^2$  and 95% kernel home range of  $61.9 (\pm 14.8) \text{ km}^2$ . With significant difference among sexes, home range size of male hyaena in Kutch ( $125.25 \text{ km}^2$ ) and average female home range size is  $66.1 \text{ km}^2$ . The average distance covered by hyaena in one night is  $14.0 (\pm 0.6) \text{ km}$  with average speed of  $1.2 (\pm 0.05) \text{ km/hr}$ . Members of a clan inhabit essentially the same area, with highly overlapped home ranges. Each clan area is largely exclusive and no overlap in area of use among adjacent clans. There was no territoriality observed in Kutch. Hyena in Kutch, spent 48% of the day resting and 52% of activity was allocated in movement (30%), search effort around villages (10%), in center of activity (10%) and active foraging (2%). From the study that female hyena dispersers are capable of extensive movements.

For studying elusive long-lived species like the striped hyena; with such variable clan dynamics and dispersal pattern, carefully planned multiple year data will be required to effectively define and compare home range estimates.

## **5 Modelling striped hyaena distribution and habitat requirements**

### **5.1 Introduction**

The concept of habitat is possibly the most fundamental, and unquestioned, paradigm in ecology (Mitchell 2005). ‘Habitats’ can be described as regions in environmental space, that depict the biotic and abiotic variables at a given place and time (Kearney 2006, Aarts et al. 2008, Hirzel and Le Lay 2008) which directly (e.g. forage biomass and quality) or indirectly (e.g. elevation) contribute to the use of a location by the animal. It is often confused with the concept of ‘Niche’. ‘Niche’ is used when describing the role or function of an organism in a particular environment; and it can therefore be seen as the mechanistic interaction that arises between an individual and the area it utilizes (Kearney 2006).

The distribution of habitats in geographical space can be complex: regions of environmental space may have a patchy distribution over landscapes (Hirzel and Le Lay 2008). It is believed that an animal chooses a specific range and combination of environmental variables to best enhance their fitness in terms of survival and reproduction (Manly et al. 1992, Ottaviani et al. 2004). Habitat use is the proportion of their time that animals spend in a particular habitat. Selection of habitat is the process by which an animal actually chooses habitat. Use is considered selective if habitat is used disproportionately compared with its availability (i.e. the amount of that habitat accessible to the animal) and preference is the likelihood of an animal selecting a given item when offered alternative choices on an equal basis (Johnson, 1980). In field studies, however, where the availability of habitat is variable, habitat preference is the use of habitat relative to its availability in the environment and is conditional on the availability of all habitats (Aarts et al. 2008).

The use of different habitats and the associated habitat characteristics can be documented by following the movements of individuals and recording information on the surroundings (Kearney 2006). Habitat preferences can be determined by analysing this

data to determine the indirect correlation that links the presence of an individual to specific environmental factors (Guisan and Zimmermann 2000, Bias and Morrison 2006). The type of habitat that animals exploit will inevitably determine the movement of species through an environment. By linking species with their general habitat requirements habitat suitability maps can be created and the distribution of animals can be predicted (Manly et al. 1992, Guisan and Zimmermann 2000, Kearney 2006).

Species distribution models (SDMs)-Models predicting the spatial distribution of species -sometimes called resource selection function or habitat suitability models (Hirzel et al. 2006), express a quantitative association between the probability of occurrence of a species by combining measurements of environmental and/or spatial covariates of occurrence at locations where the species is known to be present with measurements of the same covariates at other locations where species occurrence status (presence or absence) is unknown over its potential geographic range (Raven et al. 2002, Franklin and Miller 2009, Dorazio 2012). Predictive modelling of the spatial distribution of species is of crucial concern in ecology and conservation (Graham et al. 2004), with applications in conservation studies, reserve planning, ecology, evolution, biogeography and biodiversity monitoring programmes (Townsend Peterson and Cohoon 1999, Raven et al. 2002, Cabeza et al. 2004, Holt and Keitt 2005, Elith and Leathwick 2009, Gaston and Fuller 2009).

Different types of distribution modelling techniques are used to fit different types of species information recorded at a sample site: (1) presence-only: occurrences of the target species are recorded; (2) presence/absence: each sampled site is asserted with certainty the species presence or absence (Hirzel et al. 2006). Direct information about species occurrence is lacking for many species. In many situations presence-only data may be the only data available on a species, without reliable absence data (Pearce and Boyce 2006, Li et al. 2011). The lack of consistent absence data, can be attributed to species' characteristics (like biology and behaviour) (Hirzel et al. 2001), their local abundance and ease of detection (Kery 2002, Woolf et al. 2002, Brotons et al. 2004), and the survey design (MacKenzie and Royle 2005, Royle et al. 2012). Hence, modelling techniques that require only presence data are extremely valuable (Graham et al. 2004).

The need to maximize the utility of such resources has given rise to an array of SDM methods for modelling presence-only data. MaxEnt is a one such widely used program, designed to model and map species distribution (Phillips et al. 2006, Phillips and Dudík 2008, Royle et al. 2012) and environmental tolerances (Elith et al. 2011, Warren and Seifert 2011) using presence-only data and is deemed robust enough for sparse and biased datasets. Moreover, Maxent's predictive performance outperforms other modelling methods (Hernandez et al. 2006, Elith and Leathwick 2009, Rebelo and Jones 2010) and it has been used successfully in several species distribution and niche modelling studies.

MaxEnt estimates the area where a species is most likely to occur by using the principle of maximum entropy on presence-only data to estimate a set of functions that is closest to the expected value of each environmental variable and habitat suitability in order to approximate the species' niche and potential geographic distribution (Phillips et al. 2006). MaxEnt attempts to approximate the probability of occurrence by using a logistic transformation of its suitability index. Presence-only modelling methods only require a set of known occurrences together with predictor variables such as topographic, climatic, edaphic, biogeographic and remotely sensed variables (Phillips and Dudík 2008).

Striped hyaenas generally favours open or thorn bush country in arid to semi-arid environments (Rosevear et al. 1974, Kruuk 1976, Rieger and Ruppert 1978, Prater 1980, Leakey et al. 1999a, Wagner et al. 2008a). In the study area, hyaena use diverse habitats, like rocky terrain, scrub vegetation, eroded landscape, agricultural mosaic, fringes of Rann, grasslands and also known to use bets (islands) in Rann. Den sites play a crucial role in life history of hyaenas, as we will see in chapter.5 these sites are important centres for social activity, which in turn increases cub fitness and governs clan dynamics. Hence understanding den site selection is sufficient to understand hyaena distribution pattern in 'study area'.

In this chapter MaxEnt was used to understand environmental factors affecting hyaena occurrence and predict potential distributions for hyaena den sites in the landscape.

This model will be able to provide a tool to improve search effectiveness for hyaenas in the study area accounting for imperfect detection, as well as for the conservation and management of the species.

## 5.2 Data

### 5.2.1 Presence-only data

In MaxEnt, the ratio of density functions of the distribution of covariate means of the presence-only sample and the covariate means expected under the model is proportional to the conditional probability of species occurrence, where the constant of proportionality is species prevalence; therefore, MaxEnt also requires knowledge of species prevalence for its estimator of occurrence to be consistent (Dorazio 2012). Reliable information on absence is not easily obtained for cryptic species like hyaenas due to its elusive behaviour, poorly accessible habitats and their activity patterns. Low detection probability is expected for a nocturnal species like hyaenas in the rugged terrain of the study area, even at areas where it might be present. Also for areas outside the intensive study area, systematic biological survey data were limited by time and coverage, where indirect evidences indexes as surrogates to presence. Consequently, some of the locations where hyaenas occur in the landscape are known, but no reliable information is available on where they do not occur. Accordingly, the approach taken is ‘describing the distribution of presence-only records’. For this study presence of hyaenas are defined by field surveys, camera trapping and radio-telemetry data.

Radio telemetry studies on the species (Figure 5-4 & Figure 5-4) provide us with the information that with diverse resource units, the landscape (home ranges) is available to this wide-ranging species for their potential use, but some habitats are occupied more frequently. The hyaena radio-telemetry database for the study area contained 8618 locations (unique locations) of 7 individuals (6 females, 1 male) monitored between 2007 and 2011 (see chapter.4). All the recorded location lay within the ISA (Intensive study area). Apart from telemetry locations, other signs of hyaenas were also determined in ISA considering spoor (Figure 5-6), scats (Figure 5-6), den sites (Figure 5-8&Figure 5-8), refuge sites (Figure 5-10 & Figure 5-10), direct field observations ( Figure 5-11 & Figure 5-), camera trapping (Figure 5-2 & Figure 5-2). Outside the ISA, without radio-collared individuals, random sampling proved ineffective to locate hyaena signs. Hence, surveys were focused on searching den sites, based on my field experience in the ISA with random locations within the ‘study area’. Den site selection was examined by using

habitat variables at den sites occupied by hyaenas. These variables used were based on documented species–habitat associations (this study-field experience). Therefore, the survey was carried for den sites along rivers and minor drainages, ravines, hills and mounds, and also areas based on questionnaire surveys (see Chapter 7). Along with den sites, other signs of hyaenas like spoors, scats, refuge sites (only ones with certainty-difficult to locate these without radio telemetry), direct field observations, and dead individuals were also determined during these surveys.

Hyaena scats were cautiously identified (see chapter.2) and the spoors are unmistakable as the pads are in a roseate pattern and the foreleg impressions are larger than that of hind legs. Most of the refuge sites are difficult to locate without following the radio collared individuals. In areas with no radio collared hyaenas, only reliable sites (individuals alarmed and flushed by presence of researchers during surveys) were included in the model. Remotely operated cameras (Non-Typical Deer Cam – DC 300) were deployed in hyaenas suspected areas of the ISA, to capture uncollared individuals and to monitor their movement and associations. Direct field observations of uncollared and dead individuals were also obtained by ad libitum sampling. Hyaena dens were distinctly recognized whenever encountered, with its characteristic bone accumulations around the den site and abundance of hyaena spoors.

Presence only database defined for the study.



Figure 5-4: Radio collared hyaena: forest patch



Figure 5-4: Radio collared animal at den site



Figure 5-2: Camera trapped image of hyaena in the intensive study area (ISA)



Figure 5-2: Camera trap image of hyaena in the intensive study area (ISA)



Figure 5-6: Hyaena spoor



Figure 5-6: Typical hyaena white scat



Figure 5-10: Refuge site – in gully covered with vegetation

Figure 5-10: Refuge site- under a Euphorbia bush



Figure 5-8: Hyaena den – Characteristic bone accumulation in the vicinity of the den



Figure 5-8: Hyaena den with cub



Figure 5-11: Direct field sighting during surveys – in scrub forest habitat



Figure 5-11: Direct field sighting during surveys – in a ravine

### 5.2.2 Environmental data

We modelled the occurrence of striped hyaena and its den sites as a function of several habitat variables strongly related to its spatial distribution. We considered habitat variables related to terrain, human disturbance, and land cover. All variables were derived from the classified imagery of Kutch (LISS III) at 30 m<sup>2</sup> resolution and digitized Google earth image (Google Earth (Version 5.1)).

#### Land Cover type classification

The land Cover types in the study area were classified by using unsupervised followed by supervised Classification method in ERDAS Imagine 9.2 program. Firstly, the satellite image of the study area was extracted from 2009 (May and October) and 2010 (January) LANDSAT images at 30 m × 30 m resolution of the Kutch obtained from Global Land Cover Facility ([www.landcover.org](http://www.landcover.org)). Normalized difference vegetation index (NDVI) was used for each image using spectral enhancement index tool in ERDAS Image 9.2 (Eradas, Inc). These images were subjected to supervised classification using field based ground truthing locations. Land cover was classified into seven broad classes of: Annual crop, Seasonal crop, sparse grass type vegetation, savannah type vegetation, grassland type vegetation, rocky vegetation, and bare patch-no vegetation. Elimination tool in ERDAS was used to remove silver polygons < 1 ha in size. Multiple season information enabled accurate identification of Land cover.

DEM was not calculated-as the fine scale features required for this study (Elevation/depth of river beds) could not be reflected on 30 X 30 mts map for the landscape of Kutch- instead all the drainage (rivers/streams/ravines) in the study area was used as surrogate for DEM. The data for water bodies, dams and check dam (surrogate for water bodies), human habitation (villages, towns and cities), drainage (rivers, stream, ravines), large scale human disturbances (mines, industries and quarries) and tar roads (considering more traffic and speeding vehicles) (Figure 5-12, Figure 5-13, Figure 5-14, Figure 5-15, Figure 5-16) were digitized using Google earth and these data were then converted into distance maps in ArcView v.3.2 GIS software package (ESRI Inc., Redlands, CA). The incorporation of human habitation and large-scale activities (mines and industries) into the model is to increase its predictive power.



Figure 5-12: Drainage (rivers, streams & gullies) digitized in the study area

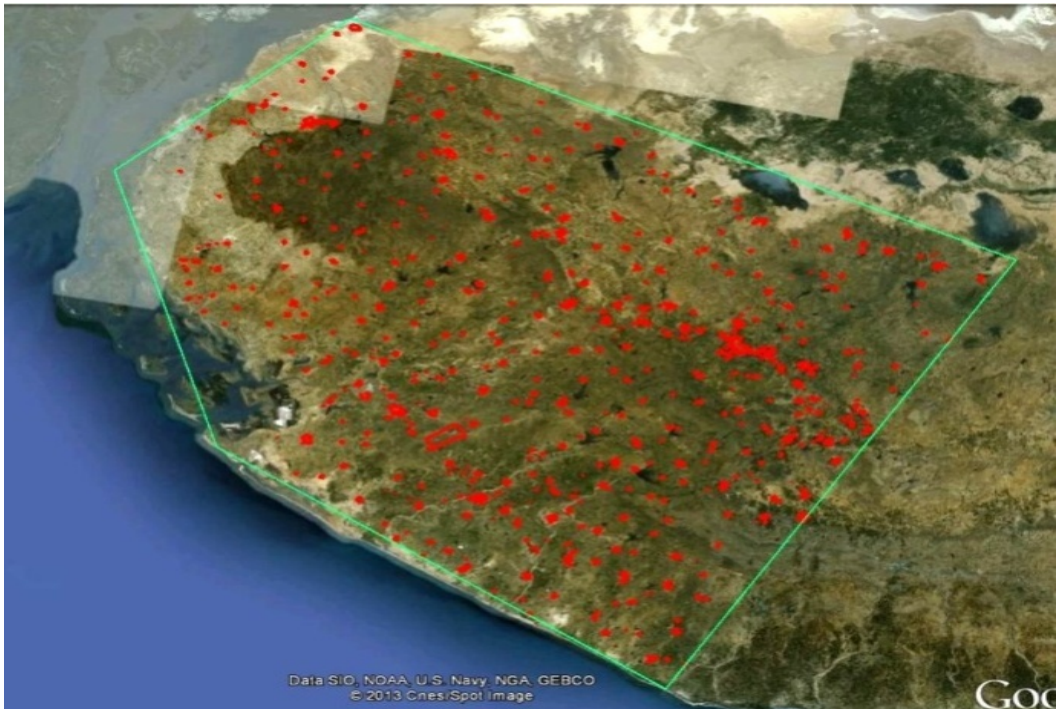


Figure 5-13: Human habitation in the study area digitized

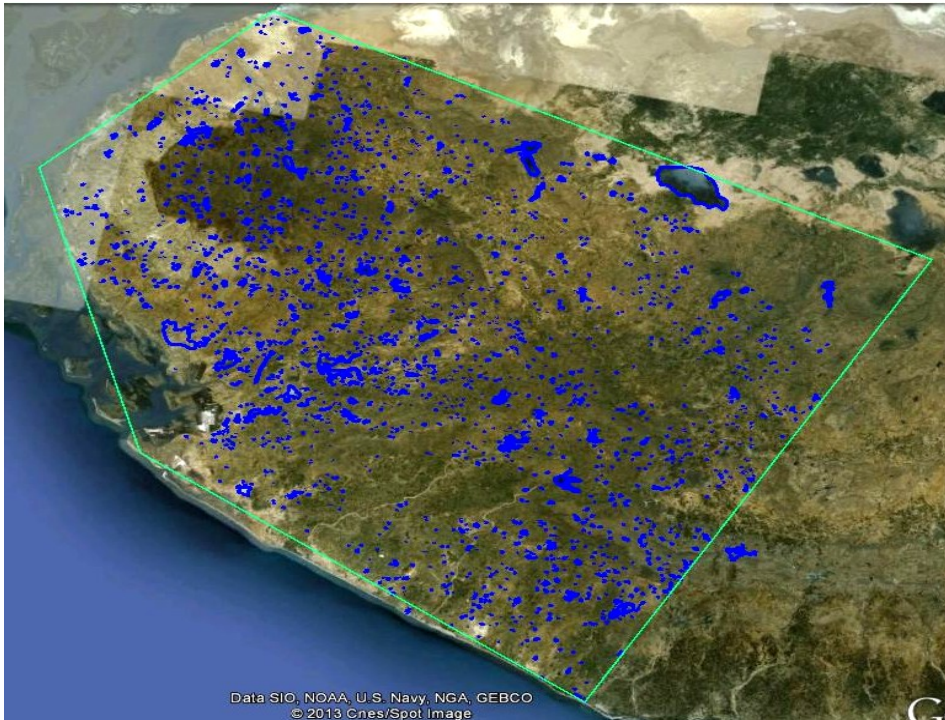


Figure 5-14: Major water bodies in the study area digitized



Figure 5-15: Mines and industries in the study are digitized



Figure 5-16: Mettled roads in the study area digitized

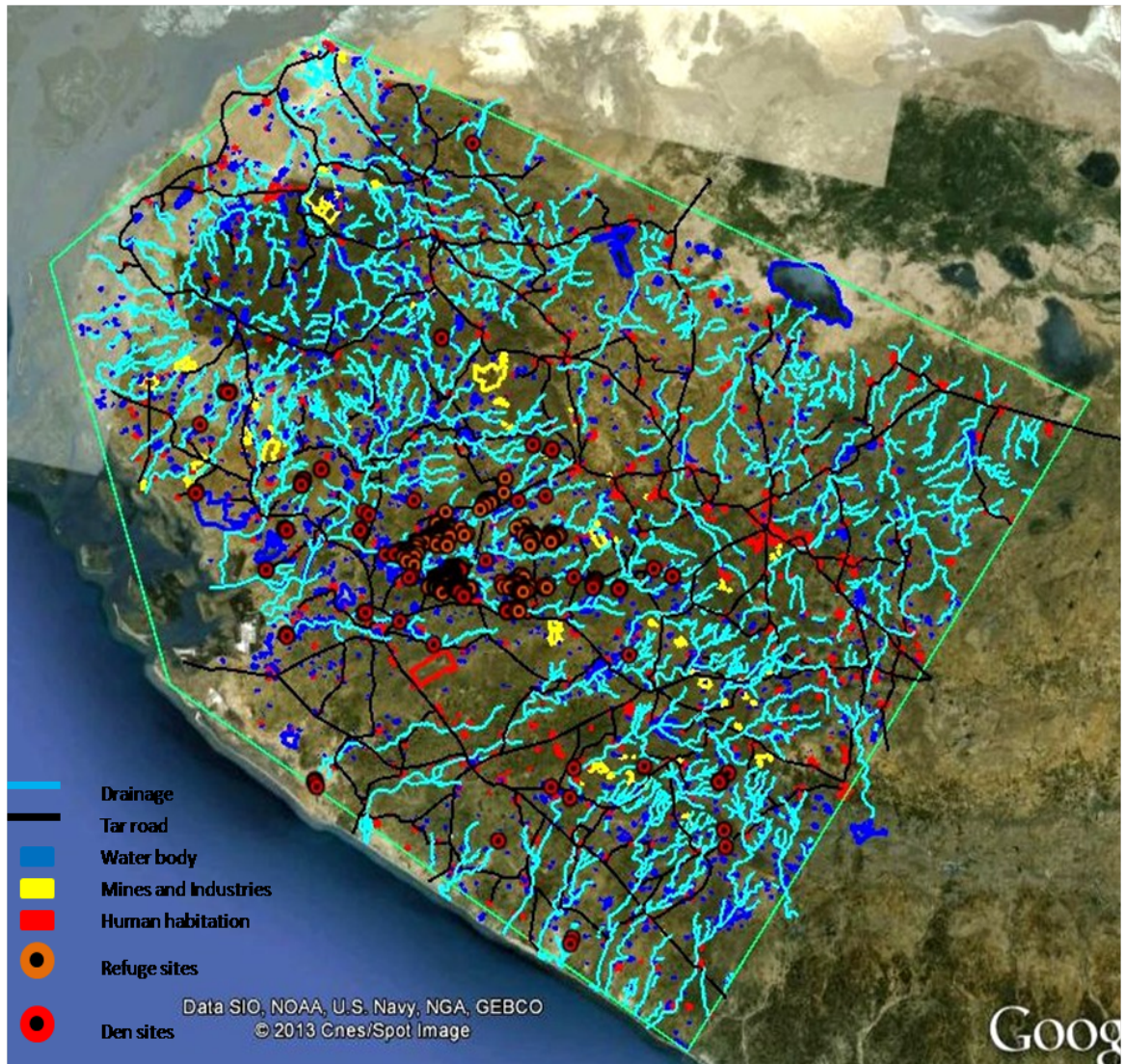


Figure 5-17: Digitized variables in the area of interest, along with hyaena den locations

### 5.2.3 Sampling unit



Figure 5-18: Details of sampling unit, Area of interest is the study area. ISA is Intensive study area.

The sampling unit for the model was 6570 sq. km, considering it to be large enough to have a reasonable probability of occupancy without losing meaning of any of the measures. We elected a model with fine-scaled habitat variables that would predict across a limited area, rather than a potentially less accurate model that could be generalized across regions. Generally, the sites from which data are collected will only represent a fraction of the greater collection of sites of which the occupancy state is of interest. It is therefore necessary that the manner in which sites are selected allow the results of the data analysis to be generalized to the entire population. All habitat types in the study area were sampled, to gather data in such a way as to be fully representative of the study area.

#### **5.2.4 Model development and validation**

MaxEnt does not require selection of absence locations for model development and is an effective tool for estimating a large number of parameters with a small sample size. It eliminates problems associated with data endogeneity and collinearity (Golan et al. 1996).

The database for hyaena in the study area comprised of presence-only data, hence to project the species-environment relationship to the area of interest area presence only models and one of the most preferred algorithms, Maximum Entropy (MaxEnt) (Phillips et al. 2006, Phillips and Dudík 2008, Elith et al. 2011) was used. ArcMap (version 9.2) was used to format all environmental data layers into ASCII grid format, same geographic bounds and cell size for use in MaxEnt. MaxEnt build the probability distribution that respects a set of constraints (environmental variables) derived from the occurrence data and the most unconstrained model developed is then considered as the MaxEnt model (Phillips and Dudík 2008).

We selected environmental variables on the basis of possible biological relevance and the availability of data. A total of 23 variables were evaluated used for correlation (Table 5-1), and potentially redundant, correlated variables were identified and were successively dropped and a batch run for finalizing variables for the model-a total of 16 variables were selected as predictor variables for all models (Table 5-2, Table 5-3). In the inclusion of selected variables, followed by a repeatable process of elimination, ensured that potentially over-fitted models were successively trimmed back, resulting in a slightly richer model because it retains important confounding variables that provide a required adjustment for one or more of the variables remaining in the model (Bursac et al. 2008).

<b>Variables used to check correlation</b>	<b>Predictor variables used for the final models</b>
Drainage distance	Drainage distance
Drainage density	Village distance
Water body distance	Village count
Water body count	Water body distance
	Dam/Check dam
Village distance	distance
Village count	Road distance
Road distance	Road density
Road density	Annual crop
Dam/Check dam	
distance	Seasonal crop
Dam/Check dam count	Scrub forest
Seasonal crop	Grassland vegetation
Annual crop	Savannah vegetation
Scrub forest	Sparse vegetation
Grassland vegetation	Barepatch-No vegetation
Savannah vegetation	Rocky vegetation
Sparse vegetation	Mines and Industries
Bare patch-No	
vegetation	
Rocky vegetation	
Agro-vegetation	
Mines and Industries	
NDVI	
Nightlife	
Erosion points	

Table 5-1: Details of all variables and predictor variables used in model development

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**Habitat variables used to obtain models of hyaena occurrence probability**

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<b>Variable</b>	<b>Description</b>	<b>Method of measurement</b>	<b>Data source</b>
Drainage distance	Drainage Euclidean mean	DGE-DM-Arc View	FW-DC
Water body distance	Water body Euclidean mean	DGE-DM-Arc View	FW-DC
Village distance	Village Euclidean mean	DGE-DM-Arc View	FW-DC
Scrub forest	Land cover type	LI-SC-ERDAS	www.landcover.org
Mines and Industries	Human disturbance Euclidean mean	DGE-DM-Arc View	FW-DC
Dam/Check dam distance	Dam/Check dam Euclidean mean	DGE-DM-Arc View	FW-DC
Seasonal crop	Land cover type	LI-SC-ERDAS	www.landcover.org
Village count	Number of village points	DGE-DM-Arc View	FW-DC
Grassland vegetation	Land cover type	LI-SC-ERDAS	www.landcover.org
Annual crop	Land cover type	LI-SC-ERDAS	www.landcover.org
Savannah vegetation	Land cover type	LI-SC-ERDAS	www.landcover.org
Sparse vegetation	Land cover type	LI-SC-ERDAS	www.landcover.org
Road distance	Road Euclidean mean	DGE-DM-Arc View	FW-DC
Bare patch-No vegetation	Land cover type	LI-SC-ERDAS	www.landcover.org
Rocky vegetation	Land cover type	LI-SC-ERDAS	www.landcover.org
Road density	Road density	DGE-DM-Arc View	FW-DC

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DGE-DM-Arc View = Digitized using Google earth - converted into distance maps in Arc View (v.3.2)

LI-SC-ERDAS = LANDSAT images -Supervised Classification in ERDAS Imagine 9.2 program.

FW-DC = Fieldwork-Data collection

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Table 5-2: Habitat variable used to obtain models of hyaena occurrence probability.

Using the habitat variables measured at presence locations, four alternatives MaxEnt models (Table 5-3) were derived for hyaena distribution using substitutable subsets of presence-only data, using same environment variables (predictors) for all: 1) Composite: radio telemetry locations and all other direct and indirect evidence 2) Combined shelter: only den and refuge sites were used 3) Refuge: used only refuge site (day resting/rendezvous site) data used and 4) Den sites: only den site (breeding site/centre of activity) data were used. We considered the possibility that a suite of four models might predict the potential distribution better than any single model. In the present study linear, quadratic, threshold and hinge features were used to generate the MaxEnt model with 10,000 background points, 100 iterations and Area under Curve (AUC) more than 85%. To avoid the bias of autocorrelation, the covariates with less than 70% correlation, checked through ENM Tools (Warren and Seifert 2011) were used

<b>Presence locations used in modelling</b>		
<b>Model</b>	<b>Presence data type used</b>	<b>Total database used (n)</b>
Composite	Radio telemetry location, Road kills, Direct sighting, Indirect signs of spoors and scats, Camera trap data, Refuge sites and Den sites	9105
Refuge sites	Day resting /rendezvous site	346
Den sites	Breeding site/centre of activity	130
Combined shelter	Den and Refuge sites	476

Table 5-3: Presence –only data set used in modeling

### **Model validation**

The area under the ROC curve (AUC) is a performance measure valid for any species modelling method, which measures the quality of a ranking of sites (Fielding and Bell 1997). A random ranking has on average an AUC of 0.5, and a perfect ranking achieves the best possible AUC of 1.0. Models with values above 0.75 are considered potentially useful (Elith 2002).

The AUC is the probability that a randomly chosen presence site will be ranked above a randomly chosen absence site. Sometimes there are no absence data with which to measure AUC (Phillips and Dudík 2008), like in the case of the current study. In such case, an AUC can be calculated by using background data chosen uniformly at random from the study area, in place of true absences. The interpretation changes accordingly: the AUC is now the probability that a randomly chosen presence site is ranked above a random background site (Phillips et al. 2006). This suggests that in the final model, a cell predicted as suitable habitat; at any threshold of suitability, will be more suitable than a randomly selected cell in the study area at least 79 % of the time for 'Composite model', 85% of the time for 'combined shelter model', 91% of the time for 'refuge model' and 79% of time for den model, respectively.

### 5.3 Results

The area under the Receiver operating characteristic (ROC) curve, AUC, is a performance measure valid for any species modelling method, which measures the quality of a ranking of sites (Fielding and Bell 1997). A random ranking has on average an AUC of 0.5, and a perfect ranking achieves the best possible AUC of 1.0. Models with values above 0.75 are considered potentially useful (Elith 2002).

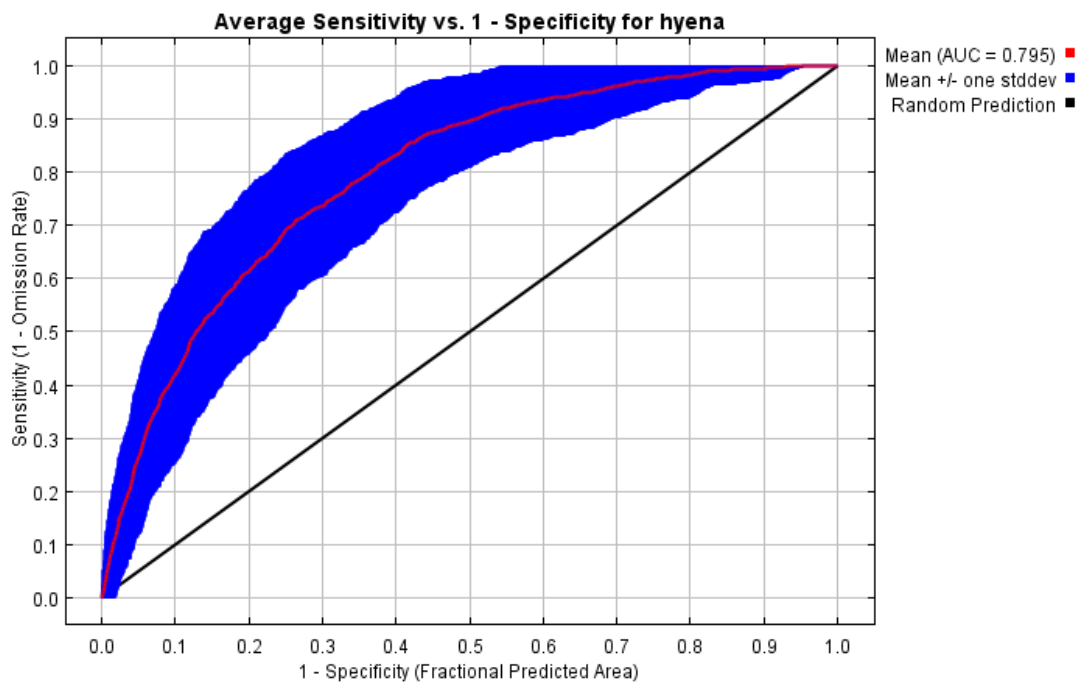


Figure 5-19: AUC - Model fit for Composite model

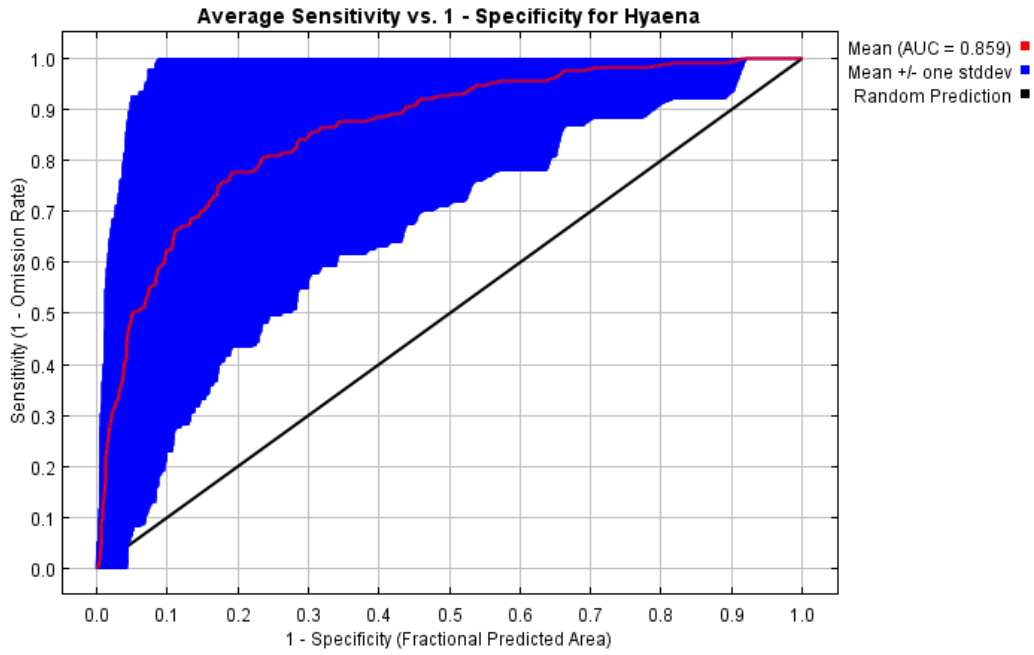


Figure 5-20: AUC- Model fit for Combined shelter model

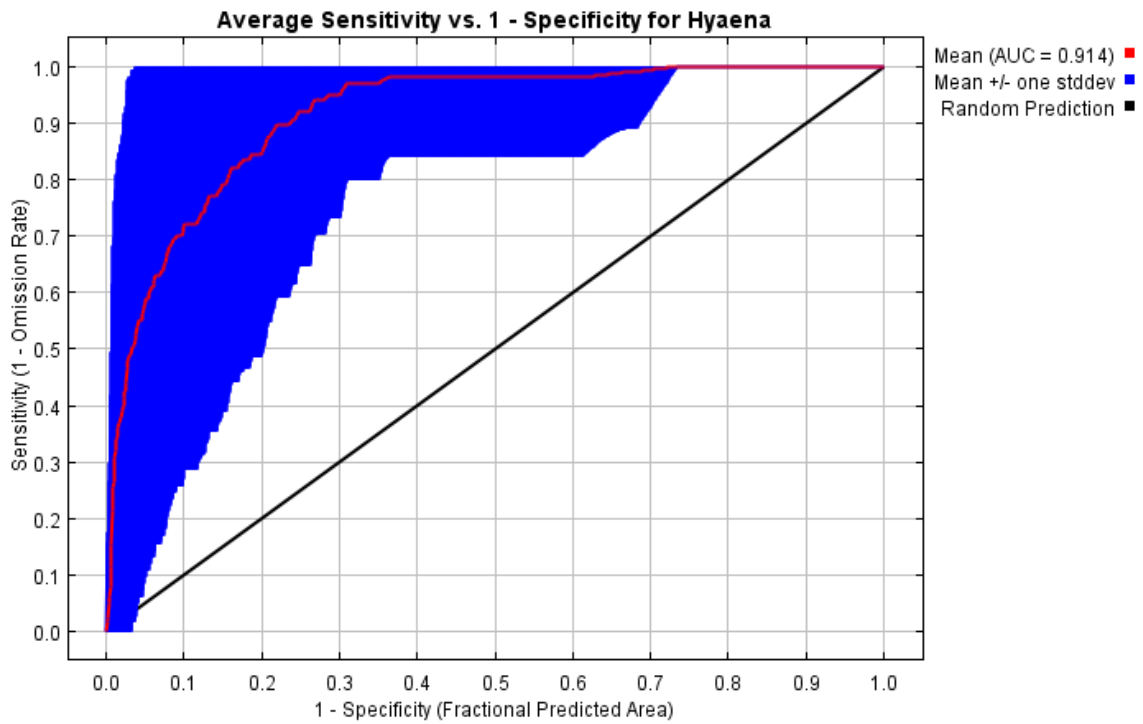


Figure 5-21: AUC- Model fit for Refuge site model

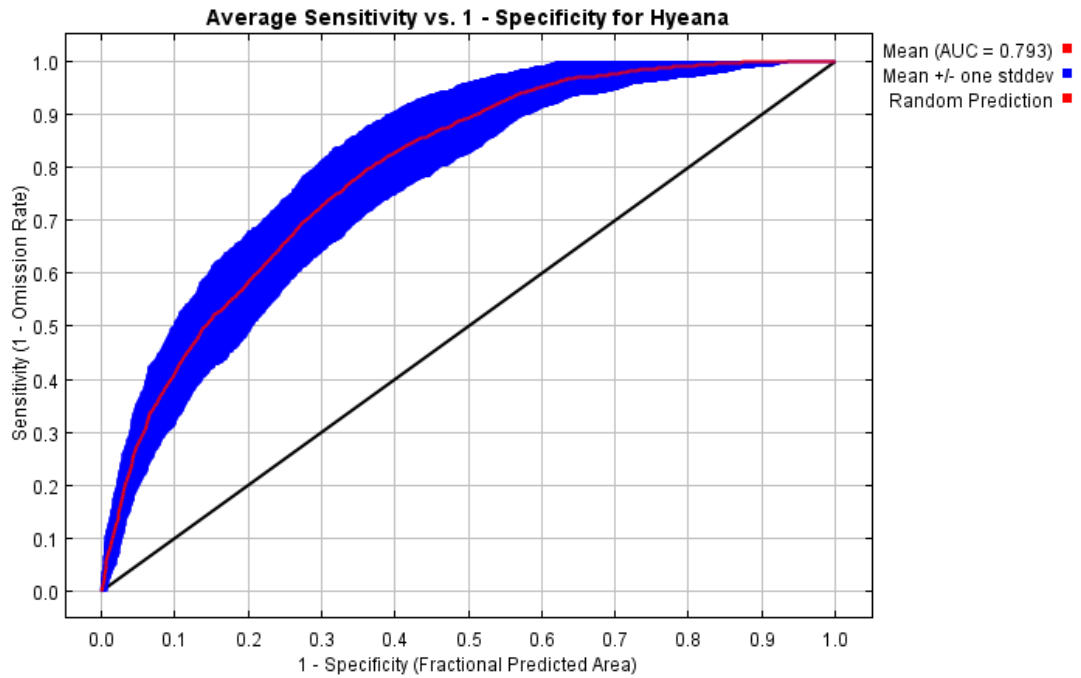


Figure 5-22: AUC- model fit for Den site model

### 5.3.1 Composite model

The final habitat suitability model shows varying levels of habitat suitability fragmented in less suitable habitat (Figure 5-23).

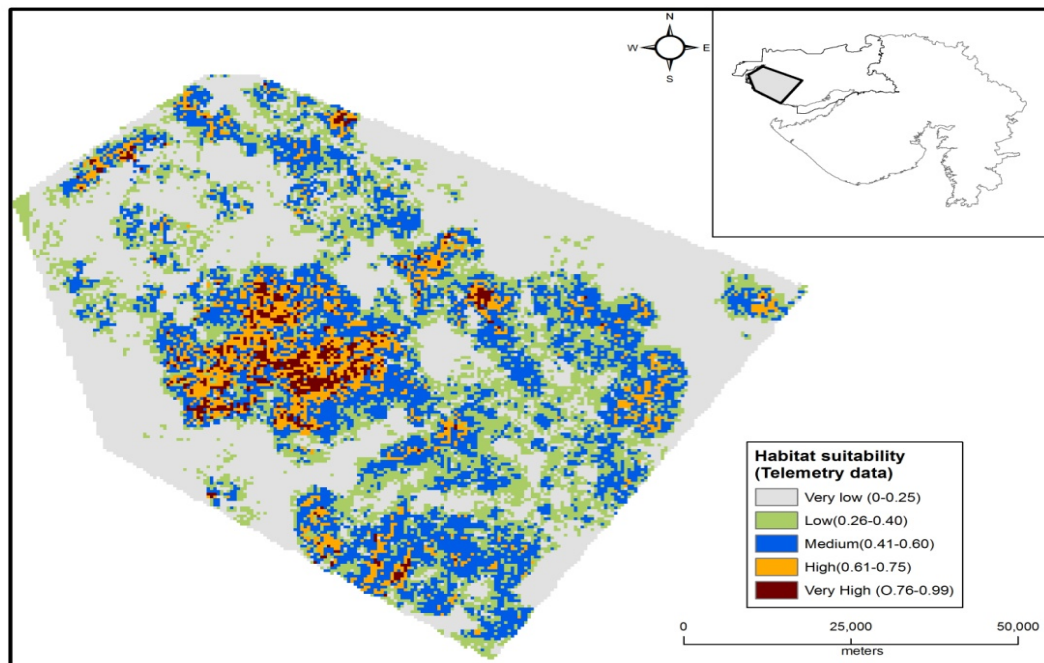


Figure 5-23: Predictive distribution model for hyaenas using composite model in the study area.

In this model, hyaena habitat selection was largely influenced by proximity to large-scale human disturbances (mines, quarries and industries), scrub forests, seasonal crops and distances from villages (Table 5-4:).

<b>Variable</b>	<b>Percent contribution</b>
Mines and Industries	20.4
Scrub forest	17.9
Seasonal crop	16.6
Village distance	11
Dam/Check distance	10.7
Water body distance	10.1
Sparse vegetation	4.2
Road distance	3.6
Drainage distance	1.5
Rocky vegetation	1.3
Savannah vegetation	1.1
Grassland vegetation	0.5
Annual crop	0.5
Bare patch-No vegetation	0.4
Village count	0.3
Road density	0.1

Table 5-4: Percentage contribution of predictor variables for Composite model.

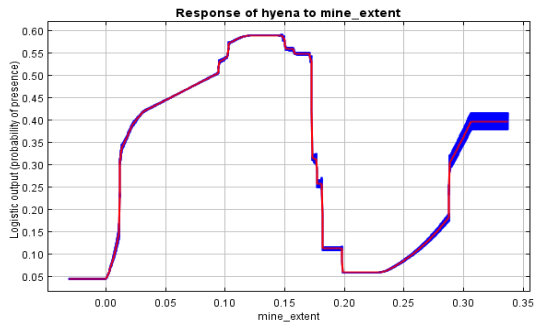


Figure 5-24: Mine and industries predictor response for Composite model

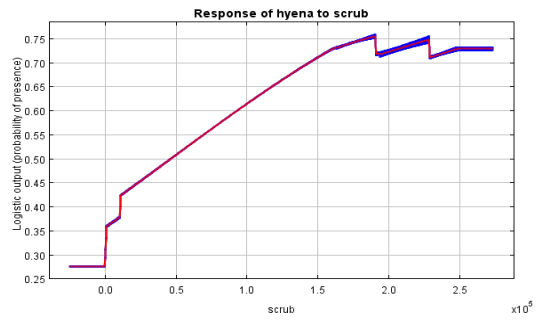


Figure 5-25: Scrub forest predictor response for Composite model

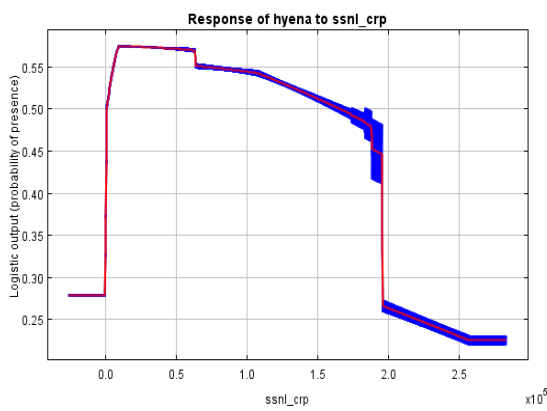


Figure 5-26: Seasonal crop predictor in composite model

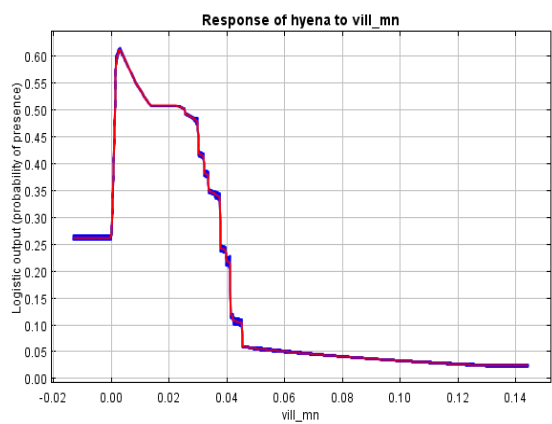


Figure 5-27: Village distance predictor response in composite model

### 5.3.2 Combined shelter model

The final habitat suitability model shows patches of habitat suitability fragmented in less suitable habitat (Figure 5-28). In this model, hyaena shelter (refuge and den site) selection was largely influenced by distance to drainage, proximity to large-scale human disturbances (mines, quarries and industries), distances from villages and distance from water body (Table 5-5).

<b>Variable</b>	<b>Percent contribution</b>
Drainage distance	30
Mines and Industries	13.6
Village distance	12.2
Water body distance	12.1
Scrub forest	9.9
Road distance	5.5
Seasonal crop	3.6
Dam/Check distance	2.8
Sparse vegetation	2.8
Annual crop	2.8
Rocky vegetation	1.7
Savannah vegetation	1.6
Bare patch-No vegetation	0.7
Village count	0.6
Grassland vegetation	0.2
Road density	0

Table 5-5: Percentage contribution of predictor variables for Combined Shelter model

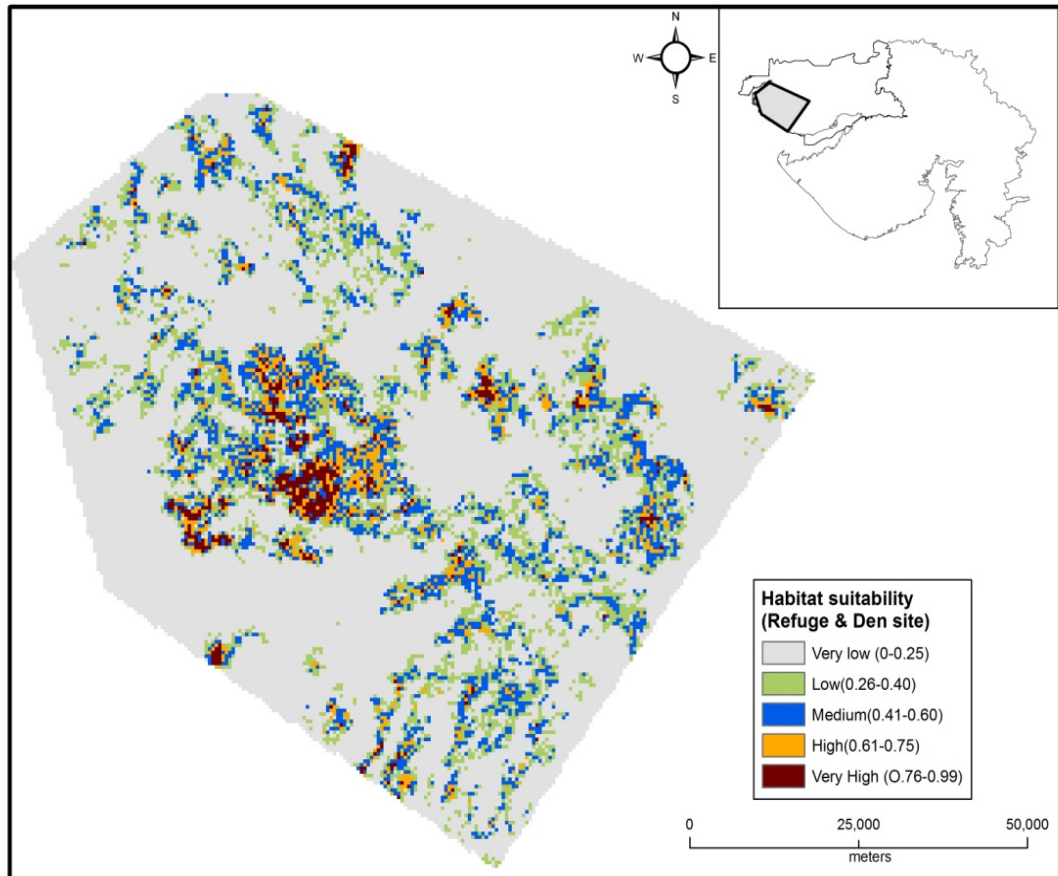


Figure 5-28: Potential distribution model for hyaenas using combined shelter model

A strong positive correlation between drainage and probability of hyaena shelter site presence and a negative relationship with distance to drainage (greater the distance from drainage areas – lesser the probability) was found. A fluctuating relationship of the hyaena with mines and industries predictors in the model (Figure 5-32) is similar to the trend observed in ‘composite model’. There is a positive response between water body and probability of hyaena shelter

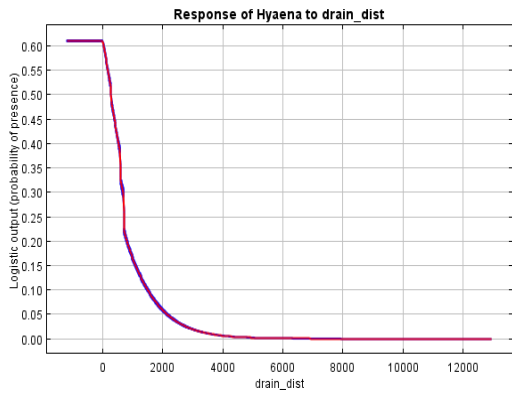


Figure 5-30: Drain distance predictor response of the Combined shelter model

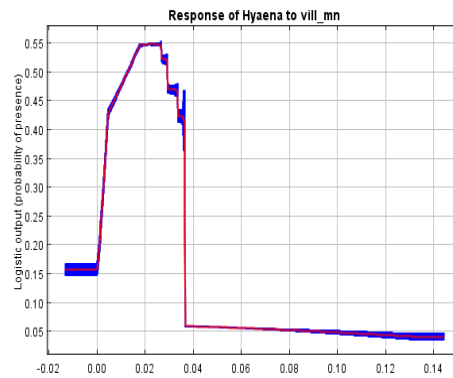


Figure 5-29: Village distance predictor response of the Combined shelter model

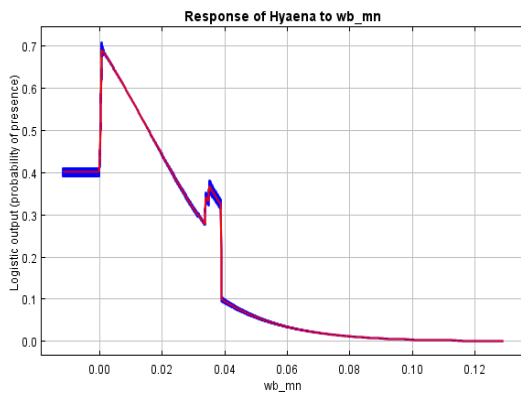


Figure 5-31: Water body predictor response of the Combined shelter model

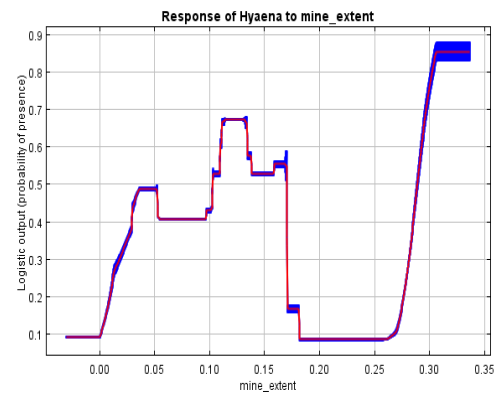


Figure 5-32: Mine and industries predictor response of the Combined shelter model

### 5.3.3 Refuge site model

The final habitat suitability model shows very few suitable refuge sites in the largely low suitability habitat (Figure 5-33). In this model, hyaena refuge site selection was largely influenced by distance to drainage, proximity to large-scale human disturbances (mines, quarries and industries), distances from dam/check dam and scrub forest (Table 5-6).

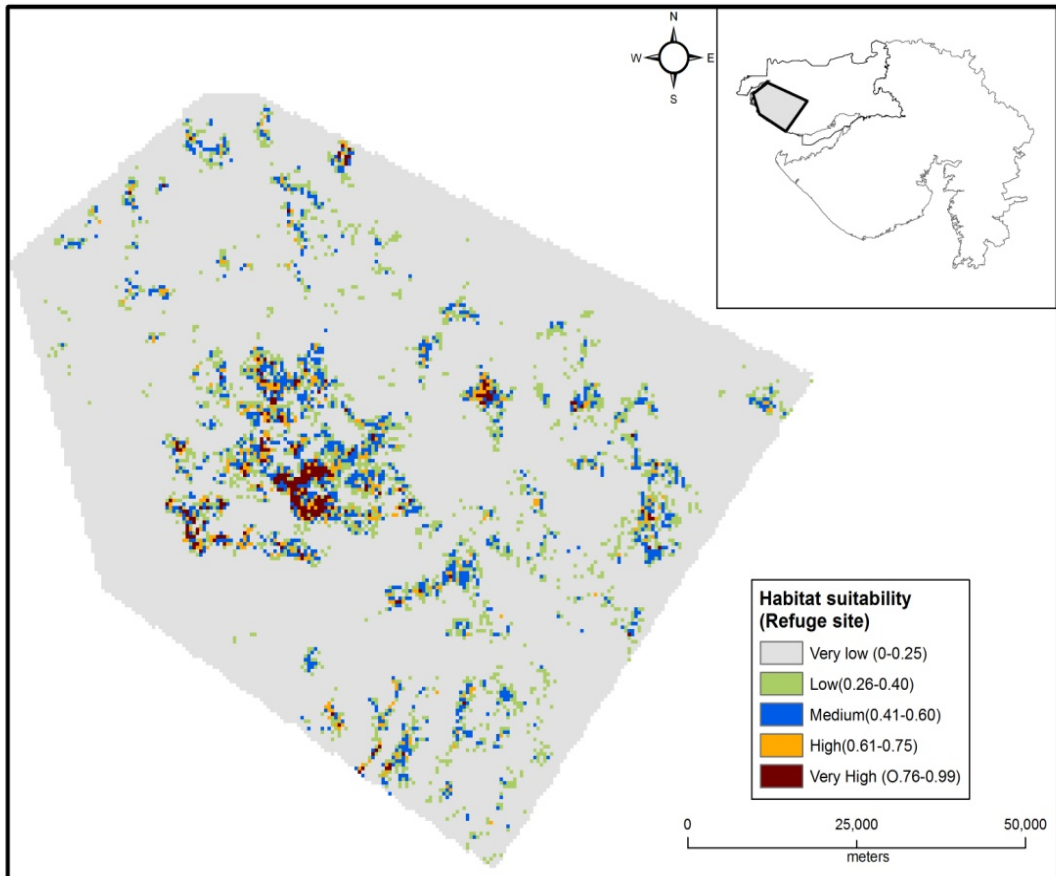


Figure 5-33: Potential distribution model for hyaenas using Refuge site model

Variable	Percent contribution
Drainage distance	18.7
Mines and Industries	14.1
Dam/Check distance	14
Scrub forest	13.4
Seasonal crop	13
Village distance	8.6
Water body distance	7.9
Road distance	3.2
Sparse vegetation	3.2
Savannah vegetation	2
Grassland vegetation	0.6
Rocky vegetation	0.4
Village count	0.4
Bare patch-No	0.3

vegetation	
Annual crop	0.2
Road density	0

Table 5-6: Percentage contribution of predictor variables for Refuge site model

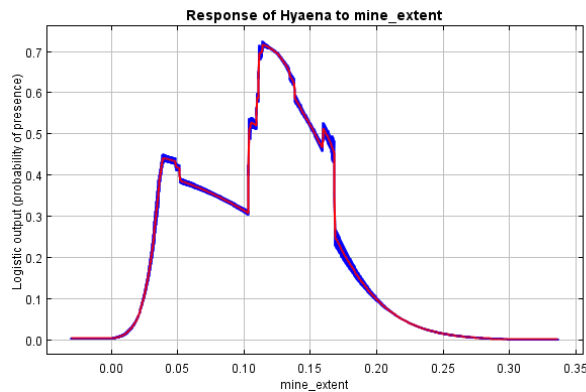


Figure 5-35: Mine and industries predictor response of Refuge site model

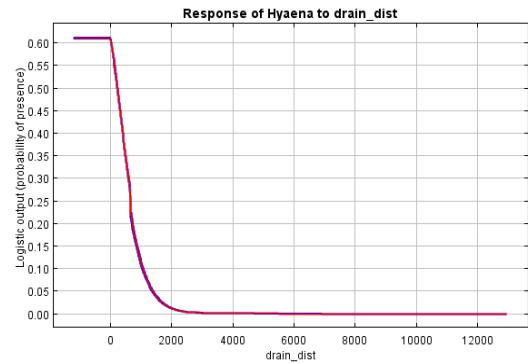


Figure 5-34: Drain distance predictor response of Refuge site model

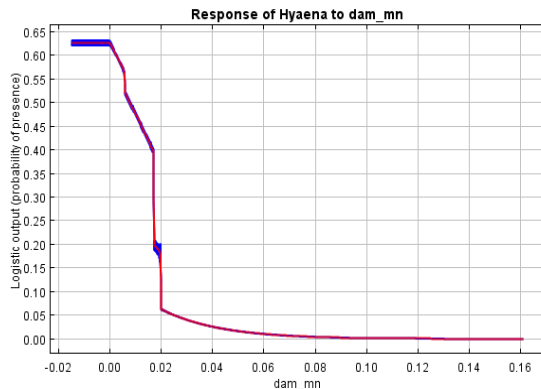


Figure 5-37: Dam/Check Dam distance predictor response

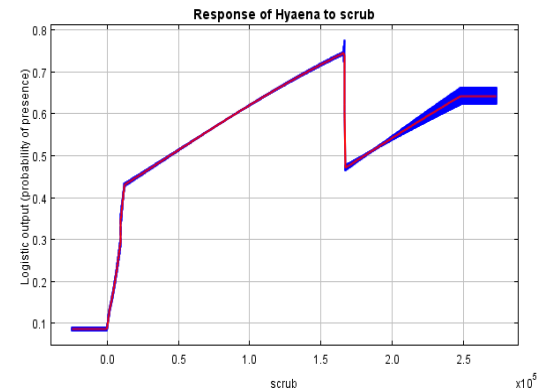


Figure 5-36: Scrub forest predictor response in refuge site model

The response to the drainage distance predictor (Figure 5-34) is similar to the pattern observed in ‘combined shelter model’. The response to the dam/check dam predictor (Figure 5-37) is similar to drainage distance predictor in this model. Like other models, for this model also a fluctuating relationship of the hyaena with mines and industries predictors is observed (Figure 5-35). An increasing trend was observed with scrub forest as predictor variable (Figure 5-36)

### 5.3.4 Den site model

The final habitat suitability model reflects proportion of area available for den sites (Figure 5-38). In this model, hyaena den site selection was largely influenced by distance to drainage, distances from water body, distance from village and scrub forest (Table 5-7).

<b>Variable</b>	<b>Percent contribution</b>
Drainage distance	33.7
Water body distance	12.9
Village distance	12.9
Scrub forest	9
Mines and Industries	6.6
Dam/Check distance	4.4
Seasonal crop	4.2
Village count	2.8
Grassland vegetation	2.5
Annual crop	2.4
Savannah vegetation	2.3
Sparse vegetation	2.1
Road distance	1.7
Bare patch-No vegetation	1.6
Rocky vegetation	0.6
Road density	0.4

Table 5-7: Percentage contribution of predictor variables for Den site model

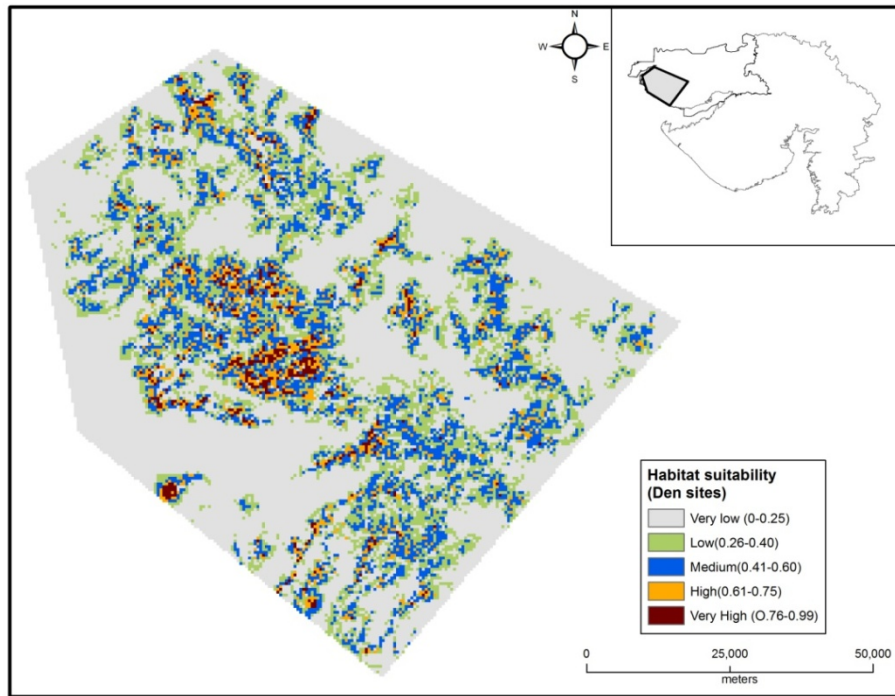


Figure 5-38: Potential distribution model for hyaenas using Den site model.

The response to the drainage distance predictor (Figure 5-39) is comparable to the pattern and trend observed in ‘combined shelter model’ and ‘refuge site model’. The relationship with water body distance predictor (Figure 5-41) is similar to drainage distance predictor and the relationship of hyaenas with village distance (Figure 5-40) is similar to that observed in ‘combined shelter model’, sites actively selected at an optimal distance from the village (which are important foraging locations, see Chapter 4)

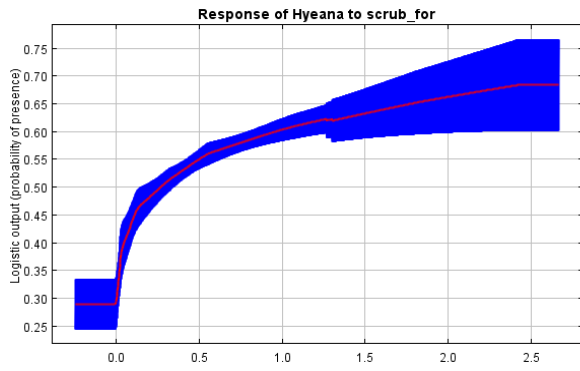


Figure 5-40: Village distance predictor response for Den site model

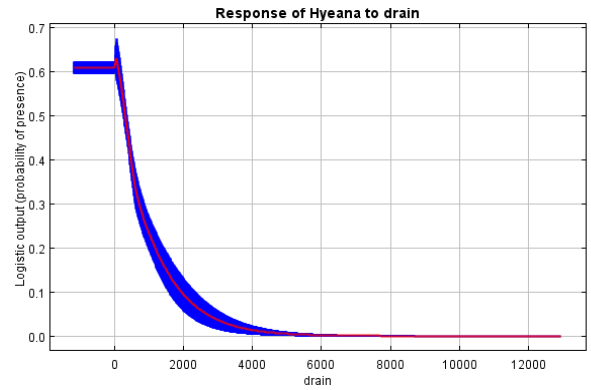


Figure 5-39: Drain distance predictor response for Den site model

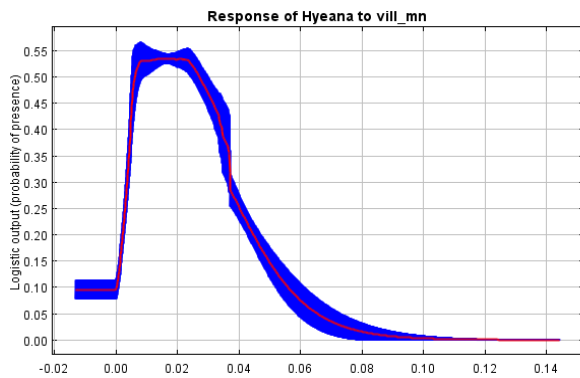


Figure 5-42: Scrub forest predictor response for Den site model

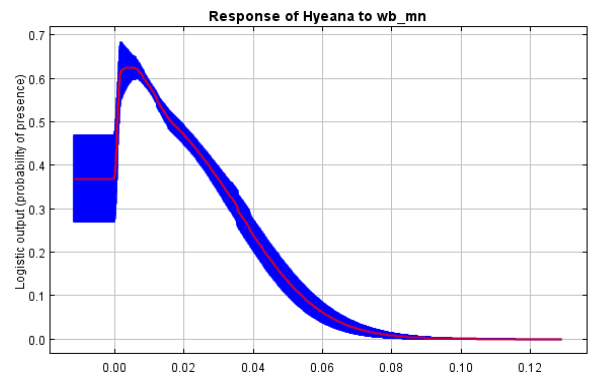


Figure 5-41: Water body predictor response for Den site model

To understand the distribution of the variables of habitation, road, mines, scrub forest cover, I quantified the frequency of these components in each grid, while also comparing the minimum distance between two grids having the same variable. In the case of scrub forest cover, the proportion was quantified.

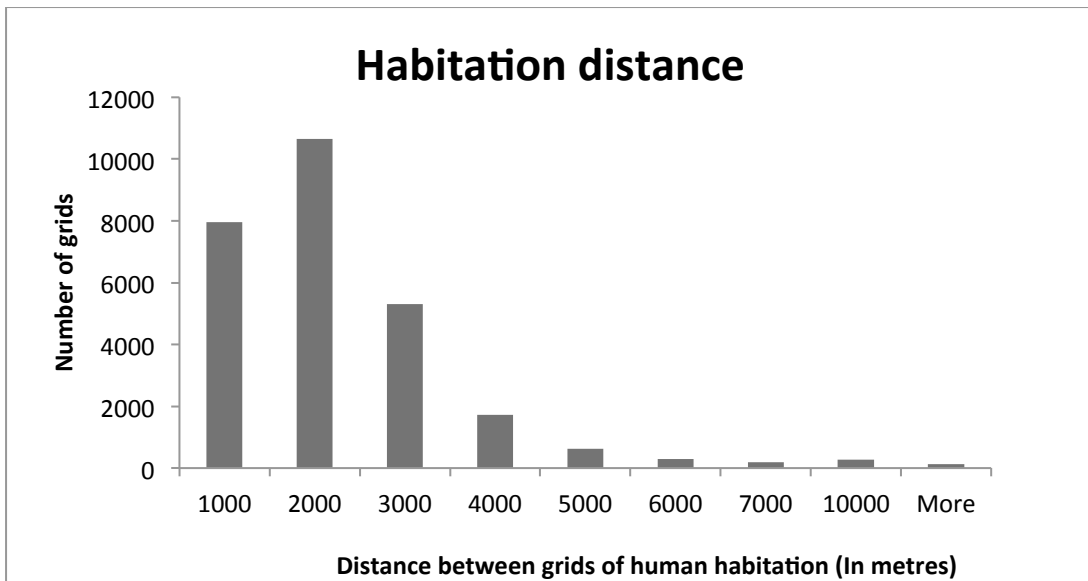


Figure 5-43: Graph showing the number of grids having human habitation and the minimum distance between them (in metres) in the study area

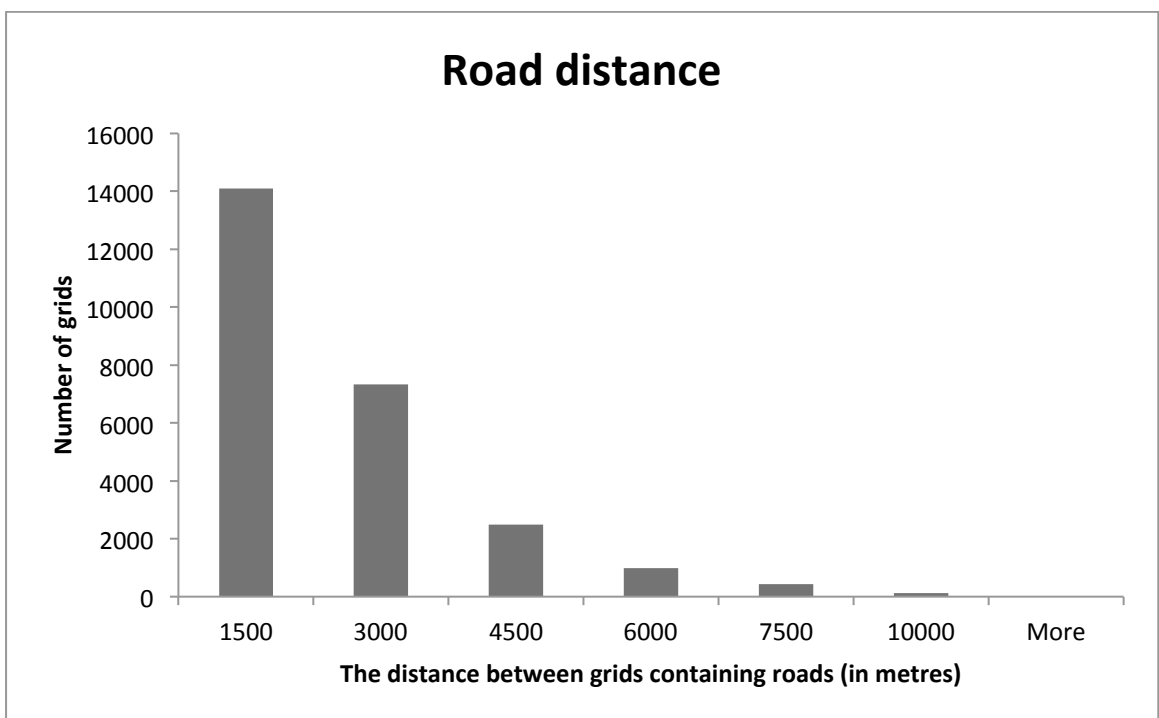


Figure 5-44: Graph showing the number of grids having roads and the minimum distance between them (in metres) in the study area

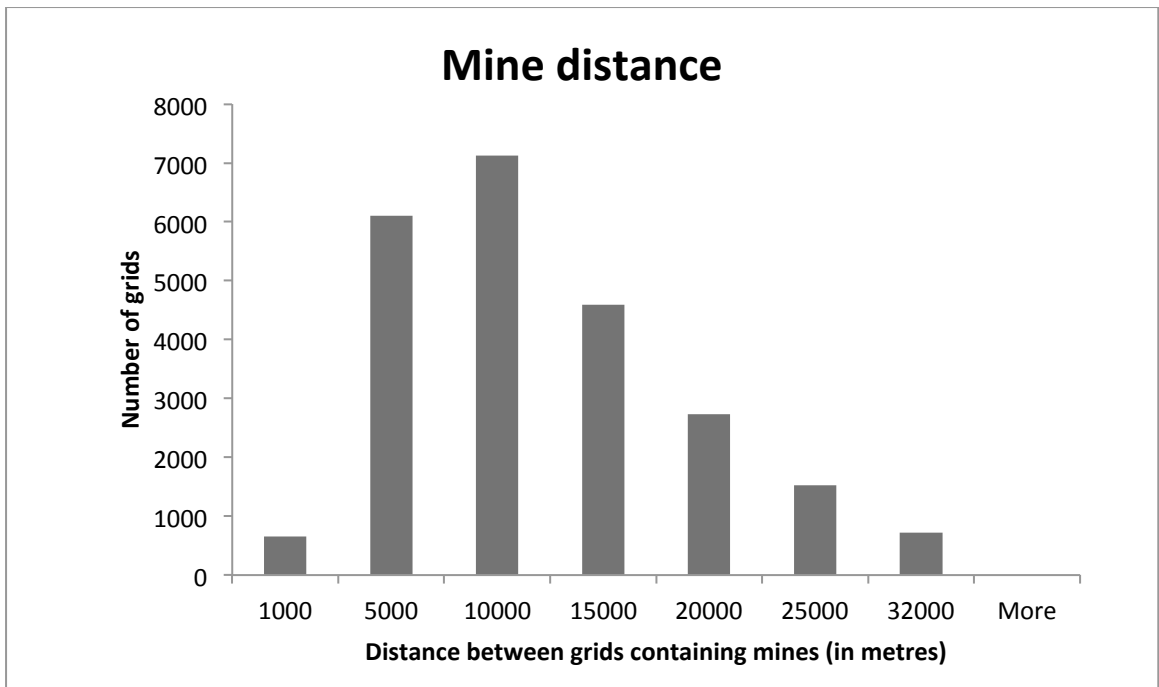


Figure 5-45: Graph showing the number of grids having mines and the minimum distance between them (in metres) in the study area

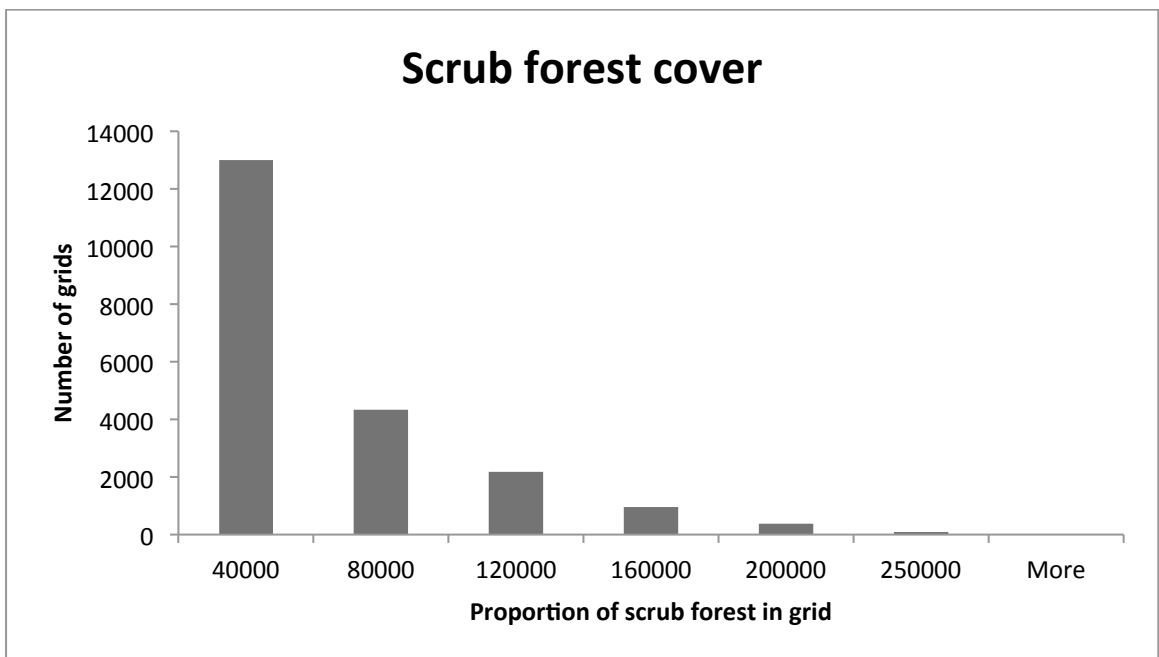


Figure 5-46: Graph showing the proportion of scrub forest in each grid and the number of grids in the study area.

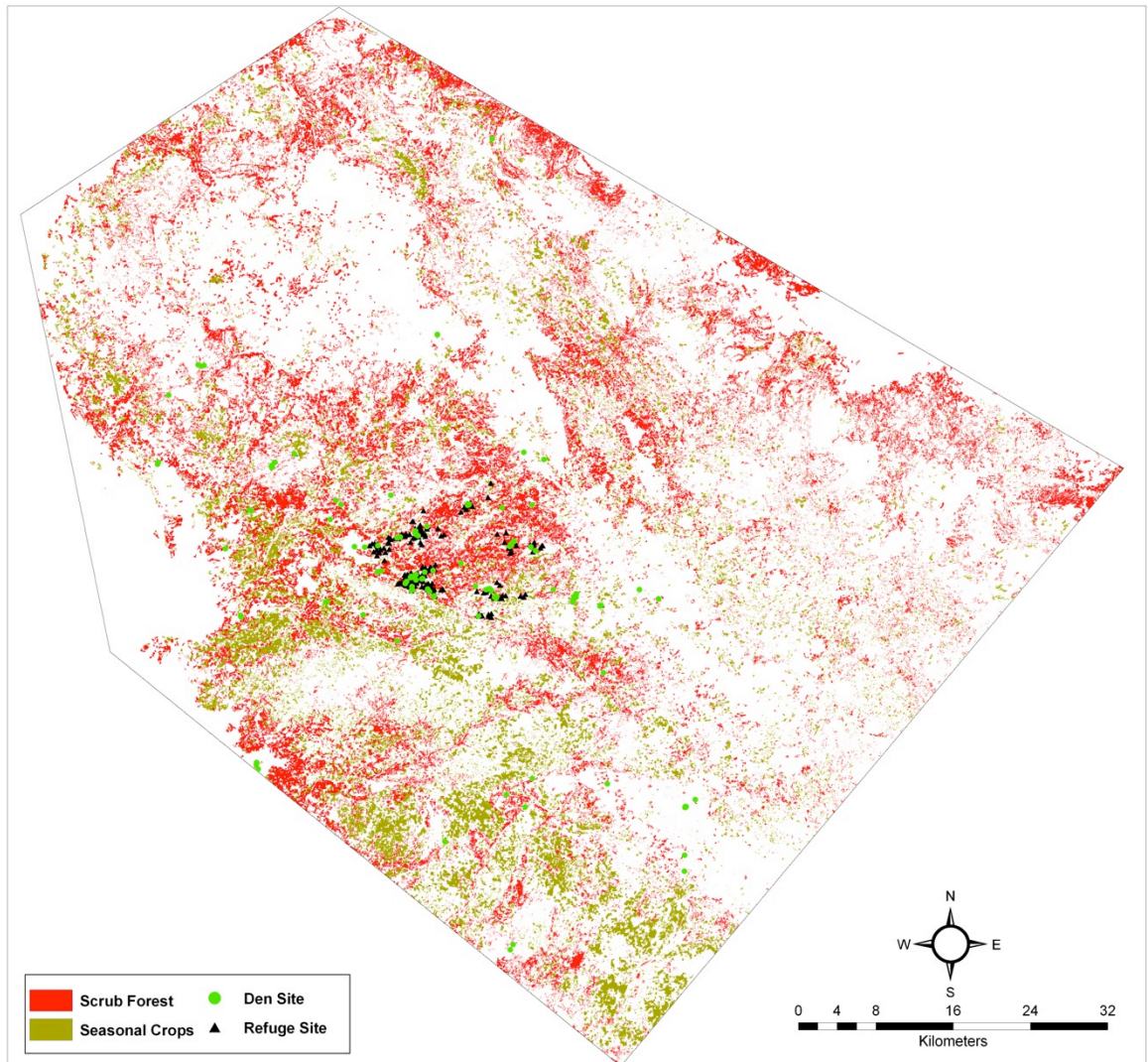


Figure 5-47: The availability of Scrub forest and seasonal cropland in the study area with Den and refuge locations.

From Figure 5-47, it is evident that the scrub forest cover is wide spread in the study area and invariably the den and refuge sites are in the proximity. This has a greater impact on the prediction modeling.

## 5.4 Discussion

### 5.4.1 Composite model

A positive response of the model to scrub forest (Figure 5-25) may be explained by the hyaena's movement pattern in the landscape, since in this model radio telemetry based database were used; along with significant locations, many incidental locations were also recorded (mostly moving between foraging locations, den sites and other important sites). Other possible explanation would be the occurrence of highly invasive introduced *Prosopis juliflora* that has colonized large tracts in the study area (Figure 5-47), which are invariably used by hyaenas. We are cautious in interpretation of scrub forest as the important environmental predictor for this model, bearing in mind that presence of an animal at a particular location does not imply it is actively selected by the animal (for some requirements cover is preferred-like refuge sites selection). But it does reflect the intensity of type habitat use.

A negative response is observed for seasonal crop in the model (Figure 5-26), avoidance of these areas by hyaenas are for apparent reasons; these croplands are guarded (guard dogs are also employed) at night time against crop raiders, the presence of humans and dogs deter hyaenas from using it. This probably also explains frequent usage of scrub habitat type for movement. But we have evidence to believe that hyaenas do occupy these croplands in transit (57% of radio collared individuals, n=4, died in snares in these seasonal agricultural areas), but the duration of usage is short, hence underrepresented in the data set.

The relationship of hyaenas with village distance (Figure 5-27) is of significance, the further we move from village areas we observe a decline in probability of hyaena presence. Village areas are important foraging sites for the species, facilitated by the maintenance of traditional pastoralist lifestyles. Most of their movement pattern is governed by the location of villages in the landscape (See Chapter 4). But, hyaena dens found at an optimal distance is not an artefact of den selection; rather the availability of space, from (Figure 5-43) it is evident that most villages in the study area are between 1 and 3 kms from each other. Therefore, hyaenas are in fact selecting the furthest point from any village as den site.

Among other predictors (See Appendix.1) Dam/check dam distance and water body distance have similar correlation like that of village distance predictor- probability of hyaena presence decline with increasing distance from these two variables. Dam/check dam are a proxy for water presence and potential shelter (den and refuge). Considering these two predictors together, water resource seem important criteria for habitat selection. But, it should be noted here that most of the dams (especially check dams) are recent feature in the landscape; so it is hypothesized these feature ideally should benefit already existing occupancy criteria, rather than governing it.

#### **5.4.2 Combined shelter model**

A strong positive correlation between drainage and probability of hyaena shelter site presence and a negative relationship with distance to drainage (greater the distance from drainage areas –lesser the probability) (Figure 5-30); may be explained by the hyaena's preference for areas that tend to be undulating, eroded, rocky, vegetated, remote and less accessible to humans and other animals (mostly livestock and dogs in the study area).

The fluctuating relationship of the hyaena with mines and industries predictors in the model (Figure 5-32) is similar to the trend observed in 'composite model', and also can be attributed to the same reasons; the high fluctuations with no clear pattern, accounts for multiple presence sites recorded from imminent developmental areas and few sites still used (especially refuge sites) in areas within their threshold of tolerance. This can viewed as the behaviour specific process of choosing habitat, in context of site fidelity, adaptability and vulnerability of the species.

The relationship of hyaenas with village distance (Figure 5-29) is similar to that observed in 'composite model', it appears that locations are actively selected at an optimal distance from the village sites (which are important foraging locations, see chapter.3); providing the opportunity of protection to resting/denning sites and easy access to known food sites, contributing to its fitness. It is true for foraging strategy, as villages are important foraging sites, but dens found at an optimal distance is not an

artefact of den selection; rather the availability of space (Figure 5-43), in the study area there is a human habitation every 1 to 3 km.

A positive response is observed between water body and probability of hyaena shelter presence and a negative relationship is evident with distance to water body (greater the distance from water body –lesser the probability) (Figure 5-31); may be explained by its ecological need for water, generally hyaenas favours environments where water is available within 10 km (Rieger and Weihe 1975).

Among other predictors (See Appendix.2) positive response of the model to scrub forest is observed; reflect the preference of hyaenas to thick vegetation for refuge sites and presence of cover in most den sites. Road distance predictor indicates that hyaena shelter like in case of villages distance, are selected at an optimal distance from road. But, like human habitations, road networks in study area are widespread (Figure 5-44); therefore the optimal distance is in fact the availability of space, rather than a preference.

#### **5.4.3 Refuge site model**

The response to the drainage distance predictor (Figure 5-34) is similar to the pattern observed in ‘combined shelter model’, also can be attributed to the same reasons; also large number of refuge points were located in gullies, gully head starts and eroded river banks (inclined towards depressions/drainages-probably the selected sites is associated with temperature difference (keeping the animal cooler during the day time).

Like other models, for this model also a fluctuating relationship of the hyaena with mines and industries predictors is observed (Figure 5-35) and can be attributed to the similar reasons; accounts for multiple presence sites recorded from imminent developmental areas and few refuge sites still used in areas within their threshold of tolerance. The sudden drop in threshold, may be explained by the sampling technique for refuge sites; majority of the sites could only be located with telemetry, hence almost all the presence sites are located within ISA (which is generally free of mines and industries), creating a bias in background information. Estimating habitat preference by pooling telemetry data from all individuals is likely to bias the results

towards certain data-rich individuals, types of individuals or regions of geographical space. (Aarts et al. 2008)

The response to the dam/check dam predictor (Figure 5-37) is similar to drainage distance predictor in this model; greater the distance from dam/check dam –lesser the probability of presence. This can be explained by the site selection for dam/check dam (especially smaller check dam) construction; many check dams are recent additions to the landscape features, sites selected were similar to refuge site selections/near refuge sites-in gullies and eroded landscape to enable water collection.

An increasing trend was observed with scrub forest as predictor variable (Figure 5-36); it can be attributed to the fact that most of the refuge sites were located in thickets (to avoid detection and to take advantage of cooler temperatures), also nearly all refuge sites in gullies, gully head starts and eroded river banks were covered in thick vegetation. The observed fluctuations can possibly be explained by the presence of few refuge sites which are not located in any vegetated habitat, rather in rock crevices, between boulders and in erosion features (pits, undercuts etc.) (Figure 5-47).

Among other predictors (See Appendix.3), the negative response to seasonal crops can be avoidance of these anthropogenic areas; and this parameter is correlated with check dams (more check dams/dams coming up in the area leads to new agricultural lands close to potential refuge sites), hence a tendency to shift refuge sites from around seasonal crop predictors areas as compared to annual crop predictors (which are mostly around villages and a regular feature in the landscape). Distance from village carries the same explanation as ‘Composite model’. A positive response to water body predictor, is similar to ‘combined shelter model’ for the similar reasons, the contribution of this predictor is more in the ‘combined shelter models’ as the accounts for additional den presence data sets.

#### 5.4.4 Den site model

The response to the drainage distance predictor (Figure 5-39) is comparable to the pattern and trend observed in ‘combined shelter model’ and ‘refuge site model’ on similar rationale. The relationship with water body distance predictor (Figure 5-41) is similar to drainage distance predictor, may be explained by its water requirement, especially during breeding season (Rieger and Ruppert 1978); and also that few dens have been located on the bunds and slopes of large water bodies/or very close to it.

The relationship of hyaenas with village distance (Figure 5-40) is similar to that observed in ‘combined shelter model’. A positive response to scrub forest (Figure 5-42) is similar to one observed in ‘refuge model’; but the trends are dissimilar here, unlike refuge sites where the site selection criteria is vegetation cover, den site selection is site specific with or without vegetation- and most of the recorded den sites do have vegetation around it (which may have come up after den selection), vegetation around the dens does have its advantages- but it is not a selection criteria.

Among other predictors (See Appendix.4), the slightly fluctuating relationship of the hyaena den sites with mines and industries predictors in the model can be explained by the presence few den sites close to mines and industries/ or establishment of mines or industries in previously known den sites. Response to dam/check dam distance predictor is similar to water body distance predictor, the contribution to the model being lower; the rationale is that few dens were located on the bunds of huge dams/ or dams and check dams were constructed close to the dens.

The species distribution predictors differed greatly between composite model and other three models – Complete shelter, Refuge sites & Den sites (but only slightly among these three). The inference derived from combination of all models indicate drainage distance, village distance, road distance, mines and industries, water body distance, dam/check dam distance, scrub forest and seasonal crop were the dominant drivers of hyaena distribution in the ‘areas of interest’. Human disturbance (mines and industries) improved the discriminatory power of all models in which it was included. Agricultural lands (seasonal crops) showed a strong relationship with hyaena habitat suitability in composite models. Interestingly, road density provided a less predictive

suitability in composite models. Interestingly, road density provided a less predictive ability, while road distance had a much lower effect on model performance. This suggests that hyaena relative habitat suitability is highly related to human habitation and activities (mines, industries and seasonal crop) in the landscape, but less related to proximity to road networks. May be this can provide some explanation for the 20 odd hyaena road kills observed during the entire study period. The comparatively weak role of different habitat types (land cover types) may also be related to the high mobility and adaptability of the species, which allows it to integrate across landscapes of different land use and land cover type, that a fragmented patch mosaic may not function as poorly connected habitat for this species, so long as the fragmentation is not by landscape elements avoided at broad scales, such as mines and industries. Within the land cover type usage, shrub forest was more influential than other types. This can be attributed to the wide spread of shrub forest in the study area (Figure 5-47, Figure 5-46) provides cover, refuge, supplementary foraging opportunities and importantly connection areas through which hyaenas can move between other habitat/resource types. Thus the spatial connectedness of shrub forest could be classified as an important factor for refuge, matrix permeability, and also in providing habitat for dispersing hyaenas. Drainage distance is the most influential in the other three models (combined shelter, refuge site and den site), supporting our argument that drainages are a major component of den site selection of the species.

## **5.5 Conclusion**

The models generated by MaxEnt have a natural probabilistic interpretation, giving a smooth gradation from most to least suitable conditions; and the models can be easily interpreted by human experts (Philips *et al.*, 2004). We were cautious in interpretation of model prediction bearing in mind the study design and the biases inherent in the presence data. All models performed well; the refuge model (AUC=0.91) displayed a higher performance than combined shelter model (AUC=0.85), composite model and den model (AUC=0.79, respectively).

Consistent with our knowledge of the area of interest, none of the models overestimated areas of potential presence; in fact refuge site model underestimated the potential distribution in the area of interest. Other models (composite, combined

shelter and den site) appear to give a reasonable estimate of the extent of the species' potential distribution.

Refuge site model was developed using only telemetry-based presence data (refuge site) restricted to ISA. Which is of likely to suffer from sample selection bias, and affecting the model prediction; and this may explain the underestimation of potential distribution. The high performance (AUC=0.91) can be attributed to large number of accurate presence data location in ISA; and probably a 'good' model for ISA, but a poor model for the intended area. Also, based on field experience it is evident that choice of refuge sites are behaviour-specific; implying that other factors apart from environment are shaping the refuge site distribution.

Combined shelter model was developed using presence data of refuge sites and den sites. The potential distribution projected has failed to account for few areas of distribution included in den models. Though the model performance was better for combined shelter (AUC=0.85) when compared to den model (AUC=0.79); the better performance can be attributed to the large number of refuge sites used as presence data. From field data, it is known that refuge sites are correlated with den sites; in the sense, refuge sites are located in the proximity of active den sites and with den shifts the location of refuge sites closer to the new den site (behaviour-specific selection of site). Refuge site and den site usage can be more complex than explained here, but it is to be understood that ecologically refuge site selection is correlated with den site selection. But in combined shelter model, because of large number of sample biased refuge presence location; the correlation is reversed, hence the failure to include certain potential areas in distribution maps.

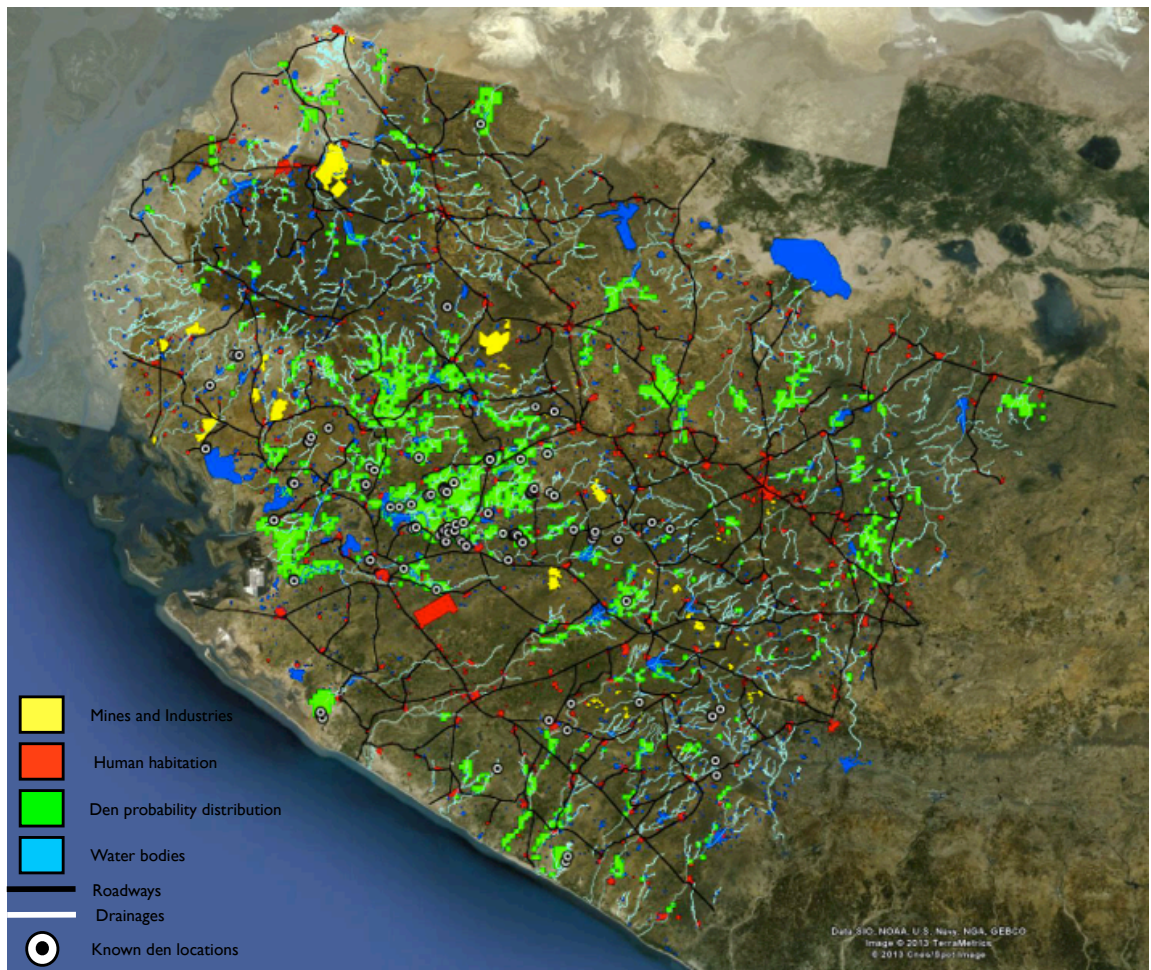


Figure 5-48: Potential hyaena distribution in the area of interest (using den sites).

Composite model was developed using all presence database for hyaena in the landscape. The potential distribution is influence by the telemetry based presence location; hence all movement patterns in the landscape are reflected as the true proportion of pixels of potential presence for the species, as well as their location. In this case, scrub forest habitat is one the major predictor in hyaena distribution. From fieldwork based knowledge and land cover type classification maps (Figure 5-47), it is can be concluded that because of the large spread of scrub land and seasonal crop land, the prediction shows that hyaenas prefer it, but in reality, hyaenas do use all kind of habitat for movement and favours no particular habitat type for movement. The use of the scrub habitat by hyaenas has more to do with the spread and prevalence of this habitat rather than their preference for it. Scrub forest has its advantage of offering cover and refuge, but it is one of the many habitats utilized.

Even habitat fragmentation was not an issue for hyaena movement in the landscape, but den site selection was specific. Ecologically this site selection is crucial to fulfil the species life-history objectives. Also from field work we are aware that these sites play an important role not only to raise litters, but are centre of activity for clan members and play very vital role in the population dynamics of hyaenas in the area. Also hyaenas use their dens for most part of the year (8 months), availability of these sites ensures other hyaena signs (movement related, refuge etc.); the rationale is that den sites are the most crucial and deciding factor for hyaenas. Based on ecological knowledge about the species, the den site model was selected as the best performing hyaena distribution model for the study area (area of interest) (Figure 5-48)

This predictive species distribution model developed with details specific to the study region and population can be applicable across the entire range to predict hyaena locations not only as a function of environmental variables, with modification in region specific variables. This model's application in predicting species distribution across a broad geographic range can be challenging because of variability within and among regions and populations.

## **6 Sociability in striped hyaena populations**

### **6.1 Introduction**

Group-living has been recognized as one of the major transitions in evolution (Lührs et al. 2013). Explaining why some species live in social groups is a long-standing evolutionary challenge, because conspecifics use, and therefore compete for, the same resources (Ridley et al. 2005).

Sociality and group-living can be related to the shared use of space, feeding in groups, foraging in groups, or breeding in groups (Gittleman 1989). Patterns of behaviour, like grouping, are most appropriately understood in terms of the selective benefits of maximizing individual fitness (Wrangham and Rubenstein 1986) directly or indirectly through kin selection (Tilson and Hamilton III 1984). Patterns of sociality in many carnivores are shaped by selection for reduced predation and/or selection for enhanced exploitation of food resources (Gittleman 1989). Social structure is often a key determinant of population biology, influencing fitness, gene flows, and spatial pattern and scale (Wilson Edward 1975).

Most (85%–90%) terrestrial mammalian carnivores are solitary, interacting exclusively with their mates and offspring or conspecifics at territorial boundaries (Holekamp et al. 2000). Among carnivores, the Hyaenidae show great inter and intra specific variability in social organization, ranging from monogamous pairs to large complex groups (Mills 1989). Aardwolves are the least sociable of the extant hyenas; living in socially monogamous pairs, where both males and females are known to mate with individuals other than their social partners (Richardson 1987). Despite this promiscuity, together with their social partners, aardwolves defend territories for food resource (termite mounds); also both males and females participate in rearing the litter. Although mates cooperate in parental care and territorial defense, individual aardwolves forage solitarily (Holekamp et al. 2007).

While, spotted hyenas represent a highly cooperative species among Hyaenidae, their societies (permanent social groups called “clans”, Kruuk (1972b)) considered more complex than those of other gregarious carnivores (Drea and Frank 2003, Holekamp et al. 2007) can consist up to 90 or more individuals with low mean relatedness

(Holekamp et al. 2012). Spotted hyena clans contain multiple adult males and multiple matrilineal lines of adult female kin and their offspring (Frank 1986); individuals within each clan can be ranked in a linear dominance hierarchy based on outcomes of agonistic interactions (Kruuk 1972b, Tilson and Hamilton III 1984, Frank 1986, Smith et al. 2008). Dominance relationships are extremely stable across years and ecological contexts (Frank 1986, Smith et al. 2011); coalition formation plays an important role in acquisition and maintenance of social rank among spotted hyenas (Zabel et al. 1992, Holekamp and Smale 1993, Smale et al. 1993, Engh et al. 2000, Smith et al. 2010). Because social status determines priority of access to kills, high rank has enormous effects on hyenas' net energy gain (Hofer and East 2003, Smith et al. 2008). Maternal phenotype and maternal rank in particular have profound effects on female reproductive success (Holekamp et al. 2012); birth rates and survivorship are greater for high- than for low-ranking hyenas (Watts et al. 2009). As a result of these large networks of allies, high-ranking hyenas have the most social capital (Van Horn et al. 2004, Smith et al. 2010).

Brown hyenas exhibit intermediate sociality that appears to be more complex than that reported in striped hyenas, but not compounded like spotted hyenas. They live in small clans ranging in size from a single female and her cubs to approximately 14 animals (Mills 1990a). Larger clans consist of extended families that include a female, her adult offspring, and immigrant males (Watts and Holekamp 2007). Males that leave their natal area either immigrate into a new clan or become nomadic, only females breed in the natal clan mating with immigrant or nomadic males; allosuckling is observed in adult females, but own offspring are prioritized. Social structuring within brown hyena clans appears to vary among populations, ranging from egalitarian groups to clans with well defined, sex-specific linear dominance hierarchies in which males are socially dominant to females (Mills 1990a). Regardless, all group members cooperate to defend a common territory and also aid in rearing young by bringing food to the den (Watts and Holekamp 2007).

Striped hyenas are the least studied of the hyenas; their social behaviours are poorly understood and are usually reported to be solitary. A recent long term study (Wagner 2006) in Africa reported that striped hyenas live in small groups composed of one adult female and one to three males sharing a common home range. Striped hyenas are behaviourally solitary, but have a polyandrous system of space use, and a

polyandrous or promiscuous mating system. Females appear to mate both with group males and males that reside elsewhere. It is not known whether sires contribute in any way to parental care, but lactating females are usually found alone at dens with their cubs, and females appear to be solely responsible for care of young. Fundamentally, Hyaena spatial groups can be considered breeding groups because all offspring can be assigned to the female of the natal group, and the majority of offspring are sired by males within the natal group (Wagner et al. 2007a). However, the social structures of striped hyaena are not completely understood, described or classified and the possibility of variations across regions can't be ruled out. Descriptions of the species in one habitat can't be generalized to the same species in another set of environmental conditions (Whitehead 2008). Wagner (2006) focused primarily on the mechanisms of group formation (permissive conditions), and not, necessarily, sociality.

Spotted hyaena clans are strikingly similar in their size, composition, and hierarchical organization to social system of Old World monkeys; it has emerged as a non-primate model for investigating the evolution and mechanisms of social cognition and testing hypotheses regarding the evolution of intelligence. Since the social organization demonstrates complex cognitive abilities, it inclines towards the hypothesis that social complexity was a key force selecting for the evolution of intelligence (Holekamp et al. 2007, Smith et al. 2012). However, to test this hypothesis suitably it will be required to compare the cognitive abilities of spotted hyenas with those of other hyena species; lack of some cognitive abilities by less gregarious species of hyenas, will find support for the hypothesis that social complexity favours the evolution of intelligence (Watts and Holekamp 2007). The variability in ecology and social structures exhibited by the extant hyaenas, rationale the importance of Hyaenidae as an exceptional non-primate mammalian model system, to address investigation pertaining to the evolution of carnivore sociality and intelligence (Mills 1989, Watts and Holekamp 2007).

This chapter is an effort to describe sociability in striped hyaena, as the pattern of relationships among clan members; also to explore mechanism of social group establishment, social bonding processes and bond maintenance. Naturalistic observation approach used to gather data on hyaena social behaviour at den sites, there was no experimental manipulations of variables by me. We believe that the results from this study will be able to develop a narrative of structural aspects of

striped hyaena social systems, enabling better understanding and prediction of hyaena behaviour in general and adaptive utility of striped hyaena groups in particular.

## **6.2 Methods**

### **6.2.1 Field work**

Den sites were identified by following collared study animals (see Chapter 4) and by den search surveys in the landscape (see Chapter 5) and social behaviour studies were carried from June 2008 onwards by direct observations. Sampling period for the study clans was considered as each breeding year. Every possible membership in each study clan were individually identified with the help of photographs obtained from hand held and remotely operated cameras; as to focus on the individual in a group and quantify the differences in behaviour of known individuals. Every identified individual was sexed if possible and aged, hyenas were assigned to certain age class based continuous data (cub: < 6 months, juvenile: 6months to 1year, young adult (referred to as sub-adult in this study): 1 to 3 yrs, adult: 3+ yrs) (Aging protocol adapted from Wagner (2006)). For the purpose of analysis, due to small sample size and similarity in behaviour of cubs and juveniles these 2 age categories were clubbed as “cubs”.

Preliminary observations, so as to develop a limited ethogram for striped hyaena, were carried out. Of all the behaviours observed in the course of this study, a subset that relate to social interactions were collected in a quantitative manner to gain an understanding of striped hyaena sociology.

Scan sampling and focal animal sampling in conjunction with behaviour sampling (all event sampling. Altmann (1974)) used to record interactions within family unit for a specific amount of observable time (between 06:00 hours to 07:30 hours, and 17:30 hours to 19:45 hours), when daylight permits observation and hyaenas are not in their den. For each interaction the identities of animals involved were recorded along with, the time, type of interaction, and the consequence of interaction. Assistants were trained to collect unbiased data, without anthropomorphism; multiple trained observers systematically recorded interaction within a group, which otherwise would be difficult to record systematically for all the study clans. All observers were tested on their ability to identify individuals in each study clan, also pictorial catalogue of

clan members were provided to avoid misidentifications. In addition to data on sex, age, reproductive status, or kinship, unusual but important behaviours were also recorded. Besides field a note, digital videography was used as a tool to record observations whenever permitted by field conditions (visibility and light conditions).



6-1: Hyenas of BND clan at den site

The advantages of video recording was the ability to watch the ‘observations’ repeatedly, so as to validate or clarify behaviour interactions and identification of interacting individuals when in doubt as the pattern of events noticed is affected by spatial scale (being close helps to reveal details). The observational strategy was to use strategic locations at optimal distance to maximize detection and systematic recording while simultaneously minimizing the effect of the observer on hyaena by concealment using ‘hides’. Restricting to ‘hides’ can have some drawbacks like frequently the focal animal disappears from view and some interesting aspects of an animal’s behaviour can be missed. Additionally, some identified individuals are difficult to spot, due to their nocturnal habits, late emergence, poor light conditions, shy nature and bad weather.

Due to the low density of the study animal, their cryptic nocturnal habit, small clan sizes and data collection procedures, sample sizes were small to permit an in depth quantitative analysis. I therefore use a descriptive approach along with simple quantitative indices to provide a meaningful analysis and understanding of hyaena sociology.

### **6.2.2 Behavioural catalogue**

Behaviour consists of a continuous stream of movements and events and before it can be measured the stream has to be divided into discrete units or categories. There are two fundamental types of behaviour patterns 1) Event: characteristic short duration actions - salient feature is their frequency of occurrence. E.g. bark, 2) State: long duration action-salient features are duration. E.g. sleep (Martin and Bateson 2007).

In this study all observed behaviour units were grouped by functional type into two broad categories 1) social and 2) non-social, based on the context in which they were most frequently seen. Only social interaction information is presented in this chapter. A baseline minimum condition for sociality was assumed to be when the members of a clan/population interacted behaviourally, if there are no interactions then there is no sociality. Social behaviour for this study was defined broadly as all non-maintenance activities, including social grooming, care giving, social play, group feeding, agonistic behaviours, territorial behaviour, attention soliciting, vocalizing and other affiliative behaviour (Whitehead 2008). A catalogue of social behaviours was prepared for use in description of interactions, these categories only include behaviours that were observed and defined in this study. In spite of extensive observation and varied circumstances encountered in the course of the study it was assumed that not all behaviours were observed (especially mating system-we propose it is best observed in captive conditions); hence a limited ethogram for the species, was created and used.

Interactions and associations were a measure of social behaviour; each interaction was recorded together with time, type, and identity of the interactants. In cases, where all individuals and actions could be observed such as on den sites, all members present were observed, recording interactions, changes in association and groups.

### 6.2.3 Social measure and analysis

Types of measures on behaviour observations (adapted from Martin and Bateson (2007)) were 1) Frequency: number of occurrences of the behaviour pattern per unit time. 2) Duration: length of time for which a single occurrence of behaviour pattern lasts, total duration can be expressed as a proportion (or %). Mean duration: refers to mean length of a single occurrence of the behaviour pattern. 3) Intensity: no universal definition. A simple and informative index of intensity is a comparative measure of behaviour intensity, developed after observing several acts of same behaviour.

To analyse the association pattern the following method adapted from Martin and Bateson (2007) was used:

Index of association between 2 individuals G and H in space can be calculated by Index of association.

$$I = \frac{NGH}{(NG + NH + NGH)}$$

Equation 6.1 Index of association formula.

Where G and H are 2 individuals associated in space, then, NGH=number of occasions G and H seen together; NG=number of occasions G is seen without H; NH=number of occasions H is seen without G. all scores are distributed between 0 (no association) and 1.0 (strong association). The information was presented in a sociogram (Martin and Bateson 2007), the sociogram diagrams were created using NodeXL (<http://nodexl.codeplex.com>).

We also estimated spearman's rank correlation, to establish the level of correlation between the age of cubs at the den, and the number of adult & sub-adult hyaenas that were observed at the den. We also calculated correlation between the age of cubs and den usage. The correlations were calculated for the BND clan from 2008-2010. The results of this analysis would give an indication of whether social grouping is correlated with growth phase of cubs.

### 6.3 Results:

A total of 24 clans were identified from den surveys (See Chapter 3 & 5) out of which 6 clans in the intensive study area (Table 6-1) were studied by telemetry (See Chapter 3), where multiple individuals from each clan were equipped with radio collars (See Chapter 3).

Clan	2005	2006	2007	2008	2009	2010	2011	mean clan size (6 (SD ±0.73))
BND	-	-	4	5	7	7	5	6 (SD ± 3.12)
H.ridge	8	5	6	6	5	7	6	6 (SD ± 1.16)
Patt	7	5	5	7	5	6	7	6 (SD ± 0.98)
Moriya	-	-	-	5	4	-	4	4 (SD ± 2.34)
A.ridge	-	-	-	-	5	-	-	5 (SD ± 2.04)
Ustia	-	-	-	-	5	7	-	6 (SD ± 3.16)

Table 6-1: Details of group composition of hyaena clans, in the ISA (intensive study area). The blanks indicate that the particular clan was not observed since it was either not discovered or did not have deployed functional transmitter

The mean group size for the 6 clans was 6 (SD ± 0.73). Out of the 6 clans, BND clan was intensively monitored for social behaviour, as successive years had collared individuals, making it easier to track active den sites for observation. H.ridge & Patt clans were moderately observed, and the remaining clans observed opportunistically. In this chapter, we describe only the social behaviour obtained from our observations of the BND clan and the supplementary observations on other clans were congruent with our findings on the BND clan social interactions. Also, we used the observational data from BND clan as all the individuals and their kinships were known (Figure 6-2), unlike other clans and this makes for a much more robust study group.

### 6.3.1 History of the BND clan: (Figure 6-2)

The BND clan was observed since the year 2007, most likely an offshoot from H.Ridge clan (which is the closest active clan to BND). In this clan, Megamass was the breeding female for all the litters, but the male that fathered each litter could not be identified and was never observed. The first litter was of two females and a male, of which one female cub died as road kill in 2007. The female cub (F08-1) was collared in 2008. The male remained in the natal den till 2009 (thunderbolt) and F08-1 till 2010. We considered them to have dispersed after this point in time, since they were not sighted again nor was any information obtained on their mortality. The second litter in 2008 consisted of 2 female cubs (Sabercross & Utopia), of which Sabercross was collared during the course of the study. While Sabercross was killed in a snare in 2009, Utopia was at the natal den till 2011, after which we considered her to have dispersed. In 2009 (Figure 6-2), the BND clan saw a third litter of two females (Shakira & 3<sup>rd</sup> cub) and a male cub (Ricky). Shakira was collared later in the study and she died in 2011 in a snare, while the Third cub died young for undefined reasons. In 2010 Ricky shifted clan and joined H.Ridge clan, and later he was killed in a snare in the same year. In the pedigree chart (Figure 6-2), we did depict Ricky as killed but, he was part of H.Ridge clan when he died. The fourth litter of two females (Cub1 & Cub2) and a male (Cub3) was observed in 2010(Figure 6-2). The litter did not survive for very long, and died in the same year; one of the main reasons being collapse of social stratification in the clan, with Shakira (Sub-adult) dying, Ricky (sub-adult) shifting den and Utopia (Sub-adult) dispersing, only Megamass (breeding female) could not provide sufficient care, furthermore Megamass had a permanently damaged hind leg sustained in the year 2009. In 2011(Figure 6-2), there were signs of rejuvenating of the BND clan with the birth of three more cubs (which were born in May, 2011 – which doesn't synchronise with the breeding time observed for the previous litters-in which birth was observed in the month of Dec-Jan). We could not carry on our observations of the clan, since the study had concluded and the fate of the three cubs is unknown to us. But we speculate that it was an attempt by Megamass to revive the use of BND den site, teaming up with other immigrant individuals.



CATEGORY	BEHAVIOUR	CATEGORY	BEHAVIOUR
<b>Agonistic</b>	Aggression -food guarding	<b>Affilitative/ Greeting</b>	Greeting-Muzzle sniffing
	Aggression-Tug of war		Greeting-Muzzle-Anal sniffing
Aggression-hard bite	Greeting-Infant cry		
Aggression-Vocalisation	Greeting-Intense infant cry		
<b>social play</b>	Play-Muzzle biting		Greeting-Submissive
	Play-Body Biting		Greeting-Falsemount
	Play-circles		Anal sniff-standing
	play-parallel walk		Anal sniff-laying
	Play-invite		Anal sniff-tail lift
	Play-invite-chase		<b>Vocalization</b>
	Play-kick	Yelping	
	Play-Paw fight	Infant cry	
	Play-Tug of war	Growl	
	<b>social grooming/ care giving</b>	object-play	<b>Group movement</b>
low playing		Rally	
Play-Intense		Exploration rally	
Allo-Nibble Groom		Follow-Dust-wallowing	
Allo-lick Groom		proximity resting	
Lie-lick-up		Food-chase	
Nuzzling		Food sharing	
<b>Attention soliciting</b>	Suckling	<b>Miscellaneous</b>	Approach
	Cub herding		Avoid
	Anal-genital sniff-licking		
	Attention seeking-Anal sniffing		
	Attention seeking-Infant cry		
	Attention seeking-Infant cry - Chase		
	Attention seeking-Infant cry-present rear		
	Attention seeking-Present Rear		

Table 6-2: Social Behaviour catalogue used in the study. Only behaviours observed in the study have been defined and catalogued.

### 6.3.2 Social behaviour

From preliminary observations and during the course of the study, we defined social interactions into predefined categories (Table 6-2). From 472 hours of observation of the BND clan (Table 3), we identified 320 instances of social interaction, lasting 46.4 hours. These observations were classified into 50 unique social interaction behaviour types under 7 broad behaviour categories (Table 6-2). Listed below are the descriptions for each behaviour type under the 7 categories.

#### Agonistic:



Figure 6-3: Agnostic social behaviour of hyaenas: Food guarding extended to chase.

Aggression-food guarding-AFG=Intolerance to presence of conspecifics while feeding-accompanied by low grunts and raised tail, usually moves the food item away - the grunt and raised tail maintained till the food item is secured.

Aggression-Tug of war-ATOW= Unwilling to share/part with food item- Circumstances crops when 'opponent' has 'griped' the food item- a rough 'pull and push' accompanied with grunts and raised tail-is followed.

Aggression-hard bite-AHB=A snap bite with force mostly in spur-of-the-moment, when annoyed/bothered or in anxiety.

Aggression-vocalisation-AVO= Vocalisation (usually groans) is part of the behaviour structure-during 'stand off' or to push back intruders. Also serves as warning call to conspecifics and cubs. Mostly heard than seen.

### Social play



Figure 6-4 Social Play interactions: Play-Chase behaviour

Play-Muzzle Bite - PMZBT = Playfully biting the muzzle of conspecific, can involve licking of muzzle and face

Play-Body Bite - PBB = Biting and grabbing conspecific's body.

Play-circles- PC= Playing in circles.

Play-parallel -PP= playing as conspecifics are walking/brisk walking/trotting next to each other.

Play-Invite-PI=initializing play

Play-Invite-Chase - ICHS = Similar to 'PI', except here after initialising play runs to and fro. The initiating actor invites chase by trotting or cantering .Play Running is the major form of play between adults and rarely is combined with any physical contact forms of play behaviour.

Play-Kick - PKC= One hyaena, is lying on its back or side and Kicks at the conspecific with both paws.

Play-Paw fight-PPF= both the animals are laying sideways, then paw each other

Play-Tug of war-PTOW=Similar to 'ATOW'-except there is no aggression-no grunts-no raised tail- non-food items are also used for this.

Object Play – OBPLA = Two or more 'subject' simultaneously carry, chew, toss etc., an object. If one obtains sole possession, the other makes attempts to take it away, which chasing and wrestling

Low playing- LP= low intensity play-low level of interest in 'participants'-short bouts with interval

Play-Intense-PI= High intensity play- may include multiple behaviour functions mentioned above-bouts for longer durations

## Greeting/Affiliative



Figure 6-5: Greeting/Affiliation behaviour of hyaenas: the series of figures depict intense greeting with infant cry

Greeting-Muzzle sniffing-GMS= The 'subject' sniffs the muzzle of a conspecific -both stand still and smell each other. Also, Licking might follow up to the eyes, face and ears,

Greeting-Muzzle-Anal sniffing-GMAS= Similar to 'GMS' in addition to the 'subject' sniffs the anal region.

Greeting-Infant cry-GICRY = The 'subject' performs similar to 'ASICRY' – except it walks towards the conspecific with lowered head-flattened/drooping ears and constant vocalization.

Greeting-Intense infant cry-GIICRY = Similar to GICRY, except it runs towards the conspecific, encircling the conspecific, raised tail, kneeling occasionally, anal sniffing, muzzle touching and constantly vocalizing (Infant cry).

Greeting-Submissive-SUB= Similar to GIICRY, except it goes flat on its belly, rolls on the back exposing belly.

Greeting-Falsemount- GF= Rare observation. Where a subject adopts any form of greeting and mounts unprovoked. Most likely, appeasement or affiliative expression.

Anal Sniff - ASN = Non greeting function- performed at random - when arrived on den site-then it is 'greeting' function. Here the 'subject' is standing and sniff conspecific's anal region.

Anal sniff-laying=ASL= Similar to 'ASN' except that both conspecifics are lying down.

Anal sniff-tail lift-ASTL= Lift tail to invite anal sniffing

## Attention Soliciting



Figure 6-6 Attention soliciting behaviour of hyaenas

Attention seeking-Anal sniffing-ASAS= The 'subject' performs usually similar to 'ASS' and anticipates reciprocal response, with semi-erect tail

Attention seeking-Infant cry-ASICRY= The 'subject' performs similar to 'ICRY' - walks along with lowered head-flattened/drooping ears

Attention seeking-Infant cry - Chase-ASICC= Similar to 'ASICRY'-except the disinterested conspecifics-' AV' and generally runs away-'subject' chases the conspecific-still vocalizing-most of the chase are of short distance

Attention seeking-Infant cry-present rear-ASICCP= A combination of 'ASICRY' and 'ASPR'.

Attention seeking-Present Rear – ASPR = The 'subject', after approaching to within one body length of another hyaena, swinging its rear around in an arc to that its rump is facing the receiver's head the tail is lifted in air from the anal-genital region.

## Social groom/Care giving



Figure 6-7: Social grooming behaviour of hyaenas

Allo-Nibble Groom - ANG = The 'subject' uses its incisors to nibble the fur/skin of the conspecifics.

Allo-lick Groom-ALG=The 'subject' licks the fur, face, genitals of the conspecifics.

Lie-Lick-up-LLU= Low intensity allo grooming, similar to' ALG'-except both hyaenas in question are laying down-performs short lick'bouts' interrupted by long intervals on the closest body part of the conspecific.

Nuzzle – NZL = The 'subject' pushes its nose against the receiver's fur and then rubs it back and forth or in circles, ruffling the receiver's fur.

Suckling-SUC= A function performed by breeding female to provide the cubs with nourishment.

Cub herding-CH=A cub protection behaviour, where the 'subject' guides the cubs back to the den-with any sign of danger

Anal-genital sniff-licking- AGL = Similar to 'ALG' -except that it is restricted only to anal-genital region licking.

### Vocalisation

Groan- GRO = prolonged vocalisation with increased pitch and tone-sounds similar to 'Mooing' of buffalo calf in anguish (hence-'pada call'-buffalo calf is called 'pada' in the local lingo). Expressed during aggressive behaviours, as warning call (threat) or in distress- the tone differs for all the three.

Yelp – YLP = A sharp (abrupt onset) vocalization with a high, rising pitch, the Yelp is of very short duration and high intensity. Performed-with an open mouth and, usually in response to unexpected aggression/bite/rough play or sudden pain.

Infant cry-ICRY= Low intensity-high pitched-prolonged modulated vocalisation-produced with a gaping mouth-usually accompanied by flattened/drooping ears. Expressed during excited greeting, attention soliciting. Sounds like 'throat singing' combined with anguish: 'throat singing' in this context is a continuous over tone sound produced from the larynx.

Grunt - GRT = Short guttural sound. Expressed during agonistic exchanges, food guarding. Depending on situation-Grunt frequently grades from a deep rumble to higher frequency screams.

## Group movement



Figure 6-8: Group Movement behaviour of hyaenas.

Follow- FOL = To match the direction while Following behind another, usually no urgency to 'catch up'. Differs from RAL, in not restricted by speed to match another hyaena.

Rally-RAL = To match speed and direction while Following behind another-to 'keep up pace', usually within two to three body lengths/at times walking ahead/at times walking parallel.

Exploration rally-EXRA = The pace and direction maintained to that of the 'leader' , not necessarily 'follow' or 'tail behind'- Brownian brisk walking-converge and diverge as an area investigated.

Rally-Dust-Wallowing-RADW= Similar to 'RAL'- except it is 'semi' movement' to 'Dust wallow' is more or less at pace-but not the 'follow back'/'back track' is not-it resembles 'FOL'.

## Miscellaneous



Figure 6-9 : Miscellaneous behaviour in hyaenas: Proximity resting

Proximity resting-PRRE=Resting (sitting/laying) at close proximity to each other or other individuals. In physical contact-body touching each other/or less than a 'body' distance between individuals.

Food sharing-FOSH=Presence of other individuals tolerated on a 'large' food item, feeding together.

Food chase-FOCH=To snatch food item from a clan member and make a run with it, chased by the 'previous owner'. Note-no aggression involved-generally a short chase, and the 'prize' easily given up.

Approach-APP= To move to the direction of other individuals, attracted by the presence of the individuals or some activity in which others are indulged. Once near the 'target', the consequence followed can be any of the other behaviours mentioned in all categories.

Avoid - AV = To actively keep away from another hyaena or situation, usually by walking, but sometimes by cantering. Mostly observed during ATTENTION SOLICITING behaviour, when certain individuals avoid 'seeker'.

Out of the 472 hours of observations on den site, only 46.4 hours (9.7%) of time was spent in social events, 90.3 % of the time they were non social (Table 6-3).

<b>Period and temporal details of social behaviour observations</b>	<b>2008 M(min)</b>	<b>2008 E(min)</b>	<b>2009 M(min)</b>	<b>2009 E(min)</b>	<b>2010 M(min)</b>	<b>2010 E(min)</b>	<b>2011 E(min)</b>	<b>Total</b>
Total time of observation	3714	5841	5676	8876	1419	2401	395	472 (hours)
Time spent in social interaction	379	414	360	1264	130	161	75	46.4 (hours)
Number of social interaction events	35	80	27	129	12	29	8	320 (n)
M (min): observation time in minutes during morning hours  E (min): observation time in minutes during evening hours  n : Total number of social interaction events for the study period								

Table 6-3: Detail of observation time and social interaction observed in BND clan.

Since dens are important activity centers governing the movement of hyaenas in the landscape (See chapter 5), we recorded the movement pattern of different members of the hyaena clan to and from the den. From our observations, it is evident that there is a negative correlation between the number of group members using den and the age of the cubs until the cubs reach a certain age, following which, the number of clan members at the den decreases (Figure 6-10, Figure 6-11). The frequency of visiting the den might also be influenced by the age of the clan members.

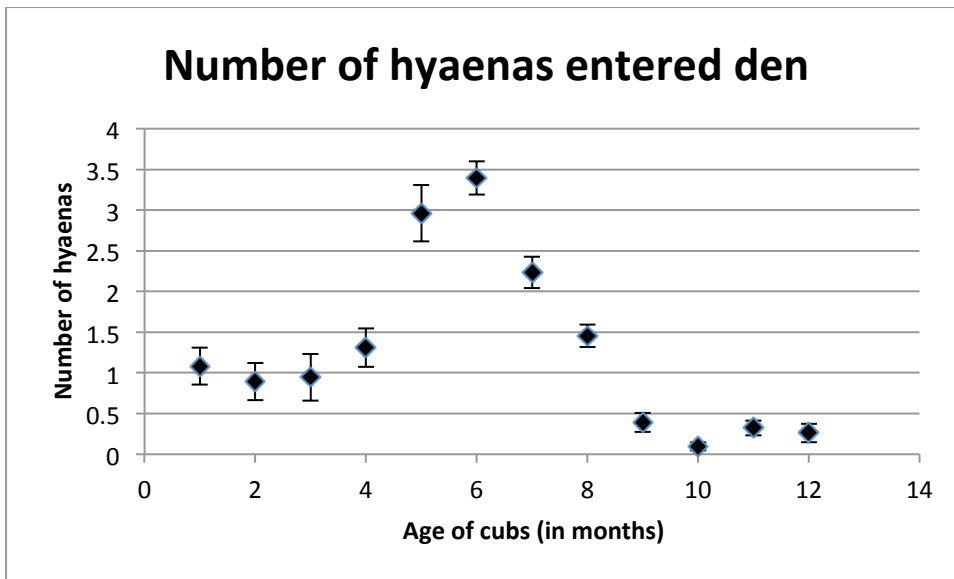


Figure 6-10: Relationship between number of clan members staying back at den and the age of cubs in BND clan from 2008 – 2010.

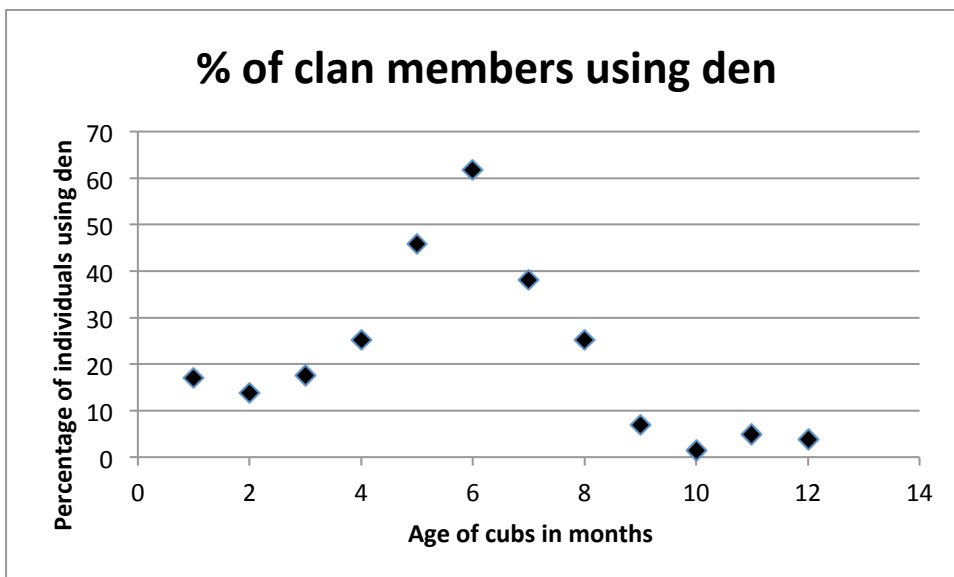


Figure 6-11: Relationship between den usage by clan members and age of cubs in the BND clan between 2008 & 2010.

The trend observed is that when the cubs are young, nearly all the clan members are present and this decreases with the increase in the age of the cubs. To the lag end of the year, the number of clan members present again increases; this could be attributed to the start of the second breeding season. This suggests a stable group composition is important for steady socializing, which might affect the fitness of the cubs and also that dens and cubs play vital role in-group cohesion. Den sites are important as active centres of socializing, but their role to provide and to protect is greatly reduced with an increase in the age of cubs. The frequency of visitation of the hyaenas to the den is

reduced as the cubs grow older and start foraging on their own; these infrequent visits are solely to socialize.

Category	Mean duration (Min) ±SE	Count of events	Frequency (%) of occurrence of behaviour counts	Total duration per event (Min)	Frequency (%) of Total duration
Affliative Greeting	2.6±0.21	79	24.69	205	7.34
Agnostic	4.6±1.01	14	4.38	65	2.33
Attention Soliciting	2.1±0.14	7	2.19	15	0.54
Group Movement	15.9±2.7	29	9.06	462	16.54
Miscellaneous	20.2±4.68	56	17.50	1129	40.42
Social Grooming	6.1±0.89	58	18.13	354	12.67
Social Play	7.8±1.1	70	21.88	543	19.44
Vocalization	2.9±1.26	7	2.19	20	0.72
Total	8.7±0.96	320		2793	

Table 6-4: Frequency percentages and mean duration of each category of social interaction observed in the BND clan from 2008-2011.

For the social interactions between the BND clan members during 2008-2011 categorized into the 7 different categories, the mean duration of the occurrence of each social behaviour was calculated (Table 6-4). While each miscellaneous event lasted on an average for 20.2 minutes, attention soliciting behaviour was the shortest at 2.1 minutes. We also counted the frequency of occurrence of each behaviour category. Out of 320 unique social interaction events, Affliative greetings were the most frequent ( $n = 79$ , 24.69%), followed closely by social play ( $n = 70$ , 21.88%). But the time spent doing each of these behaviour categories was different to that of the number of times each of these social interaction behaviours occurred. The frequency of duration per unit time was most for miscellaneous behaviours (1129 minutes, 40.42%).

Between the different age classes of the clan members (Adult, sub-adult & cub), the frequency percentage of interaction per unit time was calculated (Table 6-5). The cubs interacted longest with other cubs (45.89%), followed by their interaction with sub-adults (28.11%). Also, the cubs were the most interactive among all the age classes. The Adult-sub-adult interaction was for a short duration (4.96%). While we found that the Adult-Adult interaction is minimal, this is attributed to the low frequency of presence of more than one adult at the den.

Frequency (%) of interaction per unit time (Min)	
Adult-Sub-adult Interaction	4.96
Sub-adult-Sub-adult Interaction	9.31
Sub-adult-Cub interaction	28.11
Cub-Cub interaction	45.89
Adult-Cub Interaction	11.47
Adult-Adult Interaction	0.26

Table 6-5: Frequency percentage of interaction per unit time (mins) between different age classes of the hyaena clan observed in BND during 2008-2011.

Similarly, the frequency of the number of interaction events (Table 6-6), was highest amongst cubs (38.72%), followed by sub-adult-cub interactions (25.05%) and Adult-cub interactions (14.91%). The number of times a sub-adult interacts with a cub is more than the number of times it interacts socially with another sub-adult (11.18%).

Frequency % of occurrence of interactions.	
Adult-Adult	0.41
Adult-Sub-adult	9.73
Adult-Cub	14.91
Sub-adult-Sub-adult	11.18
Sub-adult-Cub	25.05
Cub-Cub	38.72

Table 6-6: Frequency percentage of occurrence of interactions between different age classes of the hyaena clan observed in BND during 2008-2011.

Table 6-7, Table 6-8, Table 6-9, Table 6-10, Table 6-11&Table 6-12 describe the kind of social interaction that is observed between different age classes of the hyaena clan.

### **Adult-Adult**

	Count of events	Total Duration (Min)	Frequency % of duration per unit time (Min)	Frequency % of occurrence of Events
Miscellaneous	1	10	90.91	50
Vocalisation	1	1	9.09	50
Grand Total	2	11		

Table 6-7: Details of Adult-Adult interaction showing frequency percentage of duration of each social interaction category and frequency percentage of occurrence of social interaction events observed during 2008-2011 in BND clan.

### **Adult-Sub-adult**

	Count of events	Total Duration (Min)	Frequency % of duration per unit time (Min)	Frequency % of occurrence of Events
Affiliative/Greeting	16	38	18.18	34.04
Attention Soliciting	1	2	0.96	2.13
Group Movement	11	89	42.58	23.40
Miscellaneous	7	40	19.14	14.89
Social Grooming	9	23	11.00	19.15
Social Play	2	15	7.18	4.26
Vocalisation	1	2	0.96	2.13
Grand Total	47	209		

Table 6-8: Details of Adult-Sub-adult interaction showing frequency percentage of duration of each social interaction category and frequency percentage of occurrence of social interaction events observed during 2008-2011 during BND clan.

**Sub-adult-Sub-adult**

	Count of events	Total Duration (Min)	Frequency % of duration per unit time (Min)	Frequency % of occurrence of Events
Affiliative/Greeting	14	39	9.95	25.93
Agnostic	2	4	1.02	3.70
Attention Soliciting	1	2	0.51	1.85
Group Movement	6	69	17.60	11.11
Miscellaneous	14	204	52.04	25.93
Social Grooming	7	15	3.83	12.96
Social Play	8	56	14.29	14.81
Vocalisation	2	3	0.77	3.70
Grand Total	54	392		

Table 6-9: Details of sub-adult-sub-adult interaction showing frequency percentage of duration of each social interaction category and frequency percentage of occurrence of social interaction events observed during 2008-2011 during BND clan.

**Sub-adult - Cub**

	Count of events	Total Duration (Min)	Frequency % of duration per unit time (Min)	Frequency % of occurrence of Events
Affiliative/Greeting	39	104	8.78	32.23
Agnostic	4	15	1.27	3.31
Group Movement	17	250	21.11	14.05
Miscellaneous	25	605	51.10	20.66
Social Grooming	12	41	3.46	9.92
Social Play	23	167	14.10	19.01
Vocalisation	1	2	0.17	0.83
Grand Total	121	1184		

Table 6-10: Details of sub-adult-cub interaction showing frequency percentage of duration of each social interaction category and frequency percentage of occurrence of social interaction events observed during 2008-2011 during BND clan

### Cub-Cub Interaction

	Count of events	Total Duration (Min)	Frequency % of duration per unit time (Min)	Frequency % of occurrence of Events
Affiliative/Greeting	37	112	5.79	19.79
Agnostic	7	45	2.33	3.74
Attention Soliciting	4	8	0.41	2.14
Group Movement	19	225	11.64	10.16
Miscellaneous	36	797	41.23	19.25
Social Grooming	32	295	15.26	17.11
Social Play	49	438	22.66	26.20
Vocalisation	3	13	0.67	1.60
Grand Total	187	1933		

Table 6-11: Details of cub-cub interaction showing frequency percentage of duration of each social interaction category and frequency percentage of occurrence of social interaction events observed during 2008-2011 during BND clan

In the limited number of Adult-Adult interactions ( $n=2$ ) we observed (Table 6-7), we noted only two kinds of social behaviour categorized under Miscellaneous and vocalisation. While in the Adult-sub-adult interaction (Table 6-8), we saw 7 categories of social behaviour, barring agnostic interactions. The longest amount of time spent was in-group movement (42.58% per unit time), while the shortest was spent on attention soliciting (0.96% per unit time). Whereas we observed, of the total number of social interactions, 34.05% of the times, they were involved in an affiliative greeting (the most among all the interactions) and the least in attention soliciting and vocalization (2.13%).

### Adult-Cub

	Count of events	Total Duration (Min)	Frequency % of duration per unit time (Min)	Frequency % of occurrence of Events
Affiliative/Greeting	15	43	8.90	20.83
Agnostic	1	1	0.21	1.39
Attention Soliciting	5	10	2.07	6.94
Group Movement	10	111	22.98	13.89
Miscellaneous	7	44	9.11	9.72
Social Grooming	31	262	54.24	43.06
Social Play	2	10	2.07	2.78
Vocalisation	1	2	0.41	1.39
Grand Total	72	483		

Table 6-12: Details of Adult-cub interaction showing frequency percentage of duration of each social interaction category and frequency percentage of occurrence of social interaction events observed during 2008-2011 during BND clan

While there was no agnostic behaviour observed in Adult-sub-adult interactions, we observed this (1.02% per unit time & 3.7% of the times) along with the remaining seven categories of behaviour in Sub-adult-Sub-adult interactions (Table 6-9). The most amount of time and also the longest time was spent on miscellaneous activity (25.93% and 52.04% per unit time respectively). In the Sub-adult – Cub interactions (Table 6-10), there was no attention soliciting behaviour, but the most frequent category of social interaction was affiliative greeting (32.23%) and the longest was spent under the miscellaneous category (51.10% per unit time). The cubs interacted (Table 6-11) with each other most frequently by social play (26.2%), while the longest interactions were during miscellaneous activity (41.23% per unit time). Interestingly, the adult-cub interaction (Table 6-12) was most frequently and longest during social grooming (43.06 % and 54.24% per unit time).

In the different categories of interactions, we also analysed the involvement of different age classes (Table 6-13, Table 6-14, Table 6-15).

**Adult**

	Count of events	Total Duration (Min)	Frequency % of duration per unit time (Min)	Frequency % of occurrence of Events
Affiliative/Greeting				
Agnostic	1	1	0.16	0.98
Attention Soliciting	6	12	1.95	5.88
Group Movement	13	159	25.90	12.75
Miscellaneous	9	56	9.12	8.82
Social Grooming	39	283	46.09	38.24
Social Play	4	25	4.07	3.92
Vocalisation	3	7	1.14	2.94
Grand Total	102	614		

Table 6-13: Details of the frequency percentage of duration of each social interaction category and frequency percentage of occurrence of social interaction events where an adult hyaena is involved, observed during 2008-2011 in BND clan.

**Sub-adult**

	Count of events	Total Duration (Min)	Frequency % of duration per unit time (Min)	Frequency % of occurrence of Events
Affiliative/Greeting				
Agnostic	6	19	1.23	3.35
Attention Soliciting	1	2	0.13	0.56
Group Movement	21	308	19.92	11.73
Miscellaneous	34	770	49.81	18.99
Social Grooming	23	70	4.53	12.85
Social Play	31	213	13.78	17.32
Vocalisation	2	3	0.19	1.12
Grand Total	179	1546		

Table 6-14: Details of the frequency percentage of duration of each social interaction category and frequency percentage of occurrence of social interaction events where a Sub-adult hyaena is involved, observed during 2008-2011 in BND clan.

## Cub

	Count of events	Total Duration (Min)	Frequency % of duration per unit time (Min)	Frequency % of occurrence of Events
Affiliative/Greeting	57	148	6.16	22.09
Agnostic	12	61	2.54	4.65
Attention Soliciting	6	13	0.54	2.33
Group Movement	24	389	16.20	9.30
Miscellaneous	46	954	39.73	17.83
Social Grooming	47	325	13.54	18.22
Social Play	62	497	20.70	24.03
Vocalisation	4	14	0.58	1.55
Grand Total	258	2401		

Table 6-15: Details of the frequency percentage of duration of each social interaction category and frequency percentage of occurrence of social interaction events where a hyaena cub is involved, observed during 2008-2011 in BND clan

The adults (Table 6-13) were most frequently involved in social grooming (46.09% and 38.24% per unit time), while the sub-adults (Table 6-14) spent the longest duration in interactions involving miscellaneous behaviour (48.8% per unit time) and most frequently in affiliative greeting interactions (34.08%). Social play was observed as the most important social interactions that cubs were involved in (24.03% and 20.7% per unit time). Cubs were also frequently involved (Table 6-15), along with social play, in affiliative greeting interactions (22.09%), while they spent the longest duration in interactions involving miscellaneous behaviour (39.73% per unit time).

The index of association (Equation 6.1) was calculated for the BND clan, for each clan member during each year.

Interaction between two individuals (2008)	Association Strength	Status of interacting individuals	Relationship between individuals
MM-F08-1	0.25	AD-SA	Parent-offspring
MM-TB	0.26	AD-SA	Parent-offspring
MM-SC	0.18	AD-CU	Parent-offspring
MM-UT	0.17	AD-CU	Parent-offspring
F08-1-TB	0.28	SA-SA	Sibling
F08-1-SC	0.20	SA-CU	Intergenerational sibling
F08-1-UT	0.22	SA-CU	Intergenerational sibling
TB-SC	0.24	SA-CU	Intergenerational sibling
TB-UT	0.25	SA-CU	Intergenerational sibling
SC-UT	0.52	CU-CU	Sibling

Table 6-16: Strength of association of interaction between individuals of the BND clan in 2008 (clan size =5). MM = Megamass, F08-1 = April (collared sub-adult female), TB = Thunderbolt, SC= Sabercross, UT= Utopia; AD=Adult, SA=Sub-adult, CU=Cub.

In 2008 (Table 6-16, Figure 6-12), the strength of association between the cubs (Sabercross-Utopia) was the strongest (0.52). The strength of association of the Adult (Megamass) was more with the sub-adults (April (0.25) & Thunderbolt (0.26)) than with the cubs, Sabercross (0.18) and Utopia (0.17).

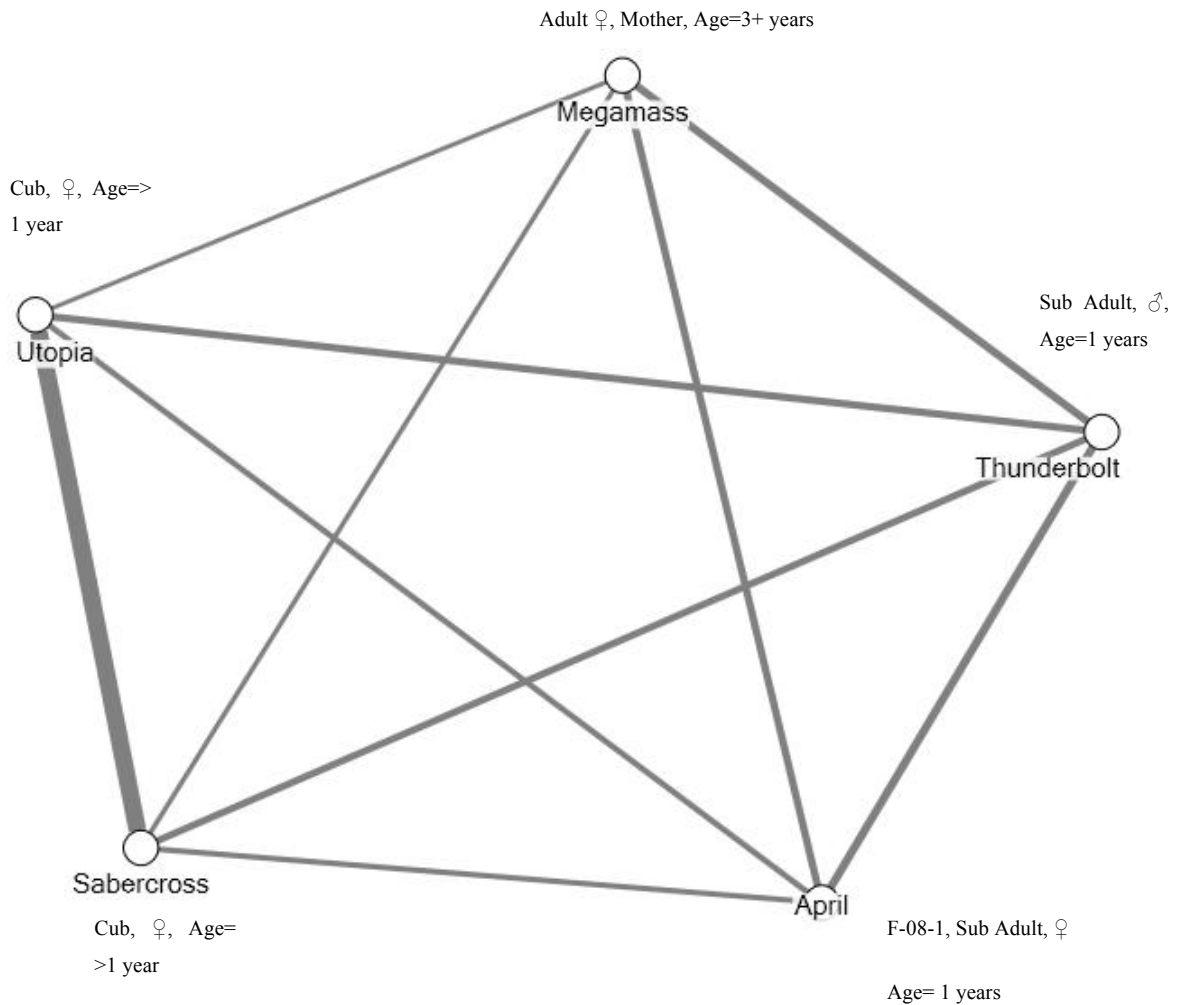


Figure 6-12: Sociogram of BND clan associations during 2008. The width of the edge indicates the strength of association between the two members.

In 2009 (Figure 6-13, Table 6-17) the sub-adult Thunderbolt dispersed very early on and therefore is absent from the sociogram (Figure 6-13) and the strength of his interaction with other clan members is zero (Table 6-17). Here, again we see that the strength of association is highest amongst cubs Shakira – Ricky (0.74), Shakira – Third Cub (0.58) and Ricky – Third Cub (0.70).

Interaction between two individuals (2009)	Association Strength	Status of interacting individuals	Relationship between individuals
MM-F08-1	0.08	AD-SA	Parent-offspring
MM-TB	0.00	AD-SA	Parent-offspring

MM-SC	0.10	AD-SA	Parent-offspring
MM-UT	0.18	AD-SA	Parent-offspring
MM-SH	0.32	AD-CU	Parent-offspring
MM-RICKY	0.30	AD-CU	Parent-offspring
MM-TC	0.32	AD-CU	Parent-offspring
F08-1-TB	0.00	SA-SA	Sibling
F08-1-SC	0.13	SA-SA	Intergenerational sibling
F08-1-UT	0.14	SA-SA	Intergenerational sibling
F08-1-SH	0.01	SA-CU	Intergenerational sibling
F08-1-RICKY	0.01	SA-CU	Intergenerational sibling
F08-1-TC	0.01	SA-CU	Intergenerational sibling
TB-SC	0.00	SA-SA	Intergenerational sibling
TB-UT	0.00	SA-SA	Intergenerational sibling
TB-SH	0.00	SA-CU	Intergenerational sibling
TB-RICKY	0.00	SA-CU	Intergenerational sibling
TB-TC	0.00	SA-CU	Intergenerational sibling
SC-UT	0.25	SA-SA	Sibling
SC-SH	0.21	SA-CU	Intergenerational sibling
SC-RICKY	0.13	SA-CU	Intergenerational sibling
SC-TC	0.13	SA-CU	Intergenerational sibling
UT-SH	0.15	SA-CU	Intergenerational sibling
UT-RICKY	0.13	SA-CU	Intergenerational sibling
UT-TC	0.14	SA-CU	Intergenerational sibling
SH-RICKY	0.74	CU-CU	Sibling
SH-TC	0.58	CU-CU	Sibling
RICKY-TC	0.70	CU-CU	Sibling

Table 6-17: Strength of association of interaction between individuals of the BND clan in 2009 (clan size =7). MM = Megamass, F08-1= April (Sub-adult collared female), TB = Thunderbolt, SC = Sabercross, UT = Utopia, SH = Shakira, Ricky = Ricky, TC = Third Cub. AD=Adult, SA=Sub-adult, CU=Cub.

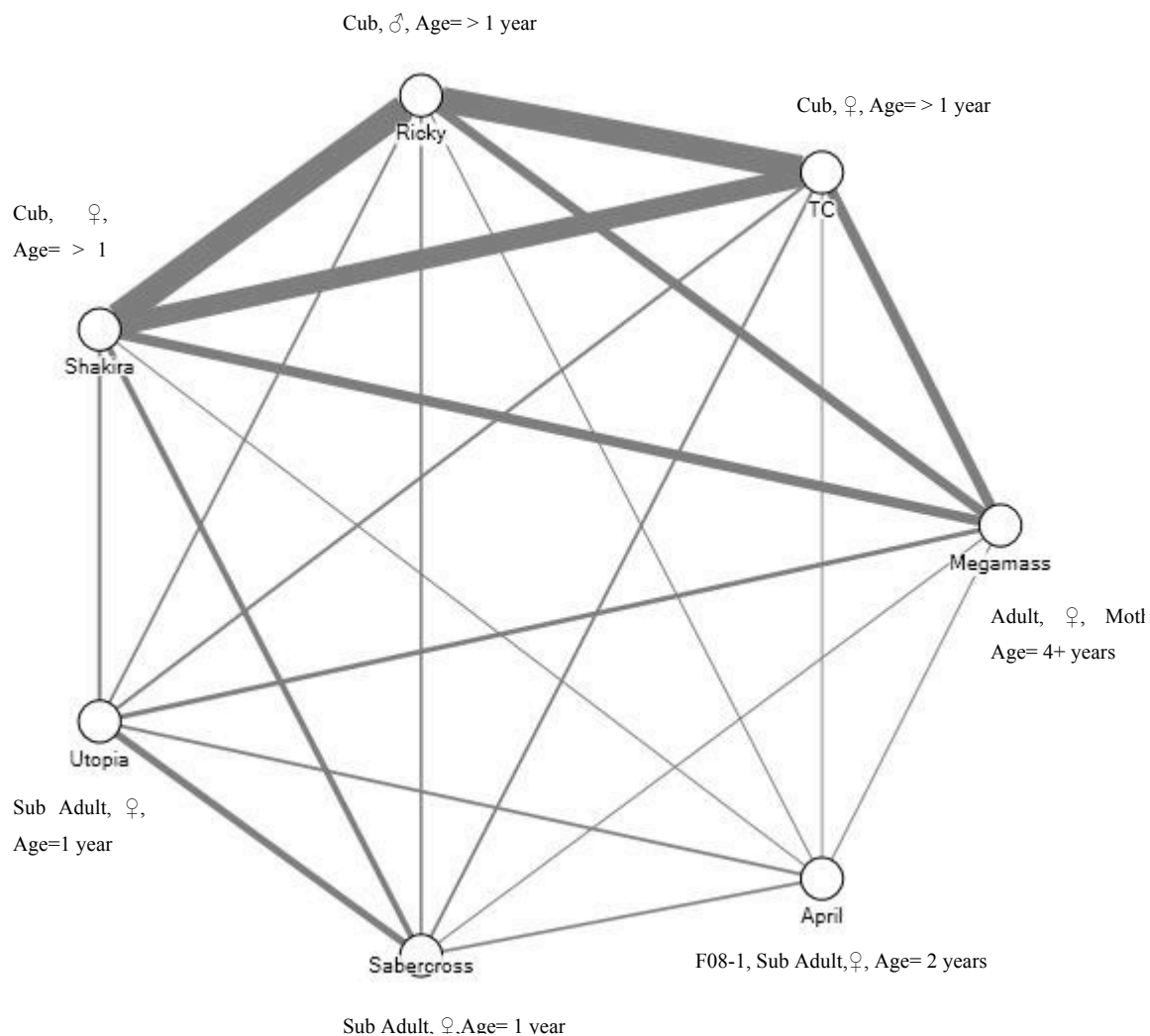


Figure 6-13: Sociogram of BND clan associations during 2009. The width of the edge indicates the strength of association between the two members

In 2010 (Table 6-18 & Figure 6-14), the fourth litter of the BND clan was present at the den. But due to the dispersal (Utopia) and den shift (Ricky) of sub-adults, during the course of the breeding season, the number of clan members was very low and the cubs also died early during their growth. The only sub-adult present was Shakira, and her interaction was higher with the cubs (Table 6-18: Shakira – Cub1; 0.44, Shakira – Cub2: 0.38) than that of Megamass with cubs (Megamass – Cub1: 0.15, Megamass-Cub2: 0.14). The strength of association was highest amongst the cubs Cub1-Cub2 (0.9). Ricky shifted den during this year, and this is reflected in his sporadic and limited interaction with other clan members (Figure 6-14)

Interaction between two individuals (2010)	Association Strength	Status of interacting individuals	Relationship between individuals
Megamass-SH	0.04	AD-SA	Parent-offspring
Megamass-Ricky	0.00	AD-SA	Parent-offspring
Megamass-TC	0.00	AD-SA	Parent-offspring
Megamass-c1	0.15	AD-CU	Parent-offspring
Megamass-c2	0.14	AD-CU	Parent-offspring
Megamass-c3	0.00	AD-CU	Parent-offspring
SH-Ricky	0.10	SA-SA	Sibling
SH-TC	0.00	SA-SA	Sibling
SH-c1	0.44	SA-CU	Intergenerational sibling
SH-c2	0.38	SA-CU	Intergenerational sibling
SH-c3	0.05	SA-CU	Intergenerational sibling
Ricky-TC	0.00	SA-SA	Sibling
Ricky-c1	0.00	SA-CU	Intergenerational sibling
Ricky-c2	0.00	SA-CU	Intergenerational sibling
Ricky-c3	0.00	SA-CU	Intergenerational sibling
TC-c1	0.00	SA-CU	Intergenerational sibling
TC-c2	0.00	SA-CU	Intergenerational sibling
TC-c3	0.00	SA-CU	Intergenerational sibling
c1-c2	0.90	CU-CU	Intergenerational sibling
c1-c3	0.03	CU-CU	Sibling
c2-c3	0.03	CU-CU	Sibling

Table 6-18: Strength of association of interaction between individuals of the BND clan in 2010 (clan size =7).MM = Megamass, SH = Shakira, Ricky = Ricky, TC = Third cub, C1, C2, C3 = Cubs of 2010. AD=Adult, SA=Sub-adult, CU=Cub.

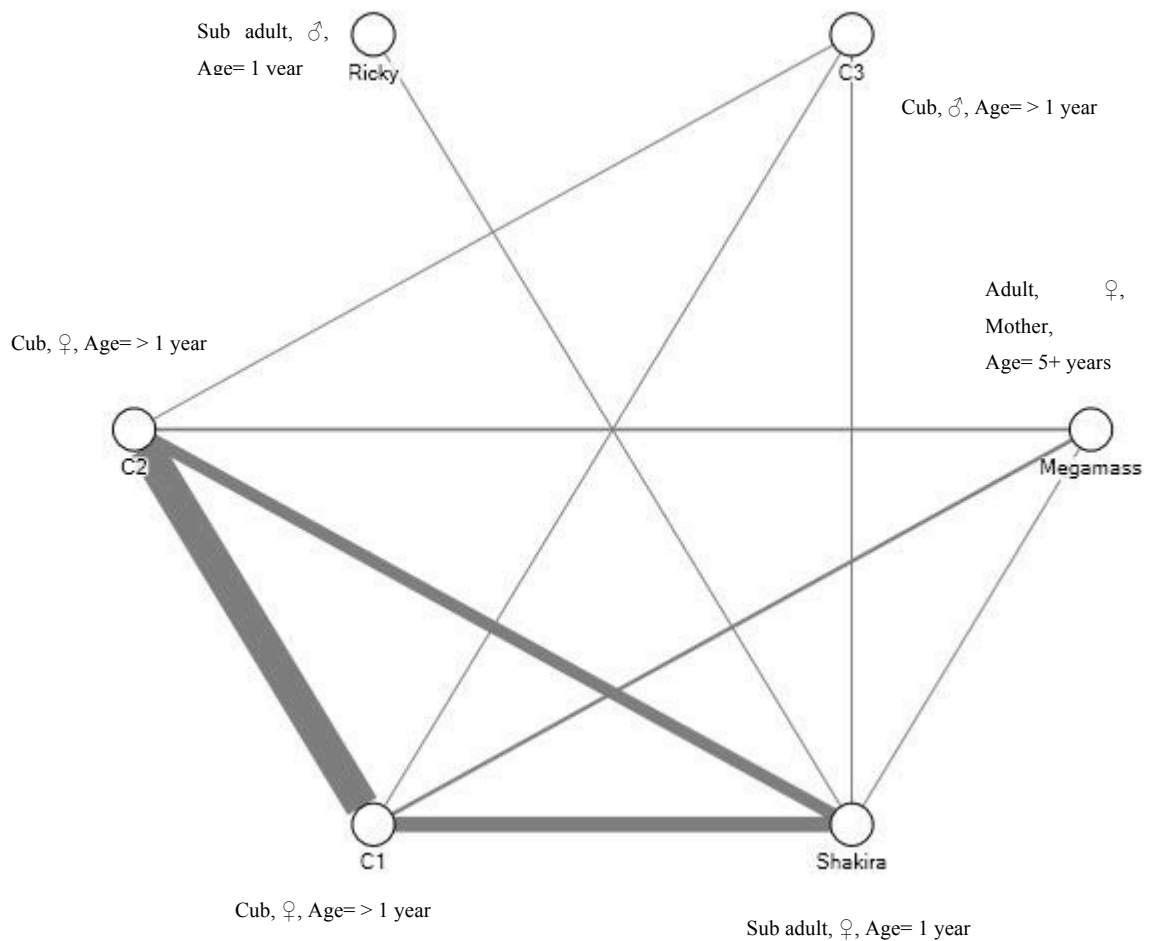


Figure 6-14: Sociogram of BND clan associations during 2010. The width of the edge indicates the strength of association between the two members.

Our observation of the BND clan in 2011 was limited (Table 6-19 & Figure 6-15) of these observations, it reflected a similar pattern to that of the previous observations in the association of the cubs, their strength of association was the highest (all interaction strengths =1). Also, this year saw the death of the sub-adult (Shakira) and there was no sub-adult left at the clan during our last recorded observation. The role of the sub-adult as the caregiver was clearly reflected in the increased association of the breeding female (Megamass) with the cubs (Table 6-19), as compared to the previous years (Megamass-Cub1: 0.5, Megamass-Cub2: 0.5, Megamass-Cub3: 0.5) after the death of the sub-adult.

Interaction between two individuals (2011)	Association Strength	Status of interacting individuals	Relationship between individuals
MM-SH	0.29	AD-SA	Parent-offspring
MM-cub1	0.50	AD-CU	Parent-offspring
MM-cub2	0.50	AD-CU	Parent-offspring
MM-cub3	0.50	AD-CU	Parent-offspring
SH-cub1	0.13	SA-CU	Intergenerational sibling
SH-cub2	0.13	SA-CU	Intergenerational sibling
SH-cub3	0.13	SA-CU	Intergenerational sibling
cub1-cub2	1.00	CU-CU	Sibling
cub1-cub3	1.00	CU-CU	Sibling
cub2-cub3	1.00	CU-CU	Sibling

Table 6-19: Strength of association of interaction between individuals of the BND clan in 2011 (clan size =5). MM = Megamass, SH = Shakira, Cub1, Cub2, Cub3 = cubs of 2011. AD=Adult, SA=Sub-adult, CU=Cub.

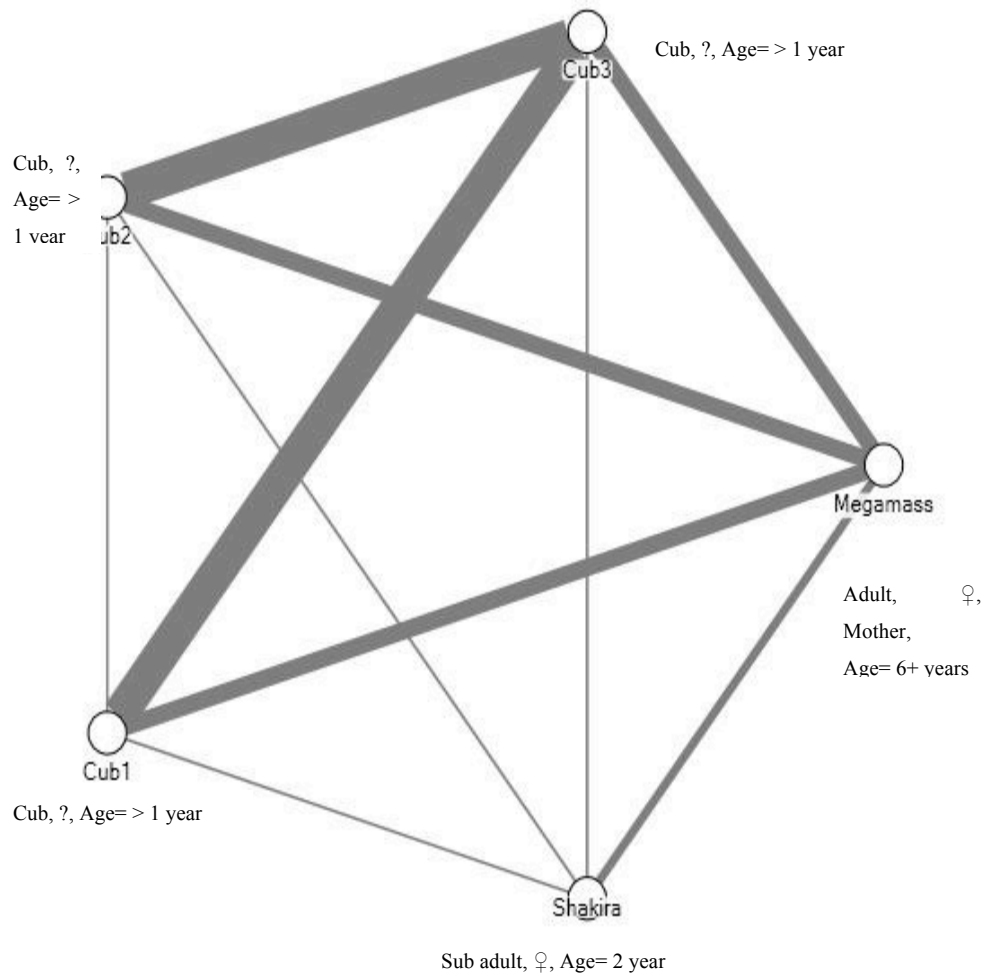


Figure 6-15: Sociogram of BND clan associations during 2011. The width of the edge indicates the strength of association between the two members.

## 6.4 Discussion

The results from our study indicate that striped hyaenas in Kutch (study area) are capable of forming stable spatially associated family units (referred to as clans in this study); composed of mostly related individuals: breeding female, sub-adults (her previous litter) of both sexes and recent litters. Despite spatial grouping in striped hyenas, group members are behaviourally solitary; they forage and feed alone (see Chapter.4). Hence, the den is a focal point of social activity for all group members, not just mothers and cubs, but most clan members visit it regularly. Even at the socially active centre, the levels of association are low and group members remain physically isolated more than 90% (Table 6-3) of the time. The social system is governed by the presence of cubs and their growth period as the role of clan members in maintaining contact with cubs and other clan members steadily declines as cubs get older (Figure 6-10, Figure 6-11). The dependency of striped hyaena cubs on dens (clan members) is for a long time, almost 10 to 11 months, the reason remains unknown; unlike spotted hyaena cubs which undergo a prolonged period of nutritional dependency (up to 2 years) because their feeding apparatus develop slowly (Watts et al. 2009), possible investigations on striped hyaena cub development can shed some light on it.

The social behaviour of the striped hyaenas we observed in our study is not similar with that of studies of striped hyaenas from Africa, (Wagner 2006, Wagner 2007, Wagner et al. 2007a, Wagner et al. 2008b). The group size and composition differ vastly, in Africa the group sizes are reported small (one female and one or two males), in our study area the mean group size for the 6 clans was 6 (SD  $\pm$  0.73) across seven years. The groups in the study area were composed of related female individuals; the male adults did not seem to play any role in cub rearing and were never observed at den sites. In Africa it is reported that lactating females are usually found alone at dens with cubs and solely responsible for care of young, which is completely contradictory to the behaviour of striped hyaenas in Kutch. Sub-adults play an important role in rearing of cubs, so much so that accidental deaths of sub-adults in 2010-2011, lead to death of all three young cubs for lack of care. This event shows that the importance of sub-adult in cub rearing. The sub-adults have higher association index with cubs, this

arrangement helps the adult (breeding female-lactating hyaena) to meet and focus her energy requirements on the suckling cubs and not on care giving, as suckling cubs for long periods (infrequent suckling till 8 months-but largely supplemented by solid foods –as observed in this study) can be costly to the individual. Sub-adults also provision cubs with food brought to the den and in providing protection. The interaction frequency and association indexes between adult (breeding female) and cubs were very low(See Table 6-16, Table 6-17, Table 6-18), except for 2011(Table 6-19) when no other clan member survived. Here since there was no sub-adult to take the role of the caregiver, we see an increased association index between the breeding female and cubs (Table 6-19). This division of duties, results in a system geared at the efficient survival of the litter. Hence, the group size of the clan plays an important role in clan dynamics.

What possible benefits would striped hyaenas is derived from grouping? Out of the 9.7 % sociable behaviour we observed in hyaenas, the cubs were the most social, followed by sub-adults. Unlike spotted hyaenas where through interactions with clan-mates, particularly those involving maternal interventions and coalition formation, cubs learn their social ranks within the group (Engh et al. 2000), while no evidence of any rank based system in striped hyaenas were observed in this study.

Watts and Holekamp (2007)in a review on hyaena societies criticized the hypothesis that predation pressure and the enhanced foraging ability in groups were important selection pressures leading to gregariousness in hyenas. In hyaenas, predation pressures have not played any role in shaping the society. Because, if predation pressures were a selective pressure leading to group formation, then the smaller of the hyaenas like striped, brown and aardwolf should evidence more gregariousness than spotted hyaenas as they are more vulnerable to predation owing to their relatively smaller body sizes. But, contradictory to this, spotted hyaenas are the most gregarious (Kruuk 1972b) among extant hyaenas. Similarly, the enhanced ability of individuals foraging in groups failed to adequately elucidate the differences in the social systems between brown and striped hyaenas. While both the brown and striped hyaena have similar foraging (solitary) and diet pattern, brown hyaenas are found to be more social than striped hyaenas, failing to explain the role of associating with conspecifics related to sociality. Even cooperative hunting among spotted hyaenas was not the paramount in the evolution of sociality, as 75% of successful hunts are conducted by

lone hyenas; only large challenging prey required more than one hyaena, representing a beneficial side effect of group living among modern spotted hyenas. Watts and Holekamp (2007) alternatively put forward that the need to defend food resources from competitors may have favoured gregariousness among hyenas. There is relatively little potential to grouping among aardwolves, striped or brown hyenas in order to protect food sources, as all rely on food resources that limit their populations from reaching high densities. Also, in striped hyaenas solitary foraging habits provide few circumstances to favour grouping (for ex: few chances of meeting another foraging conspecific) to protect carcasses (main source of nutrition in the study area) (see Chapter.3) and monopolize it.

We hypothesize that cub guard, i.e., when the cubs are young-the sub-adults/adults monitor them, staying close by when cubs are out of den, as the ultimate function of grouping in striped hyaenas. In our study, we evidenced the importance of cub guarding in maintaining the social structure and grouping of striped hyaenas. The role of the sub-adult as caregivers and food providers ensured that the group remained cohesive during the initial growth of hyaenas, as also observed in social canid like wolves (Mech 1995). During this stage, there was an increased activity at the den site and associated social interaction among the clan members and as the age of the cubs increased, the social activity and interaction at den sites decreased. We also found that, when this system of cub guarding collapsed (due to dispersal or death of sub-adult), the dynamics of the social grouping was disrupted resulting in high cub mortality, revealing that sociality for providing protection and additional food resources is indeed a strong factor driving the grouping in striped hyaenas.

Cub guarding is also hypothesized to have reproductive benefits to sub-adults/ adults, in Africa it is reported that a polyandrous or promiscuous mating system exists in striped hyaenas, where females appear to mate both with group males and males that reside elsewhere (Wagner et al. 2008b). No adult male hyaenas were observed at den sites during the 472 hours of observation spent during the study. This suggests that they play a minor role, if any in cub rearing. As we do not have sufficient data on male hyaenas, mating systems or kinships, so we refrain from making inferences regarding the benefits of group formation and mating systems. There is a need for further study to determine the importance of cub guarding in mating systems.

In conclusion, the hyaenas in Kutch have a ‘cub centric social system’; the benefit of such a coalition seems to increase fitness in cubs. Possible benefit for clan members from this type of social system is the utility from an evolutionary perspective, food utilization at den sites in form of accumulations (bone and carcass); hyaenas have accumulating habits at den site (see Chapter.3) and provisioning the cubs with food items. Solitary foraging habits directs them to forage independently of one other on spatio-temporal scale, surplus food found is bound to be carried back; members with no foraging success can benefit from these accumulations at den sites. Based on our observations, we find that all individuals do not behave in the same ‘species-typical’ way. Our observations from the BND clan and supplementary observations on other clans in the area reveal a complexity in social structures and associations in striped hyaenas. Structures, associations and interactions can get complex with multiple breeding females and multiple litters present in a clan den or different breeding females occupying different den sites within a clan home range. However, there is a strong kin based “cub-centric” social system, where adult males did not show any role. In this kind of social system (kin based “cub-centric”), relies mainly on group size and presence of sub-adults for the stability and functioning of the hyaena clan. Further studies including male hyaenas and dispersing individuals will add more information to the dynamics of striped hyaena social systems.

## **7 ATTITUDE OF LOCAL PEOPLE AND CONSERVATION OF HYAENAS**

### **7.1 Introduction**

Carnivores come into conflict with humans for a wide variety of reasons. Many species are declining rapidly due to multiplicity of factors, including loss of habitat, degradation, fragmentation, hunting, depletion of prey, diseases risks and trade in body parts. Conflict with humans is an increasingly significant factor driving declines for many species and these low population density make especially carnivores more vulnerable to environmental changes (Novaro et al. 2000, Sillero-Zubiri and Laurenson 2001, Cardillo et al. 2004, Marker and Dickman 2004, Cardillo et al. 2005, Woodroffe et al. 2005). Because of these anthropogenic pressures, the conservation of carnivores is still primarily reserve-based, mainly within the protected area network where human densities are low (Linnell et al. 2001b, Woodroffe 2001). In places where large carnivores still occur outside protected areas, they are often intentionally or accidentally killed by humans, which can limit their persistence (Woodroffe and Ginsberg 1998, Graham et al. 2005, Woodroffe and Frank 2005).

Among carnivores, all four extant hyaenid species have undergone drastic population decline, striking contractions in geographic range and often local extirpation due to persecution, habitat destruction and fragmentation (Mills et al. 1998). The striped hyaena has the widest geographical distribution among the hyaenid, and is relatively adaptable to habitat change and the impacts of human settlements. The historical distribution of the striped hyaena encompasses Sahel region and north of Sahel in Africa, eastern Africa south into Tanzania, the Arabian Peninsula and the Middle East upto the Mediterranean shores, Turkey, Iraq, the Caucasus region (Azerbaijan, Armenia, Georgia), Iran, Turkmenistan, Uzbekistan, Tajikistan, Afghanistan (excluding Hindu Kush) and the Indian subcontinent. While it still occurs across much of its historic range, the striped hyaena is already extinct in many localities and has undergone marked declines; current distribution of the striped hyaena is now patchy in most places with surviving populations small and isolated, particularly so in most west African countries, most of the Sahara desert, parts of the Middle East, the Caucasus, and central Asia (Mills et al. 1998), and smaller populations are more at

risk to go extinct than larger populations (Soulé 1987). Humans are the major cause of mortality. All hyaena species are probably tainted to some degree by the prejudices suffered by spotted hyaenas. Hyaenas are important animals in many cultures. They are viewed with contempt and fear and frequently associated with witchcraft, as their body parts are used as ingredients in traditional medicinal treatments. They are thought to influence people's spirits, snatch children, rob graves, and steal livestock (Mills et al. 1998). Striped hyaena evokes many superstitious fears, and is widely exploited as an aphrodisiac as well as for traditional healing. It is also killed because of suspected or real damage inflicted on agricultural crops and livestock. Through out the Arabian Peninsula and North Africa it is loathed as a grave robber and severely persecuted through baiting, tracking and trapping. Amongst Arabs in Israel, it is considered a demonic creature. In Armenia, Azerbaijan and Uzbekistan, the striped hyaena was held responsible for the disappearance of unattended small children. In Afghanistan striped hyaenas are caught for organized fights between domestic dogs and hyaenas for entertainment. In Jordan, the striped hyaena was traditionally considered a threat to human life, as man is supposed to be the favourite food of the striped hyaena, and hence "the more hyaenas a man can kill, the stronger and braver he is considered to be". (Gasperetti et al. 1985, Al Younis 1993, Qumsiyeh et al. 1993, Mills et al. 1998). In the Palmyra area in Syria, the species is heavily persecuted (including destruction or blockage of dens, poisoning carcasses, or the use of fire to chase animals out of dens); also illegal trade in skins, and body parts for traditional medicine and they are often kept in cages for display purposes (Arumugam et al. 2008). Like in most places in its range, the species is commercially hunted in Morocco for utilization in traditional medicine with various parts being used (especially the brain); and also hunted in Egypt for utilization of body parts (Osborn and Helmy 1980, Arumugam et al. 2008). Striped Hyaena is very susceptible to accidental or targeted poisoning as it readily accepts poisoned bait, historically it was exterminated in Israel during rabies eradication campaigns; also poisoning has been a cause in Egypt, Niger and Kenya (Osborn and Helmy 1980, Hofer et al. 1998, Wagner 2006). In Kenya, due to lack of differentiation between spotted and striped hyaena, striped hyaenas are often killed when spotted hyaenas are the intended target (Wagner 2006). Along with these anthropogenic causes, habitat destruction in most of its range is viewed as a major threat and effective protection is absent as hyaenas are viewed with contempt (Mills et al. 1998, Wagner 2006).

In India, attitudes towards hyaenas vary widely between regions. Hyaenas are persecuted by vandals who destroy dens in some areas, while in others they are ignored (Mills et al. 1998). Much of the range of hyaenas in India falls outside conservation reserves, close to human habitation and hyaenas do not enjoy the same degree of protection as in areas with conservation status. Hunting is prohibited under the Wildlife (Protection) Act 1972, schedule III, but this is only enforced inside conservation areas. There is deficiency of scientific literature on the distribution and status of hyaenas in India, especially outside protected area; there is absolutely no data on attitudes of people towards hyaena or its utilization.

Striped Hyaena is present in numerous protected areas across their vast range, including: Algeria, Burkina Faso, Cameroon, Ethiopia, Kenya, private reserves in Kenya, Libya, Morocco, Senegal and Tanzania (Mills & Hofner 1998). Recent records also indicate the species occurs outside of protected areas in a number of regions, including, for example, in Egypt, in Kenya and in India (Mills et al. 1998, Wagner 2006, Jhala et al. 2011). Because they exist outside of formally protected areas in regions where pastoralism is the norm and the potential for human-carnivore conflict is very high. Particular attention should be paid to identifying ways to reduce human-carnivore conflict through promotion of methods that ensure adequate numbers of prey persist and/or methods that reduce livestock killing by carnivores.

The interactions between people and wildlife are essential feature in shaping the perceptions of People. Consequently it is vital to appreciate the nature of these interactions and understand both ecological and human aspect of conflict problems; for effective resolution of conflict between people and wildlife, and the development of competent conservation strategies which may be beneficial to both humans and wildlife (Schmidt and Beach 1994, Happold 1995). Identifying the ecological drivers and deeper anthropological aspect of these conflicts is fundamental for developing efficient conservation strategies, as negative attitudes are a principal reason of carnivore persecution throughout the world (Woodroffe and Ginsberg 1998, Hussain 2003, Woodroffe and Frank 2005). Peoples' attitude towards wildlife can be significantly influenced by cultural or religious beliefs; also these beliefs along with indigenous knowledge and practices can form important strategy of local conservation, which may be relevant, appropriate and culturally sensitive (Hutton and Leader-Williams 2003, Hazzah 2006, Knight 2013).

This chapter is an attempt to review the current relationship between local people and the largest carnivore in the landscape, hyaena. Kutch is a major stronghold of the species with good resources and low persecution by local people (Jhala 2002, 2003). Generally the region is culturally tolerant and has a prevailing positive attitude towards wildlife; but not all species enjoy this pious protection, for instance there is a deep rooted discrepancy in the attitude towards wolf. Inclusion of wolf and other wildlife is beyond the scope of the study, the focus is on hyaena; as to understand the factors that may influence the hyaena population persistence in the landscape, whether this nocturnal animal is overlooked or actively tolerated for cultural or ecological reasons. The objective was achieved by assessing the attitude and knowledge of local people regarding hyaena, in relation to variety of characteristics like gender, age class and occupation. Also simultaneously a broad suite of variables likely to influence the perception of local people of hyaenas was examined and to any determinants of conflict in the area was identified. The results will contribute towards the deeper understanding of hyaena survival, in a landscape with many inter-related contributing factors; and provide framework to mitigate the threats endangering the species in the study area, and can be extended broadly to understand complexities of hyaena persecution in other regions where hyaena populations are declining.

## **7.2 Methods**

### **7.2.1 Survey design**

The respondents were interviewed using a semi-structured questionnaire (Appendix I). The questionnaire was divided into five sections; specifically, key issues covered were on the following:

- A. Background information: Name, age, village, Landholding and crops cultivated, Livestock owned, losses and income sources.
- B. Awareness and Knowledge: Awareness and knowledge regarding wildlife and particularly hyaena. It was important to query people about wildlife in general, and not to confine to questions only relating to hyaenas; as it was possible to get an impression of their general wildlife knowledge, and to assess their reliability
- C. Perception of hyaena: How problematic the hyaenas were considered to be? Levels of losses attributed to hyaena by depredation and crop raid and protective measures undertaken. Details of hyaena attack on livestock and humans, followed by fate of hyaena after the incident.
- D. Threats to hyaenas' survival: Direct or indirect threat from actions of people, local practices, carnivore control or other development in the landscape. Details of dead hyaenas encountered and cause of mortality. Details of hyaena body parts used in traditional medicine.
- E. Attitude towards hyaena: How locals view the animal and its conservation.

The questionnaire was pre-tested on subjects (n=10) belonging to various age, gender and occupation. Questions were modified into open-ended questions and closed questions(Geer 1988), to improve details and communicative quality. In open-ended questions depending on repetitive nature and similarity of responses, some questions were treated as closed question for analysis purposes. Some questions, which didn't suit the scope of the survey, were deleted. A few 'filler' questions that were not part of the research question were added to aid the flow of the questionnaire. It was noticed that there was time-memory bias, respondents found it difficult to recall events which occurred some time ago; hence time frame was restricted to not more

than 2 months in past for frequent events like livestock mortality, and was ‘open ended’ for infrequent events like hyaena sighting or mortality. With the intention of simplifying livestock data collection, in this study; cattle and buffalo were grouped together and referred as ‘large livestock’ and goat and sheep were grouped and referred as ‘medium livestock’. Though dogs and donkeys are free ranging and without owners in most villages; still dogs and donkeys were included as variables for livestock data targeting respondents who owned any of these, as we expect a variation in ‘reaction’ to experience of predatory losses of animals with ownership as compared to free ranging ones. Including education qualification or size of land holding didn’t prove useful, as the responses were biased towards occupation of the respondent. Hence, all respondents were grouped into one of the five ‘sectors’ (

<b>Sector</b>	<b>Occupations grouped</b>
Husbandry	cowherds, goatherds, nomadic pastoralist
Agriculture	farmers, farmhands
PIWL	labourer, drivers, butcher, skinner, fisherman, fish trader, buffalo trader, priest, panjarapole worker
Academics	students, teachers
NPIWL	shopkeepers, hotel owners, traders, vendors, factory worker, mechanic, housewife, artisan, weaver, govt servant

Table 7.1); a broad conceptualization of occupations of local people used in this study, based on the defining traits of their occupation and considering their level of exposure to wildlife associated with their occupation. A suitable questionnaire protocol was established and, participants were randomly selected across the landscape representing all occupation ‘sectors’. This treatment was an attempt to exemplify the whole study area population across different ecotypes.

Sector	Occupations grouped
Husbandry	cowherds, goatherds, nomadic pastoralist
Agriculture	farmers, farmhands
PIWL	labourer, drivers, butcher, skinner, fisherman, fish trader, buffalo trader, priest, panjarapole worker
Academics	students, teachers
NPIWL	shopkeepers, hotel owners, traders, vendors, factory worker, mechanic, housewife, artisan, weaver, govt servant

Table 7.1: Occupation grouped into ‘sectors’. PIWL=occupation with possible interaction wildlife, NPIWL=occupation with no possible interactions with wildlife.

The respondents were asked to ‘free list’ all the wildlife inhabiting their village (within a radius of 5 km), with an intention to gauge their knowledge general wildlife and particularly hyaena. In actuality not all villages will have an active hyaena den in close proximity, but it was estimated in this study that mean home ranges of hyaenas was  $80.7 \text{ km}^2 \pm 13.8$  (100% MCP) (See Chapter 4). With such large home ranges and heavy dependency on village based food resource (Ref chapter.2: diet and foraging pattern), each hyaena frequents many villages; it is anticipated that, the high rate of visitation by hyaenas to many villages will not go unnoticed by some villagers, with the impression that the animal lives in the vicinity. A question on respondents’ definite detection of any wildlife in the village neighborhood was followed; to comprehend the prospect of encountering wildlife around villages, eventually contributing to the awareness level among people. To test the difference in level of awareness to presence of hyaena around villages, among respondents from different ‘occupation sector’; a logistic regression was conducted in SPSS 16.0 (SPSS Inc, Chicago, (Norusis 2008)).

Traits	Traits	Traits
dog like	bushy tail	carrion in diet
dog sized	face black in coloration	predates dogs/pups
donkey foal sized	black throat patch	predates small livestock
long foreleg	stinky/smelly	donkey like
short hind legs	nocturnal	donkey sized
sloping back	afraid/shy of humans	buffalo calf sized
long hairs	poor runner	spotted
presence of hackle	runs/walks with a limp	long tailed
long ears	uses den as day refuge	predates wildlife
striped	uses bush as day refuge	
brown	carnivores	

Table 7.2: Description of hyaena by respondents (n=209), simplified into traits for analysis purpose

Originally an ‘open ended’ question was employed in the survey to gauge people’s knowledge of the hyaean, which enabled the respondent to provide more elaborate and complete answers. It was treated as ‘closed ended’ for the analysis, as the answers were similar and could be categorized. The description by the respondents (n=209) were categorized into 33 traits, which were repetitive during the survey not all were true depiction; hence the 33 traits were assigned a true or false status for analysis purpose (Table 7.2).

It is important to appreciate, that the respondents with desired characteristic of ‘exposure to wildlife’ are significant, as their actions and attitude might have the potential to directly influence the survival of hyaenas in the landscape; and also influence the attitude of groups with little and no exposure to wildlife. Particular views and attitude are formed in part by communities or by individuals’ perceptions and experiences (Infield and Namara 2001).Also, the age of respondents were grouped into three classes (Table 7.3)

Age class	Range
I	12 to 25
II	25 to 50
III	50 to 75

Table 7.3: Age grouping of respondents

## 7.2.2 Survey Administration

### Respondents

The study area is ethnically and culturally very diverse, respondents belonged to wide range of communities including traditional pastoralist communities like Rabari, Bharvad, Muslim maldaris (Jat, Halaypotra, Hingora, Mutwa, Royma, Bamba), scheduled tribes (Kholi, Paradhi, Nath), scheduled castes (Meghwal, Maheswari, Marwada, Charan), Recent immigrants (from states of Punjab and Haryana are settled farmers, while from states of Kerala, Bihar and West bengal are skilled workers), Muslim (Thuriya, Sangar, Samma, Pinjara, Mandra, Lodra, Saati, Kerifakir, Katri, Machiyar, Wagher, Kumbhar), Hindus (Ahir, Bhanushali, Bawaji, Maharaj, Thakker, Lohana, Sangar, Kanbi, Patel, Bhatia, Govar, Rajput (Jadeja and Soda), Kharva, Machar, Rathore, Brahman) and Vaniya (Jains). Also some respondents were from other parts of Gujarat with jobs of transferable nature , working in the region in various government departments. The study area supports a heterogeneous mix of ethnic groups and lifestyles that are generally intermixed in villages, although informal ‘vaas (clusters)’ where members of same ethnic group live close together, do exist. But these different ethnic groups have strong economic, social, structural and linguistic links with each other, attaining a unique regional identity. In the context of this study these social conditions of the respondents did not prove to be useful, and also defining and describing ethnic groups can be confusing and problematic; hence respondents were categorized based on occupation (Table 7.1).

For this study the respondents grouped into ‘Husbandry sector’ were: nomadic pastoralist-with some defining traits such as ethnicity with strong pastoral identity,

generally landless relying upon livestock for livelihood, practicing large scale movements with livestock across landscapes and not associating with villages (with exception of temporary settlements). While, shepherds and cowherds (also buffalo herders)- referred to village based herding systems, where herding is done by owner of small or medium sized herd or persons hired (who generally own no livestock) to herd the village stock; mobility is restricted around villages, returning back in the night to the villages or 'wadas' (corrals). Respondents grouped into 'agriculture sector' were: farmers-predominantly agriculturalists may own subsidiary livestock, includes both local and immigrants (from Punjab and Haryana). While, farmhands-marginalized farmers or landless peasants who seek employment or contract with the farmers, main source of income generated by working in the fields and substituted by rain fed agricultural. Respondents considered to be grouped into 'PIWL' (Occupation with possible interaction with wildlife) were respondents with occupation where there is some degree of mobility or involves working with animals or working in areas away from human habitation, increasing the likelihood of encounter with wildlife; while 'NPIWP' (Occupation with no possible interaction with wildlife) were considered as respondents with occupations based in human habitation areas where the chances of encountering wildlife is very low. The 'Academic sector' grouped students and teachers together, since education qualification was not considered as a variable for this survey this group can be treated as a surrogate for it. All the respondents were adults (above 18 years of age), with exception of 'Academic sector' where some students were below 18 year of age. Each respondent was treated as a sampling unit irrespective of number of respondent from each village.

### Interviews

Fieldwork spanned over the period of two years from January 2007 to December 2009. The local language, Kutchi was used to administer the semi-structured questionnaires. If the respondents were not clear with the questions, then the question were repeated and elaborated. Some respondents, who were pastoralists by profession, were migrating at the time of interview but for all purposes the reference village was respondents original village. Respondents who were unwilling to participate in the questionnaire survey were not included.

### 7.2.3 Analysis

Data was analyzed using the SPSS (Statistical Package for Social Sciences) program for Windows. Descriptive statistics, demographic related analyses as well as some correlations between variables were represented in proportions and percentages.

The attitudes towards hyaena are analyzed using Chi-square analysis. Statistical significance is measured in terms of  $P < 0.05$ .

The Likert scale(Likert 1932)was employed to help gauge the respondents' attitudes towards wildlife. The main analysis was qualitative in nature. The scale was based on a five-point scale that ranged from 1-5 as shown below: The responses may be given in the form of a (usually 5-point) scale, for example:

Response	Rating
Strongly agree	5
Agree	4
Neutral	3
Disagree	2
Strongly disagree	1

Table 7.4: Likert scale for attitude rating

## 7.3 Results

### 7.3.1 Background information

Out of 290 people interviewed from 130 villages across the landscape, only 267 respondents from 124 villages were included in the analysis. The rest of the survey interviews were incomplete, where the respondents or interviewers had to leave the interview midway in some emergence or the interview were interrupted by onlookers. Out of the 267 respondents, 22 % (n=58) were females and 78% (n=209) were males. Majority of the respondents 61 % (n=164) were in the ‘age class II’, the rest were in the ‘age class I’ (18%, n=49) and ‘age class III’ (20%, n=54) (Table 7.5). A large number of the respondents had greater likelihood of encountering wildlife in their occupation (63%, n=168), out of which ‘husbandry sector’ accounted for 24% (n=63), ‘agricultural sector’ included 22% (n=60) and 17% (n=45) fitted in ‘PIWL sector’; while, 37% (n=99) respondents had little or no chance of interaction with wildlife in their occupation, out of which 13% (n=35) were in the ‘academics sector’ and 24 % (n=64) in the ‘NPIWL sector’ (Table 7.6).

Age class	Range		Freq%
	(Years)	n	
I	12 to 25	49	18
II	25 to 50	164	61
III	> 50	54	20

Table 7.5: Age grouping of interviewees in Kutch for determining local attitudes towards conservation and hyaenas

Occupation	Male (n)	Male (%)	Female (n)	Female (%)	Total (n)	Total (freq %)	WL interaction	Total (n)	Total (%)
Husbandry sector	57	90	6	10	63	24	Y	168	63

<b>Agriculture sector</b>	51	85	9	15	60	22	Y		
<b>PIWL</b>	22	49	13	29	45	17	Y		
<b>Academics sector</b>	36	103	9	26	35	13	N	99	37
<b>NPIWL</b>	43	67	21	33	64	24	N		

Table 7.6: Occupation classification of respondent. WL=wildlife interaction, Y=yes, N=no, PIWL=occupation with possible interaction wildlife, NPIWL=occupation with no possible interactions with wildlife

Out of 267 respondents, 13 % (n=35) didn't own any livestock; while 87% (n=232) owned livestock of some form, accounting to a total of 9272 domestic livestock with ownership i.e. 20% (n=1833) of large livestock, 78% (n=7287) of medium livestock, 1% (n=103) dogs, 0.1% (n=13) donkeys, 0.3% (n=33) camels and 0.03% (n=3) horses; the above five domestic stock types were characteristic of the region (though some people in the region do farm chicken), the respondents didn't own any other form of livestock. The distribution of livestock was not homogenous across different occupation 'sectors'; with respondents from 'husbandry sector' showing higher average livestock holding than other occupation types for all forms of domestic livestock list in the study, which was expected (Table 7.7). The livestock (large and medium livestock) belonging to other 'sectors' (agriculture, PIWL, academics, NPIWL) were mostly attending by respondents of 'husbandry sector' (hired shepherds and cowherds) or stall-fed. The cattle has important cultural significance in the region, hence the prevalence across different 'sectors', buffalos are mostly owned by the 'husbandry sector' and few by 'agriculture sector'; medium livestock has no cultural value, but has great economical importance, hence a accepted form of stock in the landscape.

Sector	n	LLS	MLS	D	DN	C	H
Husbandry	63	21.2 ± 3.9	104.3±28.6	0.9±0.017	0.1±0.10	0.4±0.16	0.04±0.04
range		0-150	0-1500	0-4	0-6	0-8	0-3
Agriculture	60	3.3±0.4	7.1±3.6	0.4±0.13	0.03±0.02	0.08±0.05	0
range		0-15	0-150	0-4	0-1	0-3	0
PIWL	45	2.2±1.3	3±0.7	0.1±0.07	0.02±0.02	0.02±0.02	0
range		0-60	0-30	0-2	0-1	0-1	0
Academics	35	2.8±0.3	0.9±0.3	0	0	0	0
range		0-6	0-8	0	0	0	0
NPIWL	64	1.5±0.34	1.6±0.66	0.1±0.07	0	0	0
range		0-14	0-40	0-4	0	0	0
Total	267	6.8±1.08	27.2±7.2	0.3±0.05	0.04±0.02	0.1±0.04	0.01±0.01
range		0-150	0-1500	0-4	0-6	0-8	0-3

Table 7.7: Mean ± SE livestock holding of different sectors with their range. LLS: Large livestock, MLS: Medium livestock, D: Dog, DN: Donkey, C: Camel, H: Horse

Preferences to types of livestock owned were governed by economical condition, utility and ethnicity. Among the respondents who owned domestic stock, 65% (n=151) owned large livestock, 56% (n=130) owned medium livestock, 18% (n=44) owned dogs, 2% (n=6) owned donkeys, 6% (n=14) owned camels and only 0.4% (n=1) owned horse; furthermore, 62% (n=144) owned only one type of domestic stock, 28% (n=66) owned 2 types of domestic stock, 8% (n=19) owned 3 types of domestic stock, 0.8% (n=2) owned 4 types of domestic stock and only 0.4% (n=1) owned all five types of domestic stock. Out of the 144 respondents who owned only one type of domestic stock, 63% (n=91) owned only large livestock, 34% (n=49) owned only medium livestock and 3% (n=4) owned only dogs.

Sixty percent (n=159) had some land holding while, 40% (n=108) didn't own any land. 8% (n=21) had neither landholding nor livestock, 14% (n=5) had no livestock but had some land holding and 33% (n=87) had no landholding but owned domestic stock of some form. Out of 159 respondents who owned land, most of them cultivated multiple crops annually (Figure 7-1).

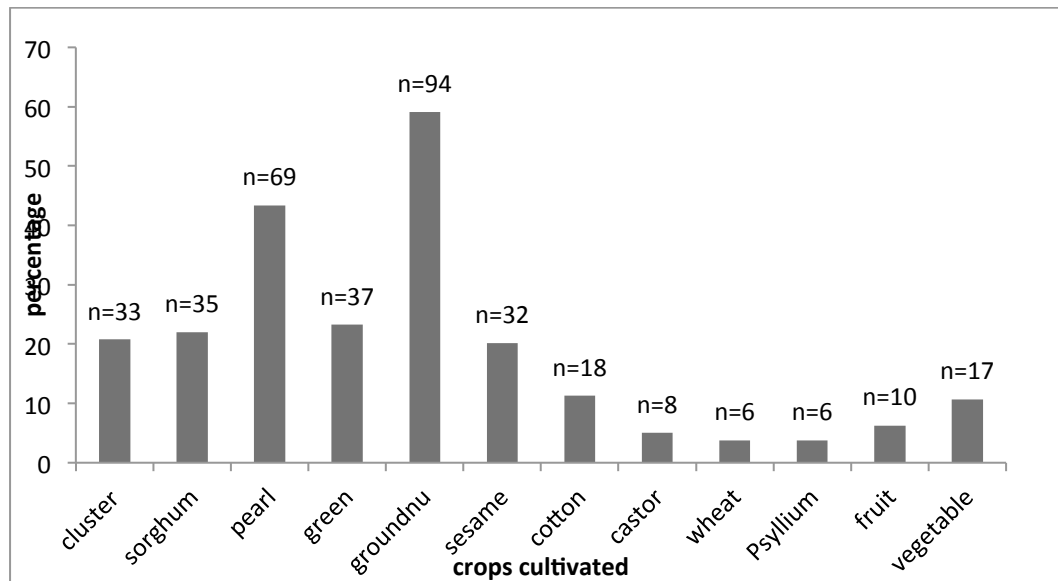


Figure 7-1: Proportion of crop type cultivated by respondents (n=159). Fruits-included dates, musk melon, honey melon, mango, sapodilla and cucumber. Vegetables-included brinjal, tomato and chillies

25% (n=58) of respondents among respondents who own livestock (n=232), claimed to have experienced loss of domestic stock in past 2 months at the time of interaction with the respondent (Table 7.8).

Domestic stock type	Number of loss	Cause of loss					
		Disease	Old age	Predation	Injury and Infection	Alkaloid poisoning	Rabies
Large livestock	27	26% (n=7)	67% (n=18)	–	–	7% (n=2)	–
Medium livestock	49	49% (n=24)	14% (n=7)	24% (n=12)	8% (n=4)	4% (n=2)	–
Dog	2	–	–	–	–	–	100% (n=2)

Table 7.8: Details of loss of domestic stock and causes obtained during survey to understand local people's attitude towards conservation and hyaenas in Kutch.

Out of the 78 domestic stocks lost, the majority of them were lost to disease (40%, n=31) and old age (32%, n=25); only a small proportion of the total reported stock loss was reasoned to predation (15%, n=12). As expected all the predatory events were reported only for medium livestock (24%, n=12), indicating the vulnerability of this size class to some degree of predation. Although there is frequent predation of dogs from villages by hyaenas (Ref chapter.2: diet and foraging pattern), it is normally overlooked as most dogs are free ranging and do not have ownership; none of the reported incidence of predation of medium livestock is attributed to hyaena (Figure 7-2).

Out of 78 domestic stock lost, 85% (n=66) of dead animals were dumped either in 'hadda khudi' (traditional village carcass dumping sites) or disposed anywhere away from human habitation (with the traditional carcass disposal system collapsing in many villages, owners dispose the carcass themselves); either way a bulk of food resource from domestic stock lost to natural and allied causes are available to scavengers. The predated livestock (15%, n=12) was completely lost to predator, hence carcass not available for disposal.

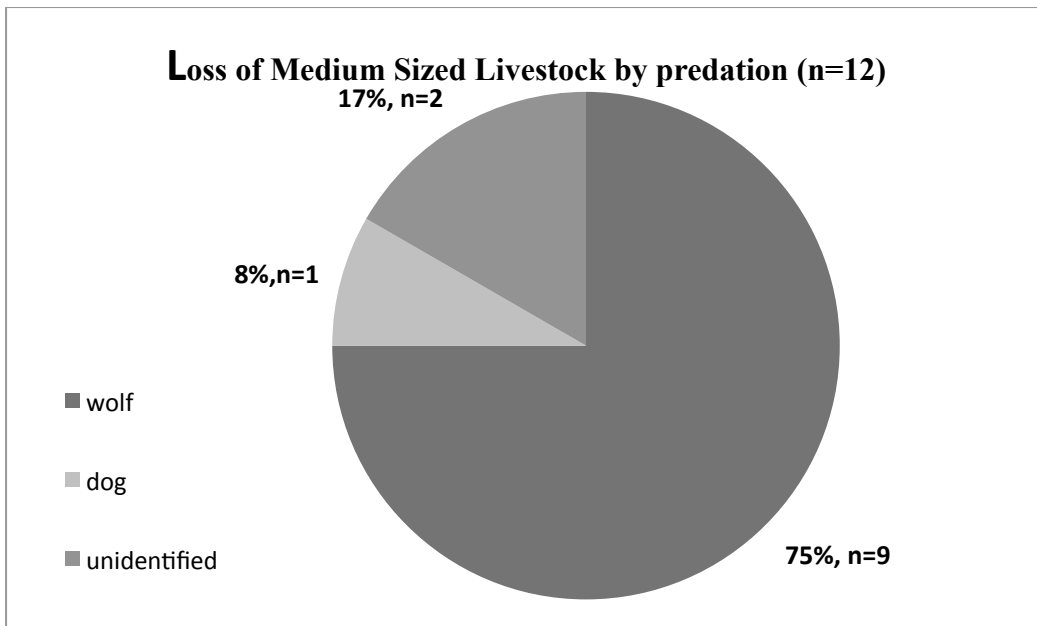


Figure 7-2: Loss of medium livestock (n=12) and predator held responsible quantified from the survey conducted in Kutch to determine awareness and knowledge of locals on hyaenas

### 7.3.2 Awareness and knowledge

Most respondents (70%, n=186) expressed a visible decline in wildlife numbers, while a small proportion (19%, n=50) didn't agree with the decline and 12% of the respondents (n=31) were uncertain (Figure 7-3).

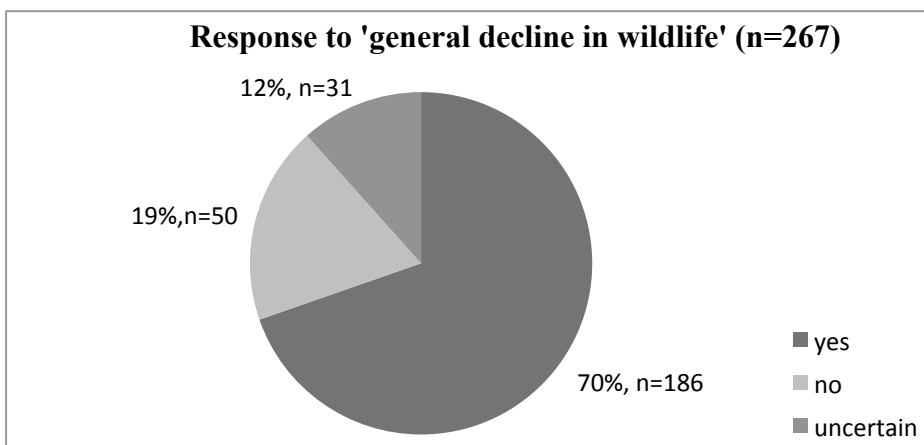


Figure 7-3: Response to general trend in decline of wildlife numbers, in the landscape (n=267) quantified from the survey conducted in Kutch to determine awareness and knowledge of locals on hyaenas.

Five factors thought by respondents (n=186) that determined the decrease of general wildlife in the region: Hunting, Lack of forage, Human population growth, Expansion of agriculture and Lack of shelter (

Figure 7-4). Hunting was considered an important factor, by a large number of respondents (n=169).

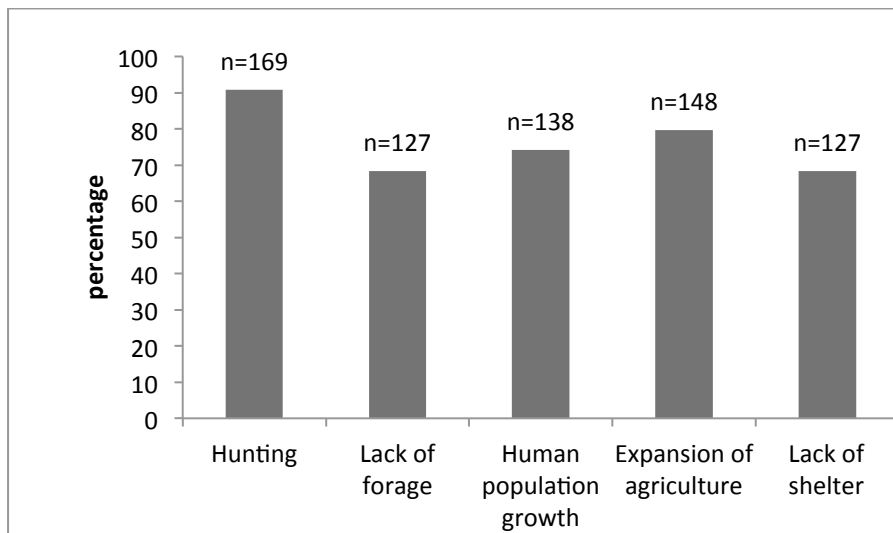


Figure 7-4: proportion of respondents (n=186) reasoning for the general visible decline in wildlife, quantified from the survey conducted in Kutch to determine awareness and knowledge of locals on hyaenas.

A total of 13 species of wild animals were listed collectively, all respondents (n=267) acknowledged the presence (range 1-13) of wildlife species around their village (within the radius of 5 km) (Figure 7-5) and the same list of 13 species were detected close to their village (within the radius of 0.5 km) (Figure 7-6).

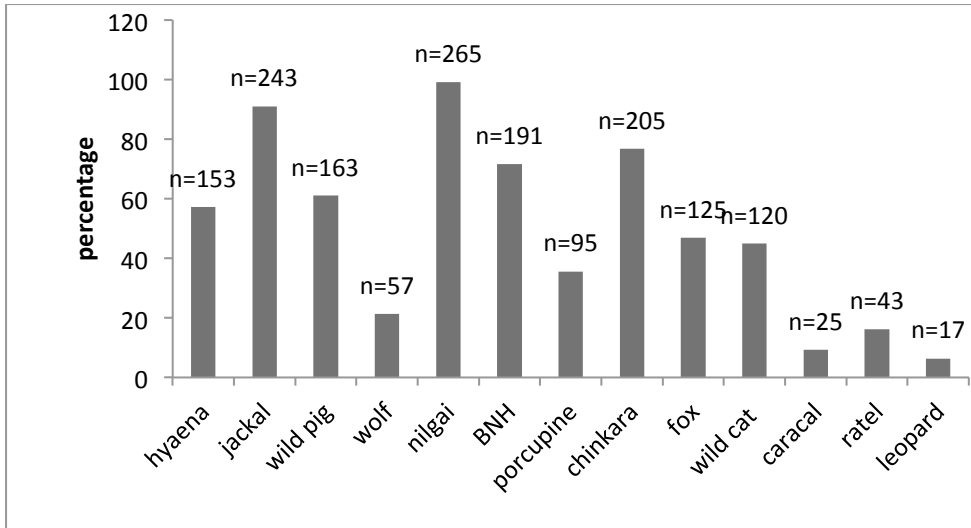


Figure 7-5: proportion of wild species listed by respondents (n=267) inhabiting around village (within radius of 5 km). BNH: black napped hare. Wildcat: includes both desert cat and jungle cat, quantified from the survey conducted in Kutch to determine awareness and knowledge of locals on hyaenas

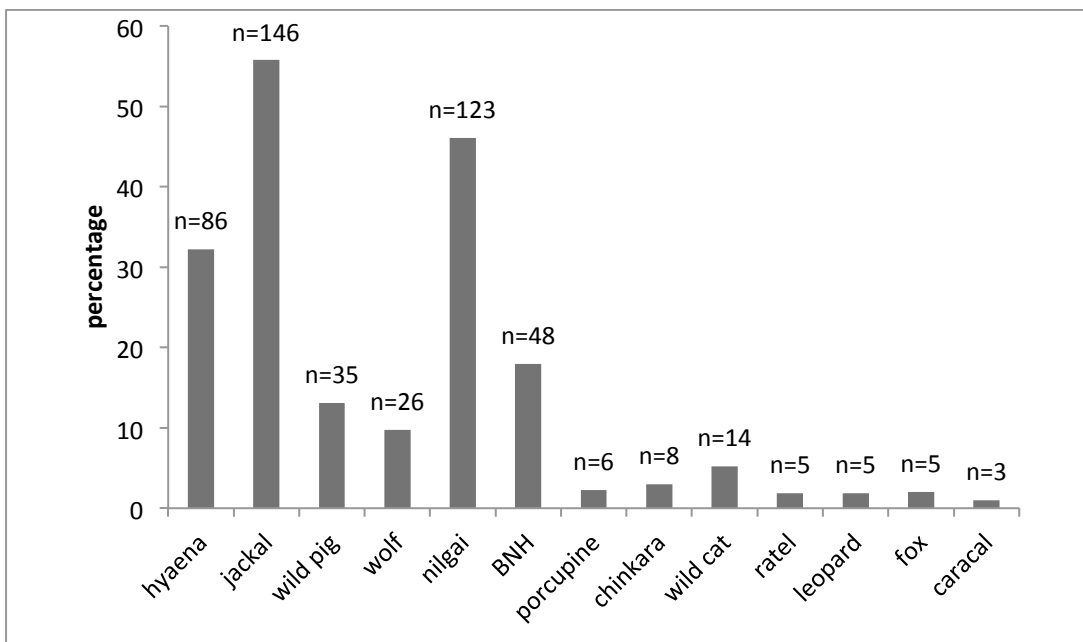


Figure 7-6: Proportion of wildlife detected by respondents (n=267) close to the village (within radius of 0.5 km). BNH: black napped hare. Wildcat: includes both

desert cat and jungle cat, quantified from the survey conducted in Kutch to determine awareness and knowledge of locals on hyaenas.

The collective wildlife species list is almost complete representation of all important mammalian fauna present in the region; with the exception of small Indian civet and mongoose and some important bird species like great Indian bustard and vultures, which were not listed (Figure 7-5&Figure 7-6). Excluding the leopard (extremely rare and restricted) and caracal (data deficient); most of the listed species are widely distributed in the landscape, with varying densities and detection probability among species. There is a difference ( $\chi^2=199.60$ ,  $df=12$ ,  $P<0.05$ ) in wildlife species detected close to village (Figure 7-6) and wildlife species listed around the village (Figure 7-5). The proportions of respondents, who have actually detected wildlife species close to village and included them in listed wildlife around their village, are far lesser. Diurnal or crepuscular species could be detected with ease within the extent of routine village activity; but the awareness of rare, cryptic and nocturnal species is likely to be influenced by other factors. Since, the focus is on people's attitude towards hyaena and the aspects that influence it; other wildlife species listed, is beyond the scope of this study.

To test the difference in level of awareness to presence of hyaena around villages, among respondents from different 'occupation sector'; a logistic regression was conducted (Table 7.9). The model was significant ( $X^2=72.1$ ,  $df=4$ ,  $p<0.001$ ) and reliably fitted the data ( $X^2=0$ ,  $df=3$ ,  $p=1.0$ ). It explained reasonable amount of information in data ( $R^2=0.32$ ), had a correct classification rate of 75%, and a predictive accuracy of 0.76 (area under the ROC curve).

Occupation sector	B	S.E.	Wald	P-value	Odd's ratio
Constant	-0.65	0.26	6.04	0.01	0.52
Husbandry	2.09	0.42	25.45	0.001	8.11
Agriculture	1.58	0.39	16.38	0.001	4.83
Academics	-1.4	0.59	5.58	0.02	0.25
PIWL	1.66	0.43	15.03	0.001	5.25

Table 7.9: Result of logistic regression used to explain awareness of hyaena presence with occupation of respondent.

NPIWL (occupation with no possible interaction with wildlife) sector was considered as a reference in the model. The result from odd's ratio (Table 7.9) indicates that respondents from 'husbandry sector' are 8.11 times more aware to the presence of hyaena around their village than 'NPIWL sector'; similarly 'PIWL sector' was 5.25 times more aware and 'agriculture sector' are 4.83 times more aware than 'NPIWL sector'.

For the question where the respondents were asked to describe the hyaena (Table 7.2), A large number of respondents (78%, n=209) were able to describe hyaena, and most of traits described (27 out of 33 traits) are actual representation of the animal's morphology, habits and diet. Few respondents included all true traits (n=27) in their description of hyaena; most of them explained only few traits (Table 7.10).

Proportion of traits, described of hyaena by respondents (n=209).					
Traits	% (n)	Traits	% (n)	Traits	% (n)
dog like	69 (145)	bushy tail	56 (118)	carrion in diet	79 (165)
dog sized	28 (58)	face black in coloration	46 (97)	predates dogs/pups	70 (146)
donkey foal sized	33 (69)	black throat patch	22 (46)	predates small livestock	32 (67)
long foreleg	40 (83)	stinky/smelly	36 (75)	donkey like	28 (58)
short hind legs	15 (32)	nocturnal	78 (164)	donkey sized	23 (48)
sloping back	42 (87)	afraid/shy of humans	57 (120)	buffalo calf sized	5 (11)
long hairs	56 (117)	poor runner	61 (127)	spotted	1 (3)
presence of hackle	35 (73)	runs/walks with a limp	60 (125)	long tailed	15 (32)
long ears	53 (110)	uses den as day refuge	48 (100)	predates wildlife	83 (174)
striped	70 (146)	uses bush as day refuge	85 (178)		
brown	78 (162)	carnivores	89 (186)		
short tailed	56 (118)	bone in diet	68 (143)		

Table 7.10: Percentage of respondents that correctly described a particular trait of the striped hyaena in Kutch (n=209)

To test the difference in level of actual description (‘description only with true traits’) of hyaena across variables (gender, age class and occupation); a logistic regression using generalized linear model was conducted in SPSS 16.0 (SPSS Inc, Chicago) (Table 7.11).

	B	S.E.	Wald	P-value	Odd's ratio
Constant	0.18	0.26	0.49	0.48	1.2
Male	0.32	0.14	5.48	0.02	1.38
Age-class	0.46	0.1	21.23	0	1.58
Husbandry	1.12	0.17	41.86	0	3.07
Agriculture	0.68	0.16	17.76	0	1.98
Academics	0.49	0.21	5.6	0.02	1.63
PIWL	0.82	0.17	21.96	0	2.26

Table 7.11: Result of logistic regression used to test the relationship between knowledge of striped hyaenas and the different categories of individuals in the local survey in Kutch.

The model was significant ( $X^2=87.9$ ,  $df=6$ ,  $p<0.001$ ). Females of ‘gender’ variable, age class I and age class II of ‘age class’ variable and NPIWL (occupation with no possible interaction with wildlife) of ‘occupation’ variable were considered as reference categories in the model. The results from odd’s ratio (Table 7.11) indicate that, males described 1.38 times more accurately than females, consecutive younger age class category described 1.58 times more accurately than the other; and respondents from ‘husbandry sector’ described 3.07 times more accurately than ‘NPIWL sector’, while accuracy in description in ‘PIWL sector’ was 2.26 times, ‘agriculture sector’ 1.98 times and academic sector 1.63 times more higher than NPIWL sector. Occupation appears to be an important factor governing the level of awareness about hyaena. Out the respondents ( $n=209$ ) who were aware of hyaena, only 64% ( $n=133$ ) of them had ever seen the animal; while 36% ( $n=76$ ) had never

seen a hyaena but still described it, is indicative of additional factors along with occupation governing awareness levels. There is a variation in detection across variables of occupation, age class and gender of respondents (n=267) (Table 7.12).

Hyaena sighting of respondents (n=267)						
	sighted	never sighted	X <sup>2</sup>	df	p value	
Sector	Husbandry	56	7	93.3	4	<0.05
	Agriculture	36	24			
	Academics	4	31			
	PIWL	27	18			
	NPIWL	10	54			
Age class	I	13	36	27.8	2	<0.05
	II	78	86			
	III	42	12			
Gender	M	119	90	19.5	1	<0.05
	F	14	44			

Table 7.12: Hyaena sighting of respondents (n=267)

Among occupation, respondents (42%, n=56) belonging to ‘husbandry sector’ had highest likelihood of detection and respondents from academics sector had lowest (3%, n=4). Respondents from age class II (59%, n=78) had higher sighting of the animal and males (89%, n=119) had detected more hyaenas than women did. Majority of respondents (n=74, 56%) have detected hyaena  $\geq 5$  times, out of which 19 % (n=25) have detected it only once; and 44 % (n=59) have detected hyaena  $\leq 10$  times, out of which only 14 % (n=19) have detected it more than 50 times (Figure 7-7). Highest proportions of detections were near villages (58%, n=77), followed by detection in wilderness (55%, n=73) (Figure 7-8). Most respondents who have

detected hyaenas only once (19%, n=25) have seen them crossing roads or as victims of traffic accidents, very few have seen them in other locations.

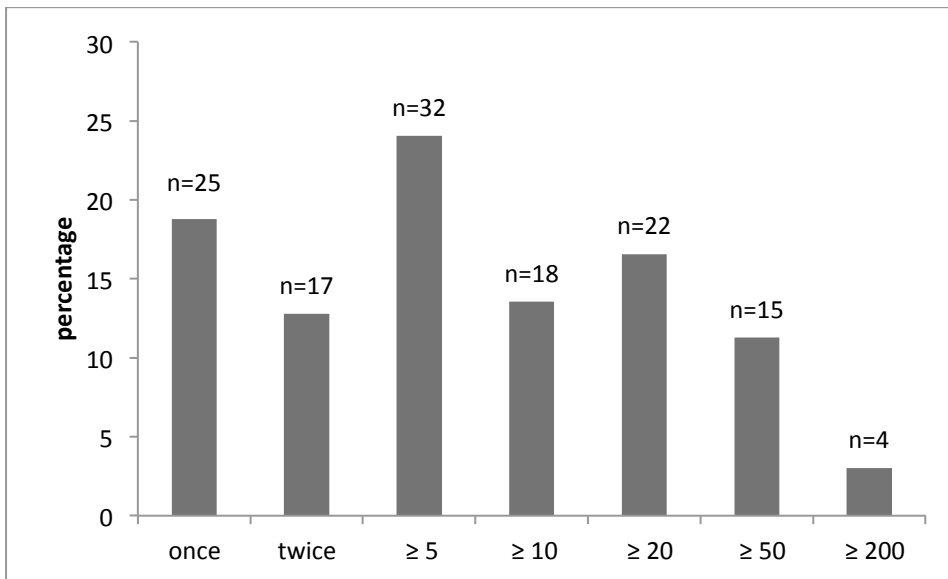


Figure 7-7: Number of times, hyaena was detected by respondents (n=133), quantified from the survey conducted in Kutch to determine awareness and knowledge of locals on hyaenas

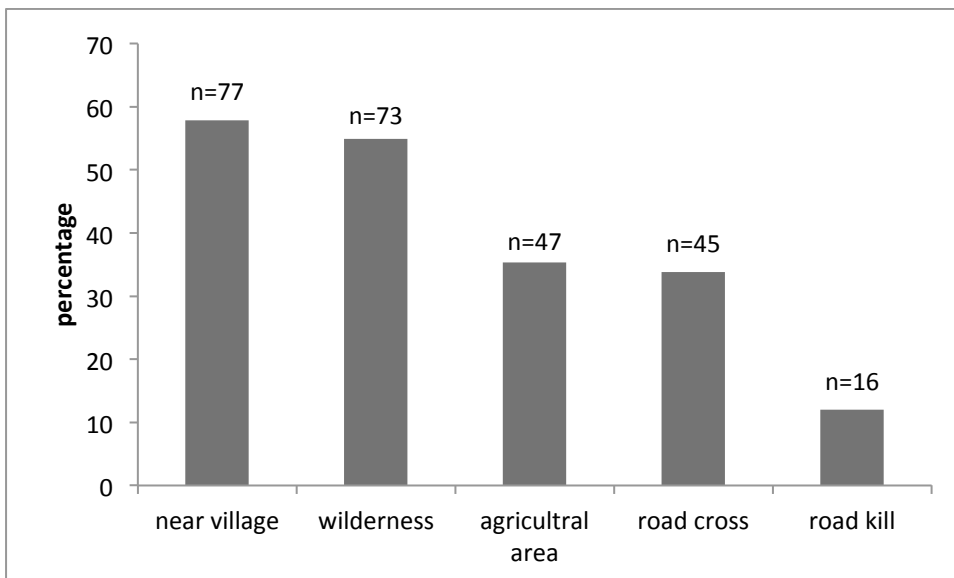


Figure 7-8: of hyaena detection in the landscape by respondents (n=133), quantified from the survey conducted in Kutch to determine awareness and knowledge of locals on hyaenas

Out 267 respondents, only 50% (n=133) have detected hyaenas in the landscape; but 78 % (n=209) out of the total respondents are aware of the species, of which 36% (n=76) have never seen a hyaena and knew about the species from gathered information (Table 7.13). Out of the 76 respondents (36%), 24 % (n=51) of the respondents gathered information from other people, while 12% (n=25) gathered information from various media sources (chiefly wildlife based channels) (Table 7.13).

Sector	n (%)	NA n (%)	AI n (%)	AI factor		
				SHn (%)	IP n (%)	MC n (%)
Husbandry	63 (23.60)	5 (7.94)	58 (92.06)	56 (96.55)	2 (3.45)	0
Agriculture	60 (22.47)	8 (13.33)	52 (86.67)	36 (69.23)	11 (21.15)	5 (9.62)
Academics	35 (13.11)	12 (34.29)	23 (65.71)	4 (17.39)	5 (21.74)	14 (60.87)
PIWL	45 (16.85)	6 (13.33)	39 (86.67)	27 (69.23)	12 (30.77)	0
NPIWL	64 (23.97)	27 (42.19)	37 (57.81)	10 (27.03)	21 (56.76)	6 (16.22)
Total	267 (100)	58 (21.72)	209 (78.28)	133 (63.64)	51 (24.40)	25 (11.96)

Table 7.13: Awareness across different occupation sectors. NA: Not aware, AI: Aware and informed, SH: Sighted hyaena, IP: Information passed, MC: print media and television channel, quantified from the survey conducted in Kutch to determine awareness and knowledge of locals on hyaenas.

Out of 51 respondents who gathered information on hyaenas, the largest proportion of information was gathered from shepherds (75 %, n=38), the rest were from elders and hunters (Figure 7-9). It is important to appreciate; that there is considerable exchange of information among different occupation groups, eventually influencing the awareness and attitude of a larger section of people in the landscape. Interestingly the exchange of information regarding hyaena, is noted in all occupation sectors; of which highest contribution in ‘NPIWL sector’ (41%, n=21) (Table 7.13). Out of respondents who were aware (n=209), 12 % (n=25) of respondents had gained awareness from media. Unlike the ‘information gathered from people’, media didn’t percolate to all sectors; so far, media did not have any influence on the awareness of respondents from ‘husbandry’ and ‘PIWL’ sectors. But media did have significant

influence on ‘academics sector’; out of 23 respondents (66%) who were aware of hyaena, 61 % (n=14) were influenced entirely by media (Table 7.13).

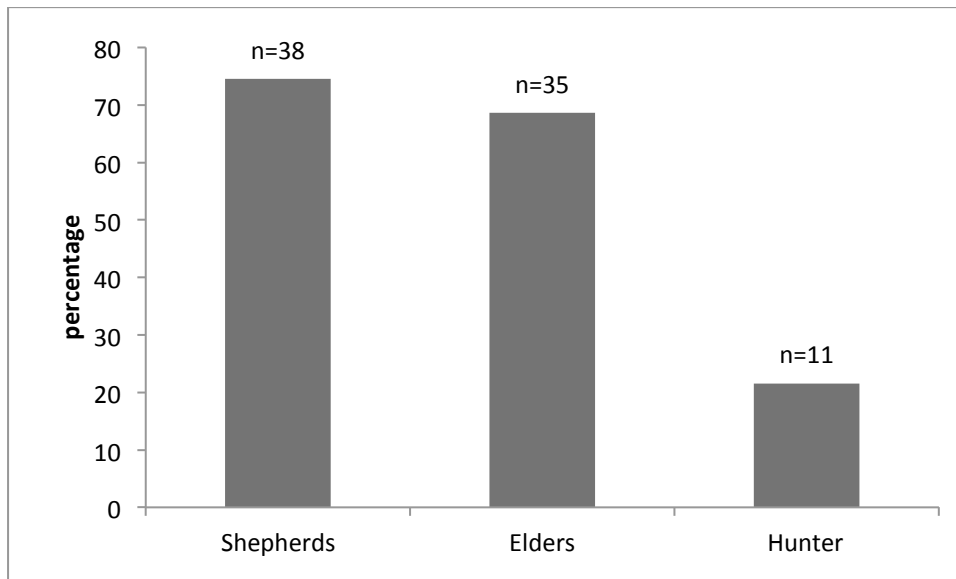


Figure 7-9: Source of Information gathered on hyaenas during survey among the locals in the study area in Kutch (n=51).

In response to the question regarding food sources of hyaenas; out of 267 respondents, 22% (n=58) were not aware. Among 78% (n=209) respondents who were aware, the highest proportion of respondents (n=159) agreed carcass to be important source of food, followed by bones, predation and crops (Figure 7-10). Only a small proportion of respondents (n=65) believed that predation was equally important as scavenging, of which 11% (n=24) respondents assumed that hyaenas obtained food only by predation. Out of the 24 respondents, 58% (n=14) belonged to ‘academic sector’ and 21 % (n=5) belonged to ‘agriculture and ‘NPIWL’ sector each. None of the above respondent had ever witnessed any predation attempt; their responses were either assumed or misinformed. The five respondents from agriculture sector were recent immigrant farmers from Punjab and Haryana, with limited interaction with people and landscape. The responses of ‘academic sector’ in this regard is notable, as all the 14 responses are the same respondents as in Table 7.13; the information acquired from media is mismatched with that of spotted hyaena and striped hyaena, as seen in Table 7.2 where ‘spotted’ is also listed as trait.

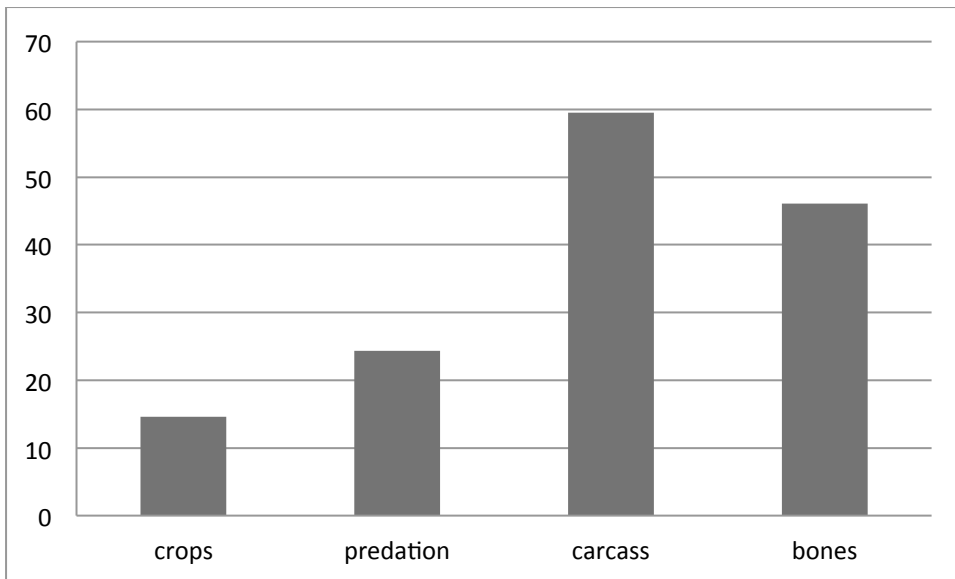


Figure 7-10: Proportion of diet composition of hyaenas listed by respondents in Kutch during survey of locals to determine attitudes and knowledge on hyaenas (n=209)

Only 6% (n=17) of the respondents reported predation attempt by hyaena (Figure 7-11); of the 17 respondents, 53% (n=9) were reported by respondents from ‘husbandry sector’ while, 29% (n=5) reported from ‘agricultural sector’, 6% (n=1) from ‘academics sector’ and 12 % (n=2) from ‘PIWL sector’. Most of these 17 predation events occurred at night (76%, n=13) and the rest (12%, n=2) occurred at morning and evening each; all events occurred in span of 10 years (ranging between 1 day to 10 years from the day of interaction with respondent), suggesting predation by hyaenas are a very rare event to occur or difficult to record.

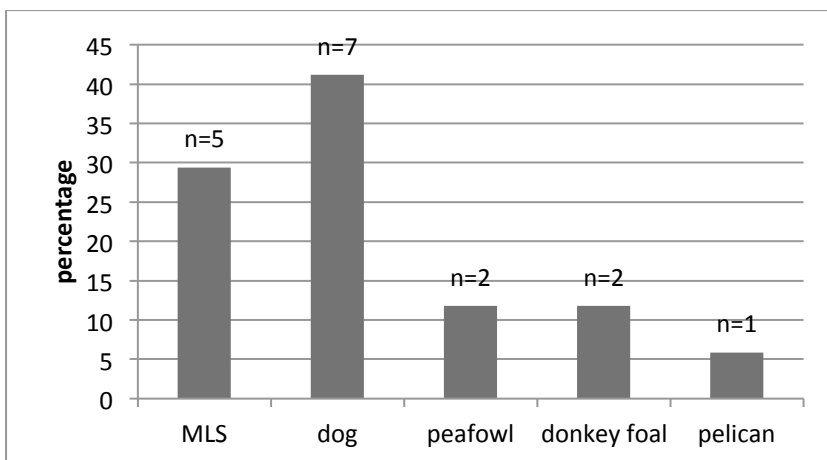


Figure 7-11: Predation attempt by hyaena as perceived by locals in Kutch during a survey to determine attitudes and knowledge on hyaenas (n=17).

Of the recorded predation events by respondents (n=17), 82 % (n=14) occurred in or near villages and the rest 18% (n=3) in wilderness. Of which 41 % (n=7) predation attempt were on dogs; followed by MLS (medium livestock) 29% (n=5), 12% (n=2) on peafowl and donkey foal each and 6% (n=1) on pelican. 76% (n=13) predation attempts were successful, while 24 % (n=4) were unsuccessful (attempts on a goat, dog, peafowl and pelican were reported unproductive).

Considering the details on its home ranges [ $80.7 \text{ km}^2 \pm 13.8$  (100% MCP)] with no overlap of territories between clans established in the region (Ref chapter.3: home range and movement pattern); in all practicality, it is unlikely that all villages (n=124) sampled for the study will have an active hyaena den in close proximity. In view of this fact all the responses to the query on “presence of hyaena den near village” were considered accordingly; where the ‘yes’ response and the confident ‘no’ response were treated as ‘aware’, whereas the ‘don’t know’ responses were treated as ‘unaware’.

Out of total respondents (n=267), 34 % (n=91) were aware and the rest 66 % (n=176) were unaware. Out of the 34 % (n=91) of respondents who were aware; 70 % (n=64) were affirmative regarding the presence of hyaena dens around their village, while 30 % (n=27) were certain that there was no presence of hyaena dens around their village (Table 7.14). Of the 70 % (n=64) respondents positive towards existence of dens, 73 % (n=47) recognized the den from a combination of factors like detection of hyaena and cubs, along with presence of spools and bone accumulations, while 27 % (n=17) assimilated information from other people (mostly shepherds and hunters). There was significant difference regarding hyaena den awareness across different occupation sectors, with respondents from husbandry sector more aware, while it did not differ considerably across age class or gender (Table 7.15).

Variables	n (%)	Den presence-aware			
		Present		Unaware (%)	
		n (%)	Not present (%)		
Sector	husbandry	63 (24)	31 (49)	19 (30)	13 (21)
	agriculture	60 (20)	19 (32)	3 (5)	38 (63)
	academics	35 (13)	1 (3)	0 (0)	34 (97)
	PIWL	45 (17)	11 (24)	3 (7)	31 (69)
	NPIWL	64 (24)	2 (3)	2 (3)	60 (94)
Age-class	I	49 (18)	12 (24)	2 (4)	35 (71)
	II	164 (61)	36 (22)	16 (10)	112 (68)
	III	54 (20)	16 (30)	9 (17)	29 (54)
Gender	M	209(78)	53(25)	22 (11)	134 (64)
	F	58 (22)	11 (19)	5 (9)	42 (72)
Total		267 (100)	64 (24)	27 (10)	176 (66)

Table 7.14: Awareness regarding, presence of hyaena den around their village in Kutch during a survey to determine attitudes and knowledge on hyaenas.

Hyaena den awareness of respondents (n=267)					
Variables	Aware (%)	Not aware (%)	X <sup>2</sup>	df	p value
Sector	Husbandry	50 (79)	13 (21)	95.1	4
	Agriculture	22 (37)	38 (63)		
	Academics	1(3)	34 (97)		
	PIWL	14 (31)	31 (69)		
	NPIWL	4 (6)	60 (94)		

Age class	I	14(29)	35 (71)	4.66	2	0.09
	II	52 (32)	112 (68)			
	III	25 (46)	29 (54)			
Gender	M	75 (36)	134 (64)	1.39	1	0.23
	F	16 (28)	42 (72)			

Table 7.15: Awareness regarding, presence of hyaena den around their village in Kutch during a survey to determine attitudes and knowledge on hyaenas

Knowledge of hyaena dens, on whether they are present or absent near villages can be considered as a measure for upmost level of awareness. As hyaenas dens are difficult to come across, and when encountered involves some level of awareness of the species to appropriately identify the dens used by it; moreover, some level of interest is required as not to ignore the find. Still the reports on their absence specify that the respondents could distinguish between dens used by hyaenas and other species; and were confident about this information, furthermore avoided incorrectly assigning dens. Also information on location of hyaena dens gathered by respondents, out of curiosity or on purpose; involves additional interest or some indefinite motive.

### 7.3.3 People's perception of hyaena

The study assumes that knowledge and perception can be useful influence on behavior, especially harmful behavior. Out of 267 respondents, 75% (n=200) alleged that some wildlife in the region could be problematic (Figure 7-12), while 13% (n=34) thought that none of the wildlife was problematic, 12 % (n=12) were uncertain. A total of five species were listed as problematic, the highest proportion was reported for nilgai (90%, n=179) for the reason of damage by crop raiding; while the lowest was for hyaena (3 %, n=6), hyaena along with wolf (41%, n=82) accounted for damage by predation mostly of medium livestock (Figure 7-2).

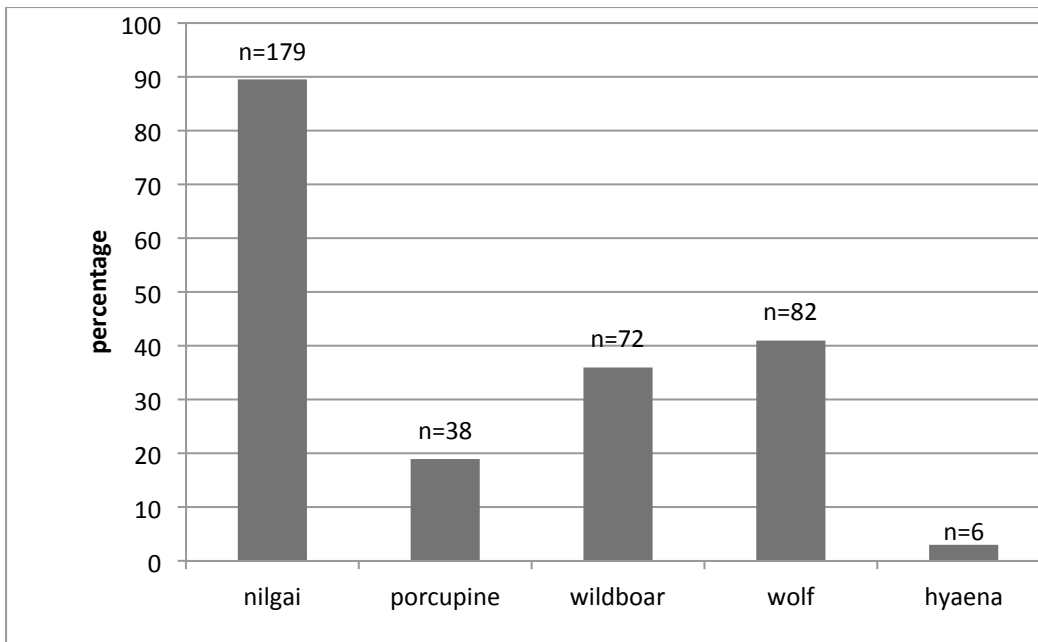


Figure 7-12: Proportion of respondents (n=200), who considered few species problematic in Kutch during a survey to determine attitudes and knowledge on hyaenas.

On the three possible conflict issues in the landscapes, 16% (n=42) of respondents believed that hyaenas cause crop damage, while 34 % (n=91) did not think so and 50 % (n=134) were uncertain (Figure 7-12). Only 10% (n=27) of the respondents suspected that hyaenas attack livestock, while majority of the respondents (55%, n=146) did not believe likewise and 35% (n=94) were unsure (Figure 7-12). Large number of respondents (57%, n=153) supposed that hyaenas could attack humans, a small fraction (13%, n=34) were confident that hyaenas do not attack humans and the rest (30%, n=80) (Figure 7-13).

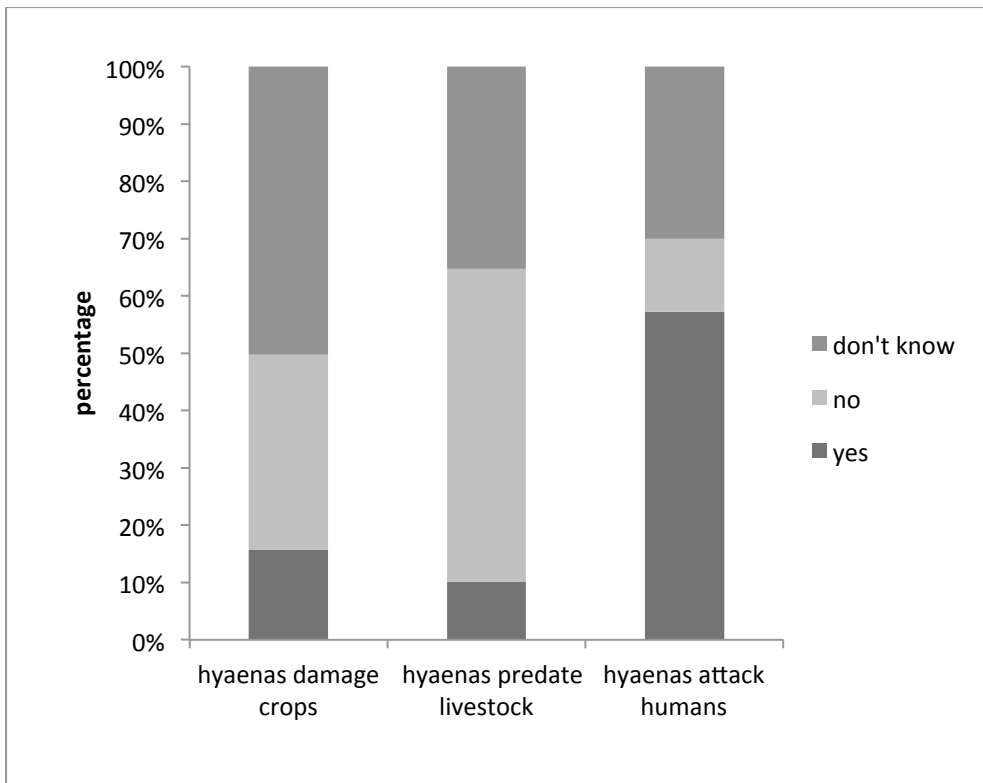


Figure 7-13: Responses (n=267) to possible conflict issues in the landscape in Kutch during a survey to determine attitudes and knowledge on hyaenas.

Out of 42 respondents, positively responding to damage of standing crop by hyaena, largest proportion (55%, n=23) identified groundnut crops damaged the most, followed by melons (48%, n=20) (Figure 7-14). However, 71 % (n=30) of the respondents considered the degree of damage to be negligible; only 29 % (n=12) held the level of damage to be 'low' (like 5 to 6 kg of melons or cucumber consumed by hyaena in a foraging bout), but agreed this intensity of damage was not consequential to their livelihood.

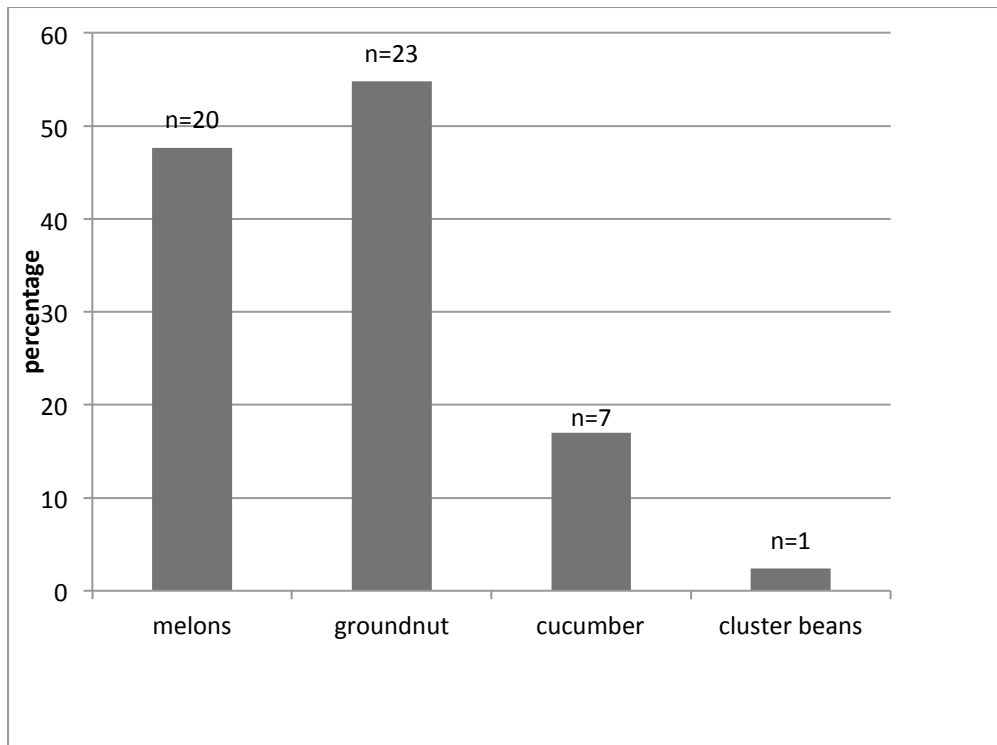


Figure 7-14: Proportion of crop damage by hyaenas (n=42) as perceived by locals in Kutch during a survey to determine attitudes and knowledge on hyaenas. Melons include both honey and musk melons.

Out of 267 respondents, only 49 % of respondents (n=130) owned medium livestock. Of the 130 respondents, 73 % (n=95) owned few MLS (ranging between 1 to 12) and kept them in their residence compound during night fall; the rest (35%, n=45), owning medium to large herds of MLS (ranging between 18 to 1500) invested in some of protection measures to safeguard their stock at nighttime. Among the 45 respondents who employed protection measures, 40% (n=18) owned medium sized herds (ranging between 19 to 40) stayed in or close to human habitations; hence, none of these respondents reported hyaena attacks on MLS. The remaining of the 45 respondents, 60% (n=27) owned medium to large sized herds (ranging between 45 to 1500) camped away from villages and reported attacks; where highest proportion of respondents (56%, n=15) reported lifting MLS from wadas (corrals) as preferred predation mode (Figure 7-15). Among the 27 respondents, respondents (67%, n=18) who used combination of various protection measures like use of guard dogs and thorny hedge/ net/barb wires as corral boundaries, were less prone to livestock loss due to hyaena predation, as compared to respondents (33%, n=9), who employed only one form of protection measure (Table 7-16)

Protective measure	% (n)	Frequency of attack	Success of attack
guard dogs, thorn hedges (wada), net or barb wire around wada	52 % (n=14)		
guard dogs, thorny bushes around wada	7% (n=2)	Infrequently (67%, n=18)	Rarely (67%, n=18)
livestock guarding with dogs, net around pens	7% (n=2)		
livestock guarding with dogs	7% (n=2)		
barb wiring around wada, hedges around the wada	7% (n=2)		
thorn hedge, gunny bags	7% (n=2)	Frequently (33%, n=9)	Infrequently (33%, n=9)
pen with net, thorny hedge	7% (n=2)		
thorn hedges	4 % (n=1)		

Table 7.16: Protection measures and its success rate (n=27) as determined during a local survey in Kutch to determine attitudes and knowledge on hyaenas.

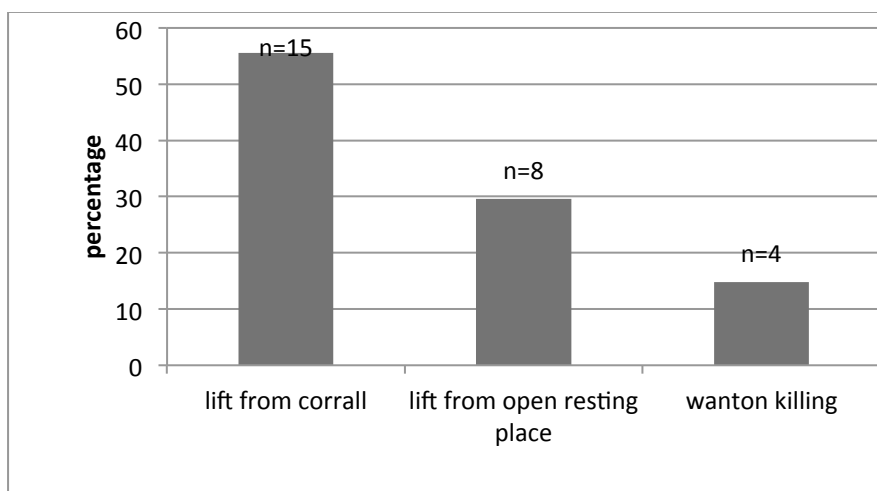


Figure 7-15: Mode of hyaena attacks on livestock quantified during a local survey in Kutch to determine the attitudes and knowledge of locals on hyaenas (n=27).

Out of 57 % (n=153) respondents, who thought hyaenas could attack humans; only, 29 % (n=44) believed that both (rabid and healthy) hyaenas were capable of attack, while 71 % (n=109) were certain only rabid hyaena could attack. Out of 109 respondents, only 34 (31%) of respondents could recollect 18 incidents of rabid hyaena attacks at different location, across time scale (approximately between 1 to 30 years from the date of interview). Fifty percent (n=9) of the incidents occurred in village premises and the rest (50%, n=9) were encountered in the wilderness; all the rabid hyaenas reported (n=18) had similar fate, all were violently killed (Figure 7-16).

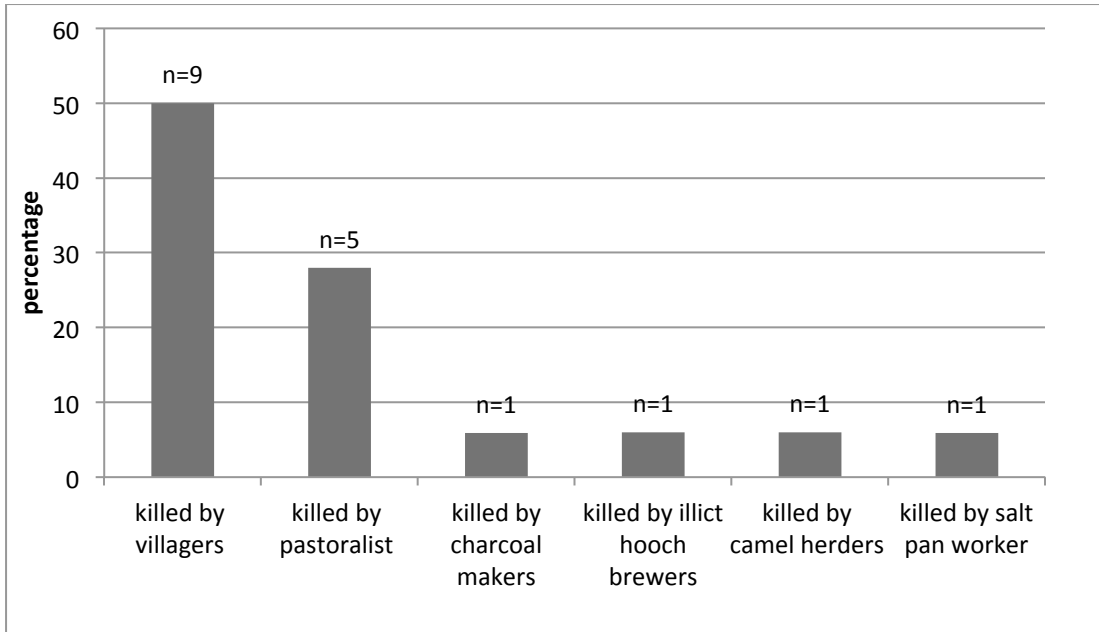


Figure 7-16: Fate of rabid hyaenas as determined during a survey in Kutch to understand the attitudes and knowledge of locals on hyaenas (n=18).

#### Threats to hyaenas' survival:

Out of 267 respondents, 12 % (n=32) had detected dead hyaenas and 88% (n=235) did not detect any; 8% (n=21) out of the total respondents (n=267) had observed dogs chasing hyaenas, the remaining 92% (n=246) never witnessed any chase/attack by dogs. 29% (n=77) were aware of hyaena body utilized for traditional medicine, while 71 % (n=190) were unaware (Figure 7-17).

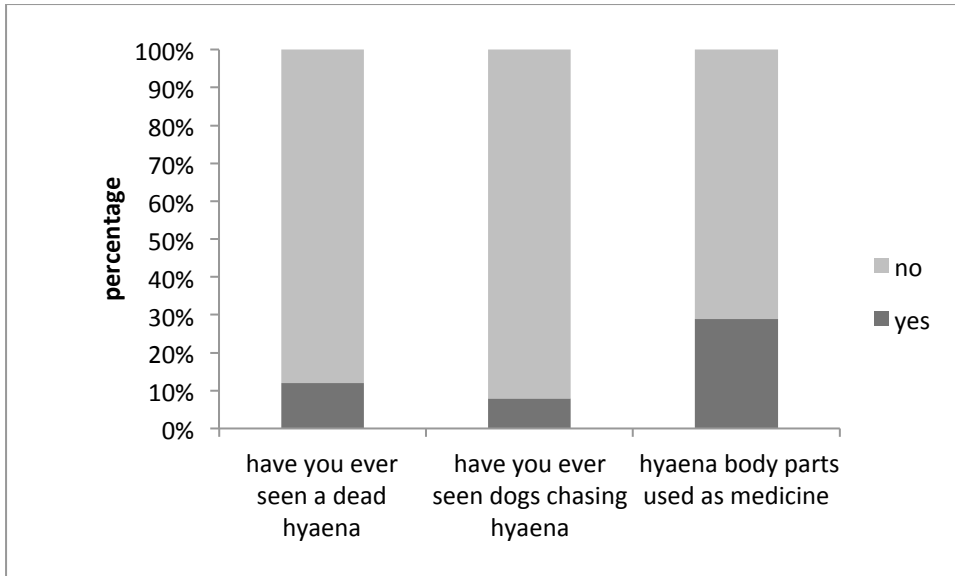


Figure 7-17: Responses (n=267) to issues considered as possible threats to hyaena survival in the landscape during a survey in Kutch to determine local attitudes and knowledge on hyaeans.

Of the 32 dead hyaenas detected by 12% (n=33) of respondents, most of them (50%, n=16) were detected on roads; followed by detection in wilderness (31%, n=10), near villages (13%, n=4) and agricultural areas (6%, n=2) (Figure 7-18). The entire detection (n=32) was in the period between approximately 1 and 10 years from the date of interaction with the respondents.

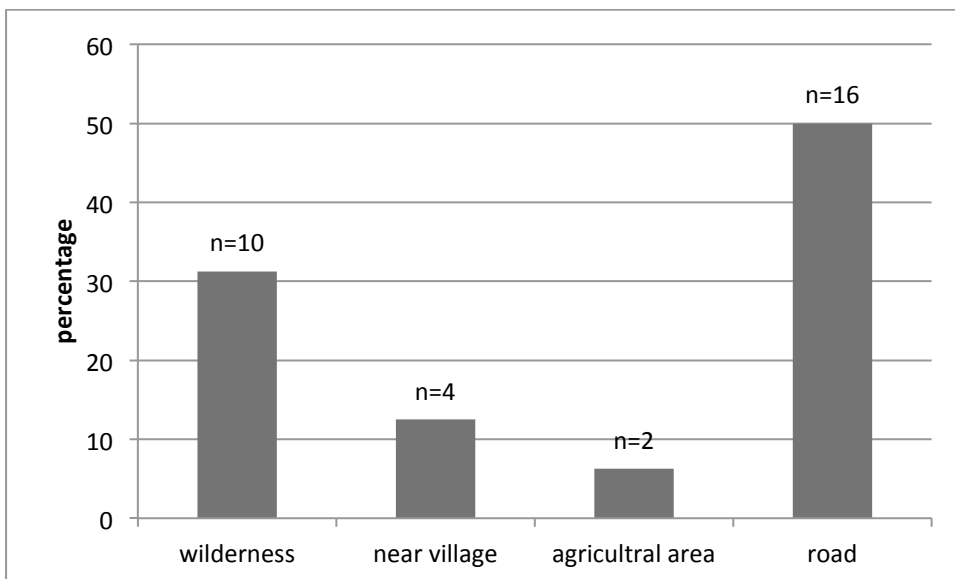


Figure 7-18: General locations of dead hyaenas (n=32) detected during a survey in Kutch to determine local attitudes and knowledge on hyaenas.

Most important mortality factor explained for all the dead hyaenas (n=32), was mortality caused by road traffic accidents (50%, n=16); followed by snaring (16%, n=5), for an equivalent number of dead hyaenas (16%, n=5) the cause of mortality was not established (Figure 7-19).

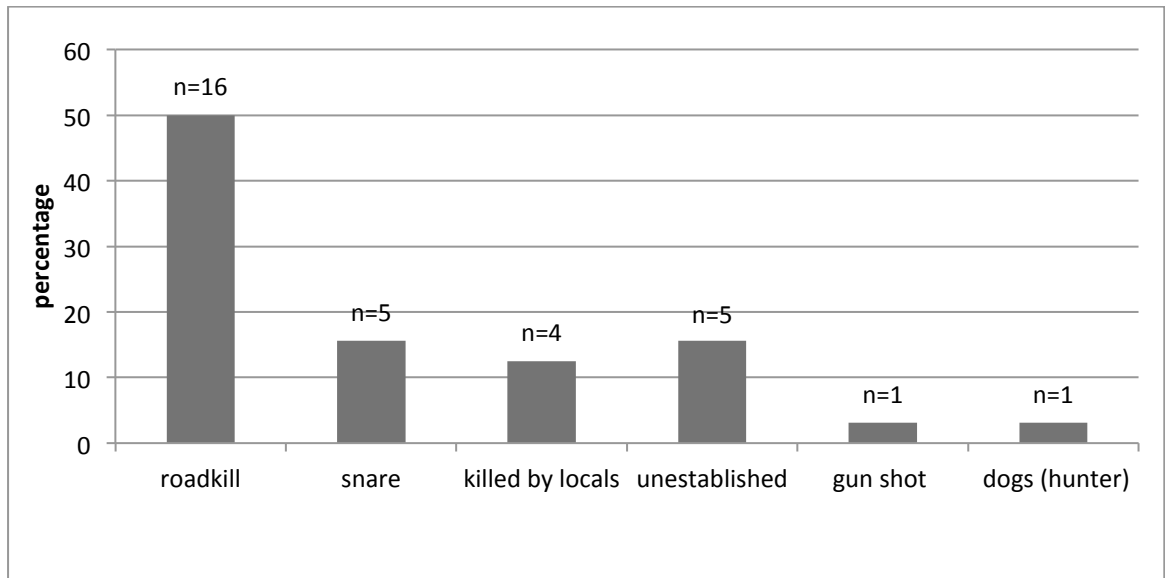


Figure 7-19: Mortality factors of reported dead hyaenas (n=32) as quantified from the survey conducted in Kutch to determine local attitudes and knowledge on hyaenas.

Entire 8% (n=21) of the recorded chase/attack by dogs were observed in the extent between 1 month and 10 years. Most of the incidents were observed near villages (67%, n=14), the rest were witnessed in wilderness (33%, n=7). Of which, 43% (n=9) was recorded in night time, 38% (n=8) at morning hours; 14% (n=3) at noon time and only 1 (5%) observation was at sundown. At the time of chase/attack by dogs, majority of the hyaenas (48%, n=10) were foraging near villages, 19% (n=4) were feeding on carcass; 4 individuals (19%) were flushed from day refuges and 14% (n=3) were near wadas (corrals) (Figure 7-20). In most of the chase/attack incidence (86%, n=18) involved village dogs/guard dogs; only in 3 incidents (14%), specialized hunting dogs (generally used in wild pig hunt) participated in the chase/attack. Most of chase/attack were unsuccessful, where majority of hyaenas (90%, n=19) escaped into safety either entering dens or fleeing into thick vegetation; 2 incidents (10%) were partly successful, as the hyaenas chased were severely injured by dogs (hunting dogs) but they managed to escape (Figure 7-21).

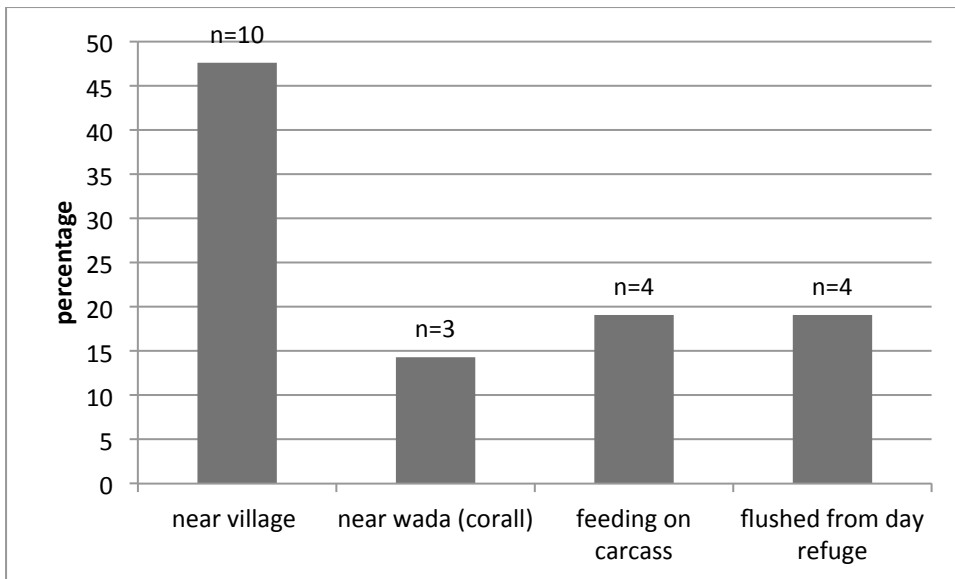


Figure 7-20: Activity of hyaenas (n=21) at the time of chase quantified from the survey conducted in Kutch to determine local attitudes and knowledge on hyaenas.

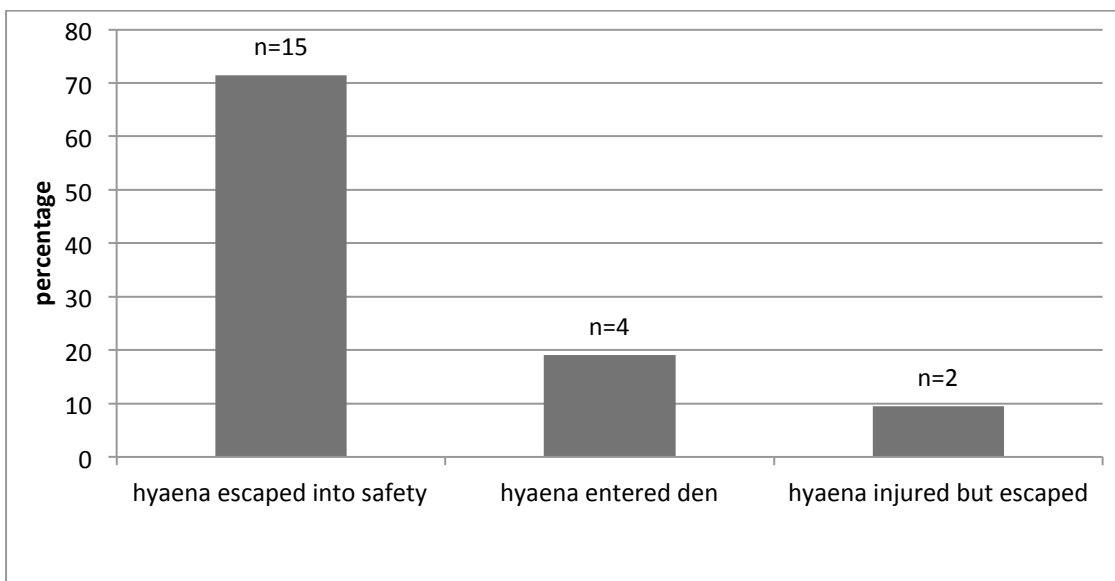


Figure 7-21: Fate of hyaenas (n=21) chased by dogs quantified from the survey conducted in Kutch to determine local attitudes and knowledge on hyaenas.

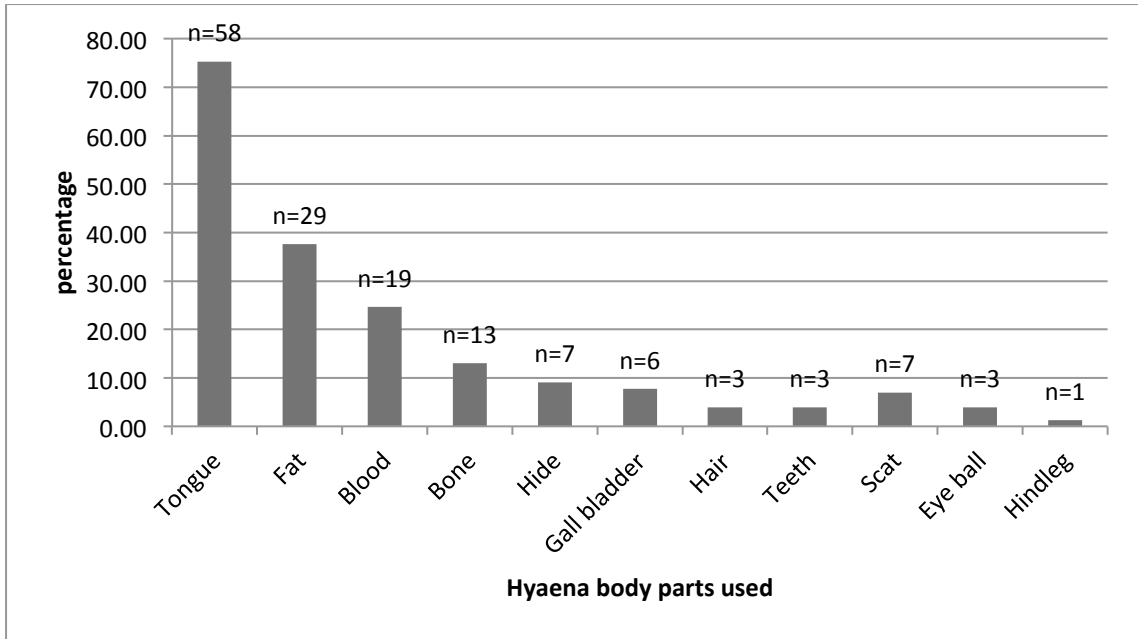


Figure 7-22: proportion of different hyaena body parts utilized in traditional healing (n=77) as quantified from the survey conducted in Kutch to determine local attitudes and knowledge on hyaenas.

Twenty nine percent (n=77) out of the total respondents (n=267) were aware of different hyaena parts used in traditional medicines. A collective total of 11 different body parts were listed (Figure 7-22), of which the tongue was mentioned by large proportion of respondents (75%, n=58) (Table 7.). Of the 77 respondents only 4% (n=3) agreed to have used hyaena body parts, of which 33% (n=1) used hyaena hair and 66% (n=2) used scat; the remaining (96%, n=74) did not use it ever. 12% (n=9) of the respondents (n=77) claimed that these traditional medicines with use of hyaena body parts are of remedial value, the remaining 88% (n=68) were uncertain regarding its beneficial value.

Body part	proportion % (n)	utilization % (n)	method of utilization % (n)
Tongue	75 (58)	bone aliment 57% (n=33), curing tumor 12% (n=7), talisman 5% (n=3), don't know 26% (n=15)	dried tongue- bandaged with cotton 57% (n=33), dried-powdered mixed with oil-massage 2% (n=1), dried and wore in amulet 2% (n=1), don't know 40% (n=23)

Fat	38 (29)	rheumatism 17% (n=5), arthritis 72% (n=21), don't know 10% (n=3)	fat-heated-massage 3% (n=1), externally applied 72% (n=21) don't know 24% (n=7)
Blood	25 (19)	asthma 74% (n=14) don't know 26% (n=5)	blood-applied on cloth-dried-fumigated 68% (n=13) don't know 31% (n=6)
Bone	17 (13)	cure for boils 15% (n=2), cure for livestock diseases 38% (n=5), don't know 46% (n=6)	powdered bones mixed with oil applied on boils 15%(n=2), powdered bones with water given to livestock 30% (n=4), don't know 57% (n=7)
Hide	9 (7)	Crop protection 57% (n=4), don't know 33% (=2)	Dried hide-tied tree-smell-crop raider-away57% (n=4), don't know 33% (n=2)
Gall bladder	8 (6)	talisman 67% (n=4), don't know 33% (n=2)	dried and used in amulet 50% (n=3), don't know 50% (n=3)
Hair	4 (3)	cure for blood clots 67% (n=2), don't know 33% (n=1)	hair burnt-mixed with oil-applied on clot 67% (n=2), don't know 33% (n=1)
Teeth	4 (3)	talisman 67% (n=2), don't know 33% (n=1)	used in amulets 67% (n=2), don't know 33% (n=1)
Scat	9 (7)	rheumatism 71% (n=5), crop protection 14% (n=1), don't know 14% (n=1)	scat-cooked in oil-applied externally 71 % (n=5), dried scat-sprinkled-fields-crop raiders- away 14% (n=1), don't know 14% (n=1)
Eye ball	4 (3)	talisman 67% (n=2), don't know 33% (n=1)	dried and used in amulet 67% (n=2), don't know 33% (n=1)
Hind leg	1 (1)	don't know	don't know

Table 7.17: Proportion of different hyaena body parts (n=11) and its mode of utilization, as mentioned by respondents during a survey conducted in Kutch to determine local attitudes and knowledge on hyaenas (n=77).

There was no positive response from the entire respondents (n=267), towards knowledge regarding mention of hyaenas in folklores, myths, folk songs, art or culture.

#### 7.3.4 Attitude towards hyaena:

Only a small fraction of the total respondents (n=267), 3% (n=9) thought that the presence of hyaenas near their villages could be a problem; majority of respondents (94%, =250) did think otherwise, while 3% (n=8) were uncertain. Eleven percent (n=30) of the total respondents (n=267) feared to commute after sundown as hyaenas also frequented their villages at nighttime (Figure 7-23).

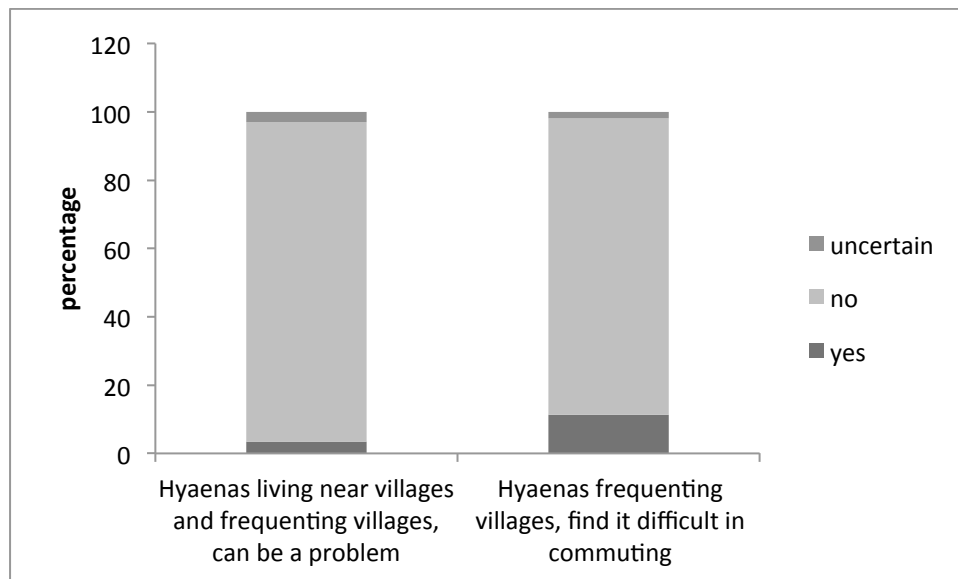


Figure 7-23: Responses to problems associated with presence of hyaena interrupting daily life as determined during a survey in Kutch to determine local attitudes and knowledge on hyaenas (n=267).

Of the 3% (n=9) of respondents, who viewed the presence of hyaenas near their villages to be a problem; 78% (n=7) feared livestock (MLS, LLS calves and pet dog) predation, while 1 respondent (11%) considered presence of more than one animal together to be a problem and another respondent (11%) feared encounter with rabid hyaena during crop guarding. Of the 11% (n=30) of respondents who felt frequent visitation by hyaena to their village, was a hindrance to commute after sundown; 53%

(n=16) of respondents were fearful of attack by hyaenas, while 47% (n=14) were fearful of chance encounter with rabid hyaena.

Most respondents had positive approach to all the attitude-based questionnaires (Figure 7-24, Figure 7-25 & Table 7.18). Fifty-eight percent (n=155) responses were positive and acknowledged that hyaenas are important part of the ecosystem, out of which 43% (n=115) agreed and 15% (n=40) strongly agreed; only 9% (n=24) disagreed, remaining 33% (n=88) were uncertain (Figure 7-24). Similarly responses were positive (55%, n=147) towards the statement that hyaenas are beneficial to ecosystem, where 39% (n=105) agreed and 16% (n=42) strongly agreed with it; 27% (n=73) differed with the statement, while 18% (n=47) were undecided (Figure 7-24). Large proportion of respondents (78%, n=209) accepted that hyaenas are important as they clean the villages and keep them disease free, of which 57% (n=153) agreed and 21% (n=56) strongly agreed; 7% (n=19) didn't agree, while 15% (n=39) remained neutral to the statement (Figure 7-24). 53% (n=141) respondents were of the opinion that increase in number of hyaena amplified the benefits derived by villages, of which 38% (n=101) agreed and 15% (n=40) viewed it strongly; 30% (n=79) were dissimilar in their views, while 18% (n=47) were unsure (Figure 7-25). 72% (n=193) of the respondent recognized that hyaenas mortality by anthropogenic factors are in fact the people's loss, of which 55% (n=147) agreed and 17% (n=46) strongly felt about it; 10% (n=28) didn't think correspondingly, while 17% (n=46) were uncertain (Figure 7-25). 66% (n=176) were supportive of the idea that government should spend money on hyaena conservation, out of which 57% (n=152) agreed to the concept and 9% (n=24) strongly agreed to it; 13% (n=34) were opposed to the idea, while 21% (n=57) were undecided.

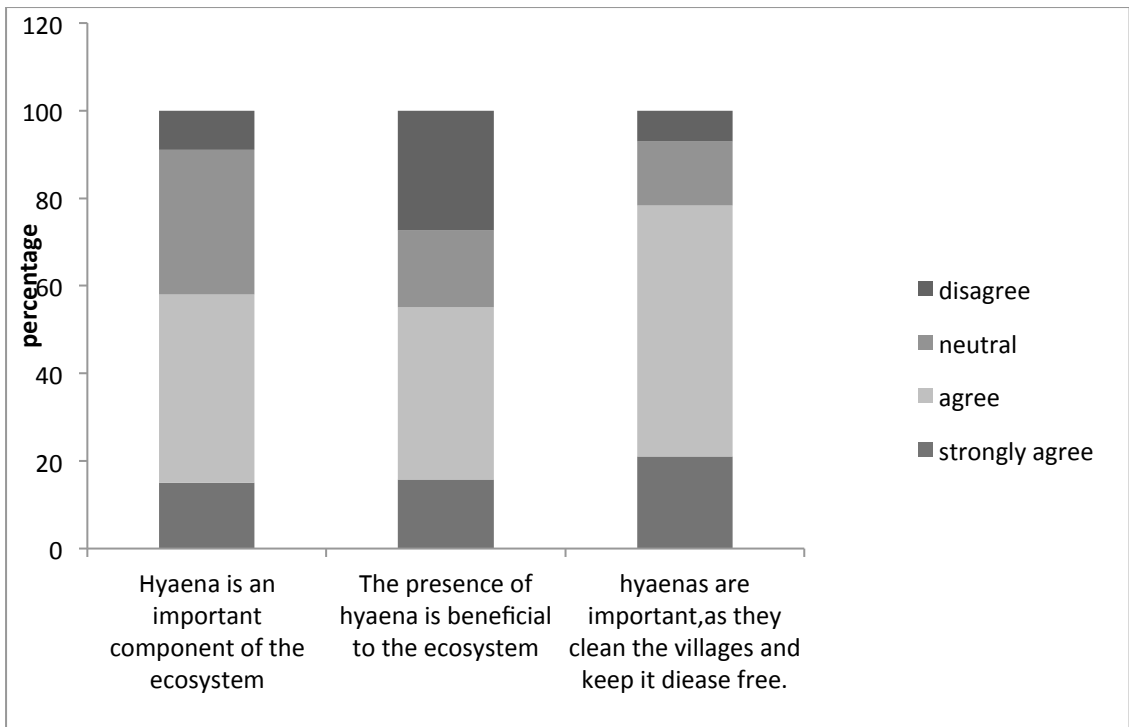


Figure 7-24: proportion of responses (n=267) to attitude related questionnaires. None of the respondents 'strongly disagreed' to any queries, hence 'strongly disagreed' not represented in figure, as quantified during a survey in Kutch to determine local attitudes and knowledge on hyaeans

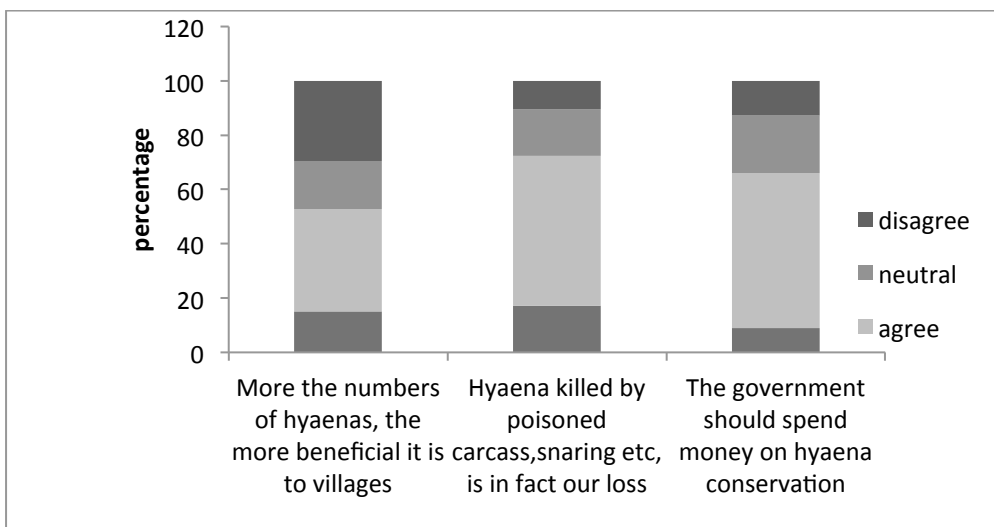


Figure 7-25: proportion of responses (n=267) to attitude related questionnaires. None of the respondents 'strongly disagreed' to any queries, hence 'strongly disagreed' not represented in figure, as quantified during a survey in Kutch to determine local attitudes and knowledge on hyaeans.

Questionnaires	Mean score (mean± SE)	Mode	Freq (freq %)
Hyaena is an important component of the ecosystem	3.64 ± 0.05	4	115 (43)
The presence of hyaena is beneficial to the ecosystem	3.43 ± 0.06	4	105 (39)
Hyaenas are important, as they clean the villages and keep it disease free.	3.92 ± 0.05	4	153 (57)
More the numbers of hyaenas, the more beneficial it is to villages	3.38 ± 0.07	4	101 (38)
Hyaena killed by poisoned carcass, snaring etc., is in fact our loss	3.79 ± 0.05	4	147 (55)
The government should spend money on hyaena conservation	3.62 ± 0.05	4	152 (57)

Table 7.18: Mean score (Likert score) and frequency of likert score (mode) of the responses (n=267) to questionnaire regarding attitude, as quantified during a survey in Kutch to determine local attitudes and knowledge on hyaeans. Mode represents the frequently occurring likert scale response. Freq (freq %) reflects frequency of occurrence of mode

## 7.4 Discussion

The present study results establish that there is an overall positive level of awareness among local people regarding hyaenas, and the conflict levels were considerably low, which compares favorably to most locations in its wide range. Like awareness regarding hyaenas was low in Turkey, where few people could describe it but were ignorant of its identity; Hyaena in Turkey has long been an object of loathing and superstition, many incidents were recorded where local hunters killed hyaenas and collected donations from villagers for saving them from a dangerous beast (Kasperek et al. 2004). It can be concluded that the persistence of hyaenas in the landscape was not subjected to any cultural beliefs, but rather to definitive knowledge of the animal's morphology, habits and behavior, which influenced their perception and attitude. Most important aspect noted in the study was the interpersonal exchange of genuine information regarding hyaenas, which enabled some people to be indirectly aware of hyaena. Such accrual of quality knowledge especially of a nocturnal species can be attributed to high detection probability, which is directly proportional to its population densities; which is governed by food resources, breeding space and general tolerance of wildlife by locals. High detection rates, helped assimilation of information; also encounter with the animal helped eliminate associated prejudice or misconceptions. The nature of occupation, i.e. mobility (involving reasonable extent of travelling), location (distance from human habitation) and timing (time of day is crucial limiting factor in detecting nocturnal species) is an vital detection factor; hence, the detection are biased towards 'husbandry section', age class II (age group for most working class in any society) and male respondents (nearly all of these labor intensive and hardship work engage men). Nearly 46 % of the proportion of detection (34% (n=45) crossing roads and 12% (n=16) as road kills) on roads, is an issue of concern considering their vulnerability to accidents. In spite of its nocturnal habits, large number of respondents (n=91, 68%) have encountered the animal multiple times (Figure 7-7). All the listed food sources; are actual diet composition (See Chapter 3 ), although predation is rare and crops are seasonally represented in diet. Likewise it can be concluded that the awareness level regarding hyaena diet is also high in the region, acknowledging the scavenging as an important mode of obtaining food. In all probability, these numerous encounters with the species have greatly influenced the

awareness level (Table 7.11), also helping in clarifying any misinformation or misconception or prejudice against hyaenas. There is no sense of vulnerability among most people with the existence of hyaenas, as it is largely considered low conflict species; though few had misplaced their fear however, the fear of rabid hyaenas is justifiable. Low intensity of damage to crops and livestock is generally acceptable and internalized by local people into their daily life; in actuality causes other than predation account for majority of losses.

In spite of widespread awareness level and tolerant approach to its presence, considerable numbers are eliminated directly or indirectly by anthropogenic induced causes. Traffic accident and non-target snaring emerge as important mortality factor. In actual fact of all collared hyaena (n=7) in the present study, 57% (n=4) died in snares and 14% (n=1) was killed in road accidents. Similarly the main cause of mortality in Tanzania was attributed to road kills and 50% of recorded deaths in central Kenya were human induced (Wagner 2006). Humans are consistently indicated as the major source of mortality throughout the evaluated range (Hofer et al. 1998).

Surprisingly it was determined from the study that use of body parts in traditional medicines and other purposes were as prevalent as in most parts of its range. But, most likely due to the sensitive character of the issue; many did not reveal their involvement, with respect to usage of these products. Undoubtedly, hyaena body parts are more widely used than previously thought. Furthermore, personal experiences during fieldwork confirmed the prevalent use of body parts; like, locals who knew that I was studying hyaenas approached me on several occasion asking if I could get them hyaena tongue or gall bladder or scat, in another incident a shepherd was seen trying to retrieve the tongue from a road kill. A total of 11 different body parts (Table 7.) utilized by locals were identified; Gupta et al. (2003) described the traditional knowledge of local communities in Kutch and identified 34 fauna used in traditional healing, and but only described use of 2 body parts (blood and fat) for hyaena. Elsewhere in India, Patil (2003) reported use of hyaena brain for curing epilepsy in Nandurba dist. of Maharashtra and Sharma (2002) reported use of hyaena fat to cure arthritis in Rajasthan. None of the authors tried to investigate the reasons or beliefs for choice of a particular animal in traditional healing. Frembgen (1998) reviewed the beliefs associated with striped hyaenas across different era and landscapes, it emerges

that apart from associating striped hyaenas with witches and demons; most characteristic views were on the striped hyena relate to the use of its body. Greeks and Romans used the blood, excrements, rectum, genitalia, eyes, tongue, hair, skin, and fat, as well as the ash of different parts of the body, as effective means to ward off evil and as aphrodisiac. The same study (Frembgen 1998) reported that in India the blood, fat and tongue of hyaena is of high significance in folk medicine. In west and south Asia parts of the body of striped hyenas play an important role in aphrodisiac and making of amulets. Amulets are reported from Iran (dry skin) and Sind (tooth). But, the attention of author is drawn to association of body parts with aphrodisiac and fertility, used across Iran (skin, female genitalia and rectum), Afghanistan (hair, female genitalia and rectum), Pakistan (hair), Khyber region (fat), Turkmenistan (female genitalia and rectum), North-West Frontier Province and Baluchistan in Pakistan (female and male genitalia and rectum); and also elaborates the rituals and utilization methods and reasons for the wide spread use of striped hyaena body parts (especially genitalia). Frembgen (1998) reasons that use of the striped hyena's genitalia and rectum emphasizes the magicality that surrounds this animal. However, the striped hyena does not possess any peculiar anatomy or behavioral traits from which magical beliefs and practices could be derived. Frembgen (1998) also theorized that in African folklores and beliefs the spotted hyaena has important role surrounded by symbolism against the background of biological facts (apparent lack of sexual dimorphism); and these beliefs travelled along with traders and migrants to west and south Asia and subsequently transferred to local striped hyaena. Also conjectured is the second possibility of the earlier existence of spotted hyaena in the region and that their extinction, transferred beliefs to the related species of the striped hyena. But no reason was mentioned for the use of other body parts of striped hyaena. Interestingly, no mention of use of hyaena parts as aphrodisiac, or use of hyaena genitalia or rectum, or any association with folklores was found in the study area; in spite of historically and culturally having close ties with Sind in Pakistan. We can only speculate that probably these historic beliefs were manipulated or lost with time and exposure to new information. At present, there is no further evidence to support these speculations.

A matter of concern is, if the uses of hyaena body parts are rampant in the landscapes, how do the locals obtain the body part? In turkey incidents of hyaenas trapped live for

the purpose of selling them to zoos have been recorded. While in Syria hyaenas were captured live for purpose of trade in body parts, especially the brain of the animal as an aphrodisiac (Kasperek et al. 2004), similarly in hyaenas are captured for trade in traditional medicines (Qarqaz et al. 2004). No incidents of capturing hyaenas for trading purpose was not observed nor did anything substantial emerge from questionnaire survey regarding this. It is likely that the faith in traditional medicines is diminishing, as most of the dead hyaenas observed during were intact (except for one incident) or possibly some hyaenas illegally harvested for this purpose. This issue needs further probing, as poaching for trading purpose can have a negative impact on populations.

The refuse and livestock carcass influence the frequency of hyaena visits to villages. Data from this study (See Chapter 3) and results from the questionnaire show that hyaenas are capable of predation on medium livestock. Leakey et al. (1999a) studied the diet of the Striped Hyaena in northern Kenya and concluded that hyaenas predate on small livestock and demonstrate an opportunistic behavior. A reduction in livestock carcass availability might push hyaenas into predation on medium livestock for protein requirements, increasing conflicts and bring drastic change in people's attitude, perception and behavior. The current trend of rapid change in land use pattern, with large scale encroachments of grazing land (gauchar) and large tracts of wastelands conversion into cultivation have affected pastoral communities; inciting change in the traditional lifestyles in varying magnitude and dimensions, many pastoralists are now in a stage of transition from pastoralism to other modes of livelihood. Traditionally various common lands were major sources for grazing livestock, of all land designated as commons, 'gauchars' are officially acknowledged as permanent pastures. As per the official standard, every village shall designate 40 acres (16 hectares) of gauchar land in non-forest areas and 20 acres in forest areas for every 100 livestock heads. Considering this standard 25.5 lakh hectares are deficient in Gujarat state. Along with gauchars, wastelands form an important grazing source and support livelihoods of pastoralists and other livestock owners; on May 17, 2005, Gujarat issued a government resolution (GR) to bring wastelands under cultivation; endangering the most important use of wasteland as pastures (Bharwada and Mahajan 2006).

The policy makers should recognize traditional approaches to biodiversity conservation and sustainable use. Grazing land protection should be prioritized and wasteland conversion resolution should be reconsidered, as these lands not only support large herds of livestock in the region, but also majority of wildlife in the region inhabit these areas. It is impractical to assign a protected area status based on distribution of widespread species like hyaena, furthermore more or less the entire landscape is human induced and becomes difficult to monitor even illegal activities like hunting. But, smaller community reserves is feasible on grazing lands or wastelands, where it is best conserved by people themselves; also 'geological parks or reserve' could be a solution, based on geological aspect of the region to protect certain sites from land use change and exploitation.

Hunting was considered an important factor (Figure 7-4) by a large number of respondents (n=169). This was surprising as hunting was not a common tradition in the region, and is practiced only by mostly Muslim and some Hindu castes traditionally. This practice is also quite rare, and only to supplement their diet. The largely Hindu non-meat eating society, which makes up for the majority of the composition of community in the area, hints at the practice of poaching for food and other forms of wildlife killing are more widespread in the region than previously thought of or these acts of hunting have been on the rise. To manage the hunting problem strict laws should be enforced, along with providing alternative to sustain the marginal groups' meager diet, by encouraging new form of food and source of income like emu or rabbit farming. All the sections of roads that are frequently used by wildlife for crossing should be identified and mitigated for wildlife safety, by constructing either overpasses or underpasses. Also proactive education and awareness program should be prioritized; for it is unstated that awareness has a profound influence on perception and behavior of people towards wildlife. All these may increase the capacity of these local communities to cohabit with carnivores.

## 7.5 Appendix I

Questionnaire

A] Background Information Section

Date:

Name:

Village:

Gender:

Age:

Community:

Occupation:

Do you own any type of livestock? And how many?

Large livestock (buffalo & cattle)	Medium livestock (goats and sheep)	Dog	Donkey	Camel	Horse	Others

Did you experience any loss of livestock in past 2 months?

Type of Livestock	Number of livestock lost	Reason	Fate of carcass
Large livestock			
Medium livestock			
Dog			
Donkey			
Camel			
Horse			
Other			

Do you have any land holdings? If yes, what crops do you cultivate?

Land holding: Yes/No

Crops cultivated

Crops cultivated	Yes/No
Cluster beans	
Pearl millet	
Sorghum	
Green gram	
Groundnut	
Sesame	

Wheat	
Cotton	
Castor	
Fruits	
Vegetable	
Others	

B] Awareness and Knowledge Section

4) Do you think wildlife has dwindled in the recent past? If yes, what are the reasons?

Hunting	Lack of forage	Human population growth	Expansion of arable lands	Lack of shelter	Any other

Name all of the wild animals that live in the area around your village (within 5 km radius) that you can think of:

- a. \_\_\_\_\_
- b. \_\_\_\_\_
- c. \_\_\_\_\_
- d. \_\_\_\_\_
- e. \_\_\_\_\_
- f. \_\_\_\_\_
- g. \_\_\_\_\_

h. \_\_\_\_\_

i. \_\_\_\_\_

j. \_\_\_\_\_

k. \_\_\_\_\_

l. \_\_\_\_\_

m. \_\_\_\_\_

6) Name all of the wild animals that you have seen in your village premises (in and around village):

a. \_\_\_\_\_

b. \_\_\_\_\_

c. \_\_\_\_\_

d. \_\_\_\_\_

e. \_\_\_\_\_

f. \_\_\_\_\_

g. \_\_\_\_\_

h. \_\_\_\_\_

i. \_\_\_\_\_

j. \_\_\_\_\_

k. \_\_\_\_\_

l. \_\_\_\_\_

m. \_\_\_\_\_

7) Do you know anything about hyaena? Can you please describe the animal, how does it look, its size, its habits and diet?

\_\_\_\_\_

—

How do you know about hyaena?

Self-detection- \_\_\_\_\_

Information from other people \_\_\_\_\_

Media \_\_\_\_\_

If information gathered from people, from whom?

Shepherds \_\_\_\_\_

Elders \_\_\_\_\_

Hunters \_\_\_\_\_

Others \_\_\_\_\_

How many times have you seen hyaena?

Where have you seen hyaena?

8) How do hyaenas obtain their food?

a) \_\_\_\_\_

b) \_\_\_\_\_

c) \_\_\_\_\_

d) \_\_\_\_\_

e) \_\_\_\_\_

9) Have you seen hyaena predate?

When did you witness this event?

What species was attacked?

What was the fate of the animal attacked?

10) Is there any hyaena dens around your village?

a) How do you know it's a hyaena den?

C] People's perception of hyaena:

11) Do you think some wildlife can be problematic?

a) If yes, which species and why?

Problematic species	Reason

12) Do you think hyaenas can damage standing crops?

a) If yes, which are the crops?

i) \_\_\_\_\_

ii) \_\_\_\_\_

iii) \_\_\_\_\_

iv) \_\_\_\_\_

v) \_\_\_\_\_

What is the degree of damage?

13) Do you think hyaenas attack livestock?

a) If yes, what is the mode of attack?

b) Do you use provide any protection to your livestock? Can you please describe the protective measures undertaken?

14) Do you think hyaenas can attack humans?

a) If yes, which one will attack, healthy, rabid or both.

b) If rabid, are you aware of any incident?

c) If yes, time and location of the incident.

d) Fate of rabid hyaenas

D] Threats to hyaenas' survival:

15) Have you ever seen a dead hyaena ?

a) If yes, time and location.

b) Cause of mortality

16) Have you ever seen dogs chasing/attacking hyaena ?

If yes, time and location of chase.

b) Fate of hyaena being chased/attacked.

17) Are you aware of any hyaena body parts used in traditional medicine.

a) If yes, can you list all body parts you know of and provide details of uses and method of use.

Hyaena body part	use	method of use

b) Have you ever used any of the products?

c) Does the body parts and traditional medicine have any benefits?

18) Are you aware of any associations of hyaena with folklores, myths, stories, art and culture?

E] Attitude towards hyaena:

19) Hyaena living and frequenting villages can be a problem?

a) If yes, why is it a problem?

20) Hyaenas frequenting villages at nighttime causes difficulty in commuting.

a) If yes, what seems to be the problem?

21) Please reply to the following question.

Questionnaire	Likert score
Hyaena is an important component of the ecosystem	
The presence of hyaena is beneficial to the ecosystem	
Hyaenas are important, as they clean the villages and keep it disease free.	
More the numbers of hyaenas, the more beneficial it is to villages	
Hyaena killed by poisoned carcass, snaring etc., is in fact our loss	
The government should spend money on hyaena conservation	

## 8 References

- Aarts, G., M. MacKenzie, B. McConnell, M. Fedak, and J. Matthiopoulos. 2008. Estimating space - use and habitat preference from wildlife telemetry data. *Ecography* 31:140-160.
- Abi-Said, M. R. and D. M. Abi-Said. 2007. Distribution of the Striped Hyaena (*Hyaena hyaena syriaca* Matius, 1882)(Carnivora: Hyaenidae) in urban and rural areas of Lebanon. *Zoology in the Middle East* 42:3-14.
- Akay, A. E., S. Inac, and I. C. Yildirim. 2011. Monitoring the local distribution of striped hyenas (*Hyaena hyaena* L.) in the Eastern Mediterranean Region of Turkey (Hatay) by using GIS and remote sensing technologies. *Environmental monitoring and assessment* 181:445-455.
- Al Younis, J. S. 1993. Hyaenas in Eastern Jordan. *IUCN SSC Hyaena Specialist Group Newsletter* 6:15-25.
- Alam, M. S., J. A. Khan, and B. J. Pathak. 2009. Status ecology and conservation of striped hyena (*Hyaena hyaena*) in Gir National park and Sanctuary, Gujarat, India. Annual progress report. Gir Hyena Ecology Project, Wildlife Society of India, Aligarh, India.
- All, S. 1945. *The Birds of Kutch*. Oxford University Press, Bombay.
- Altmann, J. 1974. Observational study of behavior: sampling methods. *Behaviour*:227-267.
- Anderson, M. D. 2004. Aardwolf adaptations: a review. *Transactions of the Royal Society of South Africa* 59:99-104.
- Andheria, A., K. Karanth, and N. Kumar. 2007. Diet and prey profiles of three sympatric large carnivores in Bandipur Tiger Reserve, India. *Journal of Zoology* 273:169-175.
- Arumugam, R., A. Wagner, and G. Mills. 2008. *Hyaena hyaena*. IUCN.
- Aschoff, J. 1966. Circadian activity pattern with two peaks. *Ecology*:657-662.
- Austin, D., W. Bowen, and J. McMillan. 2004. Intraspecific variation in movement patterns: modeling individual behaviour in a large marine predator. *Oikos* 105:15-30.
- Badgley, C. 1986. Taphonomy of mammalian fossil remains from Siwalik rocks of Pakistan. *Paleobiology*:119-142.
- Bapat, A., R. C. Kulkarni, and S. K. Guha. 1983. *Catalog of Earthquakes in India and Neighborhood from Historical Period up to 1979*. Indian Society of Earthquake Technology, Roorkee:221.
- Bearder, S. and R. Randall. 1978. The use of fecal marking sites by spotted hyenas and civets: *Carnivore*, v. 1.
- Bearder, S. K. 1977. Feeding habits of spotted hyenas in a woodland habitat. *African Journal of Ecology* 15:263-280.
- Bell, W. J. 1991. *Searching behaviour: the behavioural ecology of finding resources*. Chapman and Hall Ltd.
- Bendick, R., R. Bilham, E. Fielding, V. Gaur, S. Hough, G. Kier, M. Kulkarni, S. Martin, K. Mueller, and M. Mukul. 2001. The 26 January 2001 "Republic Day" earthquake, India. *Seismological Research Letters* 72:328-335.
- Bengtsson, B. 1978. Avoiding inbreeding: at what cost? *Journal of Theoretical Biology* 73:439-444.
- Berger, K. M. and E. M. Gese. 2007. Does interference competition with wolves limit the distribution and abundance of coyotes? *Journal of Animal Ecology* 76:1075-1085.

- Bergman, C. M., J. A. Schaefer, and S. Luttich. 2000. Caribou movement as a correlated random walk. *Oecologia* 123:364-374.
- Bertrand, M. R., A. J. DeNicola, S. R. Beissinger, and R. K. Swihart. 1996. Effects of parturition on home ranges and social affiliations of female white-tailed deer. *The Journal of wildlife management*:899-909.
- Bhandari, A., D. Mohabey, S. Bajpai, B. Tiwari, and M. Pickford. 2010. Early Miocene mammals from central Kutch (Gujarat), Western India: Implications for geochronology, biogeography, eustacy and intercontinental dispersals. *Neues Jahrbuch für Geologie und Paläontologie-Abhandlungen* 256:69-97.
- Bharwada, C. and V. Mahajan. 2006. Quiet transfer of commons. *Economic and Political Weekly*:313-315.
- Bias, M. A. and M. L. Morrison. 2006. Habitat selection of the salt marsh harvest mouse and sympatric rodent species. *Journal of Wildlife Management* 70:732-742.
- Biswas, S. 1980a. Structure of Kutch–Kathiawar region, Western India. Pages 255-272 *in Proc. 3rd Indian Geological Congress, Pune.*
- Biswas, S. 1982. Rift basins in western margin of India and their hydrocarbon prospects with special reference to Kutch basin. *AAPG Bulletin* 66:1497-1513.
- Biswas, S. 1991. Stratigraphy and sedimentary evolution of the Mesozoic basin of Kutch, Western India. *Stratigraphy and sedimentary evolution of Western India*:74-103.
- Biswas, S. 1993. *Geology of Kutch*. KD Malaviya Institute of Petroleum Exploration, Dehradun, 450p.
- Biswas, S. K. 1980b. Structure of Kutch-Kathiawar Region, W. India. Pages 255-272 *in Proceedings of 3rd Indian Geological Congress, Pune.*
- Biswas, S. K. 1992. Tertiary Stratigraphy of Kutch. *Journal of The Paleontological Society of India* 37:1-29.
- Blundell, G. M., J. A. Maier, and E. M. Debevec. 2001. Linear home ranges: effects of smoothing, sample size, and autocorrelation on kernel estimates. *Ecological monographs* 71:469-489.
- Börger, L., B. D. Dalziel, and J. M. Fryxell. 2008. Are there general mechanisms of animal home range behaviour? A review and prospects for future research. *Ecology letters* 11:637-650.
- Börger, L., N. Franconi, G. De Michele, A. Gantz, F. Meschi, A. Manica, S. Lovari, and T. Coulson. 2006. Effects of sampling regime on the mean and variance of home range size estimates. *Journal of Animal Ecology* 75:1393-1405.
- Bothma, J. d. P. and J. Nel. 1980. Winter food and foraging behavior of the aardwolf (*Proteles cristatus*) in the Namib–Nawkluff Park. *Madoqua* 12:141-147.
- Bouskila, Y. 1984. The foraging groups of the striped hyaena, *Hyaena hyaena syriaca*. *Carnivore* 7:2-12.
- Boydston, E. E., T. L. Morelli, and K. E. Holekamp. 2001. Sex differences in territorial behavior exhibited by the spotted hyena (*Hyaenidae, Crocuta crocuta*). *Ethology* 107:369-385.
- Brotans, L., W. Thuiller, M. B. Araújo, and A. H. Hirzel. 2004. Presence - absence versus presence - only modelling methods for predicting bird habitat suitability. *Ecography* 27:437-448.
- Brown, J. L. and G. H. Orians. 1970. Spacing patterns in mobile animals. *Annual review of ecology and systematics* 1:239-262.

- Bursac, Z., C. H. Gauss, D. K. Williams, and D. W. Hosmer. 2008. Source Code for Biology and Medicine. Source code for biology and medicine 3:17.
- Cabeza, M., M. B. Araújo, R. J. Wilson, C. D. Thomas, M. J. Cowley, and A. Moilanen. 2004. Combining probabilities of occurrence with spatial reserve design. *Journal of Applied Ecology* 41:252-262.
- Carbone, C. and J. L. Gittleman. 2002. A common rule for the scaling of carnivore density. *Science* 295:2273-2276.
- Cardillo, M. 2003. Biological determinants of extinction risk: why are smaller species less vulnerable? *Animal Conservation* 6:63-69.
- Cardillo, M., G. M. Mace, K. E. Jones, J. Bielby, O. R. Bininda-Emonds, W. Sechrest, C. D. L. Orme, and A. Purvis. 2005. Multiple causes of high extinction risk in large mammal species. *Science* 309:1239-1241.
- Cardillo, M., A. Purvis, W. Sechrest, J. L. Gittleman, J. Bielby, and G. M. Mace. 2004. Human population density and extinction risk in the world's carnivores. *PLoS biology* 2:e197.
- Chamberlain, M. J., L. M. Conner, B. D. Leopold, and K. M. Hodges. 2003. Space use and multi-scale habitat selection of adult raccoons in central Mississippi. *The Journal of wildlife management*:334-340.
- Champion, H. G. and S. K. Seth. 1968. A revised survey of the forest types of India. Manager of Publications Delhi.
- Chandra, U. 1977. Earthquakes of peninsular India—a seismotectonic study. *Bulletin of the seismological Society of America* 67:1387-1413.
- Charnov, E. L. 1976. Optimal foraging, the marginal value theorem. *Theoretical population biology* 9:129-136.
- Clutton-Brock, T. 2009. Cooperation between non-kin in animal societies. *Nature* 462:51-57.
- Crooks, K. R. and M. E. Soulé. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. *Nature* 400:563-566.
- Davidar, E. R. C. 1985. Den full of hyenas. *Sanctuary Magazine* V.
- Davidar, E. R. C. 1990. Observations at a hyena *Hyaena hyaena* Linn. den. *Journal of the Bombay Natural History Society* 87:445-447.
- Davies, N. and A. Houston. 1983. Time allocation between territories and flocks and owner-satellite conflict in foraging pied wagtails, *Motacilla alba*. *The Journal of Animal Ecology*:621-634.
- Dennell, R. 2007. “Resource-rich, stone-poor”: Early hominin land use in large river systems of northern India and Pakistan. Pages 41-68 *The evolution and history of human populations in South Asia*. Springer.
- Dennell, R., R. Coard, M. Beech, M. Anwar, and A. Turner. 2005. Two upper Siwalik (Pinjor Stage) fossil accumulations from localities 73 and 362 in the Pabbi Hills, Pakistan. *Journal of the Palaeontological Society of India* 50:101-111.
- Dockner, M. 2006. Comparison of *Crocota crocuta crocuta* and *Crocota crocuta spelaea* through computer tomography. Department of Paleontology, University of Vienna. Vienna.
- Dorazio, R. M. 2012. Predicting the Geographic Distribution of a Species from Presence - Only Data Subject to Detection Errors. *Biometrics* 68:1303-1312.
- Drea, C. M. and L. G. Frank. 2003. The social complexity of spotted hyenas. Pages 121-148 *in* F. B. d. waal and P. L. Tyack, editors. *Animal Social Complexity: Intelligence, Culture and individualized societies*. Harvard University Press, Cambridge, MA.

- Efron, B. and R. Tibshirani. 1997. Improvements on cross-validation: the 632+ bootstrap method. *Journal of the American Statistical Association* 92:548-560.
- Elith, J. 2002. Quantitative methods for modeling species habitat: comparative performance and an application to Australian plants. *Quantitative methods for conservation biology*:39-58.
- Elith, J. and J. R. Leathwick. 2009. Species distribution models: ecological explanation and prediction across space and time. *Annual Review of Ecology, Evolution, and Systematics* 40:677-697.
- Elith, J., S. J. Phillips, T. Hastie, M. Dudík, Y. E. Chee, and C. J. Yates. 2011. A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions* 17:43-57.
- Engh, A., K. Esch, L. Smale, and K. Holekamp. 2000. Mechanisms of maternal rank inheritance in the spotted hyaena, *Crocuta crocuta*. *Animal behaviour* 60:323-332.
- Estes, R. 1991. *The behavior guide to African mammals: including hoofed mammals, carnivores, primates*. Univ of California Press.
- Ewer, R. F. 1968. *Ethology of mammals*. Logos Press London.
- Fahrig, L. 2007. Non - optimal animal movement in human - altered landscapes. *Functional Ecology* 21:1003-1015.
- Ferretti, M. P. 2007. Evolution of bone-cracking adaptations in hyaenids (Mammalia, Carnivora). *Swiss journal of geosciences* 100:41-52.
- Fieberg, J. 2007. Kernel density estimators of home range: smoothing and the autocorrelation red herring. *Ecology* 88:1059-1066.
- Fielding, A. H. and J. F. Bell. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. *Environmental conservation* 24:38-49.
- Flower, M. S. S. 1932. 22. Notes on the Recent Mammals of Egypt, with a List of the Species recorded from that Kingdom. Pages 369-450 *in* Proceedings of the Zoological Society of London. Wiley Online Library.
- Fox, M. 1971. Ontogeny of a social display in *Hyaena hyaena*: anal protrusion. *Journal of Mammalogy* 52:467-469.
- Frank, L. G. 1986. Social organization of the spotted hyaena *Crocuta crocuta*. II. Dominance and reproduction. *Animal behaviour* 34:1510-1527.
- Franklin, J. and J. A. Miller. 2009. *Mapping species distributions: spatial inference and prediction*. Cambridge University Press Cambridge.
- Frembgen, J. W. 1998. The magicality of the hyena: beliefs and practices in west and south Asia. *Asian folklore studies*:331-344.
- Fürsich, F. T., D. K. Pandey, J. H. Callomon, A. K. Jaitly, and I. B. Singh. 2001. Marker beds in the Jurassic of the Kachchh Basin, Western India. *Journal of Palaeontological Society of India* 46:173-198.
- Gajera, N., S. Dave, and D. Nishith. 2009. Feeding patterns and den ecology of striped hyena (*Haeyena haeyena*) in North Gujarat, India. *Tigerpaper* 36:13-17.
- Garson, G. I. and E. B. Moser. 1995. Aggregation and the Pearson chi-square statistic for homogeneous proportions and distributions in ecology. *Ecology*:2258-2269.
- Gasperetti, J., D. L. Harrison, and W. Buettiker. 1985. *The carnivora of Arabia. Kingdom Saudi Arabia Meteorol. Environ. Prot. Adm. Fauna Publ.* 1985.
- Gaston, K. J. and R. A. Fuller. 2009. The sizes of species' geographic ranges. *Journal of Applied Ecology* 46:1-9.

- Geer, J. G. 1988. What do open-ended questions measure? *Public Opinion Quarterly* 52:365-367.
- Ghosh, S., G. Mohamed, J. Polara, and H. Bhint. 2012. Monsoon fishery of juvenile ginger prawns at Little Rann of Kutch, Gujarat in relation to environmental parameters. *Indian Journal of Fisheries* 59:23-27.
- Gittleman, J. L. 1989. Carnivore group living: comparative trends. Pages 183-207 *Carnivore behavior, ecology, and evolution*. Springer.
- Golan, A., G. G. Judge, and D. Miller. 1996. *Maximum Entropy Econometrics: Robust Estimation with Limited Data*. Wiley, New York.
- Goss, R. 1986. The Influence of the Food Source on the Behavioural Ecology of Brown Hyenas *Hyaena Brunnea* in the Namib Desert.
- Graham, C. H., S. Ferrier, F. Huettman, C. Moritz, and A. T. Peterson. 2004. New developments in museum-based informatics and applications in biodiversity analysis. *Trends in Ecology & Evolution* 19:497-503.
- Graham, K., A. P. Beckerman, and S. Thirgood. 2005. Human–predator–prey conflicts: ecological correlates, prey losses and patterns of management. *Biological Conservation* 122:159-171.
- Greenwood, P. J., P. H. Harvey, and C. M. Perrins. 1978. Inbreeding and dispersal in the great tit.
- Guisan, A. and N. E. Zimmermann. 2000. Predictive habitat distribution models in ecology. *Ecological Modelling* 135:147-186.
- Gupta, L., C. Silori, N. Mistry, and A. Dixit. 2003. Use of Animals and Animal products in traditional health care systems in District Kachchh, Gujarat. *Indian Journal of Traditional Knowledge*.
- Gupta, S., K. Mondal, K. Sankar, and Q. Qureshi. 2009. Estimation of Striped Hyena *Hyaena hyaena* Population using Camera Traps in Sariska Traps in Sariska Tiger Reserve, Rajasthan, India. *Journal of the Bombay Natural History Society* 106:284.
- Happold, D. 1995. The interactions between humans and mammals in Africa in relation to conservation: a review. *Biodiversity & Conservation* 4:395-414.
- Harestad, A. S. and F. Bunnell. 1979. Home range and body weight--a reevaluation. *Ecology*:389-402.
- Harihar, A., M. Ghosh, M. Fernandes, B. Pandav, and S. P. Goyal. 2010. Use of photographic capture-recapture sampling to estimate density of Striped Hyena (*Hyaena hyaena*): implications for conservation. *Mammalia* 74:83-87.
- Harris, S., W. Cresswell, P. Forde, W. Trehwella, T. Woollard, and S. Wray. 1990. Home - range analysis using radio - tracking data--a review of problems and techniques particularly as applied to the study of mammals. *Mammal review* 20:97-123.
- Harrison, D. L. 1968. The large mammals in Arabia. *Oryx* 9:357-363.
- Hazzah, L. N. 2006. Living among lions (*panthera leo*): coexistence or killing? Community attitudes towards conservation initiatives and the motivations behind lion killing in Kenyan Maasailand. University Of Wisconsin.
- Hemson, G., P. Johnson, A. South, R. Kenward, R. Ripley, and D. MacDonald. 2005. Are kernels the mustard? Data from global positioning system (GPS) collars suggests problems for kernel home - range analyses with least - squares cross - validation. *Journal of Animal Ecology* 74:455-463.
- Henschel, J. R. and J. D. Skinner. 1991. Territorial Behaviour by a Clan of Spotted Hyaneas *Crocuta crocuta*. *Ethology* 88:223-235.

- Hernandez, P. A., C. H. Graham, L. L. Master, and D. L. Albert. 2006. The effect of sample size and species characteristics on performance of different species distribution modeling methods. *Ecography* 29:773-785.
- Hirway, I., S. P. Kashyap, and A. Shah. 2002. Dynamics of development in Gujarat. Concept Publishing Company, New Delhi.
- Hirzel, A., V. Helfer, and F. Metral. 2001. Assessing habitat-suitability models with a virtual species. *Ecological Modelling* 145:111-121.
- Hirzel, A. H. and G. Le Lay. 2008. Habitat suitability modelling and niche theory. *Journal of Applied Ecology* 45:1372-1381.
- Hirzel, A. H., G. Le Lay, V. Helfer, C. Randin, and A. Guisan. 2006. Evaluating the ability of habitat suitability models to predict species presences. *Ecological Modelling* 199:142-152.
- Hofer, H. and M. L. East. 2003. Behavioral processes and costs of co-existence in female spotted hyenas: a life history perspective. *Evolutionary Ecology* 17:315-331.
- Hofer, H., G. Mills, and H. Hofer. 1998. Species accounts: striped hyena *Hyaena* (*Hyaena*) *hyaena* (Linnaeus, 1758). *Hyaenas: status survey and conservation action plan* (G. Mills and H. Hofer, comps.). IUCN/SSC *Hyaena Specialist Group*, IUCN, Gland, Switzerland, and Cambridge, United Kingdom:21-26.
- Holekamp, K. E., E. E. Boydston, and L. Smale. 2000. Group travel in social carnivores. Pages 587-627 *in* S. Boinski and P. A. Garber, editors. *On the move: How and Why Animals Travel in Groups*. University of Chicago Press, Chicago.
- Holekamp, K. E., S. T. Sakai, and B. L. Lundrigan. 2007. Social intelligence in the spotted hyena (*Crocuta crocuta*). *Philosophical Transactions of the Royal Society B: Biological Sciences* 362:523-538.
- Holekamp, K. E. and L. Smale. 1993. Ontogeny of dominance in free-living spotted hyaenas: juvenile rank relations with other immature individuals. *Animal behaviour* 46:451-466.
- Holekamp, K. E., J. E. Smith, C. C. Strelhoff, R. C. Van Horn, and H. E. Watts. 2012. Society, demography and genetic structure in the spotted hyena. *Molecular ecology* 21:613-632.
- Holt, R. D. and T. H. Keitt. 2005. Species' borders: a unifying theme in ecology. *Oikos* 108:3-6.
- Horwitz, L. K. and P. Smith. 1988. The effects of striped hyaena activity on human remains. *Journal of Archaeological Science* 15:471-481.
- Howell, F. and G. Petter. 1976. Carnivora from Omo group formations, southern Ethiopia. *Earliest Man and Environments in the Lake Rudolf Basin*. University of Chicago Press, Chicago:314-331.
- Howell, F. C. and G. Petter. 1980. The *Pachycrocuta* and *Hyaena* lineages (plio-pleistocene and extant species of the *Hyaenidae*. Their relationships with miocene *ictitheres* *Palhyaena* and *Hyaenictitherium*. *Geobios* 13:579-623.
- Hussain, S. 2003. The status of the snow leopard in Pakistan and its conflict with local farmers. *Oryx* 37:26-33.
- Hutton, J. M. and N. Leader-Williams. 2003. Sustainable use and incentive-driven conservation: realigning human and conservation interests. *Oryx* 37:215-226.
- Ibrahim, F. 2008. Islamic 'reform', the nation-state and the liberal subject The cultural politics of identity in Kachchh, Gujarat. *Contributions to Indian Sociology* 42:191-217.
- Ilani, G. 1975. Hyaenas in Israel. *Land Nat* 1975:10-18.

- Infield, M. and A. Namara. 2001. Community attitudes and behaviour towards conservation: an assessment of a community conservation programme around Lake Mburo National Park, Uganda. *Oryx* 35:48-60.
- Jacques, C. N., J. A. Jenks, and R. W. Klaver. 2009. Seasonal movements and home-range use by female pronghorns in sagebrush-steppe communities of western South Dakota. *Journal of Mammalogy* 90:433-441.
- Jadhav, G., N. Sharma, and P. Sen. 2012. Characterization of bauxite deposits from Kachchh Area, Gujarat. *Journal of the Geological Society of India* 80:351-362.
- Jarman, P. 1974. The social organisation of antelope in relation to their ecology. *Behaviour*:215-267.
- Jenks, S. and L. Werdelin. 1998. Taxonomy and systematics of living hyaenas (Family Hyaenidae). Mills, MGL, Hofer, H.(Compilers), *Hyaenas: Status Survey and Conservation Action Plan*. IUCN/SSC Hyaena Specialist Group, IUCN, Gland, Switzerland:8-17.
- Jethva, B. and Y. Jhala. 2003. Sample size considerations for food habits studies of wolves from scats. *Mammalia* 67:589-591.
- Jhala, Y. 2002. Cattle and Carnivores. *National Wildlife (World Edition)*, National Wildlife Federation 40:34J-34Q.
- Jhala, Y. 2003. Status, ecology and conservation of the Indian wolf *Canis lupus pallipes sykes*. *J. Bombay Nat. Hist. Soc* 100:293-307.
- Jhala, Y., R. Gopal, and Q. Qureshi. 2011. Status of tigers, co-predators, and prey in India, 2010. National Tiger Conservation Authority, Ministry of Environment & Forests, and Wildlife Institute of India, Dehradun.
- Jhala, Y. V. 2006. Conservation of the Indian Wolf, Final Report. Wildlife Institute of India, Dehradun.
- Joshi, P., V. Kumar, M. Koladiya, Y. Patel, and T. Karthik. 2009. Local perceptions of grassland change and priorities for conservation of natural resources of Banni, Gujarat, India. *Frontiers of Biology in China* 4:549-556.
- Joshi, V. 2002. The cultural context of development in Gujarat. *Dynamics of Development in Gujarat*:372.
- Kar, A. 1993. Neotectonic influences on morphological variations along the coastline of Kachchh, India. *Geomorphology* 8:199-219.
- Karanth, R. 2000. Neotectonic and Palaeoseismic Studies in Kutch and its adjoining areas. Page 159. Unpublished Project Report Submitted to the Department of Science and Technology.
- Kasperek, M., A. Kasperek, B. Gözcelioğlu, E. Çolak, and N. Yiğit. 2004. On the status and distribution of the Striped Hyaena, *Hyaena hyaena*, in Turkey. *Zoology in the Middle East* 33:93-108.
- Kaufmann, J. H. 1962. Ecology and social behavior of the coati, *Nasua narica* on Barro Colorado Island, Panama. University of California Press.
- Kearney, M. 2006. Habitat, environment and niche: what are we modelling? *Oikos* 115:186-191.
- Kelt, D. A. and D. H. Van Vuren. 2001. The ecology and macroecology of mammalian home range area. *The American Naturalist* 157:637-645.
- Kerbis-Peterhans, J. C. and L. K. Horwitz. 1992. A bone assemblage from a striped hyaena (*Hyaena hyaena*) den in the Negev Desert, Israel. *Israel Journal of Zoology* 37:225-245.

- Kernohan, B. J., R. A. Gitzen, and J. J. Millspaugh. 2001. Analysis of animal space use and movements. Radio tracking and animal populations. Academic Press, San Diego, California, USA:125-166.
- Kery, M. 2002. Inferring the absence of a species: a case study of snakes. *The Journal of wildlife management*:330-338.
- Khan, E. 1972. On a skull of Shivalik *Crocuta*. *Proceedings of the Indian National Science Academy* 38:142-147.
- Kharakwal, J., Y. Rawat, T. Osada, L. Patel, H. Seth, R. Meena, S. Meena, K. Singh, and A. Hussain. Kanmer: A Multicultural Site in Kachchh, Gujarat, India.
- Kie, J. G. and B. B. Boroski. 1996. Cattle distribution, habitats, and diets in the Sierra Nevada of California. *Journal of Range Management*:482-488.
- Kie, J. G., R. T. Bowyer, M. C. Nicholson, B. B. Boroski, and E. R. Loft. 2002. Landscape heterogeneity at differing scales: effects on spatial distribution of mule deer. *Ecology* 83:530-544.
- Kingdon, J. 1977. *East African Mammals: Volume IIIA, Carnivores*. University of Chicago Press, Chicago, Illinois.
- Knight, J. 2013. *Natural enemies: People-wildlife conflicts in anthropological perspective*. Routledge.
- Koenig, W. and J. Haydock. 2004. Incest and incest avoidance. In: Koenig, WD and Dickinson, JL (eds). *Ecology and evolution of cooperative breeding in birds*. Cambridge University Press, Cambridge, pp. 142-156.
- Koenig, W. D., D. Van Vuren, and P. N. Hooge. 1996. Detectability, philopatry, and the distribution of dispersal distances in vertebrates. *Trends in Ecology & Evolution* 11:514-517.
- Koepfli, K.-P., S. M. Jenks, E. Eizirik, T. Zahirpour, B. V. Valkenburgh, and R. K. Wayne. 2006. Molecular systematics of the Hyaenidae: relationships of a relictual lineage resolved by a molecular supermatrix. *Molecular phylogenetics and evolution* 38:603-620.
- Korschgen, L. 1980. Procedures for food-habits analyses [Wildlife].
- Kramer, M. and J. Schmidhammer. 1992. The chi-squared statistic in ethology: use and misuse. *Animal behaviour* 44:833-841.
- Krishna, J. 1992. Seismic zoning maps of India. *Curr. Sci* 62:17-23.
- Krishna, J., I. B. Singh, J. D. Howard, and S. A. Jafar. 1983. Implications of new data on Mesozoic rocks of Kachchh, western India.
- Krishnan, M. S. 1982. *Geology of India and Burma*. 6th edition. CBS, Delhi.
- Kruuk, H. 1972a. *The spotted hyaena*. A University of Chicago Press, Chicago.
- Kruuk, H. 1972b. *The spotted hyena: a study of predation and social behavior*. University of Chicago Press Chicago.
- Kruuk, H. 1976. Feeding and social behaviour of the striped hyaena (*Hyaena vulgaris* Desmarest)\*. *African Journal of Ecology* 14:91-111.
- Kruuk, H. and W. Sands. 1972. The aardwolf (*Proteles cristatm* Sparrman) 1783 as predator of termites\*. *African Journal of Ecology* 10:211-227.
- Kuhn, B. F. 2005. The faunal assemblages and taphonomic signatures of five striped hyaena (*Hyaena hyaena syriaca*) dens in the desert of Eastern Jordan. *Levant* 37.
- Kumar, D. R. 1985. *Fundamentals of historical geology and stratigraphy of India*. Wiley Eastern.
- Kurtén, B. 1958. A differentiation index, and a new measure of evolutionary rates. *Evolution* 12:146-157.

- Lamba, H. and D. Kapoor. 2006. Sahajeevan's Renewable Energy Programmes. Sahajeevan Trust, Bhuj, Kachhch.
- Laver, P. N. and M. J. Kelly. 2008. A critical review of home range studies. *The Journal of wildlife management* 72:290-298.
- Lawson, E. J. G. and A. R. Rodgers. 1997. Differences in home-range size computed in commonly used software programs. *Wildlife Society Bulletin*:721-729.
- Leakey, L., S. Milledge, S. Leakey, J. Edung, P. Haynes, D. Kiptoo, and A. McGeorge. 1999a. Diet of striped hyaena in northern Kenya. *African Journal of Ecology* 37:314-326.
- Leakey, L. N., S. A. H. Milledge, S. M. Leakey, J. Edung, P. Haynes, D. K. Kiptoo, and A. McGeorge. 1999b. Diet of striped hyaena in northern Kenya. *African Journal of Ecology* 37:314-326.
- Li, W., Q. Guo, and C. Elkan. 2011. Can we model the probability of presence of species without absence data? *Ecography* 34:1096-1105.
- Likert, R. 1932. A technique for the measurement of attitudes. *Archives of psychology*.
- Linnell, J. D., R. Andersen, T. Kvam, H. Andren, O. Liberg, J. Odden, and P. Moa. 2001a. Home range size and choice of management strategy for lynx in Scandinavia. *Environmental management* 27:869-879.
- Linnell, J. D., J. E. Swenson, and R. Anderson. 2001b. Predators and people: conservation of large carnivores is possible at high human densities if management policy is favourable. *Animal Conservation* 4:345-349.
- Litvaitis, J. A. 2000. Investigating food habits of terrestrial vertebrates. *Research techniques in animal ecology*:165-190.
- Loveridge, A. and D. Macdonald. 2003. Niche separation in sympatric jackals (*Canis mesomelas* and *Canis adustus*). *Journal of Zoology* 259:143-153.
- Lührs, M.-L., M. Dammhahn, and P. Kappeler. 2013. Strength in numbers: males in a carnivore grow bigger when they associate and hunt cooperatively. *Behavioral Ecology* 24:21-28.
- Lukas, D. and T. Clutton - Brock. 2011. Group structure, kinship, inbreeding risk and habitual female dispersal in plural - breeding mammals. *Journal of evolutionary biology* 24:2624-2630.
- Macdonald, D. W. 1983. The ecology of carnivore social behaviour. *Nature* 301:379-384.
- Macdonald, D. W. 2009. *The encyclopedia of mammals*. Oxford University Press.
- MacKenzie, D. I. and J. A. Royle. 2005. Designing occupancy studies: general advice and allocating survey effort. *Journal of Applied Ecology* 42:1105-1114.
- Maddock, A. 1993. Analysis of brown hyaena (*Hyaena brunnea*) scats from the central karoo, South Africa. *Journal of Zoology* 231:679-683.
- Maher, C. R. and D. F. Lott. 1995. Definitions of territoriality used in the study of variation in vertebrate spacing systems. *Animal behaviour* 49:1581-1597.
- Malik, J. N., P. S. Sohoni, S. S. Merh, and R. V. Karanth. 2001. Active Tectonic control on Alluvial fan Architecture along the Kutch Mainland Hill Range, Western India. *Zeithschrift für Geomorphologie* 45:81-100.
- Manly, B. F., L. McDonald, and D. L. Thomas. 1992. *Resource selection by animals: statistical design and analysis for field studies*. Chapman & Hall.
- Mårell, A., J. P. Ball, and A. Hofgaard. 2002. Foraging and movement paths of female reindeer: insights from fractal analysis, correlated random walks, and Lévy flights. *Canadian Journal of Zoology* 80:854-865.

- Marker, L. and A. Dickman. 2004. Human aspects of cheetah conservation: lessons learned from the Namibian farmlands. *Human Dimensions of Wildlife* 9:297-305.
- Martin, P. and P. Bateson. 2007. *Measuring behaviour: an Introductory guide*. Third edition. Cambridge University Press, Cambridge, UK.
- Mathur, N. and S. P. Kashyap. 2002. Agriculture Development in Gujarat: Problems and Prospects. Pages 238-267 *in* I. Hirway, S. P. Kashyap, and A. Shah, editors. *Dynamics of Development in Gujarat*. Concept Publishing Company, New Delhi.
- McLeod, J. 1999. *Sovereignty, Power, Control: Politics in the State of Western India, 1916-1947*. Brill Academic Pub.
- McLoughlin, P. D., R. L. Case, R. J. Gau, D. H. Cluff, R. Mulders, and F. Messier. 2002. Hierarchical habitat selection by barren-ground grizzly bears in the central Canadian Arctic. *Oecologia* 132:102-108.
- McLoughlin, P. D., S. H. Ferguson, and F. Messier. 2000. Intraspecific variation in home range overlap with habitat quality: a comparison among brown bear populations. *Evolutionary Ecology* 14:39-60.
- McLoughlin, P. D., L. R. Walton, H. D. Cluff, P. C. Paquet, and M. A. Ramsay. 2004. Hierarchical habitat selection by tundra wolves. *Journal of Mammalogy* 85:576-580.
- McNab, B. K. 1989. Basal rate of metabolism, body size, and food habits in the order Carnivora. Pages 335-354 *Carnivore behavior, ecology, and evolution*. Springer.
- Mech, L. 1970. *The Wolf: The Ecology of an Endangered Species*. Natural History Press. Garden City, New York, NY.
- Mech, L. D. 1995. The challenge and opportunity of recovering wolf populations. *Conservation Biology* 9:270-278.
- Mehta, L. 2001. The manufacture of popular perceptions of scarcity: dams and water-related narratives in Gujarat, India. *World Development* 29:2025-2041.
- Mills, M. 1983. Behavioural mechanisms in territory and group maintenance of the brown hyaena, *Hyaena brunnea*, in the southern Kalahari. *Animal behaviour* 31:503-510.
- Mills, M. 1989. The comparative behavioral ecology of hyenas: the importance of diet and food dispersion. Pages 125-142 *Carnivore behavior, ecology, and evolution*. Springer.
- Mills, M. 1990a. *Kalahari hyaenas: comparative behavioural ecology of two species*. Unwin Hyman London.
- Mills, M. 1992. A comparison of methods used to study food habits of large African carnivores. Pages 1112-1124 *Wildlife 2001: populations*. Springer.
- Mills, M. and H. Hofer. 1998. *Hyaenas, status survey and action plan*. IUCN/SSC Hyaena Specialist Group, Gland.
- Mills, M. and M. Mills. 1978. Diet of the brown hyena *Hyaena brunnea* in the southern Kalahari, South Africa. *Koedoe* 21:125-150.
- Mills, M. G., G. Mills, and H. Hofer. 1998. *Hyaenas: status survey and conservation action plan*. Iucn.
- Mills, M. G. L. 1990b. *Kalahari hyaenas*. Unwin Hyman, London.
- Mitchell, S. C. 2005. How useful is the concept of habitat?—a critique. *Oikos* 110:634-638.
- Mitra, K., S. Bardhan, and D. Bhattacharya. 1979. A study of Mesozoic stratigraphy of Kutch, Gujarat, with special reference to rock-stratigraphy and

- biostratigraphy of Keera Dome. Bulletin of Indian Geologists Association 12:129-144.
- Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37:223-249.
- Mukherjee, S., S. Goyal, and R. Chellam. 1994. Standardisation of scat analysis techniques for leopard (*Panthera pardus*) in Gir National Park, Western India. Mammalia 58:139-144.
- Nanda, A. 2002. Upper Siwalik mammalian faunas of India and associated events. Journal of Asian Earth Sciences 21:47-58.
- Nanda, A. 2008. Comments on the Pinjor Mammalian Fauna of the Siwalik Group in relation to the post-Siwalik faunas of Peninsular India and Indo-Gangetic Plain. Quaternary International 192:6-13.
- Nilsen, E. B., I. Herfindal, and J. D. Linnell. 2005. Can intra-specific variation in carnivore home-range size be explained using remote-sensing estimates of environmental productivity? Ecoscience 12:68-75.
- Norusis, M. 2008. SPSS 16.0 guide to data analysis. Prentice Hall Press.
- Novaro, A. J., M. n. C. Funes, and R. Susan Walker. 2000. Ecological extinction of native prey of a carnivore assemblage in Argentine Patagonia. Biological Conservation 92:25-33.
- Novikov, G. A. and G. A. Novikov. 1962. Carnivorous mammals of the fauna of the USSR. Israel program for scientific translations Jerusalem, Israel.
- Osborn, D. J. and I. Helmy. 1980. The contemporary land mammals of Egypt (including Sinai). DTIC Document.
- Osborne, P. E. and S. Suárez-Seoane. 2002. Should data be partitioned spatially before building large-scale distribution models? Ecological Modelling 157:249-259.
- Otis, D. L. and G. C. White. 1999. Autocorrelation of location estimates and the analysis of radiotracking data. The Journal of wildlife management:1039-1044.
- Ottaviani, D., G. J. Lasinio, and L. Boitani. 2004. Two statistical methods to validate habitat suitability models using presence-only data. Ecological Modelling 179:417-443.
- Owens, D. and M. Owens. 1979. Communal denning and clan associations in brown hyenas (*Hyaena brunnea*, Thunberg) of the central Kalahari Desert. African Journal of Ecology 17:35-44.
- Owens, D. and M. Owens. 1996. Social dominance and reproductive patterns in brown hyenas, *Hyaena brunnea*, of the central Kalahari desert. Animal behaviour 51:535-551.
- Pandey, C. N., B. Jethva, and S. Munjpara. 2008. Status, distribution and habitat surveys of Great Indian Bustard (*Ardeotis nigriceps*) in Gujarat. Gujarat Ecological Education and Research (GEER) Foundation, Gandhinagar.
- Parikh, J. K. and B. S. Reddy. 1997. Sustainable regeneration of degraded lands. Tata McGraw Hill Publishing Company.
- Patil, S. H. 2003. Ethno-medico-Scientific studies on Nandurbar district of Maharashtra. Indian Journal of Traditional Knowledge 23:297-299.
- Pearce, J. L. and M. S. Boyce. 2006. Modelling distribution and abundance with presence - only data. Journal of Applied Ecology 43:405-412.
- Petter, G. 1973. Carnivores pléistocènes du ravin d'Olduvai (Tanzanie). Fossil vertebrates of Africa 3:43-100.

- Phillips, M. and P. Catling. 1991. Home range and activity patterns of red foxes in Nadgee Nature Reserve. *Wildlife Research* 18:677-686.
- Phillips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190:231-259.
- Phillips, S. J. and M. Dudík. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography* 31:161-175.
- Pilgrim, G. E. 1932. The fossil carnivora of India. Government of India Central Publ. Branch.
- Pocock, R. 1934. The races of the striped and brown hyaenas. Pages 799-825 in *Proceedings of the Zoological Society of London*. Wiley Online Library.
- Powell, R. A. 2000. Animal home ranges and territories and home range estimators. *Research techniques in animal ecology: controversies and consequences*. Columbia University Press, New York, New York, USA:65-110.
- Prasad, K. 1996. Pleistocene cave fauna from peninsular India. *Journal of Caves and Karst Studies* 58:30-34.
- Prater, S. 1980. The book on Indian animals, 3 d edn. Oxford University Press, Bombay.
- Pusey, A. E. 1987. Sex-biased dispersal and inbreeding avoidance in birds and mammals. *Trends in Ecology & Evolution* 2:295-299.
- Qarqaz, M. A., M. A. Abu Baker, and Z. S. Amr. 2004. Status and ecology of the Striped Hyaena, *Hyaena hyaena*, in Jordan. *Zoology in the Middle East* 33:87-92.
- Qumsiyeh, M., Z. Amr, and D. Shafei. 1993. Status and conservation of carnivores in Jordan. *Mammalia* 57:55-62.
- Raju, K. 1995. Strategies to combat drought in Kutch. Page 15 in *Workshop on Strengthening of Community Participation in Disaster Reduction and Role of NGOs*, January.
- Randall, R. 1981. Fossil Hyaenidae from the Makapansgat limeworks deposit, South Africa. *Palaeontologia Africana* 24:75-85.
- Raven, P. H., J. M. Scott, P. Heglund, and M. L. Morrison. 2002. Predicting species occurrences: issues of accuracy and scale. Island Press.
- Ravikant, V. and S. Bajpai. 2010. Strontium isotope evidence for the age of Eocene fossil whales of Kutch, western India. *Geological Magazine* 147:473.
- Rebelo, H. and G. Jones. 2010. Ground validation of presence - only modelling with rare species: a case study on barbastelles *Barbastella barbastellus* (Chiroptera: Vespertilionidae). *Journal of Applied Ecology* 47:410-420.
- Rettie, W. J. and F. Messier. 2000. Hierarchical habitat selection by woodland caribou: its relationship to limiting factors. *Ecography* 23:466-478.
- Richardson, P. 1987. Aardwolf mating system: overt cuckoldry in an apparently monogamous mammal. *South African Journal of Science* 83:405-410.
- Richardson, P. and M. Coetsee. 1988. Mate desertion in response to female promiscuity in the socially monogamous aardwolf, *Proteles cristatus*. *S. Afr. Tydskr. Dierk* 23:306-308.
- Richardson, P. R. K. 1985. The social behaviour and ecology of the aardwolf, *Proteles cristatus* (Sparman, 1783) in relation to its food resources. University of Oxford.
- Ridley, J., W. Y. Douglas, and W. J. Sutherland. 2005. Why long-lived species are more likely to be social: the role of local dominance. *Behavioral Ecology* 16:358-363.

- Rieger, I. and W. Weihe. 1975. Weather dependent behaviour of captive striped hyaenas (*Hyaena hyaena*). *International Journal of Biometeorology* 19:122-126.
- Rieger, R. and E. Ruppert. 1978. Resin embedments of quantitative meiofauna samples for ecological and structural studies—description and application. *Marine Biology* 46:223-235.
- Rodgers, W. A., H. S. Panwar, and V. B. Mathur. 2002. Wildlife Protected Area Network in India: A review (Executive Summary). Wildlife Institute of India, Dehradun.
- Rohland, N., J. L. Pollack, D. Nagel, C. Beauval, J. Airvaux, S. Pääbo, and M. Hofreiter. 2005. The population history of extant and extinct hyenas. *Molecular Biology and Evolution* 22:2435-2443.
- Rosevear, D. R., R. Parsons, P. Wolseley, and M. Shaffer. 1974. The carnivores of west Africa. British Museum (Natural History) London.
- Royle, J. A., R. B. Chandler, C. Yackulic, and J. D. Nichols. 2012. Likelihood analysis of species occurrence probability from presence - only data for modelling species distributions. *Methods in Ecology and Evolution* 3:545-554.
- Sakai, S. T., B. M. Arsznov, B. Lundrigan, and K. E. Holekamp. 2011. Brain size and social complexity: a computed tomography study in hyaenidae. *Brain, Behavior and Evolution* 77:91-104.
- Sankar, K. and B. Jethwa. 2002. Notes on the food habits of striped hyena *Hyaena hyaena* Linn. 1758 in Sariska Tiger Reserve, Rajasthan. *Journal of the Bombay Natural History Society* 99:104-105.
- Sastry, M. and V. Mamgain. 1971. The marine Mesozoic Formations of India: a review. *Records of the Geological Survey of India* 101:162-177.
- Saunders, J. J. and B. K. Dawson. 1998. Bone damage patterns produced by extinct hyena, *Pachycrocuta brevirostris* (Mammalia: Carnivora), at the Haro River Quarry, Northwestern Pakistan. *National Science Museum Monographs* 14:215-242.
- Schmidt, R. H. and R. Beach. 1994. What is 'wildlife damage management'? *Wildlife Control Technology* 1:4-5.
- Schoener, T. W. 1971. Theory of feeding strategies. *Annual review of ecology and systematics* 2:369-404.
- Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. *The Journal of wildlife management*:739-747.
- Seaman, D. E. and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. *Ecology* 77:2075-2085.
- Sharma, S. K. 2002. A study of ethnozoology of southern Rajasthan.
- Sharp, S. P., M. Simeoni, and B. J. Hatchwell. 2008. Dispersal of sibling coalitions promotes helping among immigrants in a cooperatively breeding bird. *Proceedings of the Royal Society B: Biological Sciences* 275:2125-2130.
- Sillero-Zubiri, C. and M. Laurenson. 2001. Interactions between carnivores and local communities: conflict or co-existence? *Conservation Biology Series-Cambridge*:-282-312.
- Singh, C. S. P., A. K. Jaitly, and D. K. Pandey. 1982. First report of some Bajocian - Bathonian (Middle Jurassic) ammonoid and the age of the oldest sediments from Kutch, W. India. *Newsletter Stratigraphy* 11:37-40.

- Singh, N. and A. Kar. 2001. Characteristics of major soils of Banni mudflat in arid western India and their relationship with topography. *Journal of arid environments* 48:509-520.
- Singh, P., A. M. Gopalaswamy, and K. U. Karanth. 2010. Factors influencing densities of striped hyenas (*Hyaena hyaena*) in arid regions of India. *Journal of Mammalogy* 91:1152-1159.
- Sinha, S. K., R. R. Joshi, and R. I. Patel. 1972. Working Plan for Kutch. State Forest Department of Gujarat, Gandhinagar.
- Skinner, J. and R. v. Aarde. 1987. Range use by brown hyaenas *Hyaena brunnea* relocated in an agricultural area of the Transvaal. *Journal of Zoology* 212:350-352.
- Skinner, J. and G. Ilani. 1979. The striped hyaena *Hyaena hyaena* of the Judean and Negev deserts and a comparison with the brown hyaena *H. brunnea*. *Israel Journal of Zoology* 28:229-232.
- Smale, L., L. G. Frank, and K. E. Holekamp. 1993. Ontogeny of dominance in free-living spotted hyaenas: juvenile rank relations with adult females and immigrant males. *Animal behaviour* 46:467-477.
- Smith, J. E., J. M. Kolowski, K. E. Graham, S. E. Dawes, and K. E. Holekamp. 2008. Social and ecological determinants of fission–fusion dynamics in the spotted hyaena. *Animal behaviour* 76:619-636.
- Smith, J. E., K. S. Powning, S. E. Dawes, J. R. Estrada, A. L. Hopper, S. L. Piotrowski, and K. E. Holekamp. 2011. Greetings promote cooperation and reinforce social bonds among spotted hyaenas. *Animal behaviour* 81:401-415.
- Smith, J. E., E. M. Swanson, D. Reed, and K. E. Holekamp. 2012. Evolution of cooperation among mammalian carnivores and its relevance to hominin evolution. *Current Anthropology* 53:S436-S452.
- Smith, J. E., R. C. Van Horn, K. S. Powning, A. R. Cole, K. E. Graham, S. K. Memenis, and K. E. Holekamp. 2010. Evolutionary forces favoring intragroup coalitions among spotted hyenas and other animals. *Behavioral Ecology* 21:284-303.
- Snider, S. B. and J. F. Gilliam. 2008. Movement ecology: Size-specific behavioral response of an invasive snail to food availability. *Ecology* 89:1961-1971.
- Sohoni, P. S. and R. Karanth. 2003. Jointing and fracturing characteristics of central Kachchh mainland, Kachchh, Western India. *Journal of Geological Society of India* 61:673-684.
- Sohoni, P. S., J. N. Malik, S. S. Merh, and R. V. Karanth. 1999. Active Tectonics astride Katrol Hill Zone, Kutch, Western. India. *Journal of Geological Society of India* 53:579-586.
- Solla, D., R. Shane, R. Bonduriansky, and R. J. Brooks. 1999. Eliminating autocorrelation reduces biological relevance of home range estimates. *Journal of Animal Ecology* 68:221-234.
- Sollberger, A. 1965. *Biological rhythm research*. Elsevier Amsterdam.
- Soulé, M. E. 1987. *Viable populations for conservation*. Cambridge University Press.
- Spoor, C. 1985. Body proportions in Hyaenidae. *Anat. Anz.*, Jena 160:215-220.
- Spoor, C. and D. Badoux. 1986. Descriptive and functional myology of the neck and forelimb of the striped hyena (*Hyaena hyaena*, L. 1758). *Anat Anz* 161:375-387.
- Srivastava, A. and G. Babu. 2010. Total risk rating and stability analysis of embankment dams in the Kachchh Region, Gujarat, India. *Engineering Geology* 115:68-79.

- Stanley, O. D. 2004. Wetland ecosystems and coastal habitat diversity in Gujarat, India. *Journal of Coastal Development* 7:49-64.
- Stephens, D. and J. Krebs. 1986. Foraging theory: monographs in behavior and ecology. *Foraging Theory: Monographs in Behavior and Ecology*.
- Stratford, K. J. and S. Stratford. 2011. Fine - scale movements and use of space by spotted hyaena (*Crocuta crocuta*) on Ongava Game Reserve, Namibia. *African Journal of Ecology* 49:343-352.
- Swihart, R. K., T. M. Gehring, M. B. Kolozsvary, and T. E. Nupp. 2003. Responses of 'resistant' vertebrates to habitat loss and fragmentation: the importance of niche breadth and range boundaries. *Diversity and Distributions* 9:1-18.
- Technologies, A. C. a. 2008. Preparation of Guideline for Drinking Water Protection: One Year Progress report (2007 - 2008). Sahjeevan Trust, Bhuj, Kachhch.
- Thakker, M. 1988. *Sindhi Waters and Kutch*. Aaradhana Trust, Bhuj.
- Tilson, R. L. and W. J. Hamilton III. 1984. Social dominance and feeding patterns of spotted hyaenas. *Animal behaviour* 32:715-724.
- Townsend Peterson, A. and K. P. Cohoon. 1999. Sensitivity of distributional prediction algorithms to geographic data completeness. *Ecological Modelling* 117:159-164.
- Tremblay, J.-P., M. Crete, and J. Huot. 1998. Summer foraging behaviour of eastern coyotes in rural versus forest landscape: a possible mechanism of source-sink dynamics. *Ecoscience* 5:172-182.
- Tseng, Z. J. and D. Stynder. 2011. Mosaic functionality in a transitional ecomorphology: skull biomechanics in stem Hyaeninae compared to modern South African carnivorans. *Biological Journal of the Linnean Society* 102:540-559.
- Turner, A. 1986. Some features of African larger carnivore historical biogeography. *Palaeoecology of Africa* 17:237-244.
- Turner, A. 1988. On the claimed occurrence of the hyaenid genus *Hyaenictis* Gaudry at Swartkrans (Mammalia, Carnivora). *Annals of the Transvaal Museum* 34:523-533.
- Turner, A. 1990. The evolution of the guild of larger terrestrial carnivores during the Plio-Pleistocene in Africa. *Geobios* 23:349-368.
- Turner, A. and M. Antón. 1996. The giant hyaena, *Pachycrocuta brevirostris* (Mammalia, Carnivora, Hyaenidae). *Geobios* 29:455-468.
- Valeton, I. 1983. Palaeoenvironment of lateritic bauxites with vertical and lateral differentiation. Geological Society, London, Special Publications 11:77-90.
- Van Aarde, R., J. Skinner, M. Knight, and D. Skinner. 1988. Range Use by a Striped Hyena (*Hyaena-Hyaena*) in the Negev Desert. *Journal of Zoology* 216:575-577.
- Van Horn, R. C., A. L. Engh, K. T. Scribner, S. M. Funk, and K. E. Holekamp. 2004. Behavioural structuring of relatedness in the spotted hyena (*Crocuta crocuta*) suggests direct fitness benefits of clan - level cooperation. *Molecular ecology* 13:449-458.
- Viranta, S. 2003. Geographic and temporal ranges of Middle and Late Miocene carnivores. *Journal of Mammalogy* 84:1267-1278.
- Wagner, A. 2007. *Hyaena hyaena* (Linnaeus). in J. Kingdon, D. Happold, and T. Butynski, editors. *The mammals of Africa*. Elsevier Science, London, United Kingdom.
- Wagner, A. P. 2006. Behavioral ecology of the striped hyena (*Hyaena hyaena*). Montana State University Bozeman.

- Wagner, A. P., S. Creel, L. G. Frank, and S. T. Kalinowski. 2007a. Patterns of relatedness and parentage in an asocial, polyandrous striped hyena population. *Molecular ecology* 16:4356-4369.
- Wagner, A. P., L. G. Frank, and S. Creel. 2008a. Spatial grouping in behaviourally solitary striped hyaenas, *Hyaena hyaena*. *Animal behaviour* 75:1131-1142.
- Wagner, A. P., L. G. Frank, and S. Creel. 2008b. Spatial grouping in behaviourally solitary striped hyaenas, *Hyaena hyaena*. *Animal Behaviour* 75:1131-1142.
- Wagner, A. P., L. G. Frank, S. Creel, and E. M. Coscia. 2007b. Transient genital abnormalities in striped hyenas (*Hyaena hyaena*). *Hormones and behavior* 51:626-632.
- Wand, M. P. and M. C. Jones. 1995. Kernel smoothing. Chapman & Hall/CRC.
- Warren, D. L. and S. N. Seifert. 2011. Ecological niche modeling in Maxent: the importance of model complexity and the performance of model selection criteria. *Ecological Applications* 21:335-342.
- Watts, H. E. and K. E. Holekamp. 2007. Hyena societies. *Current Biology* 17:R657.
- Watts, H. E., J. B. Tanner, B. L. Lundrigan, and K. E. Holekamp. 2009. Post-weaning maternal effects and the evolution of female dominance in the spotted hyena. *Proceedings of the Royal Society B: Biological Sciences* 276:2291-2298.
- Werdelin, L. 1996. Community-wide character displacement in Miocene hyaenas. *Lethaia* 29:97-106.
- Werdelin, L. and N. Solounias. 1991. Hyaenidae: taxonomy, systematics and evolution. *Fossils and Strata* 30:1-104.
- Werdelin, L. and N. Solounias. 1996. The evolutionary history of hyaenas in Europe and western Asia during the Miocene. *The Evolution of Western Eurasian Miocene Mammal Faunas*. Columbia University Press, New York:290-306.
- White, G. and R. Garrot. 1990. Analysis of wildlife radiolocation data. Academic Press, New York.
- White, G. C. and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic press San Diego, California.
- White, R., A. Murray, and M. Rohweder. 2000. Pilot analysis of global ecosystems: grassland ecosystems., World Resources Institute, Washington, D.C.
- Whitehead, H. 2008. Analyzing animal societies: quantitative methods for vertebrate social analysis. University of Chicago Press.
- Wiesel, I. 2007. Predatory and foraging behaviour of brown hyenas (*Parahyaena brunnea* (Thunberg, 1820)) at Cape fur seal (*Arctocephalus pusillus pusillus* Schreber, 1776) colonies.
- Williams, L. F. R. 1958a. The Black Hills- Kutch in history and legend. Weidenfield and Nicholson, London.
- Williams, L. F. R. 1958b. The black hills: Kutch in history and legend: a study in Indian local loyalties. Weidenfeld and Nicolson.
- Wilson Edward, O. 1975. Sociobiology: the new synthesis. Cambridge, MA: Belknap.
- Woodroffe, R. 2000. Predators and people: using human densities to interpret declines of large carnivores. *Animal Conservation* 3:165-173.
- Woodroffe, R. 2001. Strategies for carnivore conservation: lessons from contemporary extinctions. 61–92. *Carnivore conservation*. Gittleman, JL, SM Funk, DW Macdonald, and RK Wayne. eds. Cambridge University Press. Cambridge, United Kingdom.
- Woodroffe, R. and L. G. Frank. 2005. Lethal control of African lions (*Panthera leo*): local and regional population impacts. *Animal Conservation* 8:91-98.

- Woodroffe, R. and J. R. Ginsberg. 1998. Edge effects and the extinction of populations inside protected areas. *Science* 280:2126-2128.
- Woodroffe, R., S. Thirgood, and A. Rabinowitz. 2005. *People and wildlife, conflict or co-existence?* Cambridge University Press.
- Woolf, A., C. K. Nielsen, T. Weber, and T. J. Gibbs-Kieninger. 2002. Statewide modeling of bobcat, *Lynx rufus*, habitat in Illinois, USA. *Biological Conservation* 104:191-198.
- Worton, B. 1987. A review of models of home range for animal movement. *Ecological Modelling* 38:277-298.
- Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. *Ecology* 70:164-168.
- Worton, B. J. 1995. Using Monte Carlo simulation to evaluate kernel-based home range estimators. *The Journal of wildlife management*:794-800.
- Wrangham, R. and D. Rubenstein. 1986. Social evolution in birds and mammals. *Ecological aspects of social evolution*. Princeton University Press, Princeton:452-470.
- Wright, B. E. 2010. Use of chi - square tests to analyze scat - derived diet composition data. *Marine Mammal Science* 26:395-401.
- Yalden, D., M. Lagen, D. Kock, and J. Hillman. 1996. Catalogue of the mammals of Ethiopia and Eritrea. 7. Revised checklist, zoogeography and conservation. *Tropical Zoology* 9:73-164.
- Yom-Tov, Y. and H. Mendelssohn. 1988. Changes in the distribution and abundance of vertebrates in Israel during the 20th century. *Monographiae biologicae* 62:515-547.
- Zabel, C. J., S. E. Glickman, L. G. Frank, K. B. Woodmansee, and G. Keppel. 1992. Coalition formation in a colony of prepubertal spotted hyenas. *Coalitions and alliances in humans and other animals*:113-135.
- Zollner, P. A. and S. L. Lima. 1999. Search strategies for landscape-level interpatch movements. *Ecology* 80:1019-1030.