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Human-Leopard Interactions around Gir National Park and Sanctuary, Gujarat, India

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ABSTRACT

We studied human-leopard interactions around Gir National Park and Sanctuary. We collected secondary data from the Gujarat State Forest Department (2000-2007) and further augmented primary and secondary data during our field investigation from 2008-2012. We analyzed data to understand human-leopard interactions viz-a-viz annual and seasonal pattern, magnitude and areas with high levels of interactions. Between 2000 to 2012, 1187 leopards were captured from outside the Gir National Park and Sanctuary. 2459 cases of livestock predation by leopard were recorded from outside Gir. We analyzed data using ARIMA time series. There was significant correlation between lags of captured leopards for overall trend (rk =0.380±0.09, ok=19.58, $p < 0.05$) following seasonality (t (q1) = -0.203± 0.09, $p < 0.05$); t (Qs1) = 0.595 ± 0.08, $p < 0.05$). The highest cases of interactions were recorded in winter season (38.7%). Incidences of leopards falling in agricultural wells were highest in monsoon season (38.4%). Cases of leopards entering human houses were highest in summer season (52.7%). Livestock predation by leopard outside Gir was also highest in winter season (42%). The mean livestock predation rate was 224±49 livestock/annum with majority of killing of small sized livestock (89%). Leopards captured from outside Gir showed significant preponderance of adult individuals. Cases of capturing of leopard and livestock predation were recorded as far as 53 km from the boundary of Gir. Majority of sites with high level of human-leopard interactions were, however, located within a distance of 0-12 km. The study has provided detailed insight into human-leopard interaction outside Gir and the same may be used to frame preventive strategies for reduction in such interactions around Gir National Park and Sanctuary.

Key words: Human-leopard interactions, Livestock killing, Gir National Park and Sanctuary.

INTRODUCTION

Human conflict with carnivore has been recorded as a worldwide phenomenon in recent times. A number of factors such as increase in human population and settlements, local increase of carnivore populations, habitat loss and degradation, and decrease in prey abundance have been identified as key drivers of conflict. Some of the carnivore species also have large home ranges which sometimes result in these species making forays into human-dominated landscapes (Sogbohossou et al. 2011, Ahmed et al. 2012, Meena et al. 2014, Malviya and Ramesh 2015). Human-carnivore encounters often assume serious dimension posing a serious threat to human lives and their livestock (Mishra and Fitzherbert 2004, Woodroffe et al. 2005, Balme et al. 2009). The 21st century experienced a dramatic increase in conflict occurrences, including carnivore attacks on humans and killing of livestock, even after implementing enormous mitigation measures (Marker and Shivamani 2009). In southern Asia, studies on tigers (Singh et al. 2015), leopards (Athreya et al. 2007, Dar et al. 2009, Kumar and Chauhan 2011, Malviya and Ramesh 2015), and lions (Saberwal et al. 1994, Vijayan and Pati 1994) have documented similar increases and consequences to human and livestock safety. Generally, conflict occurs due to spatial overlap in carnivore-human activities, especially where both human and carnivore populations are expanding, shrinking of natural habitats due to encroachment, agriculture and developmental projects (Treves and Karanth 2003, Mishra and Fitzherbert 2004, Treves et al. 2006, Hayward et al. 2007, Pettigrew et al. 2012, Malviya and Ramesh 2015). Such circumstances create a permanent

interference edge, termed a "co-existence edge," that results in sequential conflict incidents (Nowell and Jackson 1996, Karanth and Madhusudan 2002, Ahmed et al. 2012, Bibi et al. 2013).

Currently, conflict prevention and mitigation have become a priority for the management of carnivores of high conservation value that coexist with humans. However, people living within the co-existence edge have constant fear of these species which sometimes evokes negative opinion for their conservation. The conflict between carnivore conservation and human safety has resulted in retaliatory killing, poaching, and reduced cooperation of local peoples in the conservation of large carnivores (Macdonald and Sillero-Zubiri 2003, Hussain 2003, Kalaivanan et al. 2010, Pettigrew et al. 2012, Bibi et al. 2013, Meena et. al. 2014).

The Indian leopard (*Panthera pardus fusca*) is estimated to be locally abundant around some national parks and sanctuaries in Indian states such as Gujarat, Maharashtra, Rajasthan and Jammu & Kashmir (Athreya et al. 2007, Harihar 2009, Zehra et al. 2016, Venkatesh et al. 2017, Mandal et al. 2017). In India, leopards generally coexist with other sympatric large carnivores such as tigers and lions. These ecologically dominant carnivores often out-compete leopards for their food, habitat and shelters (Madhusudan 2003, Karanth et al. 2012). Leopards are dietary generalists, and are known for their behavioural plasticity. They are less sensitive to human disturbances, and thus leopards occupy sub optimal habitats closer to human habitations than tigers and lions (Weber and Rabinowitz 1996, Henschel et al. 2005, Yirga and Bauer 2011, Singh et al. 2015, Rayan and Linkie 2016). This has resulted in the establishment of populations of leopard on the peripheral lands around national parks and sanctuaries in some Indian states such as Gujarat, Maharashtra, Jammu & Kashmir and Rajasthan, resulting in widespread human-leopard interactions (Athreya et al. 2007, Kumar and Chauhan 2011).

The Gir National Park and Sanctuary (henceforth GNPS), in the Gujarat state of India, is a protected area where leopards are abundant on the peripheral land, resulting in frequent cases of human-leopard interaction. Therefore, a study was undertaken to investigate human-leopard interaction around GNPS.

STUDY AREA

The study was carried out around GNPS (21° 55' to 21° 20'N and 70° 25' to 71° 15'E) which covers an area of 1412 km^2. It is located in Saurashtra region of Gujarat state of India. GNPS harbours good populations of leopard, Asiatic lions (*Panthera leo persica*), Striped hyena (*Hyaena hyaena*) and Golden jackal (*Canis aureus*). The rich prey assemblage of GNPS includes wild ungulates such as chital (*Axis axis*), sambar (*Rusa unicolor*), nilgai (*Boselaphus tragocamelos*), wild pig (*Sus scrofa*), four-horned antelope (*Tetracerus quadricornis*) and chinkara (*Gazella benettii*) along with peafowl (*Pavo crestatus*) and common langur (*Semnopithecus entellus*).

The peripheral land of GNPS falls mainly in two districts, Junagadh (JND) and Amreli (AMR). The region receives mean annual rainfall of 1,000 mm with following three seasons viz. summer (average temperature 43°C), monsoon, and winter (average temperature10°C) and it falls under tropical dry deciduous forest of semi-arid zone as per classification of Champion and Seth (1968). The peripheral areas consist of reserved forest (246 km^2), protected forest (107.51 km^2) and unprotected forest (77 km^2). These districts differ in terms of human population, altitude, forest cover, precipitation, land use pattern and livestock populations (Table 1). People of both districts are heavily dependent on farming and animal husbandry. The land surrounding the sanctuary is fertile black cotton soil (Mehta 2012) that supports a rich harvest of crops such as sugar cane (*Saccharum officinarum*), cotton (*Gossypium herbaceum*), groundnut (*Arachis hypogaea*) and mango (*Mangifera indica*). When people come to work in the agriculture fields they bring along their livestock with them and leave them to graze in the field. The manifold increase in intensive agriculture farming around GNPS has created conducive conditions e.g. cover, water, prey (livestock) for survival of leopards and consequently a sizeable resident population of leopard exists in agro-farms outside GNPS.

METHODS

Primary and secondary data gathered on human-leopard interactions for the period from 2000 to 2012

Table 1. Status of climatic, demographic and land use variables in Junagadh and Amreli districts of Gir National Park and Sanctuary.

Parameters	Junagadh	Amreli	Source
Area (km^2)	8831	7397	junagadh/amrelidp.gujarat.gov.in
Human population (individuals/km^2)	311	205	www.census2011.co.in
Agriculture land	5343	5838	District Panchayat Amreli & Junagadh
Livestock	251658	182873	www.agri.gujarat.gov.in
Forest type	TAZW	ABLW	Khan et al. (1996)
Temperature (Min.-Max. in ^oC)	19.5-38.6	9-38	Kumar and Meena (2011)
Mean Rainfall (mm)	1102	492	Kumar and Meena (2011)
HLI cases in Villages	186	155	Forest Dept. (2000-2012)

TAZW = *Tectona-Acacia-Zizyphus* Woodland, ABLW=*Anogeisus-Boswellia-Lannea* Woodland, HLI=Human-leopard interaction

from around GNPS were summarized and analyzed to understand the magnitude, extent and spatio-temporal pattern of interaction around GNPS. The data comprised of details of each human-leopard interaction incidence and information gathered from the interaction site. On receipt of information about any interaction incidence, the rescue team of the Wildlife Division of GNPS comprising of forest staff and a veterinarian doctor would reach to the site immediately. At the incident site, rescue team would register the date and time of the incident, location, and nature of incident (i.e. human-leopard encounter or livestock killing). In case of livestock predation, data on species killed, location of attack, time of attack, age and sex of the livestock were recorded. A leopard attack on livestock was identified by throat bites, as leopard paralyzes a prey with a bite through the cervix.

In case of human injury or death, or sequential killing of livestock, the rescue team would focus efforts to capture the leopard. For this, they would initiate leopard rescue operation by fixing iron cages (3 feet length, 1.5 feet width) with a self-drop-door mechanism at most vulnerable locations. The leopard, after its capture, was relocated to the Gir Rescue Centre. Captured leopard was administered anesthesia by a veterinarian under supervision of forest officials in order to collect physio-morphological information and to mark the individual by inserting an electronic identification chip (EIC) intramuscularly. Age of the captured leopards was assessed as older individuals (>10 years), adult (3-8 years old), sub-adult (2-3 years old), yearling (1-2 years old) and cubs (<1 year). The assessment was done on the basis of physio-morphological clues such as weight, tooth wear, gum recession, wears on the pads, pelage, scarring, body size, and reproductive condition (Lindstedt et al. 1986).

Data were analyzed to assess status of human-leopard interaction cases on annual basis recorded from year 2000 to 2012. We assessed annual and seasonal trends of interaction to determine significance of the trends using the moving average method and autocorrelation model using time series analyses in ARIMA. Autocorrelation basically represents a co-relational dependency of order k between ith cases of the series "k which is usually called the lag" (Box and Jemkins 1976, Kendall and Stuart 1976) and examine autocorrelation at various neighborhoods lags. In this order, it predicts a value in a response time series as a linear combination of its own past values, past errors, and current and past values of other time series. We used maximum likelihood method (Melard 1984) for calculating the time dependent variable i.e. number of human-leopard interaction cases. It was important to understand factors affecting the interaction and test their veracity in the site concerned. Therefore the role played by location of interaction, characteristics

of problem leopard and livestock predation was evaluated. The cases of human-leopard interaction were evaluated in proportions of the total for their related interaction drivers. The assessment was done on overall and seasonal basis. We conducted a Friedman Two Way ANOVA to determine whether there was relationship between the number of human-leopard interaction cases at an identified location during a particular season.

All captured leopards were assessed whether or not the individual was new or it carried the EIC. The leopards were segregated into different age and sex categories on overall and seasonal basis. Sex ratio was calculated in terms of number of male to female. Number of individuals in each sex and age category was used to calculate the expected frequencies and χ^2 test was performed to determine the significance of captured individuals in each sex and age category in relation to expected value. Friedman Two Way ANOVA was used to measure seasonal differences in the capture and recapture of problem leopards.

Data on livestock predation by leopards were used to assess overall status and seasonal trend in proportion to the total number of cases. The livestock killing rate (mean±SE) was calculated for the total number of livestock predation cases. Selection of livestock in terms of size and species was also assessed using descriptive statistics (mean± SE). Spearman Rank Correlation was used between annually captured leopards and predation cases to measure the effect of leopards removal on the next consecutive year. The spatial extent of interaction and identification of most sever interaction sites was done by demarcating buffers of 0-6 km, 6-12 km, 12-18 km, and 18-24 km away from the boundary of GNPS on thematic map of the peripheral land. All cases of interactions were plotted on the thematic map. Grids of 5×5 km were superimposed on the map and grids were categorized in terms of relative number of interaction cases using an ordinal scale of low, medium, and high level of interaction by counting number of captured leopards and livestock predation cases for each grid. All statistical tests were performed using program SPSS (Version 20).

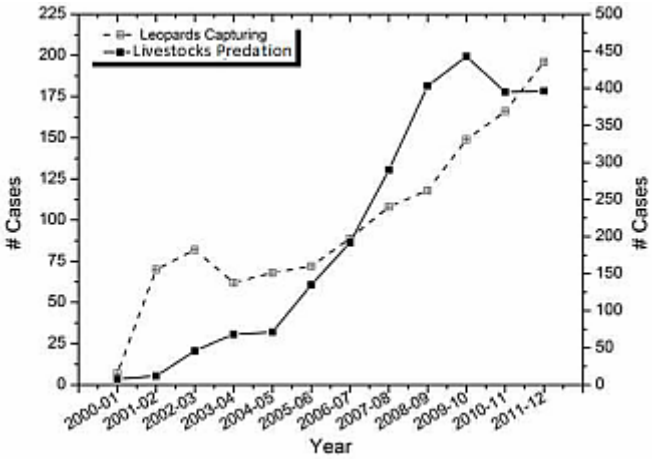

Figure 1. Annual status of capture of leopards and livestock predation from 2000 to 2012 around Gir National Park and Sanctuary.

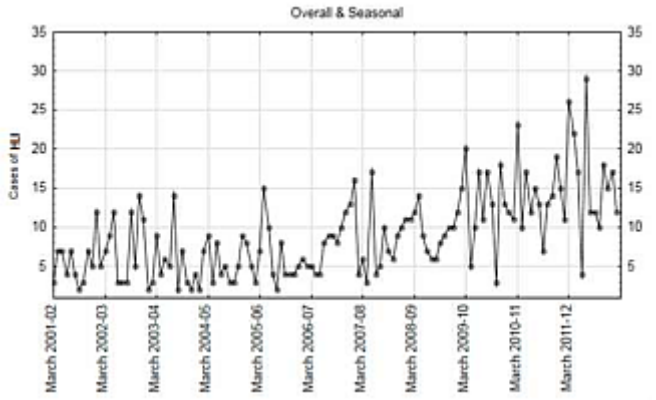

Figure 2. Monthly and seasonal pattern of human-leopard interaction (HLI) cases from year 2000 to 2012 around Gir National Park and Sanctuary.

RESULTS

Status of Human-leopard interaction around GNPS

A total of 1,187 leopards were captured due to conflicts from the peripheral land around GNPS over a period of 12 years with lowest number (n=7) in year 2000-2001 to highest number of leopard (n=196) in year 2011-2012 with a 28-fold increase (Fig. 1). The number of Human-leopard interaction cases were highest in winter (c. 36%) and lowest in monsoon season (c. 29%, Fig. 2). The ARIMA modelling [(Natural log transformation, x=ln (x)] showed significant correlation among leopards captured for consecutive years (rk = 0.380±0.09, ok = 19.58, P<0.05, Fig. 3). The partial correlation (differencing transformation [x=x-x(log)]) exhibited a significant stationary pattern (a stationary series has a constant mean, variance, and autocorrelation through time) for all consecutive years (rk = -0.371, 0.09, Qk = 16.80, P<0.5; øk = -0.354, 0.17, Fig. 4)

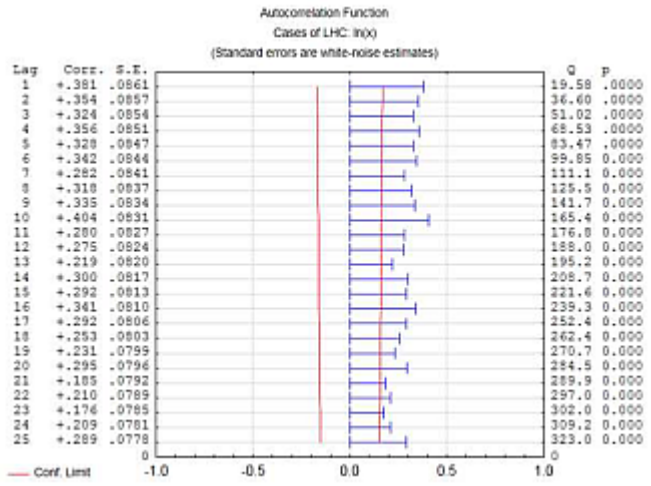

Figure 3. Correlogram showing serial correlation coefficients and SE for number of leopards captured for consecutive years in a specified range of lags from 2000 to 2012.

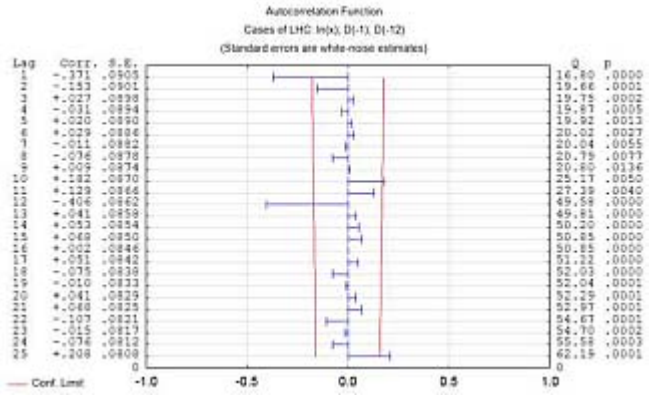

Figure 4. Correlogram showing partial correlation coefficients and SE among number of leopards captured during consecutive years in a specified range of lags from 2000 to 2012.

Figure 5. Seasonal distribution of human-leopard interaction (HLI) cases in Agro farm, open wells and human houses from 2000 to 2012 in Gir National Park and Sanctuary.

with a significant seasonal trend for the number of leopards captured, as well as a significant trend for overall period (t (q1) = -0.203± 0.09, P <0.05; t (Qs1) = 0.595 ± 0.08, P<0.05). Approximately 84% (n=818) captured leopards were released back in the core forest as per the leopard translocation strategy. Six percent (n = 63) leopards were shifted to Sakkarbaug Zoo, Junagadh as these were involved in cases of repeated attacks on livestock and humans. Among the remaining number of leopards, few died naturally and few were retained at the Gir Rescue Centre.

Figure 5 provides data on seasonal pattern of human-leopard interaction cases around GNPS. Maximum number of cases were recorded from agro farms (c.77.5%, n=920), followed by open agricultural wells (c. 12% leopards, n=143) and human houses (c. 6.23% leopard, n=79). The location of human-leopard interaction for c. 4.2% (n=50) captured leopards could not be determined. Seasonally, the cases of human-leopard interactions were highest in agro farms in winter season (39%). Cases of leopards falling in open wells and leopards entering houses were highest in monsoon (38%) and summer season (53%) respectively. However differences in interaction cases were not statistically significant between seasons viz-a-viz location (Friedman Two Way ANOVA, χ^2= 0.67, n= 3, d. f. = 2, P> 0.05).

Data on sex and age of captured leopards were summarized from 2000 to 2012. Of the total 1,187 captured leopards, sex could be determined for 1070 individuals with a sex ratio of 1.03 males: 1 female. The involvement of males in human-leopard interaction cases was significantly higher during winter season (χ^2_{yates}= 4.40, P<0.05) whereas involvement of female leopard in human-leopard interaction cases was higher in summer and monsoon seasons but the difference was not statistically significant in either summer (χ^2_{yates} = 0.69, P>0.05) or monsoon (χ^2_{yates}= 0.24, P>0.05) season.

A total of 963 leopards could be classified in different age classes. Figure 6 provides seasonal pattern of involvement of leopard in human-leopard interaction viz-a-viz different age classes. Out of 963 classified leopards, 73.5% (n=708) captured leopards were adult followed by 14.6% (n=143) old adult and 7.79% (n=75) sub-adult individuals

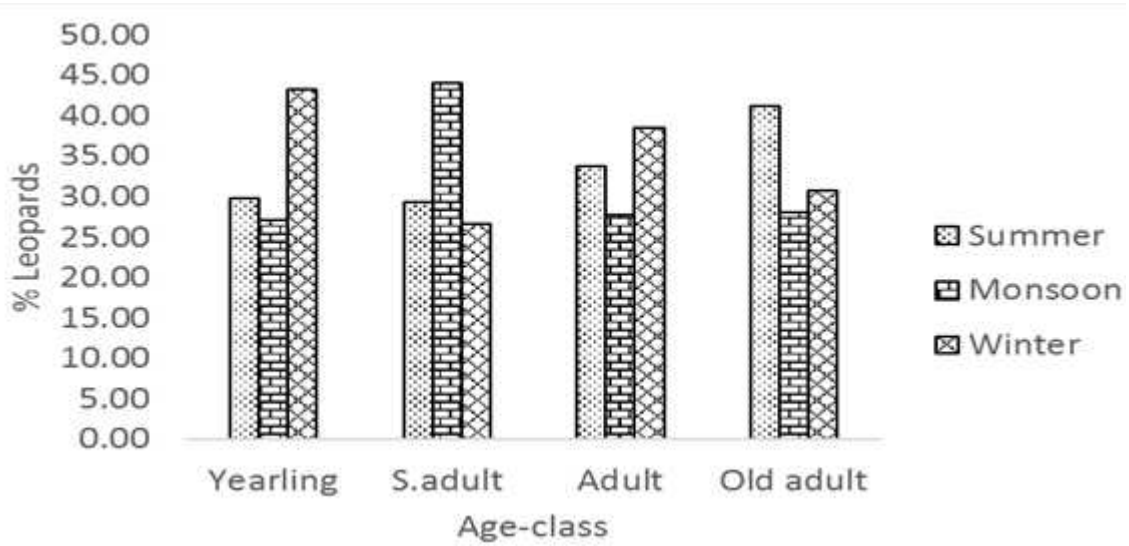

Figure 6. Seasonal pattern of various age classes of captured leopards from 2000 to 2012 around Gir National Park and Sanctuary.

respectively. Captured leopards (3.8% (n=37)) were less than a year old. There was significant difference among age classes of captured leopards with involvement of adult individuals in interaction more expected than by chance ($\chi^2 = 1233$, d.f.= 3, $p<0.05$). Adult (38.56%, n=273) and one year old (43.24%, n=16) leopards were captured more in winter season, whereas old adult leopards (41.26%, n=59) and sub-adult leopards (44%, n=33) were captured more in summer and monsoon seasons respectively. However, the differences were not significant statistically (Friedman Two Way ANOVA χ^2= 1.5, n= 4, d.f. = 3, $p>0.05$). A total of 92 cubs were captured with their mother. The majority of the cubs (n=51) were of <1 month old followed by 1 to 6 months (n= 34) and 7-10 months cubs (n=7).

Livestock predation by leopards around GNPS

The human-leopard interaction was also assessed using 2,459 cases of livestock predation by leopards that were reported to the Forest Department by the people. The cases of livestock predation increased annually from 20 cases in 2000-2001 and to 396 in 2012. Seasonally the livestock predation was highest in winter (42%, n=1036), followed by monsoon (35%, n=862) and summer (22%, n=561) (Fig. 7). The mean livestock predation rate was calculated to be 224±49 livestock/year. Table 2 provides data on livestock predation by leopard around GNPS. Leopards preyed upon small sized livestock more (200±47) comprising of cattle calves, goat, and sheep, compared to large sized livestock (24±3) comprising of cow, bull, buffalo, feral cow, horse and ass. The average annual predation was highest for cattle calves (116), followed by goat (63) and sheep (21). A significant correlation was found between annually captured leopards and predation cases ($_{rs}$= 0.78, P< 0.05).

Spatial pattern of human-leopard interaction around GNPS

Figure 8 and 9 provide spatial distribution of cases of human-leopard interaction and livestock predation around GNPS in 6 km interval buffers. The number

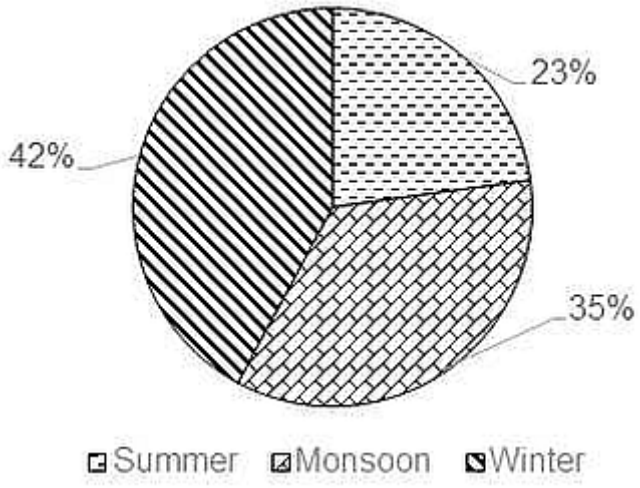

Figure 7. Seasonal livestock predation by leopards from 2000 to 2012 around Gir National Park and Sanctuary.

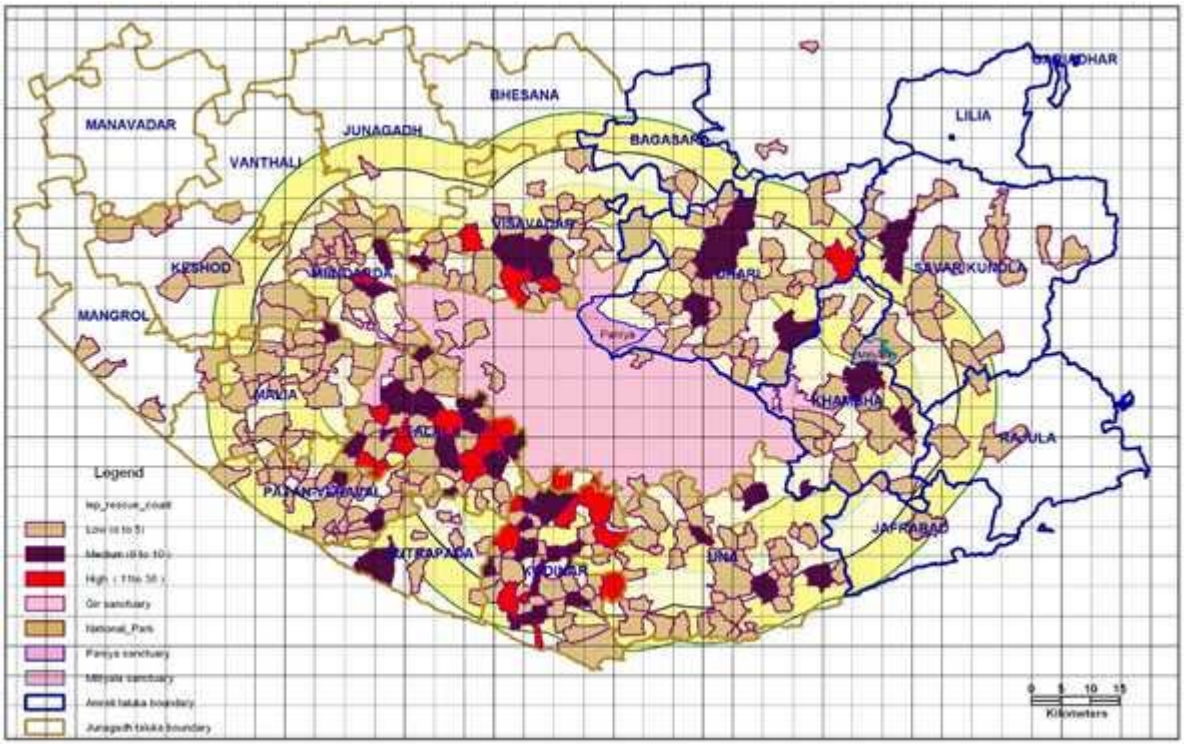

Figure 8. Spatial distribution of human-leopard interaction cases from 2000 to 2012 around the Gir National Park and Sanctuary

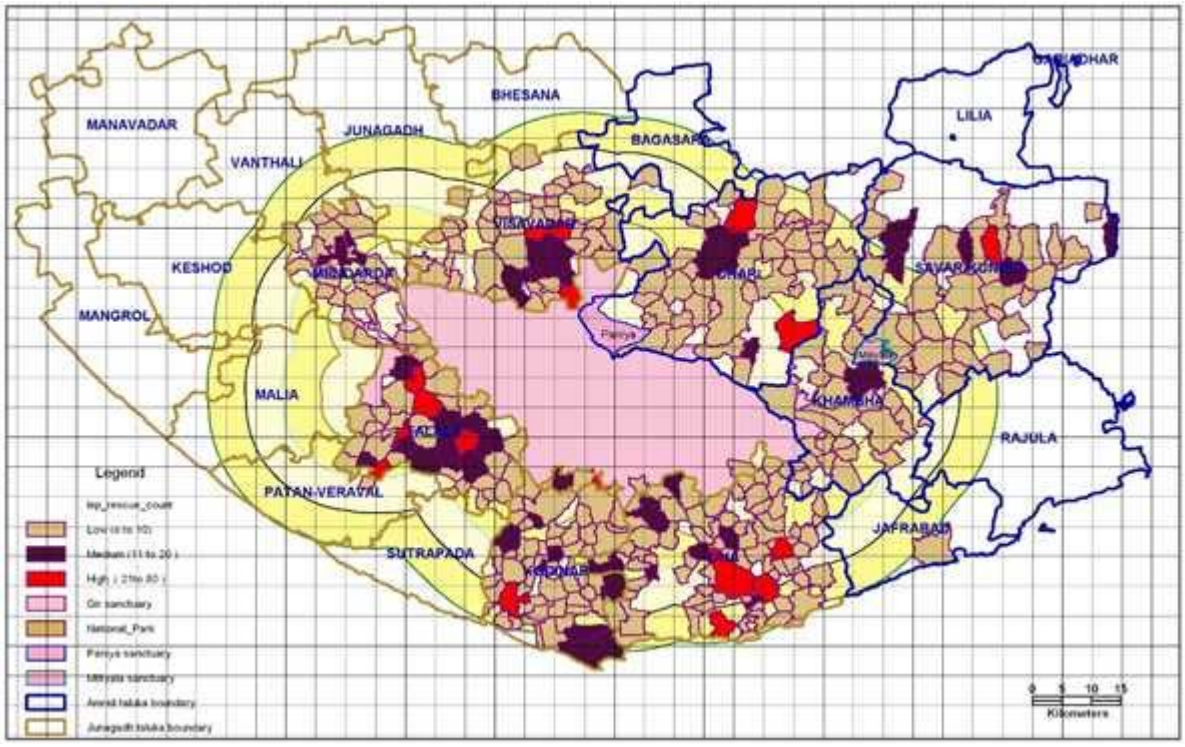

Figure 9. Spatial Distribution of livestock predation cases by leopards from 2000 to 2012 around Gir National Park and Sanctuary.

of human-leopard interaction sites differed significantly between different layers of buffers (χ^2=21.6, d.f.=6, P<0.05). The proportions of high and medium human-leopard interaction cases sites decreased with each successive 6 km buffer away from boundary of GNPS. However, the proportion of low number of interaction sites was higher in 6-12 and 12-18 km buffer. Similarly, the number of

Table 2. Status of livestock killed by leopards from 2000 to 2012 around Gir National Park and Sanctuary.

Species	Number	Percent	MPR/annum
Cow	211	8.58	19.18
Bull	37	1.50	3.36
Cattle calf	1276	51.89	116
Feral cow	4	0.16	0.36
Buffalo	10	0.41	0.91
Sheep	228	9.27	20.73
Goat	690	28.06	62.76
Horse	1	0.04	0.09

livestock predation cases also differed significantly between different layers of buffers (χ^2=13.2, d.f.=6, P<0.05) and maximum number of cases of livestock predation were recorded in 0-6 km buffer and these cases decreased with successive 6 km buffer. The combined data of human-leopard interaction and livestock predation cases also differed significantly between 6 km buffers and followed a decreasing trend as the distance from GNPS boundary increased (χ^2=26.3, d.f.=6, P<0.05). The combined data showed that the number of cases of interaction and livestock predation were higher than expected by chance in high and medium categories compared to low category in 0-6 km buffer whereas, in 6-12 km buffer the proportions in high category were less than expected by chance, higher than expected by chance in medium and equal number in low category.

DISCUSSION

The history of large carnivore-human conflict in Gir can be traced back to 1990 when lions first started moving out of the southern boundary of GNPS resulting in some level of conflict between lion and human population living in villages and settlements adjoining GNPS (Saberwal et. al 1994). The leopard too started moving out of the GNPS and the number of leopard coming in conflict with adjoining human population started growing. Sustained conservation efforts by managers, since the establishment of Gir Sanctuary and subsequent management actions, had led to significant increase in populations of lion as well as leopard much similar to the increase in ungulate populations documented by Khan et al. (1996). The densities of lion and leopard had perhaps reached the carrying capacity in mid 1980s and further rise in population within GNPS forced individuals to move out of the GNPS. The outward movement of lion and leopard was on account of saturated land tenure system in terms of space rather than on account of habitat conditions which were optimum and wild prey biomass which was also optimum and supplemented by a very high domestic prey biomass (Khan 1993).

Since 1990s there have been major changes in the agricultural practices around the GNPS. The farmers started growing sugarcane and also opted for mango cultivation. Vast expanses of agricultural areas came under sugarcane cultivation interspersed with mango orchards between 1990 to 2000. Gradually, this changed the landscape, especially on the southern boundary of GNPS. This changed landscape started providing good cover, shelter, water and ample domestic prey to the leopards. Vijayan and Pati (2002) analysed the man-animal conflict for the period from 1990 to 1999 and found a strong correlation between large carnivore-human conflict and the changing agricultural practices outside GNPS. The census data from the Forest Department suggest that the large carnivore population within GNPS continued to rise between 1990-2000 with many individuals moving out of Gir. The leopard which came in conflict with human population were captured from outside the GNPS and were released into the core areas of GNPS, with the objective that such individuals would establish themselves inside GNPS and capture and release would eventually reduce the leopard-human conflict outside GNPS. However subsequent studies proved that the released leopards moved back to the agricultural areas. For example, Khan et al. (2007) radio collared a female leopard in 2002. The female leopard was rescued from a well in Talala Division outside the GNPS. The female leopard was released inside the national park. The female leopard moved out of GNPS within 72 hours of its release and established itself in agricultural areas near Diu. It was intensively monitored for three years and was recaptured in June 2005. She gave birth twice in three years period and completely subsisted on domestic and wild prey species without coming in direct conflict with the farmers. She rested in agricultural areas during day time and became active only after the sunset. She

moved extensively in villages and human settlements within its home range in pursuit of domestic prey species.

The capture-recapture data of leopards also showed that the majority of captured leopards released inside the GNPS moved back to the agricultural areas. Therefore, the changes in landscape outside the GNPS between 1990-2000 made extensive agricultural areas suitable for establishment of resident breeding leopard population. Lion followed a similar pattern and several sub populations came to be recognized later giving rise to the concept of "Greater Gir" in context of lion conservation.

The number of leopard captured from 2000-01 to 2012 (n=1,187) and the number of livestock (n=2,459) that got prey upon by leopards during the same period shows the enormity of leopard-human conflict in Gir, especially if it is to be compared with data from 1990 to year 2000. The villagers tolerated the livestock predation due to effective compensation scheme of the Forest Department but the scenario changed due to attack on human being. The farmers started hiring labourers from Maharashtra for cutting sugarcane. The labourers generally stayed in the agricultural fields by erecting temporary huts where the families of labourers were always extremely vulnerable from attacks by leopards. There were several instances of attacks on people and child lifting where leopard initially got attracted to the huts as labourers threw left overs of fish nearby.

The managers in Gir have very limited options for management of human-leopard interactions outside GNPS as release of captured leopard inside GNPS has not yielded desirable reduction in scale of such interactions. Other factors (changed agricultural practices, large scale movement of people, resident agro farm leopard population etc.) which influence such interactions are also unlikely to change. The option of capturing leopard and keeping them in captivity is a very cost intensive affair and is not at all sustainable either in short or long term basis. The managers have done a commendable job in establishing several rescue centres at various locations in GNPS, including the Sakkarbaugh Zoo. Such rescue centres hold a sizeable captive population of leopard translocated from GNPS. Another option is culling of problem leopard as practiced in some African countries. However this is socially unacceptable in India. Population reduction through fertility control may be good option to try outside GNPS. It has not been attempted in Gir. A pilot project may be undertaken on the southern boundary of the GNPS where the conflict is severe. The farmers and villagers especially within 6 km buffer all around GNPS have lived with large carnivores through ages and tend to take leopard and lion in agro farms for granted. Provision of permanent shelters for labourers, erecting parapet wall around open wells and carnivore proof fences for domestic livestock with curtailed night time movement by people are some of the measures which can substantially reduce human interactions with leopard in the Gir National Park and Wildlife Sanctuary.

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