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Status and Habitat Use of Large Mammals in Gir National Park and Sanctuary, Gujarat, India

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ABSTRACT

Data pertains to abundance and habitat use on patch scale on large mammals was collected using camera trapping during summer 2017. Camera traps were placed systematically in a 4 km^2 grid in an area of 200 km^2. Relative Area Index was used as a measure of relative abundance of mammals and frequency of occurrence of different species in different habitat as a measure of habitat use. Difference among habitat use was tested using chi-square test. A total effort of 1581 trapping days resulted from four months of camera trapping. Among herbivores chital was the most abundant and distributed on the basis on RAI followed by sambar, wild boar and nilgai. Among carnivore's leopards was the most distributed and abundant carnivore followed by the lion and hyena. Except hyena and wild boar all other species use habitat differentially. Chital mostly use Teak-Acacia-Zizyphus habitat while sambar use Teak-Mixed habitat most. Nilgai use Mix Valley habitat most while wild boar uses all habitats equally. Leopards and lion use riverine habitat more while hyena use all habitats equally. Prey habitat use is discussed in the light of foraging, predation and abiotic factors in habitat patches while predator habitat use was discussed in light of food availability, competitor avoidance, human disturbance and abiotic factors. Relative abundance was discussed in light of present and earlier conservation efforts in Gir, and other ecological conditions affecting the abundance such as food availability and coexistence among carnivores.

Key Words: Status; Carnivores; Camera Trapping; Herbivores; Habitat Use; Predation

INTRODUCTION

Living in the Anthropocene poses an interesting situation. This era is more diverse in terms of wilderness as compared to the historical eras and also extinction rates are much faster than in earlier eras (Primack 2008). Biggest possible reasons are changes in land use pattern and increase in human population, which has subsequently resulted in competition for resource use between wild animals and humans. Large mammals due to their specific resource needs, large ranging areas, low population densities and being K-selected have been disproportionately affected by these activities and have an uncertain future. Many of the large mammals have faced loss of their historical ranges as well as their number (Wittemyer et al. 2014, Bauer et al. 2015, Jacobson et al. 2016). For example, much of the large herbivores are facing decline across their range (Ripple et al. 2015) and also large carnivores which suffered a steep decline in their range and status (Ripple et al. 2014). This loss is not limited to specialist species, but also for some of the very generalist species like leopards which have very broad diet and habitat requirement and can thrive very easily in human dominated landscapes also (Jacobson et al. 2016).

Economic, cultural, social values of large mammals put a strong rationale to manage and conserve them. Apart from that large mammals are really important for healthy and proper functioning of ecosystems (Prugh et al. 2009, Ripple et al. 2014, Ford et al. 2014, Ripple et al. 2015). For example, trophic cascade initiated by wolves in the Yellowstone National Park is solely best example to display the importance of large mammals to a healthy ecosystem (Ripple and Beschta 2012). Another strong example is elephants in savannah which by tempering of woody species pave way for other species (Pringle 2008). Despite of all this, large mammals are at the crossroads of conservation and it is of paramount importance to carry out studies which assess the status and resource needs of large mammals and that can subsequently be used in making sound conservation efforts and policies.

Forested habitats pose a challenge to study large mammals due to their secretive nature. The situation is more challenging in the case of species like leopard, hyena, sambar which are largely secretive and nocturnal in their activity. Camera traps have been proven useful for such situations due to their unbiased in the capture and round the clock working properties and proven be an important tool in case of large mammals. We assessed relative abundance and habitat use of seven large mammalian species i.e. Asiatic lion (*Panther leo persica,* Linnaeus), Leopard (*Panthera pardus fusca,* Meyer), Striped hyena (*Hyena hyena,* Linnaeus), Chital (*Axis axis,* Erxleben), Sambar (*Rusa unicolor,* Kerr), Nilgai (*Boselaphus tragocamelus,* Pallas), and Wild boar (*Sus scrofa,* Linnaeus) using camera traps. Objectives of our study are 1) To assess relative abundance of large mammals, 2) To assess habitat use by large mammals in western part of Gir, National Park & Sanctuary, Gujarat.

STUDY AREA

Gir National Park & Sanctuary (here forth GNPS) situated in semi-arid biogeographic zone in Gujarat, India (Roders and Panwar 1988; Figure 1). The total area of GNPS is 1412 km^2. According to Champion and Seth (1968) vegetation type is very dry deciduous (5A) teak forest. Khan et. al (1996) described GNPS in detail and the prevailing ecological conditions are much similar to what was reported by Khan et al. (1996).

METHODS

Camera trapping was carried out from March, 2017 to June 2017. We used two models of camera traps i.e. cuddeback attack and ambush. We selected an intensive study area (ISA here forth) of 200 km^2 in the western part of GNPS represents major habitat type and disturbance regime. ISA was further divided into 50 grids of 4 km^2 in order to cover area systematically. In each grid we placed a pair of camera traps, which was tied to tree or using a wooded block along the trails, roads. Vegetation in front of camera trap was cleared in order to avoid the unwanted captures. Camera traps were bound 25-30 cm above from the ground and operated for 24 hours with a time lag of five seconds in capture. Due to accessibility of roads and trails camera traps were monitored on a daily basis to check the battery and download pictures. In each grid camera traps were installed for 20-60 days.

In order to assess the habitat preferences, we identified the ISA in five different habitats following Khan et al. (1996):

(a) Riverine (R; dense cover and undulating terrain),
(b) Teak Mix (TM; have less cover compared to R habitat, distributed in flat, hilly and undulating terrain),
(c) Mix Valley (MV; less cover compared to R and TM and distributed in Hilly terrain),
(d) Teak-*Acacia-Zizyphus* (TAZ; have moderate cover and distributed in flat areas); and
(e) Thorn Woodland (TW; have open cover and distributed in flat plains and high hills).

Retrieved pictures were segregated in the form of independent captures defined as if the time between consecutive photograph was 30 minutes or >30 minutes or of more than one different individual (Yasuda 2004). Relative Abundance Index (RAI) was calculated for every 100 trap nights. Pictures were identified up to the species level.

$$RAI = A / N \times 100$$

Where A is the total independent captures while N is the number of trap days for particular species. Distribution was assessed using the number of grids occupied by target species.

To assess habitat use, we counted the frequency of occurrence of each species in each of the above described habitats. We used chi-square test (Zar 2006) in order to assess the significant difference in between the habitat use of the target species.

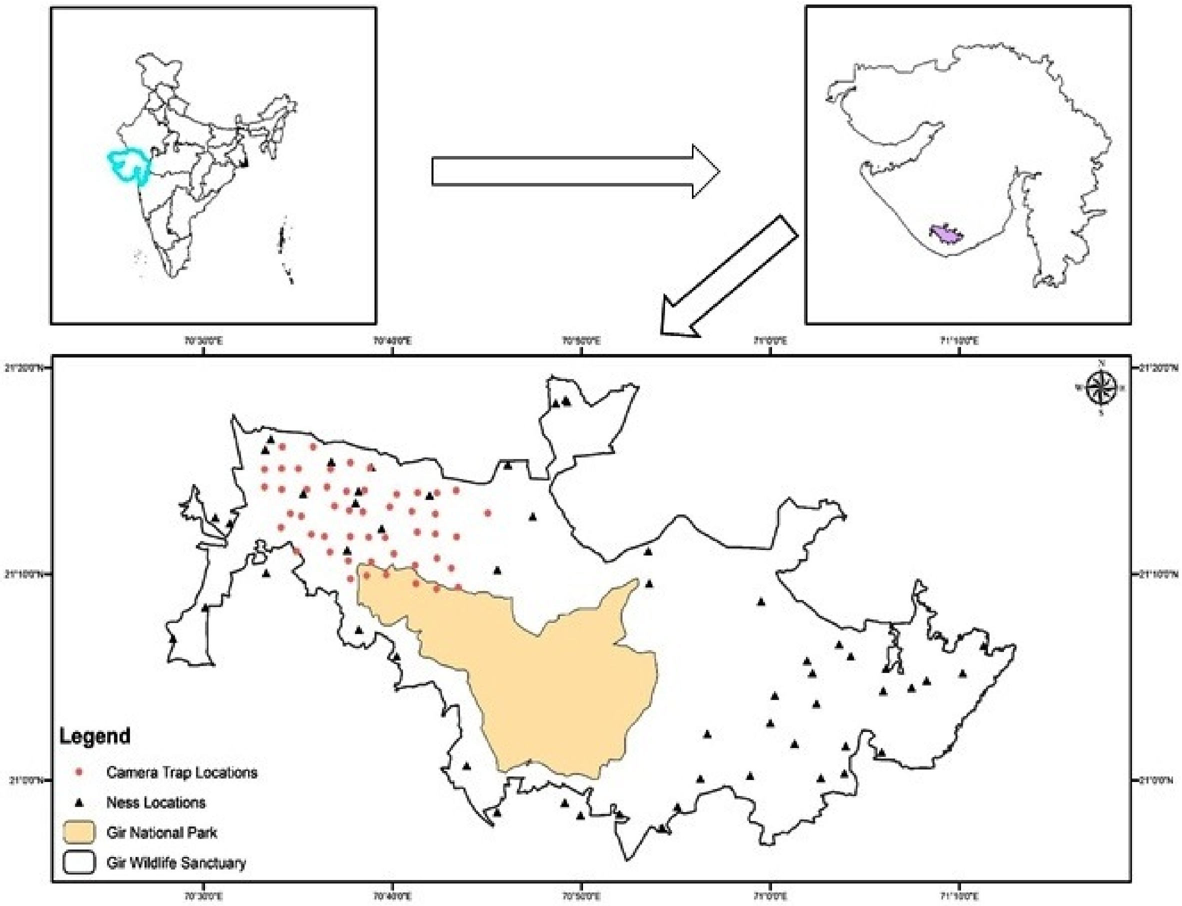

Figure 1. Map of study area along with locations of camera traps in the Gir Protected Area.

RESULTS

Status and Distribution

Our camera trapping effort resulted in a total of 1581 trap nights (Mean ± S.E.; 28 ± 2). Among carnivore's leopard was most distributed, captured in 86% (n=43) of grids followed by lions, captured in 76% (n=38) of grids and hyena in 34% (n=17) of grids respectively. While in herbivores chital was most distributed, captured from 92% (n=46) of grids followed by sambar from 64% (n=32) of grids, wild boar from 42% (n=21) of grids and nilgai from 24% (n=12) of grids. RAI follow the same pattern, highest for leopards (17.7±3.6) followed by lion (7.9±1.2) and hyena (2.7±.85; Table 1). While for herbivores it was found highest for chital (82±16) followed by sambar (8.1±1.8), wild boar (4.9±1.2) and nilgai (2.5±1.0; Table 1).

Habitat Use

Among carnivore's leopards used riverine habitat most (37.5), followed by TM, TAZ, MV and TW and this difference was not statistically significant ($p<0.05$). Lion also used riverine habitat most (31.1), followed by TAZ, TW, TM and MV and this difference was also significant statistically ($p<0.05$). Hyena used MV most (41.17), followed by TAZ, R, TW and TM however, this difference was not significant ($p>0.05$). Among herbivores chital used R habitat most (33.9), followed by TAZ, TM, TW, MV and this difference was significant statistically ($p<0.05$). Sambar used TM most (44.57), followed by R, MV, TAZ and TW and this difference was significant statistically ($p<0.05$). Nilgai used MV most (30), followed by TW, TM, R, and TAZ and this difference was significant statistically ($p<0.05$). Wild boar used TM most (42), followed by TAZ, MV, R and TW; however, this difference was significant statistically ($p>0.05$; Table 2).

Table 1. Relative abundance index (RAI) of mammalian prey and predators during present study and comparison with earlier estimates.

Species	No. of Grids with Occurrence	% Occurrence in Grids	Relative Abundance Index (RAI) Present Study	Debata et al. 2018	Palei et al. 2015	O'Brien et al. 2003
Lion	38	76	-	-	-	
Leopard	43	86	17.7	0.55	1.68	-
Hyena	17	34	2.7	0.33	0.03	-
Chital	46	92	82	5.79	0.47	-
Sambar	32	64	8.1	1.97	1.39	0.55
Nilgai	12	24	2.5	-	-	-
Wildboar	21	42	4.9	4.91	4.52	3.53

Table 2. Habitat use by large mammals in Gir Protected Area

Species	Present Habitat Use Teak Mix	Teak *Acacia Zizyphus*	Thorn Woodland	Riverine	Mix Valley	Chi square	P value
Leopard	36.2	13.1	3.4	37.5	9.6	$\chi^2 = 43.06$	df = 4, p<0.01
Lion	11.6	30	17.7	31.1	9.4	$\chi^2 = 48.12$	df = 4, p<0.01
Hyena	8.8	23.5	8.8	17.6	41.17	$\chi^2 = 15$	df = 4, p<0.05
Chital	14.8	30.7	8.9	33.9	11.4	$\chi^2 = 16.77$	df = 4, p<0.05
Sambar	44.57	13.2	2.4	22.8	16.8	$\chi^2 = 22.5$	df = 4, p<0.01
Nilgai	16.6	-	23.33	10	30	$\chi^2 = 6.6$	df = 4, p>0.05
Wildboar	42		35.7	8.9	12.5	$\chi^2 = 19.45$	df = 4, p<0.05

DISCUSSION

Status of Large Mammals

Camera trap based indices in the terms of RAI has been used earlier to assess the relative abundance of mammals (Carbone et al. 2001, Datta et al. 2008, Pelai et al. 2015, Debata and Swain 2018). RAI is bound to certain assumption important of which is ability to detect species should be constant (Carbone et al. 2001) which is not very much true in the natural conditions. Further, RAI also affected by the different season when resources abundance and distribution changes which subsequently affect the area use and further generates heterogeneity in the movement (Sollmann et al. 2013). Present study was conducted in summer season and it can be assumed that detection rates might be same and hence encounter rates. Further, assumption of constant detection is more important from the perspective of long term changes in abundance of target species.

Present study shows high RAI indices as compared to some earlier studies, especially of large carnivores (Table 1). The high abundance can be discussed separately for large herbivores and carnivores. Chital presently is the most abundant ungulate in GNPS relatively to other ungulates. Factor affecting status of ungulates globally includes poaching, competition with livestock and habitat destruction (Ripple et al. 2015). Further site specific management practices in the present and earlier times, along with availability of food also affect the status and distribution locally. Due to intense monitoring and proper management poaching is negligible in GNPS. Further, livestock overlaps largely with the mixed feeders and grazers (Wegge et al. 2009) can pose competition to the ungulates. In 1980s Stephen Berwick found that chital exist at very low densities (less than 4 chital km^{-2}; cited in Khan 1993). Khan et al. (1996) concluded that this was due to anthropogenic disturbances especially livestock which used graze in GNPS year round basis without any restriction. Cattle grazing in GNPS was posing a resource competition to chital and might be largely responsible for low densities of chital in GNPS (Khan et al. 1996, Madhusudan 2004; but see Dave and Jhala 2011). Removal of settlements and restriction on grazing released chital from livestock competition and resulted in eruption in chital densities (Khan et al. 1996). Further, availability of highly nutritious forage in the form of *Acacia* and *Zizpyhus* leaves (Dave 2008) during the crunch periods also help in stabilizing the chital population at high densities. These food species also plant by forest department on a regular basis which contributes consistency of high abundance of chital. Sambar, nilgai and wild boar abundance are low where sambar has a high abundance compared to other two. Sambar prefer forested dense & undisturbed habitat, and hilly terrain (Khan et al.1996). While nilgai is mostly restricted to the open habitat near human habitations, wild boar use forest habitat. High availability of dense habitat as compared to the open habitat makes sambar and wild boar more in number as compared to nilgai. But question can be asked if chital erupt in densities then why sambar, nilgai and wild boar don't? Predation and change in habitat structure can affect the population of large herbivores (Wegge et al. 2009). Predators generally prefer prey of their own weight range while social predators can kill prey larger than their size. Sambar and nilgai represent a fair amount in the diet of lions (Zehra et al. 2017). Already existing at low densities, predation by increased in the number of lions might be responsible for the keeping these prey densities low. Also removal of livestock and high anthropogenic disturbances from GNPS might result in a change in structure of habitat, especially western part where tree cover becomes denser compared to earlier time (Khan et al. 1996) and suppose to not suitable for nilgai which also restrict this species number. Another factor which is important to discuss regarding low abundance of large size prey is apparent competition. It is rather possible that increased chital densities may have resulted in increased predator densities (Numerical response). Predation by a high density of predator on less abundant prey either have limit the population or responsible for the decrease. This pattern was also found in Royal Bardia National Park in Nepal, where after an anthropogenic removal increase in predation by increased population of tiger was responsible for keeping large prey at low densities (Wegge et al. 2009).

Leopards abundance was higher compared to other two carnivores i.e. lion and hyena. Abundance of a sub-ordinate carnivore can be affected by prey availability, ability to avoid dominant carnivore, habitat availability and refuges (Durant 1998, Creel and Creel 1996, Harihar et. al. 2011, Mills and Mills 2014). GNPS presently supports high prey availability (Zehra et al. 2016). That too of chital which is optimal prey for leopard due to occurrence in preferred weight range (Hayward et al. 2006). This high prey availability of chital is key factor which is responsible for high abundance of leopards in GNPS. Further, interspecific competition from a dominant competitor can also affect the abundance of subordinate predator. For example, in a study in Rajaji National Park by Harihar et al. (2011) found that increase in abundance of tigers was responsible for the decrease in abundance of leopards. Despite high abundance of lions in the western part of GNPS (Keshav 2015) leopards still exist at high densities (Zehra 2014). This indicates successful avoidance of lions by leopards. Factors responsible for this include differential habitat selection by lion due to group living (Sinclair and Griffiths 1995) and adaptability like tree climbing by leopards. Lion density in the western part of GNPS is majorly concentrated in the tourism zone of GNPS to provide opportunities of lion sightings. This creates a gradient of densities which might give further escape to leopards from competition in areas where lion densities are low. High topographic variation in GNPS results in high habitat heterogeneity which further facilitates the coexistence by use of different habitat patches and hence their coexistence. Apart from an increase in prey availability, a water reservoir (Kamleshwar) has also contributed to the denseness of the area around this reservoir and hence favourable habitat for leopards.

Asiatic lion has gained quite a lot conservation attention not just from forest management but also from local people and politicians and among one of the successful conservation stories in case of large carnivores. Increase in protection and higher prey availability has resulted in higher cub survival among lions which consequently results in increase in abundance. This cause was also responsible for the increase in lion abundance in Serengeti, Africa (Sinclair and Griffiths 1995).

Hyena abundance is fairly low in GNPS as compared to other two predators and important question can be raised being a subordinate carnivore why hyena does not respond to increases in protection and prey availability as equally as leopards? Few points are important to consider here. Hyena being a scavenger does not follow the prey availability and depends actually upon the carcass availability. According to Alam and Khan (2014) hyena diet dominant with chital. Chital dominates in the diet of both lion and leopards and theory predicates that social carnivore guard kills more and leave less meat on kill to scavenge (Elbroch et al. 2012). In this light hyena might have to depend upon leopards kills majorly to scavenge which are hard to find due kill hiding habits of leopards. Apart from that lions can give hyena strong interference competition and hyena doesn't possess adaptability like tree climbing present in leopards. This also makes the hyena prone to have less carcass availability. Also lion scavenge on the livestock, which died in nesses and might drive hyena from this easy resource also. But so far we don't have information that hyena actually kills chital or scavenge them. We believe that a major proportion of the diet is from scavenging earlier work on hyena and other information is not available where hyena predate actively in GNPS apart from predating upon small mammals. Likewise, there are events when lion had killed hyena (Forest department data). Further, hyena use dens for resting and cub rearing purposes. Alam and Khan (2014) find that hyena used den in hilly areas with open cover which might be a strategy to avoid competition from other large carnivore. Much of the denning habitat is distributed in the northern part of GNPS (personal observation) which is disproportionately more hill compared to other parts. Also, our RAI were maximum around northern periphery of GNPS. Less availability of denning habitat might result in less denning areas which can further put constraint on cub rearing and hence population. Conclusively interference competition from lion and less availability of denning areas might be a reason for less abundance of hyena in GNPS.

Habitat Use

Habitat use theory at the patch scale revolves around theory of using resource rich patches or avoidance of risky patches and also tradeoff between two (Lima and Dill 1990). Large herbivores act as a prey for large carnivores which put a constraint on them in using the habitat patches, but crunch periods like summer in our study do pose strong pressure to acquire food so that survival can be assured. Chital used R and TAZ more compared to other habitat. These two habitats have high food availability. Riverine patches also provide food in the form of *Combretum* spp. leaves. Apart from that R patch also have low temperature as compared to other habitat which also might be a reason for highest use. TAZ possess highly nutritious food in the form of *Acacia* and *Zizyphus* leaves on which chital feeds. TAZ also possess high intersection of roads due to flat areas which creates an edge in these habitats and the presence of food species like *Balanites*. But these two habitats are used by lions and leopards most. Then how do chitals tradeoff between predation and foraging? It is quite possible chital used microhabitat where they can avoid predation. For example, by foraging along the roads in TAZ where traffic movement is high and create a human shield to avoid predation (Berger 2007). Also in summer cover is quite open and also TAZ habitat lack much shrub layer which is present in some other habitat like TM (Personal Observation). Further, the large group size can dilute the predation effect (Lima and Dill 1990). Chital group size is high in TAZ as compared to R (Khan et al. 1996) which dilute predation effect in TAZ habitat. Further, leopards use TAZ less due to high lion presence (Unpublished data) lions which also lower down the predation pressure. While in R habitat chital seems to forage close ecotones where they can move out in case of danger since R patches have dense vegetation which make escape tough. TM habitat have dense understory in the form of shrubs like *Helictis isora* and undulating terrain which make movement tough and less food availability which make less reward and more risk using these habitats. Also TM is highly used by leopards compared to TAZ which further reduce the award for chital in this habitat by increasing risk of predation. TW have open habitat and high temperature which during summer makes this habitat less useful compared to other habitat. MV habitat has hilly terrain which makes chital less use of this habitat.

Sambar preference for dense, undulating and undisturbed habitat (Johnsingh 1986, Khan et al. 1996) also visible very much in our results. TM was highest use by sambar. TM habitat in our area is much distributed in hilly and flat terrains which have very much less disturbance and have dense cover. Food availability was also present in these areas in terms of fruit species like *Aegele marmalos*, *Emblica officinalis*, *Helictis isora*. Riverine habitat along with the dense habitat provide food species like *Syzium rubicundum* and *Diospyros melanoxylon*. MV habitat has dense cover along with hilly terrain and less concentration of both the predators but less food availability in comparison with R and TM for sambar make this habitat use less compared to TM and R. TAZ habitat was used less as compared to both TM, R and MV. TAZ habitat highly used by lions. Large size of sambar is optimally more rewarding for lions which might make this habitat less used by sambar also high human disturbances in flatter areas also make less use of TAZ habitat. Many of the water points are distributed in the TAZ habitats because of flatter areas we believe that sambar use TAZ habitat for water which is hard to available otherwise in summer. TW patches have open cover and very much distributed near the nesses where human disturbance is maximized. These two factors might be responsible for minimum use of this habitat by sambHar.

Nigai use MV most as compared to other habitats. This is rather surprising since nilgai is always a species which used open habitat most (Khan 1993). Few factors might be responsible for it. First, quite possibly less predation pressure in Mix Valley acts as safe refuges for nilgai. Further, this area might also provide food and lower temperature as compared to TW in summer season. Apart from TW nilgai use other habitat very less might be due to high predation pressure. For example, TAZ habitat has flat terrain and open cover during summer and also have food availability used least by nilgai. Wild boar uses TM habitat most along with TAZ. TM habitat has been used by wild boar for resting purposes. Wild boar are much shy to human presence as compared to chital, sambar or nilgai (Pers. Obs.) which also a reason use of teak mix forest more where disturbance is minimum compared to TAZ. While conducting field work one of the authors (RC) has found considerable amount of *Zizyphus* seeds in pellet groups of wild boar. TAZ habitat might be used as a forage ground by wild boar and for drinking water too. Being a scavenger, it is quite possible that wild boar has found scavenging opportunities there since both large predators (leopard and lion) used this habitat. TW due to high disturbance, open cover and high temperature during day time is least used by wild boars.

Predator habitat selection depends upon the prey distribution, habitat structure, abiotic factors, presence of dominant competitor and anthropogenic disturbances (Muhly et al. 2011, Swanson et al. 2016, Penido 2017, Astete et al. 2017, Strampelli et al. 2018, Gutema et al. 2018, Green et al. 2018). Lion during the present study found to use TAZ and R almost equal and high significantly compared to TW, TM and MV. TAZ habitat present in flat areas has highest abundance of Chital which is one of the major and most abundant prey of lions (Zehra et al. 2016, Zehra et al. 2017). Also flat terrain of TAZ habitat provide easy movement which is otherwise energetic costly in other terrain. R habitat is dense and comparatively cool to other habitats. Jhala et al. (2009) while assessing the home ranges and habitat preferences of female Asiatic lions found that lions use R habitat for resting purposes. Adjacent to these habitats TW was most used. TW habitat is mostly distributed around the nesses due to continuous grazing and lopping by ness in habitants which keep forest around ness in early succession stage. Nesses hold a large number of cattle which sometimes died due to age or other causes which are thrown near the nesses. The carcasses provide opportunities for scavenging also during night time lions use the open areas to rest or walk (Jhala et al. 2016) which also contributes to the use of TW by lions. Teak mix due to their presence in hilly terrain and have a dense understory make this habitat energetically expensive to use. MV habitat due to hill terrain and low prey availability might be the reason for less use.

Leopard's habitat selection is very much affected by the presence of cover (Karanth et al. 2009). Leopards use R and TM high compared to other habitat. R habit has dense cover all around the year. Apart from that chital which is key prey species of leopard (Zehra et al. 2017) used R (and also other prey such as langur) habitat most after TAZ provide ample opportunities for hunting. This habitat also provides opportunities for prey caching to protect from lions which snatch prey from leopards (Zehra 2014). Dense vegetation of R habitat also provides avoidance of interface with lions has been also found in a recent study on African leopards (Balme et al. 2017). Further, TM habitat consists dense cover and an understory along with the low presence of lions. This habitat also has other species of prey such as sambar and smaller carnivores which make this habitat highly used by leopards. Despite of high use by chital, leopards use TAZ less due to high use by lions and vehicular disturbance which make this habitat less profitable. MV due to less prey availability and hilly terrain pose constraint on predation compared to the less hilly terrain in other habitats. TW due to very less availability of cover and human disturbance make it less profitable habitat for leopards.

Hyena habitat use does not differ significantly. This can be discussed in the light of being subordinate carnivore, scavenger in diet, predation on small mammals and critical resources such as dens. Being a subordinate hyena have to avoid interface with lion due to less adaptation like leopards to climb trees. Denning habitat could not be only important for pup raising but also act as a refuge to avoid killing by other predators. MV habitat being hilly might use for den site also these habitat very less used by leopards and lions which make them safer refuges. Alam (2012) found that dominant food item in the diet of hyena was chital, sambar and hare. Use of TAZ, TM and R by hyena might provide scavenging opportunities in the form of carcass left by large carnivores. Since these habitats are most used by lion and leopards and both predate chital and sambar dominantly. Reflectance of these prey species in the diet of hyena make strong rationale for the use of these habitats. TW as earlier discussed have scavenging opportunities in the form of dead carcass. But these opportunities are also important for lions how hyena overcome lions while having these food items is a question of research.

CONCLUSION

In a nutshell, high abundance of both ungulates and carnivores could be attributed to the keystone and charismatic approach of conservation where Asiatic lion conservation has automatically led to effective management and monitoring which consequently has proven beneficial to other species. There are certain other ecological factors which are site specific of which important ones are food availability, habitat availability, response to human disturbance and management practices. Habitat use was affected by foraging and predation and avoidance of competitors. Apart from that abiotic factors such as temperature, water availability could also play an important role in semi-arid ecosystem.

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Author Contributions: JAK, AM and RC conceived and designed the study; RC, JAK, PS and NZ conducted the field experiments; RC analyzed the data; and RC, JAK and NZ prepared the manuscript.

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