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Assessment of Prey Biomass Availability for Leopard and Lion in Gir National Park and Sanctuary, Gujarat, India

NAZNEEN ZEHRA [1]*, R.L. MEENA [2], A.P. SINGH [2], SANDEEP KUMAR [2] AND JAMAL A. KHAN [1]

1. Department of Wildlife Sciences, Aligarh Muslim University Aligarh, Aligarh-202 002,Uttar Pradesh, India.
2. Gujarat State Forest Department, Wildlife Circle, Junagadh, Gujarat
* Corresponding author; *email: catwildlifer80@gmail.com*
Other emails: RLM: *rlmeena58@gmail.com*; *APS: cf.wl.jun@gmail.com;* SK: *sandeep_iari@rediffmail.com;* JAK: *secretarywsi@gmail.com*

ABSTRACT

Census surveys using road vehicle count were carried out from 2009-2012 to determine current status of prey availability and biomass in Gir National Park and Sanctuary, Gujarat. A total of seven transects were selected and monitored on seasonal basis. Data were analysed by computer program Distance (ver.5.0). Hazard Rate Function along with Hermite Polynomial Expansion fitted data of most of the prey species. Results showed that amongst wild ungulates, chital density was highest (ca. 60.25 ±9.35 km^{-2}) followed by sambar (ca. 2.39 ±0.21 km^{-2}), wild boar (ca. 2.31 ±0.4 animals km^{-2}) and nilgai (ca. 1.42 ±0.15 animals km^{-2}). Density of Hanuman langur and peafowl was estimated to be ca.19.84 ±2.29 individuals/ km^{-2} and ca.18.94 ±2.81 individuals km^{-2} respectively. The sightings of chinkara, chousingha and black naped hare were very low. The density estimates did not show any seasonal variation. Bonferroni matrix showed significant difference between mean habitat use of five habitat types by all available prey species in each case ($F_{4, 40}$ = 5.452, $P < ά^*$) where these species used all habitats intensively except thorn woodland. The findings of present study showed Gir as a highly productive area than other tropical deciduous forests.

Key Words: Population Density; Biomass; Habitat Use; Distance Sampling; Gir National Park and Sanctuary.

INTRODUCTION

Ungulates play a vital role in ecosystem processes by influencing forest structure, composition, productivity, succession, and nutrient cycling (Crawley 1983, Jathanna et al. 2003, Rooney and Waller 2003). The survival and perpetuation of large predators also depend on the availability of adequate prey biomass (Ramakrishnan et al. 1999, Karanth et al. 2004, Chaudhari and Khadse 2006, Wang 2009). Several studies have demonstrated a strong relationship between prey-predator populations (Karanth and Stith 1999, Cavalcanti 2008). There may be a linear relationship between prey availability and predator density which may also be used to determine predator population in a given area (Karanth et al. 2004). Therefore assessing abundance of prey population in relation to seasonal variation and habitat use becomes a central theme of any ecological study of prey-predators. Conservation initiatives for large predators often focus on securing and maintaining a healthy prey base first which can also serve as baseline estimates to track changes in predator populations due to removal of disturbances and improvement of management strategies over a period of time. Gir National Park and Sanctuary is a one of the best studied protected area in southern Asia as far as prey biomass estimation is concerned. The history of prey biomass estimation as well as large predator ecology using scientific methodology dates back to 1970's in Gir National Park and Sanctuary (henceforth Gir) where studies conducted by Berwick (1974) provided an excellent baseline data on key ecological parameters. Subsequent studies have strengthened that data base. This paper summarizes the results of prey biomass estimation in Gir from 2009 to

2012. The abundance was assessed for chital (*Axis axis* Erxleben, 1777), sambar (*Rusa unicolor* Kerr), nilgai (*Boselaphus tragocamelus* Pallas, 1766), chausingha (*Tetracerous quadricornis* de Blainvile, 1816), chinkara (*Gazella bennetti* Sykes, 1831), wild pig (*Sus scrofa* Linnaeus, 1758) Hanuman langur (*Semnopithecus entellus* Pocock, 1928), black naped hare (*Lepus nigricollis* F.Cuvier, 1823) and peafowl (*Pavo cristatus* Linnaeus, 1758).

METHODOLOGY

Data Collection

We estimated availability of prey biomass for leopard and lion in Gir within an intensive study area (ISA) of 200 km^2 in west Gir. Road vehicle count method was used to estimate prey densities considering open habitat conditions and availability of motorable roads inside the ISA. Total count method was used to estimate langur population in Gir following Kumar et al. (2008). Road vehicle count has also been used in Gir in the past and the method has been found to provide robust estimates of ungulate density (Khan et al. 1996) and therefore, same sampling protocol was used under present investigation to maintain consistency in methods and estimates. Seven road transects were selected (Figure 1 and Table 1). The transect length ranged from 13 to 22 km. All selected road transects were monitored systematically to cover and scan most of the area from the vehicle within the study area. Transects used for counting prey population portrayed three different kind of topographic regimes, the plain, dissected and hilly terrain. Three transects namely T2, T4 and T5 were on the fringe of the western most part of the sanctuary and ran across the border of Balchel Village, Dedakdi and Kansia area. Transects T1, T2, T3, T4 and T5 passed through four maldhari settlements (Ness), namely Khada, Dudhala, Kadeli and Jambuthala. The forest compartments along these transects were open to access by Maldharis except T7 which was touching the boundary of the National Park. Transects T6 and T7 passed near Kamleshwar Dam while T3 and and T5 passed through the Hiran river and crossed railway track which is functional. The transects passed through habitats such as Teak Mixed Forest, Teak-*Acacia-Ziziphus* woodland, Thorn Woodland or scrub and Riverine forest. To minimize any bias arising from variation in animal activity with time, all road transects were also covered from opposite ends (Khan et al. 1996, Karanth and Sunquist 1992). Each observer counted particular species on either side of the road to

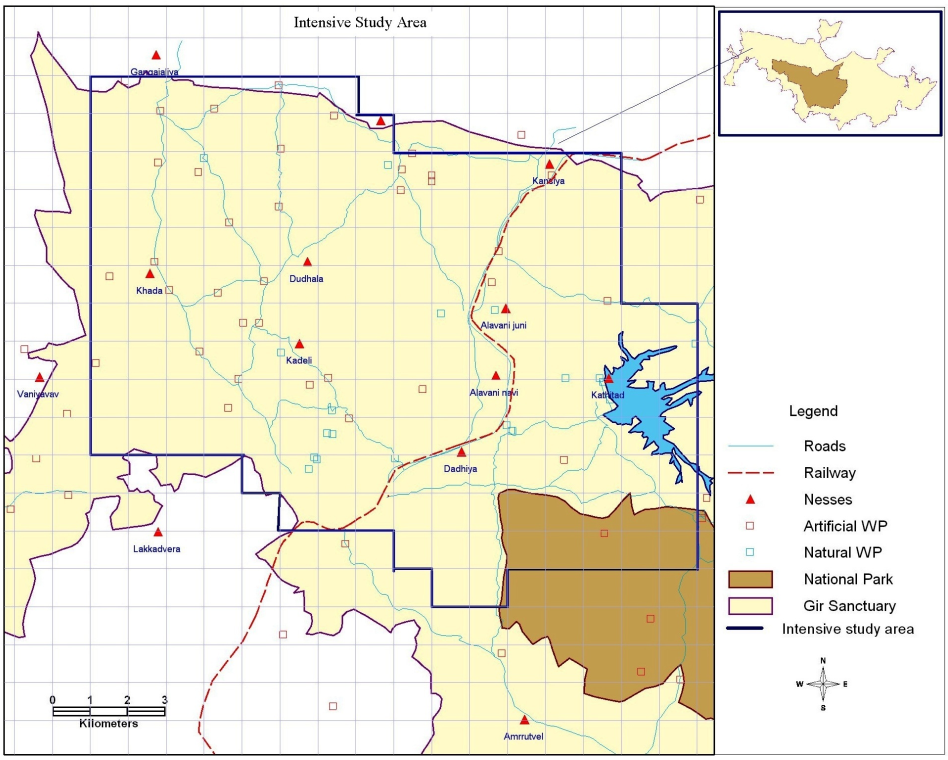

Figure 1. Location of road transects inside the intensive study area in Gir.

Table 1. Details and lengths (km) of transects monitored in the ISA during census survey (2009-2012)) in Gir National Park and Sanctuary, Gujarat.

Transect	Length (km)	Details of Transect
T1	16	Bhambaphod to Parevia turn off via Dudhala and Dedakdi.
T2	17	Khada turn off to Panchali via Parevia and Kairamba.
T3	16	Sasan Naka to Pilipat via Kadeli and Raidy.
T4	22	Bhambaphod to Dudhala via Jambuthala and Dedakdi.
T5	21	Sasan Naka to Dudhala via Kansia and Jambuthala.
T6	13	Sasan Naka to Bawalwala Chock via Valadara and Kamleshwar Dam.
T7	17	Sasan Naka to Bawalwala Chock via Valadara and Piplawali Aati.
Total	122	

eliminate the possibility of observers double counting the prey species. Sightings were recorded by cluster and number of animals. Distance measurements were made to the perceived geometric cluster centre and for almost all cases; the estimates were delayed until the object was perpendicular to the vehicle. In cases, where the prey species ran away from the first point, the vehicle was leveled to the point at which these were first observed and again the perpendicular distance was estimated subjectively (Khan et al. 1996). A Bushnell laser range finder was used for sightings detected at greater distance which was effective for up to 200 m. Occasionally, distances from vehicle to object were cross-checked by rope and footpace regularly for accuracy. Distances were recorded in the meter and attempts were made to collect data as precisely as possible in the field. In addition to distance, species, sex, age, cluster size and various habitat parameters were also recorded for each sighting. Each transect was traversed using a vehicle at a near-constant speed of 15-20 km hr^{-1} on regular basis. The counts were conducted from 06:00 to 08:00 a.m. and 17:00 to 19:00 p.m. in the summer months, and from 08:00 to 10:30 a.m. and 15:00 to 17:00 p.m. in the cooler, drier fall and winter months while in monsoon opportunistic hours were opted for census efforts.

Data Analysis

Distance data for each seasonal census were summarized and analysed for estimation of density on overall, annual and seasonal basis for each species. Data were analyzed by computer program DISTANCE (Ver. 5.0). DISTANCE analysis requires fairly large sample size of data to obtain accurate prey detection functions (PDF) and average cluster size estimations, with >50 sightings have been recommended as minimum (Burnham et al. 1980, Buckland et al. 1993). For most species data were adequate, whilst the rare species could not be analyzed using DISTANCE. Data were analyzed using clusters (herds) as observations rather than animals, since animals were not spaced randomly of one another because detection functions can vary significantly between species. Separate detection functions were fitted to each species with sufficient sightings. Histograms of sightings were plotted against distances used to initially examine the data for evidence of heaping (a human error resulting from a tendency to allocate distances to common intervals such as 5-10 m rather than to 4-9 m) and to check for any evasive movement away from the road which would both affect density estimate. Data were then fixed at 100 m to ensure a reasonable fit to the shape criterion specified by a distance (Buckland et al. 1993). Models were built manually from all combinations of three key functions offered by DISTANCE (Uniform, Half Normal, and Hazard Rate) and three series expansion functions (Cosine, Simple Polynomial, Hermite Polynomial). Each of these fits the desired robustness, shape criterion and estimator efficiency required for models fitting distance data, with a uniform, the half normal, and the hazard rate functions (Burnham et al. 1980, Buckland et al. 1993). Data were constrained on fitting function and automatic selection of distance intervals and tests were activated. Expansion terms could then be used to adjust the models by adding one or two parameters to improve the fit. Akaike's Information Criterion (AIC) was used to select the most appropriate key function whilst sequential adjustment terms were added to the best chosen using a likelihood ratio test. AIC hence chooses the model of the best fit with the least terms (i.e. the most parsimonious model).

The method of the best model to the data was accessed using a Chi-Squared Goodness of Fit Test (GOF). To calculate densities of individuals average cluster size was required. However, taking a simple mean often overestimates cluster size. Due to the higher likelihood of detecting larger clusters with increasing distance, therefore log cluster size was first regressed against log detection probability. If the regression was significant at the P=0.05 (Buckland et al. 1993), the predicted cluster size estimate adjusted for distance for the regression was used, and if the regression was not significant or insufficient data available for a regression, the mean of the cluster size was used. Biomass densities (kg/km^2) of different prey species were computed by multiplying the estimated mean numerical densities (D) by the published average weights of the respective species (Khan et al. 1996, Prater 1993). Computer program SPSS (Ver.11) was used for further analysis. Spearman's Rank Order correlation was run to determine the relationship between cluster densities of identified prey species and their encounter rates. Wilcoxon Signed-Rank Test was used to detect differences between density scores of summer and winter season. The t-test was used to compare mean density estimates of all abundant prey species (i.e. chital, sambar, nilgai, wild pig, langur, and peafowl) during all census surveys viz. overall, summer and winter simultaneously.

RESULTS

Monitoring of 2998 km of selected road transects resulted in detection and recording of 6845 clusters of chital containing 24099 individuals (Table 2). The maximum clusters were recorded in mixed party and ranged from 1 to 79. Single individuals were detected higher (19.35%), followed by two individuals (16.94%), three individuals (13.83), four individuals (10.59%). Clusters containing 5-14 individuals (33.29%) whereas large clusters containing individuals from 15 to 79 were recorded on fewer occasions (4.94%) only. 383 clusters of sambar having 715 individuals were recorded with mostly groups of single animal (47%), two animals (29%). Sambar formed large groups containing 1-7 animals only around water points and at feeding sites (24%). 178 clusters having 370 individuals of nilgai were recorded and these groups mostly contained single and two individuals (53% and 20%) respectively. 96 packs of wild pig having 340 individuals were recorded and group size varying from 1 to 15 animals per pack. 33% packs conprised of 1, followed by 18% of 2 animals, 12% of 3 animals, 9% of 4 animals and 7% of 5 animals respectively. Chinkara and chousingha were sighted very rarely. In other prey species peafowl was most abundant with 4069 clusters and 8416 individuals and the group size ranged from 1 to 15 birds in aggregation and one group had largest with 28 birds. In total, ca. 55% sightings were recorded for single bird, 20% for two birds, and 10% for three birds. Whilst, 14% sightings were recorded for groups containing >4 birds. 506 troops having 5914 individuals of Hanuman langur were counted during total count and the troop size ranged from 5 to 60 individuals. In total, 8% troops were detected containing less than 10 individuals while 90% of troops detected had more than 10 individuals.

For overall combined data, based on lowest AIC values, the Hazard Rate Key function along with Hermite Polynomial Expansion fitted chital, sambar, langur and wild pig data whilst, the Uniform along with Cosine Expansion Function provided best fit for peafowl. For seasonal population estimates, the Hazard Rate Key Function along with Hermite Polynomial and Half Normal along with Simple Polynomial Expansion best fitted the data for majority of prey species. Maximum numbers of detections of ungulate clusters were recorded on road side at a distance of ca. 5 to 45 m excluding wild pig packs which were detected at 20 to 55 m. Peafowl detections were recorded from 5 to 35 m, although a large number of sightings were detected at 0 distances too. Langur troops were detected mostly on river banks at distance of ca. 5 to 30 m including some troops on roads at 0 distances (Figure 2).

The overall encounter rate (clusters km^{-1}; Table 3 and Figure 3) was highest for chital (1.14) followed by sambar (0.13), nilgai (0.12), wild pig (0.09), chousingha (0.06) and chinkara (0.07). The encounter rates showed variation in case of chital and peafowl only. Chital and sambar encounter rates were higher in winter season (1.03 and 0.12) than in the summer season whereas the encounter rates of nilgai and wild pig were almost similar (0.07 and 0.06) during both seasons. Estimates of density and biomass of all wild prey species in the ISA are given in Tables 3 and 4. Among ungulates, the overall density was highest for chital (60.25±9.3 km^{-2}), followed by wild pig (3.05 ±0.14 km^{-2}), nilgai (2.78±0.42 km^{-2}), sambar (2.48 ±0.33 km^{-2}), chinkara (ca. 0.86 ±0.57 individuals km^{-2}) and chousingha (ca. 0.66±0.2 individuals km^{-2}). Among other prey species, the density of langur (ca. 19.84±2.29 individuals km^{-2}) was higher than those of peafowl (ca18.94 ±2.81 individuals km^{-2}) and

Table 2. Number of clusters and number of individuals recorder during study period (2009-2012) in Gir National Park and Sanctuary, Gujarat.
N= number of census efforts, c = number of clusters, n = number of individuals, BNH = Black naped hare.

Duration	N	Effort	Chital		Sambar		Nilgai		Chousingha		Chinkara		Wildboar		Peafowl		Langur		BNH	
			c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n
Overall	21	2988	6845	24099	383	715	178	370	4	9	6	7	96	340	4069	8416	506	5914	3	3
Summer	7	1264	2973	10045	148	249	69	105	2	5	4	5	36	119	1522	3010	194	1913	2	2
Winter	7	1425	3792	13288	230	459	104	264	2	4	2	2	59	220	2391	5130	300	3924	-	-
Monsoon	7	299	80	766	5	7	5	1	-	-	-	-	1	1	156	276	12	77	1	1

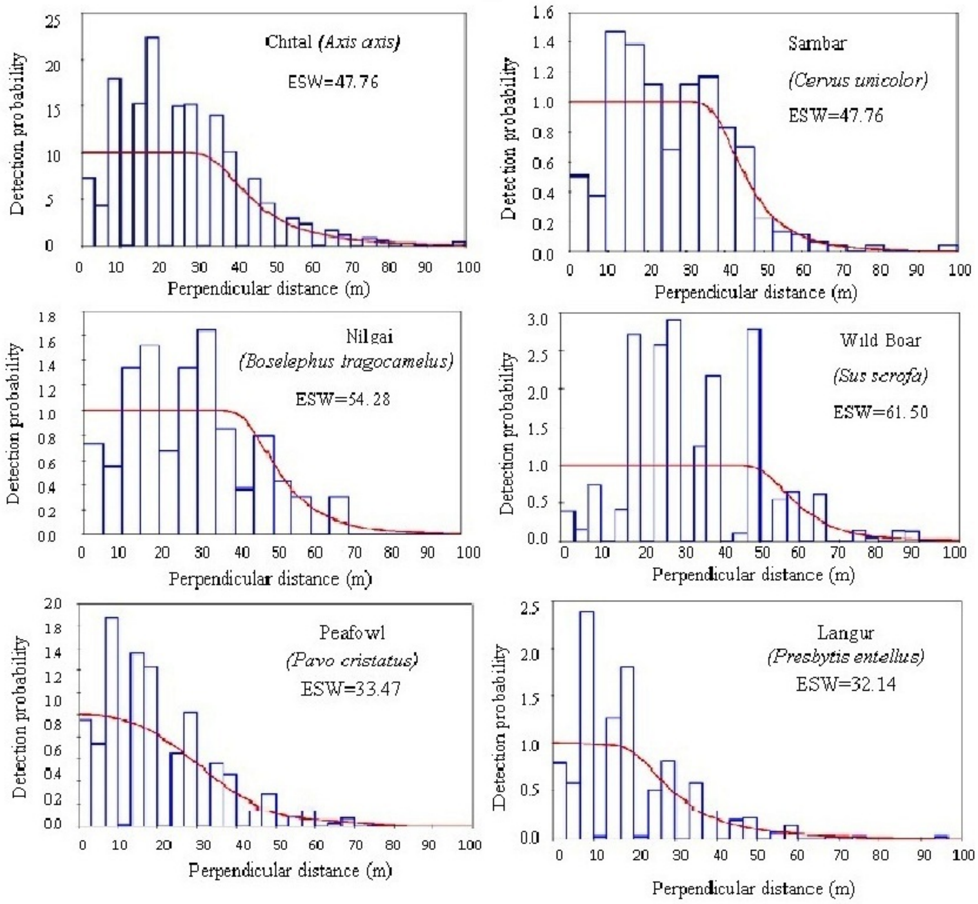

Figure 2. Detection probabilities in relation to distance for different prey species inside the intensive study area in Gir

and black naped hare (ca 2.31±1.08 individuals km^{-2}) respectively. Prey densi-ties were higher during winter season than in the summer season except in case of peafowl which had higher density in summer. The densities were high for chital (ca. 57.09 ±5.59 animals km^{-2}), sambar (ca. 2.39 ±0.21 animals km^{-2}), wild pig (ca 2.31±0.4 animals km^{-2}), nilgai (ca 1.42 ±0.15 animals km^{-2}) and langur (15.88 ±1.17 individuals km^{-2} respectively. Chinkara and chousingha were detected during winter season only and density was low for both species (ca. 0.95±1.15 individuals km^{-2} and ca. 0.6±0.01 individuals km^{-2}). The correlation between density estimates and mean cluster size (MCS) was statistically significant for overall ($r = 0.763$, $p > 0.01$) as well as seasonal data ($r = 0.891$, $p > 0.01$ for summer season, $r = 0.842$, $p > 0.01$ for winter season). The overall biomass of chital

Table 3. Overall population estimates of all wild prey species during study period (2009-2012) in Gir National Park and Sanctuary, Gujarat. E.R.= Encounter rate , MCS= Mean cluster size.

Prey Species	Density of individuals km^{-2}	Density of clusters km^{-2}	E.R	MCS	Biomass (kg km^{-2})
Chital	60.25 ±9.35	11.94 ±1.85	1.14 ±0.18	5.05 ±0.06	2711.25
Sambar	2.48 ±0.33	1.28 ±0.17	0.12 ±1.01	1.93 ±0.05	411.68
Nilgai	2.78 ±0.42	1.34 ±0.18	0.13 ±0.01	2.08 ±0.14	511.52
Peafowl	18.94 ±2.81	9.29 ±1.37	0.62 ±0.09	2.04 ±0.02	75.76
Black naped hare	2.31 ±1.08	2.31 ±1.08	0.06 ±0.001	1	6.93
Chousingha	0.66 ±0.2	0.29 ±0.03	0.06 ±0.006	2.25 ±0.63	13.86
Chinkara	0.86 ±0.57	0.72 ±0.46	0.07 ±0.007	1.2 ±0.2	13.32
Langur	19.84 ±2.29	1.67 ±0.18	0.11 ±0.01	11.87 ±0.44	158.72
Wild Boar	3.05 ±0.14	0.74 ±0.03	0.09 ±0.004	4.13 ±0.08	97.6

Table 4. Seasonal density estimates (summer and winter) of all wild prey species during study period (2009-2012) in Gir National Park and Sanctuary, Gujarat. E.R.= Encounter rate, MCS = Mean cluster size.

Season	Prey species	Density of individuals km^{-2}	Density of clusters km^{-2}	E.R	MCS	Biomass (kg km^{-2})
Summer	Chital	56.19 ±7.71	10.95 ±1.48	0.86 ±0.11	5.13 ±0.12	2528.55
	Sambar	2.34 ±0.28	1.39 ±0.15	0.11 ±0.12	1.68 ±0.07	388.44
	Nilgai	1.35 ±0.2	0.75 ±0.08	0.07	1.79 ±017.	248.4
	Peafowl	21.08 ±2.85	10.66 ±1.42	0.75 ±0.1	1.98 ±0.04	84.32
	Langur	14.39 ±1.68	1.29 ±0.13	0.07	11.18 ±0.62	115.12
	Wildboar	2.12 ±0.61	0.64 ±0.15	0.06	3.3 ±0.55	67.84
Winter	Chital	57.09 ±5.59	11.22 ±1.08	1.03 ±0.09	5.07 ±0.01	2569.05
	Sambar	2.39 ±0.21	1.2 ±0.91	0.12 ±0.007	1.99 ±0.83	396.74
	Nilgai	1.42 ±0.15	0.69 ±0.04	0.07	2.06 ±0.18	261.28
	Peafowl	14.88 ±1.08	6.94 ±0.49	0.3 ±0.14	2.14 ±0.04	59.52
	Langur	15.88 ±1.17	1.19 ±0.06	0.06	2	127.04
	Wildboar	2.31 ±0.4	0.62 ±0.07	0.08	1	73.92
	Chousingha	0.6 ±0.01	0.3 ±0.01	0.07	13.35 ±0.69	12.6
	Chinkara	0.95 ±1.15	0.95 ±1.15	0.06	3.73 ±0.46	11.4

was estimated to be ca 2711.25 kg km^{-2} which was about 67% of the total biomass available in the ISA. Other species contributed about 33% of biomass which included nilgai (511.52 kg km^{-2}), sambar (ca. 411.68 kg km^{-2}), wild pig (ca. 97.6 kg km^{-2}), common langur (158.72 kg km^{-2}), peafowl (75.76 kg km^{-2}) and black naped hare (6.93 kg km^{-2}).

Habitat Use by Ungulates

Habitat use of available prey species was estimated in proportions where, it was found that teak mixed forest (TMF) was used more intensively by major prey species such as chital (54%), sambar (50.60%), wild pig (53.85%), langur (54.29%) and peafowl (45.85%) followed by use of Teak-*Acacia-Ziziphus* Woodland (TAZW) and Riverine forest respectively (Figure 4). Bonferroni matrix showed significant difference ($F_{4,40}$= 5.452, $P < ά*$) between mean habitat use of five habitat types by nine prey species (chital, sambar, nilgai, wild pig, peafowl, langur, chinkara, chousingha and black naped hare).

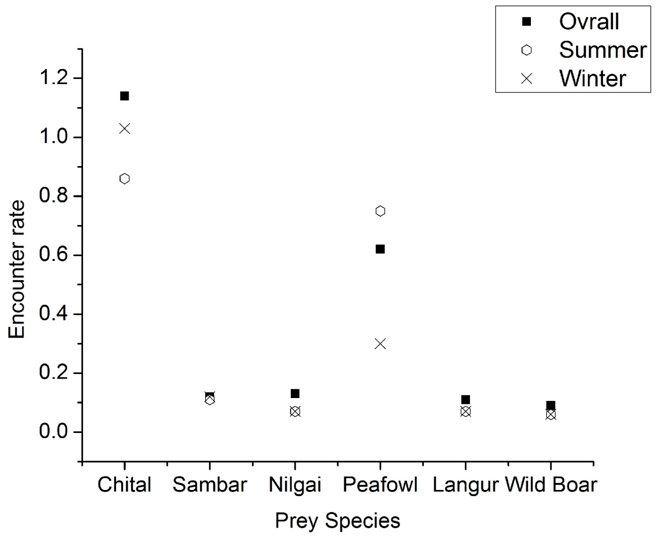

Figure 3. Seasonal encounter rates of the prey species inside the Intensive Study Area in Gir.

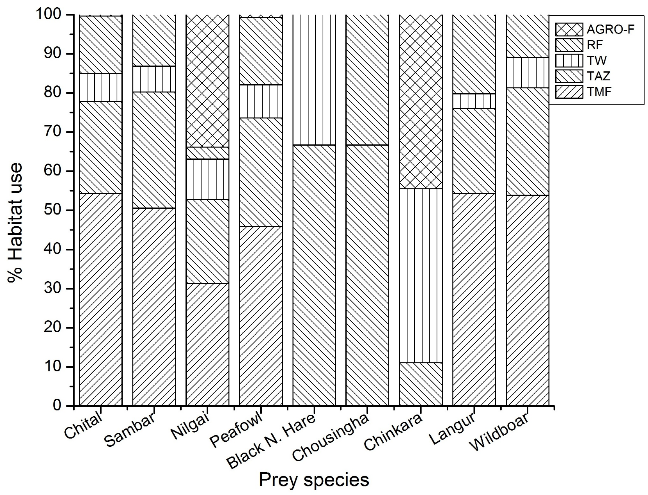

Figure 4. Habitat use pattern of different prey species inside the intensive study area in Gir.

Table 5. Comparison of prey densities estimated in present study with past estimates from Gir National Park and Sanctuary, Gujarat.

Source	Method	Species density km^{-2}							
		Chital	Sambar	Nilgai	Wildboar	Peafowl	Langur	Chousingha	Chinkara
Present study*	Road- count	60.25	2.48	2.78	3.05	18.94	19.84	0.66	0.86
Khan et al. 2007	Road-count & Foot-count	47.8	2.0	0.32	1.48	14.00	7.3	0.4	-
Khan 1997	Line transect	25.2	1.8	0.39	2.10	-	-	0.42	1.20
Khan et al. 1996	Road- count	50.8	2.09	0.58	-	-	-	0.42	2.40
Berwick 1974	Road-count	3.57	0.24	0.85	-	-	-	0.22	0.17

DISCUSSION

Since 1960s, variants of distance sampling have been used widely for simple abundance estimation of prey species, monitoring of trends in population size, assessing efficacy of management action in terms of impact on prey abundance and also to quantify food availability for carnivores (Dasmann and Mossman 1962, Berwick (1974), Seidensticker 1976, Karanth and Sunquist 1992, Varman and Sukumar 1995, Khan et al. 1996, Jathanna et al. 2003, Fattorini et al. 2004, Bagchi et al. 2004). Road counts using a vehicle is one such variant and Hirst (1969) used it in African conditions. The method has certain advantage over use of foot transect as it allows rapid coverage of large areas which is not possible to achieve with foot transects. Its applicability also lies in adequate number of detections of prey species along road sides especially in open habitat conditions. Berwick (1974) used road counts in Gir and later Khan et al. (1996) used this method to monitor 700 km of road network of Gir. The present investigation also used the same method to make the data comparable with previous studies (Table 5). Monitoring of 2998 km of road transects resulted in adequate number of detections for all available prey species which allowed objective estimation of densities. Khan et al. (1996) dealt in detail on factors which were responsible for tremendous increase in chital densities in Gir. A comparison of results of present investigation with that of Khan et al. (1996) suggests that there has been further increase in densities of all ungulate species. The increase is marginal in case of sambar and wild pig but substantial in case of chital and nilgai. In case of chital alone, there is a difference of 10 individuals km^{-2} in density. Food

Table 6. Comparison of ungulate densities estimated in Gir National Park and Sanctuary with estimates from other Protected Areas in India.

Locations	Habitat	Method	Species density; Number km $^{-2}$				
			Chital	Sambar	Nilgai	Wildboar	Langur
Present study *	DDF	Road-count	60.25	2.48	2.78	3.05	19.1
Bandhipur [1]	DDF	Line transects	20.1	5.6	-	-	
Bardia[2]	MDF/Tall Grass	Strip census	190	NA	0.1	4.2	
Bhadra1[3]	MDF	Foot transects	4.51	0.89	-	-	22.62
Chitawan[4]	RF /Tall Grass	Belt transect	43.9	8	-	4.2	
Corbett TR[5]	MDF	Foot transects	31.1	3.2	0.1	2.5	31.2
Kanha NP [6]	MDF	Line transects	49.7	1.5	-	-	
Keoladeo NP [7]	-	-	9.79	0.75	7.0	2.24	
Mudumalai[8]	TDF	-	55.30	2.80	-	0.40	
Nagarahole [9]	MDF	Foot transects	50.6	5.5	-	-	23.8
Pench [10]	DDF	Foot transects	80.70	6.09	0.43	2.59	
Rajaji NP [11]	-	-	22.90	9.23	8.29	-	
Ranthambore [12]	TDF	Foot transects	31.00	17.15	11.36	9.77	21.7
Sariska TR [13]	DDF, Thorn Forest	Foot transects	20.47	19.13	52.76	25.53	21.97
Satpura NP[14]	D & MDF	Road -count	3.7	2.3	0.5	3.3	36

Source: * Present study, [1] Karanth and Nichols 2000, [2] Wegge and Storaas 2009, [3] Jathanna et al. 2003, [4] Karki et al. 2009, [5] Khan et al. 2008, [6] Karanth and Nichols 1998, [7] Haque 1990, [8] Ramesh et al. 2009, [9] Karanth and Sunquest 1992, [10] Biswas and Sankar 2002, [11] Mondal 2006, [12] Bagchi et al. 2004, [13] Mondal 2011, [14] Edgaonkar 2008. - = Data are not available.

habit studies in Gir by direct as well as indirect method showed chital to be principal prey species providing bulk of food to leopard directly and in case of lion directly as well as indirectly as lion stole approximately 40% of chital kills made by leopard (Zehra et al. 2012). Since 1988, the populations of leopard and lion have almost doubled in Gir which must have resulted in substantial increase in predation pressure on chital also. However the chital population in Gir shows no sign of stabilization and perhaps leopard and lion population despite their high densities, are not able to regulate chital population in Gir. Khan (1995) attributed high abundance of chital in Gir to availability of abundant grass and quality browse as the shrub layer comprised of different species of *Acacia, Ziziphus, capparis* with several other browse species such as *Balanites aegyptica*, *Helicteris isora* etc. which provided ample browse to these species round the year and allowed chital population to attain such high densities. Recent surveys (Jamal A. Khan, personal observations) show a disturbing trend in vegetation structure as browse layer is almost missing at a large number of locations with poor regeneration. The quality of ground layer has also gone down over the last 25 years as several weed species dominate the ground cover. Such downward trend in quality of shrub and ground layer may affect the ungulate biomass adversely leading to decline in numbers of prey and predators. Prey densities in winter were higher compared to summer season except in case of peafowl. This change in density is linked to changing pattern of food availability and water in Gir. Resources are evenly distributed during winter season and during this period the ungulate populations are also distributed evenly on spatial scale. However water tend to become limiting factor in summer when ungulate populations concentrate around water sources thus altering the distribution pattern and causing decline in density. Khan et al. (1996) also found that densities of ungulates were higher in winter season due to higher availability of forage at edges (availability of fresh grass, browsing sprouts, fallen leaves and fruits of trees etc.). Bagchi et al. (2004) added that sambar being browser tend to be migratory, moving onto the plains from hilly topography during winter. The peafowl density was significantly higher in summer season. Being a ground dwelling bird, drastic reduction in ground and shrub cover during summer season in Gir allowed higher number of detections leading to higher abundance estimates for this bird in summer.

Table 6 provides a comparison of ungulate densities in Gir with that of other protected areas. Chital density in Badia and Pench tiger Reserve were higher than Gir. Chital densities in Chitawan, Kanha, Mudumali and Nagarhole National Park were within the range of Gir and other sites had densities which were much lower than Gir. Sambar, Nilgai and wild pig densities were highest in Sariska Tiger Reserve whereas langur densities were highest in Satpura and Corbett Tiger Reserve. One notable pattern is obvious that densities of sambar, nilgai and wild pig are much lower in relation to chital in most of the sites except in case of Sariska and Ranthambore Tiger Reserve. The ratio of densities in ungulate species in Sariska was similar to Gir in early 1990's (Khan, J.A. Personal observations, 1986). However the number for sambar, nilgai and wild pig has increased substantially and the density for nilgai is exceptionally high (52.76 km^{-2}). The tiger population declined gradually from Sariska and it became locally extinct until re-introduction program undertaken around 2007. Gradual reduction in tiger predation perhaps allowed build up in populations of sambar, nilgai and wild pig densities to an extent that nilgai density surpassed the density of chital. Sariska, Ranthambore and Gir have almost identical dry deciduous habitat having similar topography, water regime, disturbance gradients etc. and it is high leopard and lion predation which does not allow increase in densities of these species in Gir.

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