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POPULATION DENSITY AND BIOMASS OF THE WILD PREY SPECIES IN A TROPICAL DECIDUOUS FOREST, CENTRAL INDIA

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Abstract
For proper management of a wildlife reserve, it is essential to estimate density and biomass of herbivores that in turn determine the density of carnivores. We estimated the population density and biomass of three ungulates and two other species in the Melghat Tiger Reserve, Central India. The study was conducted from September 2010 to April 2011. We used distance sampling to estimate the population density of wild prey species. The 225km^2 intensive study area was found to have high prey species density (69.5±8.3 individuals/km^2), with gray langur being the abundant prey species (42.9±7.2 individuals/km^2), followed by sambar (10.5±3.5 individuals/km^2), gaur (5.8±1.7 individuals/km^2), barking deer (2.7±0.3 individuals/km^2), and peafowl (7.6±0.6 individuals/km^2). When the density figures were multiplied by the average weight of each prey species, biomass of 6501.8 kg/km^2 was obtained.

Key Words: Abundance; Anthropogenic; Carnivore; Gugamal National Park; Melghat Tiger Reserve.

Introduction

The population density and biomass of large herbivore species have often been used to compare the carrying capacity of different habitats. As the herbivore biomass forms the bulk of the prey base, it also determines the population density of large carnivores (Dinerstein, 1980; Kumara *et al*., 2012). Recent biological modeling demonstrated that the prey depletion can lead to drastic decline in the tiger population size; thus the population sizes of prey and predator are interdependent (Karanth *et al*., 2004). Maintenance of the healthy population of herbivore species is indeed required for the survival and maintenance of viable population of large carnivore species. This necessitates the need for data on the density and biomass of potential prey species of large carnivore habitats in the protected areas. Population estimation, either by direct or indirect surveys, is crucial to determine abundance, density and distribution of wild animals (Dinerstein, 1980). In case of semigregarious animals such as gaur (*Bos frontalis*) and sambar (*Rusa unicolor*) etc., use of line transect based direct sightings have been commonly applied to estimate their density (Kumara *et al.,* 2012). Information regarding population density, biomass and grouping tendency of the wild prey species in tropical deciduous forests is scanty (Karanth *et al*., 2004) particularly in Melghat Tiger Reserve (MTR), where only limited information is available in the recent past (Buckland *et al*., 2001). So, in order to fill the information gap we conducted a systematic survey to estimate wild prey density through distance sampling method. Distance sampling by line transect method is more robust as it allows a more accurate estimate of population size than other methods, and it addresses detectability issues (Buckland *et al.,* 2001; Jathanna *et al*., 2003). Moreover, the method has been proved to work well in tropical forests of the Indian subcontinent (Harihar *et al.,* 2009; Karanth & Nichols, 2002; Narasimmarajan *et al*., 2012). Distance sampling offers a reliable estimation of animal densities comparable to results of the mark-recapture method, and has also proven to be cost-effective and less invasive (Kumara *et al*., 2012).

Materials and Methods

Study Area: MTR almost entirely falls in the Satpura and Mikal landscape characterized by rugged hills ranging from 600–1,100m a.s.l with a low water table and streams disappearing into permeable sediments during summer. The total area of the tiger reserve is about 1,676km^2, including 361km^2 notified as Gugamal National Park (20°51′–21°46′N, 76°38′–77°33′E) which falls under two districts, Akola and Amravati in Maharashtra (Narasimmarajan *et al.,* 2012). Within the Gugamal NP, Dhargad, Dhakna and Chikaldara forest ranges (FR) covering 225km^2 were selected as the study area. The Melghat region experiences tropical climate with temperatures ranging from 13°C in winter and 45°C during summer. The annual rainfall ranges from 1000–1800mm. The overall land cover matrix consists of natural forests interspersed with agricultural and forestry crops. The natural vegetation consists of both moist as well as dry deciduous forests, with the north facing hills dominated by *Tectona grandis* (Lamiaceae) and the south facing slopes covered by mixed forests comprising of tree species such as *Terminalia alata* (Combretaceae), *Anogeissus latifolia* (Combretaceae), *Lagerstroemia parviflora* (Lythraceae), *Terminalia bellerica* (Combretaceae), *Madhuca indica* (Sapotaceae), and *Dendrocalamus strictus* (Poaceae) (Narasimmarajan *et al*., 2012). Extensive shrubs of *Colebrookea oppositifolia* (Lamiaceae), *Azanza lamaps* (Malvaceae), and *Carvia callosa* (Acanthaceae) occur in relatively undisturbed valleys and the grasslands comprising of *Cynodon dactylon* (Poaceae), *Themeda triandra* (Poaceae) and *Eragrostis curvula* (Poaceae) occur intensely in un-grazed areas. Tiger (*Panthera tigiris*), leopard (*Panthera pardus*) and dhole (*Cuon alpinus*) are the principal large carnivores. The Indian gaur (*Bos frontalis*); sambar (*Rusa unicolor*); nilgai (*Boselaphus tragocamelus*); wild pig (*Sus scrofa*); red muntjak (*Muntiacus muntjak*); southern gray langur (*Semnopithecus dussumieri*); Indian hare (*Lepus nigricollis*); and peafowl (*Pavo cristatus*) are the more commonly encountered wild prey in the study area. Domestic livestock (*Bubalus bubalis*, *Bos Taurus*) ranging from the villages on to the forest boundaries also forms potential prey base for the large carnivores. The chital (*Axis axis*) is found only in few localities of the park (Mahabal, 2005).

Assessing Population Density: To assess the population abundance of wild prey species, we used line transects with conventional distance sampling (Anderson *et al.,* 1979; Buckland *et al*., 2001) carried out from September 2010 to April 2011. In total, 34 line transects covering 340km were walked during the survey period. The line transects varied in length from 1.8–2.5km and were laid out following a stratified random design within the study area (Harihar *et al.,* 2009). On every walk we recorded the encountered species and their group size; sighting angle measured using a hand-held compass and sighting distance measured by a laser range finder (Jathanna *et al*., 2003). We modelled detection functions to estimate the population density of principal prey species using program Distance 5.0 (Thomas *et al*., 2008). We used the distribution of these distances to estimate the proportion of animals sighted in the strip that is detected *i.e.*, probability of detecting the animal as a function of perpendicular distance (y), the detection function g(y), which allows us to estimate animal density and abundance. If the animals occur in well-defined clusters (e.g. flocks or herds) then detections refer to clusters rather than to individual animals. Conceptually, this could be considered in terms of effective strip width (μ), which is the distance, from the line for which as many objects are detected beyond μ as are missed within μ of the line. Thus density of individuals (*Di*) can be estimated using the following formula: $Di = n/2\mu L$, (n = population numbers, L = length of the transect), A better way to view is that we expect to detect a proportion *P* of the objects in the strip of length *L* and width 2*w*, so that density *D* is estimated by $Di = n/2wLP$. It is often convenient to measure the sighting by 'radial distance ***r***' and sighting angle θ, rather than perpendicular distance *x*, for each of the *n* objects detected. The ***x*** is calculated by a simple trigonometry formula: $x = r.sin\theta$.

To model detection functions, we examined the data for each species for signs of evasive movement and peaking at great distance from the line transect. Following this, the data was either truncated at great distances or re-classed so as to ensure a reliable fit of key functions and adjustment terms to the data. Akaike Information Criterion (AIC^i) and goodness-of-fit (GOF-p) tests were used to judge the fit of the model. Using the selected model, estimates of group density (*Dg*), group size (*GS*), and individual density (*Di*) were derived and tabulated (Buckland *et al*., 2001; Karanth *et al*., 2004).

Assessing Body Biomass: We derived the biomass (in kg/km^2) in the study area by multiplying population density (*Di*) of each species by its average unit weight which was estimated from published data on body weights and expressing it on a per-km^2 basis (Eisenberg & Lockhart, 1972; Johnsingh, 1983; Scheller, 1967; Tamang, 1982). However we compared the biomass of MTR with other South Asian Park. Body biomass was calculated using this formula (x × y = z). Whereas, ***x*** is density of the species; whereas, ***y*** is avg. body weight of the species and multiplied both values to arrive the body biomass (Johnsingh, 1983; Scheller, 1967).

Results

***Population Density*:** The individual population density and mean group density were estimated for all the observed prey species. The best fit model is half normal key with cosine adjustment, was suited model for density estimation of all prey species (Fig. 1). This was selected on the basis of the lowest Akaike Information Criterion (AIC^i). The overall prey density was (69.5±8.3 individuals/km^2). Ungulate density was 19.0±5.5 animals/km^2. Peafowl and langur together contributed 50.5±7.7 individuals/km^2. The density of langur (42.9±8.2 individuals/km^2) was higher than sambar (10.5±3.5 individuals/km^2), peafowl (7.6±0.6 individuals/km^2), gaur (5.8±1.7 individuals/km^2) and barking deer (2.7±0.3 individuals/km^2). The mean group size between the species is shown in the Figure 2. The variation in density estimates and abundance was partly related to the species encounter rate that tended to decrease from langur to red muntjak (Table 1). However, chital was not encountered anywhere except outside the survey area near Dharani. Also, wild boar, nilgai, rhesus macaque (*Macaca mulatta*) and livestock were encountered ≤5 sightings, but due to insufficient data we could not estimate their density.

Body Biomass: We present body biomass, based on population density of the study area. The population density of each species was multiplied by average body weight each category to estimate biomass of the species. The average group size of observed prey species was differing from each other (Table 2). Gaur serves as a principal prey species with higher body biomass of 4632 kg/km^2 than Sambar 1407.0kg/km^2 and least in the case of barking deer 57.7kg/km^2. The overall prey species body biomass was about 6501.8kg/km^2 as estimated from the study area.

Discussion

Comparison of Population Density: The results revealed that the density of langur was higher than sambar, peafowl, gaur and barking deer. The density estimate figures clearly indicate that MTR has healthy wild prey population. The estimated wild prey density was 69.5 individuals/km^2, which is higher than the previously reported density of about 5.2 animals/km^2 from the same study area a decade ago by Karanth *et al*. (2004). Though the previous and present estimates were followed same line transect by distance sampling method, the data were analysed in different ecological softwares in both studies. Notably the present sampling effort was higher than the previous study (Karanth, 2004). Besides this reason, after 2006, several tribal villages have voluntarily vacated from the core area of the Park, resulting in the recovery of native vegetation and wildlife contributing to undisturbed habitat. Earlier studies also document similar recoveries in tiger population (Dinerstein *et al.*, 1999; Dinerstein, 2003; Harihar *et al.,* 2009; Karanth & Sunquist, 1992). It is evident that ensuring long-term conservation of the prey base requires formulating and implementing appropriate management interventions to eliminate / minimize anthropogenic disturbances. Jhala *et al.* (2011) estimated the Tiger density of about 3.04 individuals/100km^2 from the MTR. So, the increased prey density may indeed be able to support large carnivore population of the park. These results are comparable with other sites of the Indian subcontinent (Sankar *et al*., 2010). Sariska Tiger Reserve harbors relatively high density of wild prey species, than Nagarhole and other south Asian sites given in the Table 3.

Table 1: Estimated wild prey species density in MTR (SE, standard error; T, total effort; AIC, akaike information criterion; *Ďi* ±SE, population density; Dg ±SE, average group density; n/L, encounter rate; ESW, effective strip width; 95% CI, lower limit and upper limit).

Species	T (km)	AIC^i	*Ďi* ± SE	Dg ± SE	n/L	ESW	95% CI
Gaur	340.0	198.9	5.8 ± 1.7	0.9 ± 0.2	0.11	60.4	3.2–10.5
Sambar	340.0	201.6	10.5 ± 3.5	1.4 ± 0.3	0.17	40.7	5.5–20.1
B. Deer	340.0	253.4	2.7 ± 0.3	1.2 ± 0.2	0.12	48.1	1.2–04.5
Langur	340.0	855.0	42.9 ± 7.2	6.1 ± 1.2	0.35	40.9	30.8–59.7
Peafowl	340.0	316.6	7.6 ± 0.6	1.7 ± 0.9	0.10	46.1	6.4–08.9
All Prey	340.0	191.5	69.5 ± 13.3	11.4 ± 2.8	0.85	59.3	39.5–88.9

Table 2: Biomass density of the wild prey species recorded from the MTR (RgY, range of observed group sizes; Ñ, number of group detected); Body biomass estimated using this formula: $\boldsymbol{x} \times \boldsymbol{y} = \boldsymbol{z}$.

Species	RgY	Ñ	*Di ± SE* *x*	Avg. body Weight (kg) *y*	Body Biomass (kg.km^2) *z*
Gaur	1–20	25	5.8 ± 1.7	800	4632
Sambar	1–7	70	10.5 ± 3.5	212	1407
Barking deer	1–4	29	2.7 ± 0.3	20	57.8
Langur	1–20	112	42.9 ± 7.2	8	386.1
Peafowl	1–7	42	7.6 ± 0.6	2.5	19.0
Total	-	176	-	-	6501.8

Comparison of Body Biomass: The reported body biomass of gaur and sambar in MTR are comparable with other protected areas in the tropical forests (Karanth *et al*., 1995). However, the reported biomass density of sambar in MTR was lower than Sariska (3510.8kgkm^2), the langur body biomass was higher in MTR (386.1 kg/km^2; Sankar *et al*., 2010) and details about other sites' body biomass details are given in Table 4. The estimated gaur body biomass was lower than Nagarahole and higher than other sites compared. The attribution seems to be not relevant to gaur. MTR has a large area of continuous deciduous forest (≥1600km^2) that can support a good population of langur and other ungulate species. However, their contribution to prey could be limited as is the case of other smaller prey species (Ramesh *et al*., 2012). The population densities of large carnivores are directly related to biomass density of the wild prey (Karanth *et al*., 2004; Ramesh *et al*., 2009). Thus, wild prey species are indicators to the health of forest ecosystems and monitoring their populations through non-invasive technique such as distance sampling is proving to be much more cost effective and providing robust results (Lancia *et al*., 1994). This study provides baseline information on wild prey base density and biomass in the MTR, one of the few protected areas (PA) representing India's remnant contiguous forests.

Implications for conservation: MTR is one of the protected areas showing increasing trend of wild prey density. Tigers are mostly dependent on wild prey rather than domestic livestock for food as in many other areas of the Indian subcontinent (Jathanna *et al*., 2003; Karanth &

Nichols, 2002; Karanth *et al*., 2004). From the present study it can be concluded that MTR, due to its high density of wild prey base, has the potential to accommodate a viable population of tigers (Buckland *et al*., 2001; Harihar *et al*., 2009; Narasimmarajan *et al*., 2012). Some villages situated near the park boundaries should be relocated, because fishing and grass cutting are perceived to be most serious threat to the MTR (Narasimmarajan *et al*., 2012). Thus, strict protection of the habitat supplemented by regular foot patrolling and monitoring of tigers and their prey population using comparable scientific methods is essential for MTR to emerge as one of the most important areas for tiger conservation landscape in Central India.

Table 3: Comparison of wild prey species density in South Asian reserves, Sources: ESA, Nagarahole (Karanth & Nicols, 1992); BPR, Bandipur (Johnsingh, 1983); KNH, Kanha (Schaller, 1967); WPT, Wilpattu (Eisenberg & Lockhart, 1972); BRD, Bardia (Dinerstein, 1980); CHN, Chitwan (Tamang, 1982); KMTR, Kalakad-Mundanthurai (Ramesh *et al*., 2012); and STR, Sariska (Sankar *et al*., 2010); NA, data not reported.

Species	Densities (animals/km^2) at different sites of South Asia								
	MTR	**ESA**	**BPR**	**KNH**	**WPT**	**BRD**	**CHN**	**KMTR**	**STR**
Gaur	5.7	9.6	0.5	0.7	NA	NA	NA	3.6	0
Sambar	10.5	5.5	7.0	0.9	1.2	3.5	16.8	7.0	26.2
Barking Deer	2.7	4.2	1.0	0.4	1.7	6.6	NA	NA	0
Langur	42.9	23.8	7.5	46.2	2.8	9.6	NA	9.9	22.8
Peafowl	7.5	NA	NA	NA	NA	NA	NA	0.41	125.2

Table 4: Comparison of biomass of wild prey and domestic herbivores at tropical sites. Sources: the same as in Table 3; 0, data not reported by source.

Area	Habitat type	Biomass density kg/km^2		
		WLBD	**DMBD**	**Total**
Melghat Tiger Reserve	Dry deciduous forest	6501.8	0	6501.8
Nagarahole	Deciduous forest	14744	350	15094
Bandipur	Dry forest-woodland	14520	0	14520
Kanha	Moist forest-meadows	1592	2925	4517
Wilpattu	Moist forest-meadows	766	0	766
Bardia	Moist forest-grasses	3101	0	3101
Chitwan	Moist forest-grasses	2581	0	2581
Kalakad-Mundanthurai	Moist evergreen-swamps	2648	0	2648
Sariska	Semi-arid forest	10072	11545	21618

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PLATE 1

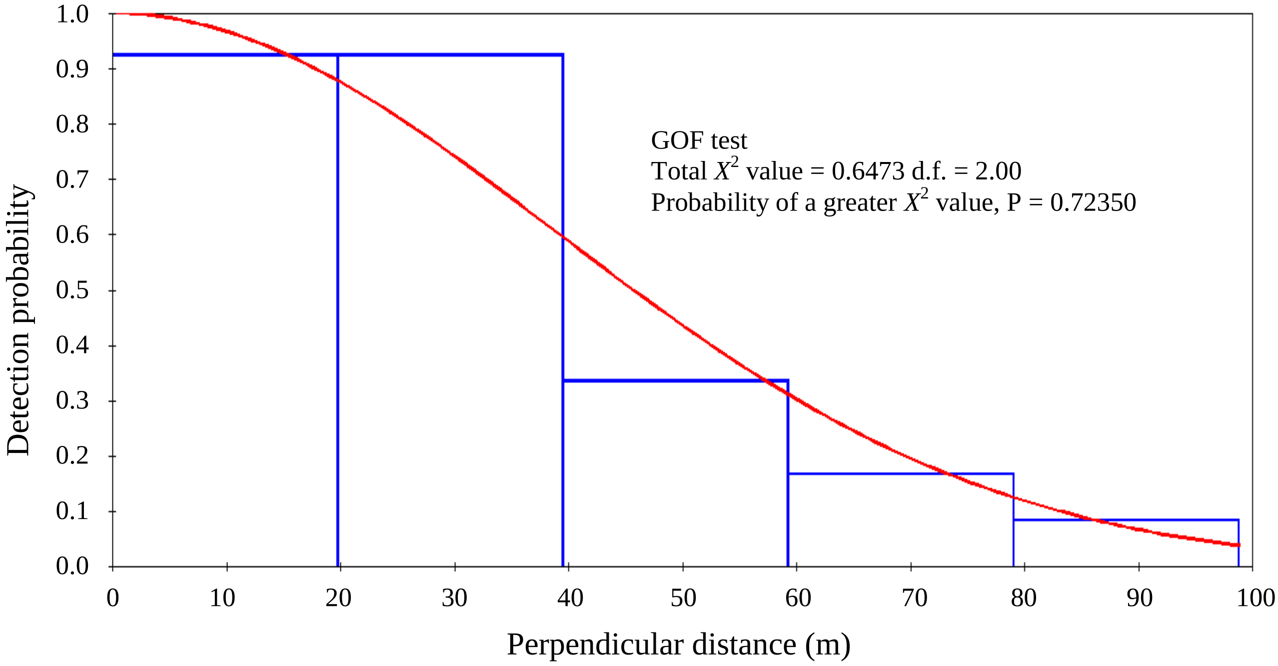

Figure 1: Results of model fitted in the DISTANCE to estimate detection probability and effective strip width of all prey species sightings in the dry deciduous habitats of MTR.

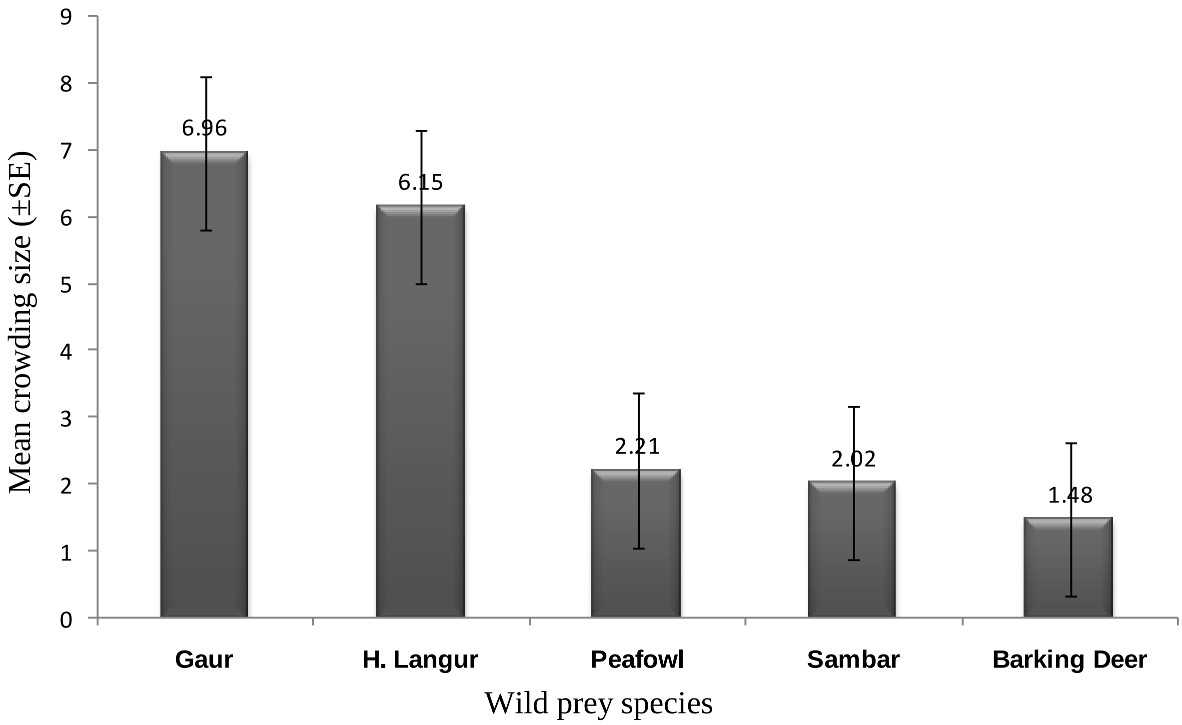

Figure 2: Mean crowding size of the observed wild prey species in the MTR between from September 2010 to April 2011.