Conservation status of wild mammals in Biligiri Rangaswamy Temple Wildlife Sanctuary, the Western Ghats, India

Honnavalli N. Kumara[1], S. Rathnakumar[2], R. Sasi[3] and M. Singh[4,*]

[1]Sálim Ali Centre for Ornithology and Natural History, Anaikatty (P.O.), Coimbatore 641 108, India
[2]A. V. C. College, Mannampandal, Mayiladuthurai 609 305, India
[3]Department of Anthropology, University of Madras, Chennai 600 005, India
[4]Biopsychology Laboratory, University of Mysore, Mysore 570 006, India

For proper management of a wildlife reserve, it is essential to get estimates of occurrence, abundance, density and biomass of herbivores that in turn determine the density of carnivores. The Biligiri Rangaswamy Temple Wildlife Sanctuary (BRT WLS) is a critical conservation region as it is a living bridge between the Eastern and the Western Ghats of southern India. We made repeated walks of 795.5 km on 33 random line transects covering a total distance of 93 km in the sanctuary. During these walks, we recorded the sightings of herbivores using rangefinder, compass and GPS. We also surveyed the sanctuary driving a jeep during nights to detect typically nocturnal mammals. We analysed the data using DISTANCE software. We recorded 31 species of herbivores and the density of these species differed among habitats that included evergreen, moist deciduous, dry deciduous and scrub forests. Several nocturnal species, including elusive small cats were sighted. We found that leaving out elephants, the herbivore biomass in BRT WLS was 4,127.82 kg/km^2. This places BRT among some of the herbivore-rich wildlife reserves in the country. We recommend that BRT be notified as a Tiger Reserve.

Keywords: Biomass, density, herbivores, nocturnal mammals, wildlife sanctuary.

THE population density and biomass of large herbivore species have often been used to compare the carrying capacity of different habitats[1,2]. As the herbivore biomass forms the bulk of the prey base, it also determines the population density of large carnivores. Karanth and Stith[3] have demonstrated using modelling that prey depletion can lead to drastic decline in the tiger population size; thus the population sizes of prey and predator are interdependent. Maintenance of the healthy population of herbivore species is indeed required for the survival and maintenance of viable population of large carnivore species[3–7]. This shows the need for data on density and biomass of large herbivore species from all potential forests and parks in the habitat of large carnivores[8,9].

Considering the evolutionary history and geographical features, the hills in southern India are grouped as two systems, viz. the Western Ghats and the Eastern Ghats[10]. Biogeographically, the Biligiri Rangaswamy Temple Wildlife Sanctuary (BRT WLS) is located at the easternmost edge of the Western Ghats, between 11°N and 12°N latitudes along its north–south running chain and meets the hills of the Eastern Ghats at 78°E longitude. Thus the sanctuary has been considered as a live bridge between the Eastern Ghats and the Western Ghats[11]. BRT WLS is a part of the Nilgiri Biosphere, which includes major protected areas, viz. Mudumalai Wildlife Sanctuary, Bandipur National Park, Nugu Wildlife Sanctuary and Nagarahole National Park (also known as Rajiv Gandhi National Park). The entire stretch of the forest complex is also part of an important elephant reserve, the Mysore Elephant Reserve, with the largest population of Asian elephants[12]. BRT WLS is also part of the forest complex which holds the largest population of tigers[13,14]. The estimate of density for large herbivore species for few parks of the forest complex, including Mudumalai[15], Bandipur[16,17] and Nagarahole[8] shows that a promising and relatively good prey base is available. However, such data on density and biomass of herbivore species is lacking from BRT WLS, a critical region linking the Eastern Ghats and the Western Ghats. Thus the study was carried out in BRT WLS to record the current status of large mammals and their importance in conservation.

BRT WLS is located between 11°40′–12°09′N lat. and 77°05′–77°15′E long. With an area of 610 km^2 and five forest administrative ranges, the sanctuary presently is a part of the Chamarajanagara district of Karnataka (Figure 1). The altitude ranges between 600 and 1800 m amsl. The temperature varies between 8°C and 16°C in winter and between 20°C and 38°C in summer. The low-lying plateau lands receive a low rainfall of 600 mm and the upper hills receive 3,000 mm of rainfall annually. The forests of the sanctuary have been classified as evergreen forest (EF – 10.3%, which includes evergreen, shola and high altitude grassland), moist deciduous forest (MDF – 25%), dry deciduous forest (DDF – 36.1%) and scrub forest (SF – 28.2%)[18]. About 7,000 indigenous tribes and villagers manning a famous temple reside inside the sanctuary. In addition, there are a few patches of commercial plantations (coffee *Coffea arabica*; pepper *Piper nigrum*; cardamom *Elettaria cardamomum*, etc.) scattered across the sanctuary. The human activity, therefore, has brought tremendous biotic pressure on the flora and fauna of the region.

We used transect walk and night surveys using a jeep to assess the status of animals (excluding small rodents, chiropterans and large carnivore species) in the sanctuary. We estimated the density of large prey species using line transect method. To understand the abundance of the

*For correspondence. (e-mail: mewasinghltm@gmail.com)

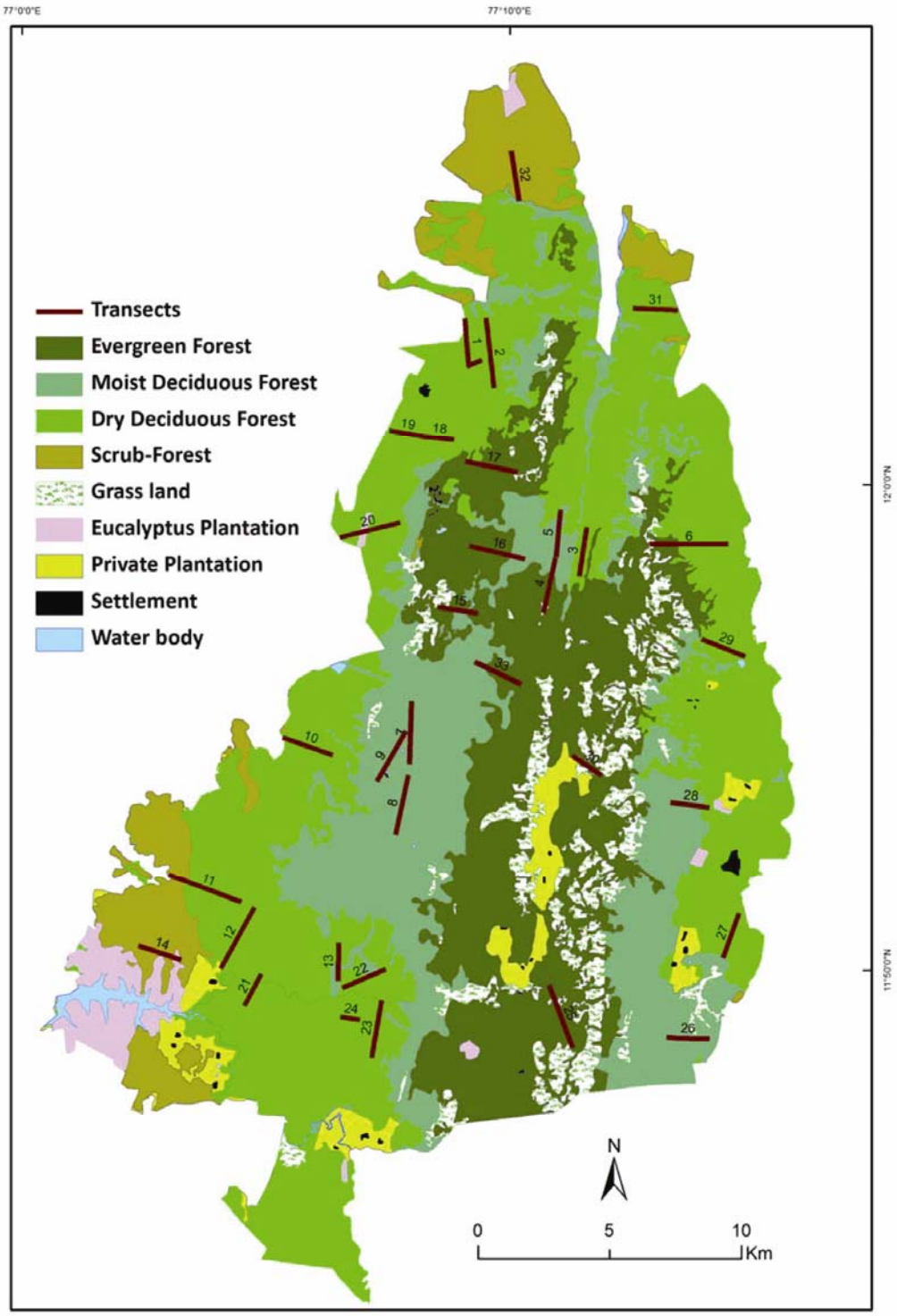

Figure 1. Map of the study area with vegetation types and locations of line transects.

large mammals in different forest types, we computed the encounter rate for each species and represented them as number of sightings per kilometre, as the detections for each species from line transect walks was not enough (less detections) to estimate the density for different forest types. Some of the species which are strictly nocturnal could not be assessed for their abundance during the day transect walk and hence we conducted night surveys to find the occurrence and to assess the abundance of such species in the sanctuary. We drove the jeep at a speed of 10 km/h between 19.00 and 24.00 h. The distance driven was recorded by the jeep odometer. We used a flashlight

to spot animals. The abundance of nocturnal mammals is presented as encounter rate (animals sighted/km). Incidental sight records were also maintained with coordinates as occurrence data.

We decided the total number of transects and their locations in the sanctuary using vegetation maps. We laid a total of 33 random line transects, which represented all the forest types and altitudinal gradients of the sanctuary. The length of the transects varied between 2 and 4 km, totalling to 93 km and each of the transects was walked a minimum of five times and a maximum of 11 times between 06.00 and 10.00 h as well as 16.30 and 18.30 h. We walked the transects between October 2009 and April 2010, which is the dry season and also visibility is better than other times of the year. A total of 795.5 km was walked on the transects. During a transect walk, for every sighting of the animal, we recorded data on the name of the species, number of individuals, animal to observer distance and angle of the detection from main bearing. The observer to animal distance was measured using OPTI-LOGIC 1000 XL and OSPREY rangefinder and the angle of the detection using a compass. When species were encountered in clusters (animals aggregating within 30 m radius[8]), we noted the distance and angle to the centre of each cluster. We recorded the coordinates for each sighting using GARMIN eTrex H and GARMIN 72 GPS units.

We analysed the data from transects using the DISTANCE software and computed the estimate of density for each species. The data from temporal replicates were pooled and treated as a single sample (sample size = 33). The density was estimated separately for each species using DISTANCE version-5 (ref. 19). The farthest sightings of the large herbivore species on the transect were truncated to achieve a reliable density estimate[20]. However, the density estimates for all the species were performed using both truncated and untruncated data, and those estimates were chosen which had minimum coefficient of variation for the final estimate. Checking for size bias in detection of animal clusters led to a non-significant regression equation at $\alpha = 0.10$ for all the species[21] and hence we used the mean cluster size for analysis. Variances in encounter rates of animals between transects were estimated empirically[20]. We judged the fit of possible alternative models to each specific dataset using Akaike's information criterion (AIC) value and goodness of fit tests generated using DISTANCE and the best possible model was selected by the software. Encounter rate, average probability of detection, cluster density, cluster size and animal density were generated using the selected model in DISTANCE.

To understand the abundance of large mammals in different forest types, we computed the encounter rate for each species and represented them as the number of sightings per kilometre. We used ANOVA to compare the mean sightings per kilometre between the forest ranges and forest types. For data on occurrence alone, we obtained additional information from the Forest Department and the tribes living inside the sanctuary.

The occurrence of all mammals in different forest types is shown in Table 1. Of the 34 species considered based on their nominal distribution range for the sanctuary, 31 species were sighted during the study and one species was confirmed by secondary information. No information was available on the occurrence of Indian gray wolf *Canis lupus pallipes* and striped hyena, *Hyaena hyaena*. Arboreal mammals including Hanuman langur *Semnopithecus priam*; bonnet macaque *Macaca radiata*; Indian giant squirrel *Ratufa indica* and common giant flying squirrel *Petaurista petaurista* were recorded from the forests with good canopy, whereas slender loris *Loris lydekkerianus* was recorded from deciduous forests. We sighted three small cats in the sanctuary. While jungle cat *Felis chaus* and rusty spotted cat *Prionalilurus rubiginosus* were recorded in deciduous and scrub forest, leopard cat *Prionalilurus bengalensis* was recorded in MDFs. Jackal *Canis aureus* and fox *Vulpes bengalensis* were restricted to marginal areas of the sanctuary, where fox was found to inhabit the open SFs. Small Indian civet *Viverricula indica* and Asian palm civet *Paradoxurus hermophroditus* were recorded in all forest types, whereas striped-necked mongoose *Herpestes vitticollis* and ruddy mongoose *H. smithii* were not recorded from SF and EF respectively. Smooth-coated otter was found in reservoirs in and around the park. Herbivore species were recorded in all the forest types, except four-horned antelope *Tetracerus quadricornis* and blackbuck *Antilope cervicarpa*, which were restricted to drier forests in the foothills. Though we did not spot the pangolin (*Manis crassicaudata*) in the sanctuary, the Forest Department personnel revealed the capture of one animal from the edge of the dry forests. Though we sighted tiger, leopard, dholes and sloth bear in the sanctuary, we did not attempt to collect any data on them because these species require different field methods to estimate their abundance and distribution pattern.

Though the sanctuary has diverse vegetation types, we broadly classified them as evergreen forest (high elevation shola and grassland, semi-evergreen and evergreen forests), MDFs, DDFs and SFs. The mean encounter rate for each species in different vegetation types is shown in Table 2. The mean encounter rate of some species differed significantly between the vegetation types, viz. gaur: $F_{3,69} = 6.090$, $P = 0.001$; sambar: $F_{3,69} = 2.677$, $P = 0.05$; muntjac: $F_{3,69} = 6.299$, $P = 0.001$; Hanuman langur: $F_{3,69} = 8.445$, $P = 0.001$ and bonnet macaque: $F_{3,69} = 5.113$, $P = 0.003$. Encounter rates for Asian elephant ($F_{3,69} = 1.163$, $P = 0.33$), chital ($F_{3,69} = 2.407$, $P = 0.75$), four-horned antelope ($F_{3,69} = 1.381$, $P = 0.26$) and wild boar ($F_{3,69} = 0.925$, $P = 0.433$) did not differ among vegetation types. The mean encounter rate of gaur (0.25 ± 0.08) and sambar (0.40 ± 0.04) in EF was more

Table 1. Occurrence of mammals in major forest types of the Biligiri Rangaswamy Temple Wildlife Sanctuary (BRT WLS)

Species	IUCN status	Forest type			
		EF	MDF	DD	SF
Hanuman langur (*Semnopithecus priam*)	LC	P (1)	P (1)	P (1)	–
Bonnet macaque (*Macaca radiata*)	LC	P (1)	P (1)	P (1)	–
Slender loris (*Loris lydekkerianus*)	LC	–	–	P (1)	P (1)
Tiger (*Panthera tigris*)	EN	P (1)	P (1)	P (1)	P (2)
Leopard (*Panthera pardus*)	NT	P (1)	P (1)	P (1)	P (2)
Jungle cat (*Felis chaus*)	LC	P (4)	P (4)	P (1)	P (1)
Leopard cat (*Prionalilurus bengalensis*)	LC	P (1)	P (1)	P (4)	N
Rusty spotted cat (*Prionalilurus rubiginosus*)	VU	P (1)	P (1)	P (1)	N
Indian gray wolf (*Canis lupus*)	LC	–	–	–	N
Dhole (*Cuon alpinus*)	EN	P (1)	P (1)	P (1)	P (1)
Golden jackal (*Canis aureus*)		N	N	P (1)	P (1)
Bengal fox (*Vulpes bengalensis*)	LC	–	–	N	P (1)
Small Indian civet (*Viverricula indica*)	LC	P (1)	P (1)	P (1)	P (1)
Asian palm civet (*Paradoxurus hermophroditus*)	LC	P (1)	P (1)	P (1)	P (1)
Stripe-necked mongoose (*Herpestes vitticollis*)	LC	P (1)	P (1)	P (1)	–
Common mongoose (*Herpestes edwardsi*)	LC	N	N	P (1)	P (1)
Ruddy mongoose (*Herpestes smithii*)	LC	P (1)	P (1)	P (1)	P (1)
Smooth-coated otter (*Lutra perspicillata*)		Found in reservoirs			
Indian giant squirrel (*Ratufa indica*)	NT	P (1)	P (1)	P (1)	–
Common giant flying squirrel (*Petaurista petaurista*)	LC	P (1)	P (1)	P (1)	–
Southern red muntjac (*Muntiacus muntjak*)	LC	P (1)	P (1)	P (1)	P (1)
White spotted chevrotain (*Tragulus meminna*)	LC	P (1)	P (1)	P (1)	N
Indian wild pig (*Sus scrofa*)	LC	P (1)	P (1)	P (1)	P (1)
Chithal (*Axis axis*)	LC	P (1)	P (1)	P (1)	P (1)
Sambar (*Rus unicolor*)	VU	P (1)	P (1)	P (1)	P (1)
Gaur (*Bos gaurus*)	VU	P (1)	P (1)	P (1)	P (1)
Elephant (*Elephas maximus*)	EN	P (1)	P (1)	P (1)	P (1)
Four-horned antelope (*Tetracerus quadricornis*)	VU	–	–	P (1)	P (1)
Blackbuck (*Antilope cervicarpa*)	NT	–	–	–	P (1)
Indian crested porcupine (*Hystrix indica*)	LC	P (1)	P (1)	P (1)	P (2, 3, 4)
Thick-tailed pangolin (*Manis crassicaudata*)	NT	N	N	P (4)	N
Sloth bear (*Melursus ursinus*)	VU	P (1)	P (1)	P (1)	P (1)
Striped hyena (*Hyaena hyaena*)	NT	N	N	N	N
Black-naped hare (*Lepus nigricollis*)	LC	P (1)	P (1)	P (1)	P (1)

P, Present; N, No information. 1, Sighted; 2, Faecal deposit; 3, Body parts; 4, Local information. EN, Endangered; LC, Least concerned; NT, Near threatened; VU, Vulnerable.

Table 2. Relative abundance (mean number of herds/groups per km ± standard error of mean) of diurnal mammals in different forest types of BRT WLS

Species	Forest type				Overall	ANOVA	
	EF	MDF	DD	SF		$F_{3,69}$	P
Asian elephant	0.17 ± 0.10	0.07 ± 0.02	0.13 ± 0.03	0.08 ± 0.08	0.11 ± 0.02	1.163	0.330
Gaur	0.25 ± 0.08	0.18 ± 0.03	0.06 ± 0.01	0.04 ± 0.02	0.12 ± 0.01	6.090	0.001
Sambar	0.40 ± 0.04	0.22 ± 0.04	0.20 ± 0.03	0.19 ± 0.07	0.22 ± 0.02	2.677	0.05
Chital	0.18 ± 0.08	0.08 ± 0.03	0.16 ± 0.03	0.28 ± 0.08	0.14 ± 0.02	2.407	0.075
Indian muntjac	0.24 ± 0.06	0.27 ± 0.04	0.11 ± 0.03	0.01 ± 0.01	0.17 ± 0.02	6.299	0.001
Four-horned antelope	0	0	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.00	1.381	0.256
Wild boar	0.01 ± 0.01	0.05 ± 0.02	0.06 ± 0.02	0	0.05 ± 0.01	0.925	0.433
Hanuman langur	0.23 ± 0.09	0.20 ± 0.04	0.03 ± 0.01	0.03 ± 0.03	0.10 ± 0.02	8.445	0.000
Bonnet macaque	0.06 ± 0.04	0.07 ± 0.02	0	0	0.03 ± 0.01	5.113	0.003

EF, Evergreen Forest; MDF, Moist Deciduous Forest; DDF, Dry Deciduous Forest; SF, Scrub Forest.

than in the other forest types and it gradually declined towards deciduous forest. The mean encounter rate of muntjac in MDFs (0.27 ± 0.04) and EFs (0.24 ± 0.06) was higher than in the dry forests. The mean encounter rate of Hanuman langur and bonnet macaque was higher in EFs (Hanuman langur: 0.23 ± 0.09, bonnet macaque:

Table 3. Relative abundance (mean number of animals per km ± standard error of mean) of nocturnal mammals in different forest types of BRT WLS

Species	N	EF	MDF	DDF	SF	Overall
Small carnivore species						
Jungle cat	8	0	0	0.04 ± 0.08	0.12 ± 0.17	0.03 ± 0.07
Leopard cat	3	0	0.02 ± 0.04	0	0	0.006 ± 0.02
Rusty spotted cat	11	0	0.01 ± 0.02	0.03 ± 0.05	0	0.02 ± 0.04
Small Indian civet	22	0	0.05 ± 0.05	0.05 ± 0.06	0	0.04 ± 0.05
Asian palm civet	50	0.09 ± 0.08	0.13 ± 0.08	0.14 ± 0.15	0	0.12 ± 0.12
Other mammals						
Slender loris	4	0	0	0.01 ± 0.04	0	0.009 ± 0.03
Common giant flying squirrel	51	0.17 ± 0.29	0.16 ± 0.17	0.06 ± 0.08	0	0.1 ± 0.15
White spotted chevrotain	42	0.06 ± 0.10	0.06 ± 0.07	0.11 ± 0.18	0	0.08 ± 0.14
Indian crested porcupine	15	0.09 ± 0.08	0.05 ± 0.06	0.04 ± 0.08	0	0.04 ± 0.07

N, Number of animals.

0.06 ± 0.04) and MDFs (Hanuman langur: 0.20 ± 0.04, bonnet macaque: 0.07 ± 0.02) than in other forest types. Four-horned antelope was confined to DDF and SF and the mean encounter rate was 0.01 ± 0.00. Though the mean encounter rate of chital statistically did not show significant difference among the vegetation types, the mean encounter rate in SFs (0.28 ± 0.08) was higher than any other vegetation types.

During the night survey, we sighted five species of small carnivores including jungle cat, leopard cat, rusty spotted cat, small Indian civet and Asian palm civet, and four species of other mammals including slender loris, common giant flying squirrel, white spotted chevrotain and Indian crested porcupine (Table 3). Among the small carnivores, Asian palm civet was commonly found in the entire sanctuary (0.12 ± 0.12), except in SFs, while jungle cat was encountered in dry forests but found in low abundance (0.03 ± 0.07). Interestingly, we had 11 encounters of rusty spotted cats, especially in the dry forests (0.02 ± 0.04). Conversely, leopard cat was encountered less (0.006 ± 0.02) in the sanctuary. Giant flying squirrel (0.1 ± 0.15) and chevrotain (0.08 ± 0.14) were encountered more than the slender loris (0.009 ± 0.03) and porcupine (0.04 ± 0.07).

The estimated densities of individuals and groups, and the calculated biomass for the eight large herbivore species along with sample size, mean cluster size, coefficient of variation and associated confidence intervals are summarized in Table 4. In terms of density of groups, muntjac (3.67 km^2) was the most dominant species, followed by chital (3.54 km^2), sambar (3.42 km^2), bonnet macaque (2.27 km^2), gaur (1.89 km^2), Hanuman langur (1.86 km^2), four-horned antelope (1.77 km^2) and wild pig (1.62 km^2). However, estimates for four-horned antelope and wild pig were not good as the number of detections was negligible and the estimate may be biased with large coefficient of variation. In terms of density of individuals, the density of chital (13 km^2) was more than the others, followed by Hanuman langur (6.34 km^2), bonnet macaque (3.56 km^2), sambar (6.01 km^2), wild pig (5.33 km^2), gaur (5.08 km^2), muntjac (3.70 km^2) and four-horned antelope (2.44 km^2). The total large herbivore density was 49.42 animals/km^2 that included terrestrial herbivore (ungulates) density of 36.52 animals/km^2 and arboreal herbivore density of 12.90 animals/km^2. The density of large herbivore species when multiplied with the average weight of the respective species[1] gave a density of biomass for each species (Table 4), and by addition of biomass of all the prey species, it gave a prey species biomass density of 4,044.55 kg/km^2, even if the primates are left out.

Elevation in BRT WLS varied highly and accordingly, vegetation also varied from open scrub or open wooded deciduous forests at lower elevation to MDFs, EFs with shola and grassland towards higher elevation. Variation in the elevation and diverse vegetation types determined the distribution of many mammal species in the sanctuary.

Primates and giant squirrels are indeed canopy-living animals and hence EFs and MDFs harbour good populations than deciduous forests and SFs. However, primates are highly adaptable species and are known to occur in SFs of the plains to human-dominated landscapes[22]. Probably the reason for their absence or low abundance in DDFs and SFs can be attributed to the presence of predator species, especially the leopard which can climb trees and prey on the arboreal mammals.

Slender loris in South India includes two subspecies, viz. Malabar slender loris, *L. lydekkerianus malabaricus* and Mysore slender loris, *L. lydekkerianus lydekkerianus*. The former is restricted to EFs on the western slopes of the Western Ghats, whereas the latter is restricted to the dry forests of the Eastern Ghats, Deccan Plateau and southern plains. The loris subspecies found in BRT WLS is the Mysore slender loris and it is a first sight record for the sanctuary. Sightings are very few and restricted to the dry forests in the southern part of the sanctuary. Kumara

Table 4. Density and biomass estimates of large herbivores in the BRT WLS

Species	n	$\hat{D}_g$ (km^2)	$\hat{Y}$	$\hat{D}$ (km^2)	CV ($\hat{D}$) (%)	95% CI (km^2)	Weight (kg)	Biomass (kg/km^2)
Gaur	66	1.89	2.67	5.08	19.05	3.49–7.38	450	2286.00
Sambar	155	3.42	1.76	6.01	12.75	4.67–7.74	134	805.34
Chital	72	3.54	3.94	13.96	21.25	9.17–21.27	47	656.12
Muntjac	131	3.67	1.01	3.70	18.36	2.56–5.34	21	77.70
Indian wild pig	13	1.62	3.27	5.33	33.48	2.72–10.45	32	170.56
Four-horned antelope	9	1.77	1.38	2.44	19.93	1.63–3.67	20	48.8
Hanuman langur	77	1.86	3.41	6.34	20.46	4.22–9.51	9	57.06
Bonnet macaque	43	2.27	2.88	6.56	25.63	3.97–10.83	4	26.24

n, number of detections; $\hat{D}_g$, Density of clusters; $\hat{Y}$, Mean cluster size; $\hat{D}$, Density of individuals; CV ($\hat{D}$), Percentage coefficient of variation; 95% CI, 95% confidence interval.

et al.[23] reported that the southernmost sightings were at the north of Cauvery river in Bangalore and Tumkur districts; however, the modelled niche for the Mysore slender loris shows drier forests of BRT WLS as a possible habitat[24]. The present sighting of slender loris not only confirms the prediction, but it is also the westernmost sighting of its distribution range in the state. Further exploration in the adjoining Sathyamangalam forests and M. M. Hills will throw more light on its population contiguity and distribution pattern. The low abundance could be attributed to the periphery of the distribution range in Karnataka.

During the present study we could not obtain any information on hyena, however our interviews with the Soliga tribe suggest the possible occurrence of the species in the southern drier forests of the sanctuary. Wolf was once thought to be present in the larger area of the state, including marginal areas of BRT WLS[25]. However wolf ranges have shrunk in the state and the species may have probably disappeared from the surrounding areas of the sanctuary[26]. The rusty spotted cat was sighted in the sanctuary for the first time. The abundance was more in the deciduous and marginal forests. There have been few sight records of rusty spotted cat in the state[27], and this probably is due to lack of proper exploration. However, 11 encounters of the species emphasize the importance of the forest for its conservation.

Herbivore species including elephant *Elephas maximus*; gaur *Bos gaurus*; sambar *Rus unicolor* chital and muntjac *Muntiacus muntjak* are relatively generalist species and they occur in all the forest types. However, the availability of browse and grass in the forests determines the habitat preferred by these species. Conversely, antelopes have adapted to live in open wooded forests, where they can see over long distance and run to escape predators. Perhaps, both blackbuck and four-horned antelopes were confined to the foothills of BRT WLS with open deciduous forests and SF as the MDF and DDF at high altitude is infested with lantana. Gaur and sambar have adapted to browse and graze, while the chital is largely a grazer. The relative abundance of gaur and sambar decreases from wet forests to dry forests, whereas the relative abundance of chital increases in the other way since grass is more available in the open forests than the moist forests with thick lantana in the sanctuary. Muntjac being solitary in nature[8] preferred closed canopy forests than open forests.

Estimate of large herbivore density in the present study, when compared with that from other parks in the country (Table 5), revealed that BRT WLS holds high density of muntjac, medium density of sambar and gaur, and comparatively low density of chital and Hanuman langur. Nevertheless, the density of sambar was similar to that in other parks of the same landscape (Bandipur and Nagarahole) and though the gaur density in BRT WLS was lower than in these parks, it shows a promising value. However, the density of large prey species is much better than in the Bhadra Tiger Reserve. High degree of undulating terrain and thick lantana decrease the grass availability for the grazers. Lantana is found from relatively high-elevation DDF to MDF; this may have restricted the grass availability to deciduous forests at the foothills and highly worked MDF. This habitat of the forest favoured browsers[1] like gaur and sambar and wherever habitat heterogeneity favoured grazers like the chital. The low density of Hanuman langur may be due to hunting of the animal in the past. Local people and old Forest Department personnel mentioned hunting activities in the past by tribal community and people from neighbouring villages. Later the forests faced severe hunting pressure by a notorious elephant poacher for more than two decades, during which protection and management of the forest was weak. From 2005, the protection and management of the sanctuary realized the normal functioning; yet hunting pressure exists in marginal areas. Thus the Hanuman langur in most of the areas of the sanctuary is shy and its density is low.

Blackbucks *Antilope cervicapra* live in low abundance and are restricted to marginal areas and cropland in the periphery of the sanctuary and hence they were not

Table 5. Comparison of estimated densities of five herbivore species in different Indian forests

Location*	Gaur	Sambar	Chital	Muntjac	Hanuman langur
Nagarahole	9.6	5.5	50.6	4.2	23.8
Bipur	7.0	5.6	20.1	0.7	NA
Bhadra	1.48	0.89	4.51	3.64	22.6
BRT	5.08	6.01	13.96	3.70	6.34
Pench	0.7	9.6	51.3	NA	NA
Kanha	NA	1.5	49.7	0.6	NA
Ranthambore	SA	17.15	31.0	SA	21.75
Gir	SA	2.0	50.8	SA	NA
Mudumalai	0.5	6.61	25.03	NA	NA
Anamalai	12.34	6.54	20.54	0.28	NA
KMTR	3.6	7.0	NA	NA	9.9

*Source: Nagarahole[8]; Bipur, Pench, Kanha[17]; Bhadra[32]; Ranthambore[7]; Gir[29]; Mudumalai[15]; Anamalai[33]; KMTR (Kalakad–Mundanthurai Tiger Reserve)[34]; BRT, Present study; SA, Species absent; NA, No estimate available.

Table 6. Biomass density of large herbivore species from different tropical regions in the Indian subcontinent

Location	Biomass density (kg/km^2)	Forest type
Nagarahole[8]	7,638.00	Tropical dry moist deciduous
Bandipur[17,*]	5,007.30	Tropical dry deciduous
Bhadra[32,*]	1,277.25	Tropical dry moist deciduous
BRT (present study)	4,127.82	Tropical dry moist deciduous, evergreen forest
Pench[6]	6,013.25	Tropical dry deciduous
Kanha[35]	3,902.3–4,805.70	Tropical moist deciduous
Gir[29]	3,292.00	Tropical dry deciduous thorn
Kaziranga[17,*]	4,252.00	Tropical moist with alluvial grass lands
Ranthambore[7,*]	6,418.83	Tropical dry deciduous

*Available density estimate was converted to biomass density by taking average weight of species[1].

sighted during the transect walks. The proportion of suitable habitat (open wooded forests like deciduous forests with opened canopy[28]) for four-horned antelope is restricted to the foothills and it is marginal in the sanctuary. Hence the number of detections was less and the estimate may be biased. Nevertheless, the present estimate for four-horned antelope (2.44 km^2) shows the presence of a promising population in the sanctuary when compared to estimates from Pench (0.7 km^2)[17] and Gir (0.42 km^2)[29].

Since elephants rarely contribute to the diet of large carnivore species[4,16,30], their estimates were omitted while comparing the prey biomass density between BRT WLS and other parks in the country. Biomass density varied from as low as 1,277.25 kg/km^2 in Bhadra to 7,638 kg/km^2 in Nagarahole (Table 4). Seven parks in the country support more than 4,000 kg/km^2 of prey biomass, including Nagarahole, Ranthambore, Pench, Bandipur, Kaziranga, BRT WLS and Kanha, which reveals that BRT WLS is one of the highest biomass-rich areas in the country. The overall herbivore density in BRT WLS was lesser than in many other protected areas. However, the density of large-bodied species like gaur and sambar was very high, which has contributed to high biomass density for the sanctuary. As the density of biomass of large prey species is high, there is a possibility of high density of tigers in the sanctuary. As these forests are a part of one of the largest forest complexes in the Indian subcontinent holding the largest population of the highly threatened tiger, population monitoring of large herbivores and large carnivores is highly essential. Karanth and Stith[3] pointed out that the critical determinant of tiger population viability is prey depletion. Since the marginal areas of the sanctuary have been facing various anthropogenic pressures, including hunting of animals[31], further management steps are required to enhance the density of prey species in the marginal areas to ensure long survival of viable populations of large carnivores. With the promising prey base available and good population of tigers (28–34 individual tigers, unpublished Forest Department annual census report, Chamarajanagara Wildlife Division) in the sanctuary, we recommend that BRT WLS be notified as a Tiger Reserve, which would help in ensuring proper protection of the major tiger habitat in the country and also at a global level.

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