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ACKNOWLEDGEMENTS. We thank the Forest Departments of Junagadh and Gujarat for giving permission to work in the National Sanctuary, Girnar Researve Forest. We also thank Dr A. L. Singh (Directorate of Groundnut Research, Junagadh), Dr Chetanaben Mandavia, Dr V. P. Chovatia, Dr H. L. Dhaduk (Anand Agricultural University, Anand) and Dr P. S. Nagar (M.S. University, Vadodara) for technical input.

Received 11 November 2013; revised accepted 26 September 2014

Estimate of primate density using distance sampling in the evergreen forests of the central Western Ghats, India

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Although the evergreen forests of the Western Ghats harbour seven species of primates, estimate of their density is not available for most of the area. The Aghanashini Lion-tailed Macaque Conservation Reserve in central Western Ghats, a newly notified protected area in Karnataka, harbours lion-tailed macaque *Macaca silenus*, bonnet macaque *Macaca radiata* and Southern plains gray langur *Semnopithecus dussumieri*. We estimated their densities using line transect method. The estimate of cluster density for lion-tailed macaque, bonnet macaque and southern plains gray langur was 1.62, 4.28 and 10.67 groups/sq. km respectively, with the individual's density of 14.95, 12.40 and 25.06 individuals/sq. km respectively. The conservation importance of the present findings is also discussed.

Keywords: Density estimate, distance sampling, evergreen forests, line transects, primates.

THE Western Ghats is a series of hill ranges that passes through the states of Gujarat, Maharashtra, Goa, Kerala, Karnataka and Tamil Nadu[1], spanning about 1600 km from southern Gujarat to Kanyakumari in Tamil Nadu, running parallel to the western coast of southwestern India. Tropical evergreen forests are found at the western slopes and the ridges of these hills, and deciduous and scrub forests in the rainshadow areas on the eastern slopes[2]. The Western Ghats is home to a large number of endemic and endangered flora and fauna, and has the highest human density amongst 'biodiversity hotspots' of the world[3]. Due to canopy contiguity, high diversity of plant species and the availability of fruit-bearing trees throughout the year, the forests of the Western Ghats harbour many arboreal fauna, including seven species of primates, namely lion-tailed macaque (*Macaca silenus*), bonnet macaque (*Macaca radiata*), Nilgiri langur (*Trachypithecus johnii*), southern plains gray langur (*Semnopithecus dussumieri*), black gray langur (*S. hypoleucos*), tufted gray langur (*S. priam*)[4], and two subspecies of loris, Mysore slender loris (*Loris lydekkerianus*

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lydekkerianus) and Malabar slender loris (*L. lydekkerianus malabaricus*). Primates are the major group of animals contributing to the mammal biomass in the evergreen forests of the Western Ghats, and play a major role in seed dispersal and regeneration of the forests. Primates in the Western Ghats are under threat due to severe hunting pressure[5], and they have been eliminated from several parts of the Ghats[6]. Therefore, the remaining populations require attention and consideration for the proper management. The fundamental information required for this is their population status in each of the forest areas, including protected areas, which is not available for most part of the Western Ghats. This is due to undulating terrain of the Ghats, where strictly adapting the proper survey techniques was believed to be difficult. Thus, there was no attempt to estimate the population density of any primate species for the evergreen forests of the Western Ghats. Nevertheless, lion-tailed macaques have been estimated for a few forest patches using total count method[7–11]. Kumara and Singh[10] reported one of the largest populations of lion-tailed macaque in the forests of Sirsi–Honnavara in central Western Ghats, and highlighted the forest as one of the important areas for conservation in the entire Western Ghats. In 2011, this forest was declared as 'Aghanashini Lion-tailed Macaque Conservation Reserve (ACR)'[12,13].

The forests of Sirsi–Honnavara have been under modification over a period, especially the evergreen forests[14]. Langurs and bonnet macaques in these forests have been highly susceptible to a viral infection known as 'Kyasanur forest disease', and they often die due to these epidemic outbreaks[15]. Unfortunately, their population dynamics has not been documented for any of the virus-active regions. The goal of the present study was to explore the possibility of using the line transect method to estimate the density of primates and provide their population status for the evergreen forests of the Western Ghats. This will also help in their future monitoring with respect to viral infection and anthropogenic activities.

The study was carried out in the forests of Sirsi–Honnavara (large part of ACR and its adjoining forests), Uttara Kannada district situated in the central Western Ghats (between 14°15′–14°25′N and 74°35′–74°47′E, 275 sq. km) (Figure 1). The study site is located in the ridge of the Ghats extending in a westerly direction towards the west coast. The forest was broadly classified as 'low altitude rainforest' by Pascal[1] and as 'west coast tropical evergreen forest' by Champion and Seth[16]. Many villages are scattered throughout the forest and large areas under cultivation include commercial crops, like areca nut (*Areca catechu*) and paddy (*Oryza sativa*), and monoculture plantations of different species of acacia[17]. The altitude varies from 300 to 800 m amsl. The terrain is highly undulating with the slope varying from 20% to >35% in general, and receives major rainfall from the southwestern monsoon (June to October) and little rainfall from the retreating monsoon in November. The mean annual rainfall is 5000 mm.

The study species included lion-tailed macaque, bonnet macaque and southern plains gray langur. The study was conducted between December 2012 and May 2013. A total of eight (sample size = 8) transects were laid randomly throughout the study site, avoiding human habitation[18,19]. Transect lines could not be laid at the northwestern part of the study site due to steep slope and rocky sheets. Nevertheless, transect lines were distributed in the entire study site representing all existing habitat types. The minimum distance between the closest transects was 2–5 km. The length of a transect line varied between 2.5 and 4.6 km, totalling to 32.1 km. All the assumptions of the line transect method were taken care of in the study. Each transect was walked 15 times between 07 : 00–09 : 00 h and 15 : 00–18 : 00 h, at a speed of 1.5 km per hour. A total distance of 481.50 km was covered on the transect lines. During the transect walks, once a species was detected, sighting time, species, number of individuals, angle of a sighting to the transect line using compass (θ) and sighting distance (animal to observer; r) using Nikon Forestry Pro range finder were noted. All the three species live in group, thus, when the species was detected in clusters (animal group aggregating within 30 m radius), we noted the distance and angle to the centre of each cluster.

The data was analysed using 'Distance' software (v. 6.0)[20] and the density was computed. The data from temporal replicates were pooled and treated as a single sample (sample size = 8). Checking for size bias in the detection of animal clusters led to a non-significant regression equation at $\alpha = 0.10$ (ref. 21), and we therefore used the mean cluster size for analysis. We estimated the variance in encounter rates of animals between transects empirically[22]. We examined the best-fit model using

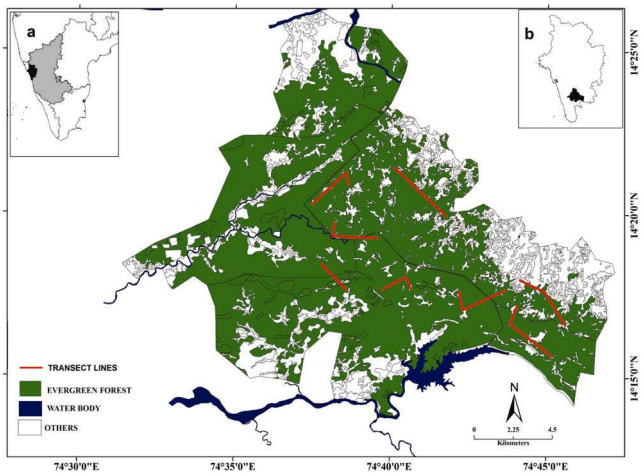

Figure 1. Forests of Sirsi–Honnavara showing transect lines. Degraded forests, monoculture plantations and built-up area are also shown.

Table 1. Details of detection of bonnet macaque, lion-tailed macaque and southern plains gray langur on transect walk (effort 481.50 km)

Particulars of detection	Bonnet macaque	Lion-tailed macaque	Southern plains gray langur
Total no. of detections	100	45	228
Mean no. of detections (SD)	12.50 ± 4.78	5.63 ± 3.93	28.50 ± 5.13
No. of detections on eight transects: minimum–maximum	6–20	1–13	21–34
No. of detections/km	0.21	0.09	0.47

Table 2. Density estimates for primates in the forests of Sirsi–Honnavara

Parameter	Lion-tailed macaque	Bonnet macaque	Southern plains gray langur
No. of detections	45	100	228
No. of individuals sighted	397	311	551
Key function	Hazard rate	Hazard rate	Hazard rate
Minimum AIC	314.84	686.84	1506.98
ESW	27.42	24.26	21.72
Detection probability – p (SE)	0.78 ± 0.06	0.61 ± 0.04	0.51 ± 0.02
% CV	8.28	6.64	3.95
95% confidence interval	0.66–0.92	0.53–0.70	0.48–0. 56
Encounter rate – n/L	0.09	0.20	0.46
% CV	25.13	15.55	7.66
95% confidence interval	0.05–0.16	0.14–0.30	0.38–0.55
Cluster size – Y (SE)	9.22 ± 0.94	2.90 ± 0.18	2.34 ± 0.08
% CV	10.18	6.46	3.66
95% confidence interval	7.51–11.32	2.55–3.30	2.18–2.52
Cluster density – DS (SE)	1.62 ± 0.41	4.28 ± 0.73	10.67 ± 0.86
% CV	25.87	17.09	8.07
95% confidence interval	0.89–2.91	2.94–6.24	8.88–12.83
Individual density D (SE)	14.95 ± 4.15	12.40 ± 2.27	25.06 ± 2.22
% CV	27.80	18.27	8.86
95% confidence interval	8.16–27.37	8.40–18.34	20.68–30.36

Akaike's information criterion (AIC) value and goodness-of-fit tests generated by the program 'Distance'[20], and selected the best possible model. We generated encounter rate, average probability of detection, cluster density, cluster size and animal density using the selected model in 'Distance'[20].

The number of clusters detected (total individuals) for lion-tailed macaque, bonnet macaque and southern plains gray langur was 45 (397), 100 (311) and 228 (551) respectively. All the three species were detected in all the transect lines, and the mean number of detections for the three species varied significantly (Kruskal Wallis, $\chi^2 = 18.296$, $df = 2$, $P < 0.000$; Table 1). Details of different parameters of detection and encounter rate of each species are provided in Table 1, and density estimates are provided in Table 2, including effective strip width, detection probability, encounter rate, cluster size and density and animal density.

The estimated detection probability for bonnet macaque, lion-tailed macaque and southern plains gray langur was 0.61, 0.78 and 0.51 respectively. Density was estimated for all the primates based on minimum AIC values in different key functions. Depending on the outliers, we truncated the detection distances for each species to achieve a best model. Hazard rate key function gave a minimum AIC value for all the species (Figure 2). Cluster density for lion-tailed macaque, bonnet macaque and southern plains gray langur was estimated as 1.62, 4.28 and 10.67 clusters/sq. km, where the density of individuals was 14.95, 12.40 and 25.06 individuals/sq. km respectively.

This is a first ever density estimate of primates in the evergreen forests of the Western Ghats using line transect (distance sampling) survey technique. Monitoring of various other species, especially prey and predator species in the moist deciduous and dry deciduous forests in the rainshadow areas of the Western Ghats is in practice by the Forest Department and researchers. However, the same has not been attempted for the wet forests of the Western Ghats, including the protected areas. This may be due to high undulating terrain which hinders laying of straight transects. In the present study, though the

transect lines were laid in undulating terrain, they were straight and were walked 15 times to achieve the minimum detections (40) required[18] to obtain a robust estimate by satisfying the four assumptions of the 'Distance' sampling. The estimated effective strip width was less for all the species; the reason may be due to the closed canopy of thick vegetation that hinders visibility.

Although the hunting pressure on primates is relatively less in the forests of Sirsi–Honnavara, the same on other animals perhaps may be rampant[5]; the loss of forest cover and fragmentation is apparent and is a major threat to the primates[13]. Further, since bonnet macaque and southern plains gray langur often raid crops, they flee on sighting humans due to frequent chasing. On the other hand, lion-tailed macaques are naturally shy and avoid the presence of humans. The hazard rate key function provided a better estimate of density that may have been the result of high variation in detection distances as shown by their evasive movement.

The lion-tailed macaques were highly restricted to narrow patches of evergreen forests within the study site,

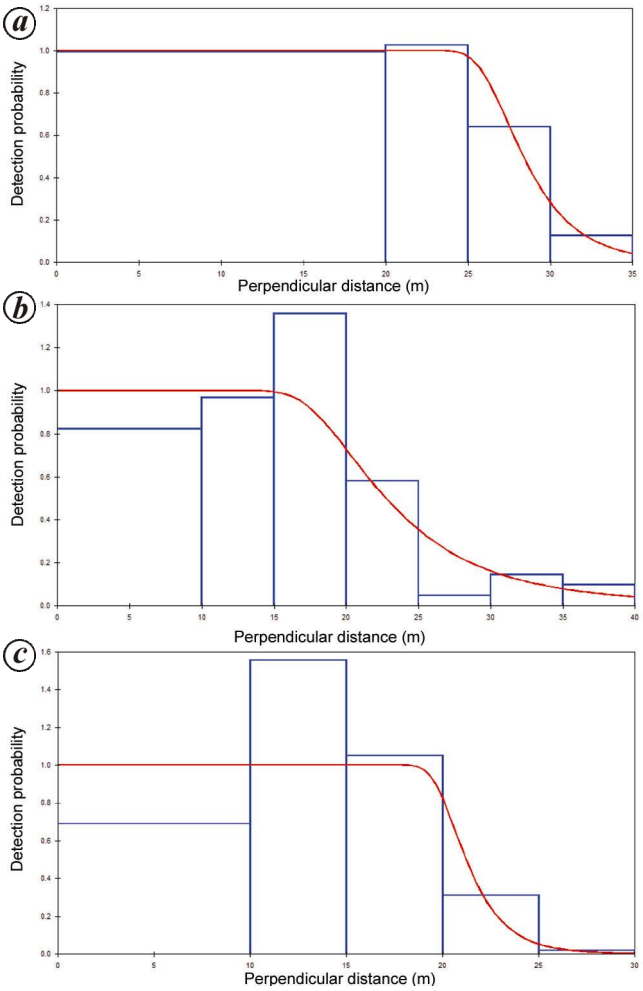

Figure 2. Detection distances for (***a***) lion-tailed macaque, (***b***) bonnet macaque and (***c***) southern plains gray langur.

and furthermore, detections were very close to the transects. The number of individuals counted was also more than the other species. Thus, the cluster size of lion-tailed macaque (9.22) was more than the bonnet macaque (2.90) and southern plains gray langur (2.34). Kumara and Singh[10] reported higher group size for lion-tailed macaque than the other two species in the study site that supports the higher cluster size for lion-tailed macaque. However, the cluster density and animal density were more for langur than bonnet macaque and lion-tailed macaque. These estimates will be comparable if assessments are made using the same sampling protocol over a period, which will help in understanding the population dynamics of the species.

We compared the density of bonnet macaque with the estimates available from other tropical forests in India (Table 3). Density of bonnet macaque was available only for Nagarahole[23] and BRT Tiger Reserve[24]. The density in Sirsi–Honnavara is relatively higher than that in the other two parks. Bonnet macaque is a habitat generalist and found from evergreen forests of the Western Ghats to urban and rural areas in southern India. However, the densities not being available for most of the protected areas, make it more difficult to account for the variation in their population density. However, the present study reports that the densities in evergreen forests are more than those in the dry forests of Karnataka.

Furthermore, our interaction with local people revealed regular raiding of crops (areca nut and paddy) by bonnet macaques in the study site. The gradual increase in agriculture in the landscape[14] probably resulted in the relatively high density of bonnet macaques in the study site than in the other two parks where there are no such palatable agricultural crops available.

The Hanuman langur was reclassified as seven species based on variation in their morphology[25,26]. Irrespective of this classification, all earlier estimates have been represented as 'Hanuman langur'. Thus for the present comparison, we also consider all the species or subspecies as Hanuman langur. Table 3 lists their density from different protected areas. The density estimate for Hanuman langur was available for 12 protected areas, viz. Nagarahole[23], BRT[24], Pench[27], Kanha[28], Melghat[29], Bori-Satpura[30], Mudumalai[31], Bhadra[32], Ranthambore[33], Sariska[34] and Bandipur[35] (Table 3). The mean density for Hanuman langur was calculated as 29.26/sq. km using the estimates from different sites. The density of Hanuman langur in ACR remained close to the mean density of all the sites. The density also varied highly within and between the forest types. Thus, the forest type alone is not the determining factor for the density of Hanuman langur in each site. We suspect that many other factors like availability of food resources, occurrence and density of predators and human disturbance may influence the density of Hanuman langurs in each site than the forest type.

Table 3. Density of bonnet macaque and Hanuman langur across different study sites in the Indian subcontinent

Location	Major habitat type	Density/sq. km	
		Bonnet macaque	Hanuman langur
Bandipur[35]	Tropical dry deciduous	NA	7.50
Kanha[28]	Tropical moist deciduous	NA	46.20
Nagarhole[23]	Tropical dry moist deciduous	5.50	23.80
Bhadra[32]	Tropical dry moist deciduous	NA	22.62
Ranthambore[33]	Tropical dry deciduous	NA	21.75
Bori–Satpura[30]	Tropical dry and moist deciduous	NA	28.30
Sariska[34]	Tropical dry deciduous and thorn	NA	14.13
Mudumalai[31]	Tropical dry thorn, moist, dry deciduous and evergreen	NA	25.90
Pench[27]	Tropical dry and moist deciduous	NA	82.50
BRT[24]	Tropical dry moist deciduous and evergreen forest	6.56	6.34
Melghat[29]	Tropical dry and mixed deciduous	NA	42.90
	Mean density	6.03	29.26
Sirsi–Honnavara (present study)	Tropical evergreen	12.40	25.06

The present study provided the possibility of using 'Distance' sampling to estimate the density of primates and baseline data on density of primates present in the evergreen forests of the central Western Ghats. The minimum detections required for the robust estimate can be achieved with increased efforts. The relative high density of primates also reflects their high biomass in the site. Further, lesser abundance of terrestrial mammals[5] increases the importance of the forests of Sirsi–Honnavara for the arboreal mammals, since they are the only animals contributing to the large mammal biomass. Thus, management of the newly notified conservation reserve (ACR) requires considering population monitoring and conservation of the remaining population of arboreal mammals. Although currently the lion-tailed macaque is not known for crop raiding, it is susceptible to fragmentation and habitat loss[14], which can later become a major issue for its management[8,36,37]. Conversely, the bonnet macaque and Hanuman langur–human conflict is on the rise as revealed by the local people. This needs to be considered as an urgent management issue to retain the confidence of local people for the conservation of these species in ACR and its adjoining forests.

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ACKNOWLEDGEMENTS. We thank Rufford Small Grants for financial support. We also thank Karnataka Forest Department for all the permissions, encouragement and support; Stephen Buckland and Eric Rexstad for help in analysing the data, running the model and suggestions. We also thank P. A. Azeez, Director, SACON, Coimbatore for encouragement and support; Avadhoot Velankar for preparing the required map, and Gangadhara, Dyavru, Marrya and Suresha for assistance in fieldwork. We also thank the three reviewers for their inputs which helped improve the manuscript.

Received 7 March 2014; revised accepted 16 September 2014