SACON Technical Report-117

Status of primates in the wet forests of Parambikulam landscape, Kerala, India with special reference to the lion-tailed macaque *Macaca silenus*

Technical Report

Mewa Singh, R. Sasi, Honnavalli N. Kumara and Werner Kaumanns

UNIVERSITY OF MYSORE

SACON

Suggested citation:

Singh, M., Sasi, R., Kumara, H.N. and Kaumanns, W. (2013). Status of primates in the wet forests of Parambikulam landscape, Kerala, India with special reference to the lion-tailed macaque *Macaca silenus*. Technical Report, University of Mysore and Sálim Ali Centre for Ornithology and Natural History, India.

Status of primates in the wet forests of Parambikulam landscape, Kerala, India with special reference to the lion-tailed macaque *Macaca silenus*

Technical Report

Submitted to

Dr. Scott Carter, Detroit Zoo, USA

Dr. Leopold Slotta-Bachmayr, Tiergarten Wels, Austria

and Dr. Wolfgang Ludwig, Zoo Dresden, Germany

Mewa Singh[1], R. Sasi[2], Honnavalli N. Kumara[3] and Werner Kaumanns[4]

[1]Biopsychology Laboratory, University of Mysore, Mysore 570006, India
[2] Department of Anthropology, University of Madras, Chennai 600 005, India
[3]Sálim Ali Centre for Ornithology and Natural History, Anaikatty (PO), Coimbatore 641108, India
[4]Eschenweg 5, D-37130 Gleichen

Acknowledgements

We are thankful to the Principal Chief Conservator of Forests (Wildlife) and Chief Wildlife Warden Shri V. Gopinathan, IFS, Kerala Forest Department for granting us necessary permission to carry out the study. We thank Shri K. Vijayanandan, IFS, Wildlife Warden and Deputy Director, Parambikulam Tiger Reserve, for his constant support. We acknowledge the support of forest range officers and other department personnel of the division during the study. We thank Srini, Prabhu and Anand helping us in the field.

Grants for this study were obtained from Dr. Scott Carter, Detroit Zoo, USA, Dr. Leopold Slotta-Bachmayr, Tiergarten Wels, Austria, and Dr. Wolfgang Ludwig, Zoo Dresden, Germany. Dr. Werner Kaumanns, Germany, made the grants from Europe possible.

We thank Dr. H.S. Sushma for helping and providing the inputs to analyse the data and running the models. We thank Dr. Babu and Dr. Suganthasaktivel for their inputs in the analysis of the data.

Singh, Sasi, Kumara and Kaumanns

Status of primates in the wet forests of Parambikulam landscape, Kerala, India with special reference to the lion-tailed macaque *Macaca silenus*

Introduction

The rainforests of the Western Ghats are extremely rich in arboreal fauna due to their continuous canopy and the availability of a variety of fruit-bearing trees throughout the year. The most conspicuous of arboreal mammals are the four species of diurnal nonhuman primates including the lion-tailed macaque *Macaca silenus*, Nilgiri langur *Semnopithecus johnii*, bonnet macaque *M. radiata* and the Hanuman langur (*S. entellus*). While the lion-tailed macaque and Nilgiri langur are endemic to the Western Ghats, the other two species are widespread throughout southern India. The effect of rainforest fragmentation and habitat deterioration has been most drastic on the lion-tailed macaque. Because of its highly selective feeding habits, limited range of occupancy (about 2500 km2), delayed sexual maturity, long inter-birth intervals, low population turnover and a small remaining wild population (about 3500 individuals), this species has been classified as 'endangered' (IUCN 2012). Furthermore, the remaining population consists of 49 subpopulations isolated in rainforest fragments in eight locations (Molur et al. 2003) although there have not been detailed studies on many of these populations. A few studies have, however, documented the intense human pressure faced by primates in some of these rainforest fragments and the significant effects of such pressures on the demography, ranging patterns, feeding habits and reproductive rates of lion-tailed macaques in these fragments (Kumar et al. 1995; Singh et al. 2001). Even earlier, Karanth (1992), while outlining the conservation prospects for the Western Ghats, emphasized the importance of the lion-tiled macaque as a flagship species of the rapidly declining rainforests of this biodiversity hotspot.

Large populations of lion-tailed macaques are expected to occur only in very few regions over the entire Western Ghats and the conservation status of this species is likely to differ across these sparse populations. The Kalakad-Mundanthurai Tiger Reserve, for example, has large tracts of rainforest, amounting to ~ 400 km^2, and it harbors ~ 31 groups with ~ 460

animals (Sushma et al. communicated). A viable population of the lion-tailed macaque with 32 groups have been located in the Sirsi-Honnavara region of the state of Karnataka (Kumara and Singh 2004b). The Indira Gandhi Wildlife Sanctuary has about 32 groups of lion-tailed macaques, all of which are restricted to severely fragmented forests (Singh et al. 2002) and, hence, the future of this population is uncertain. The Silent Valley National Park has received the attention of the entire country because of its 14 groups (with about 260 animals) of lion-tailed macaques (Joseph and Ramachandran 1998). Ten groups of lion-tailed macaques have been reported earlier from the Brahmagiri Wildlife Sanctuary in the northern Western Ghats (Karanth 1985); however, recent studies have revealed the virtual local extinction of this population due to extensive hunting (Kumara and Singh 2004a, b). We have observed similar drastic declines, sometimes leading to the loss of even 65 % of the existing groups, during our recent surveys of the Talakaveri Wildlife Sanctuary, Pushpagiri Wildlife Sanctuary, Sharavathi Valley Wildlife Sanctuary and the adjacent ranges of each of these protected areas (Kumara and Sinha 2009).

The body of literature reveals the need of population assessment in other unexplored habitats of the species. Similarly, information on status of other primates is also not available in many of such areas. Though the lion-tailed macaque is known to occur in evergreen forests of the Western Ghats, we presume that the species is highly selective for habitat which they actually occupy since they are known to be habitat specialist and to occupy highly suitable habitat with low population density. Further, since the primary habitat of the lion-tailed macaque was 'worked' (historically logged and converted as monoculture plantations) that has changed the current habitat status over a period, the suitable habitat may be fragmented within the habitat matrix and also highly influenced by various anthropogenic activities. Thus, in addition to anthropogenic factors, we suspect some of the habitat parameters influence the occupancy of lion-tailed macaque more than the other primates like Nilgiri langur and bonnet macaque in Parambikulam landscape which has a history of 'working'. We conducted a survey of all the primate species in Parambikulam Tiger Reserve between October 2010 and May 2012. Here, we present and discuss the status, group size, population characteristics and conservation of primates, with special reference to occupancy of lion-tailed macaques in the Parambikulam landscape.

Study area

Forests of the Parambikulam landscape include Nemmara, Chalakudy and Vazhachal forest divisions and Parambikulam WLS lying between 76° 34’ to 76° 50’ E and 10°16’ to 10°27’N (Fig. 1). Altitude of the study area varies from 300 m to 2000 m above msl. Annual rainfall spatially varies between 400 and 3200 mm, however the mean annual rainfall is 2000 mm, mostly during the monsoon (June to October). The major vegetation types include: tropical evergreen forests, semi-evergreen forests, moist deciduous, dry deciduous, bamboo and reed brakes. We surveyed part of the Parambikulam landscape i.e. Parambikulam WLS between October 2010 and May 2012.

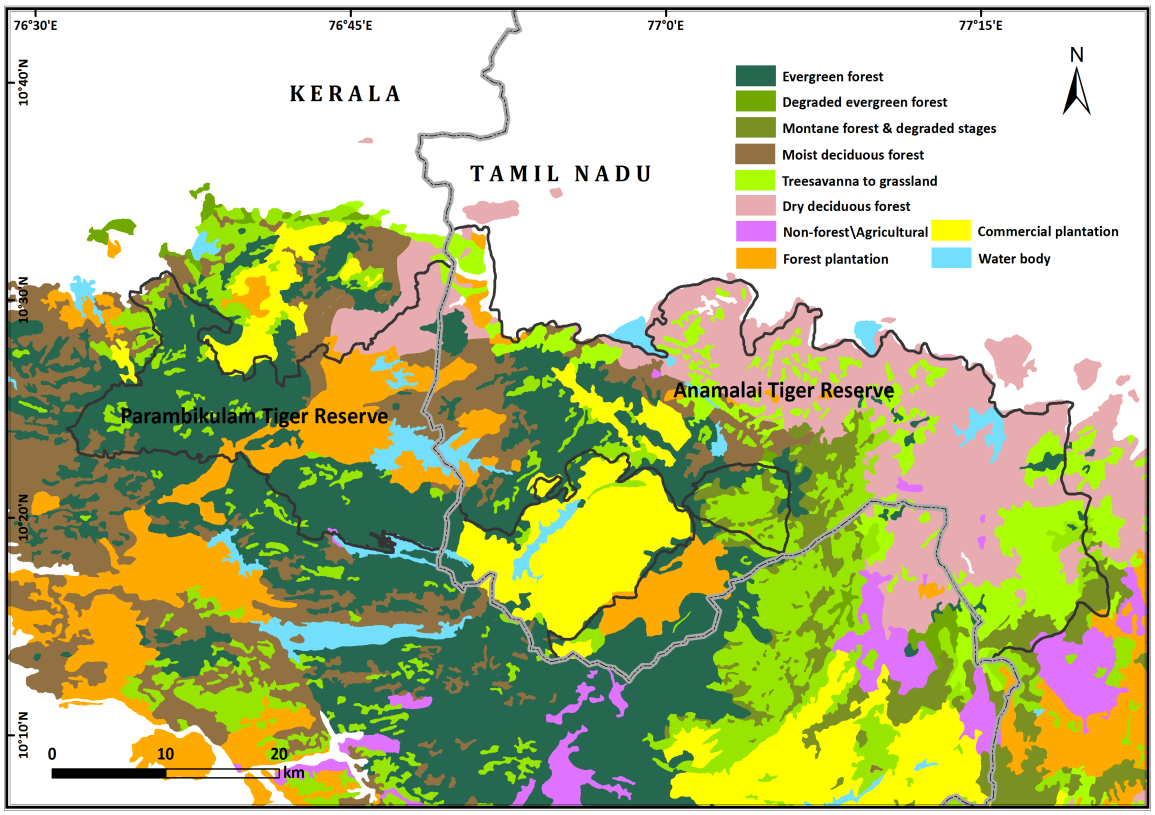

Figure 1 Vegetation map of Parambikulam –Anamalai landscape

Methods

Survey design and data collection:

Though the Nilgiri langurs occur in a variety of habitats, lion-tailed macaques occur in low numbers in the wild and are highly restricted to narrow strips of rainforests in the Western

Ghats. Thus the estimation of their density through line transect survey or distance sampling requires an enormous effort. Laying of transect lines is often not possible over much of the species' range. The total count method (NRC 1981) has thus been widely adopted to estimate populations of such rare and patchily distributed species (Whitesides et al. 1988; White and Edwards 2000). The total landscape of the present study area was gridded into five square kilometer blocks. Among these blocks, 64 grids were selected based on vegetation cover dominated by evergreen forests (Fig. 2). Four consecutive walks were made in each grid using existing trails or animal paths (of varying length). The route that was used to walk was tracked using handheld GPS (Garmin HCx Vista), and the same was mapped and measured using ArcGIS software. Sightings of all primate species were recorded during the walk. For each sighting of the species, group location, group size, and age sex of the individuals in the group was recorded. More time was spent with the each sighting of a group of lion-tailed macaques to identify the characteristic animals in the group, and to collect the proper data on group size and age sex of individuals. Covariates such as canopy height and disturbance index were recorded at regular intervals of 250 m.

Canopy height: We collected the height of 10 largest trees at each sampling location on a trail. We averaged the height of those trees and treated that as an average canopy height. Further, we computed the mean height from all the averaged height from all the locations in the grid.

Disturbance index: We developed a matrix considering the rate of lopping, stumps, grazing pressure and human movement. Based on the scores (10 point scale), we considered degree of disturbance as high, medium and low.

We have used the vegetation map prepared by French Institute, Pondicherry for the entire Western Ghats, to estimate the proportion of forest type in each grid. The grid layer was laid on the classified map of the study area, and the area of each forest type in the grid was extracted. We then computed the proportion of forest type for each grid.

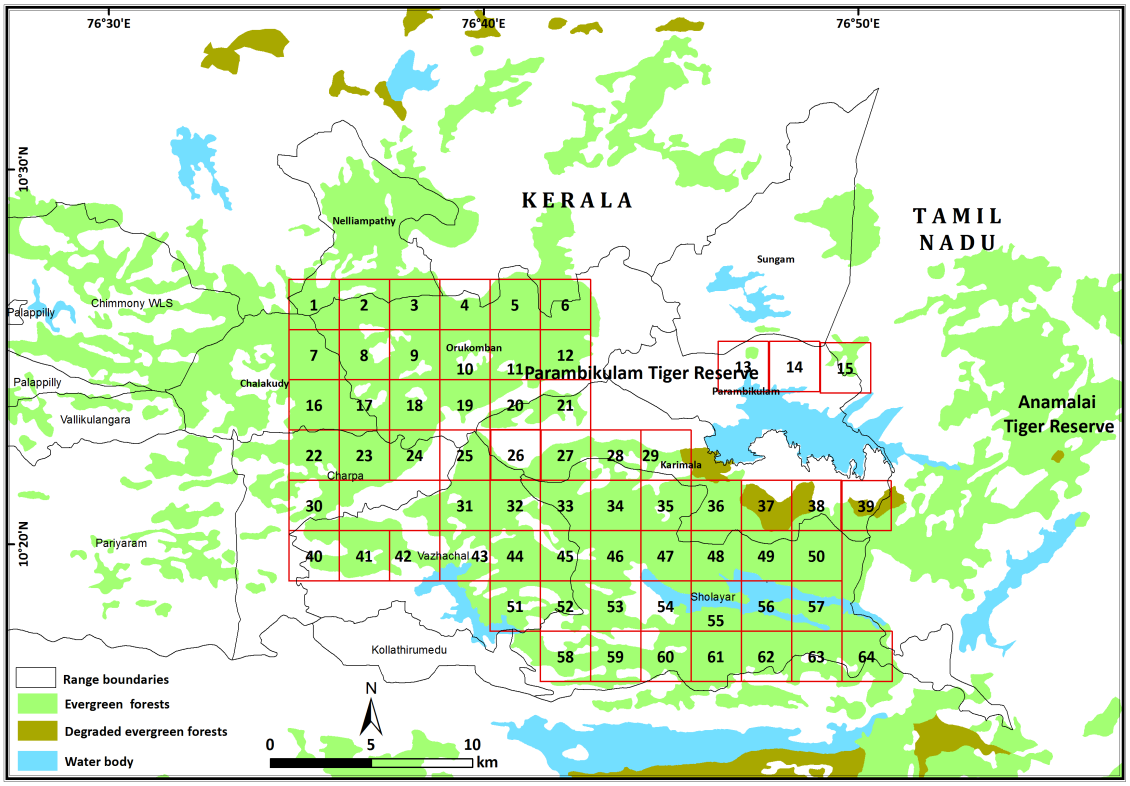

Figure 2 Sampling grids overlaid on evergreen forests of the Parambikulam Landscape

Analysis:

Abundance: number of groups encountered per km was calculated for each grid using data from temporal replications, and the mean encounter rate was computed from the encounter rate from each grid.

We were able to collect the data on complete group size and age sex of individuals only for few groups, and those data were used to calculate the mean group size and age-sex ratio for each species.

Occupancy modeling: The data from each temporal replication (four replicates) was considered as one sampling and the detection and non-detection of a species was recorded as '1' (detection) and '0' (non-detection). We constructed the detection histories for all the grids from four temporal replications. The probability that a grid is occupied by the species

(ψ) and the detection probability (p) were estimated using likelihood functions (MacKenzie et al. 2002). The data were analysed using single season models available in program PRESENCE -ver.3.0 (Hines 2006) to derive maximum likelihood estimates of model parameters.

Trail length (KM) and duration of the trail walk (DUR) were considered as covariates for detection probability, whereas proportion of evergreen forest in the grid (PEGF), mean canopy height (CANO) and disturbance index (DISTU) were considered as site covariates for species occupancy in the grid (Table 1). The influence of the covariates on occupancy (ψ) and detection probability (p) was explored. A logistic model with logit link and binomial error was employed to evaluate the effect of covariates on model parameters occupancy and detection probability. Effects of covariates on p were modelled first and then ψ was modelled.

Table 1 Predicted species response to each covariate based on our a priori hypotheses for LTM

Covariates	ψ	P
KM	+	+
DUR	0	+
PEGF	+	0
CANO	+	0
DISTU	-	0

KM: trail length; DUR: duration of the walk; PEGF: proportion of evergreen forests; CANO: Height of the canopy; DISTU: disturbance index. '+' signifies a positive effect on the response variable, '_' signifies a negative effect on the response variable and '0' signifies that the covariate has no effect on the response variable. ψ: probability of occurrence; p, species detection probability;

Since the trail length varied among the grids and also depending on various factors, the duration of the walk during each grid also varied. Thus, we expected that these factors will have impact on the detection of a species, and this factor was used to model p. Since the lion-tailed macaque is habitat specialist and inhabits narrow range of the evergreen forests, good canopy contiguity and canopy height were expected to be very crucial for the species since they are largely frugivorous and cover a long distances in the forest. Thus we

speculated that the proportion of evergreen forests and the height of the canopy would positively influence the 'inhabitance' of the species. However, these forests were historically highly exploited and further, people residing at both in and around the forest are dependent on various resources, these factors can have negative influence on the occurrence of the species. Thus we speculated the negative influence of disturbance on the species (Table 1).

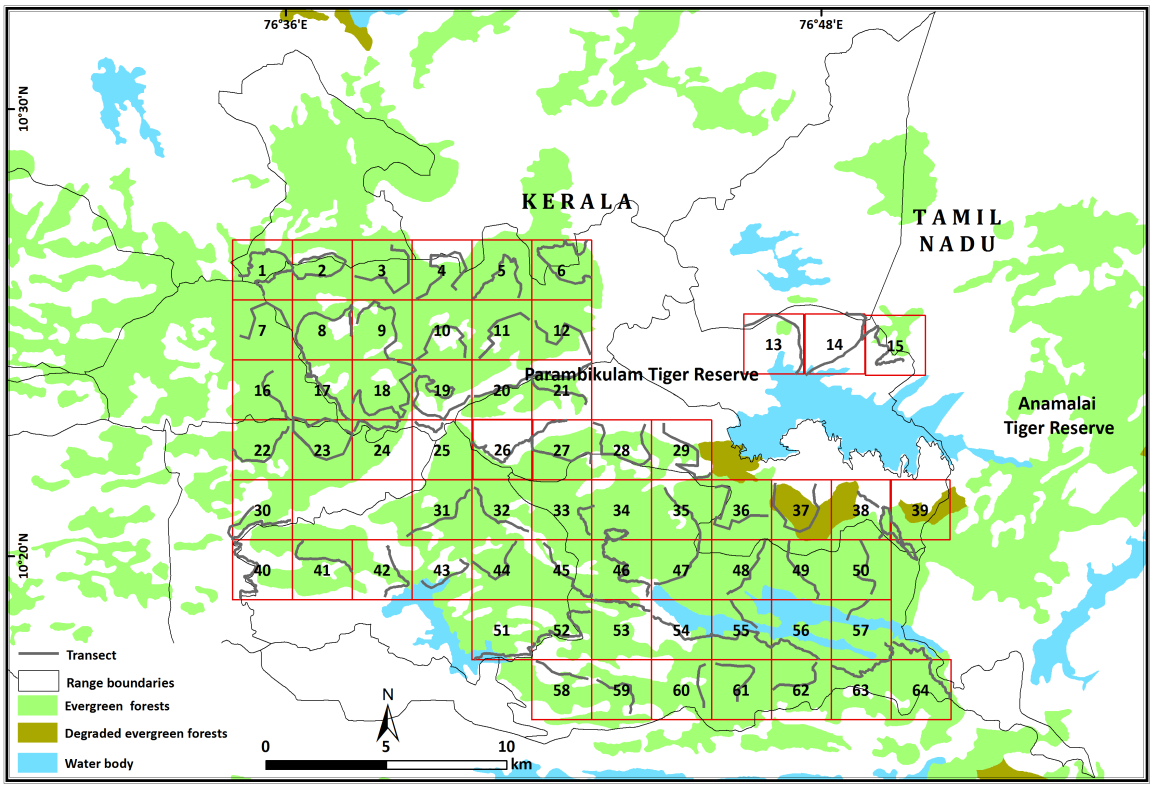

Figure 3 Map showing the trails that were used to walk in each grid in Parambikulam Landscape

Pair-wise correlation matrix did not identify presence of correlated covariates/predictors and hence all model selections were unbiased. Using this information, we formulated a candidate set of 10 *a priori* models to investigate the influence of covariates on occurrence. Model selection, computation of model weights and averaging of parameters followed the framework of Burnham and Anderson (1998). Models were tabulated in ascending order of ΔAIC_c values. Relative influence of each covariate was established through computation of model weights that were summed over all models containing the particular covariate (Burnham and Anderson 1998).

Sampling effort: A total of 274.5 km of trails was walked during the survey. The trail length varied from 2 to 7 km per grid depending on the terrain and feasibility. A total of 1098 km of walk was made during the survey in 64 grids.

Results

Abundance of primates in wet forests of the Parambikulam landscape: We had 28, 55 and 362 sightings of lion-tailed macaque, bonnet macaque and Nilgiri langur groups respectively. The relative encounter rate varied significantly between the species ($F_{2, 189}$ = 114.38, p <. 001). Nilgiri langurs were encountered in all the grids, whereas bonnet macaques and lion-tailed macaques were encountered only in 50% and 75% of the grids respectively. The relative encounter rate of Nilgiri langurs (0.36± 0.02) was more than that of bonnet macaques (0.06 ± 0.01) and lion-tailed macaques (0.03 ± 0.01) (Fig. 4).

Group size and age-sex composition of primates in wet forests of the Parambikulam landscape: We obtained data on age-sex and total count of the individuals in the group for few groups, which provided the mean group size of 18.00 ±8.52, 17.88±1.56 and 13.94 ±1.15 for lion-tailed macaques (LTM), Bonnet macaques (BM) and Nilgiri langurs (NL) respectively (Table 2). The proportions of different age - sex of the individuals are provided in Table 3, and the age sex of the lion-tailed macaque groups are provided in Table 4. Proportion of adult male in the group was 8.8, 14.0 and 10.0 in LTM, BM and NL respectively. Though the proportion of adult females in BM (49.7) was higher than in LTM (46.3) and NL (42.0), the proportion of infants was relatively lesser in BM (11.9) than in LTM (16.7) and NL (19.6). Number of adult females per adult male was 5.26, 3.55 and 4.20 in LTM, BM and NL respectively (Table 5). Both infants and immature per adult female were relatively lesser in BM (0.24 and 0.70) than in LTM (0.47 and 0.95) and NL (0.47 and 1.14).

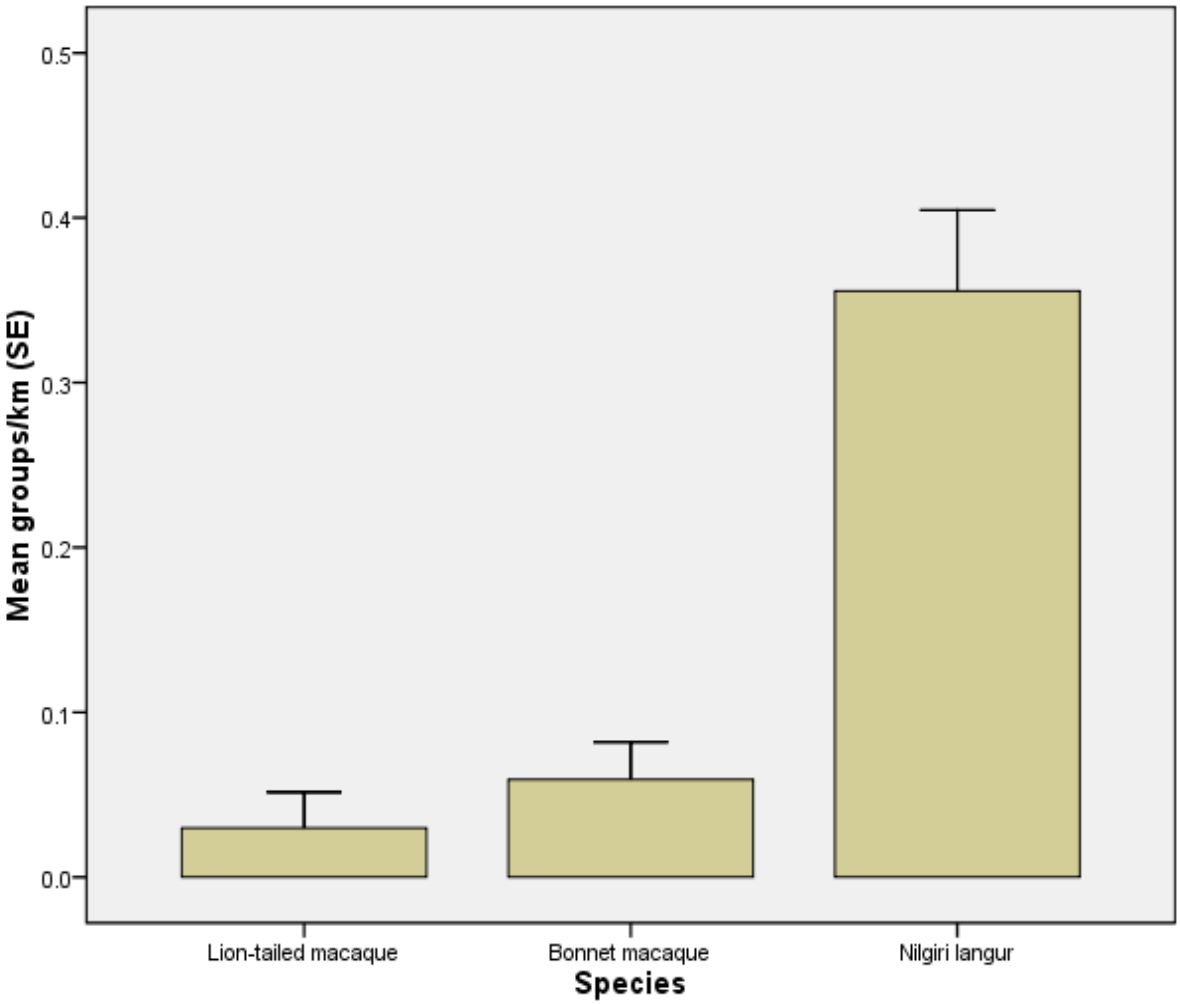

Figure 4 Relative encounter rates (mean groups/ km) of primates in the wet forests of Parambikulam landscape

Table 2 Group size of primates in wet forests of Parambikulam landscape

Species	Group size range	Mean group size (SD)
LTM (12)*	5-30	18.00 (8.52)
BM (8)*	11-23	17.88 (1.56)
NL (20)*	3-23	13.94(1.15)

*Number of groups for computing group size

Table 3 Percent of different age-sex class animals in the population of primates in wet forests of the Parambikulam landscape

Species		ADM	ADF	SAD	JUV	INF	Total
LTM (12)*	No. of individuals	19	100	12	47	36	214
	Mean/group	1.58	8.33	1.00	3.92	3.00	
	% of group	8.8	46.3	5.6	21.8	16.7	
BM (8)*	No. of individuals	20	71	10	23	17	141
	Mean/group	2.50	8.88	1.25	2.88	2.13	
	% of group	14.0	49.7	7.0	16.1	11.9	
NL (20)*	No. of individuals	25	105	17	54	49	250
	Mean/group	1.40	5.83	0.85	3.00	2.72	
	% of group	10.0	42.0	6.8	21.6	19.6	

*The data available on demography

Table 4 Group characteristics of lion-tailed macaques in Parambikulam landscape (data available only for 12 groups)

Groups	ADM	ADF	SAD	JUV	INF	Total
Orukumban1	2	8	1	2	4	17
Orukumban2	1	6	1	2	3	13
Orukumban3	1	3	0	1	0	5
Orukumban4	1	4	0	0	1	6
Vengoli	2	13	2	8	3	28
Padukutty	1	6	1	2	1	11
Karimala	1	7	1	4	2	15
Kottayali2	2	11	2	5	5	25
Kottayali1	3	14	1	9	3	30
Poopara	1	8	1	2	5	17
Shekalmudi	2	9	1	7	3	21
Porigalkuttu	2	11	1	5	6	28
Total	19	100	12	47	36	216
Mean/group	1.58	8.33	1.00	3.92	3.00	18.00
% of group	8.8	46.3	5.6	21.8	16.7	

Table 5 Age-sex ratios of primates in the wet forests of Parambikulam Landscape

Species	ADM/ADF	ADF/INF	ADF/IMM
LTM (12)*	1:5.26	1:0.47	1:0.95
BM (8)	1:3.55	1:0.24	1:0.70
NL (20)	1:4.20	1:0.47	1:1.14

*The data available on group size

Habitat factors affecting the occupancy of lion-tailed macaque in wet forests of the Parambikulam landscape: A total of 28 sightings of lion-tailed macaques in 16 grids were made during the sampling. The estimate for the detection probability was $0.31 \pm 0.07_{SE}$. Both the covariates (KM and DUR) did not influence the detection probability (w_i = 0.13(KM) and 0.05 (DUR)) (Table 6). Thus the subsequent models were run for the occupancy without them as a function of p. Various models were assessed to estimate occupancy rates which are presented in Table 7. Compared to few models, the ψ (.), p(.) model performed poorly, however, many other models also performed poorly with high AIC_c value.

None of the models from the analysis showed as best model and it was difficult to judge a single best model from all the models. Thus the model averaging was undertaken to estimate the occupancy rate. The occupancy estimate $\hat{\psi}$ and associated standard error $S\hat{E}$ were averaged across the models. This gave the estimate of $\hat{\psi}$ = $0.39 \pm 0.08_{SE}$. Each of the sampled grids was plotted for the lion-tailed macaque occurrence using the occupancy estimate from the first model (the model with lowest AIC_c value) (Fig. 5).

The summed model weights were computed to understand the relative influence of each covariate on occupancy; DISTU (0.54), CANO (0.50) and PEG (0.36) were the three main factors influencing the occupancy of lion-tailed macaques (Table 8). The β- coefficient shows that the DISTU (β = $-0.63 \pm 0.41_{SE}$) and PEG (β = $-0.38 \pm 0.29_{SE}$) has negative influence on the occupancy whereas the height of the canopy (CANO: β = $0.56 \pm 0.37_{SE}$) was positively correlated with the lion-tailed macaque occupancy.

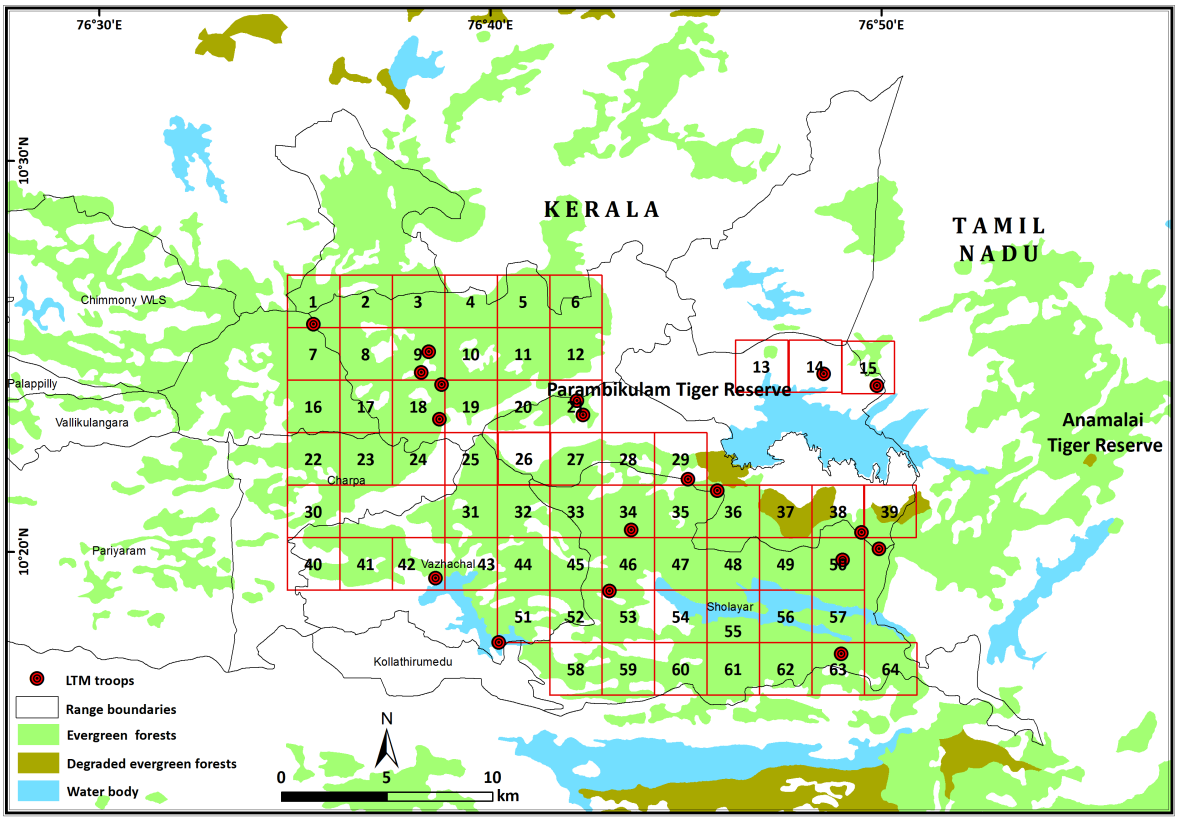

Figure 4 Location of lion-tailed macaque groups encountered in Parambikulam landscape

Table 6 Detection probability

Model	$\hat{p}$	AIC_c	ΔAIC_c	w_i	K
ψ (.), p(.)	0.31	157.04	0.00	0.81	2
ψ (.), p(KM)	0.27	160.68	3.64	0.13	3
ψ (.), p(DUR)	0.27	162.67	5.63	0.05	3

$\hat{p}$: is the estimated species detection probability; AICc: AIC corrected for small-sample bias; ΔAIC_c: difference in AICc values between each model and the model with the lowest AICc; wi: AICc model weight; K: number of parameters estimated by the model. KM: trail length; DUR: duration of the walk

Table 7 Model for occupancy for LTM

Model	$\hat{\psi}$	($S\hat{E}$)	AIC_c	ΔAIC_c	w_i	K
ψ (CANO, DISTU), p(.)	0.32	0.09	155.97	0	0.23	3
ψ (DISTU), p(.)	0.32	0.07	156.45	0.48	0.17	2
ψ (.), p(.)	0.31	0.07	157.04	1.07	0.13	2
ψ (PEG, CANO, DISTU), p(.)	0.32	0.11	157.08	1.11	0.13	4
ψ (PEG, DISTU), p(.)	0.32	0.09	157.42	1.45	0.11	3
ψ (CANO), p(.)	0.49	0.05	157.58	1.61	0.10	2
ψ (PEG, CANO), p(.)	0.49	0.11	159.11	3.14	0.04	3
ψ (PEG), p(.)	0.49	0.08	159.35	3.38	0.04	2
ψ (PEG, KM), p(.)	0.49	0.12	160.41	4.44	0.02	3

$\widehat{\psi}$:Estimated occupancy parameter; $S\hat{E}$: Associated standard error; AICc: AIC corrected for small-sample bias; ΔAIC_c: difference in AICc values between each model and the model with the lowest AICc; wi: AICc model weight; K: number of parameters estimated by the model. CANO: Canopy height; DISTU: Index of disturbance factor; PEG: proportion of evergreen forests; KM: trail length; DUR: duration of the walk

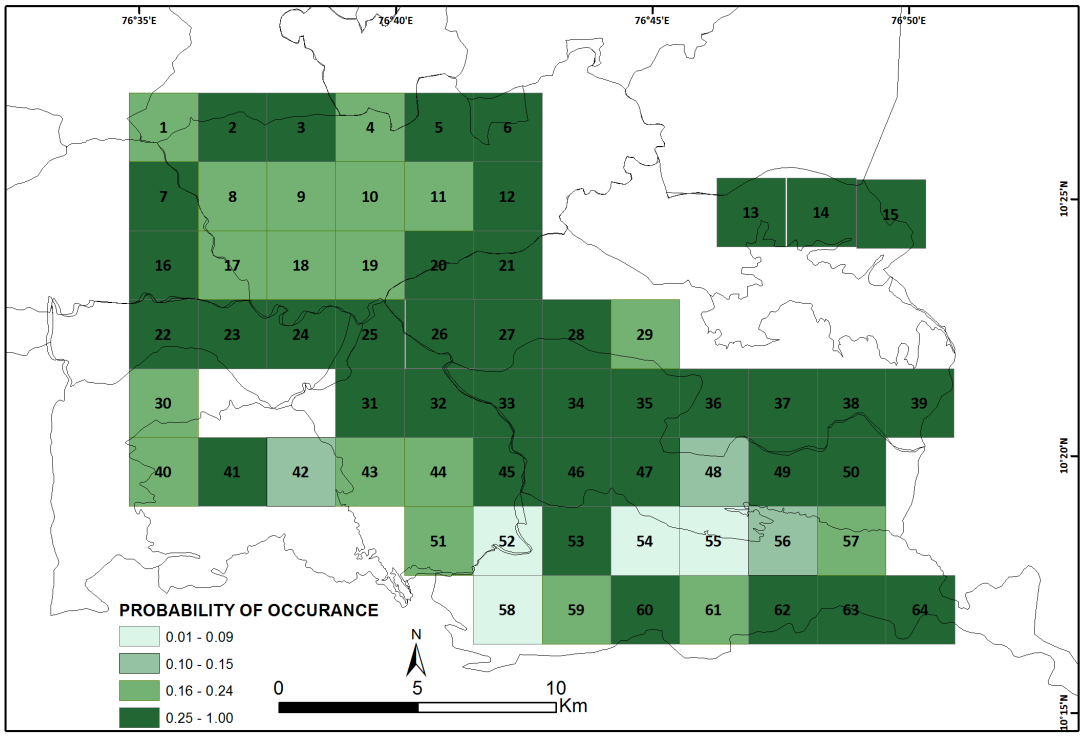

Figure 5 Rates of the lion-tailed macaque occupancy across the study site

Table 8 Covariates influencing the lion-tailed macaque occupancy ranked on the basis of summed model weights of covariates, with beta coefficient and associated standard error

Covariate	Summed AIC_c weights	β co-efficients	$S\hat{E}$
DISTU	0.54	-0.63	0.41
CANO	0.50	0.56	0.37
PEG	0.36	-0.38	0.29
KM	0.02	-0.44	0.43

Discussion

Parambikulam Wildlife Sanctuary has been upgraded as Tiger Reserve including many adjoining forest ranges which has a good forest cover with evergreen forests and semi-evergreen forests. This has established a connection with the Anamalai Tiger Reserve on south-east and reserve forests of Nelliampathy on north. The status of primates especially in evergreen forests has been established for Anamalai Tiger reserve (Singh et al, 1997a, b, 2002) and in Nelliapathy (Ramachandran and Suganthasakthivel 2010; Suganthasakthivel 2011). The present findings in the Parambikulam have filled the gap in our understanding of the primate distribution, and specifically status of lion-tailed macaques at this landscape level.

Nilgiri langur predominates and it is widely distributed in the study area and also in the entire landscape, whereas the lion-tailed macaque shows restricted distribution and lower abundance. The bonnet macaque is habitat generalists and it is found in a variety of habitats including evergreen forests, however, the abundance of them was relatively lesser than the Nilgiri langur but more than the lion-tailed macaque.

Though, the group size of lion-tailed macaques varied between 5 and 30, but the mean group size (18.0) remained relatively smaller than in Silent valley: 19.6 (Ramachandran and Joseph 2001), Sringeri: 20.1 (Singh et al. 2000) and Sirsi-Honnavara: 24.7 (Kumara and Singh

2004b) but more than Anamalai Hills: 16.3 (Singh et al. 2002), however, it is not too different from other regions.

Since the major focus of the study was to look at the factors determining the presence of the species within a major habitat of the lion-tailed macaque, the grids which were with large proportion of evergreen forests, semi-evergreen and moist deciduous forests were considered for the present study. We considered proportion of evergreen forests in the grid; canopy height and disturbance factors are the covariates for the occupancy of LTM. On the other-hand, trail length in each grid and duration of trail walk was considered as covariates for the detection function; however, they did not affect the detection function of the lion-tailed macaque as it was hypothesised. We considered site covariates (canopy height, % of evergreen forests and disturbance) for the occupancy modelling.

Both detection probability (0.31) and occupancy (0.39) of lion-tailed macaques was very low, which indicates the lion-tailed macaque has restricted distribution and it is rare in the study site. The predication is apparent, since the species is known to live in low density with large home range size (~5 sq. Km: Green and Minkowaski 1977)

Habitat heterogeneity is very high in Parambikulam due to earlier plantation activity. Thus, many of the grids have got different forest types including evergreen forests, semi-evergreen and moist deciduous forests. Few groups of lion-tailed macaques were also recorded from isolated evergreen forest fragments having other vegetation types including teak plantations and deciduous forests. Thus, among the three covariates, model shows that the proportion of evergreen forests negatively correlated with the occupancy of lion-tailed macaques which is against the one of *a priori* hypothesis, since, the species occupies the forest with different degree of proportion of evergreen forests.

The major determinants for the occupancy of lion-tailed macaques within the wet forests of the Parambikulam landscape were disturbance factors and the canopy height. Disturbance factor negatively correlated with the occupancy whereas the canopy height positively influenced the occupancy of lion-tailed macaques in the landscape. The major inference that can be drawn from this study is that within the habitat of the lion-tailed macaques, higher

canopy with relatively lesser disturbance level increases the occupancy of the lion-tailed macaque.

References

Burnham, K.P. and Anderson, D.R. (1998). *Model selection and inference: a practical information-theoretic approach.* Springer-Verlag, New York, USA.

Green, S.M. and Minkowski, K. (1977). The lion-tailed macaque and its south Indian rainforest habitat. In *Primate Conservation* (eds Bourne, G.H. and Rainier, H.S.H), Academic Press, New York, USA, pp. 289-337.

Hines, J.E. (2012). Program Presence (Version 3): Software to compute estimates patch occupancy rates and related parameters. USGS-PWRC, http//www.mbr-pwrc.usgs.gov/software/presence.html.

IUCN (2012). *IUCN Red List of Threatened Species Version 2012.2*. <www.iucnredlist.org>. Downloaded on 01 March 2013.

Joseph, G.K., and Ramachandran, K.K. (1998). Recent population trends and management of lion-tailed macaque (*Macaca silenus*) in Silent Valley National Park, Kerala, India. *Indian Forester* 124: 833-840.

Karanth, K.U. (1985). Ecological status of the lion-tailed macaque and its rainforest habitats in Karnataka, India. *Primate Conservation* 6:73-84.

Karanth, K.U. (1992). Conservation prospects for lion-tailed macaques in Karnataka, India, *Zoo Biology*, 11: 33-41.

Kumar, A., Umapathy, G. and Prabhakar, A. (1995). A study of the management and conservation of small mammals in fragmented rain forests in the Western Ghats, south India: a preliminary report. Primate Conservation, 16: 53–58.

Kumara, H.N. and Singh, M. (2004a). The influence of differing hunting practices on the relative abundance of mammals in two rainforest areas of the Western Ghats, India. *Oryx* 38: 321-327.

Kumara, H.N. and Singh, M. (2004b). Distribution and abundance of primates in rainforests of the Western Ghats, Karnataka, India and the conservation of *Macaca silenus*. *International Journal of Primatology* 25: 1001-1018.

Kumara, H.N. and Sinha, A. (2009). Decline of the endangered lion-tailed macaque in the Western Ghats, India. *Oryx* 43:292-298.

MacKenzie, D.I., Nichols, J.D., Lachman, G.B., Droege, S., J.A. and Langtimm, C.A. (2002). Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, 83: 2248–2255.

Molur, S., Brandon-Jones, D., Dittus, W., Eudey, A., Kumar, A., Singh, M., Feeroz, M.M., Chalise, M., Priya, P., Walker, S. (2003). *Status of South Asian Primates: Conservation Assessment and Management Plan (C.A.M.P.) Workshop Report, 2003.* Zoo Outreach Organisation/CBSG-South Asia, Coimbatore.

NRC (NATIONAL RESEARCH COUNCIL) (1981). Techniques for the Study of Primate Population Ecology. National Academy Press, Washington, DC, USA.

Ramachandran, K.K., and Joseph, G. (2001). Distribution and demography of diurnal primates in Silent Valley National Park and adjacent areas, Kerala, India. *Journal of Bombay Natural History Society* 98:191-196.

Ramachandran, K.K. and Suganthasakthivel, R. (2010). Ecology and behaviour of the arboreal mammals of the Nelliampathy forests. KFRI Research Report No. 382.

Singh, M., Singh, M., Kumar, M.A., Kumara, H.N. and D`Souza, L. (1997a). Distribution andresearch potential of non-human primates in the Aliyar-Valparai sector of Indira Gandhi Wildlife Sanctuary, Tamil Nadu, India. *Tropical Biodiversity* 4: 197-208.

Singh, M., Singh, M., Kumara, H.N., Kumar, M.A. and D`Souza, L. (1997b). Inter-and intra-specific associations of non-human primates in Anaimalai hills, south India. *Mammalia* 61: 17-28.

Singh, M., Kumara, H.N., Kumar, M.A., Sharma, A.K. and Defalco, K. (2000). Status and conservation of lion-tailed macaque and other arboreal mammals in tropical rainforests of Sringeri Forest Range, Western Ghats, Karnataka, India. *Primate Report* 58: 5-16.

Singh, M., Kumara, H.N., Kumar, M.A. and Sharma, A.K. (2001). Behavioral responses of lion-tailed macaque (*Macaca silenus*) to a changing habitat in a rain forest fragment in Western Ghats, India. *Folia Primatologica* 72: 278-291.

Singh, M., Singh, M., Kumar, M. A., Kumara, H.N., Sharma, A.K. and Kaumanns, W. (2002). Distribution, population structure and conservation of lion-tailed macaque (*Macaca silenus*) in Anaimalai hills, Western Ghats, India. *American Journal of Primatology* 57: 91-102.

Suganthasakthivel, R. (2011). Ecology and behaviour of selected arboreal mammals in the southern Western Ghats, India. PhD thesis submitted to FRI University, Dehra Dun.

Sushma, H.S., Rohini, M., Kumara, H.N. and Udhayan, A. (Communicated). Status of the endangered lion-tailed macaque *Macaca silenus* in Kalakad-Mundanthurai Tiger Reserve, India. (IJP)

Whitesides, G.H., Oates, J.F., Green, S.M. and Kluberdanz, R.P. (1988). Estimating primate densities from transects in a West African rain forest: a comparison of techniques. *Journal of Animal Ecology* 57:345-367.

White, L. and Edwards, A. (2000). *Conservation research in the African rain forests*: a technical handbook, Wildlife Conservation Society, New York.