Int J Primatol (2014) 35:976–989
DOI 10.1007/s10764-014-9776-2

Distribution, Demography, and Conservation of Lion-tailed Macaques (*Macaca silenus*) in the Anamalai Hills Landscape, Western Ghats, India

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Received: 16 December 2013 / Accepted: 11 March 2014 / Published online: 10 May 2014
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Abstract The status of the endemic and endangered lion-tailed macaque (*Macaca silenus*) has not been properly assessed in several regions of the Western Ghats of southern India. We conducted a study in Parambikulam Forest Reserve in the state of Kerala to determine the distribution, demography, and status of lion-tailed macaques. We laid 5km^2 grid cells on the map of the study area (644km^2) and made four replicated walks in each grid cell using GPS. We gathered data on lion-tailed macaque group locations, demography, and site covariates including trail length, duration of walk, proportion of evergreen forest, height of tallest trees, and human disturbance index. We also performed occupancy modeling using PRESENCE ver. 3.0. We estimated a minimum of 17 groups of macaques in these hills. Low detection and occupancy probabilities indicated a low density of lion-tailed macaques in the study area. Height of the tallest trees correlated positively whereas human

Electronic supplementary material The online version of this article (doi:10.1007/s10764-014-9776-2) contains supplementary material, which is available to authorized users.

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disturbance and proportion of evergreen forest correlated negatively with occupancy in grid cells. We also used data from earlier studies carried out in the surrounding Anamalai Tiger Reserve and Nelliyampathy Hills to discuss the conservation status in the large Anamalai Hills Landscape. This landscape harbors an estimated population of 1108 individuals of lion-tailed macaques, which is about one third of the entire estimated wild population of this species. A conservation plan for this landscape could be used as a model for conservation in other regions of the Western Ghats.

Keywords Anamalai Tiger Reserve · Anamalai Hills landscape · Conservation · Lion-tailed macaque · Nelliyampathy Hills · Parambikulam · Western Ghats

Introduction

Many species of mammals, especially primates, are becoming increasingly threatened due to changes in their habitats (Primack 2006). There is a need for ecological studies examining species–habitat relationships in the context of changing habitat conditions and increasing anthropogenic pressures on the existing forested landscapes. Such investigations are critical for species that are endemic to narrow ranges of forests. One such species is the lion-tailed macaque (*Macaca silenus*), a primate endemic to the rain forests of the Western Ghats, southern India (Kumar 1987). Rain forest fragmentation and habitat deterioration in the Ghats have affected the range and the population structure of the lion-tailed macaque severely (Kumara and Sinha 2009; Singh et al. 2009). This species has been classified as Endangered (IUCN 2013) because of its selective feeding habits, limited range of occupancy (*ca*. 2500 km^2), low population turnover, and the small number of individuals remaining in the wild (Singh et al. 2009). The remaining population is distributed in 49 subpopulations isolated in rainforest fragments at eight locations (Molur et al. 2003). Viable populations of lion-tailed macaques occur only in very few regions (Kumara and Sinha 2009), and the conservation status of this species is likely to differ across these populations.

Although the lion-tailed macaque has been reported to occur in the evergreen forests of the Western Ghats (Molur et al. 2003), our field experience with this species over several decades led us to believe that the actual areas occupied by the species were far smaller than the total ranges of the rain forests. Further, most of the lion-tailed macaque's natural habitats have been logged and converted to monoculture plantations

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(Ramachandran and Suganthasakthivel 2010). The most suitable habitat for lion-tailed macaques, therefore, may be fragmented within the habitat matrix and highly influenced by various anthropogenic activities.

The Anamalai Hills Landscape in the southern Indian states of Kerala and Tamil Nadu is made up of Parambikulam Forest Reserve, the Anamalai Tiger Reserve, and Nelliyampathy Hills. A large part of Parambikulam has recently been declared as a Tiger Reserve (Ministry of Environment and Forests 2008). These hills have a long history of logging, and a large proportion of the natural vegetation has been converted to monoculture plantations of teak *Tectona grandis* (Sasidharan 2002). However, the region still retains some suitable tracts of evergreen forests. Lion-tailed macaques are found throughout this landscape. The status of lion-tailed macaques in Anamalai Tiger Reserve has been monitored since 1985 (Kumar 1987; Singh et al. 1997a, b, 2002; Kumar et al. 1995; Umapathy et al. 2011), whereas the population in Nelliyampathy Hills was assessed systematically only recently (Ramachandran and Suganthasakthivel 2010; Suganthasakthivel 2011). The population in Paramabikulam has not been systematically assessed. Hence, we assessed the status of lion-tailed macaques and the factors correlating with their occurrence in the evergreen forests of Parambikulam between October 2010 and May 2012, and used data from earlier studies in the other two Reserves to assess the conservation status of lion-tailed macaques in the entire Anamalai Hills landscape. The lion-tailed macaque is a habitat specialist, largely frugivorous and covers a long distance in the forest each day (Kumar 1987). We therefore expected contiguity of the canopy and height of the tallest trees to be crucial determinants for the species. We predicted that the proportion of evergreen forests and the height of the tallest trees would positively influence the likelihood of "inhabitance" of the species. However, exploitation of these forests and the dependence of local people on forest resources can have negative influence on the occurrence of the species. Thus we predicted that the "human disturbance index" would have a negative influence on the species' occurrence.

Methods

Study Area

We conducted our study in Nemmara, Chalakudy, and Vazhachal Forest Divisions and Parambikulam Tiger Reserve between October 2010 and May 2012. The study area lies between 76°34′ –76°50′ E and 10°16′ –10°27′N (Fig. 1). The altitude of the study site varies between 300 m and 2000 m asl. Annual rainfall varies spatially between 400 and 3200 mm, and the mean annual rainfall is 2000 mm, received mostly during the monsoons (June–October). The major vegetation types include tropical evergreen, semi-evergreen, moist deciduous, dry deciduous, bamboo, and reed brakes (Sasidharan 2002). Details of Anamalai Tiger Reserve and Nelliyampathy Hills are available in Singh et al. (2002), and Ramachandran and Suganthasakthivel (2010) and Suganthasakthivel (2011) respectively.

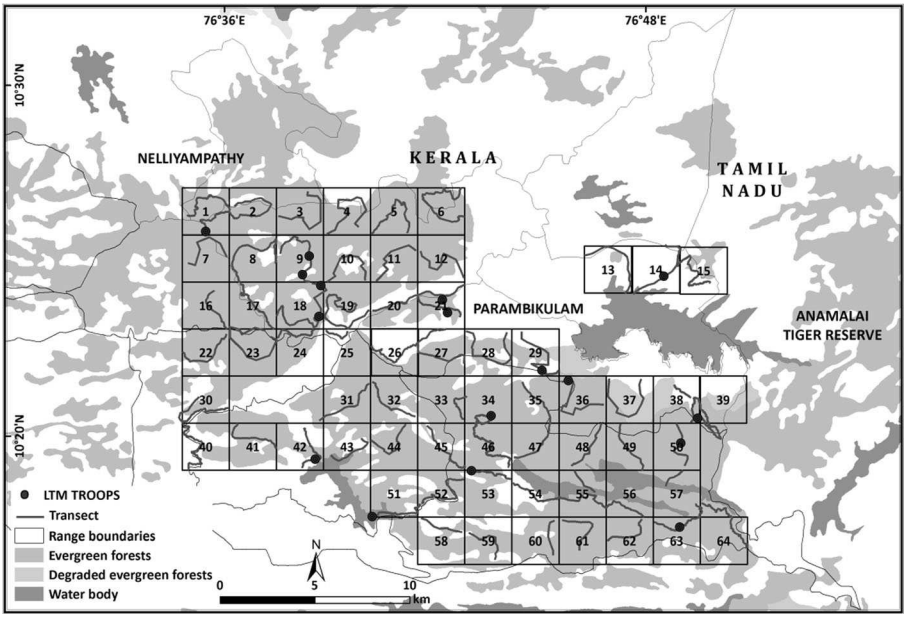

Fig. 1 Map of Parambikulam Hills with locations of grids, map of grid walks (wavy lines in each grid cell), and locations of lion-tailed macaque groups (round dots) between 2010 and 2012.

Survey Design and Data Collection

Lion-tailed macaques occur in low densities in the wild and are restricted to narrow strips of rain forests in the Western Ghats (Singh et al. 2009). Thus the estimation of their density using line transect surveys or distance sampling requires enormous efforts due to low detectability. Laying transect lines is often not possible over much of the species' range. The total count method (NRC 1981) has been widely adopted to estimate populations of such rare and patchily distributed species (White and Edwards 2000; Whitesides et al. 1988). We laid a 5 km^2 grid over the landscape of the study area to divide it into blocks. Among these blocks, we selected 64 grid cells for intensive survey based on vegetation cover dominated by evergreen forests, and leaving out a few patches of monoculture plantations generally not inhabited by lion-tailed macaques (Fig. 1). We made four replicated walks in each grid cell using existing trails or animal paths of varying length. We walked a total length of 274.5 km of trails during the survey. Trail lengths varied 2–7 km per grid cell depending on the terrain and feasibility. The four replicated walks on each trail amounted to a total walk of 1098 km over the course of the study. We tracked the route we used to walk using a handheld GPS, and mapped and measured it using GIS software (Fig. 1). We either sighted macaque groups directly or found them after hearing vocalizations. For each sighting, we spent 15–20 min with the group to collect data on group location, group size and age/sex composition.

We recorded the following site covariates including height of the tallest trees and human disturbance index at regular intervals of 250 m.

Height of the Tallest Trees. Because lion-tailed macaques largely forage in the upper parts of the canopy (Singh et al. 2011; Sushma and Singh 2006), we measured the height of the 10 tallest trees using Nikon Forestpro Laser Rangefinder at each sampling location on each trail. We took the mean height of these trees as height of the tallest trees. Further, we computed the mean of the height of the tallest tress for all locations in the grid.

Human Disturbance Index We used data on lopping, human movement, presence of stumps, and grazing in each grid cell and used these data to categorize human disturbance as high, medium, and low. At each location, we recorded the occurrence of lopping and movement of people on a 10-point scale. The scoring of 1–10 was done considering the proportion of locations with these signs (0: 0; 10 %: 1; 20 %: 2; 30 %; 3……100 % of locations: 10). Presence of stumps and grazing was recorded as Yes or No: Yes = 4, No = 0. However, we could not follow the same method as that for lopping and movement of people for stumps and grazing because grazing was lesser in the thick vegetation and more in the islands of grasslands in between the forest patches where cattle was taken through the existing trails. Further, the tree cutting was on either side of the trail which we failed to represent in the locations on regular intervals, though prevalent. Thus, we represented overall presence of cattle movement or stumps in any part of the grid or trail. The total scores of ≤6, 7–15, and ≥16 were categorized as Low, Medium and High disturbance respectively.

Forest Type We used the vegetation map prepared by the French Institute Pondicherry for the Western Ghats (Ramesh et al. 2002) to estimate the proportion of forest type in each grid cell. We laid the grid layer on the classified map of the study area, and extracted the area of each forest type in the grid cell, then computed the proportion of forest type for each grid cell.

Data Analysis

Abundance We calculated mean group encounter rate for each grid cell from the encounters during the four replicated walks. We then used the mean values from each grid cell to calculate group encounter per km of trails. We were able to collect the data on complete group size and age/sex of individuals for 12 groups and used these data to calculate the mean group size and age/sex composition.

Occupancy Modeling We considered the data from each temporal replication (four replicates) as one sample and recorded the detection of lion-tailed macaques as 1 and non-detection as 0. We constructed the detection histories for all the grid cells from the four replications. We estimated the probability that a grid cell is occupied by the species (ψ) and the detection probability (p) using likelihood functions (MacKenzie et al. 2002). We analyzed the data using single season models in PRESENCE ver. 3.0 (Hines 2012) to derive maximum likelihood estimates of model parameters.

We considered trail length (KM) and duration of the trail walk (DUR) as covariates for detection probability, and proportion of evergreen forest in the grid cell (PEGF), mean height of the tallest trees (HTT), and human disturbance index (DISTU) as site

covariates for species occupancy in the grid cell (Table I). We employed a logistic model with logit link and binomial error to evaluate the effect of these covariates on detection probability (p), and then occupancy (ψ).

The duration of the walk in each grid cell varied due to variation in trail length, so we used this factor to model p. We inspected pairwise correlation of model predictors and found no cases of strong colinearity that would have prohibited modeling both predictors in one model. We then 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). We tabulated models in ascending order of ΔAIC_c values. We established the relative influence of each covariate through computation of model weights summed over all models containing the particular covariate (Burnham and Anderson 1998).

Landscape Level Analysis We used data from Anamalai Tiger Reserve (Singh et al. 2002; Umapathy et al. 2011) and Nelliyampathy Hills (Ramachandran and Suganthasakthivel 2010; Suganthasakthivel 2011) to examine population characteristics and conservation issues at the landscape level. Group size data was available for 48 groups (IGTR: 23; Parambikulam: 12; Nelliyampathy: 13) and data on age/sex composition of groups was for 39 groups (IGTR: 18; Parambikulam: 12; Nelliyampathy: 9). For the purpose of analysis, we categorized individuals as adult males, adult females, and immatures (subadults, juveniles, and infants).

Many lion-tailed macaque groups are restricted to isolated fragments in the landscape owing to monoculture plantation or earlier forest operations and construction of dams (Singh et al. 2002). We categorized the groups living in forest sizes of <2500 ha as occupying fragments and in >2500 ha as occupying continuous forest. We explored the data to examine how isolation affected demographic parameters. We considered fragments and areas of continuous forests as isolated from each other irrespective of interfragment distance because lion-tailed macaques do not use tree-less matrix between fragments (Kumar et al. 1995). We used ANOVA to compare group size, number of adult males, adult females, and immatures between the three study sites; t-tests to compare group size and age/sex ratios between fragments and continuous forests (data were normally distributed); and Mann–Whitney U tests to compare the mean number of individuals in each age/sex class per group between fragments and continuous forests

Table I Predicted species response to each covariate based on our a priori hypotheses for lion-tailed macaques

Covariates	ψ	p
Trail length (KM)	+	+
Duration of walk (DUR)	0	+
Proportion of evergreen forest (PEGF)	+	0
Height of tallest trees (HTT)	+	0
Human disturbance index (DISTU)	−	0

+ 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.

(data were not normally distributed). We used a χ^2 test to compare the number of adult males, adult females, and immatures across the three study sites, and to compare the proportions of adult males, adult females, and immatures and age/sex ratios per group across the three study sites.

Results

Abundance and Population Characteristics in Parambikulam

We recorded 28 sightings of lion-tailed macaque groups with an encounter rate of 0.03 ± SD 0.01/km. We estimated a minimum of 17 groups in the Parambikulam Landscape (Fig. 1). The mean group size was 17.8 ± SD 8.5 individuals, with 1.6 males, 8.3 females, and 7.9 immature individuals per group (Table II).

Habitat Factors Affecting the Occupancy of Lion-Tailed Macaques in Parambikulam

The overall estimate for the detection probability was 0.31 ± SE 0.07, indicating a *ca.* 31 % chance of locating macaques if they were present in the area. Neither trail length nor duration of the trail walk influenced detection probability ($w_{i\ (KM)} = 0.13$, w_i (DUR) = 0.05; Table III) so we ran subsequent models without KM and DUR as a function of p.

It was difficult to judge a single best model from all the models (Table IV). The mean occupancy estimate across the models was $\widehat{\psi} = 0.39 \pm \text{SE } 0.08$. We plotted each

Table II Group characteristics of lion-tailed macaques in Parambikulam landscape between 2010 and 2012 (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	22
Porigalkuttu	2	11	1	5	6	25
Total	19	100	12	47	36	214
Mean/group	1.58	8.33	1.00	3.92	3.00	17.83
% of group	8.8	46.3	5.6	21.8	16.7	

ADM = adult male; ADF = adult female; SAD = subadult; JUV = juvenile; INF = infant.

Table III Detection probability

Model	$\widehat{p}$	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

$\widehat{p}$ = 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; w_i = AICc model weight; K = number of parameters estimated by the model; KM = trail length; DUR = duration of the walk.

of the sampled grid cells using the occupancy estimate from the model with lowest AIC_c value (Fig. 2).

Of the five site covariates, the three main factors influencing the occupancy of lion-tailed macaques were human disturbance index, mean height of the tallest trees, and proportion of evergreen forest in the grid cell (Table V). The disturbance index and proportion of evergreen forest had a negative influence on the occupancy whereas the height of the tallest trees correlated positively with occupancy.

Lion-Tailed Macaques in the Anamalai Hills Landscape

Although some groups are isolated in forest fragments, lion-tailed macaque populations in Parambikulam, Anamalai Tiger Reserve, and Nelliyampathy Hills are contiguous across much of the landscape (Fig. 3). Group size ranged from 4 to 90 individuals. However, group size was <20 for 73 % of the 48 groups, and only 4 groups had >30 individuals. A total of 844 individuals were recorded in 48 groups, and mean group size was 17.6 ± SD 13.5 (Table VI). We extrapolated the mean group size for the remaining

Table IV Model for occupancy for lion-tailed macaques

Model	$\widehat{\psi}$	S $\widehat{E}$	AIC_c	ΔAIC_c	w_i	K
ψ (HTT, 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, HTT, 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 (HTT), p(.)	0.49	0.05	157.58	1.61	0.10	2
ψ (PEG, HTT), 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 $\widehat{E}$ = 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 = w_i = AICc model weight; K = number of parameters estimated by the model; HTT = height of tallest trees; DISTU = index of disturbance factor; PEG = proportion of evergreen forests; KM = trail length; DUR = duration of the walk.

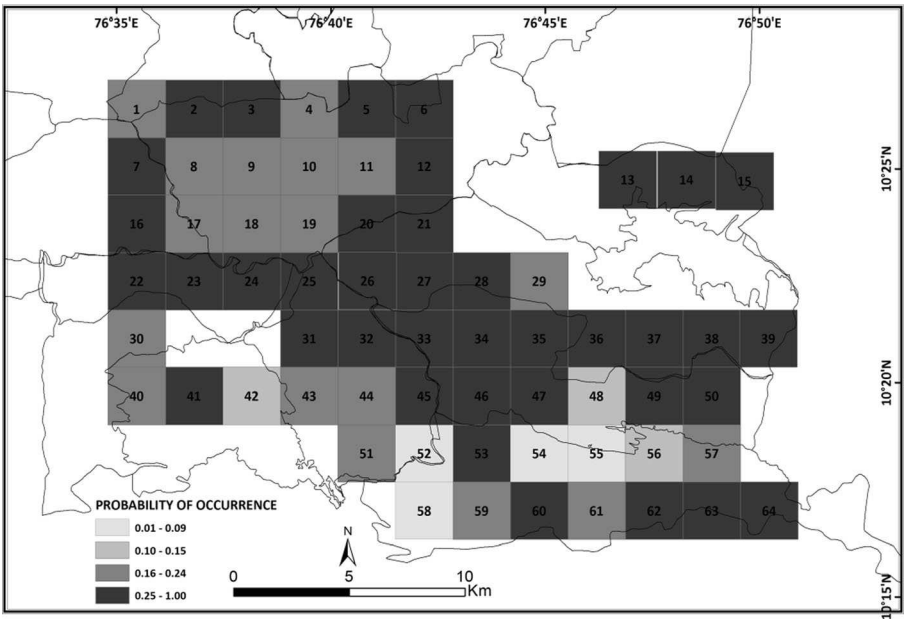

Fig. 2 Rates of lion-tailed macaque occupancy at Parambikulam between 2010 and 2012.

15 groups, giving a total of 264 individuals, and an estimated population size of 1108 lion-tailed macaques in the Anamalai Hills landscape.

Mean group size did not vary significantly between the three hill systems (Table 6). Nor did the mean number of adult males, adult females and immature individuals differ among the three sites. The proportion of adult males, adult females, and immatures per group, and the ratio of adult males to adult females did not vary between the sites. However, the ratio of females to immatures did differ across sites, and was highest in Anamalai Tiger Reserve, followed by Nelliyampathy Hills and Parambikulam.

The mean group size in forest fragments (23.1 ± SD 19.6) was higher than in continuous forests (14.3 ± SD 6.2, $t = 2.30$, df = 46, $P < 0.05$) (Fig. 4). Mean numbers of adult males ($U = 95.0$, $N = 39$, $P < 0.01$), adult females ($U = 98.5$, $N = 39$, $P < 0.01$), and immatures ($U = 76.0$, $N = 39$, $P < 0.01$) per group were higher in forest fragments than in continuous forests (Fig. 4). However, the proportion of adult male/adult female and adult female/immature did not vary ($t = 0.02$, df = 37, $P < 0.98$ and $t = 1.81$, df =37, $P < 0.08$ respectively) between forest fragments and continuous forests.

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

Covariate	Summed AIC_c weights	β coefficients	S $\widehat{E}$
Human disturbance index (DISTU)	0.54	−0.63	0.41
Height of tallest trees (HTT)	0.50	0.56	0.37
Proportion of evergreen forest (PEG)	0.36	−0.38	0.29
Trail length (KM)	0.02	−0.44	0.43

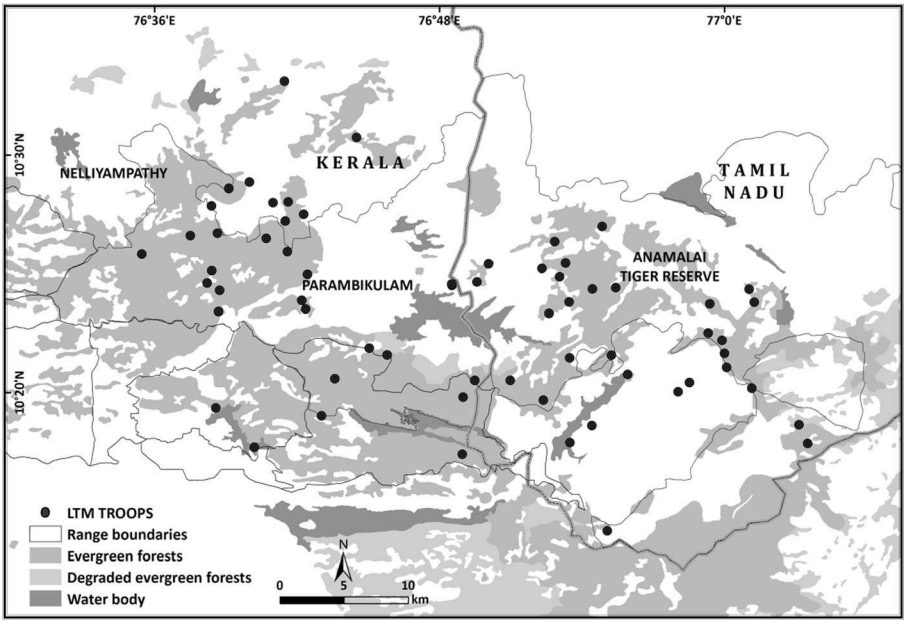

Fig. 3 Locations of lion-tailed macaque groups in the Anamalai Hills landscape that includes Parambikulam (2010–2012), Anamalai Tiger Reserve (1994–2001), and Nelliyampathy Hills (2004–2008).

Discussion

Paramabikulam harbors an estimated 17 groups of lion-tailed macaques with a mean group size of 17.8. Low detection and occupancy indicated rarity of this species in the study region. Human disturbance and height of the tallest trees were the major determinants of occupancy. Both detection probability (0.31) and occupancy (0.39) of lion-tailed macaques were very low, which indicates the lion-tailed macaque is rare in the study site. This is in line with earlier reports that the species occurs at a low density with large home range size of *ca.* 5 km^2 (Green and Minkowski 1977). The present findings from the Parambikulam Tiger Reserve fill a gap in our understanding of the distribution of the lion-tailed macaque at landscape level. The group size of lion-tailed macaques at Parambikulam varied from 5 to 30 and the mean group size (17.8) was similar to that of other major lion-tailed macaque localities, including Silent Valley (19.6: Ramachandran and Joseph 2001), Sringeri (20.1: Singh et al. 2000), and Sirsi-Honnavara (24.7: Kumara and Singh 2004a) and Anamalai Hills (16.3: Singh et al. 2002).

Habitat heterogeneity is very high in Parambikulam owing to earlier plantation activity (Sasidharan 2002). Thus, many of the grid cells had different forest types including evergreen, semi-evergreen, and moist deciduous forests. We recorded few groups of lion-tailed macaques in isolated evergreen forest fragments with mixed vegetation types. Thus, the selected model shows that the proportion of evergreen forests correlated negatively with lion-tailed macaque occupancy, opposite to our prediction. This is surprising, and we suggest that the history of human disturbance has altered the forest structure, and a study of the availability of food resources in

Table VI Population characteristics of lion-tailed macaque in three hills of the Anamalai Hills landscape (Anamalai Tiger Reserve 1994–2001; Parambikulam 2010–2012; Nelliyampathy 2004–2008)

Parameters	Anamalai TR	Parambikulam Tiger Reserve	Nelliyampathy	Total	Test statistics	*P*
Minimum number of groups	32	17	14	63		
N for group size	23	12	13	48		
Mean group size (SD)	18.78 ± 17.15	17.83 ± 8.29	15.23 ± 9.91	17.58 ± 13.46	$F_{2,45} = 0.28$	<0.76
Min–max group size	6–90	5–30	4–39	4–90		
N for demography parameters	18	12	9	39		
Adult male (ADM)						
No. of ADM	39	19	11	69		
Min–max no. of ADM in the group	1–7	1–3	1–2	1–7		
Mean ADM/Gr	2.17	1.58	1.22	1.77	$F_{2,36}$=2.49	<0.10
Proportion of ADM/Gr	0.10	0.09	0.08	0.09	χ^2=0.93	<0.63
Adult female (ADF)						
No. of ADF	144	100	62	306		
Min–max no. of ADF in the group	3–36	3–14	2–17	2–36		
Mean ADF/Gr	8.00	8.33	6.89	7.85	$F_{2,36}$=0.15	<0.86
Proportion of ADF/Gr	0.39	0.47	0.44	0.42	χ^2=4.02	<0.13
Adult immature (IMM)						
No. of Imm	190	95	67	352		
Min–max no. of Imm in the group	2–47	1–13	1–20	147		
Mean Imm/Gr	10.56	7.92	7.44	9.03	$F_{2,36}$=0.63	<0.54
Proportion of Imm/Gr	0.51	0.44	0.48	0.48	χ^2=2.35	<0.31
Age/sex ratios						
ADM/ADF	3.67	5.39	5.44	4.61	χ^2=3.24	<0.20
ADF/Imm	1.35	0.87	1.02	1.13	χ^2=50.72	<0.01

different forest types at present may help to understand why the presence of lion-tailed macaques correlated negatively with proportion of rain forest. The major determinants of lion-tailed macaque occupancy in Parambikulam were the degree of human disturbance (which had a negative impact) and height of the tallest trees (which had a positive impact). These factors can also be considered as a proxy for other regions where such systematic study of habitat covariates has not been undertaken.

Lion-Tailed Macaques in the Anamalai Hills Landscape

Only a few regions in the Western Ghats harbor >10 groups of lion-tailed macaques within a contiguous forest: *ca.* 30 groups in Kalakad-Mundanthurai Tiger Reserve (Sushma et al. 2010), *ca.* 32 groups in the forests of Sirsi-Honnavara (Kumara and

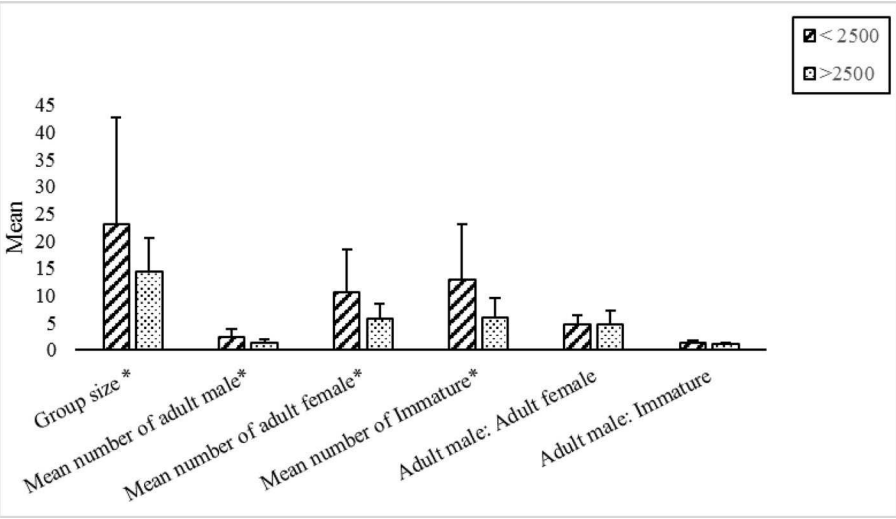

Fig. 4 Mean number and ratio for various demographic parameters in forest fragments (<2500 ha) and in continuous forests (>2500 ha).

Singh 2004b), and *ca.* 14 groups in Silent Valley National Park (Joseph and Ramachandran 1998). Because the forests of Parambikulam, Anamalai Tiger Reserve and Nelliyampathy Hills are contiguous, this landscape harbors ≥48 groups of lion-tailed macaques. Of the *ca.* 3500 estimated individuals in the wild (Molur et al. 2003), this landscape accounts for nearly one third of the population, with 1108 estimated individuals. The region, therefore, is of special importance for lion-tailed macaque conservation. However, some of the groups are restricted to forest fragments, resulting in a substantial variation in the adult female to immature ratio across the three sites. Nearly 80% of the isolated groups in the entire landscape are found in the Anamalai Tiger Reserve. The dispersal of individuals appears to be more restricted across the fragmented habitats of Anamalai Tiger Reserve than in the other two sites. Absence of dispersal of males between the forest fragments is likely the major reason for variation in the demographic parameters and the increased numbers of males in the lion-tailed macaque groups of Anamalai Tiger Reserve (Singh et al. 2002). However, if we consider the entire population of the Anamalai Hills Landscape, group size and mean number of adult males, adult females, and immatures was higher in forest fragments than in continuous forests.

The Anamalai Hills Landscape provides a representative sample of the Western Ghats complex, with rain forest fragments, several hydropower dams, tea and coffee plantations, commercial plantations of teak and eucalyptus, and a history of human disturbance. The major challenge of conservation in this region is to manage the human activities within the forest fragments. Two important conservation steps required at this stage are 1) enhancing the quality of resources in the fragments (Kumar et al. 1995) and 2) linking the forest fragments with corridors that may facilitate dispersal of monkeys (Singh et al. 2002). Based on satellite data, Anitha et al. (2013) have identified potential wildlife corridors in the fragmented Valparai Plateau region of the Anamalai Tiger Reserve where the forest fragments are interwoven with a matrix of mostly tea plantations. These corridors would require only 156 ha of land to establish links with the surrounding

protected areas. However, the rain forest fragments in the protected areas are intermixed with a matrix of commercially planted deciduous forests. It should be possible to identify potential links between the rainforest fragments using satellite data. Such a plan for the management of lion-tailed macaques in this region could be used as a model for conservation of the lion-tailed macaque, as well as other rain forest-dwelling species, in other parts of the Western Ghats.

Acknowledgments We thank Kerala Forest Department for permission to conduct research in Parambikulam. Partial financial support for this work was provided by Detroit Zoo, USA; Tiergarten Wels, Austria; Zoo Dresden, Germany; and Ramanna Fellowship to M. Singh by SERB, Government of India. We thank the anonymous reviewers and the editors, Oliver Schulke and Joanna Setchell, for their helpful comments.

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