

Habitat Isolation and Resource Availability Effects on the Demography of Lion Tailed Macaque (*Macaca silenus*) in the Rainforest Fragments of Anamalai Tiger Reserve, Western Ghats, Southern India

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Abstract: We have studied habitat isolation, resource availability and demographic parameters of 15 lion-tailed macaque groups in eight different rainforest fragments in the Anamalai Tiger Reserve, which are controlled by private (PF; n=4) and forest department (FF; n=4) with reference to fragment size, tree density, canopy cover, tree height and GBH of food trees. Group size ranged from 5 to 62 individuals but was not related to habitat variables. Both FF and PF habitats harbor fairly same ratio of adult males (FF- 2.44±0.9 and PF- 2.83±2.1) but female ratio has slight variation (FF- 4.22±1.9 and private- 5.0±3.3). The mean group size (FF- 11.65±3.3) varies in both habitats (PF- 19.50±9.2) respectively. The FF are larger in size (971.25 ha, n=4), than the PF (43.50 ha, n=4). Tree density, Tree height and GBH of food tree all showing strong differences. Sub adults (%) do not differ in both fragmented habitats. Of the 4 small fragmented habitats, two fragments have big group size with high adult male ratio. Small fragments with high population (Puthuthottam) become more vulnerable they need serious conservation concern. Using our results, we have examined the factors that may contribute towards maintenance of viable population of the flagship species in tropical rainforests.

Abbreviation: LTM- Lion tailed macaque • FF- Forest Fragments • PF- Private Fragments • SD- Standard Deviation

Key words: Anamalai Tiger Reserve • Demography • Fragmented Habitats • Habitat Isolation • *Macaca Silenus* • Resource Availability

INTRODUCTION

India is famous for tigers, lions and even elephants but not Monkeys. According to our mythology monkeys are the Hindu God, but what have we left to them. Isolated population of a rare species may be disproportionately affected by both stochastic and deterministic factors such as biotic pressure, fires, hurricanes, change in habitat quality and inbreeding/genetic drift [1]. The lion-tailed macaque (*Macaca silenus*) is an endangered and endemic species [2] representing isolated rainforest fragment of the Western Ghats hill ranges of southern India [3]. Their approximate number in the wild is less than 3500 individuals and is distributed in 49 subpopulations at seven locations; however the Anamalai Hills alone harbor a population of about 500 lion-tailed macaques [4].

Information on ecology and life history parameter of LTM has mostly come from Anamalai hills, where the species has been studied intensively [3, 5-9]. Most of these subpopulations are found in small and isolated forest fragments [7]. The species is a serious conservation concern and several studies have been taken up on the species, both in its natural habitats and in captivity [10].

Tropical rainforests are the centers of bio-diversity. These forests cover about 6% of the land surface of the world [11]. Extensive removal of these forests is therefore a matter of global concern and isolation process continues the progressive loss of an endangered species from these fragments [12]. Furthermore the effects of fragmentation on many forests could ultimately have the same consequences as extinction [13]. Wilcox and Murphy [14] stated that, "Habitat fragmentation is the

most serious threat to biological diversity and forms the primary cause of the present extinction crisis". At the current rate of habitat loss and fragmentation of tropical rainforests, the survival of significant components of bio-diversity would depend on the retention and management of a network of fragmented forests [15]. These include alterations in the activity pattern, feeding ecology changes in predation pressure, inter-specific competitions and host-parasite relationships [16]. The demography consequences are the final response of the species to habitat fragmentation leading earlier to its decline and gradually to the extinction [1, 16]. The demographic changes in primates might be due to habitat degradation and severe resource depression [17- 20]. Dispersal can increase the persistence and stability of fragmented population through various ways [21, 22]. However, there is a considerable variation among species in their ability to disperse among habitat islands [8]. Due to extensive plantation of beverages; which, rainforests are highly fragmented, *Macaca silenus* habitat is degraded and surrounded by coffee and tea estates [10].

MATERIALS AND METHODS

The Study Area: Anamalai Tiger Reserve (formally Indira Gandhi Wildlife Sanctuary) situated (10°11'08"N to 10°33'27"N and 76°49'02"E to 77°21'09"E) in the state of Tamil Nadu is one of the largest Tiger reserve in Southern India (Figure 1) with an area of 987sq km. The western part

of Tiger reserve receives rainfall between from 800 mm to 5000 mm annually. The day temperature varies from 23°C to 40°C at the foothills and from 20°C to 30°C at higher elevations *i.e.* above 1800m a.s.l [3, 8]. The study was conducted in eight selected rainforest fragments in Anamalai Tiger Reserve in Western Ghats, Southern India. It was extensively clear felled between 1860s and 1930s for cultivation of tea, coffee and cardamom; later teak, eucalyptus and economic fruit-bearing trees plantations, leaving behind fragments varying in area less than 10 hectares to more than 200 hectares [3, 8].

Extensive clear-felling has reduced the tropical rainforest in the Tiger Reserve and adjoining areas to 30 fragments ranging in the area from less than ca. 10 h to about ca. 2000 h [8, 10]. Only five fragments are more than ca. 200 h in area. Most of the smaller fragments (≤ 100 h) occur as islands surrounded by tea, coffee and cardamom estates and are privately owned *viz.* the larger fragments (≥ 100 h) of the sanctuary are bordered by teak and eucalyptus plantations and in some cases *viz.* by tea plantations on one side. This area has a town (Valparai) with a human population of nearly 2, 00,000 people [18].

Demographic Parameter: A study was conducted intensively in eight rainforest fragmented habitats during January 2008 to July 2008, in Anamalai Tiger Reserve, including Iyyerpadi, Chinnakalar, Sekalmudy and Andhiparai, (Forest department fragments; FF); Korangumudi, Pannimedu, Varattupparai

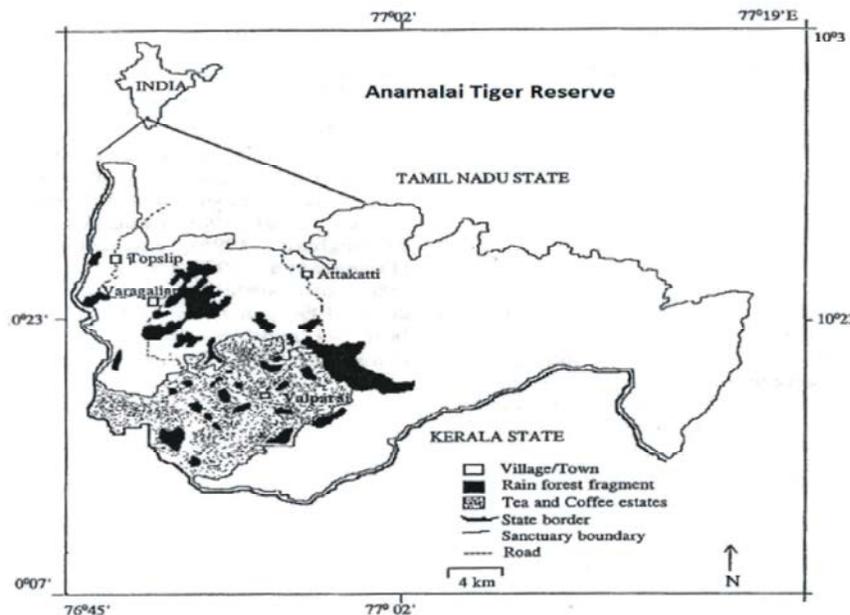


Fig. 1: Map showing the rainforest fragmented habitats of Anamalai Hills, Western Ghats

and Puthuthottam, (Privately owned fragments; PF). The growth rate of *Macaca silenus* in these fragmented habitats compared with earlier data published. The survey was conducted following Merenlender *et al.* [23] method, which relies on repeatedly identifying social groups and obtaining demographic data on all the identified groups. At most sites, data were collected on pre-existing forest trails, abundant forest roads and nallah (marked at 5 km intervals) that had either been created by forest department or by researchers working in the area. Each trail, road and nallah was surveyed from early morning to early afternoon, at a slow pace. The age sex composition of all detected monkeys groups were estimated using the morphological features known from monkey in captivity at Arignar Anna Zoological Park, Chennai. Data collection was repeated 4-5 times at each site, over 3-day period intervals [3].

Vegetation Data: Vegetation in these fragmented habitats was assessed using parameters such as tree density, Girth at Breast Height (GBH) of the trees, canopy spread and tree height. These were estimated from forty to fifty 10×10 meters quadrat in LTM studied fragmented habitats [24]. In each quadrat all trees were enumerated and along with the measurement of GBH in each quadrat the number of tree species, number of food species and basal area were assessed. Percentage of canopy cover and canopy height was estimated visually [18, 25]. *M. silenus* groups were observed through Nikon Action series binocular 8 x 40X.

Data Analysis: We have analyzed data on habitat and demographic parameters using nonparametric statistics. We used Mann-Whitney *U* tests for differences between samples. We examined the grouping significants of both FF and PF of populations using multiple regression model (RC). We used SPSS (v. 11.1) for statistical analyses [25].

RESULTS

Both private owned and forest department fragmented habitats had a significantly similar canopy cover but GBH of the food trees was precisely not similar. FF had positively big sized trees and the tree height was not similar in both fragmented habitats. Also, the tree density in the FD and private owned fragments were significantly different. Interestingly FF had high density of food trees ($973.7 \pm 239.8/ha$) than the PF ($753.7 \pm 144.9/ha$) (Table 1).

Table 2 showed the demographic parameters of 15 LTM groups, including 222 monkeys. The number of individuals in a group ranged between from 5 to 62. The smallest and largest groups were both found in private owned small size fragmented habitats. Group size was significantly small in FD fragmented habitats but the number of groups was higher (2.25 groups/fragments, n=9), moreover variable like big groups with high adult males occurred in PF (1.5 groups/fragments, n=6). The mean (SD) size of juveniles 5.00 ± 3.6 and infants 2.33 ± 1.6 showed strong differences in both fragmented habitats, the small privately owned fragments harbor significantly higher population.

Most importantly the FF were larger in size (971.25 ha, n=4) when compared to private owned fragmented habitats (43.50 ha, n=4). However the tree density and tree height show scanty sources when compared with larger fragments. Canopy cover positively shows the correlations but the saplings and seedlings were clear-felled in the privately owned fragments because of coffee and tea plantation practice. However the lion tailed macaques densely populated in Puthuthottam and the growth rate was impressive in two privately owned fragments (Table 3).

Table 1: Landscape and habitat variables of eight rainforest fragments in the Anamalai Hills in which were studied lion-tailed macaque groups between January 2008 and July 2008.

Fragment Name	Forest Type	Area (ha)	Tree Density (/ha)	GBH of food tree (cm)*	Canopy spread (m)	Tree height (m)	No. of Troops	Total no. of Individuals
Governments fragments								
Iyyerpadi	Evergreen	1800	1140 (24.6)	239 (201.2)	3.05 (1.4)	20.72 (6.0)	4	47
Chinnakalar	Evergreen	1300	1080 (213.5)	167 (114.7)	2.74 (1.0)	17.37 (7.2)	1	15
Sekalmudy	Evergreen	600	1115 (424.2)	104 (76.6)	2.13 (1.1)	13.10 (6.1)	2	25
Andhiparai	Wet evergreen	185	560 (80.0)	123 (112.8)	2.74 (1.3)	11.58 (7.6)	2	20
Mean (SD)		971.25	973.7 (239.8)	158.2 (51.9)	2.60 (0.3)	15.6 (3.5)	2.25	26.75
Private owned fragments								
Korangumudi	Coffee plantation	35	820 (240.0)	117 (46.6)	2.13 (0.5)	15.84 (5.4)	1	27
Pannimedu	Tea plantation	50	620 (116.6)	101 (44.6)	3.05 (1.7)	14.93 (3.4)	1	5
Varattupparai	Coffee plantation	24	615 (231.5)	51 (10.5)	1.52 (0.8)	3.65 (0.5)	1	8
Puthuthottam	Coffee plantation	65	960 (412.7)	179 (139.3)	3.04 (1.8)	18.28 (6.5)	3	77
Mean (SD)		43.50	753.7 (144.9)	112 (45.7)	2.43 (0.6)	13.63 (5.63)	1.5	29.25

SD values are in parentheses *considered as tree >15cm

Table 2: Demography of Lion tailed macaques in different rainforest fragments in the Anamalai Tiger Reserve, during January 2008 and July 2008.

Fragment Name	Adult Males	Adult Females	Sub Adult Males	Sub Adult Females	Juveniles	Infants	Group Size
Government							
Iyyerpadi (1)	1	2	1	2	1	1	8
Iyyerpadi (2)	4	2	1	1	2	0	9
Iyyerpadi (3)	2	2	0	2	4	0	12
Iyyerpadi (4)	4	8	2	0	3	1	18
Chinnakalar	2	5	1	2	2	1	13
Sekalmudy (1)	2	5	1	3	2	2	15
Sekalmudy (2)	3	5	0	2	0	0	10
Andhiparai (1)	2	6	2	0	0	3	13
Andhiparai (2)	2	3	2	0	0	0	7
Mean (SD)	2.44 (0.9)	4.22 (1.9)	1.11 (0.7)	1.33 (1.05)	1.56 (1.3)	0.89 (0.09)	11.57 (3.3)
Private							
Varattupparai	1	4	1	0	0	2	8
Pannimedu	1	2	0	0	0	2	5
Korangumudi	3	6	2	5	6	5	27
Puthuthottam (1)	1	1	0	1	3	0	6
Puthuthottam (2)	1	2	0	0	6	0	9
Puthuthottam (3)	10	15	7	10	15	5	62
Mean (SD)	2.83 (2.01)	5.00 (3.3)	1.67 (0.6)	2.67 (2.4)	5.00 (3.6)	2.33 (1.6)	19.5 (9.2)

SD values are in parentheses

Table 3: Comparison with earlier data on Group count of the lion tailed macaques (*Macaca silenus*) in the Anamalai Tiger Reserve, Western Ghats.

Fragments	1994a	1996b	2002c	2008
Govt. Fragments				
Iyyerpadi*/ Akkamalai complex	DNA	DNA	100	47*
Chinnakalar	DNA	DNA	DNA	15
Andhiparai	23	26	30	20
Sekalmudy	DNA	DNA	DNA	25
Private Fragments				
Korangumudi	19	21	21	27
Pannimedu	7	8	8	5
Varattupparai	13	15	15	8
Puthuthottam	40	47	70	77
Umapathy (1998)a	DNA= Data Not Available			
Umapathy and Kumar (2000)b	Singh <i>et al.</i> (2002)c			

Table 4: Influence of age classes of *Macaca silenus* on different group sizes using Multiple Regression model in both fragmented habitats of Anamalai Tiger Reserve, between January 2008 to July 2008

Fragments	Age classes	RC	SE	T	p value	R ²
Government						
	Adult male	0.17	0.18	-0.99	0.333	0.35
	Adult female	0.31	0.09	3.88	0.002	0.31
	Sub adults	0.86	0.15	1.8	0.000	0.81
	Juveniles	0.41	0.14	2.98	0.090	0.51
	Infants	0.67	0.18	3.41	0.000	0.90
Private						
	Adult male	1.42*	0.29	5.52	0.011	0.90
	Adult female	0.97*	0.31	3.64	0.018	0.55
	Sub adults	0.81	0.39	1.29	0.227	0.83
	Juveniles	0.39	0.33	1.38	0.289	0.27
	Infants	1.11*	0.5	2.74	0.049	0.88

RC= Regression Coefficient, SE= Standard Error, * significant at <0.05

Statistical analysis of group size was also carried out in relation to habitat types. Groups living in FF had a mean group size of 11.67 (SD = 3.30; n = 9) individuals, while group living in PF had a mean group size of 19.50 (SD = 9.20; n = 6) individuals (Mann-Whitney $U = 38$; n = 15; p = 0.13). Group living in FF ranged in size from 7 to 18 individuals while group living in PF ranged in size from 5 to 62 individuals.

Similarly, although the mean number of individuals in PF (29.25; n = 4) and FF (26.71; n = 4) did not differ statistically (Mann-Whitney $U = 30.00$; n = 8; p = 0.19), the SD in PF (9.20) was significantly higher than the SD in FF (3.30). The variation in group size increased with increasing habitat disturbance. The analysis of multiple regression models between group size and different age/sex categories of both fragmented populations indicated that a substantial part of variation in group size was accountable by adult male in the group, followed by infants and adult females, there was no significance for sub adults (Table 4).

DISCUSSION

We have studied the habitat isolation, resource availability and demography of endangered Lion-tailed Macaques (*Macaca silenus*) in eight selected rainforest fragments in the Anamalai Tiger Reserve with references to fragmented area, tree density, canopy cover, tree height and GBH of food trees. Results indicated that the lion tailed macaques densely inhabit two privately owned fragments. Puthuthottam and Korangumudi fragments show a positive growth rate of lion tailed macaques. While Pannimedu, Varattupparai and Andhiparai populations show a fairly decline. Vegetation parameters such as tree density, tree height and GBH of food trees show strong differences between private and governments owned fragments. Among the four government fragments Andhiparai had low tree density. However the small fragments, such as Puthuthottam harbors highest density of LTM (77 individual per km²), moreover one fifth of the Anamalai population inhabits this (65 ha) area because of inadequate space and another reason for the population explosion is lack of natural predators. Presence of few tea garden workers quarters and continuous vehicle movement are safeguarding the existing population. But, due to inadequate resources at Puthuthottam, LTMs currently manage to survive by changing their food habits, consuming secondary/exotic food sources (Fig 2, 3 and 4).

The small size PF is under constant human pressure and the forest continues to degrade [7]. The resource base in fragments remains unpredictable on an annual basis and hence, isolated populations may find it difficult to cope with the demands of such pressures in the long run [10]. Such isolated populations resemble island populations which have a higher probability of extinction due to certain disasters [26]. Already, in the Anamalai Hills, fragmentation, increased habitat disturbance and inadequate resource availability has resulted in a significant increase in group size and density, although the overall age-sex ratio has not shown much variation over the years [10, 18]. Many other macaque species get access to human foods, which may in turn support larger group size. The lion-tailed macaques have been observed to utilize such resources at Puthuthottam and Korangumudi fragments (Figure 5).

Kumar *et al.* [24] suggested that if selected tree species whose fruits are preferred by lion-tailed macaques could be raised along streams or hill slopes between the fragments, it could at least provide paths for males to migrate between fragments. Although not impossible, it is difficult to currently link these fragments through rainforest corridors because several villages and roads has established near private owned fragments. A characteristic behavior of lion-tailed macaques is frequent inter-group adult male migrations [5, 24]. Inter-group male migration is impossible without forest contiguity because the neighboring fragments are at least a few kilometers far from these PFs (*see map*), moreover the saplings and seedlings density is scanty. In spite of space and quality shortage in small fragments, they have continuously planting *Vannila* (ice-cream ingredient) at Korangumudi and Pannimedu fragments [27].

The lion-tailed macaque is a typical arboreal species requiring uninterrupted canopy contiguity [8, 9]. the obtained results have suggested some steps to manage the fragile lion-tailed macaque groups in the following steps: 1) Size and quality of fragments are shrinking because of the regular plantation practices, 2) continuous clear felling, timber extraction and fuel wood collection may increase the insecurity of food source in these small privately owned fragments and 3) shifting the LTMs into large fragments, which are exist in the small isolated fragments, or strictly prohibit further degradation and plantation on these privately owned fragments, increasing food source scanty rising trends in mortality of macaques eventually leading to decline in their populations in the long term run.

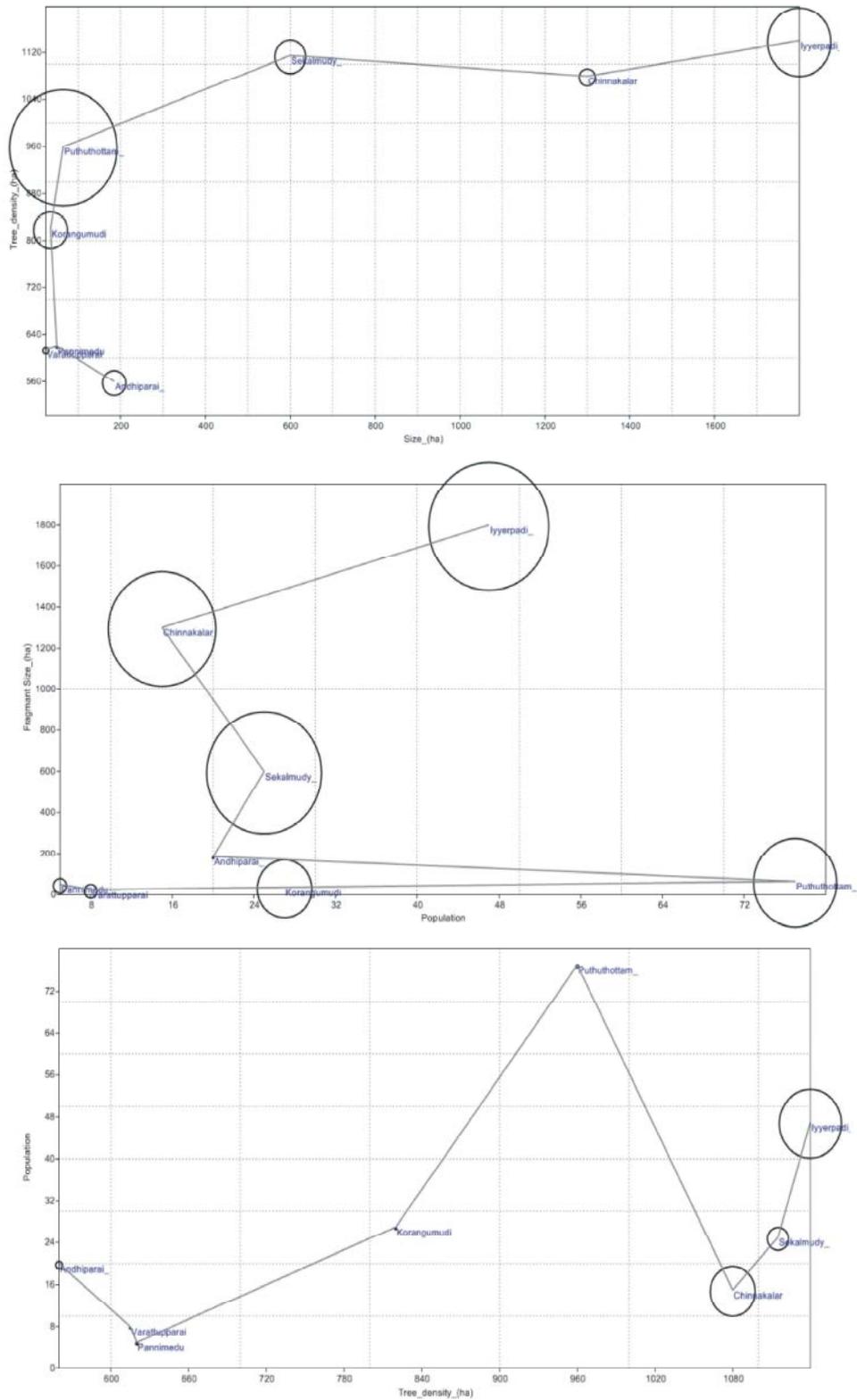


Fig. 2, 3 & 4: Comparison of relationship between the fragment size, tree density and population size of the lion tailed macaques in the rainforest fragments of the Anamalai Tiger Reserve.



Fig. 5: As a result of inadequate space and resource availability, LTMs now depend on exotic food resources at Puthuthottam. It showing the greater risk of road accidents and also consuming polythene is danger for the existing population.

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