Distribution, abundance, group size and demography of dark-bellied bonnet macaque *Macaca radiata radiata* in Karnataka, South India

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We carried out an extensive survey on bonnet macaques in the south Indian state of Karnataka over a period of five years. We travelled 9697 km covering all districts and recorded the distribution, encounter rate and demographic features of bonnet macaque groups on roadsides and villages, temples and several different forest types, and walked 1736 km in selected Protected Areas and Reserve Forests. Bonnet macaque groups were encountered at a rate of 2.11 groups/ 100 km in a road survey. Encounter rates were high in the districts of Chamarajanagar, Shimoga, Bangalore, Kolar, Kodagu and Mysore. Encounter rates were higher in wet evergreen forests than in deciduous forests. Mean group size was highest in human habitations followed by deciduous forests, roadsides and evergreen forests. The groups in highly provisioned places had the highest size compared to medium or low degree of provisioning. Age–sex ratios were observed to be the same in all habitat types. We propose that large-scale surveys of the present type provide baseline data for long-term management and conservation of a species.

Keywords: Bonnet macaque, demography, distribution, group size, provisioning.

BONNET macaque is a common and widely distributed but endemic primate in peninsular India[1]. The northward distribution range is believed to be up to the rivers Godavari in the east and Tapti in the west[2]. Fooden *et al.*[3] showed the northward distribution till the end of the Western Ghats specifically up to the town of Surat, Gujarat in the west and the town of Guntur, Andhra Pradesh in the east.

Bonnet macaques live in a wide variety of habitat types, including montane evergreen forests, deciduous forests, scrub forests, agriculture fields and human habitats from sea level to 2100 m asl (ref. 4). However, no report of their occurrence is available from the high range 'Shola' forests of the Western Ghats. Kurup[5] estimated the population density in rural and urban areas of southern India to be about 0.34 individual/km², with the largest population in Karnataka. These macaques live in multi-male and multi-female groups. The group size ranges from 5 to 75 individuals[5], with a mean value of 17.7. Group size shows high variability across ecological conditions and degree of exposure to human habitations. It may be much smaller in forests than in the urban and rural areas[4,6–9]. Though many researchers have addressed the variation in group size in different habitat types, it was with small sample sizes and the data were largely from a single habitat type. Some studies have shown the variation in group size with data collected on roadside groups present in and out of Bandipur National Park[4,7,8]. Kurup[5] projected the mean group size for the bonnet macaques living in rural and urban habitats. The age–sex ratios were also found to vary across habitat types.

The primate survey carried out by Kurup[5] during late 1970s had the objective of determining population density of primates in urban and rural areas. He gathered the data mostly through a questionnaire distributed to the panchayats (an elected village-level governing council). Though he was able to record the demography for many groups, they were not classified according to habitat type or dependency on different types of food. We surveyed the entire state of Karnataka, both roadside and some forest areas, and collected a large amount of data on group size and age–sex composition of bonnet macaques during a span of five years (2002–2007). Unlike Kurup, we did not attempt to determine population density, but only encounter rates in different habitat types and in relation to the degree of provisioning. A large set of data covering thousands of kilometres of survey and almost all types of habitats inhabited by a species may contribute to provide general demographic patterns of the species, which can serve as a reference point for future research.

We carried out the study over entire Karnataka, located between 11°31′–18°45′N and 74°12′–78°40′E, with a total area of 191,791 km². The state receives an annual rainfall between 450 and 7500 mm, with a mean of 1975 mm. Karnataka has been divided into four representative ecozones, including coastal Karnataka with mangrove forests, hill region (the Western Ghats) with rainforests and moist deciduous forests, southern plateau and northern plains with deciduous forests, scrub forests and open grasslands[10,11]. The state includes 26 administrative units known as 'districts' (A district is a revenue jurisdictional unit of 8000–10,000 km²). Each district includes five to nine taluks (A taluk is a revenue administrative unit with a defined boundary and an area of about 1000 km²).

We carried out the study between 2001 and 2007. During this period, we travelled across all 26 districts of the state. We conducted a vehicular (jeep/motorcycle) road survey of 9697 km covering all districts. The vehicle was driven at the speed of < 20 km/h. Once the bonnet

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macaques were spotted, the vehicle was stopped and data on details about location and habitat type were collected. We were not able to repeat the surveys because they were carried out in a large spatial area, and the results are presented per 100 km. We also walked in the forests of seven Protected Areas (PAs) and three Reserve Forests (RFs) (1736 km). We walked at the average speed of 0.8 km/h on pre-existing trails, animal paths or pre-determined transect lines. We used a pedometer to calculate the distance walked. After sighting a group, sufficient time was spent to get a proper count of the individuals. The individuals were classified as adult male, adult female and immature (including sub-adults, juveniles and infants), based on morphological characteristics.

Although each major forest type may be further classified into several subcategories of forests, for our purpose, we broadly grouped the available habitat types as evergreen forest, deciduous forest, plantation–scrub–roadside trees–agriculture, and human habitation. The evergreen and deciduous forests were classified following Champion and Seth[12], and Pascal[13]. A large number of groups found in plantations, scrub forests and agricultural areas were associated with roadside trees either for roosting or for occasionally receiving handouts from humans. Hence we considered all such groups under a single category. Groups living in urban areas, including temples and tourist spots were considered under 'human habitation'. In addition to comparing encounter rates in broad habitat types, we also compared these rates among different forests.

Though we did not calculate the degree of handouts received from humans for each group, considering several factors such as location, behaviour of the group towards humans, and availability and distance to the major attractive locations, we broadly classified the groups as less, medium and highly provisioned. Some of the groups living in forest areas frequently visited campsites where they received food from humans. Such groups were also considered highly provisioned.

Table 1 presents data on the occurrence and status of bonnet macaques in Karnataka. Barring a few districts, macaques were found throughout the state. The mean encounter rate was 2.11 groups/100 km. The encounter rates were higher than the mean in some districts, including Chamarajanagar, Shimoga, Kolar, Bangalore, Uttara Kannada, Kodagu and Mysore. Resident populations of bonnet macaques were absent in the districts of Bidar, Bijapur and large parts Gulbarga, where they were reported to make only occasional visits during the fruiting seasons of mango (*Mangifera indica*) and tamarind (*Tamarnidus indica*). In the districts of Udupi and Dakshina Kannada, bonnet macaques were found only in the foothills of the Western Ghats and in a few Hindu temples. In the remaining districts, the encounter rates were lower than the mean rate.

The major forest types of PAs and RFs are considered as drier forests (deciduous forest and moist deciduous forests) and wet forests (evergreen forests). The two PAs with drier forests include Bandipur National Park (NP) and Rajiv Gandhi NP, and the eight PAs and RFs with wet evergreen forests include Brahmagiri Wildlife Sanctuary (WS), Makut RF, Talakaveri WS, Pushpagiri WS, Bisale RF, Sringeri Forest Range, Sharavathi Valley WS and Sirsi–Honnavara RF (Table 2). The encounter rate ranged between 0.033 and 0.278 groups/km and the overall encounter rate differed significantly between different forest types ($G = 94.77$, $df = 9$, $P < 0.001$). However, the encounter rate did not differ between the forest patches within drier forests ($G = 0.01$, $df = 1$, NS), whereas it differed significantly between the forests with wet evergreen forests ($G = 63.13$, $df = 7$, $P < 0.001$). The encounter rate in wet evergreen forests of PAs and RFs was relatively higher in the northern forests than in the southern forests.

We collected data on group size for 126 groups, and on age–sex for only 103 groups. Though the group size varied between 3 and 68, the minimum value was three in all the habitat types, except human habitation (minimum group size was 23). Conversely, the maximum group size varied highly between the habitat types. Evergreen forest, deci-

Table 1. Bonnet macaque groups encountered during the road survey in different districts of Karnataka

District	Distance travelled (km)	Bonnet macaque	
		No. of groups	Groups/ 100 km
Bidar	284	1	0.35
Gulbarga	769	2	0.26
Bijapur	452	0	–
Bagalkot	233	5	2.15
Belgaum	899	7	0.78
Uttara Kannada	227	14	6.17
Dharwad	194	1	0.52
Gadag	522	4	0.77
Koppal	351	1	0.28
Raichur	452	6	1.33
Bellary	493	10	2.03
Davangere	247	1	0.40
Haveri	466	3	0.64
Shimoga	177	22	12.43
Udupi	170	1	0.59
Dakshina Kannada	220	2	0.91
Chikmagalur	140	2	1.43
Chitradurga	305	1	0.33
Tumkur	916	16	1.75
Hassan	254	3	1.18
Kodagu	198	12	6.06
Mysore	160	8	5.00
Chamarajnagar	151	21	13.90
Mandya	384	4	1.04
Bangalore	478	21	4.39
Kolar	555	37	6.67
Total	9697	205	2.11

Table 2. Bonnet macaque groups encountered in different Protected Areas (PAs) and Reserve Forests (RFs) of Karnataka

PA/RF	Forest type	Distance travelled (km)	No. of groups	Groups/km
Bandipur National Park	Deciduous forest, moist deciduous forest	245	8	0.033
Rajiv Gandhi National Park	Deciduous forest, moist deciduous forest	261	9	0.034
Brahmagiri Wildlife Sanctuary	Wet evergreen forest	118	8	0.068
Makut Reserve Forest	Wet evergreen forest	113	7	0.062
Talakaveri Wildlife Sanctuary	Wet evergreen forest	302	23	0.076
Pushpagiri Wildlife Sanctuary	Wet evergreen forest	184	6	0.037
Bisale Reserve Forest	Wet evergreen forest	129	11	0.085
Sringeri Forest Range*	Wet evergreen forest	78	9	0.115
Sharavathi Wildlife Sanctuary	Wet evergreen forest	186	31	0.167
Sirsi–Honnavara Reserve Forest	Wet evergreen forest	198	55	0.278
Total		1736	158	0.091

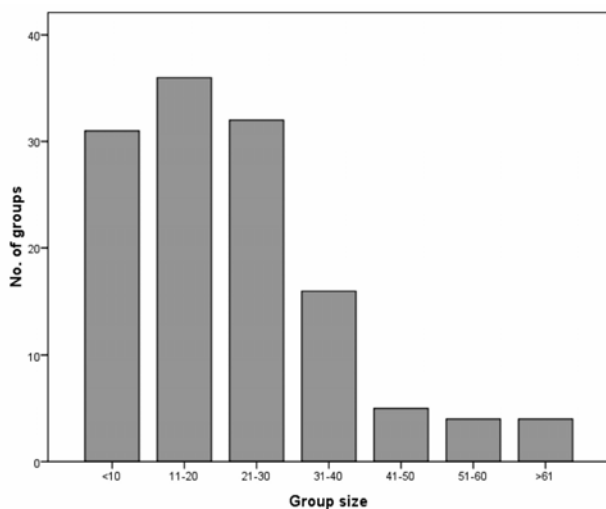*One of the forest ranges of Kudremukh National Park.

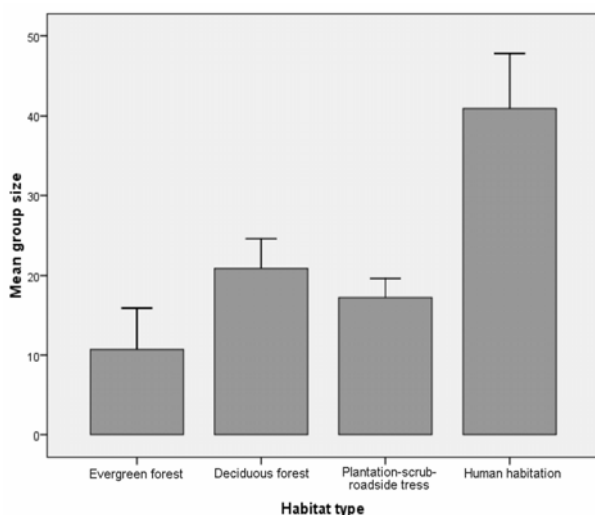**Figure 1.** Number of groups of bonnet macaques in various size categories.

Figure 2. Mean group size of bonnet macaques in different habitat types.

duous forest, plantation–scrub–roadside trees–agriculture land, and human habitation had a mean group size of 24, 52, 38 and 68 respectively. However, about 77% of the groups had a size between 3 and 30 (Figure 1). The overall mean group size was 21.47 ($\pm$ 13.672), yet it differed significantly between the habitat types ($F = 24.976$, $df = 3$, $P < 0.001$), where the groups in evergreen forests had the lowest mean group size (10.7 $\pm$ 7.2730) and those in human habitation had the highest mean group size (40.94 $\pm$ 13.760; Figure 2). The mean group size with different degrees of exposure to provisioning also differed significantly ($F = 39.996$, $df = 2$, $P < 0.001$). The groups that received highest provision had a mean group size of 34.18 ($\pm$ 13.648), whereas those that received minimum provision had a mean group size of 14.59 ($\pm$ 9.381; Figure 3).

Data on proportion of different age–sex animals in different habitat types are presented in Table 3. The proportion of adult male was 13.88% ($n = 306$), adult female was 32.49% ($n = 716$) and immatures was 53.63% ($n = 1182$). The proportion of adult males ($G = 0.7515$, $df = 3$, NS), adult females ($G = 2.5441$, $df = 3$, NS) and immatures ($G = 1.4708$, $df = 3$, NS) did not differ significantly across habitat types. Likewise, the proportion of adult males ($G = 0.2434$, $df = 3$, NS), adult females ($G = 2.8312$, $df = 3$, NS) and immatures ($G = 1.1925$, $df = 3$, NS) also did not differ between the groups with different degrees of provisioning.

We present in Table 4, the age–sex ratio for each age–sex class to understand the survivorship rate of different age–sex animals in different habitat types. The overall ratio for one adult male was 2.34 adult females, 1.65 immatures for one adult female and 1.16 immatures for one adult. The χ^2 test did not show any difference in the ratio of adult male to adult female ($\chi^2 = 1.65$, $df = 3$, NS), adult female to immatures ($\chi^2 = 2.76$, $df = 3$, NS) and adults to immatures ($\chi^2 = 1.61$, $df = 3$, NS) across habitats. Likewise, χ^2 test did not show any difference in the ratio of adult male to adult female ($\chi^2 = 1.71$, $df = 2$, NS), adult female to immatures ($\chi^2 = 4.03$, $df = 2$, NS) and adults to immatures ($\chi^2 = 2.52$, $df = 2$, NS) among groups with different degrees of provisioning.

The major results of the present study revealed that the relative abundance and group size of bonnet macaques

Table 3. Number of individuals in various age–sex classes in bonnet macaque groups in different habitat types

| Group type	No. of individuals	No. of adult males (%)	No. of adult females (%)	No. of immatures (%)
Habitat type				
Evergreen forest	107	15 (14.02)	40 (37.38)	52 (48.60)
Deciduous forest	778	107 (13.75)	267 (34.32)	404 (51.93)
Plantation/scrub/agriculture/roadside	822	109 (13.26)	258 (30.41)	455 (55.35)
Human habitation	497	75 (15.09)	151 (30.38)	271 (54.53)
G test for proportion		$G = 0.75$, d$f = 3$, NS	$G = 2.54$, d$f = 3$, NS	$G = 1.47$, d$f = 3$, NS
Degree of provisioning				
Less provisioned	413	54 (13.1)	152 (36.8)	207 (50.1)
Medium provisioned	740	104 (14.1)	232 (31.4)	404 (54.5)
Highly provisioned	1051	148 (14.1)	332 (31.6)	571 (54.3)
G test for proportion		$G = 0.24$, d$f = 2$, NS	$G = 2.83$, d$f = 2$, NS	$G = 1.19$, d$f = 2$, NS
Total	2204	306 (13.88)	716 (32.49)	1182 (53.63)
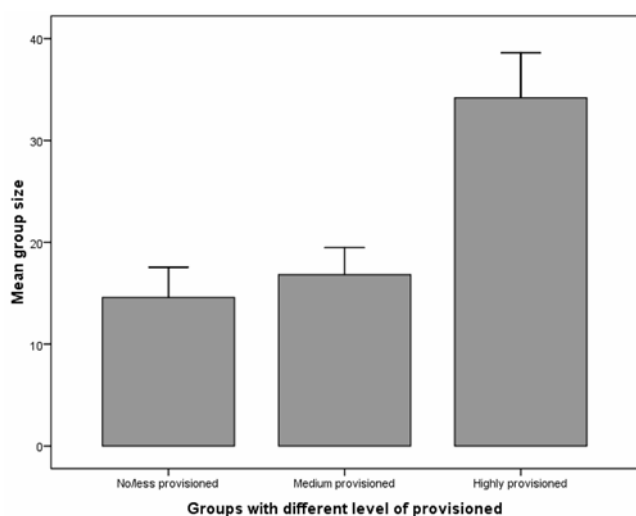
Figure 3. Mean group size of bonnet macaques in regions with different degrees of provisioning.

varied across habitats and in relation to degree of provisioning, but the age–sex ratios showed no such variation. The overall encounter rate of 2.11 groups/km observed in the present study matches well the value of 2.16 groups/km recorded by Kurup[5]. Bonnet macaques have adapted to live in a wide variety of habitats varying from mid-elevation evergreen forests to the scrub forests of the plains and human-dominated ecosystems, including villages and towns. Thus the species is known as a habitat generalist and it is considered as 'Least Concern' species in conservation priority. Since the bonnet macaque habitats differ in tree cover and availability of resources, it is expected that the relative abundance as well as the demographic features would show differences across habitats. We also expected that the bonnet macaques would be equally abundant in PAs where there is little anthropogenic pressure. Although bonnet macaques were found in most of the districts of Karnataka, the relative abundance varied among the districts and PAs. This variability could be accounted for the availability of forests and roadside trees. Singh and Kumara[14] have listed the forest area in

each district of the state. There is negligible forest cover in the districts in northern plains (e.g. Bider, Bijapur, Gulbarga), as these receive very low rainfall and produce only one dry crop annually. The Forest Department has also grown *Eucalyptus* and *Acacia* tree species along the roads and these do not provide any forage for the monkeys. In many other districts where year-round agriculture is predominant, the variability in abundance of monkeys may be explained by other anthropogenic factors, including elimination of the bonnet macaque groups, capturing animals from a group resulting in skewed adult-sex ratios, releasing the captured animals in unfamiliar/unsuitable habitats[15], and removal of roadside trees due to road expansion and construction purposes[16]. On the other hand, the low density of bonnet macaques in the forests of the PAs, especially in the dry deciduous forests, may be due to competition with the large variety and abundance of herbivores and predation by the large carnivores, including tigers, leopards and dholes. In the wetter forests, the variability in abundance among different regions is due to differential hunting pressure[17,18].

Factors like density of conspecifics, resource availability, interspecies competition, density and diversity of predators, and anthropogenic factors, including hunting might influence the mean group size in a given habitat. In some of the habitats, many factors collectively influence group size. For a species to have a small group size may be beneficial to avoid within-group competition for food when the predator pressure is low. On the other hand, if the predator pressure is high, the increased group size may reduce individual predation risk[19]. Bonnet macaques were observed to have higher abundance, but smaller group size in evergreen forests, where terrestrial mammals are in low abundance, but arboreal mammals are in higher abundance. On the other hand, there was a low abundance but a larger group size in deciduous forests, where terrestrial mammals are in higher abundance due to the availability of graze and browse. Since the food resources in either forest type are more distributed compared to provisioned places, the group size in forest areas

Table 4. Age–sex ratio of bonnet macaques in different habitat types

Group type	Adult male to adult female	Adult female to immatures	Adults to immatures
Habitat type			
Evergreen forest	1 : 2.67	1 : 1.30	1 : 0.95
Deciduous forest	1 : 2.50	1 : 1.51	1 : 1.08
Plantation/scrub/agriculture/roadside	1 : 2.37	1 : 1.76	1 : 1.24
Human habitation	1 : 2.01	1 : 1.80	1 : 1.20
χ^2 test for contingency table	$\chi^2 = 1.65$, d$f = 3$, NS	$\chi^2 = 2.76$, d$f = 3$, NS	$\chi^2 = 1.61$, d$f = 3$, NS
Degree of provisioned			
Less provisioned	1 : 2.81	1 : 1.36	1 : 1.01
Medium provisioned	1 : 2.23	1 : 1.74	1 : 1.20
Highly provisioned	1 : 2.24	1 : 1.72	1 : 1.19
χ^2 test for contingency table	$\chi^2 = 1.71$, d$f = 2$, NS	$\chi^2 = 4.03$, d$f = 2$, NS	$\chi^2 = 2.52$, d$f = 2$, NS
Total	1 : 2.34	1 : 1.65	1 : 1.16

was smaller than that in the provisioned places. Provisioning has been known to increase not only the local population density but also group size, as systematic records on the provisioned Japanese macaques have shown over several decades[20,21]. However, the most interesting observation was that despite variations in abundance and group size across habitats, the age–sex ratios were the same in all habitats. This points to the characteristic trait of the species remaining invariable[22].

Although widespread and considered a 'Least Concern' species, several recent publications[15,16] have shown declining trends in the populations of bonnet macaques and have pointed to a serious concern about their long-term conservation. Large-scale surveys of the present type covering a variety of habitats provide the necessary data for management and conservation of the remaining populations of these largely commensal primates.

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