Ranging Pattern in Bonnet Macaque (*Macaca radiata*)

A thesis

submitted to

Indian Institute of Science Education and Research, Pune

in partial fulfillment of the requirements for the

BS-MS Dual Degree Programme

by

Karan Chandrakant Gajbe

Indian Institute of Science Education and Research Pune

Dr. Homi Bhabha Road

Pashan, Pune 411008, India

April 2018

Supervisor: **Dr. H. N. Kumara**

सालिम अलि पक्षिविज्ञान एवं प्रकृति विज्ञान केन्द्र
SÁLIM ALI CENTRE FOR ORNITHOLOGY AND NATURAL HISTORY
(Aided by the Ministry of Environment & Forests, Government of India)

CERTIFICATE

This is to certify that this dissertation entitled "Ranging pattern in Bonnet macaques (*Macaca radiata*)" towards the partial fulfillment of the BS-MS dual degree programme at the Indian Institute of Science Education and Research, Pune represents study/work carried out by "Karan Chandrakant Gajbe at Salim Ali Center for Ornithology and Natural history (SACON), Coimbatore, Tamil Nadu." under the supervision of "Dr. H. N. Kumara, Senior Scientist, Conservation biology, SACON." during the academic year 2017-2018.

Kgajbe

Student's Signature

Supervisor's Signature

आनैकट्टी, कोयम्बटूर – 641 108 इंडिया
Anaikatty P.O., Coimbatore - 641 108 (INDIA)
Telegram : SACON Phone : 91 (422) 2657101, 2657102, 2657131, 2657199
Director's Office : 91 (422) 2657086, 2657088 (Telefax) Website : www.sacon.in, E-mail : salimali@vsnl.com, salimalicentre@gmail.com

सालिम अलि पक्षिविज्ञान एवं प्रकृति विज्ञान केन्द्र
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DECLARATION

I hereby declare that the matter embodied in the report entitled "Ranging pattern in Bonnet macaque (*Macaca radiata*)" are the results of the work carried out by me at the Department of Conservation Biology, Sálim Ali Center for Ornithology and Natural history (SACON), under the supervision of Dr. H. N. Kumara and the same has not been submitted elsewhere for any other degree.

Student's Signature

Supervisor's Signature

आनैकट्टी, कोयम्बटूर – 641 108 इंडिया
Anaikatty P.O., Coimbatore - 641 108 (INDIA)
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ABSTRACT:

Patterns of ranging behavior of a species depend on distribution and abundance of different resources including food resources and roosting trees, further also depend on group size, intergroup encounters, phenology and movements of the group on previous days, season variability and rainfall. If a species is exposed to humans and live commensal with humans, then the degree of provisioning influences their ecology which includes activity and ranging pattern of that species. To understand this phenomenon, I selected Bonnet Macaque (*Macaca radiata*) as a model organism to understand the ranging pattern where there are developmental activities and alteration to their habitat. For the study, four groups of bonnet macaque were selected from Chamundi Hills, Mysore, Karnataka. I have collected 12:00 hrs of observations for 106 days over 7 non-consecutive months (June 2017- February 2018) of study. The data was collected on Daily path length (DPL), activity budget and feeding ecology of these groups. The DPL was significantly varied between the study groups. The groups were found to spend more time in resting activity and very small time in movement activity. The feeding activity did not differ significantly between study groups. The study groups feed >40% on a natural resource. This result concludes the amount of provision food is a prime mover of ranging pattern in primates. The results are also important to develop the conservation strategies for conservation of bonnet macaque and any other commensal species living in habitat fragmented area.

Keywords: Season variability, Daily path length, feeding ecology, Conservation.

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Acknowledgements

I would like to thank Dr. H. N. Kumara, Senior Scientist (Conservation Biology), SACON, Tamil Nadu, for his expert advice, encouragement and support in this thesis project, as well as Prof. Raghav Rajan, IISER Pune, for his support. I thank Arijit Pal, PhD Scholar, SACON, Tamil Nadu, for his help in analysis of data and support. I also thank Upendra Arya for helping me in the vegetation sampling.

I thank DST-INSPIRE and IISER Pune for the financial support to the research project.
I would like to thank my family and friends for their constant support to complete the project.

1. Introduction:

A fundamental issue in ecology is to determine ecological factors that affect the density of a species and its capability to adapt against variability in those factors (Santhosh *et al,* 2015; Strier, 2008; Sinha, 2001). A deep perception of these factors is important to develop effective management strategies to conserve a species (Chapman and Peres, 2001; Twinomugisha and Chapman, 2007). Animal or group of animals tends to move in an established range called "Home range" while performing its normal daily activities such as feeding, resting and social behaviour (Burt, 1943). Metabolic requirements of animals determine the range size. They move in such a way, so they can boost their nutrients uptake and lower their energy consumption (Pyke, 1984). Evaluation of this area gives us a better insight of animals space and habitat use (Boonratana, 1999). In primates, there are several ecological factors including group size, food availability, seasonal variation, and intergroup encounters may cause variation in home range and daily path length (DPL).

For social species like primates, group size contributes to range size (Dias and Strier, 2003; Fashing *et al*, 2007; Izumiyama, 2008). Due to increase in feeding competition, social animals must have longer range size to satisfy their energy requirements. One example is Muriquis in Minas Gerais Brazil, where an increase in group size caused an increase in range size (Dias and Strier, 2003).

There are some studies which show effects of food availability over ranging pattern (Clutton and Brock, 1975; Twinomugisha and Chapman, 2008; Maruhashi *et al*, 1998). Distribution and abundance of food in a given area should affect how far individual must go to satisfy its metabolic requirements. The decrease in density of food in an area should increase an individual's foraging range (South, 1999). Maruhashi (1998) compared range size of Japanese macaques from evergreen and deciduous forest and he reported range size of macaques in the evergreen forest where food abundance is more was shorter than macaques in the deciduous forest where food abundance in less. Santhosh et al. (2015) also found a positive correlation between fruit tree density and DPL in lion-tailed macaques in the Western Ghats.

Apart from the group size and food availability, seasonal variation can be a factor which affects range size of primates (Santhosh et al, 2015; Kaplin, 2000; Kurup, 1993; Izumiyama, 2003; Boaping et al, 2009). Boaping (2009) suggests snub-nosed monkeys travel greater distances in longer days than in shorter days.

Another factor, intergroup relations is expected to affect variation in ranging pattern. Due to neighbouring pressure for food and space between adjacent groups with overlapping territories results in the emergence of competitive ability in groups which might cause variation in movement patterns of the individual in each group. Power asymmetries in terms of fighting abilities of groups and/or group size determine dominance relationships (Adams, 2001; Harris, 2006). In general, larger groups and/or groups having more fighting abilities can defend larger territories. In Chimpanzee's, intergroup pressure negatively affects range size (Goodall, 1986). Frequent intergroup encounters between two adjacent groups occur in those patches where quality and quantity of food is higher than in the rest of the home range (Wrangham, 1980). *Colobus guereza* frequently encountered other groups in the food resource core area than in the rest of the home range (Harris, 2006). In primate species, males involve in intergroup encounters intent to protect their offsprings or to gain access/defend mates. Getting access to more females increases male's reproductive success (Trivers, 1972). In contrast, female reproductive success depends on the food source. Males are used by the females as 'hired guns', they use males to defend space and food resources from the intruding groups (*Colobus guereza:* Fashing, 2001; *Macaca radiata*: Cooper et al. 2004; *Macaca fuscata*: Maruhashi et al. 1998).

Commensalism may have a wide impact on DPL and home range of primates. Especially macaques and baboons, who can successfully exploit human habitat. Development of commensalism in primates is due to their ecological flexibility in dietary requirements (Riley, 2008). DPL and home range can be different for the macaque species which is living in the forest and the one which is living in commensal with humans. In the forest, use of space is affected by predation pressure and competition with sympatric species. The tonkean macaques which are living in the human-altered area use more home range area per individual than the forest's tonkean macaques. Although there was no significant difference in the DPL of those two groups (Riley, 2008). Riley also found the groups living

in altered habitat spend more time in the agriculture field than in central forest and fed on coffee and crops.

In this thesis, I studied the home range size, habitat use and activity pattern in commensal bonnet macaque at Chamundi Hills, Mysore, India.

Background:

1.1. Bonnet macaques: Origin and evolution

Apart from humans, the macaques are the most widespread, ecologically adaptable animals. One can found them in a variety of habitats, from dense rain forests to human localities. There are five primate species in southern India. One of them is bonnet macaque (*Macaca radiata*). *Macaca radiata* is endemic to South India. Paleontological, morphological and biogeographical studies indicate that the ancestral genus Macaca groups which include the bonnet macaques, Assamese macaque (*Macaca assamensis*), torque macaque (*Macaca sinica*) and Tibetan macaque (*Macaca thibetana*) emerged in Burma region about 1 million years ago. Then, these groups may have moved to the peninsular India, where they have to compete with the native primate species Lion-tailed macaques *Macaca silenus* (Delson, 1980). About 0.5 million years ago, M. silenus may have restricted to the south-west part of India and the other four species may have genetically isolated in the north-south part of India.

1.2. Morphology of bonnet macaque:

The bonnet macaques are omnivores, diurnal in nature and sociable. They live in the groups in their own marked territories. These are moderate-sized, long-tailed monkey having a cap-like tuft of hair radiating outward and backward which form centre parting in the front (McCann, 1933; Sinha, 2001). Dorsally, they are greyish- brown in colour. Inner parts of the limbs and ventral side of the body is covered with whitish gray hairs. The pale pinkish face of bonnet macaque is lacking in hairs. Pregnant and lactating female gets dark red coloured face mainly during the end of the lactating period. Generally, adult males are always heavily built with larger head and canines than adult females. Bonnet macaques possess ‘chick pouches’ which help them to forage food. An interesting feature of bonnet macaque, they do not show much variation in sexual dimorphism in their weight

and morphology as compared to the other macaque species. It appears that the bonnet living in the urban/rural areas are larger in size than those in forests (Krishnan, 1972).

1.3. Distribution:

The bonnet macaque occupies a variety of habitats in Southern India. Their distribution is limited mainly to Godavari and Tapti River to the east and west. It is believed that the distribution of bonnet macaque is limited northward due to their competition with another macaque species, rhesus macaque (*Macaca mulatta*) of northern India (Fooden *et al*.1981). Rhesus macaque is much more geographical successful and their better adaptability to the habitat, more aggressive nature might have constrained bonnet macaque in the limited area.

1.4. Habitat preference:

Bonnet macaques are omnivores. They can occupy in a wide array of habitat. Mainly, there are situated in two types of ecological habitat: forests and human habitats/civilizations. Bonnet macaques are commensal with humans.

The types of forests which are populated by bonnets include a dry deciduous forest of Karnataka and Tamil Nadu, bamboo jungles, rainforests situated on the Nilgiri Hills, and the semi-evergreen forests from the coastal region of Kerala. Strangely, they are very uncommon in *Shola* forest which is just beside to the Nilgiri hill's grassland (Sinha, 2001).

In urban and rural areas, they can be found in agricultural field/farm feeding on maize, rice, jowar, bajra, and various grams and pulses. A recent survey says, 31% of bonnet macaque found in temple sites and tourist spots. However, 48% of bonnets are disappeared or eliminated from these locations (Joseph *et al*. 2017; Kumara *et al*. 2009). Bonnet macaques also encountered in big cities like Bangalore, Chennai (Kurup, 1981; Simonds 1965).

The roosting sites for bonnet in forests used to be near to the lakes and river (Krishnan, 1972; Ali, 1981, Sinha 2001). In urban areas, they prefer to roost on temples, sides of buildings (Kuruvilla, 1980). The height was they roost may differ according to age/sex class. Lower height is a preference of Adult males for roosting (Ali, 1981).

1.5. Feeding ecology of bonnet macaque:

Bonnet macaque can feed on a variety of food including leaves- flower- the fruit of different trees, Shrubs, herbs, roots, stems, tendrils, seeds and grasses (Kuruvilla, 1980; Ali, 1981; Sugiyama, 1971). There are 86 plant species from deciduous forests and 39 species from evergreen rainforests known which bonnet macaque feed on (Sinha, 2001; Ali, 1986; Krishnamani, 1994). Some of the plant species that bonnet macaque feed on is Banyan (*Ficus benghalensis*), Neem (*Azadirachta indica*), Pongamia (*Pongamia pinnata*), Tamarind (*Tamarindus indica*), Mango (*Mangifera indica*), Gulmohar (*Delonix regia*), Copperpod (*Peltophorum ferrugenium*) and Cashew (*Anacardium occidentale*). Bonnet macaques are also seen eating grasshoppers, crickets, termites, spiders and birds eggs (Ali, 1986; Kuruvilla, 1980). Due to their commensal behaviour with humans, they get food by provision by humans (Sinha, 2001). In places like temples and wildlife sanctuaries, they get a large amount of food from tourist and worshippers.

Feeding behaviour of bonnet macaque is interesting to study. While foraging, if they get food on the ground, they store the food in their chick pouches. Later, they go to any quiet places or some height on the tree and feed on the stored food. Another interesting behavior is they feed on the solid food; they rub the food with their upper palms and eat it (Roonwal and Mahnot, 1977).

1.6. Breeding biology of bonnet macaque:

In the natural environment, bonnet females sexually mature at the age of $2^1/_2$ to 4 years and sexual maturity in males is attained at the age of 3 to 4 years (Simonds, 1965). In captivity, females mature at the age of 3 years ± 4 months and males mature at about 6 years of age (Rao *et al.* 1998).

There is a chain of oestrus cycle occurs in mature female bonnet macaque in a year. The length of each cycle is staying approximately 28 ± 4.3 days (Rao *et al.* 1998). In every cycle, females may be receptive for only 4 to 5 days (Rahaman and Parthasarathy, 1971). It takes 9 to 10 days for receptivity in captive females (Rao *et al.* 1998).

The reported gestation period for natural troop females is 6 months (Prater, 1980). In captivity, it takes 166 ± 5 days (Rao *et al.* 1998). Bonnet female reproduces only one

individual at a time (Krishnan, 1972). The female fertility is negatively correlated with the number of females in a group (Silk, 1988).

The average longevity of Bonnet macaque in the natural troop is 20 to 25 years (Sinha, 2001) and in captive monkeys, it can go up to 30 years (Prater, 1980).

1.7. Reproductive Strategies in Bonnet macaque:

Like all macaque, Bonnet macaques live in multimale-multifemale groups (Cooper et al. 2004). There is linear ranking order among adults (Sugiyama, 1971). The kin-biased pattern of affiliation and alliance formation is seen among the females of bonnet macaques (Cooper *et. al* 2004). Females remain in their natal group throughout their life. An adult male may emigrate to another group to get more reproductive success. Males may join a troop of females and restrict other males from having sexual intercourse with those female. This type of defence is called “Female-defense polygyny” (van Schaik et. al 1992; Cooper et. al 2004). Females get resource defence by males from other groups and as a favour; they expected to mate with males which actively involved in between group encounters and resource protection. Males are used as “hired guns” by females for resource defence (Cooper et al. 2004).

1.8. Intergroup relations in bonnet macaques:

The territories of bonnet macaque troops may overlap with each other. In such condition, every group is expected to protect their resources from the other groups. In adjacent groups, a dominant group with more fighting power is expected to affect the movement of the other group. The dominance among groups is dependent on the number of adult individuals in a group, fighting experience of individuals in a group, number of males in a group.

The rate and the behaviour of bonnet during intergroup encounters may be altering between forest living macaques and macaques which are living in urban conditions (Cooper *et al.* 2004). Generally, encounters between bonnet groups occur either to get food sources or to get access to mate (Cooper et al. 2004). Cooper (2004) found out, the

group encounters are more in forest group (1.40 encounters per day) than in temple group (0.77 encounters per day).

1.9. The scope of the study:

There is a drastic decrease in population of bonnet macaque in the past few decades. A recent study showed the decrease of population of bonnet macaque is due to rhesus macaque's 'range extension' (Kumara *et al*. 2011). Habitat loss and fragmentation of land lead to the decline in the population of bonnet macaque (Singh *et al*. 2011). Farmers do not prefer bonnet macaque's raiding crops in villages and urban areas. Due to increase in conflict with people, there is translocation and elimination of bonnet macaques from these areas (Kumara *et al*. 2009; Singh *et al*. 2011). In Karnataka, elimination rate of bonnet macaque from the temple and tourist-related spots from different regions are as follows: 90.32% from coastal, 53% from western and 36.59% from southern region (Kumara *et al*. 2009). Since bonnet macaque shares many traits with the other commensal species, it can be a model species for commensal species which living among humans. We can develop conservation strategies by studying the species and the factors affecting the species.

1.10. Goals of this Dissertation:

In this thesis, I investigate space use and ranging pattern in commensal bonnet macaques at Chamundi Hills, Mysore, India. I have collected scan sampling data (Altmann, 1974) on feeding ecology to study activity budget on feeding by bonnet macaque.

2. Materials and methods:

2.1. Study sites and study groups*:*

The study was conducted at Chamundi Hills, which is located 13 km east of Mysore, Karnataka (12° 18'N and 76°39'E). Chamundi Hills is a rocky outcrop with deciduous scrub forest at large section. The forest of Chamundi Hills is a reserved forest in 2001 by Karnataka state forest department. At the top of the Chamundi Hills, an ancient Temple surrounded by a village and tourist related shops are present.

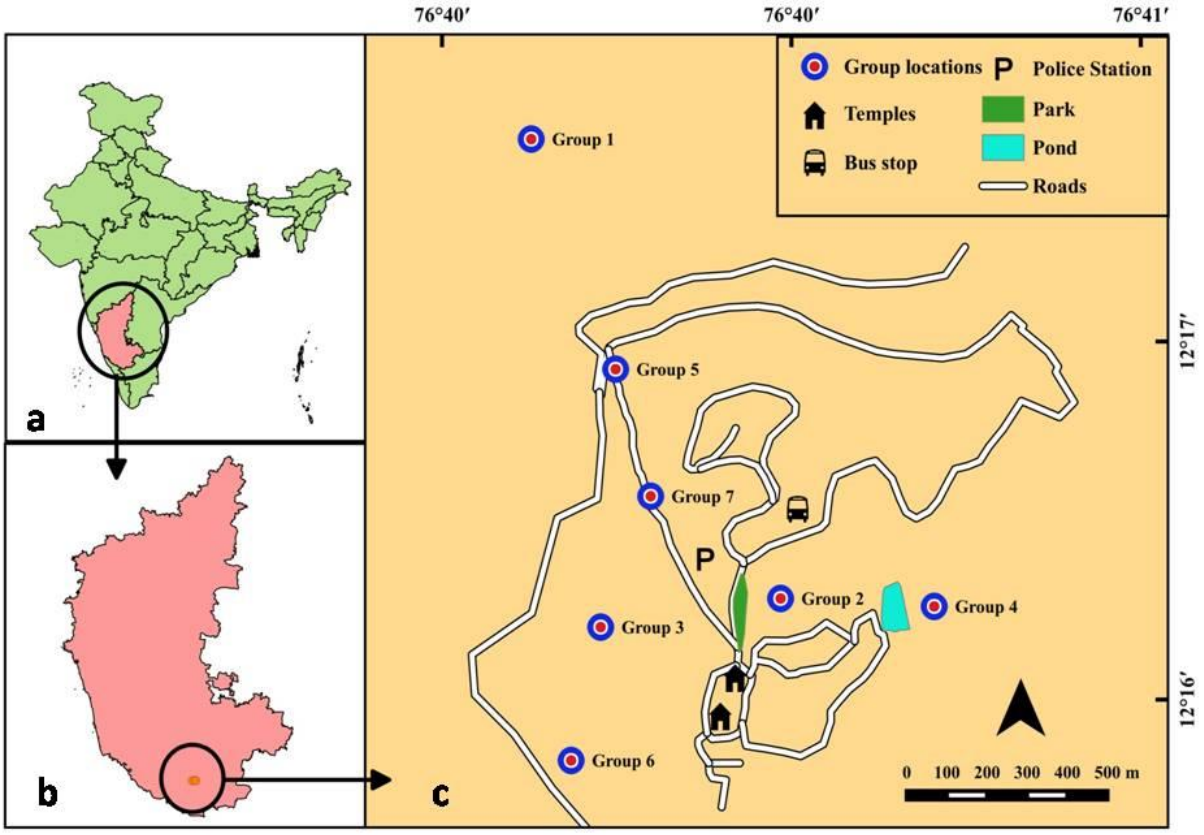

Figure 1. The map of South India showing the location of the study site in the Karnataka.

The Chamundi Hills has a long history of monitoring of bonnet macaque for different ecological studies (Copper et al. 2004; Singh and Rao, 2004; Kumara et al. 2010; Mangalum et al. 2014; Erinjery et al. 2017). Because of the previous studies, bonnet macaques are habituated to the presence of humans including observer. Bonnet macaques are known to get food from worshippers and tourists at the temple and also

groups in the same forest depend on the natural food resources (Cooper et al. 2004). They also have a habit of stealing food from shops and local houses.

I selected four groups of bonnet macaque for the current study. One group (Group 1) is situated at the foothill and other three are the adjoining groups (Group 2, Group 3, Group 4) at the top of the hill. Groups are identified based on individual identification of some individuals within the group, their locations and their demography.

2.2. Field method for collecting ranging and DPL data:

I observed bonnet at Chamundi Hills for total 7 non-consecutive months. Bonnet macaques live and move in a group. Occasionally, they split into small groups while doing daily activities. To retrieve information on ranging behaviour of bonnet macaque, I carried out a full day observation for each group from dawn (6:00hrs) to dusk (18:00hrs) or until the group reaches its sleeping site for four days in a month. While following a group, geo-coordinates were recorded using a handheld GPS (eTrex H, Garmin, Kansas city) in every 30 minutes interval from dawn to dusk. Roosting site coordinates are also taken for each group in the morning. All possible interactions of macaques with humans and geo-coordinates of the roosting site have been recorded (Boonratana 2000; Santhosh et al. 2015) throughout the study period. The data on group spread area was calculated by recording the distance between two outmost individuals at two ends along two perpendicular axes in every 30-minute interval (Santhosh *et al.* 2015) while following a particular group.

The demography data is recorded for each group based on their age/sex. Every group is divided into five categories: Adult male (AM), Adult female (AF), Sub-adult male (SM), Juvenile (J) and infants (I) to quantify group size. The mean sizes of Group 1, Group 2, Group 3 and Group 4 are 40.64 ± SD 0.92, 31.94 ± SD 0.42, 31.67 ± SD 1.35 and 40 ± SD 0.38 respectively.

Table 1.Demography of each study groups with SD (Standard Deviation)

Groups	Adult Males	Adult females	Sub-adult males	Juveniles	Infants	Total
Group 1	4.36 ± 0.5	13.00 ± 0.00	3.13 ± 0.50	15.09 ± 1.30	4.55 ± 0.52	40.64 ± 0.92
Group 2	4.50 ± 0.62	10.94 ± 0.24	3.56 ± 0.51	10.50 ± 0.51	2.44 ± 0.51	31.94 ± 0.42
Group 3	3.07 ± 0.26	14.00 ± 0.00	2.80 ± 0.41	7.40 ± 0.51	4.40 ± 0.51	31.67 ± 1.35
Group 4	7.13 ± 0.35	15.00 ± 0.00	3.13 ± 0.35	12.13 ± 0.83	2.60 ± 0.83	40.00 ± 0.38

For resource availability estimation (Twinomugisha and Chapman, 2007) and to calculate the home range, a shapefile of the entire study site was created on QGIS. The entire habitat range of the study groups is gridded with 1 ha (100m × 100m) grid cells, a total of 65 grid cells. The location points of each group in a grid cell will give the intensity of use of that particular grid, basically, home range use (Santhosh et al. 2015). To calculate home range, 'Grid cell' method was used.

Grid Cell method:

This method was used to calculate home range size. In this method, the area covered by the group is splice into grids of cells. The intensity of location points in grids gives us use of habitat, and the count of all the grids used is the home range size (Grueter *et al*. 2008). This is a choice of method to calculate home range size if a group is followed over a long period of time. If this method is used in a small duration study, it might underestimate the home range size because many location points according to seasonal variation go undetected (Grueter *et al*. 2008).

2.3. Activity Budgets:

The group's scan sampling method (Altmann, 1974) was used to measure activity budget and feeding ecology of groups. The focal group was scanned for 5 minutes at every 30 minutes interval from dawn to dusk. I have recorded activity behaviour based on four categories: Resting, Feeding, Social (includes grooming, play, aggression within the group and agonistic interaction) and Movement. If the individuals are feeding, I am

recording information about feeding species and which part (fruit, stem, leaves etc.) that has been eaten. The Movement includes movement between two different strata and it also includes the movement happened while foraging food. The Height of the strata and the animals' height on the strata were recorded. Scan-sampling data on the infants is not been collected as infants are highly dependent on the adults (Santhosh et al. 2015).

2.4. Rainfall and Temperature:

The 30 years annual data on Rainfall and temperature of Mysore was collected from Indian Meteorological Department site (www.imd.gov.in/), since the rainfall and temperature are suspected ecological factors influencing the ranging pattern.

2.5. Vegetation Sampling:

The vegetation data were collected on February 2018. A 1 ha (100m × 100m) grids were superimposed by QGIS on the digital map of Study area obtained from Google earth pro. In every grid, 10m × 10m quadrates for trees and 2m × 2m quadrates for shrubs and grasses were laid. A total of 130 quadrates were laid to estimate the vegetation types. From every quadrate, a number of each feeding tree/shrub/grass species is recorded. A species with Girth at Breast Height (GBH) > 20m were considered as tree species and a species with GBH < 20m considered as a shrub. The species identity is recorded to measure tree density.

2.6. Intergroup Encounters:

When two groups come close to each other at a visible distance approximately 150m that I considered as an inter-group interaction. When groups move away from each other, the encounter was ended. I saw few encounters between three study group (Group 2, Group 3, and Group 4). *Ad libitium* data was collected on the intergroup encounter between these groups.

The intergroup encounter data includes geo-coordinates (at which encounter happened), time duration, participants of the focal group with their age/sex class and the other group with age/sex class and their behavior during intergroup encounters.

The behavior was divided into non-aggressive encounters and aggressive encounters. Further, non-aggressive encounter is divided into three categories as type1, type 2, and type 3; aggressive encounters are divided into type 4 and type 5.

	Types of Behavior	Description
Non-aggressive encounters	Type 1	After seeing another group, members of the focal group start monitoring the area.
	Type 2	When two groups are at a visible distance, avoidance of other group or move away from another group.
	Type 3	The movement towards members of another group without any aggressive approach
Aggressive encounters	Type 4	Includes behavior like chasing, vocal communication display.
	Type 5	Includes fighting, biting, scratching the members of other groups.

There was difficulty in observing all the group members involved in intergroup encounters in this method, due to the presence of houses and buildings. So the number of individuals involved in these encounters might have underestimated. But the data probably give an accurate estimate of recognizable behavior like aggression and flee.

2.7. Data analysis:

For parametric and non-parametric statistics, I used SPSS v16.0 (SPSS Inc. 2007) to analyze all the data. We compared all the scan data on the major activities (resting, feeding, social and movement) between the study groups. Also, we compared the data on major activities between Wet season (June-November) and Dry season (December-May) for every group. We use the chi-square test of goodness-of-fit and G-test of independence (Riley, 2008; Santhosh, 2015) to measure the percentage time taken for each activity in Dry and Wet season. The feeding scan data of each group were compared from the Dry and Wet season for various food resources. The percentage of major food eaten by a group was calculated in Dry and wet season.

We used all the data of DPL from June 2017 – February 2018 for all the groups. The Geo-coordinates of location points travelled by groups for each day was collected from the GPS. The DPL for each study day was calculated by connecting the location points travelled by groups in every single study day on Ranges 7 v0.64 (Anatrack Ltd. 2005). Then we calculated the mean DPL for dry and wet season. We compared the mean DPL across study period using ANOVA. Other data like temperature and rainfall also used for the analysis. The mean rainfall for the study site was 100.57±SD43.94 for wet season (June - November) and 35.90 ± SD46.49 for dry season (December – May).

To estimate the grid cell use, the frequency of total location points in each grid is divided into five categories: a) not used, b) <5%, c) 5-25%, d) 25.01-50% and e) >50%. The grid size was 1 hectare. The home range use for overall, wet and dry season is calculated.

To check variation in intergroup group per day between three study groups (Group 2, Group 3, and Group 4), Chi-square test is used to calculate the expected and observed frequencies of intergroup encounters, Ideal gas model (Kumara et al. 2014; Wasper, 1976) was used.

$$f=4pv/\pi(2d+s)$$

Where p is the group density/km^2 , v is the DPL in km/day, d is the distance between two groups in intergroup encounters in km and s is the group spread area in km (Kumara et al. 2014).

The weight of adult bonnet macaques from every study groups was compared using ANOVA.

3. Results:

3.1. Activity budget of study groups:

The percent scan on time spent on different activities between the study groups was not significantly different (Friedman test; $\chi^2 = 0.900$, df = 3, p = 0.825). Similarly, percent time spent on different activities between the study groups in dry (Friedman test; $\chi^2 = 0.300$, df = 3, p = 0.960) and wet season (Friedman test; $\chi^2 = 0.900$, df = 3, p = 0.825) were also not different (Table 2). The group spends more time on resting than other activities by all the groups and in both the seasons.

Table 2.Percent activity spent in different activities in dry and wet season by the bonnet macaque study groups, Chamundi Hills, Mysore.

	Dry Season			
	Resting	**Feeding**	**Social**	**Movement**
Group 1	65.34%	17.53%	12.26%	4.87%
Group 2	69.25%	16.38%	11.07%	4.88%
Group 3	71.67%	14.07%	15.97%	3.07%
Group 4	64.92%	15.92%	11.78%	6.96%

	Wet Season			
	Resting	**Feeding**	**Social**	**Movement**
Group 1	59.37%	20.77%	14.52%	5.34%
Group 2	66.35%	17.10%	11.63%	8.38%
Group 3	65.22%	15.66%	24.26%	5.68%
Group 4	69.65%	15.56%	12.075	1.72%

Group 1:

The resting (dry=65.35% and wet=59.37%) was more in wet and dry seasons. Then comes, feeding (dry=17.53% and wet=20.77%); Social (dry=12.26% and wet=14.52%) and Movement (dry=4.87% and wet=5.34%). The resting goes down and movement goes up between 12:00 hrs to 14:00 hrs in the dry season. Feeding was more or less constant in both the seasons (fig 2).

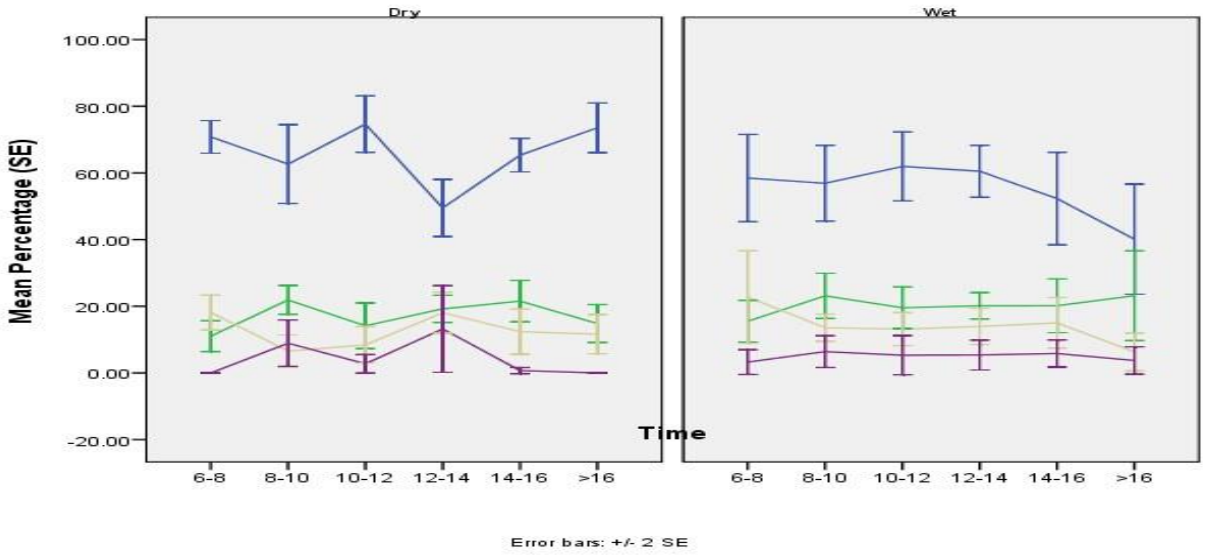

Figure 2.The season wise mean percentage time spent on different time period for major activities by bonnet macaque study group 2 (Blue = resting, Green = feeding, Brown = social, Purple = Movement) with SE (Standard error).

Group 2:

Resting (Dry=69.25% and Wet=66.35%) is more than feeding (Dry=16.38% and Wet=17.10%), Social (Dry=11.07% and Wet=11.63%) and Movement (Dry=4.88% and Wet=8.38%). In Group 2, resting decreased between 14:00 hrs to 16:00 hrs, during this time interval movement activity, increased in the wet season (fig 3).

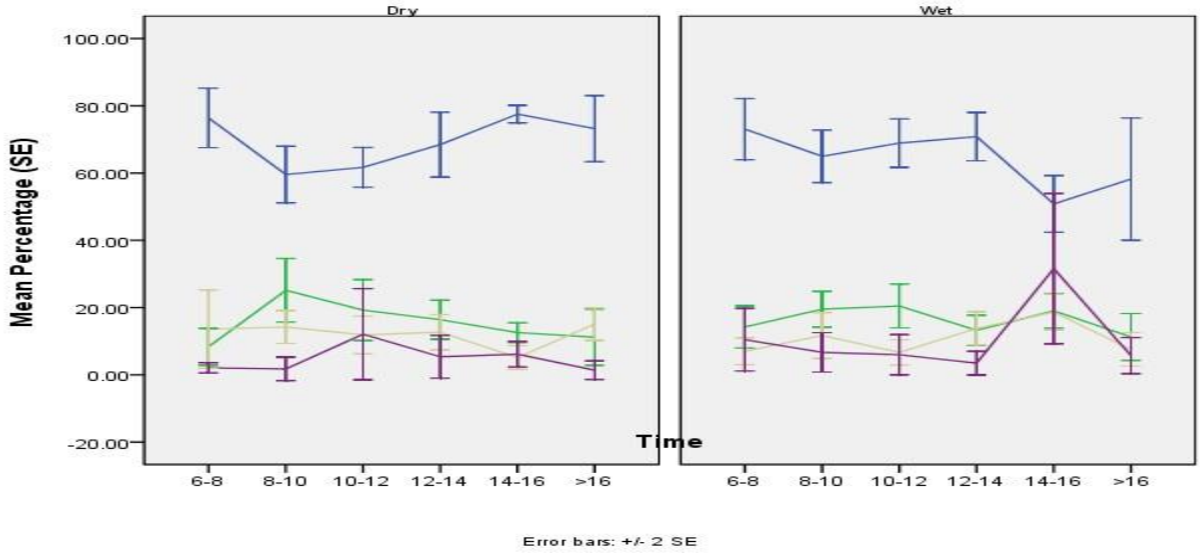

Figure 3. The season wise mean percentage time spent on different time period for major activities by bonnet macaque study Group 1 (Blue = resting, Green = feeding, Brown = social, Purple = Movement) with SE (Standard error).

Group 3:

For Group 3, resting (Dry=71.67% and Wet=65.22%) is more than feeding (Dry=14.07% and Wet=15.66%), Social (Dry=15.67% and Wet=24.26%) and Movement (Dry=3.07% and Wet=5.68%). Social activity was more in other than any other activities in wet season during time interval 12:00 hrs to 14:00 hrs. Other activities (resting, feeding and movement) are constant in both seasons (fig. 4).

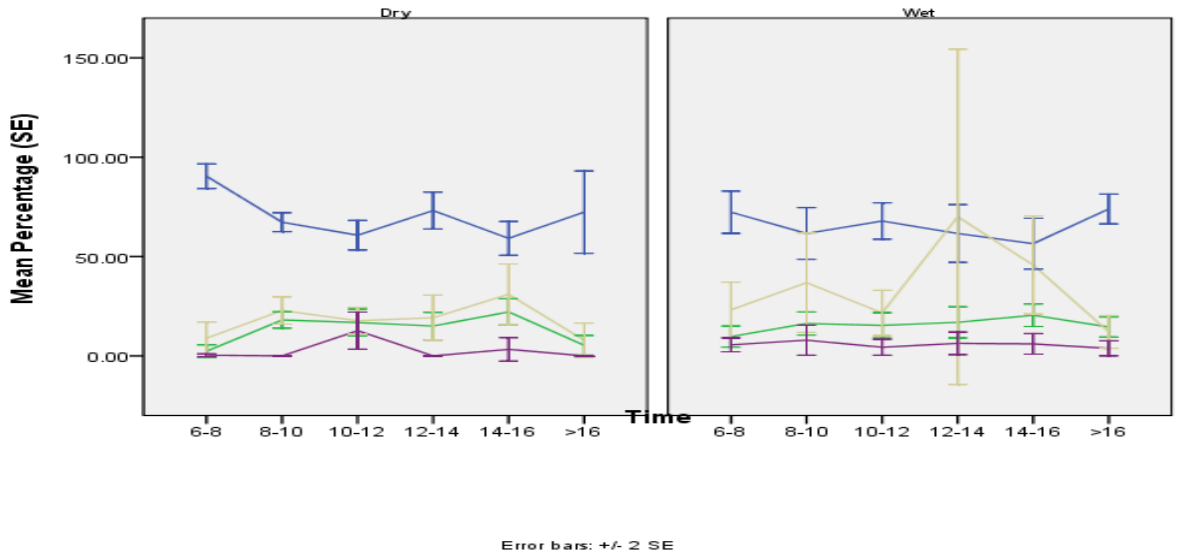

Figure 4. The season wise mean percentage time spent on different time period for major activities by bonnet macaque study Group 3 (Blue = resting, Green = feeding, Brown = social, Purple = Movement) with SE (Standard error).

Group 4:

For Group 4, resting (Dry=64.19% and Wet=69.65%) was more than feeding (Dry=15.92% and Wet=15.56%), Social (Dry=11.78% and Wet=12.07%) and Movement (Dry=6.96% and Wet=1.72%). Movement activity is constant all over a day in wet season, whereas it changes gradually in the dry season from dawn to dusk (fig. 5).

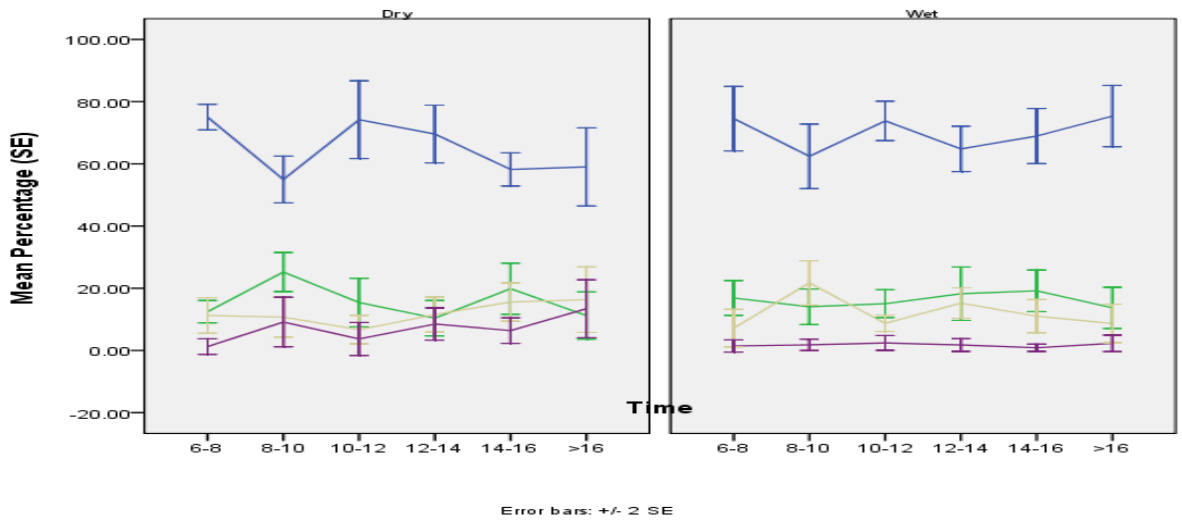

Figure 5. The season wise mean percentage time spent on different time period for major activities by bonnet macaque study Group 4 (Blue = resting, Green = feeding, Brown = social, Purple = Movement) with SE (Standard error).

3.2. Daily path length:

During the wet season, the mean DPL between Group 1 (462.57 ± SE 119.43, N = 15 days); Group 2 (738.39 ± SE 119.43, N = 15 days); Group 3 (889.65 ± SE 237.77, N = 14 days) and Group 4 (828.76 ± SE 221.49, N = 14 days) varied significantly ($F_{3, 54} = 20.268$, P = 0.000). Similarly, the DPL also varied significantly in Dry season ($F_{3, 40} = 5.208$, $p < 0.01$) between Group 1 (555.79 ± SE 196.50, N = 8 days); Group 2 (800.09 ± SE 230.97, N = 12 days); Group 3 (791.03 ± SE 228.35, N = 12 days) and Group 4 (935.57 ± SE 270.08, N = 12 days) (Fig.6).

The mean DPL between Group 1 (494.96 ± SE 32.13, N = 23 days); Group 2 (778.68 ± SE 33.13, N = 27 days); Group 3 (844.14 ± SE 46.91, N = 26 days) and Group 4 (878.06±SE 32.28, N = 26 days) varied significantly ($F_{3, 98} = 20.840$, p = 0.000) throughout study period (Fig. 7). Tukey's honestly significant difference (HSD) post hoc test further indicated that Group 1 is significantly different than the other groups.

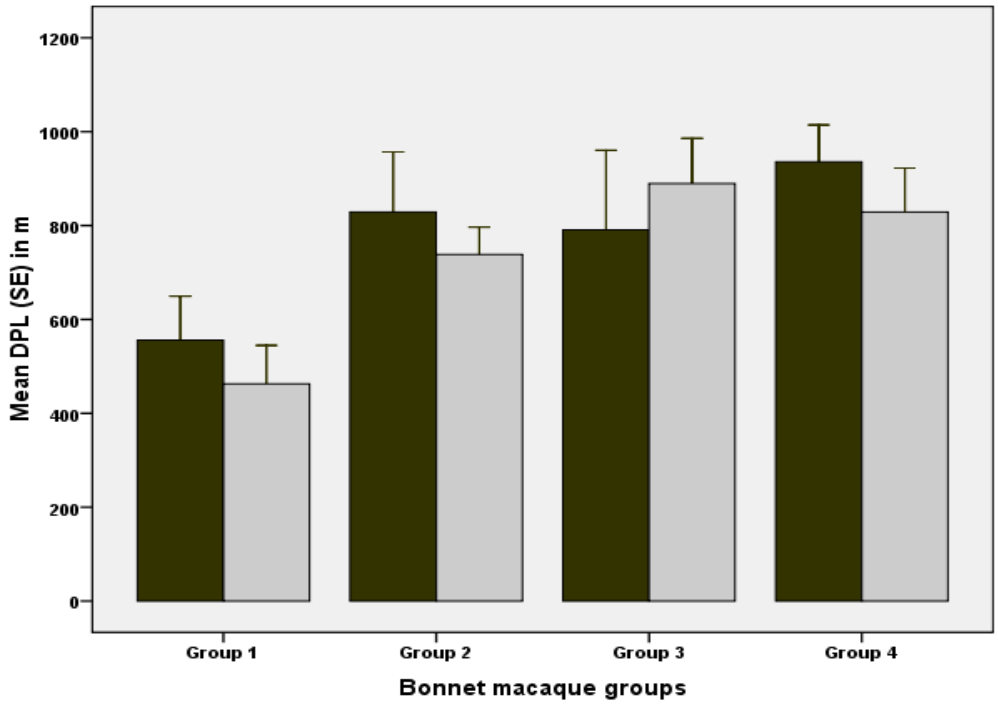

Figure 6. ***Mean daily path length in meters with standard deviation (SE) by bonnet macaque study groups in dry and wet seasons (Black: Dry season; Grey: Wet season*****).**

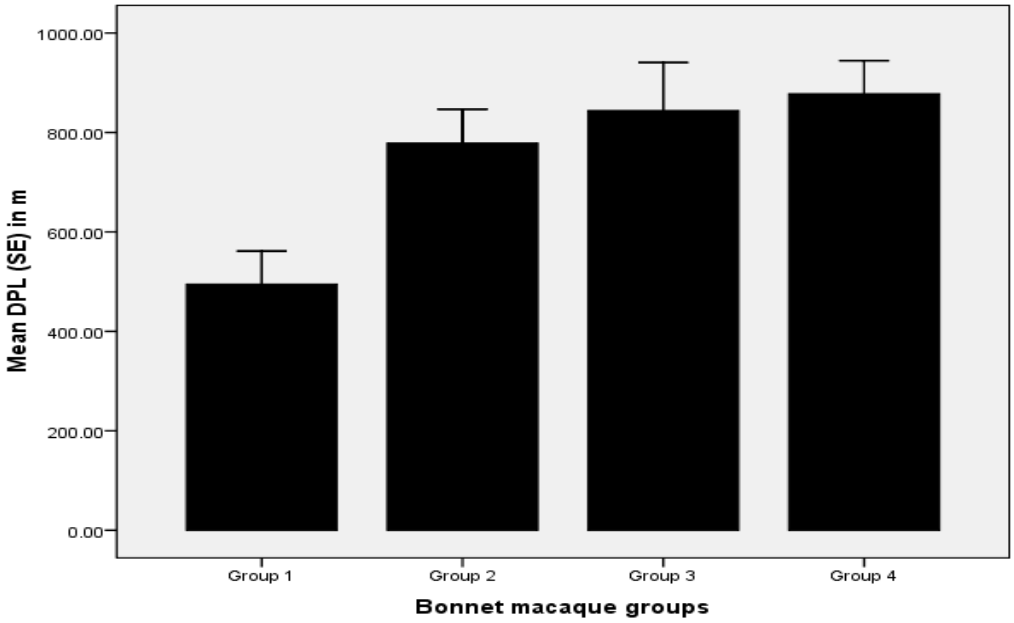

Figure 7. Overall Mean daily path length in meters by bonnet macaque study groups with standard error (SE)

3.3. Home Range use:

Group 1:

The size of each grid cell is 1 ha. The study group 1 used five grids for overall study time period. In the wet season, it uses all five grids. In the dry season, it uses only four grid cells. The group spend more time (>50%) in the same grid cell in both wet and dry season.

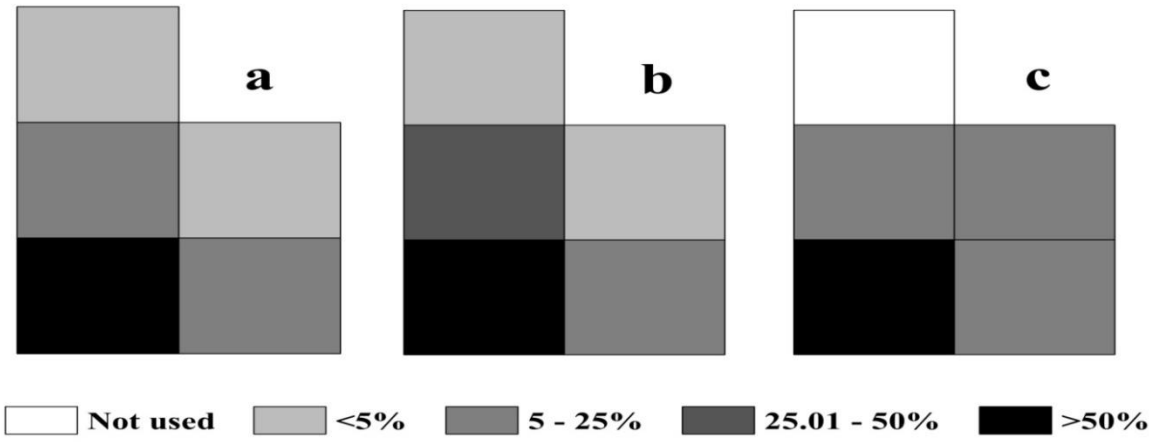

Figure 8. Percentages use of grid cells by the Group 1 bonnet macaque from Chamundi Hills, Mysore in (a) Overall, (b) wet season and (c) dry season.

Group 2:

The group 2 uses, a total of 9 ha land (9 grid cells) throughout the time period. In the wet season it uses 8 grid cells, whereas in the dry season it uses all the 9 grid cells for their activities. Not a single grid cell was used for more than 50% in dry season and only one grid cell was used for more than 50% for daily activities in wet season.

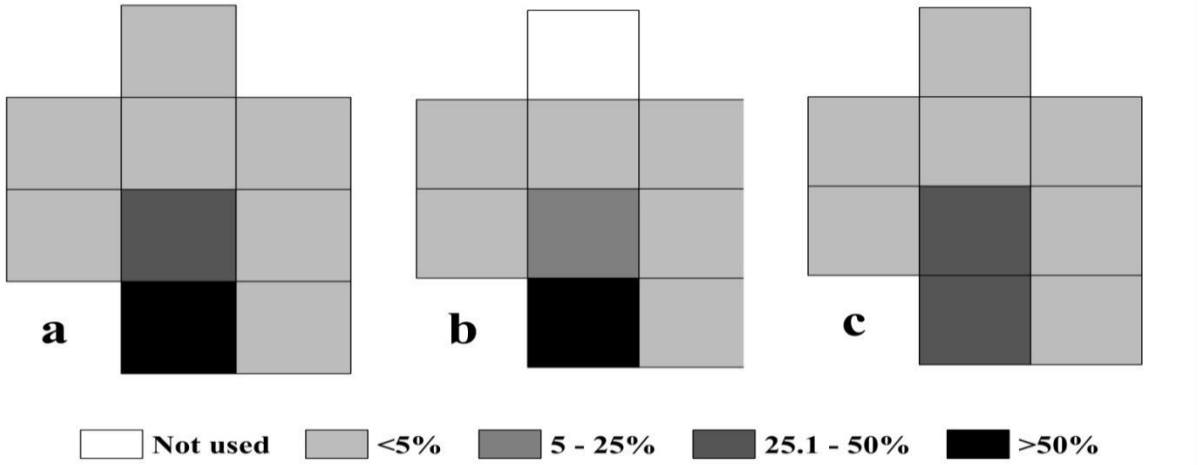

Figure 9. Percentages use of grid cells by the Group 2 bonnet macaque, Chamundi Hills, Mysore in (a) Overall use, (b) wet season and (c) dry season.

Group 3:

The group 3 uses 7ha (7 grid cells) throughout the time period. 6 grid cells were being used in wet season. In the dry season, it uses 6 grid cells. But the one grid cell which was not been used is different in wet and dry season. One grid cell is used for more than 50% in a dry season. In the wet season, the group didn't use any grid cell for >50% (Fig 10).

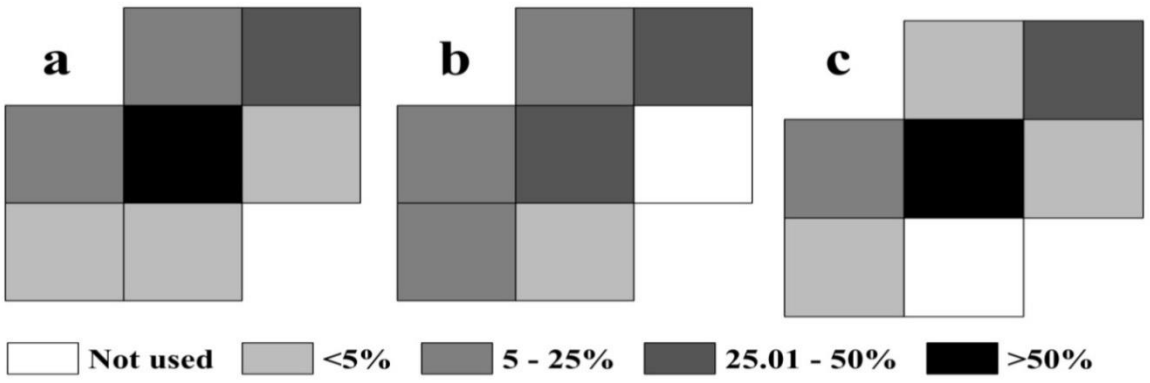

Figure 10. Percentages use of grid cells by the Group 3 bonnet macaque, Chamundi Hills, Mysore in (a) Overall use, (b) wet season and (c) dry season.

Group 4:

The group for uses 8 grid cell for its activities in both wet and dry season. One grid cell was used for more than 50% in wet season. In dry season, almost all the grid cells were used equally. Not a single cell is used for more than 50% in dry season (Fig. 11)

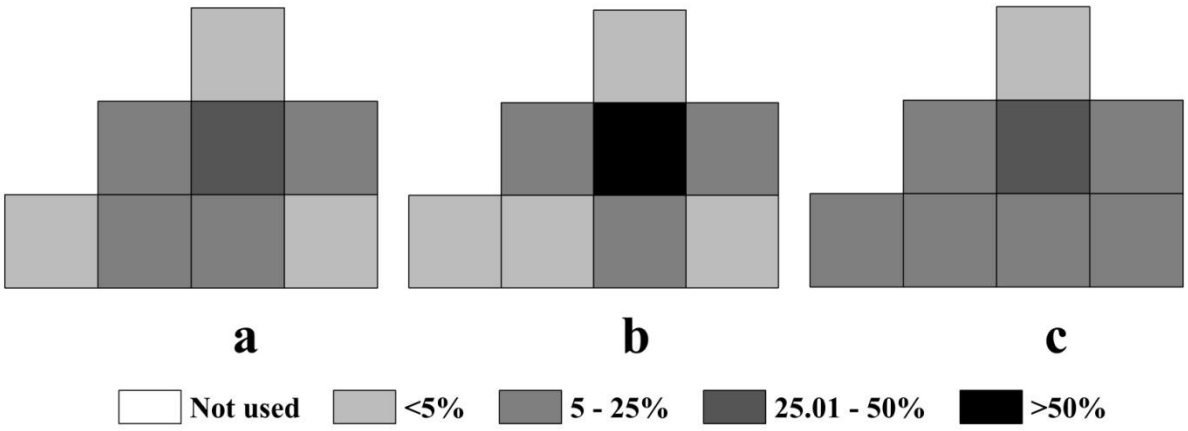

Figure 11. Percentages use of grid cells by the Group 4 bonnet macaque, Chamundi Hills, Mysore in (a) Overall use, (b) wet season and (c) dry season.

Table 3. Home range use in hectare (ha) by bonnet macaque groups

Groups	*Overall*	*Wet season*	*Dry season*
Group 1	5ha	5ha	4ha
Group 2	9ha	8ha	9ha
Group 3	7ha	6ha	6ha
Group 4	8ha	8ha	8ha

3.4. Feeding ecology:

The bonnet macaques found feeding on 16 plant species. The food resource which they get from humans is divided into four categories: fruits, nuts, baked food and cooked food.

Of the 732 feeding scans for group 1, it fed more on the provision food (67.75%) than the natural food resources (32.24%). From 697 feeding scans, the group 2 fed on natural resources (50.93%) over the food from the humans (49.06%). The group 3 was spent its more time on natural resources (57.65%) over the food from the humans (42.34%) in 558 feeding scans. Group 4 also had food from natural resources (83.49%) over the food from the humans (16.50%) in 612 feeding scans.

The feeding on the natural food resources and the food resources from the humans significantly varied between the study groups (Natural food resources: $G = 239.10$, $df = 3$, $p = 0.000$ and Food resources from the humans: $G = 151.18$, $df = 3$, $p = 0.000$). The feeding on natural food resources by group 4 is significantly higher than other groups. Also, the feeding on human's food resources was much lower than the other groups.

Table 4. Percentages feeding activity on Natural and Provision food in wet and dry seasons by bonnet macaque groups.

-	Group 1		Group 2		Group 3		Group 4	
Food resources	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Natural resources	N= 197	N=152	N=115	N=240	N=167	N=172	N=244	N=267
Ficus religiosa	13.83	19.15	-	-	-	-	16.78	7.84
Ficus benghalensis	8.87	9.26	1.48	4.86	-	-	9.26	5.88
Azadirachta indica	0.15	-	-	-	-	-	-	-
Albizia saman	1.56	5.22	0.67	-	-	-	7.73	11.84
Tamarindus indica	1.60	1.57	-	-	20.57	29.54	12.30	22.82
Delonix regia	-	2.40	-	3.45	-	-	1.39	-
Peltophorum pterocarpum	-	-	3.97	31.31	-	-	2.19	19.55
Pongamia pinnata	-	-	5.08	24.35	-	-	-	1.26
Nyctanthes arbor-tristis	-	-	0.24	-	-	-	-	-
Muntingia Calabora	-	-	0.30	-	-	-	-	-
Mangifera indica	-	-	-	-	1.16	3.79	0.34	-
Hibiscus rosa sinesis	-	-	-	-	-	0.93	-	-
Artocarpus heterophyllus	-	-	-	-	-	-	4.62	3.61
Lantana camara	-	-	-	-	-	-	1.37	5.27
Tagetes (flower)	0.45	0.93	0.28	-	5.06	11.81	0.27	0.67
Zoysia tenuifolia	12.83	9.14	14.75	31.31	24.64	18.87	23.78	8.72
water	2.34	1.09	-	-	-	-	1.25	0.63
insects	-	-	0.51	-	-	-	-	-
soil	-	4.88	2.06	6.58	-	1.28	-	-
Food from humans	N=275	N=121	N=247	N=95	N=156	N=93	N=64	N=37
Fruits	28.64	24.36	43.83	19.79	29.68	18.75	9.05	6.09
Nuts	8.51	5.12	21.35	7.02	6.48	3.97	3.89	2.26
Baked food	17.80	14.01	5.49	1.74	6.67	4.96	2.80	3.57
Cooked food	3.42	2.86	-	-	5.75	6.12	2.96	-

3.5. Intergroup encounters:

The expected frequencies of Intergroup encounters per day for group 2, group 3 and group 4 are 0.26, 0.33 and 0.33 respectively. Out of 14 Intergroup encounters, 78.57% encounters are non-aggressive encounters and 21.47% are aggressive encounters. There are 10 encounters come to pass between group 2 and group 3, from which 20% encounters were aggressive and 80% encounters were non-aggressive. Aggressive encounters were 25% and non aggressive encounters were 75% between group 3 and group 4 in 4 group encounters. No Intergroup encounter was recorded between group 2 and group 4.

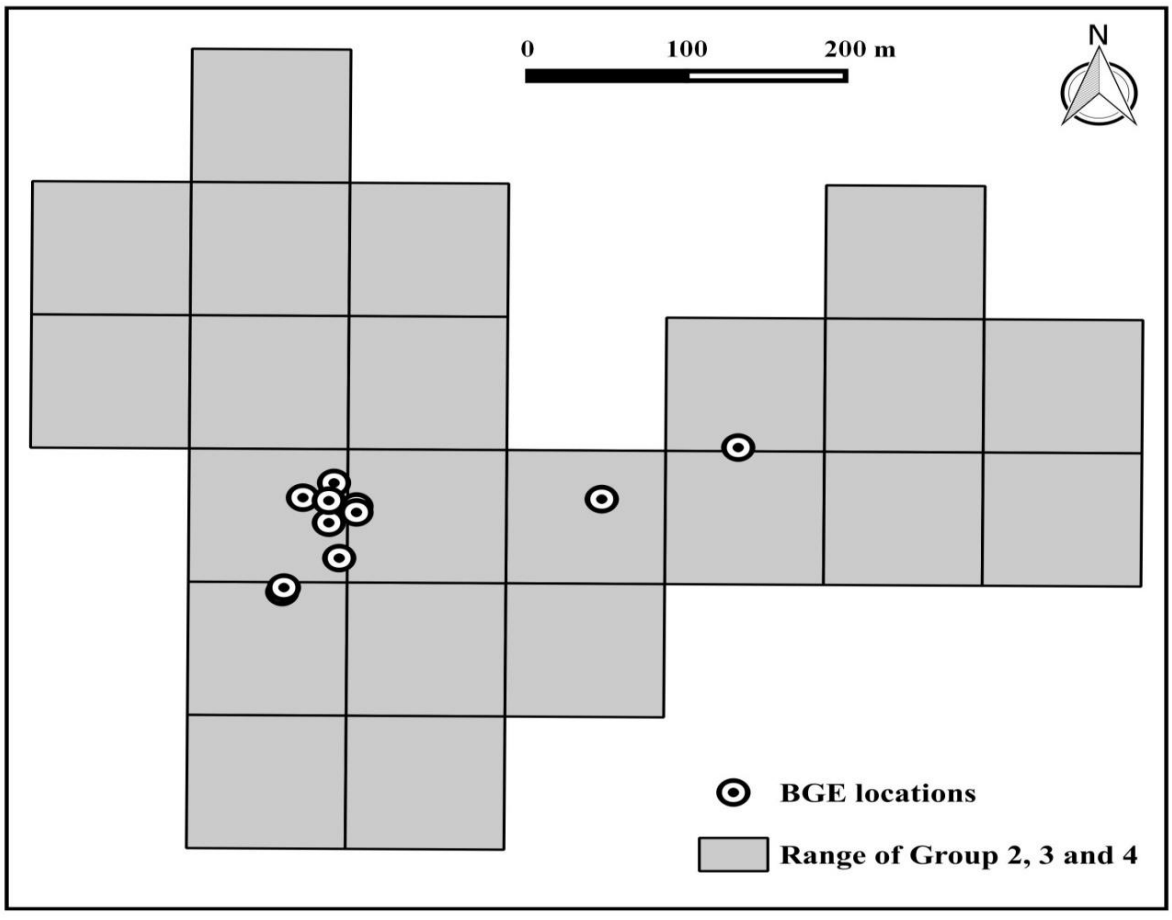

Figure 12. The ranges of Group 2, Group 3 and Group 4 and their group encounter rates on Chamundi Hills, Mysore, Karnataka.

Table 5.The expected frequencies and the observed frequencies of between-group encounters per day for bonnet macaque study groups.

Focal Group	*ρ (km2)*	*v(km/day)*	*d(km)*	*s (km)*	*Expected frequencies/day*	*Observed frequencies/day*
Group 2	1.2	0.78	0.1	0.02	0.26	0.22
Group 3	1.2	0.99	0.1	0.02	0.33	0.23
Group 4	1.2	0.99	0.1	0.02	0.33	0.08
Mean	1.2	0.84	0.1	0.02	0.28	0.18

3.6. Body weight of bonnet macaque:

The body weight of adult males and adult females from studied bonnet macaque groups was not significantly different between groups (ANOVA: $F_{3, 54} = 1.182$, $p = 0.325$). During this study, the highest weight recorded for an adult male was 15.50 kg. The highest weight of adult female was found 14.70 kg during this study. Both male and female are from the same group (Group 1).

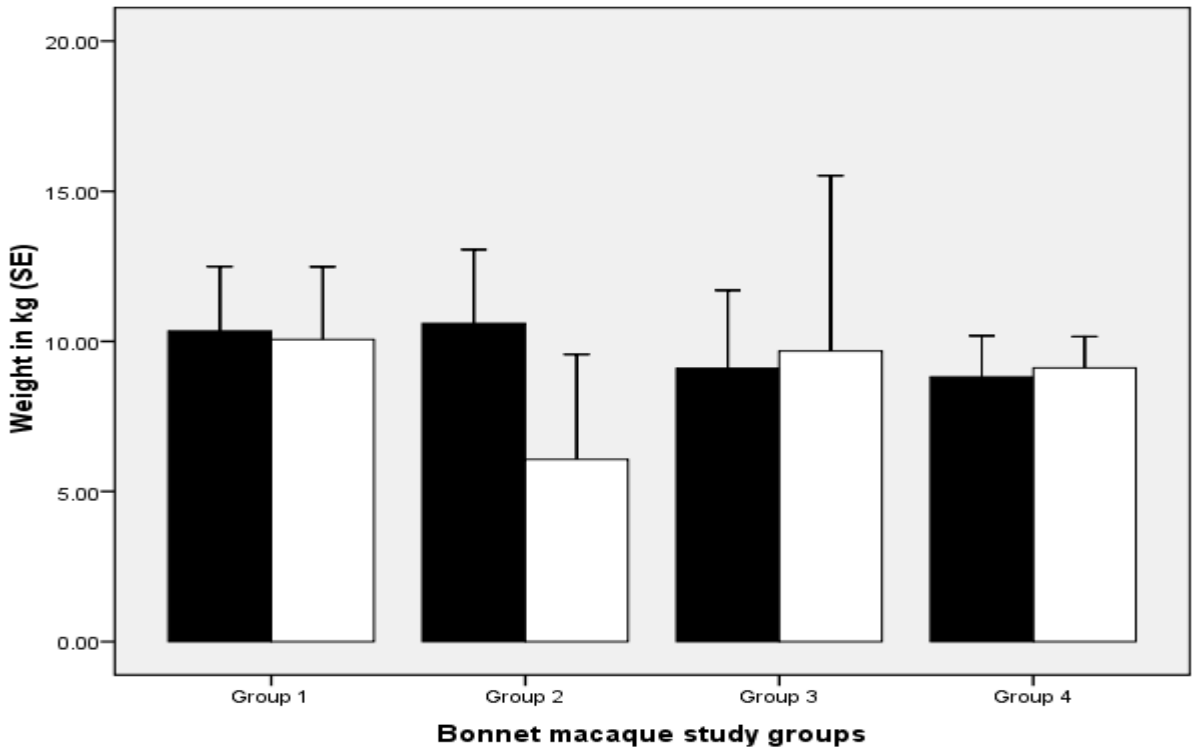

Figure 13. The weight of bonnet macaque study groups in kg with standard error (SE), Chamundi Hills, Mysore. (Black: Adult male and White: Adult female).

Table 6. Comparison of ranging pattern with other parameters.

Group	DPL (m)	Home range size (ha)	ADF Body weight (kg)	Food Provision (%)
1	494	5	10.06	67.7
2	778	9	6.06	49.06
3	844	7	9.69	42.34
4	878	8	9.11	16.5

Due to less number of groups that we focused on the study, we could not optimize the data for parametric correlation test. However, we performed non-parametric correlation test (Spearman rho) with Daily path length (DPL), home range size, mean adult female weight (ADF) from each group and food provision in each group. We found the daily path length decreases with increased provision ($r = -1.000$, $df = 3$, $P = 0.00$) and decreased home range size increases the female body weight ($r = -1.000$, $df = 3$, $P = 0.00$).

4. Discussion:

The aim of the study was to investigate variation in the ecological factors affecting the ranging pattern of the commensal bonnet macaque (*Macaca radiata*) and also the ecological plasticity of bonnet macaque to adapt such changes.

In this study, all the study groups have very high 'resting' activity and very low 'movement' activity. In the similar study, Singh and Vinathe (1990) found the urban bonnet macaques spend more time in 'movement' than any other activities. The time budget activity depends on the type of habitat, age/sex class of animal, home range size, availability of food and water in the home range, and group size and its composition (Singh & Vinathe, 1990; Sinha, 2004). The DPL varied between the groups, however; the difference is due to the amount of the food in the respective home ranges of the groups. There was a positive relation between DPL and the amount of food got from humans by a group. The group 1's home range is very close to human locality. This group gets a large amount of food from local people and tourists. The primary food source for the group is the food from humans (67.75%). Schlotterhausen observed the bonnet macaque living in human

habitation have ~70% of provision food in their diet (Schlotterhausen, 1999). The Group 4 lives little away from the human locality as compared to the other groups. The primary food source for this group is the natural food resource (83.49%). Members of the group 4 have to travel more in search of food. The patterns in the behavior of habitat use by a group living commensal with humans depend on the presence of neighbouring groups (Riley, 2008). The group 4 has two neighbouring groups (Group 2 and Group 3) in the area.

The bonnet macaque fed on 16 plant species in this study, in that the important plant species are *Ficus benghalensis (*Banyan) and *Tamarindus indica* (Tamarind). In the previous studies on the bonnet macaques banyan and tamarind were the preferable trees for feeding (Simonds, 1965; Kurup 1981), From the food which they get from human, fruits are their favourite, that too especially banana. The major feeding plant species is different for different groups. The consumption of plant species was higher in the dry season as compared to the wet season for all the groups, except group 1 (Table. 4). The group 1 got the most provision food from the people in the study. The choice of major food can be different for different groups depending on the habitat characteristics (Riley, 2008). The detailed information of major food resources is important to understand the ecology of bonnet macaque troops. This information also helps us in developing management strategies of conservation (Santhosh et al. 2015).

The documented home range size of bonnet macaque in forest varied from 40 ha to 520 ha (Sugiyama, 1971 and Simonds, 1965). In this study the highest home range size calculated was 9 ha for group 2. The resource availability and their dependency on handouts increase the sedentary life, that further increases the body weight that might have affected the home range size of the bonnet macaque groups in Chamundi hill. Because of metabolic requirements/energy expenditure of an animal is influenced by body weight, the amount of food eaten by an animal, the body weight shows an association with daily path length (Amsler, 2009). The reported weight of adult bonnet macaque is 5 kg -11.5 kg (Sinha, 2001). In our study group, there are macaques which have weight >11.5 kg. The group 1 has 6 individuals with weight >11.5 kg. Similarly, in group 2, group 3 and group 4 have 3, 1 and 2 individuals respectively. Also, we found

the negative correlation of between average weight of adult female for each group and home range use for the respective group. All the groups have higher mean DPL in the dry season and lower mean DPL in wet season except group 3, which has higher mean DPL in the dry season than wet season. A Lot of constructions work happened in the patches of group 4's home range during December'17 – February'18 (dry season). The increase in human activities than usual might have restricted the movement of bonnet macaque group.

The observed encounter rate for the between-group encounter was 0.18 per day, which is much lesser than the expected; further Cooper (2004) recorded 0.77 per day encounter with other groups on the Chamundi Hills. The mean aggressive encounter was 22.5% in our study. The documented aggressive encounters between bonnet macaque groups from Chamundi Hills are 29.3% (Cooper et al. 2004). The lower rate of between-group encounters in these groups may be due to increased handouts from the people, and they feed on food from provisions in a short period, then they shift to feed on grass and other natural food resources, that has to lead a smaller home range and highly confined to one or two grids.

Further research is needed at temporal and spatial scale to understand the degree of plasticity of habitat use by bonnet macaques living in urban areas.

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