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Land Use, Nature Conservation and the Stability of Rainforest Margins in Southeast Asia

With 87 Figures

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Home Range, Diet and Behaviour of the Tonkean Macaque (*Macaca tonkeana*) in Lore Lindu National Park, Sulawesi

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Introduction

According to Fooden (1969, 1980) there are 19 species in the genus *Macaca*, of which seven occur endemically on Sulawesi, an area covering less than 2% of the total generic range (Albrecht 1978 cited in Bynum et al. 1997). Although there are already several field studies on *Macaca nigra, Macaca nigrescen,* and *Macaca maura* (MacKinnon 1980, Sugardjito et al. 1989, Supriatna 1991, Kohlhaas 1993, Kinnaird and O'Brien 1995, 1996, Reed et al. 1997, Rosenbaum et al. 1998, Okamoto and Matsumura 2002), only little has been done on the behaviour and ecology of the Tonkean macaque *Macaca tonkeana*. The Tonkean macaque (*Macaca tonkeana*) is a Central Sulawesi endemic and considered at lower risk/near threatened (Lr/nt) by IUCN categories (Hilton-Taylor 2000). Sulawesi Macaques are found in lowland and hill forests but only uncommon at elevations above 1500 m (Sarasin & Sarasin 1905, cited in Whitten, 1987). For *Macaca tonkeana*, the primary conservation issue at this time appears to be the ability of populations to persist in highland protected areas, since habitat encroachment, hunting and eradication as crop raiders appear to pose problems at moderate elevations (Bynum *et al*. 1999). The Lore Lindu National Park in Central Sulawesi is located in the centre of the species' range and is comprised of generally mountainous terrain with over 90% of the park area located above 1000 m (Wirawan 1981).

In this paper we present data from this area on the species' home range, diet and behaviour. During four months of fieldwork at lower montane elevations, two neighbouring groups were studied, one being situated in flat but anthropogenically disturbed forest and one in hilly near-primary forest. The main objectives were to identify and describe (1) group size and composition, (2) diet, (3) home range and daily path lengths, and (4) activity patterns.

We assumed that habitat quality is positively correlated with group size and that – since animal movement is energetically expensive – it is negatively related to daily path lengths and home range size. We also assumed that the proportion of time that animals spend with different activities should be closely related to variability in resource abundance and hence habitat quality (Terborgh 1983; Robinson 1986; Kinnaird 1990 in O'Brien and Kinnaird 1997).

Methods

Study site

This study was conducted in the Lore Lindu National Park (LLNP), Central Sulawesi [01° 25' S, 120 ° 18' E] (Fig. 1). The 229,000 ha comprising the Park range from c. 200 to 2,610 m above sea level (Watling 1983). Annual precipitation lies between 2,500 and 3,500 mm (Wirawan 1981 in Watling 1983). A 120 ha study area near the village of Wuasa in the Napu valley was established ranging in elevation from 1000 to 1500 m a.s.l. The study area was made accessible by parallel trails at 100 m distance and all trails were marked at 50 m intervals. A map was drawn from the study area on which 0.25 ha blocks were delineated. The forested area was characterised mainly by two different vegetation types: (a) an almost flat area with a mosaic of disturbance regimes including secondary forest and mixed coffee/cocoa gardens under natural forest tree cover and (b) a near-primary hilly area with steep slopes without gardening activities but frequent rattan collection and hunting. Annual cultures, mainly maize fields or beans dominated the farmland bordering the forest.

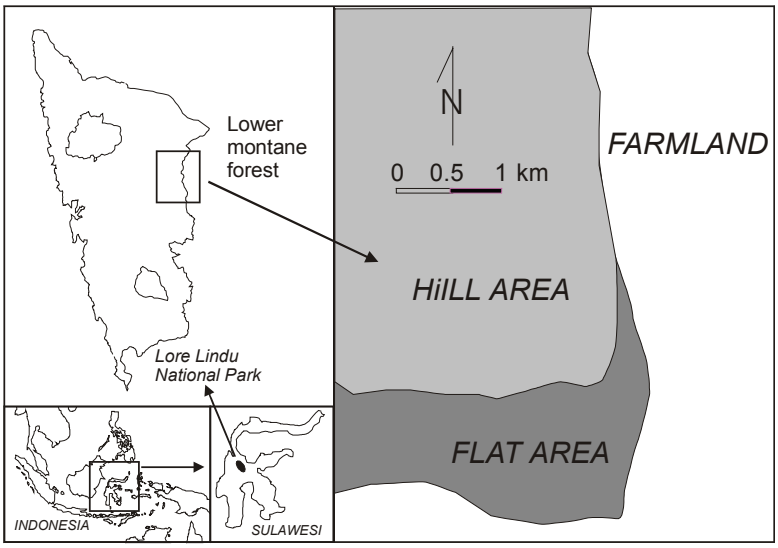

Fig. 1. Location of Sulawesi, Lore Lindu National Park and habitats of the study area. The hilly area (pale grey) was covered by largely undisturbed forest while the flat area (darker grey) was moderately disturbed by farming and tree felling.

Data collection

During a preliminary survey, six separate macaque groups and two solitary individuals were located in or near the study area, the groups ranging from *ca.* 10 to 25 individuals (x = 16 individuals). Two neighbouring groups that were located near the forest margin were selected for data collection. Both groups were habituated to human observers.
After a habituation period of four weeks (November 2001), each group was followed for four months and 5 days per week from 06.00 to 18.00 hrs and accompanied for 20-30 min more if necessary to map previously unknown sleeping trees. Every 0.5 hr each group's location was determined by assigning the group centre to a 0.25 ha block being part of a 50x50 m grid system that was measured from the ground. The daily path lengths for each group was also measured using this grid. Behavioural data were collected via scan samples (Altman, 1974; Martin and Bateson 1986; Paterson 1992) on 3 days/week and ad libitum, and inter-group interactions were also recorded. Activities were recorded during a 10 min period at 30 min interval. When feeding, food items were collected using samples of leaves and fruit and later identified at the Herbarium Celebensis in Palu. Four classes of activities were recognised:

- Moving: locomotion including walking, running, climbing and jumping
- Feeding: reaching for, picking, manipulating, masticating, or placing food in mouth, as well as manipulating the contents of a cheek pouch.
- Resting: body stationary, usually sitting or lying down.
- Social: playing, grooming, sexual and aggressive behaviour.

Results

Group size and composition

The two groups observed differed in size: the large group (group A) consisted of 25 and the small group (group B) of 14 individuals. The male-female ratio was 1:1.2 for group A and 1:1.3 for group B. Both groups showed a complete sex and age composition (Table 1) with two adult females being pregnant in group A. In this group, a new infant was born during the fieldwork after which three members left the group. Group A was composed of 44% adults, 44% juveniles, and 12% infants while group B was composed of 50% adults, 43% juveniles, and 7% infants.

Home range and daily path lengths

The two groups were observed for a total of 85 days. Fig. 3 shows that the home range of the larger group was almost completely within the level forest area that was disturbed by small forest gardens and secondary forest while the smaller

group's home range was situated mainly within the hilly but undisturbed forest. The frequency of use of 0.25 ha quadrats varied from 1-30 scores per quadrate during the study. The home ranges of both groups were overlapping slightly in the transition between the flat and the hilly area. The sizes of the home ranges estimated from measurements along the transect grid revealed that the home range of the large group was smaller with 44.5 ha than the one of the small group which covered 99.1 ha. However, the horizontal projection of the home ranges using the GPS measurements did not reveal such a large difference in home range size between the groups indicating the extreme hillside character of the small group's home range (Fig.2). The average path length of the large group was 707m (±249m) and was significantly higher with a mean of 1500m (±292) in the small group (Wilcoxon test, Z=-6.93, p<0.001).

Diet

During the study, 46 plant species were recorded providing food for *Macaca tonkeana* (Table 2). Fruits (71.7%) were the most preferred food item and Moraceae were the most important family constituting 15.6% of all species.

The macaques exclusively fed on ripe fruits and young leaves. Only the soft tissue of fruits was used, and usually parts of the fruit fell down to the ground. Also a small proportion of other plant parts such as flowers and stems and also bird eggs and insects were taken.

Activity budget and behaviour

The percentage of time spent moving was approximately 1.8 times higher in the smaller than the larger group (see below). The large group (A) spent most of its time resting (51%), followed by socialising (19.9%), moving (17.7%) and feeding (11.4%), while the small group (B) spent most of its time resting (35%), followed by moving (31%), socialising (14.7%), and feeding (19.3%) (Fig. 3). The time budgets differed significantly between the groups (Crosstables, χ^2=1086, d.f.=3, p<0.001).

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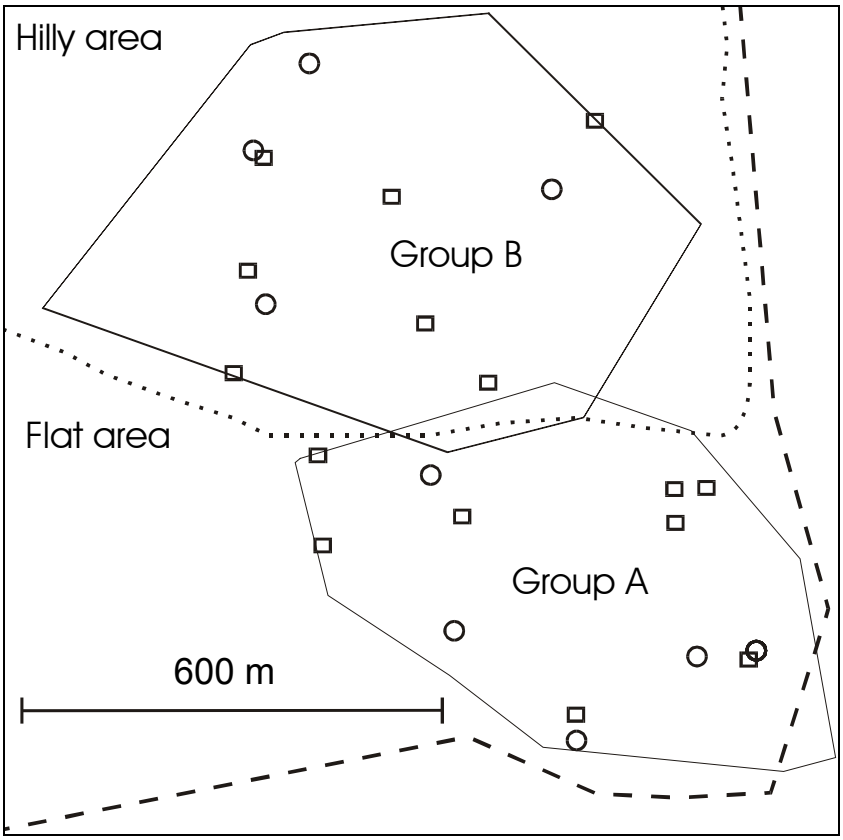

Fig. 2. Minimum convex polygons of home ranges of two groups of Tonkean Macaques, as well as forest border (dashed), delimitation of hilly area (dotted), and location of sleeping (squares) and feeding trees (circles).

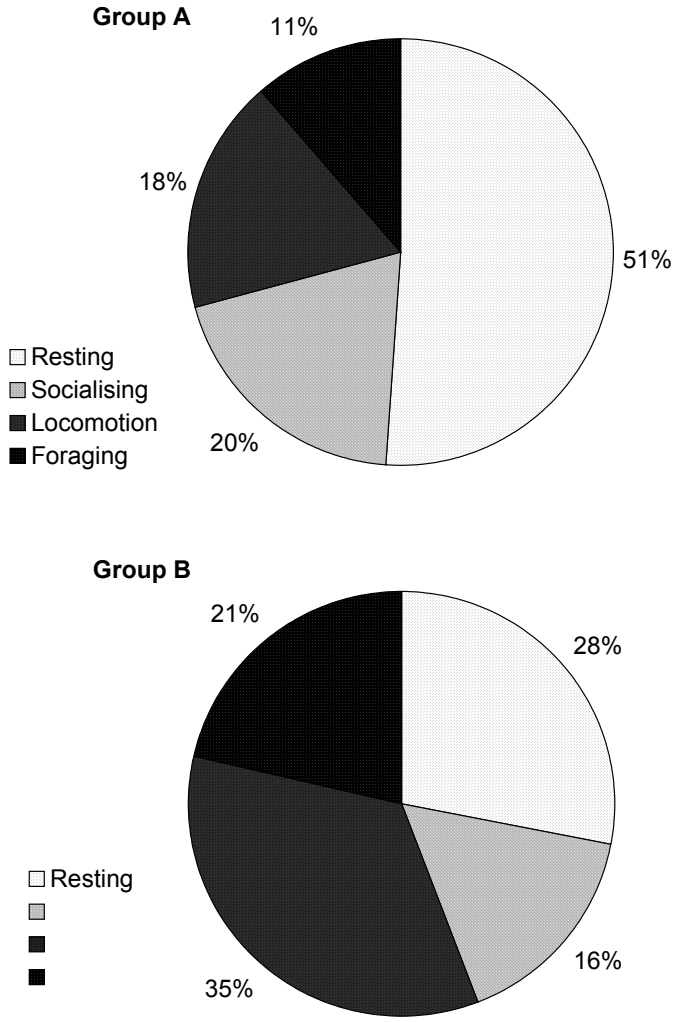

Fig. 3. Activity budgets for two *Macaca tonkeana* groups at Lore Lindu National Park during 41 days of scan sampling. Group A (6657 observations) consisted of 25 individuals while Group B (7380 observations) consisted of 14 individuals.

Table 1. Age and sex composition of two groups of Tonkean macaques *Macaca tonkeana* at Lore Lindu National Park, Central Sulawesi

Group	Adult		Juvenile		Infant		Total
	M	F	M	F	M	F	
A	5	6	4	7	3	-	25
B	3	4	4	2	-	1	14

Table 2. List of plant species and plant parts consumed by *Macaca tonkeana* at Lore Lindu National Park, Central Sulawesi.

No	Local Name	Scientific Name	Family	Parts consumed
1	Mbalahapu (1)	*Ficus variegata*	Moraceae	L Fr
2	Pangarehea	*Elastostema sp*.	Urticaceae	St
3	Mbalahapu (2)	*Ficus sp.*	Moraceae	L
4	Weli-weli	*Photos sp.*	Araceae	St
5	Nuhu	*Ficus sp.*	Moraceae	L Fr
6	Pondo	*Pleomele angustifolia*	Liliaceae	L
7	Bangkakara (1)	*Cryptocarya sp*.	Lauraceae	St
8	Bangkakara (2)	*Litsea sp.*	Lauraceae	Fr
9	Tambekakau	*Eugenia sp.*	Myrtaceae	L Fl Fr
10	Nunu tea	*Ficus sp.*	Moraceae	L Fr
11	Tohiti	*Calamus sp.*	Palmaceae	Fr St
12	Aropi	*Antidesma tetrandum*	Euphorbiaceae	Fr
13	Tiro-tiro	*Elaeocarpus sp.*	Elaeocarpaceae	Fr
14	Betau	*Calophyllum sp.*	Guttiferae	Fr
15	Andolia	*Canangium odoratum*	Annonaceae	L Fr
16	Kaulele	*Rapanea sp.*	Myrsinaceae	Fr
17	Pepolo	*Biscoffia javanica*	Euphorbiceae	Fr
18	Lekatu	*Duabanga mollucana*	Sonneratiaceae	L
19	Warani	*Semecarpus sp.*	Anacardiaceae	L
20	Tea uru	*Artocapus teijsmanii*	Moraceae	Fr
21	Wala	-	Leguminosae	L
22	Kumowatu	*Guiou sp.*	Sapindaceae	L Fl
23	Nunu	*Ficus caulocarpa*	Moraceae	L Fr
24	Nunu Manete-tawena	*Ficus sp.*	Moraceae	L Fr
25	Taite	*Dysoxylum sp.*	Meliaceae	L Fr
26	Wale nunu	*Ficus sp.*	Moraceae	Fr
27	Pisang monyet	*Musa sp.*	-	L Fr L
28	Harao	*Areca vestiaria*	Arecaceae	Fr
29	Harao maeta	*Arenga sp.*	Arecaceae	Fr
30	Mangkulobi	-	-	Fr

Abbreviations: Fr - fruit, L - leaf, Fl – flower, St – stem

Table 2 (cont.)

No	Local Name	Scientific Name	Family	Parts consumed
31	Kolombio	-	-	Fr
32	Aren	*Arenga pinnata*	Arecaceae	Fr
33	Lebanu	*Nauclea cyrtopoda*	Rubiaceae	L
34	Pala hutan	*Knema cinerea*	Myristicaceae	Fr
35	-	*Memecylon gibbosum*	Melastomataceae	L Fr
36	Pangi	*Pangium edule*	Flacourtiaceae	Fr
37	Kedondong hutan	*Spondia pinnata*	Anacardiaceae	L Fr
38	Anggrek	-	Orchidaceae	Fl L
39	Pondang	*Pandanus sp.*	Pandanaceae	L
40	Manggis hutan (1)	*Garcinia sp.*	Clusiaceae	Fl Fr
41	Manggis hutan (2)	*Garcinia celebica*	Clusiaceae	Fl Fr
42	Jamur	*Fungus*	-	
43	Liana (1)	*Alangium sp.*	Alangiaceae	L Fr
44	Kayu telor	*Alstonia ranvolfia*	Apocynaceae	Fl Fr
45	Kanari	*Canarium sp.*	Burceraceae	Fr
46	Jambu batu	*Psidium guajava*	Myrtaceae	L Fr

Discussion

Group Size and Composition

Macaques (*Macaca* spp.) usually live in large, stable groups. *Macaca nigra* groups can contain 30-90 individuals, also *Macaca fascicularis* can reach 100 individuals (Kohlhaas 1993). In such large groups, the females usually outnumber males 4 to 1, with the society being centred around female families, while males move away from their natal groups (Matsumura 1998). The groups of *Macaca tonkeana* we found were only between 10-30 individuals. With a male-female ratio of 1:1.2 to 1:1.3 we expected our groups to have the capability to develop into bigger associations, but the fact that three group members left group A to form a new group suggests that larger groups might be less frequent in the species.

Although much has been written about factors affecting group size in primates, this subject is still much in debate. Factors proposed to favour grouping in primates include protection from predators, defense of resources, improved foraging efficiency, and improved care giving opportunities (Dunbar 1988 in Kohlhaas 1993). On Sulawesi, where predation must be relatively low and fruit availability – at least at lower altitudes - is usually high, larger groups than those observed by

us can be expected. However, it is yet unclear whether fruit availability at submontane elevations of Lore Lindu is comparable to the lowland areas so far studied within the ranges of *Macaca nigra*.

Home Range and Daily Path Length

Since forest primates usually use food resources that are heterogeneously distributed in space and time, the search for food is a crucial part of their life, affecting also other behavioural patterns. The balance between the time and energy required for moving between food resources and the food's nutritional quality is therefore also affecting primate daily path lengths (Strier 1987). In *Macaca nigrescens*, daily path lengths of 850 m per day were recorded (Bismark 1982, cited in Whitten et al. 1987), and a group of *M. nigra* covered approximately 2 miles. The daily path lengths of the groups of *Macaca tonkeana* in our study were also within this range.

Ranging patterns and home range use of our *Macaca tonkeana* groups were almost certainly linked to the spatial distribution of natural feeding trees or the availability of crops at the forest border, respectively. Although food availability was not measured in this study, it seems likely that it differed between the two habitats studied. The small group was living on a much steeper terrain that was probably less productive than the flat forest margin where the larger group was living. Despite moderate disturbance, this group had probably access to a higher number of feeding trees and could also use farm crops at the forest border including nutritious ones such as maize, papaya, banana and cocoa.

Diet

Sulawesi macaques are predominantly frugivorous. E.g. *Macaca nigra* in North Sulawesi uses fruits in 66% of all feeding bouts and consumes more than 145 species (O'Brian et al. 1997). In this species, the Moraceae family accounted for 30.4 % of all fruit records, with all but one being *Ficus* species. *Dracontomelum dao* (Anacardiaceae) was the most frequently eaten fruit species and responsible for continuous food supply during the year. Invertebrate food is also important and believed to influence routes taken between fruit trees (O'Brian et al. 1997).

Due to the availability of a herbarium in Palu, we were also able to determine the diet *Macaca tonkeana* although still many tree species on Sulawesi are yet undescribed. Our observations show that the species actually exploits a wide variety of foods. Given the relatively short period of our study, the diet of the species at our study site was composed of relatively many plant species (46). As in *M. nigra* (see above), Moraceae was the most important family and fruits, mostly ripe, were the main class of food eaten. Our data are therefore comparable with what is known from other Sulawesi macaques (O'Brien and Kinnaird 1997; Kohlhaas 1993).

Activity Budget and Behaviour

The amount of time spent with various activities is a reflection of how an animal balances its energy budget with the demands of life. A monkey that can easily obtain food can spend more time resting and grooming than feeding and moving.

Group differences in activity budgets can often be attributed to gross habitat differences. Both macaque groups studied spent most of their time in trees and less on the ground which appeared to be in contrast to *Macaca nigra* with which the first author is also familiar. It is yet unclear whether this behaviour is a diagnostic character for *Macaca tonkeana* but it could be related to thicker ground cover in our – submontane – study area compared to the sparse understorey of the Tangkoko Reserve where *Macaca nigra* has been studied. Another potential explanation could be uncompleted habituation: indeed, long-term studies and ecotourism activities have made *M. nigra* certainly much more habituated to humans.

The larger group spent most of its time resting and socialising and less time moving and feeding while the smaller group spent more time moving and feeding than resting and socializing. The various macaque species often have very different time budgets to cope with environmental circumstances. It is possible that those with reduced resting and social activities are ecologically stressed (Dunbar 1992 in Kohlhaas 1993).

Other environmental factors than resource availability have probably affected several activities in *Macaca tonkeana*. We observed that high rainfall, storm and high daytime temperature increased the resting time of both groups. This has also been reported by Rinaldi (1993) who found the Javan Gibbon to take a rest during rainfall and storm and also Kohlhaas (1993) reports high daytime temperatures to increase resting time and decrease social activities.

Due to group-living, *Macaca tonkeana* individuals have many social contacts everyday. Most social activities during the day were spent with grooming. Adult females were most likely to groom others of any age or sex class, a behaviour which serves not only for cleaning purposes but also reduces aggression and tightens the group members bond. Thierry et al. (1990) found that in a captive colony of *Macaca tonkeana*, adult females groomed and received most often and that adult female-adult female grooming bouts were usually of especially long duration and carried out facing each other. In contrast, adult males more often groomed on the back and for shorter times.

Conclusion

- *Macaca tonkeana* lives in multimale-multifemale groups, showing a complete age and sex composition and a variable group size.
- Out of two groups observed, the larger group had a smaller home range (44.5 ha) probably containing more abundant food resources compared with the smaller group (91.5 ha) which home range was larger probably containing a lower feeding tree density.

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- *Macaca tonkeana* is primarily frugivorous, its diet consisted mainly of fruits with Moraceae being the most important family.
- *Macaca tonkeana* is active during the day (diurnal) and spends most of its time in trees.
- The two groups studied showed differences in their activity budget with the larger group spending more time with social activities.

Recommendations

- Since there are human-monkey conflicts (crop raiding of maize), it may be possible to focus near the forest border on production of crops that are less attractive to macaques (rice, beans).
- Since Lore Lindu National Park is an important protected area in Central Sulawesi and the major refuge for *Macaca tonkeana*, there is a need to carry out further research concerning the species' ability to survive in montane forest areas.
- A field primate research station and/or captive breeding program fro Sulawesi macaques is recommended to be established on long term-scale for monitoring, research and captive breeding.
- On a short-term scale, efficient protection of Sulawesi's protected areas by a combination of increased law enforcement, environmental awareness campaigns and village agreements is urgently needed, especially in areas such as Lore Lindu where both hunting and forest loss are major problems.

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