DIET PREFERENCES AND HABITAT USE IN RELATION TO REPRODUCTIVE STATES IN FEMALES OF A WILD GROUP OF *MACACA MAURA* INHABITING KARAENTA FOREST, SOUTH SULAWESI

CRISTINA SAGNOTTI

PASCASARJANA PROGRAM

HASANUDDIN UNIVERSITY

MAKASSAR

2012/2013

DIET PREFERENCES AND HABITAT USE IN RELATION TO REPRODUCTIVE STATES IN FEMALES OF A WILD GROUP OF *MACACA MAURA* INHABITING KARAENTA FOREST, SOUTH SULAWESI

Thesis

Required to Achieve Master

Study Program

Forestry

Prepared and Submitted by

CRISTINA SAGNOTTI

To

PASCASARJANA PROGRAM

HASANUDDIN UNIVERSITY

MAKASSAR

2012/2013

THESIS

DIET PREFERENCES AND HABITAT USE IN RELATION TO REPRODUCTIVE STATES IN FEMALES OF A WILD GROUP OF *MACACA MAURA* INHABITING KARAENTA FOREST, SOUTH SULAWESI

Prepared and Submitted by

CRISTINA SAGNOTTI

ID Number P3700211007

Approved by

Advisory Committee

Prof. Dr. Ir. Ngakan Putu Oka, M.Sc.	Dr. Risma Illa Maulany, S.Hut, M.Sc
Supervisor Senior	Co-Supervisor

Dr. Monica Carosi, PhD

Co-Supervisor

THESIS STATEMENT OF AUTHENTICITY

The undersigned

Name: Cristina Sagnotti

ID Number: P3700211007

Study Program: Forestry

It states that the thesis I wrote is really a result of my own work, not an expropriation or the writing of other people. If later can be proven that most or the whole thesis is the results of other people's work, I am willing to accept sanctions for such actions.

Makassar,

Who Stated

Cristina Sagnotti

ACKNOWLEDGMENTS

This research was part of the Dr. Monica Carosi's research project "Ecology, costs & benefits of sexual swelling in *Macaca maura*", in cooperation with Tor Vergata University (Italy), Hasanuddin University and Bantimurung Bulusaraung National Park (Indonesia). Funding was provided by the Ministry of Education, University and Research of Italy.

I acknowledge Dr. Monica Carosi for allowing me to conduct this research at Karaenta forest (South Sulawesi) and for providing all equipment needs to live in the field (including the courage and confidence), and valuable advice.

I thank all my graduate committee, in particular: Prof. Dr. Ir. Ngakan Putu Oka, M.Sc., Dr. Risma Illa Maulany, S.Hut, M.Sc and Dr. Monica Carosi for providing advice, insight and mentorship. I thank Dr. Erin P. Riley for sharing her GPS data, experience and advices and Iskandar Kamaruddin for elaborating the home range map and helping me in many occasions.

Special thanks go to the Rektor of Hasanuddin University, Prof. Idrus A. Paturusi, MD., for all the help and the trust that has given to me during these three years in Indonesia.

Ph.D., Dr. Dwia Aries Tina P., MA, Prof. Dr. Ir. Muh. Restu, MP and Prof Etty Bazergan are acknowledged for their support and encouragement despite difficulties.

I thank also Pak Haro and all National Park staff for the field assistance. Thanks to my family and all my friends, for the patience and the courage that they transmitted to me from far away.

A special thanks to Amir for his indispensable help without which I could not finish my studies.

Thank you all…

ABSTRAK

CRISTINA SAGNOTTI. Pemilihan Pakan dan Penggunaan Habitat dalam hubungannya dengan kondisi reproduktif pada kelompok betina liar *Macaca maura* di Hutan Karaenta, Sulawesi Selatan .

Kondisi lingkungan dan ketersediaan sumber daya makanan yang memadai dapat mempengaruhi hasil reproduksi mamalia betina. Kebutuhan energi terutama pada primata betina sangat besar (masa kehamilan yang lama, menyusui, pengasuhan bayi), oleh karena itu mungkin dapat mempengaruhi tingkat konsepsi dan dalam jangka panjang dapat mempengaruhi jumlah populasi. Kami meneliti bagaimana pakan (diet), aktivitas harian dan variasi penggunaan habitat dalam status reproduksi yang berbeda pada betina *Macaca maura* di hutan Karaenta (Taman Nasional Bantimurung Bulusaraung). Kelompok kera diikuti selama 6 hari / minggu dari Agustus 2010 hingga Februari 2011 (7 bulan). Data perilaku dikumpulkan melalui scan sampling. Betina *M. maura* mengonsumsi berbagai macam makanan (74 spesies tanaman dan jamur), tetapi buah lebih mendominasi pola makan (82%) dan kebanyakan bergantung pada buah *Ficus* (31%). Betina dalam fase peri-ovulasi menunjukkan keragaman makanan yang paling berbeda dalam komposisi spesies pakan/diet (tumbuhan, jamur, dan serangga), sementara betina yang hamil menunjukkan keragaman yang paling tinggi dalam hal bagian tanaman (buah, daun, bunga, pucuk dan batang) yang dikonsumsi. Alokasi waktu kegiatan terkait dengan pemanfaatan strata hutan bervariasi tergantung pada status reproduksi: betina yang menyusui menghabiskan sebagian besar waktu mereka di tanah dengan kegiatan yang dominan yaitu bergerak (30%) dan istirahat & interaksi sosial (51%); sedangkan betina periovulatory cenderung berada di strata yang lebih tinggi (2-10 meter) di mana kegiatan yang pokok adalah mencari makanan dan makan (62%).

ABSTRACT

CRISTINA SAGNOTTI. Diet Preferences and habitat use in relation to reproductive states in females of a wild group of *Macaca maura* inhabiting Karaenta Forest, South Sulawesi

Environmental conditions and adequate availability of food resources may affect the reproductive outcome of female mammals. Energetic requirements are large on especially female primates (long gestation, lactation, carrying of the infant), possibly affecting conception rate which, in the long-term may affect local population size.

We investigated how diet, activity budgets, and habitat use may differ in different reproductive states in wild female moor macaques (*Macaca maura*) in Karaenta (BABUL NP). Monkeys were followed 6 days every week for 7 months (August 2010-February 2011). Behavioral data were collected using scan sampling method. Results of this study indicated that female moor macaques consume a wide range of foods (72 plant and 2 fungi species), but are predominately frugivorous (82%) and relied heavily on fig fruits (31%). Females in the *peri-ovulatory* phase showed the most dietary diversity in terms of different items consumed (plants, fungi, and insects) while pregnant females showed the most diversity in terms of plant parts eaten (fruits, leaves, flowers, shoots and stems). Activity budgets differed depending on vertical (forest strata) use of the habitat and reproductive state: lactating females spent most of their time on the ground with predominant activities being locomotion (30%) and resting & social interactions (51%); *peri-ovulatory* females tended to be at higher strata (2-10 meters) where main activities were foraging and feeding (62%).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

A. Background

Sulawesi is the largest Indonesian island in the ecoregion of Wallacea, South East Asia, which is very important in a biogeographical perspective. This is due to its location at the biogeographic crossroads between Asian and Australian continental shelves which has placed Sulawesi as an important conservation area at a global level. Sulawesi, especially for mammals, shares some elements of its fauna with that from both the Asian and Australian continents which are also characterized by high levels of endemism (Cannon *et al*., 2007). The object of this study is an endemic primate species of Sulawesi, *Macaca maura* (moor macaque).

M. maura is classified as endangered according to IUCN (2008). This spesies has experienced ≥ 50% decline of its population over the last three generations (30-36 years). At present, the populations of this species are extremely sparse in highly fragmented habitat, and are increasingly restricted to South Sulawesi limestone karst areas (Supriatna *et al*., 2008), with only 50 percent of that particular ecosystem included in protected areas (Achmad, 2011) such as Bantimurung Bulusaraung National Park.

In order to maintain adequate population size of moor macaque therefore to counteract the progressive risk to extinction, it is necessary to protect an appropriate "quantity" and "quality" of habitat which is suitable for the species. While the extension of potential habitat of moor macaque is guaranteed by the extension of protected areas (such as Bantimurung Bulusaraung National Park), habitat quality can only be ensured by a detailed knowledge of the species needs.

One of the most important factors that affect the effective population size (*Ne*) of a species is its reproductive success (Stiver *et al*., 2008). In mammal species, and particularly in k-selected species as primates, females are key factors in ensuring reproductive success as they have to deal with considerable energy costs associated with reproduction itself and maintenance of the offspring. Beyond body basic metabolism, moor macaque females need energy to face costs related to reproductive states and phases such as those possibly related to the *peri-ovulatory* phase which in this species is characterized by a particular swelling of the *ano-genital* area; to pregnancy, lactation and prolonged infant carriage. Energetic constraints impact reproductive function in female primates (Key and Ross, 1999).

By analyzing some aspects of the female interaction with their habitat in terms of both behavior and diet selection, this study aims at identifying elements which may be crucial in their impact on female reproductive function and success, which, in turn, are essential for the maintenance of proper population size. This study is also aimed to expand our knowledge about moor macaque female biology and ecology with particular emphasis on how wild adult female moor macaques use the habitat (forest strata) and allocate their time across different activities (feeding, foraging, locomotion, social and resting) depending on different reproductive states, which have been identified as follows: *peri-ovulatory* phase females (around the likely conceptive period); pregnant females; lactating females; and neutral phase females (not experiencing any of the previously mentioned conditions). These elements, in addition to a fine analysis of diet composition and nutrient content, will be discuss in light of a more general framework of energetic/nutrient balance depending on dietary inputs and energetic outputs (maintenance of basic metabolism, daily activities, and likely demanding reproductive states) (Murray *et al*., 2009).

Based on the above mentioned, females in different reproductive states are expected to show differences in terms of diet selection (detectable from nutrient composition of different plant species and plant parts) and this, in turn, might be reflected by a different use of the forest strata according to different edible/preferred plant species distribution along the vertical axis of the forest. Females in high energy demanding reproductive states are expected to optimize the balance between energy inputs/energy outputs by either increasing inputs (switching the diet selection towards high energy food) or decreasing outputs (avoiding energy consuming behaviors, e.g., locomotion, and/or increasing resting, or else avoiding upper levels of canopy by increasing time spent on the ground). Lactating phase is usually considered as the most energetic demanding reproductive phase in a female mammal (see Murray *et al.*, 2009). In the present study, we will consider high energetic reproductive states lactating females as well as *periovulatory* phase females, based on the potential high energetic cost due to the formation of the anogenital swelling at every single cycle.

To test these hypotheses, a detailed analysis of the female diet in terms of plant species and specific plant parts consumed, the nutritional content of those foods, and pattern of habitat use is required.

This study took place in Karaenta, *ex Nature Reserve* now within the boundaries of Bantimurung Bulusaraung National Park, and focused on diet, habitat use and behavioral activity budgets of females living in a social group (known as Group B), with particular attention to the relationship between reproductive state and estimated energetic demands.

B. Research Questions

The research questions of this study are:

1. How do *M. maura* females use the habitat and divide their time across different activities in order to balance energetic inputs and outputs throughout their reproductive cycle?
2. What is the diet composition of moor macaque females and what nutrient contents are they likely searching for throughout their reproductive cycle and in different reproductive states?

C. Objectives of the study

The objectives of the study are to:

- determine the home range of the targeted social group and to develop a home range map of the group.
- examine the daily use of habitat (forest strata) by adult females throughout their reproductive cycle
- investigate daily time allocation in different activities (feeding, foraging, locomotion, social and resting) of adult females throughout their reproductive cycle
- examine the adult female diet in terms of plant species eaten, specific parts of plant eaten and nutritional content per specific item eaten

D. Applications of the study

This study focuses on females of a wild group of moor macaques located in a particular protected area (Karaenta, Bantimurung Bulusaraung National Park) characterized by a unique limestone karst ecosystem that still harbors patches of intact forest. If we assume that the ecological conditions of the habitat studied are optimal for the persistence of this species, we can then compare this condition with that of other groups inhabiting different habitats in South Sulawesi. This would allow to understand the level of adaptability of moor macaques as well as identify new important areas for the conservation of this endemic species.

Through a systematic study of this species that includes an ecological approach is possible to identify new strategies for the conservation of the species and the ecosystem in which it lives. For example, data about diet, in terms of plant species composition and proportion of time spent feeding on it, could be used to identify key plant resources that should be protected throughout the species' range and identify additional areas in their overall range that could be designated as new protected zones. Data on habitat use are important to understand which forest strata are used for feeding, foraging, moving, resting or socializing. For example, if moor macaques (living in limestone karst ecosystem) prefer high forest strata (>10m) for feeding and foraging, we may assume that the most important food resources in this habitat are allocated on high trees and also likely on karst rocks. For this reason, we could recommend an expansion of protected areas to include all limestone karst ecosystem present in South Sulawesi province, in order to promote the conservation of an endemic species such as *M. maura.* In addition, home range data could be used to understand the minimum relative area sufficient for the survival of each social group in a given ecosystem. We could then use these data to extrapolate the minimum size of potential protected area necessary for the survival of this species for future generations on the basis of data coming from investigations on population size and rate of reproduction (Zeigler *et al*., 2010).

CHAPTER II

LITERATURE REVIEW

A. Taxonomy, Morphology and Genetic Characteristics

Macaques constitute a monophyletic group of the *Cercopithecinae* subfamily. There are three main lineages of extant macaques, corresponding to three dispersal waves from Africa to Asia and within Asia itself since 5-6 million year ago (Table 1).

Table 1. Macaque species and geographical distribution of the three main lineages in the world (Thierry, 2007)

	Common name	**Scientific name**	**Distribution**
***Silenus-sylvanus* lineage**	Liontaled macaque	*Macaca silenus*	Southwest India
	Barbary macaque	*Macaca sylvanus*	Algeria, Morocco
	Siberut macaque	*Macaca siberu*	Mentawai: Siberut Island
	Pagai macaque	*Macaca pagensis*	Mentawai: Pagai and Sipora islands
	Pigtailed macaque	*Macaca nemestrina*	Indochinese peninsula, Sumatra, Borneo
	Black Crested macaque	*Macaca nigra*	North Sulawesi
	Gorontalo macaque	*Macaca nigrescens*	North Sulawesi
	Heck’s macaque	*Macaca hecki*	North Sulawesi
	Tonkean macaque	*Macaca tonkeana*	Central Sulawesi
	Booted macaque	*Macaca ochreata*	Southeast Sulawesi
	Muna-Butung macaque	*Macaca brunnescens*	Southeast Sulawesi
	Moor macaque	*Macaca maura*	Southwest Sulawesi

Table.1 Continued

***Sinica-arctoides* lineage**	Toque macaque	*Macaca sinica*	Sri Lanka
	Stumptailed macaque	*Macaca arctoides*	South China, Indochinese peninsula
	Bonnet macaque	*Macaca radiata*	South and West India
	Assamese macaque	*Macaca assamensis*	Continental Southeast Asia
	Arunachal macaque	*Macaca munzala*	Northeast India
	Tibetan macaque	*Macaca thibetana*	East and Central China
***Fascicularis* lineage**	Longtailed macaque	*Macaca fascicularis*	Indochinese peninsula, Indonesia, Philippines
	Rhesus macaque	*Macaca mulatta*	Continental South and East Asia
	Japanese macaque	*Macaca fuscata*	Japan
	Taiwan macaque	*Macaca cyclopis*	Taiwan

1. *Silenus-sylvanus* lineage

Silenus-sylvanus lineage has the patchiest geographical distribution, indicating an early dispersal. The pig-tailed macaque is the only species among the others with a large distribution range. The lion-tailed macaque is limited to the evergreen forests of Southern India. The other species of the lineage inhabit Sulawesi and Mentawai Islands.

2. *Sinica-arctoides* lineage

Sinica-arctoides lineage may be the second lineage to have dispersed because it has a moderately fragmented distribution in Southern Asia. Four of its species are found in tropical and subtropical continental areas, while the fifth species, the toque macaque, lives on Sri Lanka.

3. *Fascicularis* lineage

Fascicularis lineage is likely to be the third lineage to have dispersed because it is the most broadly and continuously distributed lineage. The long-tailed macaque is found in equatorial and tropical regions; the other three species in subtropical and temperate Asia (Thierry, 2007).

4. Sulawesi macaques

Fooden (1976) classified Sulawesi macaques into seven species: *Macaca maura*, *Macaca tonkeana*, *Macaca hecki*, *Macaca nigrescens*, *Macaca nigra*, *Macaca ochreata* and *Macaca brunnescens* (Figure 1).

Macaca maura is one of the seven species of macaques endemic to Sulawesi Island (*silenus-sylvanus* lineage) and it inhabits the Southwestern peninsula which is part of the South Sulawesi province (Okamoto *et al.,* 2000).

According to Rowe (1996), morphological characteristics that distinguish *M. maura* from other species are evident. The body fur is brown to dark brownish with a pale brownish gray rump patch. The male head and body length is 640-690 mm and the female head and body length is 500-585 mm.

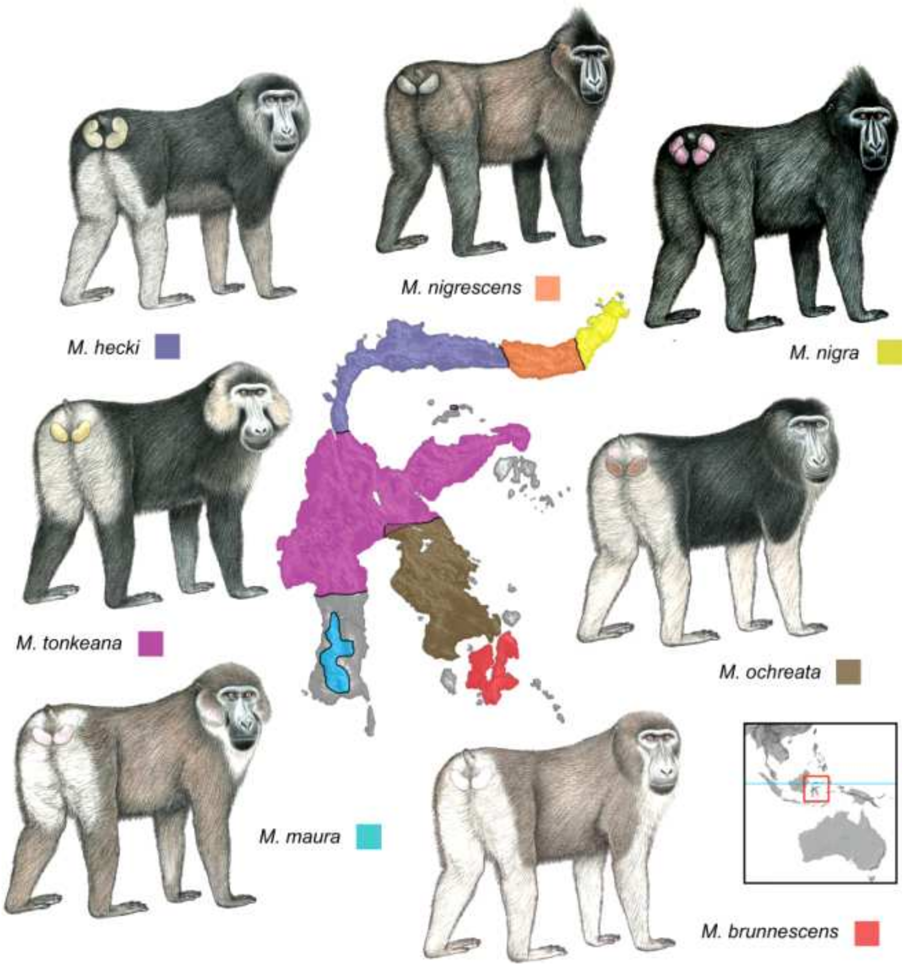


Figure 1. Sulawesi macaque species and their geographical distribution (Riley, 2010)

Ischial callosities of *M. maura* are pink. *Ischial callosities* are specialized regions of skin and subdermal tissue in the form of fibro-fatty cushions with a tough, non-slip surface, situated on the buttocks. They occur in primates of the families *Cercopithecidae* and *Hylobatidae*. *Ischial callosity* usage helps animals to adopt stable sitting postures on the tops of branches, particularly during feeding, resting and sleeping (Rose, 1974).

M. maura is classified as semi-terrestrial *quadrupedal* species. Animals that move *quadrupedally* tend to have hindlimbs with same length as their forelimbs. The commonest index calculated to include a primate species in a locomotion category is the “intermembral index” which is effectively the forelimb length/hindlimb length × 100% (Napier and Napier, 1985). The Old World Primate species, in which moor macaques is included, show an intermembral index value between 77-100, that is typical for *quadrupedal* species (Napier and Napier, 1985).

A portion of *M. maura*’s distribution area is in contact with that of *M. tonkeana.* Despite their contact zone and the level of hybridization, *M. maura* and *M. tonkeana* clearly represent two distinct species because they have diagnosable distinct morphology, monophyletic *mtDNA* and microsatellite differences. A phylogeny of *mtDNA* of macaques on Sulawesi and the Sunda shelf suggests that *M. maura* and *M. tonkeana* may be derived from separate dispersal events of *M. nemestrina* from Borneo to Sulawesi (Evans *et al*., 1999). The hybrid zone between *M. maura* and *M. tonkeana* is probably maintained by a balance between dispersal of males from each species into neighboring *philopatric* groups and selection against resulting hybrid progeny. However, the selection is not so severe as to prevent second- and third-generation backcrossing (Evans *et al.,* 2001). Hybridization occurs among all *parapatric* species of Sulawesi macaque except the insular species *M. brunnescens.*

Behavioral data on Sulawesi macaques seem to support the hypothesis of gene flow between all populations. Little difference in mating season seems to be present between the various species (Ciani *et al.,* 1989). Alarm vocalizations seemed to be different but clinal, from low barks in *M. maura* to high-pitched trills in *M. nigra.* Watanabe and Brotoisworo (1985) suggested the absence of any major behavioral differences between the various Sulawesi species.

B. Distribution, population density and habitat use

Macaca maura can be found from 5.5° to 5.6° S to North of Tempe Lake at approximately 3.4° to 3.5° S, 116° to 121° E (Supriatna *et al*., 1992). In the North of its range this species is found in rainforest as well as karst "islands", while in the Southern parts it tends to occur in mosaics of forest with some grasslands. They occur below 2,000 m above sea level (Supriatna *et al.*, 2008).

The habitat of *M. maura* is fragmented into small forest patches. Supriatna *et al.* (1992) reported that moor macaques live mostly in unprotected forest, with less than 2% of their range overlapping with nature reserves.

The forest of the Southwestern province of Sulawesi (Figure 2) is highly modified by human activity with only scattered and highly isolated pieces of good forest. The large area of lowland alluvium (0-850 m) has been completely converted (less than 0.1% remaining in good condition) and lowland intermediate forests (0-850 m) have little more than 1% in good conditions forest. The scattered pieces of Limestone karst in the midwestern area contain some of the best condition forest and represent a unique ecosystem that contains a high level of endemism (*M. maura* included). The mountainous area in the South is characterized by montane (1500-2200 m) and tropalpine (> 2200 m) forest (Cannon *et al*., 2005).

Moor macaques have been studied by Japanese researchers since 1981 at Karaenta Natural Reserve (now included in Bantimurung Bulusaraung National Park). This site (1000 ha) is characterized by Limestone Karst ecosystem with a mixture of primary and secondary forest. Most groups in the reserve consisted of 15-40 individuals and home range size was 20–30 ha (Okamoto *et al.*, 2000). The home range size of moor macaque is relatively small if compared with the mean home range of 216 ha for Black Crested macaques (*M. nigra*) in North Sulawesi (Riley, 2010). The population density reported by Matsumura in the 1998 was 3.5 groups/km2 or more than 70 individuals/km2. Population density of moor macaques in Karaenta Nature Reserve appears relatively high, this particular condition may be a result of two important characteristics of the area: the high density of fig trees (23.3 trees/ha) as well as the partial isolation of this site from other forest tracts. In addition, the relatively small home range of moor macaques at Karaenta Nature Reserve could be due to the combination of these two factors (Riley, 2010).

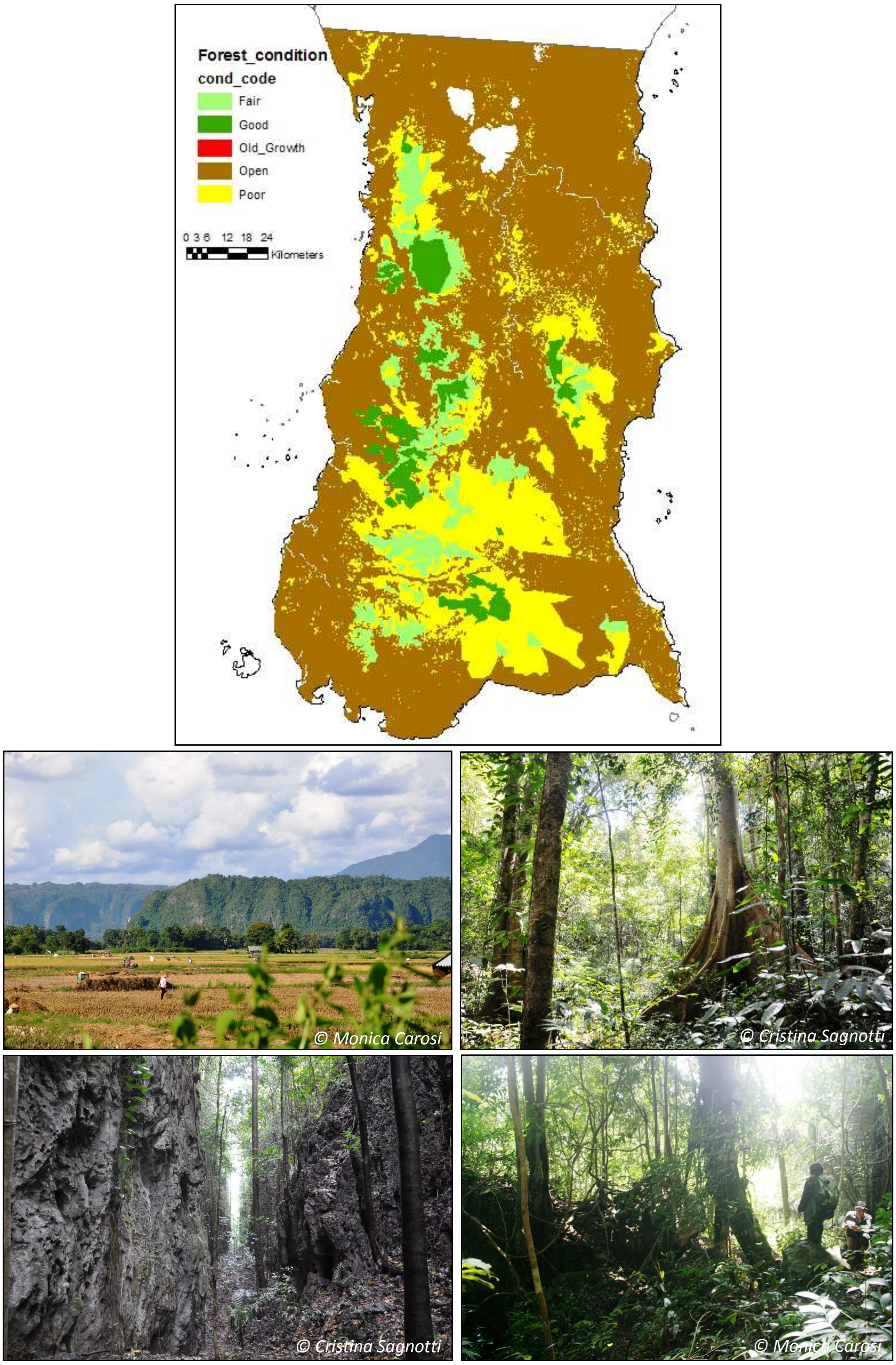


Figure 2. Forest condition of Southwestern part of Sulawesi: map (Cannon *et al*., 2005), lowland forest converted in rice field (first picture on the left) and habitat condition in limestone karst ecosystem (second, third and fourth picture)

Sulawesi macaques show differences in the use of forest strata in their habitat. Following O'Brien and Kinnaird (1997), Black Crested macaques spent most of their time on the ground (60% in the day), while Tonkean macaques show differences between groups living in minimally altered habitat and groups living in heavily altered habitat. Groups in good forest condition spent most of their time on the canopy (86% of the observation records) and groups in poor forest condition spent a significantly greater proportion of the observations on the ground (Riley, 2008). To date, there are no data about the use of forest strata for *M. maura*.

C. Characteristics of reproduction

Matsumura (1993) reported that the *perineum* of wild adult female moor macaques shows repeated and regular swelling (Figure 3). The average *ovulatory* cycle length is 36.2 days. The mean duration of swelling is 11.9 days. The first swelling experience occurs when females are between 4–6 year old, and the first birth could happen when females are in the age of 6 to 7 year old (Okamoto *et al*., 2000). The estimated duration of gestation is around 176 days (Matsumura, 1993).

The inter-birth interval following the first successful birth is 32 months on average (Okamoto *et al*., 2000).

There seemed to be a peak in birth from the end of the rainy season to the beginning of the dry season. Moor macaques are categorized as moderately seasonal breeders who have 33–67% of their births in a single three-month period (Okamoto *et al*., 2000). The peak may be related to annual increases in food availability, and in particular to an increase in fruit production. As fruiting is reported to peak just before the rainy season (Whitten *et al*., 1988), the birth peak (June) of moor macaques seemed to occur about four months before the peak of fruit season (October) (Okamoto *et al*., 2000).

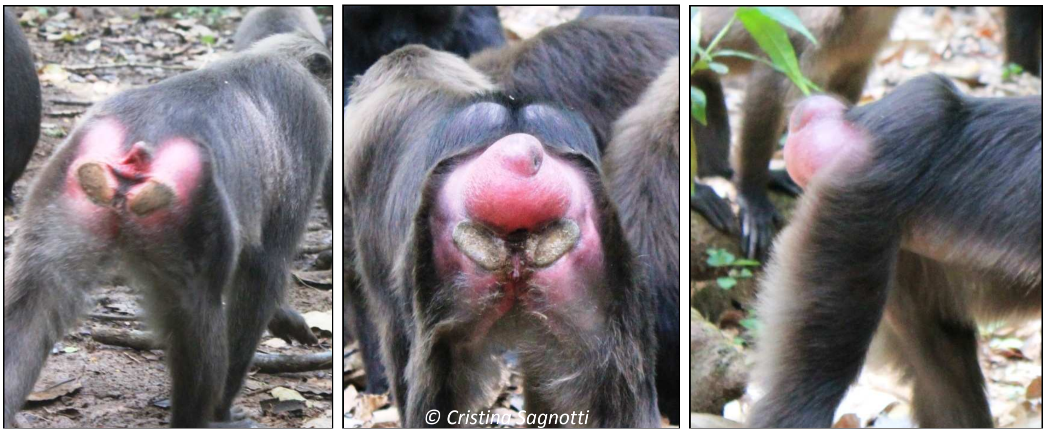


Figure 3. *Perineum* of wild adult female moor macaque. From the left: without sexual swelling, with sexual swelling from behind and from the right side.

As in other macaque species, gene flow among social groups is mostly guaranteed by males, who leave their natal group to move between different groups while females stay in their natal groups. There is considerable variation among macaque species in relation to the age of male natal dispersal. On average, male macaques leave their natal groups at around 4–6 years whereas moor macaques males leave their natal group at 7–9 years (Okamoto *et al.*, 2000).

D. Energetic requirements

Theoretical considerations suggest that, in adult mammals, female energetic costs should be higher than male energetic costs. This is because females are biologically obliged to meet the energetic costs of gestation and lactation (Key and Ross, 1999).

The energetic investment in female primates - and more generally in female mammals - is limiting element for the reproduction. In a female primate, strain energy related to the reproduction includes the energy required for menstrual cycle and ovulation, conception, pregnancy, lactation and also to transport the infant. A successful reproduction is strongly influenced by the availability of suitable habitat and food resources. Females in fact, consume food not only for the maintenance of their body, but also for transferring energy to the offspring as well as for enhancing their development. Most studies have considered gestation and lactation as the most important reproductive events with respect to energy expenditures. The amount of energy required (calories consumed) by female mammals increases 20% during gestation and 80% during lactation (Gittleman and Thomson, 1988).

In terms of conservation, the study of females and their energetic needs, may lead to the individuation of the basic ecological characteristics necessary to the survival of the population in a given site, and, in perspective, the comparison among populations inhabiting areas with different ecological characteristics can help assessing the degree of adaptability of the species and intervention priorities for conservation programs.

E. Activity budgets

The time spent in different activities is highly influenced by food resources availability and habitat quality. Different sex-age classes partition their time differently. In *Macaca nigra,* adult males moved and rested more but fed, foraged and socialized less than adult females. Small juveniles socialized more and fed less than large juveniles and adults (O'Brien and Kinnaird, 1997).

Among adult females there are differences in the activity budget depending on their reproductive states. Murray *et al.* (2009) reported that pregnant female chimpanzees in Gombe National Park reduced their physical activity and spent less time traveling than females in other reproductive states. This energy conservation strategy may allow pregnant females to store fat that can later be used in lactation for milk production. In addition, lactating females fed on fruits more than pregnant females. A study on the activity budgets may provide in depth understanding on how moor macaque females respond to different energetic demands throughout their reproductive cycle and in different reproductive states.

F. Diet

Dietary composition of non-human primates is primarily constrained by resource availability and habitat quality. Riley (2007) reported that Tonkean macaques living in heavily altered forest had a lower dietary diversity, fed more on insects and 50% of the plant specific diet was a single palm, *Arenga pinnata*. In contrast, macaques living in a good forest condition showed a higher dietary diversity and fed less on insects.

Moor macaques are prevalently *frugivorous* (Watanabe & Brotoisworo, 1982), though eating a variety of other plant parts and insects as well.

According to Matsumura (1991), *M. maura* consumed around 61 plant species, however, many of them have been only identified bymeans of the local name. The diet was composed primarily by species belonging to the family of *Moraceae*. The food items list included fungi, insects and lizards also. The list provided by Matsumura (1991) shows food items of moor macaques inhabiting intact mixed primary and secondary forests of Limestone karsts ecosystem in Karaenta ex Natural reserve. Instead, Supriatna *et al.* (1992) reported that moor macaque range is composed primarily by heavily disturbed forest and areas of human habitation. For this reasons *M. maura* is considered as a crop raider species and information by farmers reported the list of crops eaten by Moor and Tonkean macaques (Table 2) (Supriatna *et al.*, 1992).

According to Achmad (2011) there are additional 15 plant species eating by moor macaques which are not reported by Matsumura (1991).

Interestingly, although the social group studied by Achmad (2011) lived in a different habitat from that studied by Matsumura, all plant species eaten are reported to be present in both field sites (Achmad, 2011).

Table 2. Crops raided by *M. maura* and *M. tonkeana* (Supriatna *et al.*, 1992).

Common name	**Family**	**Botanical name**
Corn	Poaceae	*Zea mays*
Banana	Musaceae	*Musa paradisiaca*
Tomato	Solanaceae	*Lycopersicum* sp
Coconut	Arecaceae	*Cocos nucifera*
Long Bean	Fabaceae	*Vigna sinensis*
Soybean	Fabaceae	*Phaseolus radiatus*
Peanuts	Fabaceae	*Arachis hypogaea*
Bushbean	Fabaceae	*Phaseolus vulgaris*
Eggplant	Solanaceae	*Solanum* sp
Cassava	Euphorbiaceae	*Manihot utilissima*
Sweet Potato	Convolvulaceae	*Ipomoea batatas*
Jackfruit	Moraceae	*Artocarpus heterophyllus*
Cacao	Malvaceae	*Theobroma cacao*
Orange	Rutaceae	*Citrus* sp
Cashews	Anacardiaceae	*Anacardium occidentalis*
Guava	Myrtaceae	*Psidium guajava*
Mango	Anacardiaceae	*Mangifera indica*

Differences in diet composition (plant species) of these two social groups are likely due to both differences in relative abundance of plant species in the two field sites (*i.e.*, groups' home ranges) and/or different periods of data collection. Diet composition may vary throughout time (*e.g.*, seasonality, weather condition) and space (*e.g.*, habitat).

Faced with variations in food quantity and quality at diverse spatial and temporal scales, animals must adjust their diets to meet their nutrient requirements (Rothman *et al.*, 2008). For this reason, diet composition varies also depending on the nutritional needs of individuals at different stages of their life cycle. For example, in adult female chimpanzees there is a relationship between mean dietary quality and waiting time to conception that suggests a cumulative effect of dietary quality on reproductive capacity (Thomson and Wrangham, 2008). To understand needs in terms of nutrients, it is necessary to accumulate data over time and compare results between individuals of moor macaque groups living in different ecosystems.

CHAPTER III

RESEARCH METHOD

A. Study site and study period

This project was conducted in Karaenta ex Natural Reserve (1000 Ha), now included in the Bantimurung Bulusaraung National Park (TN Babul hereafter), South Sulawesi, Indonesia (Figure 4). This part of the National Park is characterized by limestone karst ecosystem and for this reason it's defined as Core Zone (*Zona Inti*) of the Park. The area consists of mixed forests with primary and secondary elements.

The study lasted from April 2010 to March 2013. At the beginning of the study period (from April to July 2010) was carried out a preliminary survey of the moor macaque group and habitat conditions, in order to optimize the data collection techniques and to start learning plant recognition with a training directly in the field (416 hours). The intensive data collection period (836 hours) lasted for 7 months (from August 2010 to February 2011) for 6 days/week alternating observations in the morning (6.00 a.m.-12.00 p.m.) and in the afternoon (10.00 a.m.- 6.00 p.m.). During last period (from February 2011 to March 2013) the study site was periodically monitored in order to verify changes in the composition of the social group (*e.g.* births, deaths, immigrations/emigrations) and to complete the plant species sample collection for the study about the diet.

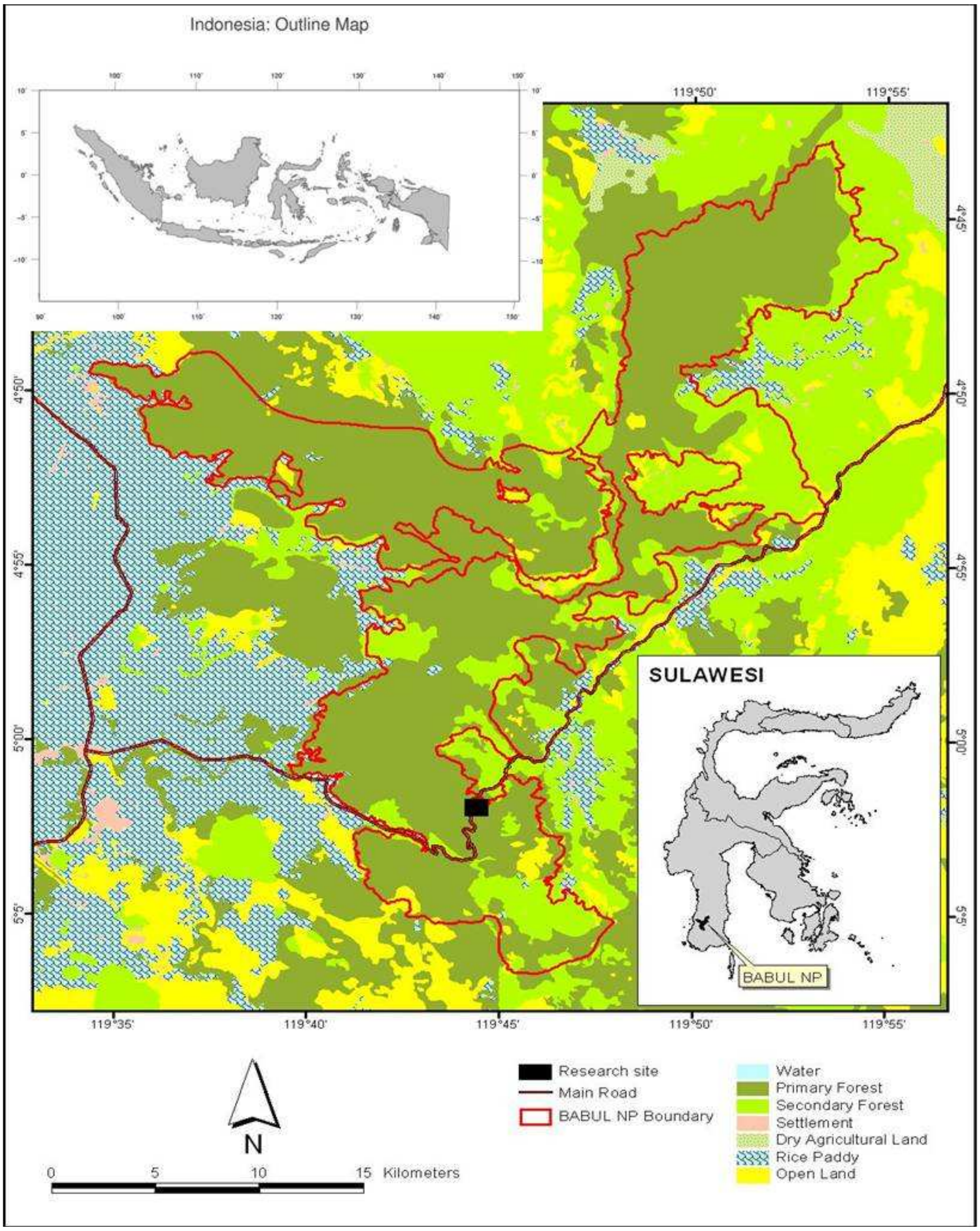


Figure 4. Map of the boundaries of Bantimurung Bulusaraung National Park and research site (Riley, unpublished data)

B. Study subjects: “Group B”

The macaque social group, focus of this study, inhabits an area in Karaenta which is located near the provincial road. The subjects were N=11 adult females belonging to the group known as “Group B”, since the pioneer study by Kunio Watanabe and Shuichi Matsumura (Kyoto University, Japan) in 1981, who named it. The study group was selected on the basis of the habituation to the presence of the human observer. This particular group, in fact, had been habituated to the presence of researchers since the early 80’s by the group of Japanese scientists and continuously had interaction until present with a Senior Ranger of the National Park (Mr. Haro). For this reason, this group was considered suitable for the objectives of this study for which detailed data on specific behaviors and dietary components (*e.g.,* plant species, plant part eaten) were needed. In order to do so, for the purpose of the study, it was necessary to identify each individual of the group. During a two month training period, all individuals of the group were identified and named, based on morphological characteristics used to confirm gender and infer approximate age (Table 3, for group size, age/sex class composition, and further details see RESULTS).

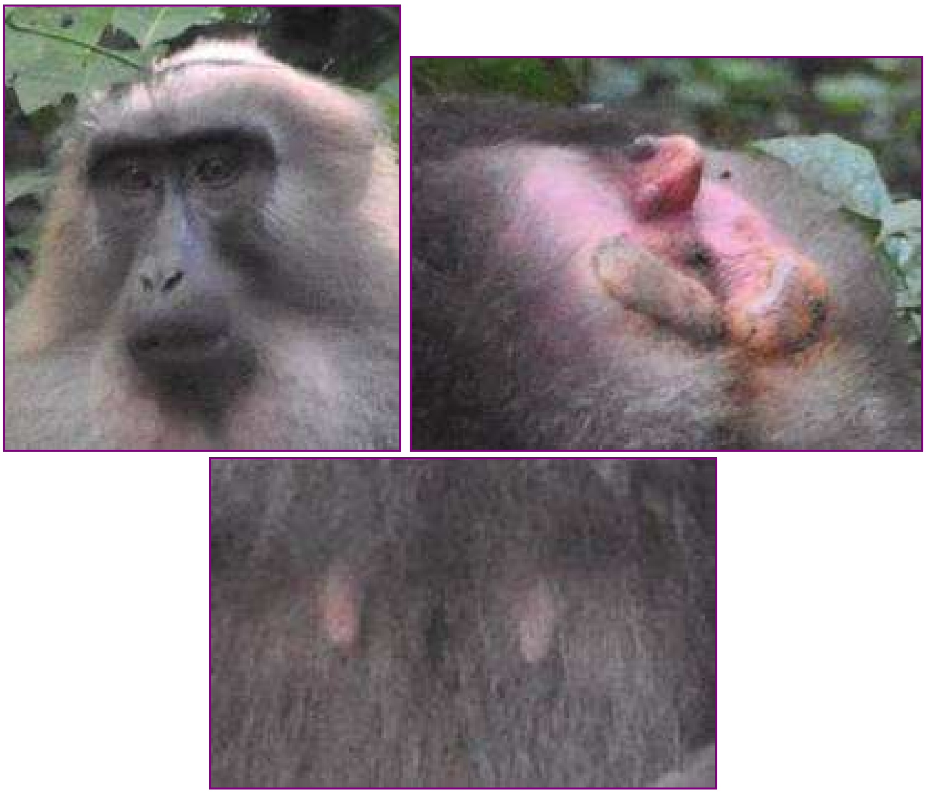


Figure 5. Morphological characteristics used for individual identification. From right to left: face, *ano-genital* area (tale and *ischial callosities)* and udders (pictures: © Cristina Sagnotti).

C. Tools and equipment

The necessary equipment in the study consisted of:

1. binoculars
2. notebook
3. clock
4. 2 stopwatches
5. camera
6. GPS - Garmin GPSmap 60CSx

7. plastic and paper bags for plant sample collection for the herbarium and nutritional analysis
8. oven for drying plant samples for nutritional analysis
9. alcohol and bags for storing the specimens for the *herbarium*.

D. Methods

The study involved the use of non-invasive techniques, and no capture or animal contact was required. Behavioral sampling was carried out by observational sessions and using the following techniques: (1) a combination of instantaneous recording and group scanning techniques; (2) *ad libitum* sampling (Altmann, 1974). In the instantaneous recording technique the observer records the behavior of an individual at fixed observation points, occurring at regular time intervals. In the group scanning, the behavior of many individuals is recorded during an "extended observation point" which allows the observer to visually scan the whole group and record the behavior/activity of each individual at the time the individual is found (at the "*behavioral sampling point*"). In the present study the "extended observation point" was a "*10 minute scanning period*", occurring at every 30 minute intervals for a total of N=1,025 scan.

In *ad libitum* sampling the observer takes descriptive notes in an opportunistic way. Typically, due to the nature of these data they are not statistically analyzed, however they are used to acquire qualitative data.

1. Habitat use

a. Horizontal habitat use: the “home range”

In order to study the horizontal use of the habitat the geographical position of the group was measured with a GPS (Garmin GPSmap 60CSx), whose data point were obtained every 40 minutes .(at the end of the “10 minute scanning period”). The home range size has been calculated over two different time periods: 7 month period (August 2010-February 2011) based on N=887 mark points collected in the present study by the author; 1 year period (June 2010-July 2011), based on a total of N=1,104 mark points which resulted from the addition to the present study data of further N=217 mark points, collected during two months (June-July) over two year period (2010 and 2011) by E.P. Riley. The one year data together, were then used to build the polygon (see Data Analysis later in this chapter) indicating the home range of the moor macaque group.

b. Vertical habitat use: the forest strata and visibility

The use of the habitat has been studied by dividing the forest in 4 levels at four heights: 0m, >0-2m, 2-10m, >10m (m=meters), now on referred to as forest strata (Figure 6). During the group scanning the forest strata at which female subjects were located was noted at the behavioral sampling point. Due to the habitat characteristics (the highly variable density of lower forest vegetation stratum, consequent variable light conditions, the presence of karst rocks on top of which often monkeys spent time, and cryptism of monkey coat color) monkey visibility was sometimes not optimal. It has been possible to identify Individual females in 42% of the behavioral sampling points. In addition, when the group was located on top of the canopy and individual females could not be identified, it was assumed that all females (unless otherwise noted) were using the same forest *stratum* together with the rest of the group (31,6% of recordings) and, as such, it was analyzed.

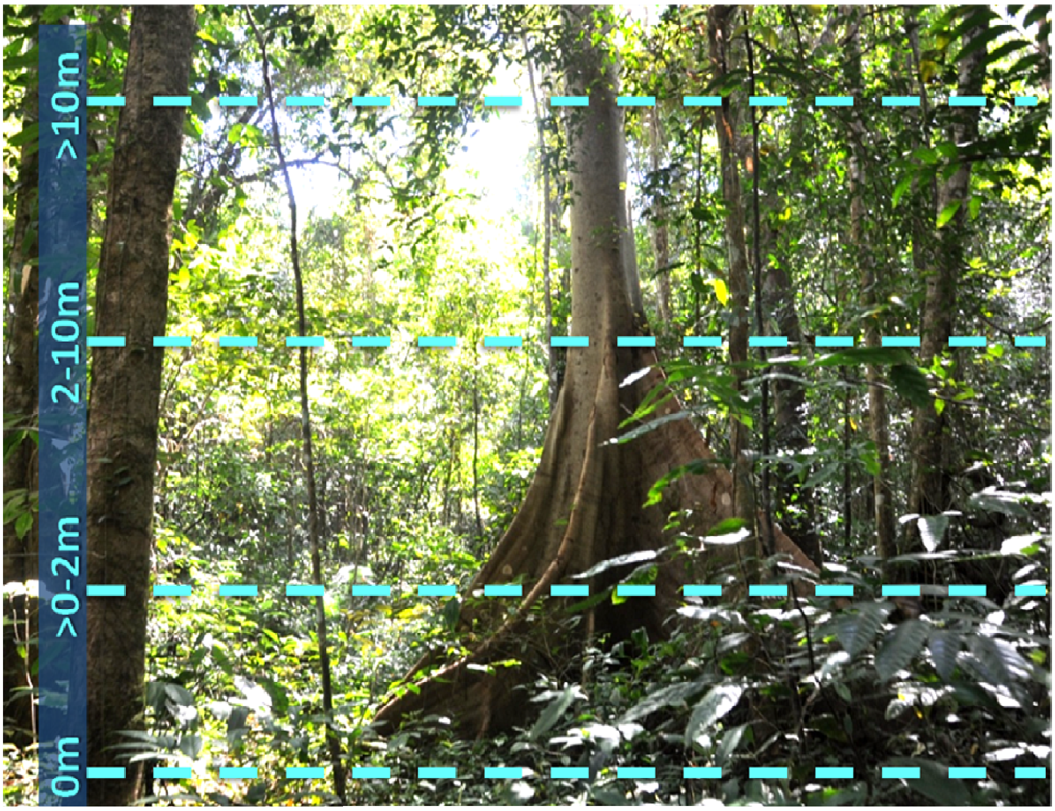


Figure 6. Forest strata

2. Activity budgets

During the 10 minute visual scanning the observer scored each female behavior/activity at the time the female was first seen. If all females were visible during one scanning period, the observer would score 11 behavioral sampling points. The behavior/activity recorded for each female was (a) the first one seen performed by the female at the time she was found and identified and (b) the one which had been sustained for at least 5 seconds consecutively. This rule normally limited the number of behavioral categories which could be used, since the time to note the behavior of all individuals should be as short as possible in order to maximize chances to collect data for as many individuals as possible. However, at the same time, this rule maximized the reliability of data registered. In this study target animals were the females in the group.

Selected activities:

a. locomotion (walking, running, climbing, jumping)

b. foraging (including searching for food and processing food items)

c. feeding (food consumption, including chewing)

d. social behavior (for example grooming, play, agonism, sexual interactions)

e. resting (sleeping, body maintenance activities, no activity)

All activities considered were mutually exclusive. Only in the case of foraging/feeding possibly occurring while locomoting, the activity registered was foraging/feeding (Figure 7).

Figure 7. Activity budgets. From top on the left: locomotion, foraging, feeding, social behavior, resting (pictures:© Cristina Sagnotti)

3. Diet

In order to study the moor macaque diet, plant identification (at local name level) was needed, and was realized thanks to the training by and continued assistance of a senior ranger, Mr. Haro.

During the "10 minutes scanning period", when a female was feeding or foraging, types of food (insect, fungi or plant) consumed were recorded and, in case of plant, the parts of the species eaten have also been noted.

Sample specimens for each plant were collected, processed and stored for species identification purposes (Figure 8). Sample specimens were placed in special plastic bags, wetted using 75% ethanol and mailed to the "*Herbarium Bogoriense"* (Bogor) for further identification by Mr. Ismail, a senior technician of the *Herbarium Bogoriense*.

Figure 8. Sample collection and process for plant species identification

Parts of plant consumed (whether fruits, flowers, leaves, shoots, stems or else) were collected, cut in small pieces and dried in an oven (Figure 9). Before and after drying, the weight of the sample was measured. Dried samples were stored in special paper bags and sent to the *Laboratorium Nutrisi, Fakultas Peternakan, UNHAS,* for nutritional content analysis. Nutrients analyzed were: crude proteins, crude fat, fibers, assimilable carbohydrates, ash, calorie content (Kilocalories/Kg), water content.

Figure 9. Process of cutting and drying for plant species nutritional content analysis

Plant species eaten by the whole group were further classified in trees, shrubs and herbaceous following the FAO classification of life forms (Di Gregorio & Jansen, 2000) (Table 3).

Table 3. FAO classification of different plant life form (Di Gregorio and Jansen, 2000).

LIFE FORM	DESCRIPTION	NOTES
TREES	Woody perennial plants with a single, well-defined stem carrying a more or less defined crown and being at least 3m tall.	Trees lower than 5m are classified as Shrubs. This general rule is subject to the following exception: a woody plant with a clear physiognomic aspect of trees can be classified as Trees even if the height is lower than 5m but more than 3m.
SHRUBS	Woody perennial plants with persistent and woody stems and without any defined main stem, being less than 5m tall. The growth habit can be erect, spreading or prostrate.	
HERBACEOUS	Plants without persistent stem or shoots above ground and lacking definite firm structure.	

Though focused on the female macaques, in order to increase the knowledge about *M. maura*'s diet, data on items eaten by any of the group members (males included) was also recorded in an opportunistic way (*ad libitum* sampling). In particular, data on group diet have been recorded both during months of preliminary survey and during the intensive data collection period. In the latter, *ad libitum* data were recorded only during the 30 minute intervals, while the observer was not involved in the scan observations.

To summarize, variables measured above were then used as dietary composition descriptors such as: a) relative percentage of fungi, plants and insects; b) number of species and diversity of plant eaten; c) relative percentage of different parts of plant eaten; d) nutrient composition for each item/species eaten together with calorie and water content. All variables represented basic information used in understanding the ecological characteristics and habits of this population and could also represent the initial step to gather important (and necessary) knowledge that was useful to survivability of moor macaque in the area. Data on diet composition in terms of plant species diversity were later on compared with the data collected by the Japanese research group on the same macaque population (Matsumura, 1991).

4. Reproductive states: definition

Reproductive states have been defined as follows (see Introduction, “Characteristics of reproduction”):

1. **PO** – Peri-ovulatory

The beginning and the end of this state was calculated from the day in which first signs of swelling of the anogenital area were noted until the end of the tumescence.

2. **P** – Pregnant

Detection of pregnancy in primates usually is not an easy task. In this species, the occurrence of an obvious visual signal of ovulation (the sexual swelling) indicates that conception has not occurred. Therefore when the cyclical swelling (corresponding to the cycle of the ovulation) is not showing when expected (about every 36 days, Matsumura, 1993) the human observer have an indication that a pregnancy might already be occurring. Confirmation of pregnancy by visual inspection of the female's body it is only possible at a very late pregnancy phase, when the monkey body mass has greatly increased. Taking all these difficulties into account, the "pregnancy state" (P) was calculated "*a posteriori*" with two different methods: (1), from the date of infant birth back to the date of last sexual swelling recorded (in which presumably conception has occurred) (2) counting back from the infant birth date until about 176 days, which is the duration of pregnancy reported for the species (Matsumura, 1993).

3. **L** – Lactating

The lactating period was calculated from the day of birth of a surviving infant up until usually three months of the infant age, when the weaning was usually started (Fooden, 2000).

4. **N** – Neutral (not belonging to any of the categories listed above).

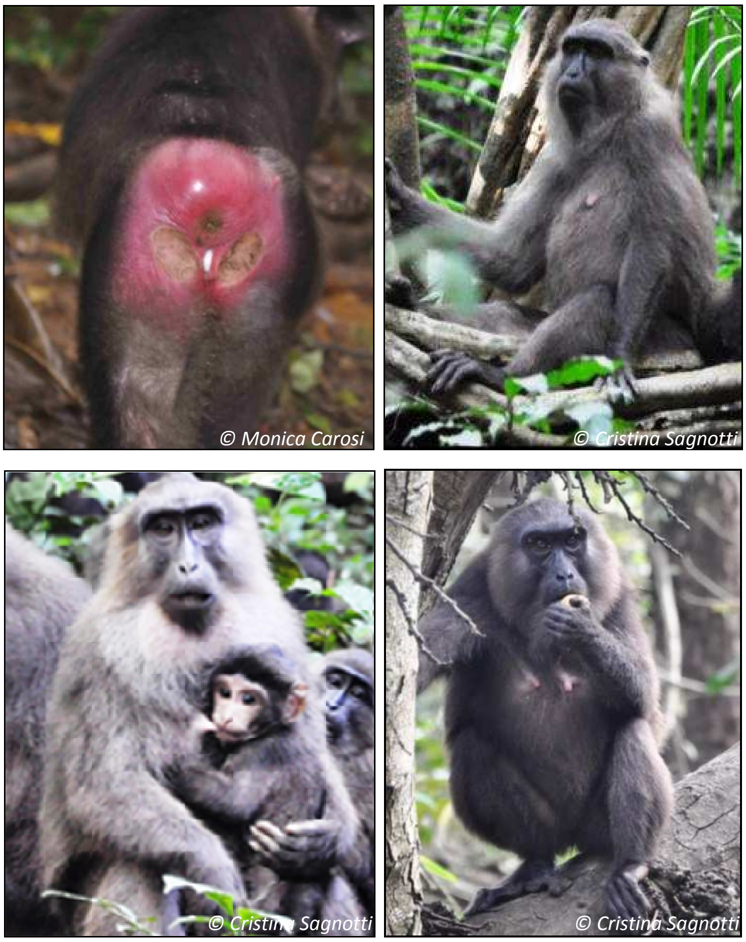


Figure 10. Reproductive states. From top on the left: Peri-ovulatory, Pregnant, Lactating, Neutral

E. Data analysis

Behavioural data collected were standardized by calculating the proportion of time spent in each activity per each female and further divided in subsets according to these criteria: 1) the female reproductive states (N, PO, P and L), 2) the location of the female in the forest strata (0m, 0-2m, 2-10m and >10m) and 3) a combination of the previous two criteria (*e.g.*, N0m, N0-2m, N2-10m, N>10m; PO0m, PO0-2m, PO2-10m, PO>10m; P0m, P0-2m, P2-10m, P>10m L0m, L0-2m, L2-10m, L>10m). Due to the not normal distribution of behavioural data all statistical analysis made, used non-parametric tests.

A multivariate analysis of variance (MANOVA) was used for evaluating the effects of independent variables (forest strata and reproductive state) on behaviors collected during scan sampling (activity budgets and diet): (1) one-way Manova, for analyzing behavior in relation with either forest strata or reproductive states; (2) two-way Manova for analyzing behavior in relation with both forest strata and reproductive states together. A one-way Manova was further used to analyze the proportion of *Ficus* species eaten at different forest strata (software Past, Paleontological Statistic 2001, version 2.16).

The relative frequencies with which females in different reproductive states spent time at each forest strata (0 m, 0-2 m, 2-10 m, >10 m) were used to produce a frequency table which was analyzed with a Correspondence Analysis (CA) in order to evaluate whether reproductive states and habitat use through the forest strata would covary. CA is a descriptive/exploratory technique whose primary purpose is to produce a simplified (low-dimensional) representation of a frequency table. No statistical significance is provided, however some auxiliary statistics is given to monitor for the quality of the analysis (see Results for further details) (software, Statsoft Inc., 2007, STATISTICA, version 8.0)

The Shannon-Wiener Index (H’) was used to evaluate levels of diet diversity among females in different reproductive states as for a) proportion of fungi, plant and insects eaten; c) parts of plant eaten.

In order to assess whether female’s feeding behaviour was correlated to the diet nutrient content, behavioral and nutrient content data were analyzed by using a Kendall’s Tau_b Correlation Analysis. Data about plant items eaten only once have not been included in the correlation, and only items eaten at least 2 times have been used. By doing so, the analysis would not be biased by marginal food items (software, SPSS, 2007, version 16.0).

Finally, GPS data were used to obtain a home range map of the social group and to measure its size. In order to produce the map a two step procedure had to be followed. GPS mark points were elaborated with the k-LoCoH application (Local Convex Hull, Getz and Wilmers, 2004). However, the area regularly used by the monkey group studied, is characterized by the presence of high karst rocks where the monkeys regularly go during the day. Due to the difficulty for the human observer of reaching those places, those areas were typically not covered by the GPS data. For this reason, in order to include those areas in the actual home range of the group, data elaboration required the MCPs method to be applied (Minimum Convex Polygons, Getz and Wilmers, 2004). The entire procedure was then able to generate a home range map that would include also areas inaccessible to the human observer. The MCPs method was used to measure total home range size (based on the 1-year data, N=1,104 mark points) and also to monitor size variability throughout months (based on this study N=887 mark points) (software, ArcView GIS, version 3.3). This analysis have been carried out with the expert assistance of a ranger of Bantimurung Bulusaraung National Park, Iskandar Kamaruddin.

CHAPTER IV

RESULTS AND DISCUSSION

A. Group composition

During the study period (2010-2011) the Group B was composed of 32-36 individuals belonging to different sex and age classes (Table 4). For more details about Group B composition from 1981 to 2013, see appendix 10.

Table 4. Sex-age class composition of Group B (2010-2011)

Sex and Age classes (32-36 individuals)	**Number (Individual)**	**Identifying name**
Adult Male	4(-1;+2)	*Haro, Jaya, Isal, Hendra*
Adult Female	11 (-1)	*Ayu, Bulan, Caca, Dina, Eli, Lani, Nopi, Putri, Ramla, Sri, Titi*
Sub-adult Male	2	*Roni, Pino*
Sub-adult Female	2	*Kamila, Finny*
Juvenile	9	No identifying name
Infant	6 (+3;-1†?)	No identifying name

Note: signs -;+;†? are referred respectively to missing, immigrated or dead individuals

At the beginning of the study period (April 2010), an unknown adult male (later named *Haro*) supplanted the most dominant male (Jaya) *i.e.*, the male with the highest rank in the social hierarchy (called the α-male), becoming the new dominant male in the group. On May, another unknown adult male (later named *Hendra*) started to approach the group and in few weeks has been accepted by *Haro, Jaya* and *Isal* (the older male) as a low dominance rank member of the group.

During the study period, 3 infants were born - 2 infants in July 2010 (by adult females named *Ramla* and *Dina*) and 1 infant in September 2010 (by adult female named *Nopi*). An adult female (*Dina*) has been chased out of the group (on November 2010) and its infant (born in July 2010) disappeared (probably dead) few days after its mother was forced to leave.

During the study the 11 females (Figure 11) have been experiencing all four reproductive states distributed over the months as shown in Table 5.

Figure 11. Females studied with identifying names (Pictures: © Cristina Sagnotti)

Table 5. Reproductive states for each female (N=11 females) from August 2010 to February 2011 (N= Neutral; L= Lactating; P= Pregnant; PO= *Peri-ovulatory*)

	AYU	BULAN	CACA	DINA	ELI	LANI	NOPI	PUTRI	RAMLA	SRI	TITI
Aug	N	N	N	L	N	N	P	N	L	N	N
Sep	N	N	N	L	N	N	L	PO+N	L	N	N
Oct	N	N	N	L	N	N	L	PO+N	L	N	N
Nov	N	N	N	N	N	N	L	PO+N	N	N	N
Dec	N	N	N	No data	N	N	L	PO+N	N	N	N
Jan	N	N	N	No data	N	N	N	P	N	N	PO+N
Feb	N	N	N	No data	N	N	N	P	N	N	PO+N

The most representative reproductive state was Neutral (N). The rarest reproductive states were Pregnant (P) and *peri-ovulatory* (PO) both occurring in 2 females (P, *Nopi* and *Putri*; PO, *Putri* and *Titi*). The mean duration of *peri-ovulatory* state was 11.5 days.

B. The horizontal use of the habitat: home range

In Figure 12 it is possible to observe two different parts of the home range: the dark grey part (which includes all mark points) that represents the area where the social group could be seen and followed (22,99 Ha); and the light grey part, characterized by limestone karst rocks where the observer could not follow the group. The home range size over 1-year data (dark and light grey parts) was 29,27 Ha.

The home range size changed throughout months from 15.06 Ha (in September) to 8.90 Ha (in November) (Appendix.1). The most frequented portion of the home range, the *core zone*, is showed in Fig. 13.

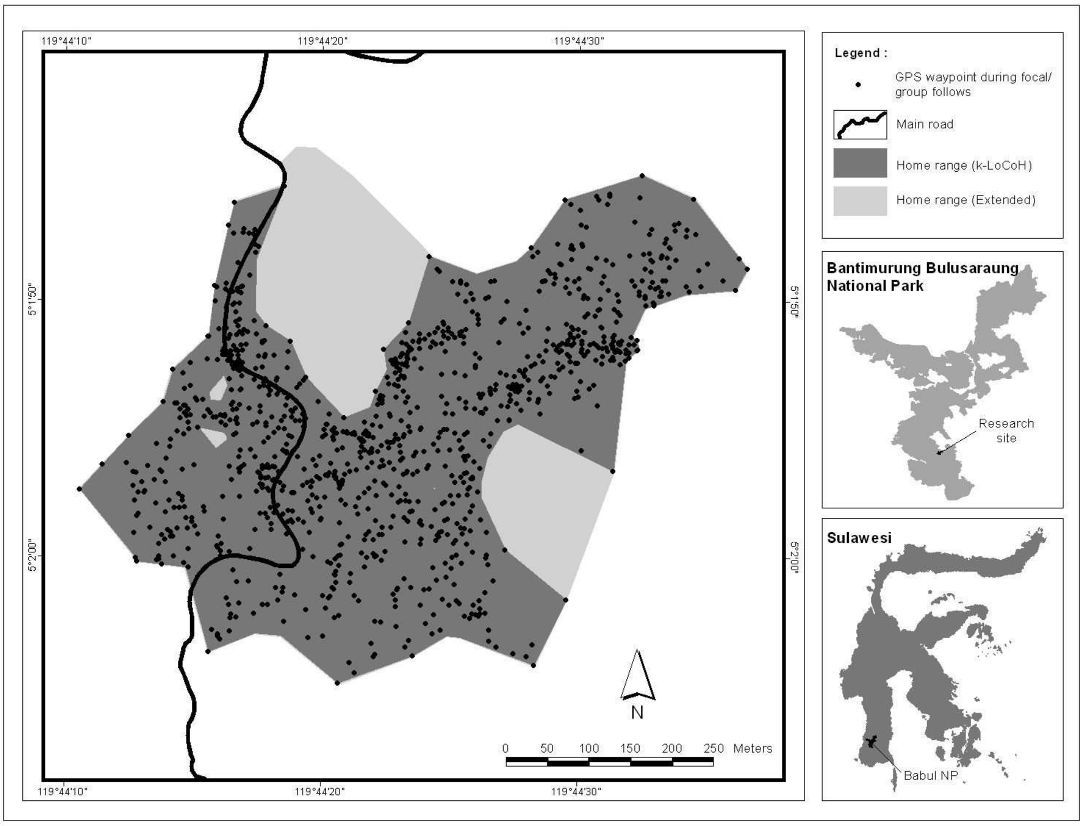


Figure 12. Group home range

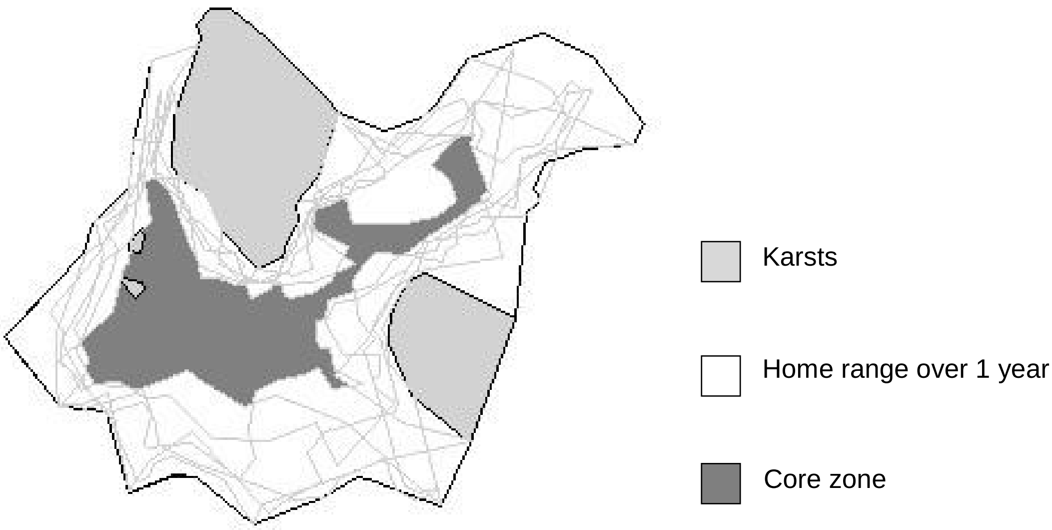


Figure 13. *Core zone* of the home range

C. The vertical use of the habitat: the forest strata

The group spent a comparable amount of time on the ground (35%) and at the highest forest stratum (42% of time), the latter being the most preferred of all strata. However, on average, the group spent most of the time above the ground (65%) (Figure 14).

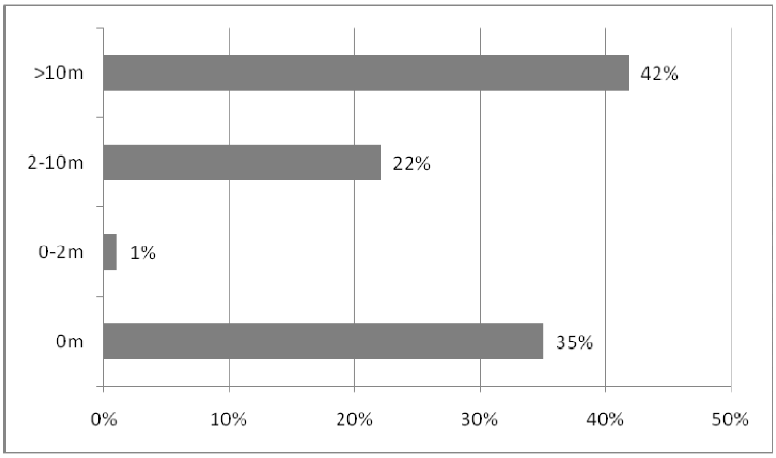


Figure 14.Vertical use of the habitat by females and their social group (all sex-age classes included)

D. Activity Budgets

Activity budgets of all females were based on N=4783 behavioral sampling points. Feeding and foraging (FOR+FEED) are the most preferred daily activities during the study period (33.41%), followed by locomotion (32.85%), social (21.76%) and resting (11.98%) (Figure 15).

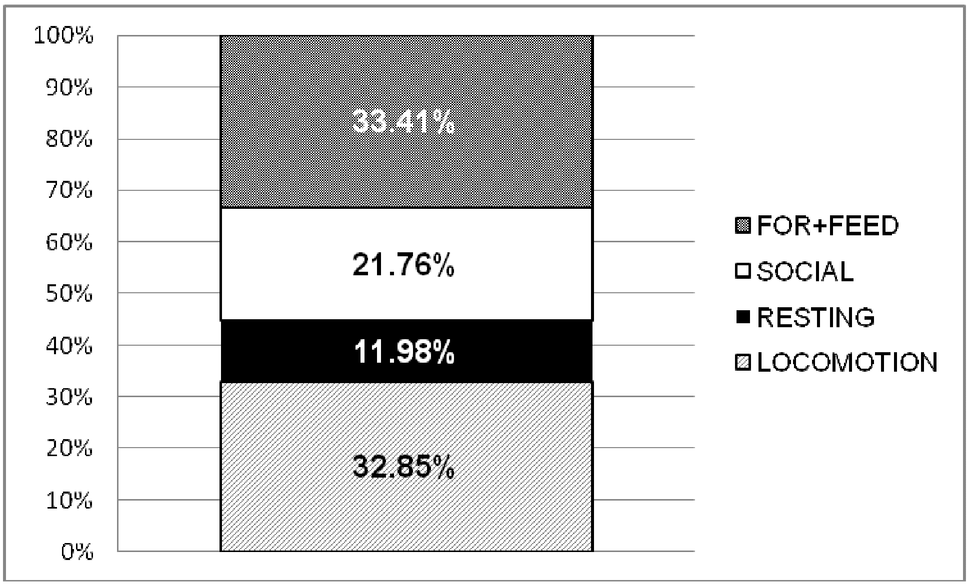


Figure 15. Female daily activity budgets

E. Activity budgets & forest strata

Depending on the forest stratum, female activity budgets were highly diversified (Figure 16). Foraging and feeding (FOR+FEED in figures) were the major activities at the higher strata, progressively decreasing from >10m to 0m as opposed to social activities. Locomotion would mainly occur on the ground (0m) while resting activity occurred in similar proportions throughout the forest strata.

F. Activity budgets, reproductive states and forests strata

In Figure 17, activity budgets are shown in relation to the female reproductive states.

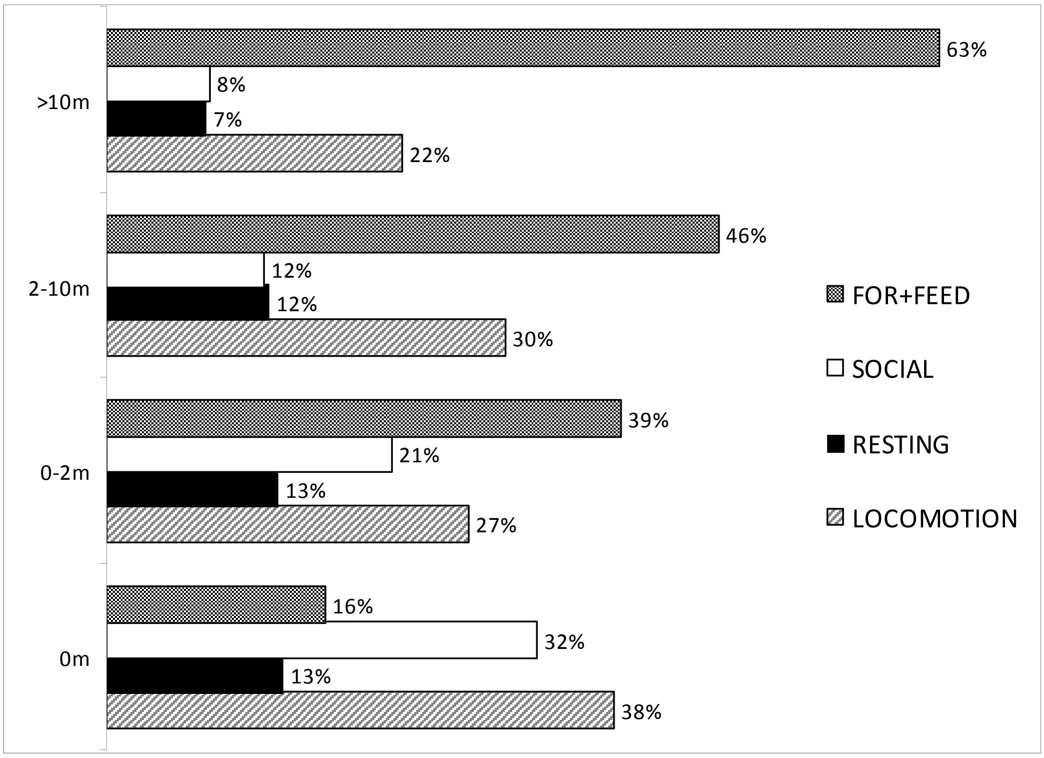


Figure 16. Effects of forest strata on female activity budgets

distributed in PO and L females compared to the N and P females. In addition, PO and L females also differed compared to each other by showing opposite trends in two out of three activities: FOR+FEED and REST+SOC. PO females spent more of their time in FOR+FEED activities (47%), and less in REST+SOC (25%), whereas L females spent more of their time in REST+SOC (45%) and less in FOR+FEED (27%). However, an overall effect of reproductive states on the female activity

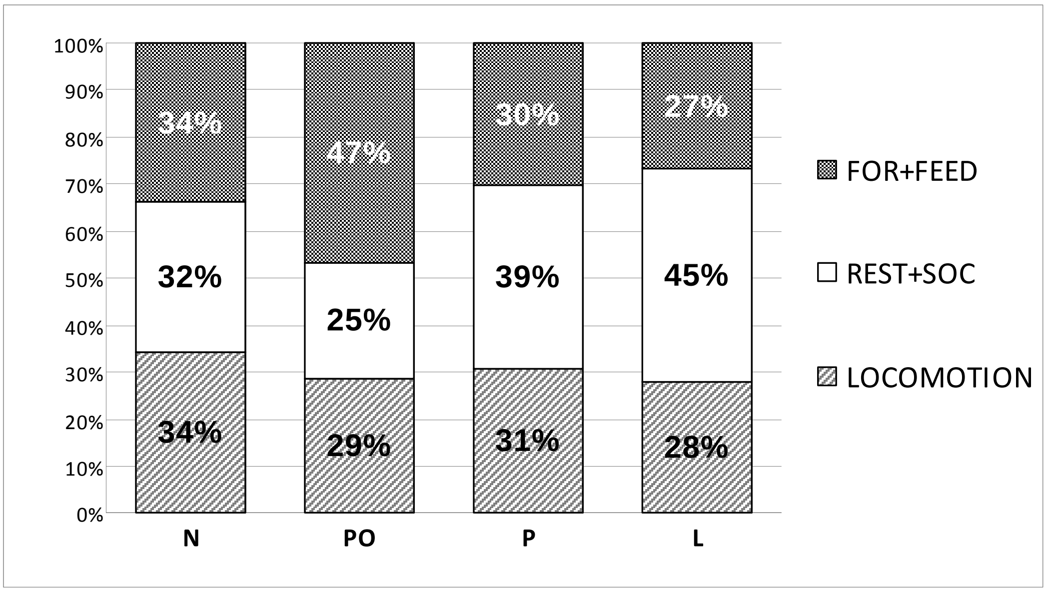


Figure 17. Effect of reproductive states on activity budgets (N=Neutral; PO=*Peri-ovulatory*; P=Pregnant; L=Lactating)

The female activity budgets appeared to be more unevenly In fact, budgets was not significant (ONE WAY PERMANOVA, F= 1,525; p=0,181). Nevertheless, when the effects of reproductive states on the female activity budgets were analyzed together with the forest strata results revealed a slightly different scenario (Figure 18).

As results of a multivariate analysis, forest strata (FS) were shown to stronlgy affect the female activities and although reprodutive state (RS) only approached a significant effect, its interaction with forest strata was highly significant (TWO-WAY PERMANOVA, FS, df=3, F=6.8, p=0.0001; RS, df=3, F=1.07, p=0.052; interaction RS-FS, df=9, F=-1.7, p=0.007). How did forest strata and reproductive states interact? How did females in different reproductive states use forest strata?

The relationship between these two independent variables was analyzed by measuring the correspondence between the four identified reproductive states (N, PO, P and L) and the four categories of forest strata (0m, 0-2m, 2-10m and >10m). By extracting the minimum number of axes (N=2) to describe the variable variance in a simple bi-dimensional space, 99.7%. of all sample variance (cumulative variance) was explained. As shown in Table 6, the first axis (Dimension 1) explained a disproportionate amount of the total variance (97.1%) while the second one (Dimension 2) only the 2.6%.

This means the almost all variance of the variables is distributed and well distinguished by the first axis only.

As shown in Figure 19, it appears that the first axis well distinguishes both between the different reproductive states (particularly between PO and L states) and, similarly, between the forests strata (particularly between 2-10m and the 0m strata).

It is interesting to note that the PO state is close to the 2-10m stratum along the first axis, as the L state is to the 0m stratum (see also the Coordinates of the Dimensions 1 and 2, Table 7 and 8).

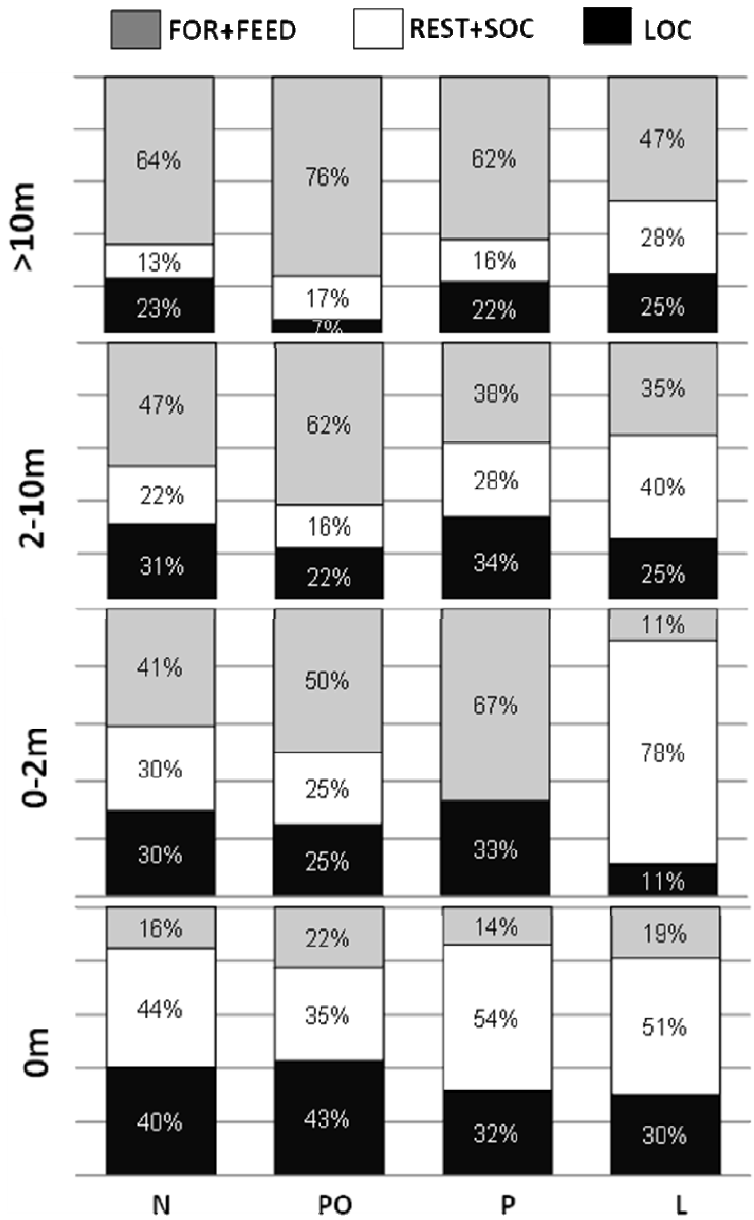


Figure18. Combined effect of reproductive states and forest strata on activity budgets (N=Neutral; PO=*Peri-ovulatory*; P=Pregnant; L=Lactating)

Table 6. Inertia for all dimensions

Dimension	Percent of Inertia	Cumulative Percent
1	97.122	97.122
2	2.548	99.671

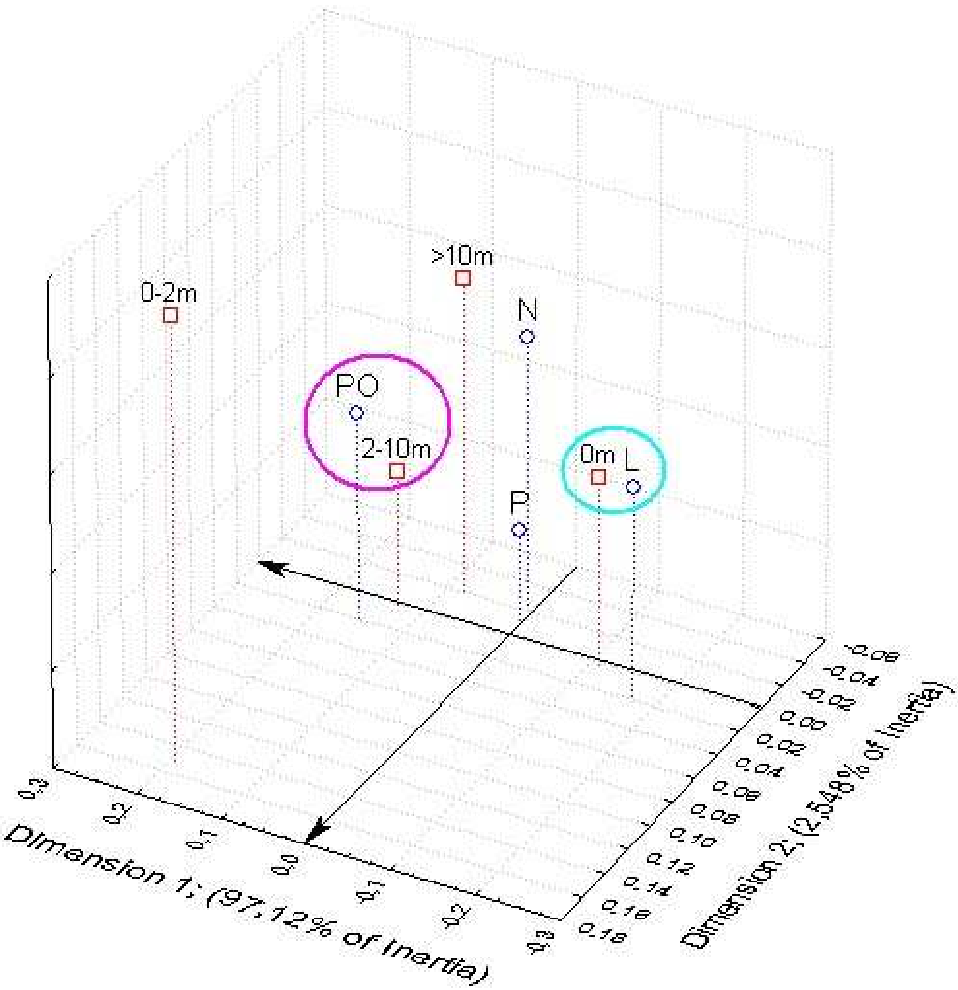


Figure 19. Correspondence Analysis between forest strata and reproductive states

Table 7 Column Coordinates and Contributions to Inertia

Forest stratum	Coordinates Dimension 1	Coordinates Dimension 2	Quality	Relative Inertia
>10m	0.082	-0.021	0.980	0.089
2-10m	0.130	0.002	0.998	0.394
0-2m	0.195	0.151	0.989	0.054
0m	-0.111	0.002	0.999	0.463

Table 8 Row Coordinates and Contributions to Inertia

Reproductive state	Coordinates Dimension 1	Coordinates Dimension 2	Quality	Relative Inertia
N	0.010	-0.024	0.917	0.013
PO	0.154	0.019	0.999	0.451
P	0.003	-0.013	0.587	0.005
L	-0.169	0.016	0.999	0.530

Though no significance levels are provided by an exploratory technique such as the Correspondence analysis, the strength of these data is confirmed by some auxiliary statistics as shown in Table 7 and 8: the "quality", whose value close to one means that the dimensional space chosen well represents that variable, and the "relative inertia" which represents the proportion of the total variance accounted for by the respective sample point.

G. Diet

1. Dietary composition

The study of the female diet was based on N=4783 behavioral sampling points (August 2010-February 2011). Based on these data, females mainly fed on plant species (84%), fungi (2%) and insects (14%). The importance of fig fruits was found to be pronounced as it represented 31% of the whole diet (Table 9).

Table 9. Dietary composition and proportion of different food items consumed by moor macaque females

Diet Diversity	**Dietary Proportion**	**Proportion of fruits in the diet**	**Proportion of fig in the diet**	**Plant parts eaten**	**Proportion of plant parts**
Plants	84%	71%	31%	Fruits	85%
Fungi	2%			Leaves	10%
Insects	14%			Stems	1%
				Flowers	2%
				Shoots	3%

Data collected on the whole group diet (April 2010 - February 2011) combined with the identification of plant species by the *Herbarium Bogoriense* allowed to list 72 plant species and 2 fungi species (Appendix 1). The diet mainly consisted of species belonging to the family *Moraceae* with the genus *Ficus*. In the list, there are four fig species that are distincted as *Ficus tinctoria* 1, 2, 3 and 4. By direct observation on the shape, size and color of fruits found on different trees, those species might be seen as distinct species. However, may be due to the lack of fruits and flowers in the samples analyzed by the staff of *Herbarium Bogoriense* this samples were identified as a single species (*Ficus tinctoria Forst. F*.).

The moor macaques diet was also composed by several insect species which were not reported in the list (not identified yet).

Plant species eaten by the group (2010-2011) were compared with the list of species eaten reported by Matsumura (1991), N.S. Achmad (2011, cited in A. Achmad 2011) and Achmad (2011), (Appendix 2,3,4,5). Following botanical names identified at species level, 10 species were similar with Matsumura's list, and 1 overlap was found with A. Achmad's list. The difficulties in plant identification to the species level, the differences in food resource availability and data collection period may explain this inconsistency.

Based on Di Gregorio and Jansen (2000) classification, moor macaque females mainly fed on tree species (86%), followed by herbaceous (9%) and shrubs (5%) (Figure 20). This evident preferences for trees might explain why feeding and foraging were the main activities on the two highest forest strata (Figure 16).

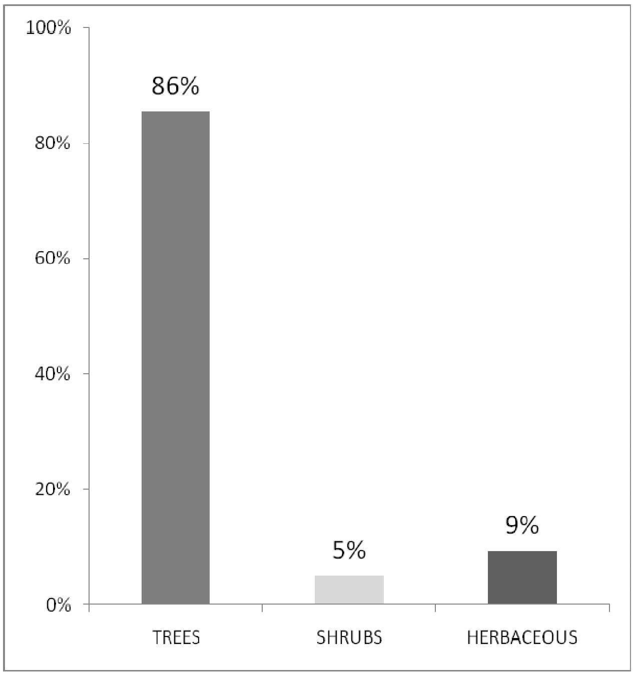


Figure 20. Proportion of trees, shrubs and herbaceous species eaten by moor macaque females

2. Diet diversity in different reproductive states

PO females seemed to enrich their diet by increasing the diversity in terms of proportion of plants, fungi and insects (highest H'=Shannon – Wiener Diversity Index). In contrast, L females showed the lowest diversity in terms of diet composition mainly feeding on plants (lowest H') (Table 10 and Figure 21).

Table 10. Diet diversity in reproductive states (N=Neutral; PO=*Peri-ovulatory*; P=Pregnant; L=Lactating)

Plants-Fungi-Insects Diversity	**N**	**PO**	**P**	**L**
Shannon-Wiener Index (H')	0.70	0.82	0.73	0.53

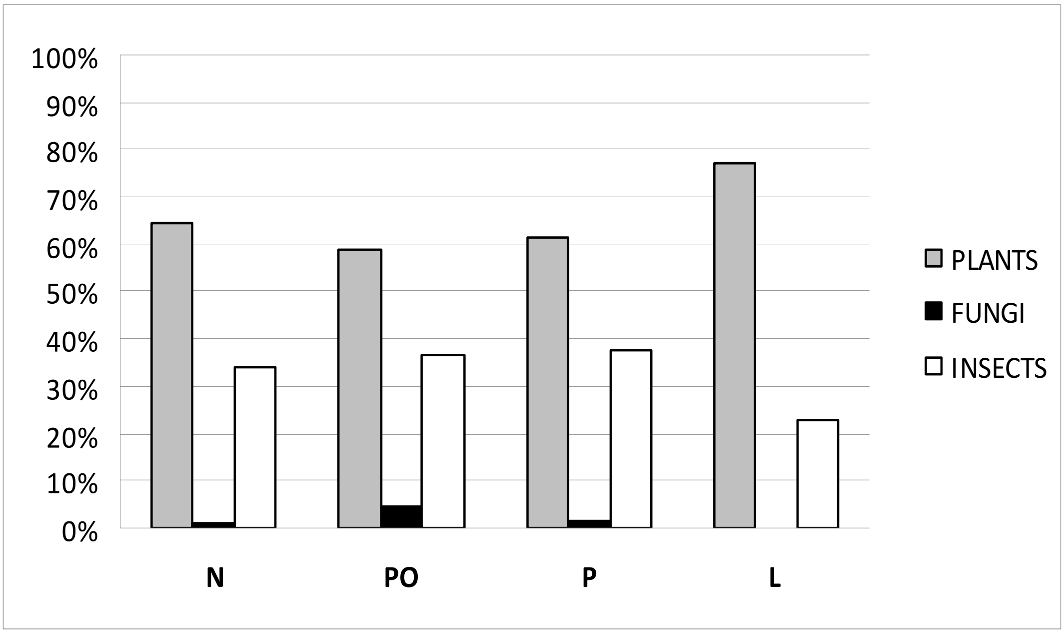


Figure 21. Female diet composition in different reproductive states (N=Neutral; PO=*Peri-ovulatory*; P=Pregnant; L=Lactating)

In terms of diversity of plant parts consumed, the highest (H') was shown by P females. This preference might be related with strategy to enrich their diet by diversifying parts of plants being eaten. Instead, lactating females showed the lowest (H') in plant species eaten and also fed mainly on fruits (Table 11 and Figure 22).

Table 11. Plant parts diversity in reproductive states (N=Neutral; PO=*Peri-ovulatory*; P=Pregnant; L=Lactating)

Plant parts diversity	**N**	**PO**	**P**	**L**
Shannon-Wiener Index (H')	0.61	0.54	0.90	0.32

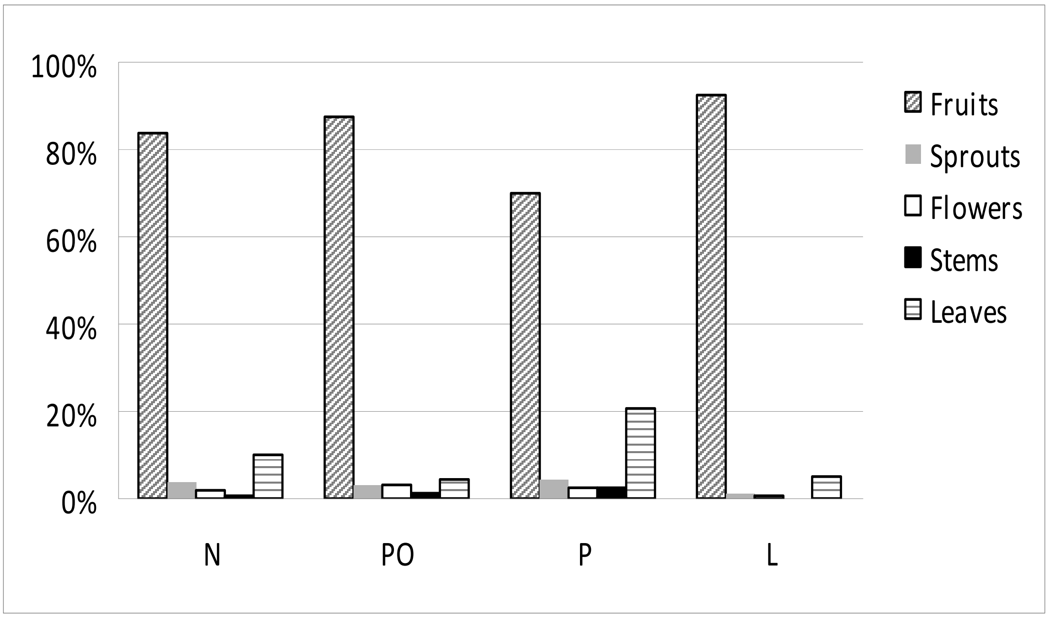


Figure 22. Diversity of plant parts eaten in different reproductive states (N=Neutral; PO=*Peri-ovulatory*; P=Pregnant; L=Lactating)

3. Diet composition & forest strata use

Forest strata was found to affect the diet composition of all females (ONE WAY PERMANOVA, F=20.55, p=0.0001). Females used the highest and the lowest strata mainly for feeding on plants and the other strata for feeding on insects and fungi (Figure 23).

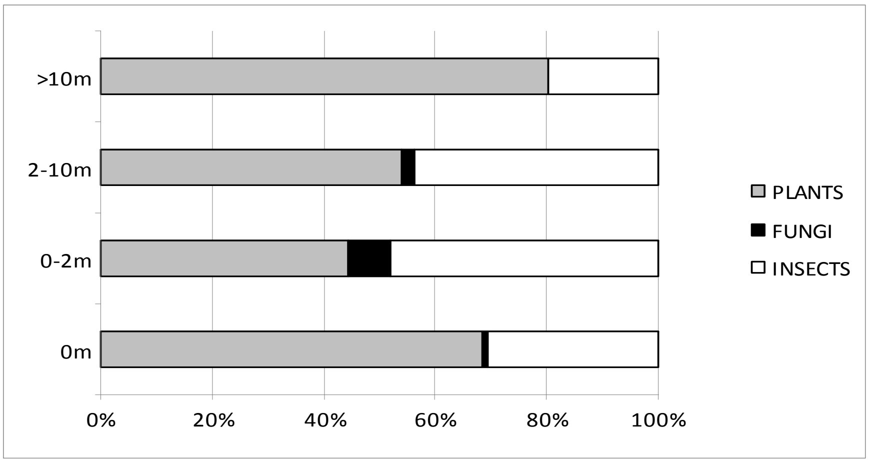


Figure 23. Effect of forest strata on diet composition

In addition, the effect of forest strata was evident in terms of plant parts eaten as well (ONE WAY PERMANOVA, F=45.64, p=0.0001). Fruits were the plant part mostly consumed with a peak located on the highest forest stratum (>10m) (Figure 24).

Females utilized the forest upper strata mainly for foraging and feeding (see Results, “Activity budgets and forest strata”) with feeding peaking at the height >10m (53% of all activities) and mostly consumed fig fruits (*Ficus spp.,* 61%) (ONE WAY PERMANOVA, F=21.7 p=0.0001) (Figure 25).

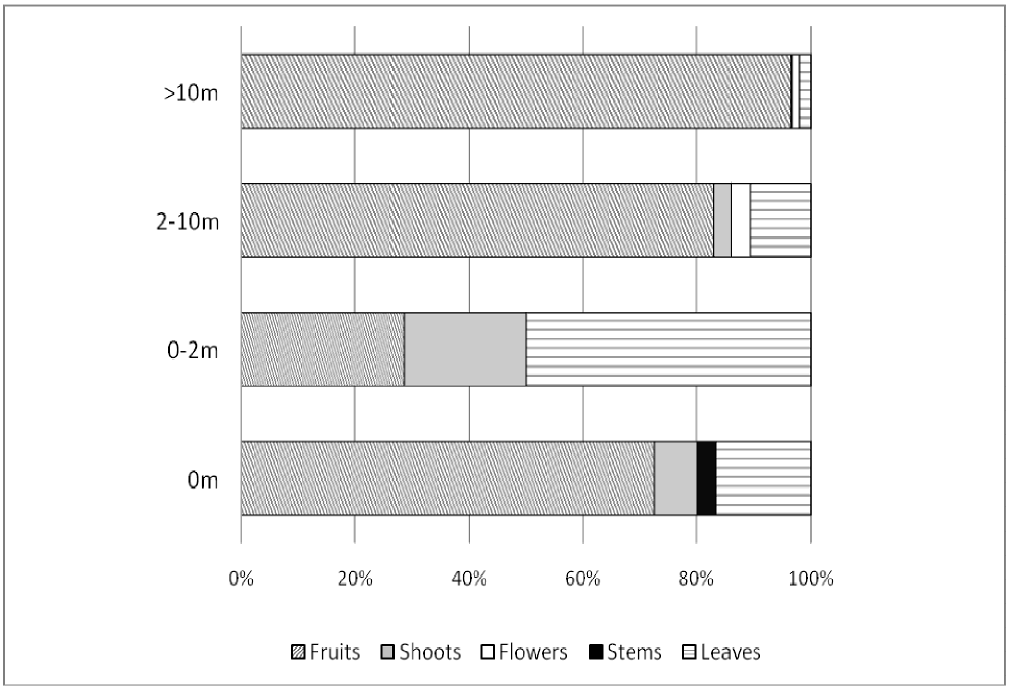


Figure 24. Effect of forest strata on plant parts consumed

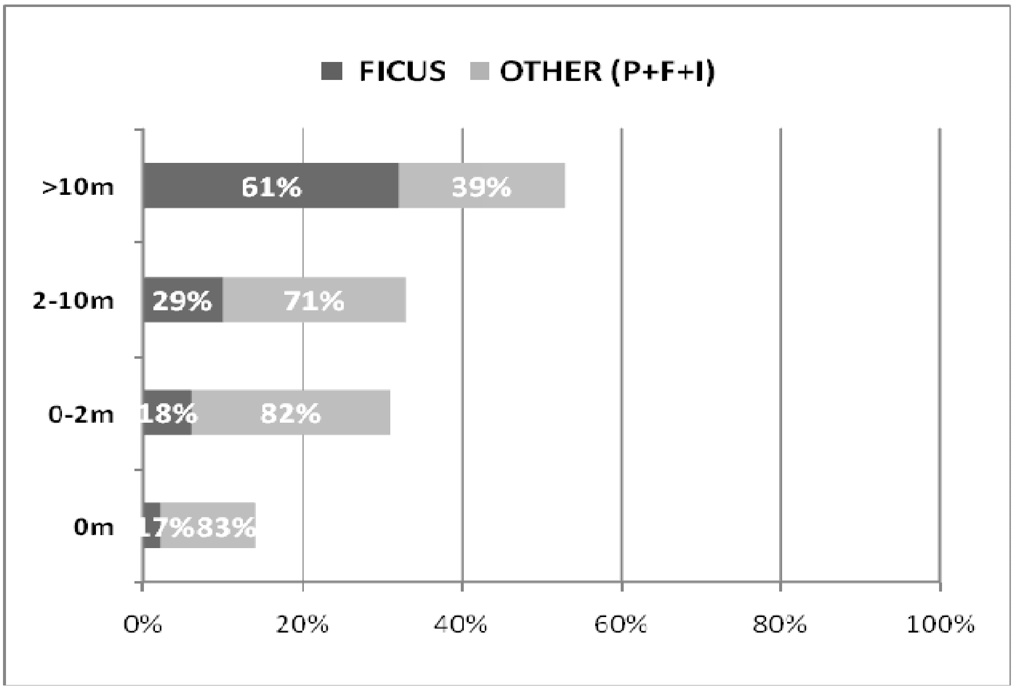


Figure 25. Proportion of figs actually ingested (during feeding activity). by all females at different forest strata

4. Nutrient contents

Nutrient contents varied in females diet based on species and plant parts eaten. Fruits showed the highest content of fat and fibers. (Table 12). Fungi had the highest value in terms of Proteins, Kilocalories/Kg and Water. Instead, Stems had the highest Carbohydrates and Ashes content. In Figure 26 the comparison between the average values of fat content in figs compared with plant parts of different species is shown.

A nonparametric Correlation analysis between different reproductive states and nutrient contents in different food items showed L females feeding mainly on food items rich in fat content (Kendall's tau_b, Correlation Coefficient=0.255; p=0.025). Females in other reproductive states had no positive correlation with any nutrient content (Appendix 6, 7, 8, 9).

Table 12. Nutrient contents in different plant parts

	FRUITS	LEAVES	FLOWERS	STEMS	FUNGI
Crude proteins	8.48	17.65	22.60	4.19	**27.05**
Crude fat	**5.97**	3.32	1.17	0.98	3.89
Fibers	**32.24**	23.31	24.54	31.63	32.14
Carbohydrates	42.64	44.39	42.63	**47.21**	31.62
Ash	10.67	11.32	9.07	**15.99**	5.30
Calorie content (Kilocalories/Kg)	3581.63	3752.08	3342.31	2892.94	**4280.21**
Water content	14.09	12.46	10.87	17.52	**29.23**

Note: In Bold the highest nutrient content value among plant parts.

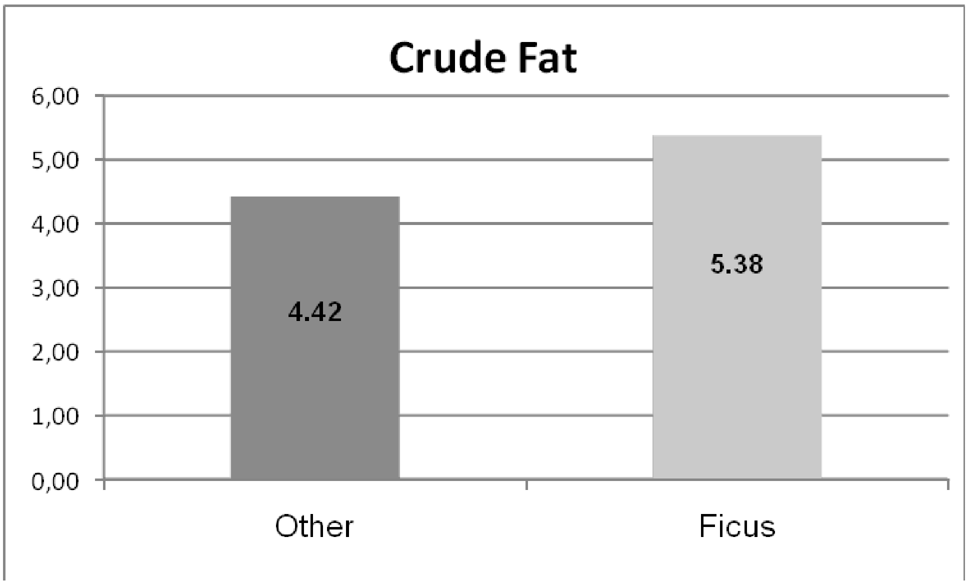


Figure 26. Fat content value, on average, in the Genus *Ficus* and other species plant parts

H. DISCUSSION

Habitat use and activity budgets may depend on a variety of variables as for example availability and distribution of food and water resources, sleeping sites, climate, the need to patrol home range boundaries, the predation risk etc. (*e.g.,* Altmann and Altmann, 1970; Clutton-Brock, 1977; Goodall, 1986; Watts and Mitani, 2001; Williams *et al*., 2002). The habitat structure, in terms of available substrates, such as trees, rocks, etc., and distribution and abundance of food resources are likely to affect both ranging patterns (an horizontal use of the habitat) and use of the forest through its vertical strata (*e.g.,* O'Brien and Kinnaird, 1997; Poulsen *et al.,* 2001). Distribution of food resources, in turn, are stronlgy affected by seasonal changes and climate conditions, and by the presence of food competitors, which, particularly in case of primates, might be both neighboring groups of conspecifics, or else other species, including other primate species, humans as well (*e.g.,* Janson and van Schaik, 1988; Riley, 2007).

The present study aimed at describing how *M. maura* females utilize their habitat and allocate their time for different daily activities, with a particular interests in foraging and feeding behavior in order to assess the composition of their diet, food nutrient content and preferences. A further step was to analyze how all these activities (habitat use, activity budgets and diet) might be influenced by the female different reproductive states – whether pregnant, lactating, ovulating or else.

Over one year period, maximum home range size of the group studied was 29,27 Ha (karst rocks included) which well fit to the average home range size for moor macaque groups in the same area, as reported by Okamoto *et al.* (2000). Although data collected during the present study covered a time period which did not correspond to a complete dry and a rainy seasons, nevertheless they included some months of both, August-September (dry season) and October to February (rainy season). Suitable data for monitoring seasonal variation in the home range size are, therefore, not availbale however, even within the 7-month study period, home range size did vary throughout time. From September – when home range size was the largest - to October/November, size drastically decreased from 15.06 Ha to 8.90 Ha. Similar findings were interpreted based on the peak of fruits production which occurred in October, as typically happened at the end of the dry season and the beginning of the rainy season in this area (see also Okamoto *et.al.,* 2000). In fact, availability and distribution of resources may vary in time, and are likely to affect the shape of primates' ranging patterns, such as size and shape of their home range (*e.g.,*Harvey and Clutton-Brock (1981); Olupot *et al*., 1997). In the present study it might be hypothesized that before the peak of fruits production (August/September) food resources were scarce and the group had to expand its home range to satisfy nutrient requirements. In contrast, when food resources were abundant (starting from October/November), the home range size decreased. Since our data only infer this interpretationt as related to food abundance and ignore how pattern of food resource distribution varies, it is necessary to conduct further research over multiple years in order to verify this hypothesis.

The effect of food resources availability is evident both on horizontal (home range size) and on the vertical use (forest strata) of the habitat. As reported by Achmad (2011), the composition and distribution of plant species in limestone karst ecosystem were affected by topography and relative abundance of soil. In topographic terms, there are 6 habitat types in this ecosystem (upper slope habitat, downslope, ridge, the rest of the hill, canyon and cliff). These types had relatively different species composition that may affect the moor macaques food resources distribution. In this study, activity budgets were significantly affected by different forest strata: the group spent 42% of the daily time above 10m in the canopy, and females used the high strata prevalently for foraging and feeding while the lowest stratum was mainly used for resting, socializing and locomoting. Habitat quality in forest dwelling primates, has been related to higher tree species richness because, such an habitat may offer more foraging options during periods of food scarcity (Poulsen *et al.,* 2001). Therefore in the present study, the preference for foraging and feeding on higher strata could likely be explained by the presence of food items, such as fruits, in more elevated strata.

This interpretation might be supported by the following considerations. Based on the results of the present study, moor macaque females mainly fed on plant species (84%), in particular tree species (86%), followed by insects (14%) and fungi (2%). However, if calculated on the total amount of items eaten (including all different plant parts, insect and fungi) fruits represented 71%, meaning most of their diet (see also *M. nigra*, O'Brien and Kinnaird, 1997; *M. tonkeana*, Riley, 2007). Therefore though consuming a variety of other food types, they might be easily labeled as frugivorous. In terms of nutrient contents, and only among food items analyzed in the present study (flowers, leaves, stems, fruits and fungi), fruits showed the highest fat content. This could partly explain the importance of this food item in the lactating females diet. In female mammals, the lactation period is considered as the most demanding reproductive phase from an energetic point of view (Pond, 1977; Widdowson, 1977), and female primate, in addition to milk production, need extra-energy for infant carrying. However, fat storing should occur in preparation to this period (*i.e.,* during pregnancy) in that milk production induces the use of fat reserves which must have already been stored (*e.g*., Murray *et al.,* 2009).

Among fruits, *Ficus* is one of the most widespread genera of tropical plants (Janzen, 1979), and represent important resources for many tropical frugivores (Leighton and Leighton, 1983; Terborgh, 1986; Shanahan *et al*., 2001;), included Sulawesi wildlife (Kinnaird *et al.,* 1999; for *M. tonkeana* Fashing, 2001; Kinnaird and O'Brien, 2005). Figs also provide a range of essential macro- and micro-nutrients (Conklin and Wrangham, 1994; O' Brien *et al*., 1998). The importance of fig fruits is also evident in the present study in that it represents 31% of the whole diet. In fact, since fig fruits constituted 61% of the entire diet above 10m, they are also likely to be the target preferred food of foraging and feeding, being main activities occurring at higher strata. Females have been observed also feeding on figs at lower strata in the forest when, for example, individual trees growing on the ground and/or fruiting from the trunk and/or leaning down from karts tower, can be easily reached (*e.g*., *Ficus obscura*, *F. miquelli, F. glomerata).* Nevertheless, the preference for figs fruits at highest strata might be interpreted as a preference for large fig trees, well exposed to sun radiation and consequently very rich in fruits with high nutrient contents (Ngakan Putu Oka, personal communication). In fact, figs showed on average, a higher fat content (5,38%) than any of the other plant species parts and were typically located on top of high limestone karsts. It might be interesting also to consider that *Ficus spp* become staple food resources for many tropical frugivores, because of some characteristics such as a production of large amount of fruits and at short intervals (in order to favor its symbiotic species of wasp which is important for its impollination) (Janzen, 1979), and an asynchronous intra-population fruiting, which make them better available over time (*e.g.,* Shanahan *et al*., 2001)

In terms of balance between the acquisition of energy and the metabolic cost of different behaviors and body maintenance, it appears that diet and habitat structure are key factors affecting individual's activity budgets, with time spent foraging and distance traveled in order to find food. If, in addition to these basal metabolic expenses, reproductive investments in a female mammal are also considered, one might expect that different reproductive states would represent an additional limiting factor.

In about 7% of primate species, the anogenital area gets swollen around the time of ovulation, producing an obvious visual signal (sexual swelling, see Dixson, 1983) which is reported in the literature as energetically costly (*e.g*., Nunn, 1999; Setchell and Kappeler, 2003). Although in female primates, the lactating phase is widely known as the most energetically expensive phase, the *peri-ovulatory* phase might represent an additional energetically expensive phase for the species which possess sexual swelling.

In this study, PO and L females showed some differences in their behavioral strategies which could be interpreted in light of their inferred energetic demands. In fact, while the PO females had the highest Diversity Index in terms of plants, fungi and insects eaten and showed highest foraging and feeding activities at higher strata, L females showed the lowest Diversity Index both in terms of diet composition and parts of plant eaten however, tended to be associated more to the ground (0m) where socializing and resting were major activities. These results might indicate two opposite strategies however aimed at the same result: a positive energy balance. *Peri-ovulatory* females looked for more variety in the diet and invested more moving upwards in the forest strata, whereas L females would rather save energy resting and socializing on the ground rather than investing time looking for a variety of food types. McCabe and Fedigan, (2007) reported how lactating female *Cebus* would maximize energy intake by increasing ingestion rate and choosing protein rich food rather than feeding for longer. In the present study moor macaque females might compensate a slightly poorer diet in terms of variety by eating more fruits than females in other reproductive states. These results seem to be supported by Murray *et al*. (2009) on chimpanzee females. In fact, both species seem to adopt energy conservation strategy during energy consuming states (*e.g.,* pregnancy and lactating states, Clutton-Brock *et* *al.*, 1989), although, while in the present study the evidence mostly comes from lactating females, in chimpanzees an energy conservation strategy seem to be adopted by pregnant females.

Unfortunately in this study, due to the only slightly seasonal pattern of reproduction in moor macaque, the unpredictability of occurrence of female fertile cycles has not allowed to have the four different reproductive states being equally frequent and so represented by a comparable sample size. In particular, samples of *peri-ovulatory* phases and of pregnancies have been dramatically little represented. This in turn, will not allow to draw suitable conclusions after the study, but only track the trail for the follow up of this project.

CHAPTER V

A. CONCLUSIONS

The home range of the studied group responded to seasonal changes in food sources availability by changing size accordingly: during months in which it was assumed that food resources were relatively abundant, size was smaller than during months in which nutritive resources were scarce, the group being forced to expand its home range searching for food.

This indicates that moor macaque habitat use and daily activity patterns are likely to be affected by availability and distribution of food resources. More so it is likely for females whose energetic balance is more at risk, due to their reproductive investments. In this study, females used the lower forest stratum mostly for locomotion, socializing and resting while climbed up to the highest forest strata mainly for foraging and feeding. The reason why females spent energy to climb up to the canopy might be explained by the presence of preferred food resources, in particular figs, which are rich in fats.

Females moor macaques seem to adopt different strategies in terms of habitat use and activity budgets to likely meet energy requirements depending on their reproductive state. Both *peri-ovulatory* and lactating females – presumably facing energy and nutrient demanding states – aimed at a positive energetic balancing in order have extra energy. *Peri-ovulatory* females would invest more in foraging, however earned a more diversified diet, while lactating females would rest more, however compensated a less varied diet by feeding more on fruits, rich in nutrients.

C. Recommended conservation strategy

Moor macaque is endemic to just a portion of one of the 5 provinces in the island of Sulawesi. In order to preserve moor macaques from extinction, it's necessary to collect data from populations inhabiting other ecosystem types.

In general, species belong to the genus *Ficus* can be appointed as keystone plant resources for *M. maura* and should be included in special state of protection. This key plant species seem to be present mainly on limestone karsts higher than 10m that are still home for large trees due to their inaccessibility for human activities. For this reason, it might be likely that Limestone karsts still harbor some of intact forest and that macaques find there precious food sources. In order to ensure the persistence of each monkey social group inhabiting the area, annual home ranges should be large enough to accommodate an annual cycle of fruit resources and to include sufficient alternative food items during seasons of low fruits availability.

As reported by Cannon *et al*. (2005), the large area of lowland *alluvium* has been completely converted and only a little more than 1% lowland intermediate forests are in good condition. To date, only scattered pieces of Limestone karst ecosystem in the midwestern area still contain forests in good condition and activities threatening this ecosystem are being carried on. The main threat is the extraction of karst rocks for the production of cement and marble. There are two cement industries (Tonasa and Bosowa) that extract karst rocks for nationwide requests and marble and stones are being used for the construction of local houses and roads. Other activities that disturb the ecosystem are cultivation at the base of the karst massifs, timber extraction, illegal hunting, uncontrolled tourism, invasion of alien species, air and noise pollution (Achmad, 2011). For this reason, a recommended conservation strategy should be an expansion of protected areas to include almost all limestone karst ecosystem throughout South Sulawesi province, allowing the minimum extraction of rocks and marble for local use. Furthermore would be required a program area management aimed at sustainable use of the resources present in this ecosystem that promotes economic well-being of the local population without causing damage to forests and wildlife. A typical strategy could be the promotion of ecotourism, economic disincentives to the extraction of marble and rocks and controlled use of these resources in order to counter the illegal extraction.

REFERENCES

Achmad, A. 2011. Rahasia Ekosistem Hutan Bukit Kapur. *Brilian Internasional*.

Altmann, S.A., Altmann J. 1970. Baboon Ecology: African Field Research. *University of Chicago Press, Chicago*

Altmann, J. 1974. Observational Study of Behavior: Sampling Methods. *Behaviour* 49: 227-265.

Cannon, C.H., Harting, J.R., Salim, A., Summers, M. 2005. The Vegetation of Sulawesi: Coarse filter analysis. *Ecoregional Conservation Assessment*.

Cannon, C.H., Summers, M., Harting, J.R., Kessler, P. J. A. 2007. Developing Conservation Priorities Based on Forest Type, Condition, and Threats in a Poorly Known Ecoregion: Sulawesi, Indonesia. *Biotropica* 39(6): 747–759.

Ciani, A.C., Stanyon, B., Scheffrahn, W., Sampurno, B. 1989. Evidence of Gene Flow Between Sulawesi Macaques. *American Journal of Primatology* 17: 257-270.

Clutton-Brock, T.H. 1977. Primate Ecology: Studies of Feeding and Ranging Behavior in Lemurs, Monkeys and Apes. Primate Ecology: Studies of Feeding and Ranging Behavior in Lemurs, Monkeys and Apes. *London: Academic Press*. p 449–479.

Clutton-Brock, T.H., Albon, S.D., Guinness, F. E. 1989. Fitness costs of gestation and lactation in wild mammals. *Nature*, 337 , 260– 262.

Conklin, N.L., Wrangham, R.W. 1994. The value of figs to a hind-gut fermenting frugivore – a nutritional analysis. *Biochemical Systematics and Ecology*, 22, 137–151

Di Gregorio, A., Jansen. 2000. Land Cover Classification System (LCCS). *FAO Corporate Document Repository*. http://www.fao.org/DOCREP/003/X0596E/X0596E00.HTM

Dixson, A.F. 1983. Observations on the evolution and behavioural significance of ‘‘ sexual skin ’’ in female primates *Adv*. *Study Behav*.13, 63–106

Evans, B.J., Morales, J. C., Supriatna, J. and Melnick, D. J. 1999. Origin of the Sulawesi macaques (*Cercopithecidae*, *Macaca*) as inferred from a mitochondrial DNA phylogeny. *Biol. J. Linn. Soc*. 66:539–560.

Evans, B.J., Supriatna, J. and Melnick, D. J. 2001. Hybridization and Population Genetics of Two Macaque Species in Sulawesi, Indonesia. *Evolution* 55(8) pp. 1686-1702.

Fashing, P.J. 2001. Feeding ecology of guerezas in the Kakamega Forest, Kenya: The importance of *Moraceae* in their diet. *Int. J. Primatol.* 22: 579–609.

Fooden, J. 1976. Provisional Classification and Key to Living Species of Macaques (Primates: *Macaca*). *Folia Primatol*. 25: 225-236.

Fooden J. 2000. Systematic review of the rhesus macaque, *Macaca mulatta* (Zimmermann, 1780). *Field Zool* 96: 1-180.

Getz, W.M., Wilmers, C.C. 2004. A local nearest-neighbor convex-hull construction of home ranges and utilization distributions. *Ecography* 27: 489-505.

Gittleman, J.L., Thompson, S.D. 1988. Energy Allocation in Mammalian Reproduction. *Integr Comp Biol*. 28:863–875.

Goodall, J. 1986. The chimpanzees of Gombe: patterns of behavior. *Harvard University Press*, Cambridge (Massachusetts). 673 pages

Janzen, D.H. 1979. How to be a fig. *Annual Review of Ecology and Systematics*, 10,13–51.

Key, C., Ross, C. 1999. Sex differences in energy expenditure in non-human primates. *Proc. R. Soc. Land.* B 266: 2479-2485.

Kinnaird, M.F., O’Brien, T.G., Suryadi, S. 1999. The importance of figs to Sulawesi’s imperilled wildlife. *Trop. Biodivers*.6: 5–18.

Kinnaird, M.F., O'Brien, T.G. 2005. Fast Foods of the Forest: The Influence of Figs on Primates and Hornbills Across Wallace’s Line. *Tropical Fruits and Frugivores*. pp. 155-184.

Leighton, M., Leighton, D.R. 1983. Vertebrate responses to fruiting seasonality within a Bornean rain forest. In Sutton, S.L., Whitmore, T.C., and Chadwick, A.C. (eds.):Tropical Rain Forest: Ecology and Management. *Blackwell, Oxford*, pp. 181–196.

Matsumura, S. 1991. A preliminary report on the ecology and social behavior of moor macaques (*Macaca maurus*) in Sulawesi, Indonesia. *Kyoto University Overseas Research Report of Studies on Asia Non-Human Primates* 8: 27-41.

Matsumura, S. 1993. Female Reproductive Cycles and the Sexual Behavior of Moor Macaques *(Macaca maurus)* in Their Natural Habitat, South Sulawesi, Indonesia. *Primates* 34(1): 99-103.

Matsumura, S. and Okamoto, K. 1997. Factors affecting proximity among members of a wild group of moor macaques during feeding, moving and resting. *International Journal of primatology* Vol. 18, No.6

McCabe, G.M., Fedigan, L.M. 2007. Effects of reproductive status on energy intake, ingestion rates and dietary composition of female (*Cebus capucinus*) at Santa Rosa, Costa Rica. *Int J Primatol* 28(4): 837-851.

Murray, C.M., Lonsdorf, E.V., Eberly, L.E., Pusey, A.E. 2009. Reproductive energetics in free-living female chimpanzees (*Pan troglodytes schweinfurthii*). *Behavioral Ecology*, 20(6): 1211-1216.

Napier, J.R., Napier, P.H. 1985. The Natural History of the Primates. *London: British Museum (Natural History)*.

Nunn, C. 1999. The evolution of exaggerated sexual swellings in primates and the graded-signal hypothesis. *Animal Behavior*, 58, 229–246.

O’Brien, T.G., Kinnaird, M.F. 1997. Behavior, diet, and movements of the Sulawesi crested black macaque. *International Journal of Primatology* 18:321–351.

Okamoto, K., Matsumura, S., Watanabe, K. 2000. Life history and demography of wild Moor macaques (*Macaca maurus*): Summary of ten years of observations. *American Journal of Primatology* 52: 1-11.

Okamoto, K. and Matsumura, S. 2001. Group Fission in Moor Macaques (*Macaca maurus*). *International Journal of Primatology*, Vol.22, No. 3.

Olupot, W., Chapman, C.A., Waser, P.M., Isabirye-Basuta, G. 1997. Mangabey (*Cercocebus albigena*) ranging patterns in relation to fruit availability and the risk of parasite infection in Kibale National Park, Uganda. *Am. J. Primatol*. 43: 65-78.

Pond, C.M. 1977. The significance of lactation in the evolution of mammals. *Evolution*, 31, 177–199

Poulsen, J.R., Clark, C.J., Smith, T.B. 2001. Seasonal variation in the feeding ecology of the Grey-Cheeked Mangabey (Lothocebus albigena) in Cameroon. *Am. J. Primatol*. 54: 91–105.

Riley, E.P. 2007. Flexibility in Diet and Activity Patterns of *Macaca Tonkeana* in Response to Anthropogenic Habitat Alteration. *International Journal of Primatology* 28 (1): 107-133.

Riley, E.P. 2008. Ranging patterns and habitat use of Sulawesi Tonkean macaques (*Macaca tonkeana*) in a human-modified habitat. *American Journal of Primatology* 70: 670–679.

Riley, E.P. 2010. The Endemic Seven: Four Decades of Research on the Sulawesi Macaques. *Evolutionary Anthropology* 19: 22-36.

Robinson, J.G. 1987. Seasonal Variation in Use of Time and Space by the Wedge-capped Capuchin Monkey, *Cebus olivaceus:* Implications for Foraging Theory. *Smithsonian Contribution to Zoology*, 431.

Rose, M.D. 1974. Ischial tuberosities and ischial callosities. *Am. J. Phys. Anthropol* 40: 375–383. Abstract.

Rothman, J.M., Dierenfeld, E.S., Hintz, H.F., Pell, A.N. 2008. Nutritional Quality of Gorilla Diets: Consequences of Age, Sex, and Season. *Oecologia* 155:111–122.

Rowe, N. 1996. The Pictorial Guide to the Living Primates. *Pogonia Press, Charlestown*. p 126.

Shanahan, M., So, S., Compton, S.G., Corlett, R. 2001. Fig-eating by vertebrate frugivores: A global review. *Biological Reviews* , 76, 529–572.

Setchell, J.M., Kappeler, P.M. 2003. Selection in Relation to Sex in Primates. *Advances in the Study of Behavior*, Vol. 33 87-173.

Stiver, J.R., Apa, A.D., Remington, T.E., Gibson, R.M. 2008. Polygyny and Female Breeding Failure Reduce Effective Population Size in the Lekking Gunnison sage-grouse. *Biological Conservation* 141: 472-481.

Supriatna, J., Froehlich, J.W., Erwin, J.M., Southwick, C.H. 1992. Population Habitat and Conservation Status of *Macaca maurus, Macaca tonkeana* and Their Putative Hybrids. *Tropical Biodiversity* 1 (1): 31-4.

Supriatna, J., Shekelle, M., Burton, J. 2008. *Macaca maura*. In: IUCN 2011. *IUCN Red List of Threatened Species*. Version 2011.2. <www.iucnredlist.org>. Downloaded on 01 May 2012.

Terborgh, J. 1986. Keystone plant resources in the tropical rain forest. In Soul´e, M.E. (ed.), Conservation Biology: The Science of Scarcity and Diversity . *Sinauer Associates, Sunder-land, MA*, pp. 330–344.

Thierry, B. 2007. Unity in diversity: Lessons From Macaque Societies. *Evolutionary Anthropology* 16: 224-238.

Thomson, M.E., Wranghman, R.W. 2008. Diet and Reproductive Function in Wild Female Chimpanzees (*Pan troglodytes schweinfurthii*) at Kibale National Park, Uganda. *American Journal of Physical Anthropology* 135:171–181.

Watanabe, K., Brotoisworo, E. 1982. Field Observation of Sulawesi macaques. *Kyoto University Overseas Research Report of Studies on Asian Non-Human Primates*, 2: 3-9.

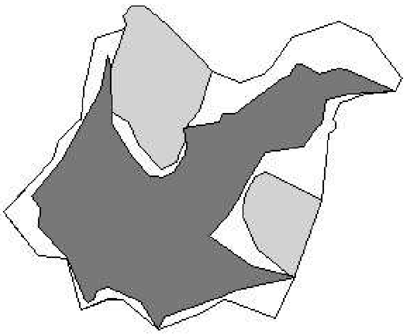
Watanabe, K., Brotoisworo, E. 1985. Ecological survey of Sulawesi macaques. *Kyoto University Overseas Research Report of Studies on Asian Non-Human Primates*, 4: l-3.

Watts, D. and Mitani, J.C. 2001. Boundary patrols and intergroup encounters in wild chimpanzees. *Behaviour* 138: 299-327.

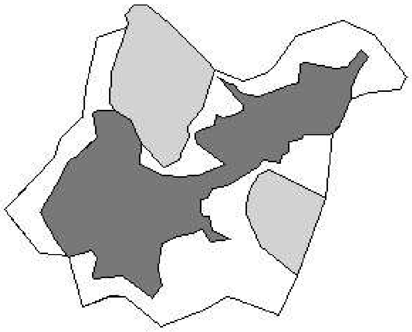
Widdowson, E.M. 1977. Nutrition and lactation. In M. Winick (Ed.), *Nutritional disorders of American women* (pp. 67 –75). New York: John Wiley & Sons.

Whitten, A.J., Mustafa, M., Henderson, G.S. 1988. The ecology of Sulawesi. *Yogyakarta: Gadjah Mada University Press*. 777 p.

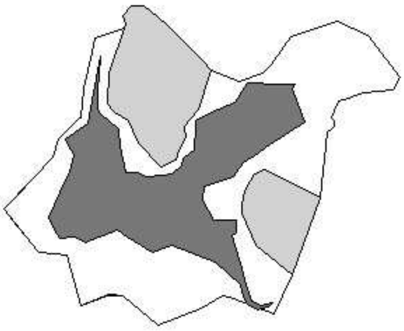
Appendix 1. Monthly home range



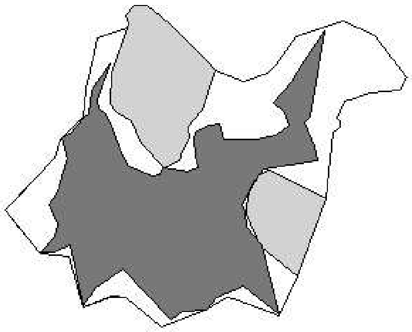
September 2010 (15.06 Ha)



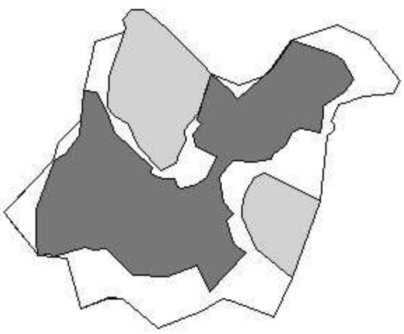
October 2010 (10.77 Ha)



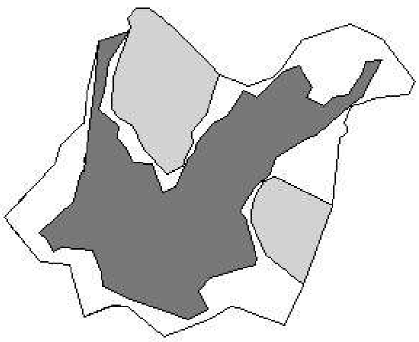
November 2010 (8.90 Ha)



December 2010 (13.44 Ha)



January 2011 (13.14 Ha)



February 2011 (12.91 Ha)

Karsts (no GPS points)

Home range over 1 year (GPS points)

Home range per month (GPS points)

Appendix 2. Plant and fungi species consumed by the group (2010-2011)

No.	Local name	Family	Botanical name
1	Accang	Anacardiaceae	*Spondias malayana A.G.J.H. Kosterm.*
2	Bakan	Lauraceae	*Litsea mappacea Boerl.*
3	Banga	Pandanaceae	*Pandanus sp.*
4	Ba'ru	Arecaceae	*Caryota mitis Lour.*
5	Bingkuru	Rubiaceae	*Morinda citrifolia Linn.*
6	Bole-bole	Clusiaceae	*Garcinia tetrandra Pierre*
7	Buebueanja	Fabaceae	*Calopogonium mucunoides Desv.*
8	Bukkang-bukkang	Urticaceae	*Villebrunea rubescens Blume*
9	Bu'ne	Euphorbiaceae	*Bridelia insulana Hance*
10	Bunja	Borraginaceae	*Cordia dichotoma Forst. f.*
11	**Bu'rung**	**Maranthaceae**	***Donax cannaeformis Rolfe***
12	Cambulubulu	Convolvulaceae	*Merremia vitifolia Hallier.f*
13	**Cendrana**	**Fabaceae**	***Pterocarpus indicus Willd.***
14	Duajeng	Moraceae	*Ficus glomerata Roxb.*
15	Empallasa Kaci	Moraceae	*Ficus sp.*
16	Ga'mi	Sterculiaceae	*Pterocymbium tinctorium Merril*
17	Ganjeng	Dioscoreaceae	*Dioscorea laurifolia Wall.*
18	Ganjeng-ganjeng	Rhamnaceae	*Ziziphus angustifolius (Miq.) Hatusima*
19	Inru/Areng	Arecaceae	*Arenga pinnata* (Wurmb.) Merr.
20	Jambu Biji	Myrtaceae	*Psidium guajava Linn.*
21	Kajuara “Batan Putih”	Moraceae	*Ficus obliqua Forst.f.*
22	Kajuara “Batu”	Moraceae	*Ficus tinctoria Forst. f.1*
23	Kajuara “Besar”	Moraceae	*Ficus virens Ait. var. glabella*
24	Kajuara “Jahi-jahi”	Moraceae	*Ficus chrysolepis Miq*
25	Kajuara "Gua"	Moraceae	*Ficus sp.*
26	Kajuara "Heli"	Moraceae	*Ficus sp.*
27	Kajuara “Kecil”	Moraceae	*Ficus tinctoria Forst. f.2*
28	Kajuara “Menyebrang”	Moraceae	*Ficus virens Ait.*
29	Kajuara “Rangkong”	Moraceae	*Ficus drupacea Thunb.*
30	Kajuara “Tangga”	Moraceae	*Ficus tinctoria Forst. f.3*

Appendix 2 Continued

No.	Local name	Family	Botanical name
31	Kajuara “Umpang”	Moraceae	*Ficus tinctoria Forst. f.4*
32	Kaleleng Susuan	Thymelaeaceae	*Phaleria capitata Jack*
33	Kalukenrang	Moraceae	*Ficus variegata Blume*
34	Kapa-kapasa	Fabaceae	*Mucuna reticulata Burck*
35	Katabo	Commbretaceae	*Terminalia supitiana Koord.*
36	**Katimbang**	**Zingiberaceae**	***Etlingera polycarpa (K. Schum.) A.D. Poulsen***
37	**Keru-keru**	**Moraceae**	***Ficus sp.***
38	**Kirasa**	**Clusiaceae**	***Garcinia dulcis Kurz.***
39	Lalatan (Tidak tahu 3)	Urticaceae	*Dendrocnide microstigma (Gaud.ex Wedd) Chew.*
40	Lambere	Moraceae	*Ficus miquelli King*
41	**Lassa-lassa**	**Meliaceae**	***Aphanamixis polystachya (Wall.) R.N. Parker***
42	**Lento-lento**	**Araliaceae**	***Arthrophyllum diversifolium Blume***
43	Limpujeng	Zingiberaceae	*Zingiber cf. odoroferum Blume*
44	**Lobe-lobe**	**Flcourtiaceae**	***Flacourtia inermis Miq.ex Hook.f.& Thoms***
45	Lumbatang	Poaceae	*Oplismenus compositus Beauv.*
46	Mali-mali	Leeaceae	*Leea aequata L.*
47	**Mana-mana**	**Moraceae**	***Ficus fistulosa Reinw.***
48	**Mara-mara sikapa**	**Rutaceae**	***Melicope confusa (Merr.) Liu***
49	Marihallasa	Moraceae	*Ficus congesta Roxb.*
50	Mballung	Acanthaceae	*Strobilanthes imbricatus Nees*
51	Nato	Sapotaceae	*Palaquium obovatum Engl.*
52	Pacci-pacci dare	Icacinaceae	*Phytocrene hirsuta Blume*
53	Pa'da	Moraceae	*Ficus obscura Blume*
54	Pala-pala	Myristicaceae	*Knema cinerea (Poir.) Warb.*
55	**Paliasa**	**Sterculiaceae**	***Kleinhovia hospita L.***
56	Pangi	Silacaceae	*Pangium edule* Reinwardt.
57	Pu'cak	Lauraceae	*Beilsmiedia gemmiflora (Blume) Kosterm.*
58	Ranging	Dilleniaceae	*Dillenia obovata (Blume) Hoogl.*
59	Rao	Anacardiaceae	*Dracontomelon dao Merrill & Rolfe*
60	Rotan	Arecaceae	*Calamus cf. koordersianus Becc.*
61	Tambung-tambung	Moraceae	*Ficus gul K.Schum. & Lauterb.*
62	Tataimanu	Verbenaceae	*Lantana camara Linnaeus*

Appendix 2. Continued

No.	Local name	Family	Botanical name
63	Tidak tahu 1	?	*?*
64	**Tidak tahu 2**	**Myrsinaceae**	***Ardisia lanceolata Roxb.***
65	**Tidak Tahu 4**	**Annonaceae**	***Xylopia peekelii Diels.***
66	Tidak tahu 5	Tiliaceae	*Grewia multiflora Juss.*
67	Tidak Tahu 6	Vitaceae	*Tetrasigma pisicarpum (Miq.) Planch.*
68	Tidak tahu 7	Aristolochiaceae	*Aristolochia tagala Cham.*
69	**Tidak tahu 8**	**Actinidiaceae**	***Saurauia tristyla DC.***
70	Tire Halus	Araceae	*Amorphophalus oncophyllus Prain. ex Hook.f.*
71	Tire Kasar	Araceae	*Amorphophalus campanulatus Blume*
72	**Tokka**	**Moraceae**	***Artocarpus elasticus* Reinw. ex Blume**
73	Pipisi		*Fungus*
74	**Kalumemere**		***Fungus***

Note: in BOLD are species (N=14) that have never been eaten during the scan sampling ("10 minutes period" every 30 minutes interval) but were seen eaten by any member of the group at least once during the entire study period (April 2010-February 2011)

Appendix 3. Food items of moor macaques in Karaenta Natural Reserve (Matsumura 1991)

Local name	Family	Botanical name
Mbarrung	Acanthaceae	*Strobilanthes cf. imbricata*
Rao	Anacardiaceae	*Dracontomelon mangiferum*
Binkuru	Apocynaceae	*Tabernaemontana sphaerocarpa*
Tire	Araceae	*Amorphophallus*
Kirasa	Cluciaceae	*Garcinia celebica*
Cambulubulu	Convolvulaceae	*Merremia vitifolia*
??4	Ebenaceae	*Diospyros sp.*
Pangi	Flacourtiaceae	*Pangium edule*
Pacci-pacci dare	Icacinaceae	*Phytocrene macrophylla*
Kande-kande alo	Lauraceae	*Litsea ampala?*
Bakan	Lauraceae	*Litsea firma*
Langoting silayara	Lythraceae	*Langerstormia speciosa*
Bunga-bunga	Melastomataceae	*Memecylon grassiform*
Arese	Meliaceae	*Diysoxylum sp.*
Langiri	Mimosaceae	*Albizzia saponaria*
Tokka	Moraceae	*Artocarpus elasticus*
Nanka-nanka	Moraceae	*Artocarpus glaucus*
Capuko	Moraceae	*Artocarpus sp.*
Duajeng	Moraceae	*Ficus adenophilla*
Kalukenrang	Moraceae	*Ficus adenophilla*
Emparasa karambu	Moraceae	*Ficus ampelas*
Kajuara	Moraceae	*Ficus annulata*
Kajuara bunga manu	Moraceae	*Ficus drupacea*
Kajuara jahi-jahi	Moraceae	*Ficus sinuata/tinctoria*
Lambere	Moraceae	*Ficus hispida*
Pa'da	Moraceae	*Ficus obscura*
Mana-mana	Moraceae	*Ficus schwarzii*
??-3	Moraceae	*Ficus subulata*
Marihallasa	Moraceae	*Ficus variegata*
Emparasa kaci	Moraceae	*Ficus sp.?*
Pala-pala	Myristicaceae	*Knema cinera*
??-1	Myrsinaceae	*Maesa perlarius*
Kaleleng susuan	Myrtaceae	*Eugenia sp.*

Appendix 3. Continued

Local name	Family	Botanical name
Raukan	Palmae	
Inru	Palmae	*Arenga pinnata*
Bingtahan	Rubiaceae	*Morinda brancteata*
Lassa-lassa	Sapindaceae	*Harpullia sp.*
Nato	Sapotaceae	*Palaqium sp.?*
Lalatan	Urticaceae	*Laportea sp.*
Tataimanu	Verbenaceae	*Lantana camera*
Tobo-tobo		
Banga		
Bunja		
Attebulu		
Bukkang-bukkang		
Accang		
Alan-alan		
Katakatala		
Buebueanja		
Kapakapasa		
Upang		
Lumbatang		
Keru-keru		
Poddo-poddo		
Mampu		
Kahukahuromang		
Mali-mali		
Mahai?	Annonaceae	*Polyalthia celebica?*
??-2		
Pipisi		*Fungus*
Kalumemere		*Fungus*
TOTAL		61
Several kind of insects		
Lizard		

Note: in yellow species in common in both plant list (present study 2010-2011 and Matsumura 1991)

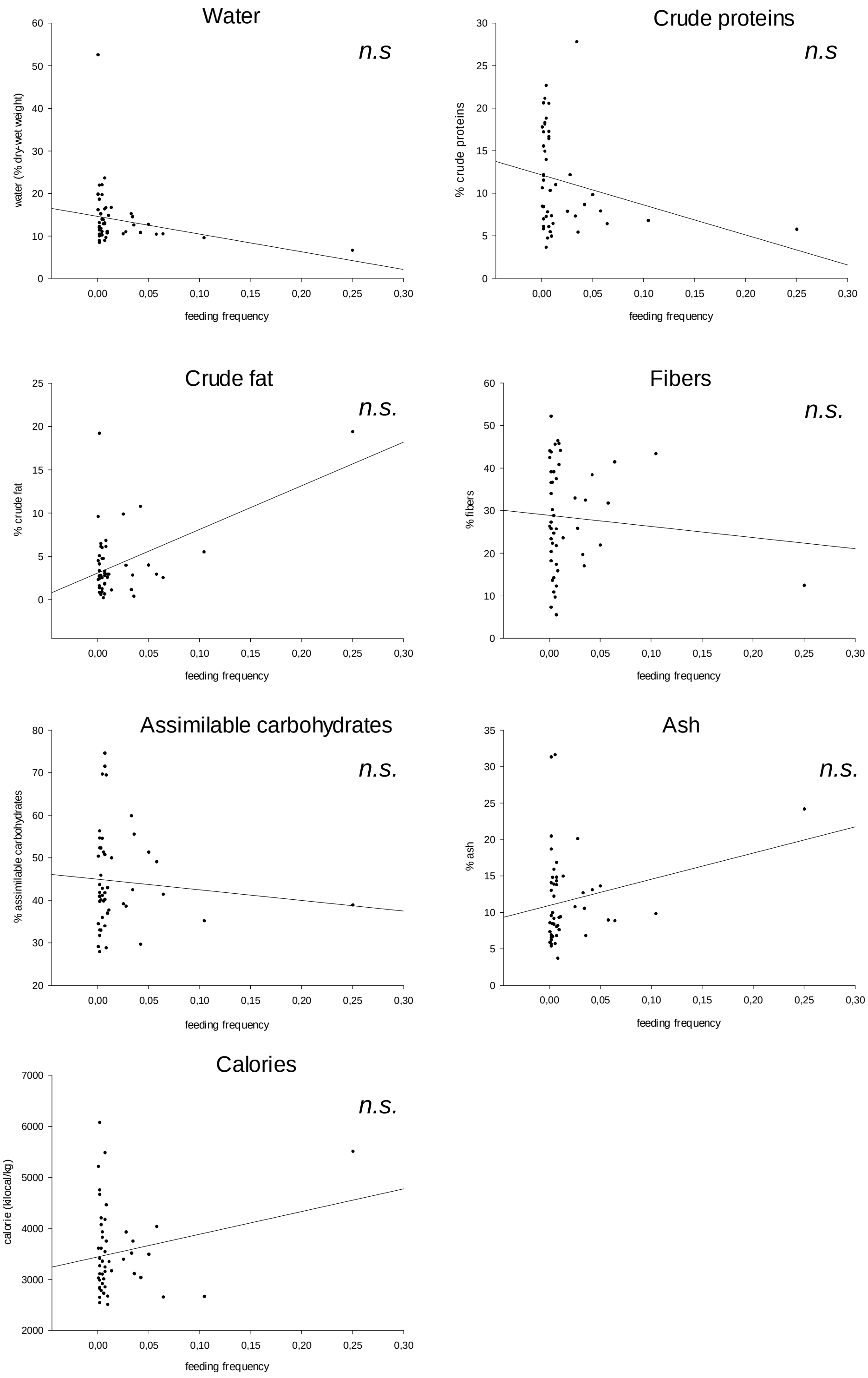
Appendix 4. Plant species eaten by moor macaques in Karaenta forest reported by Achmad (2011) not yet reported by Matsumura (1991)

Local name	**Botanical name**
Puca	*Barringtonia asiatica*
Dama'-dama'	*Canarium sp.*
Jambu hutan	*Eugenia sp.1*
Jambu hutan	*Eugenia sp.2*
	Garcinia sp.1
	Garcinia sp.2
	Castanopsis
Kayu manis	*Cinnamomum celebicum*
Kopi ale	
Langsat hutan	*Lansium sp.*
Lobe-lobe	*Flacortia rucam*
	Buchanania arborescens
Mara siapa	*Vitex sp.*
	Myristica sp.1
	Myristica sp.2

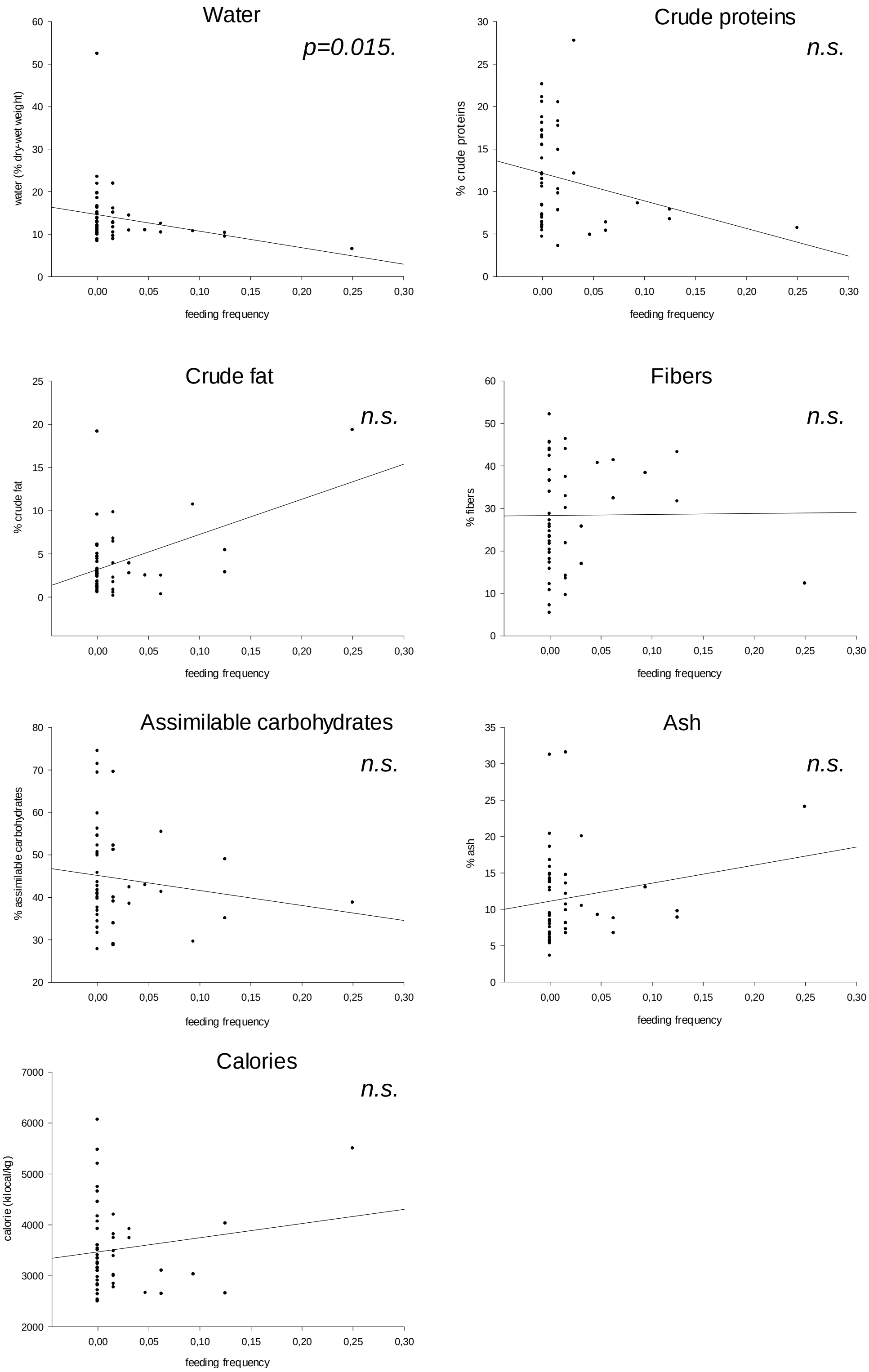
Appendix 5. Other plant species eaten by moor macaques reported by Achmad (2011)

Local name	**Botanical name**
Lento-lento	*Arthrophyllum sp.*
Kemiri	*Alleurites moluccana*
	Ficus sp.1
	Ficus sp.2
	Ficus sp.3
	Morinda citrifolia
	Leea indica
	Aqualaria sp.
	Albizzia sp.
	Knema sp.

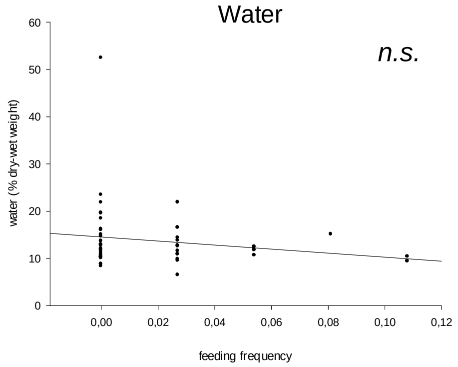
Appendix 6. Non parametric Kendall's tau_b Correlation between nutrient contents in parts of plant eaten and feeding frequency (total number of scan per plant part/total feeding scan) in the Neutral state

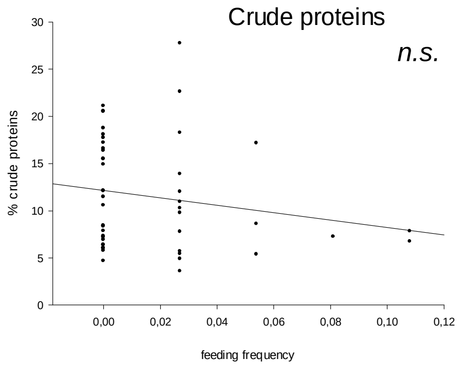


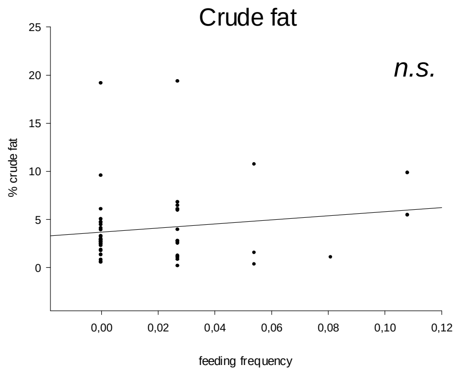
Appendix 7. Non parametric Kendall's tau_b Correlation between nutrient contents in parts of plant eaten and feeding frequency (total number of scan per plant part/total feeding scan) in the Periovulatory state

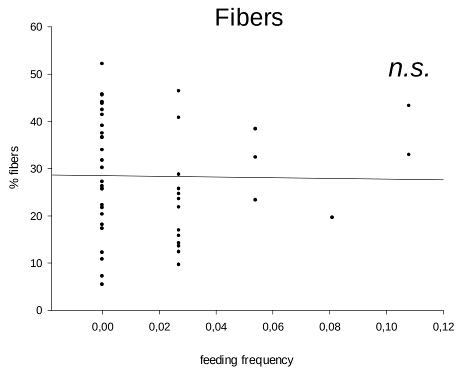


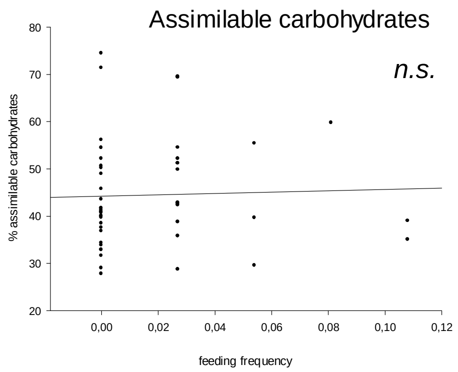
Appendix 8. Non parametric Kendall's tau_b Correlation between nutrient contents in parts of plant eaten and feeding frequency (total number of scan per plant part/total feeding scan) in the Pregnant state

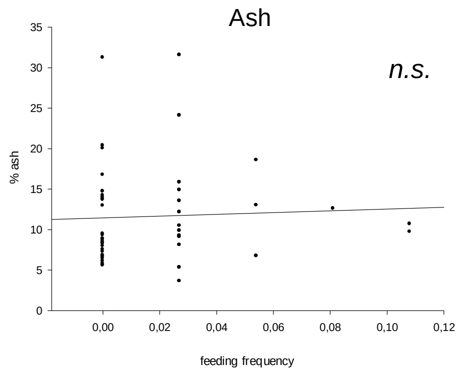


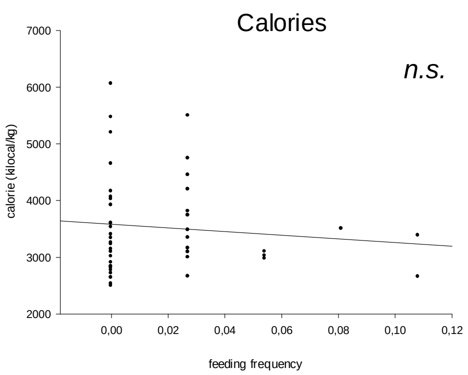




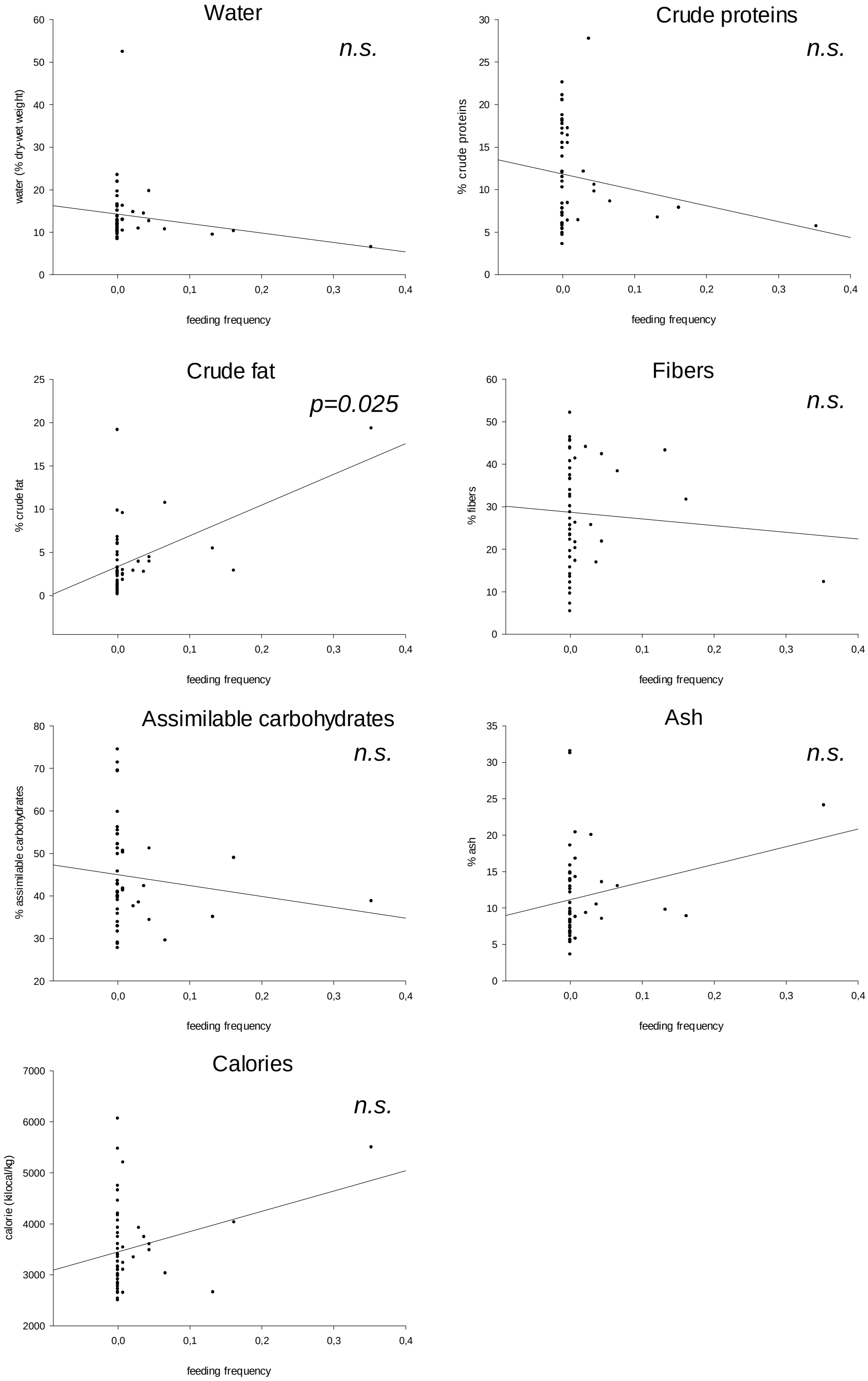








Appendix 9. Non parametric Kendall's tau_b Correlation between nutrient contents in parts of plant eaten and feeding frequency (total number of scan per plant part/total feeding scan) in the Lactating state



Appendix 10. Group B sex-age class composition from 1981 to 2013

Year-month	Adult Male	Adult female	Subadult male	Subadult female	Subadult (sex not specified)	Juvenile	Infant	Total	References
1981	1	7	?	?	3	5	4	20	Watanabe and Brotoisworo, 1982
1988	?	?	?	?	?	?	?	20	Okamoto and Matsumura, 2001
1990-1991	1	7	2	2	4	10	?	22	Matsumura, 1991
1992	?	?	?	?	?	?	?	28	Okamoto and Matsumura, 2001
1993 *	3	11	?	?	?	8	5	27	Matsumura and Okamoto, 1997
1994	?	?	?	?	?	?	?	27	Okamoto and Matsumura, 2001
1996 *	4	11	?	?	?	10	10	35	Matsumura and Okamoto, 1997
1998	?	?	?	?	?	?	?	43	Okamoto and Matsumura, 2001
1999 *	8	14	?	?	?	16	5	43	Okamoto and Matsumura, 2001
2000 Group B1 **	9	8	?	?	?	10	0	27	Okamoto and Matsumura, 2001
2000 Group B2 **	4	7	?	?	?	5	0	16	Okamoto and Matsumura, 2001
2009	3	9	?	?	?	?	?	27	Carosi and Riley unpublished data
2010-april §	3	11	2	2	4	8	6	32	Present study
2010-may	4	11	2	2	4	8	6	33	Present study
2010-july	4	11	2	2	4	8	8	35	Present study
2010-sept	4	11	2	2	4	10	7	36	Present study
2010-nov	4	10	2	2	4	10	6	34	Present study
2011-june	3	10	1	2	3	16	1	33	Present study
2011-dec	2	7	1	2	3	16	1	29	Present study
2012-july	2	8	1	0	1	17	4	32	Present study
2012-sept	2	8	1	0	1	18	3	32	Present study
2012-dec	2	8	1	0	1	18	4	33	Present study
2013-mar	2	8	1	0	1	22	2	35	Present study
2013-may	2	8	1	0	1	22	3	36	Present study
2013-july	2	7	1	0	1	22	3	35	Present study

Notes: * age classes: <1.5 years old=infant; 1.5-5 years old=juvenile; >5 years old=adult

** Group fission

§ from 2010 to 2013 age classes: ≤ 1 year old=infant; >1 ≤ 4 years old=juvenile; females >4 ≤ 7 years old=subadult; males >4 ≤ 9 years old=subadult; females > 7 years old (until first swelling)=adult, males > 9 years old=adult