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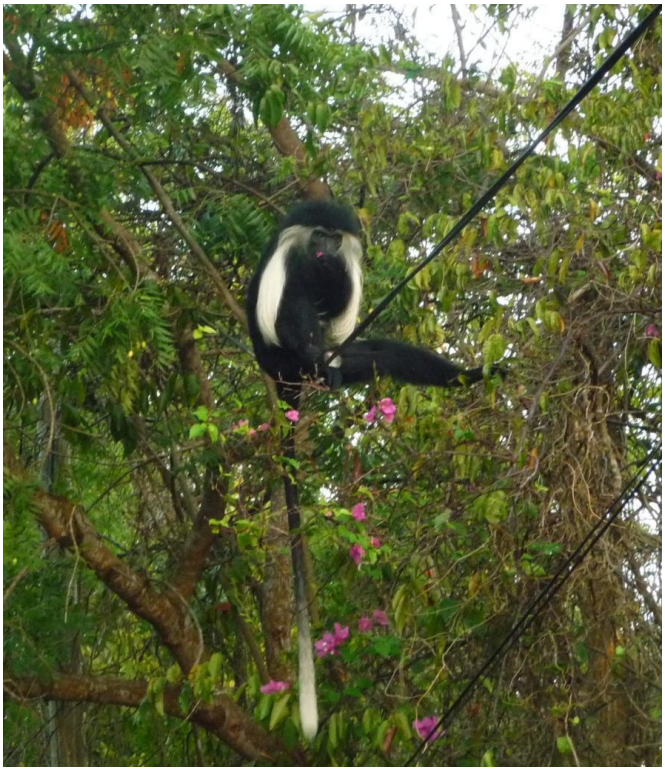
Robert O' Dwyer
Ecology and Conservation



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ABSTRACT

The loss of habitat is one of the greatest threats to global biodiversity today. Consequences to a species inhabiting fragmented habitats include: group size changes, altered diets and altered foraging behaviours.

In my study I observed *Colobus anlgolensis palliatus* troops living in the forests of Diani, a highly developed area on the Kenyan coast. I looked for differences in behaviours between three troops inhabiting pristine forest patches and three troops inhabiting highly degraded forest areas. I used focal animal sampling with instantaneous sample points. Morning and evening observations were carried out over two months during the rainy period.

The results of my study imply that during the long rains period colobus monkeys in Diani are mainly leaf eaters, fruit or the seeds of these fruit being their next most consumed food item. There were very little differences in sex and age class behaviours except for juveniles. They rested less, groomed themselves less, were more social and moved more than adults. Colobus monkeys foraged more in the evening and rested more in the morning, which may be due to differences in temperature or food digestion time.

The troops in the degraded forest areas spent more time in the morning foraging than the troops in the pristine forests, which may be related to diet. The troops in the pristine forests foraged mostly from native plants, and the troops in the degraded forest areas foraged more from exotics than the troops in the pristine forests. The troops in the degraded forest areas also had a higher dietary diversity per observation period than the troops in the pristine forests. Ranging behaviours differed between forest types, possibly reflecting home range quality. The troops in the pristine forests home ranges were slightly bigger than the troops in the degraded forest areas home ranges on average. Home range over lap was a lot higher for the troops in the degraded forest areas, and the troops in the degraded forest areas had to travel further each day. Overall the troops in the pristine forests seemed to be in better shape than the troops in the degraded forest areas. I conclude that if habitat fragmentation continues in Diani, then these highly florivorous monkeys will have a hard time adapting.

SAMMANFATTNING

I dagsläget är förlusten av habitat ett av de största hoten mot den biologiska mångfalden i världen. Konsekvenserna för en art som lever i fragmenterade habitat är bland annat förändringar i gruppstorlek, diet och födosöksbeteende.

I denna studie observerades olika grupper av *Colobus anlgolensis palliatus* i ett mycket exploaterat område på Kenyas kust kallat Diani Beach. Skillnader i beteenden studerades mellan tre grupper av apor bosatta i mindre urskogsområden och för tre grupper bosatta i brukade men inte återplanterade skogar. Djuren observerades med fokaldjursobservation och momentan registrering. Observationerna utfördes morgon och kväll i två månader under regnperioden.

Resultaten från studien visar att under regnperioden livnär sig colobusaporna i Diani Beach främst på löv. Frukt eller mer troligtvis fruktens frön observerades som deras andra huvudsakliga föda. Ingen större beteendeskillnad observerades mellan kön och åldersklass med undantag för de juvenila aporna. Colobusaporna åt betydligt mer under kvällen och vilade betydligt mer under morgonen. Detta kan bero på skillnaden i temperatur eller på matsmältningstiden.

Grupperna i den brukade skogen åt betydligt mer på morgonen jämfört med grupperna i urskogen vilket kan bero på skillnader i dieten mellan grupperna. Aporna i urskogsområdena åt mestadels från inhemska växter medan grupperna i den brukade skogen även åt från exotiska växter i stor utsträckning. Dessa grupper i den brukade skogen hade även en större variation i sin diet vid varje observationstillfälle. Förflyttningen vid födosök varierade också mellan grupperna i de olika skogarna vilket reflekterar kvalitén på de olika hemområdena. Grupperna i urskogsområdena hade generellt lite större hemområden än de i den brukade skogen medan överlappningen av hemområdena var större för de grupperna i den brukade skogen, dessa grupper förflyttade sig också längre sträckor varje dag. Generellt verkade grupper i urskogen vara i bättre form än de i den brukade skogen. Om habitatfragmenteringen fortsätter i Diani Beach, vilket den troligen kommer att göra, kommer dessa växtätande apor ha svårt att anpassa sig.

INTRODUCTION

The loss of habitat is one of the greatest threats to global biodiversity (Chapman *et al* 2007). For tropical forests this loss is occurring at a rate of 9.4 million hectares annually (Wong and Sicotte 2006a). Remnant forest patches surrounded by grazing or agricultural land is now common place where human populations are present, and it is increasing as populations increase (Wahungu *et al* 2005). In these landscapes, the likelihood of the local extinction of a species increases with decreasing patch area and increasing isolation. Before local extinction occurs, a number of changes happen to a species inhabiting forest fragments; group size changes, altered diets and foraging behaviours, as well as a disruption to gene flow among populations in other fragments (Mbora and Meikle 2004). Plant size and diversity can vary between forest fragments or disturbed forests compared with continuous ones. This in turn can affect food availability for specific species using the habitat (Wong *et al* 2006b). Any loss in food availability for a resident species may increase competition levels for food, by way of forcing animals into the remaining smaller patches. This habitat overlap may lead to an increase in aggressive behaviours. Food reduction and aggressive interactions among animals may increase stress levels and thereby increase the likelihood of illnesses, further expediting their disappearance from an area (Mbora and McPeek 2009).

In order to help conserve a threatened species conservationists need much more information on their habitat requirements. A lot of this information is behavioural such as diet choice, social systems, breeding behaviour and home range (Sutherland 1998). By studying the species activity and behaviour these applied questions can begin to be answered (Wilson *et al* 2008).

Home ranges are defined as 'the area traversed by the individual in its normal activities of food gathering, mating, and caring for young'. Animal movements leading to these home ranges are determined by many social, ecological and environmental factors. (Grigione *et al* 2002, Wartmann *et al* 2010). Therefore any changes in these factors may produce observable changes in home range size, which could be used as an indicator for habitat quality.

The study of primates is invaluable for determining the effects of habitat fragmentation. They respond differently to fragmentation dependent on the community (Onderdonk and Chapman 2000). Primates are particularly vulnerable to habitat fragmentation because they live in forests which are currently undergoing heavy exploitation (Chapman *et al* 2007). In total 120,000km^2 of forest is being lost annually from the countries that have primate populations (Wong and Sicotte 2006a). Around 348 primate species exist in the world today; of these 79 are endemic to Africa, and 13 are considered as endangered (Mcgoogan *et al* 2007).

Background

Colobus monkeys

Colobine monkeys are old world monkeys. They evolved foregut fermentation in the early Miocene epoch, separating from cercopithecines and becoming highly adapted to their forested habitats. For this reason, they are one of the primate species on Earth today most highly reliant on forested areas (Delson E. 1994 and Schienman J.E. *et al* 2006). The first populations most likely originated in East or North-east Africa and were red, brown and white in colour (Johnston 1920). They lived in one big forested area that was fragmented several times by climatic

changes, resulting in new species within the colobine genus, and giving us the various different coloured colobines on Earth today (Rodgers 1981). Most of the red types are found at the purported origin, with different mixes of colours radiating out from there (Johnston 1920). African colobus monkeys are those colobines found across central Africa today. Adults range in size from 4kg to 23kg (Shruhsaker and Leland 1987). According to the IUCN, there are 12 extant species of African colobus monkeys. Out of the 12 species, three are considered as endangered and two as critically endangered (IUCN 2011).

Social structure & behaviour

Colobus monkeys generally live in small social groups of several adult females and a single adult male (Oates and Davies 1994). Group size tends to number about 10 to 15 individuals. Some troops may contain multiple adult males but this may be associated with either male replacements or young males maturing in their natal groups. Adjacent groups act aggressively towards each other with the males usually being involved in the fights, but females and younger age classes may also be involved. Birth peaks are observed in most species of colobus, in some species, peaks coincide with rainy months (Shruhsaker and Leland 1987).

Feeding habits

Colobus monkeys are diurnal primates, with trichromatic vision allowing them to see more shades of colours than other primates. This is good for spotting ripe and unripe fruit, but also young darker coloured leaves. As such they spend a large part of their day foraging for food in high to low light conditions (Yamashita *et al* 2005). Colobus monkeys are folivores-frugivores having a diet mainly of leaves, but buds and fruits can also be included (Johnston 1920). 35-75% of their diet consists of young leaves which are easier to digest and are less toxic (Usongo and Amubode 2001). At times they may not have the choice of young leaves and so have to feed on more difficult to digest mature leaves. However they possess a multichambered stomach with special microbes that break down cellulose over an extended time allowing fermentation to occur (Tovar *et al* 2005). Some authors found that their diet consisted of 33-57% leaves and 42-58% fruit (Fashing 2001a), while others found that seeds accounted for 33% of their diet (Davies *et al* 1999). Either way, although a lot of observations of colobus foraging may be of leaf eating, some populations diets come from multiple sources (Chapman *et al* 2002).

Habitat choice and size

Colobus monkeys are for the most part arboreal. However the types of forest they can inhabit are wide ranging; from primary and secondary forests, highland and lowland forests, tropical rainforests, coastal evergreen forests, swamp forests, semi deciduous forest, riverine and gallery forest. They can also be found in degraded or partially logged forests (IUCN 2011). Colobus monkeys are generally forest bound and do not leave a forest patch unless to colonise a new fragment, but this is rare (Chapman *et al* 2007). Use of trees for foraging and travelling appears to be species specific, for example *Procolobus verus* use the understory (0-15m) whereas *Colobus polykomos* and *Colobus badius* use higher up in the canopy (5-40m) (Mcgraw 1998).
Home range size can be quite variable from 2.5 hectares to over 100 hectares. Distance travelled per day by a group of colobines averages 500 to 600 m (Shruhsaker and Leland 1987)

Threats to Colobus monkeys

Africa contains a number of the worlds biodiversity hotspots, including; the Western African Forests and the Eastern Arc and Coastal Forests of Tanzania and Kenya, (the latter is listed as the 8th hottest hotspot in the world) all crucial habitats of colobus monkeys (Myers *et al* 2000). In addition to ongoing deforestation; hunting, diseases and climate change are major threats to colobus monkey populations in these forests (McGoogan *et al* 2007). Particularly for East African tropical forests rapid human population growth has had a drastic effect. These forests are increasingly used for bushmeat, fuelwood, poles, timber and charcoal production and are levelled for growing crops and exotic trees. This has led to widespread forest fragmentation. Colobus monkeys being highly arboreal, are especially vulnerable to these threats, as they require leaves, fruits and seeds for survival (Anderson *et al* 2007a).

Colobus Angolensis

Colobus angolensis, a black-and-white colobus monkey species, lives in forests of northeast Angola, the Democratic Republic of Congo, Rwanda, Tanzania and Kenya (Anderson *et al* 2007a). They are 1 of 5 species of black-and-white colobus monkeys that live in the tropical forests of Africa. They occupy a large variety of habitats including coastal gallery, lowland and montane forests (Fashing *et al* 2007). They form groups of 2-20 individuals consisting of one adult male, several adult females and their young. Nyungwe is an exceptional forest where permanent groups of more than 300 individuals exist. They are quite ecologically diverse in terms of diet but a number of studies have observed that leaves comprise a large part of their diet (Fashing *et al* 2007). Although as a species they are listed by the IUCN as least concern (Kingdon *et al* 2008), McGoogan et al (2007) found that they are among the African primates that represent the highest levels of phylogenetic diversity and for this reason they should be protected. In this study I focused on a subspecies of *Colobus angolensis* called *Colobus angolensis palliatus*, which faces a number of threats from humans in one of its native habitats Diani Beach Kenya.

Aims

The purpose of the current study was:

- To study the behaviour of *Colobus angolensis palliatus* in Diani Beach.
- To compare the use of different habitat types: pristine forest patches and areas of highly degraded forest, by troops of *Colobus angolensis palliatus*.
- If there are differences in habitat type use, to look at what these might mean in terms of the future conservation of this subspecies in Diani Beach.

Areas focused on were: general behaviour, sex and age class behaviours, foraging behaviour, home range size, home range overlap, and distance travelled per observation period.

To be able to live in forest patches a primate species must have at least more than one of the following attributes: Small home range, an ability to move between patches, a broad diet. Black and white colobus monkeys have not been shown to move between patches but they can survive in small forest patches. And although they have an ecologically diverse diet for the range of their species, their ability to survive in a small forest patch is most likely attributable to their ability to survive on whatever is available (Wahungu *et al* 2005).

MATERIALS AND METHODS

Study Area

This study was conducted 30 kilometers south of Mombasa in Diani beach (4˚19' S, 39˚34' E). The forest in Diani is counted as one of the Kwale districts 124 forest fragments. The Kwale district stretches from Mombasa to the Kenyan border with north-eastern Tanzania. Average annual temperature is 26˚C with a mean high of 33˚C between November to April, which constitutes the dry season. Rainfall occurs in two periods throughout the year; one period of long rains from April to June and one period of short rains from October to November (Kanga and Heidi 1999). Rainfall is highest within 36 kilometers from the sea, with 900-1500 mm falling in the coastal forest belt annually (Anderson *et al* 2007a). The Kwale districts forest fragments are coming under extensive destruction because of the massive human population growth, agricultural expansion and tourist development there. For these reasons the entire area is listed as one of the 11 priority regions for international conservation investment (Anderson *et al* 2007b). Diani forest is an unprotected forest, most of which occurs on privately owned land (Anderson *et al* 2007c). It is a coral rag lowland forest with surrounding sacred Kaya forests. The forest is separated into individual forest patches by cleared and developed land. The original forest was bisected with the construction of a 10 km paved road in 1972. Since then human development, including the building of a large number of hotels, has lead to the loss of over 75% of forest cover. With the loss of so much forest, leopards, lions and elephants have also disappeared. Mammals found there today include; sykes's monkeys, vervet monkeys, colobus monkeys, yellow baboons, greater galagoes, Senegal galgoes, bush pigs, sunis, red-bellied coast squirrels and bush squirrels (Kanga and Heidi 1999). The current major threats to primates in Diani are habitat loss, road deaths, electrocution and snares (Colobus Trust 2011).

Study species

The subspecies *Colobus angolensis palliatus* is confined to the forest fragments in coastal Kenya, Tanzania and the Eastern Arc Mountains. As a species they are not listed as threatened but are vulnerable to extinction due to deforestation caused by tourism developments (Anderson *et al* 2007a). In Kenya they are restricted to the southern coastal forests of the Kwale District (Anderson *et al* 2007c). Populations inhabit 55 out of the 124 coastal forest fragments in this region. Diani forest hosts the second biggest population of *Colobus angolensis palliatus* in the Kwale District next to Shimba Hills (Anderson *et al* 2007c). In Diani forest *Colobus angolensis palliatus* exist in groups of 6 individuals (Anderson *et al* 2007a). *Colobus angolensis palliatus* are subjected to the same threats other primates face in Diani beach. Colobiologists at the Colobus Trust have been counting the monkeys every year for the past 14 years. In 2004 400 individuals were counted. But only 200 were counted in 2006, a massive reduction in such a short period (Colobus Trust 2011).

Pilot study

A pilot study was first performed to test the methods used and habituate the monkeys. The pilot study was conducted by myself and three bachelor students from SLU Skara. We divided into two teams of two, with the members of each team differing on a daily basis. Additionally each team had a local plant expert to identify the plant species the monkeys foraged from. Before we started the study, Andrea Donaldson the Colobus Trust manager drove us around Diani beach stopping at potential study sites all containing one or more colobus troop (Fig. 1). Out of ten

potential study sites ranging from degraded to semi degraded to pristine forests, we chose two sites based on how it suited our goals, the amount of time needed to reach the site and the level of safety going there on a daily basis. One degraded forest and one pristine forest were chosen. The degraded forest included was the Colobus Trust grounds and another location 300 meters north of this. One troop was chosen at each of these locations. The pristine forest was split in two by the main road that runs through Diani. This forest was called Baobab forest due to the name of the hotel built there. The forest was located approximately 800 meters north of the Colobus Trust. On the left side of the road is the staff quarters to the hotel and a forest in very good condition save for the staff buildings built in the middle of it. On the right side of the road is where the hotel was built and the forest there was restricted to the edge of the road. The vegetation around the hotel was mainly scattered exotics. Again we chose two troops here, one troop on each side of the main road. In total there were four troops, two in the degraded forest and two in the pristine forest. The pilot study took place from the 25th of March to the 2nd of April. This was at the end of the dry season and the conditions were still very hot and dry.

Study sites

After the pilot study was completed I was not happy with the location of one of the troops, the troop in the pristine forest on the baobab hotel grounds. Having observed them for the pilot study I noticed they stayed very close to the hotel and forged from a lot of exotics, rarely entering the pristine forest near the road. I then chose another troop on the left side of the main road, just slightly north of the troop in the hotel staff quarters. This was followed for 3 full days and considered to be a pristine forest troop. I then discovered another troop between the two degraded forest troops and decided to include this in the study also. However to have an even number of troops in both forest types I needed another pristine forest troop. Just north again of the new pristine forest troop I found another troop. It's forested area was separated from the two troops south of it by a side road off of the main road and a large wall. So in total I had two close by pristine forest patches and one large degraded forest area, and three troops of colobus monkeys from both habitats (Fig. 1).

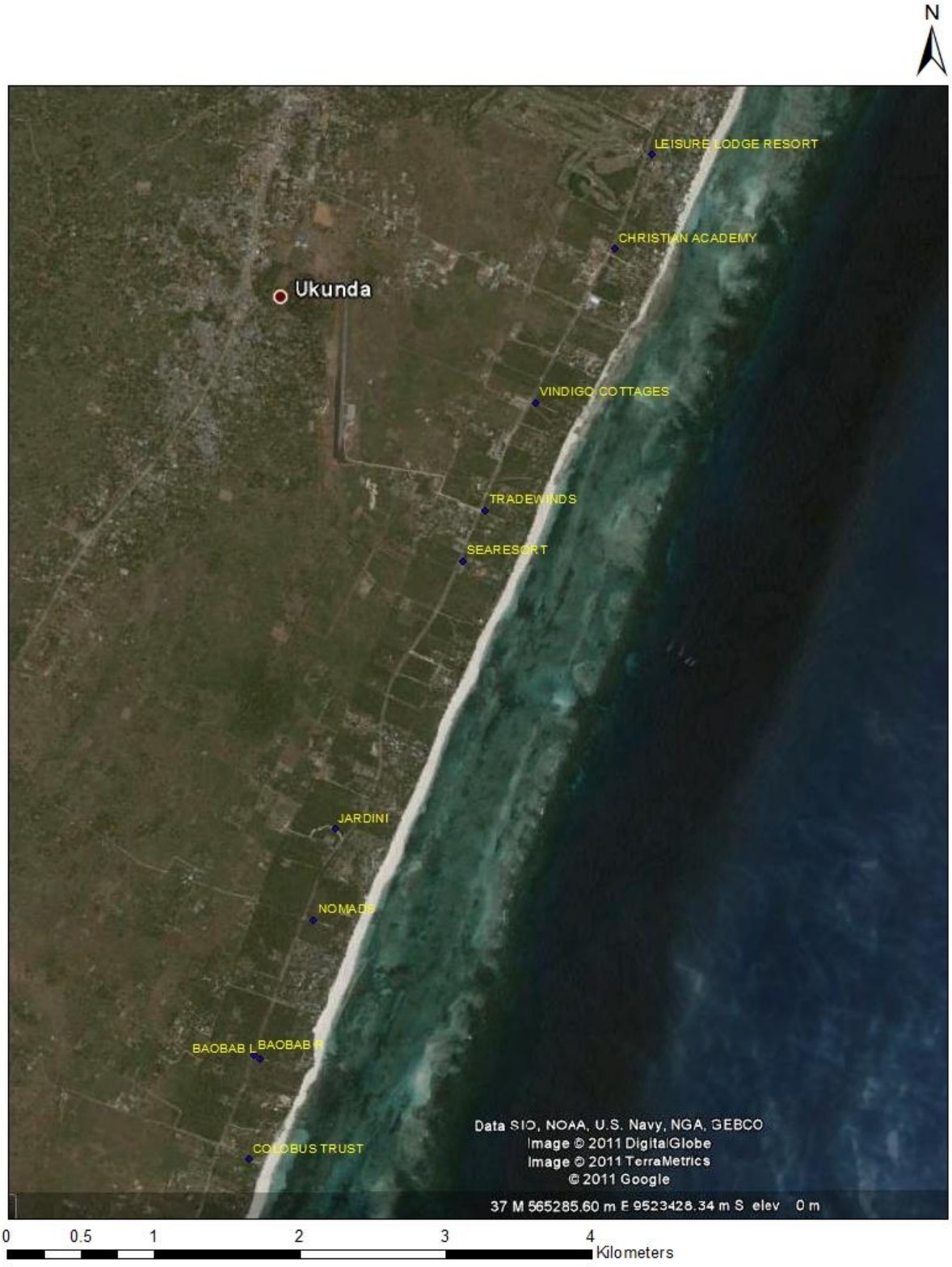

Figure 1. There are ten study site options along Diani Beach, ranging from pristine to semi pristine and degraded. The pristine forest Baobab left and the degraded forest Colobus Trust were finally chosen.

Study subjects

Starting at the furthest south troop in the pristine forest on the left side of the main road at the Baobab hotel staff quarters, this troop was referred to as BB1 for Baobab one, and the two troops north of this were BB2 and BB3 respectively. These were the troops in the pristine forests (PF). Starting at the Colobus Trust in the degraded forest, the troop here was referred to as CT1 for Colobus Trust 1, and the two troops north of this were CT2 and CT3 respectively. These were the troops in the degraded forest area (DF). The two new troops in the pristine forests were followed for 3-4 full days each to try and habituate them. The new troop in the degraded forest area, CT2, was followed for two full days but did not seem to fear humans and behaved the same way CT1 and CT2 did after the pilot study, so this was deemed enough. The PF troops appeared to very rarely come close to humans and the DF troops were constantly surrounded by humans on a daily basis, and did not seem to fear them. In this study individual age and sex were based on those described in (Kanga and Heidi 1999), but with a few differences and additional observations. I chose an adult male to be a fully grown male (~12kg) involved in copulation and or territorial defense. Sub adult males (~5kg) were those that did neither of these and were somewhat smaller than the adult males. An adult female was a fully grown female (~7.5kg) involved in copulation and or infant/juvenile care and occasionally territorial defense. Sub adult females (~5kg) were not involved in these activities and were somewhat smaller than the adult females. Juveniles (~2kg) were much smaller than the sub adults but bigger than the infants and also much more independent than the infants. Table 1 shows the makeup of each troop in terms of sex and age class. Combining all three PF troops there were 22 individuals excluding infants. For the DF troops there were 25 individuals in total excluding infants.

Table 1. Sex and age class of individuals in the study troops

	Pristine forest			**Degraded forest**		
Sex/Age class	**BB1[b]**	**BB2[a,b]**	**BB3[a,b]**	**CT1[b]**	**CT2[b]**	**CT3**
Adult male	1	2	2	2	1	2
Adult female	3	2	3	2	2	2
Sub adult male	2	0	1	1	2	2
Sub adult female	1	1	1	2	1	1
Juvenile male	2	0	0	1	0	2
Juvenile female	0	1	0	1	1	0
Total p/t	9	6	7	9	7	9
Total p/f			22			25

[a] troop with one infant

[b] troop with one noticeably pregnant female at the end of the study

Aside from the PF and DF troops, a troop at Kaya Kinondo, a sacred forest about six kilometers south of the Colobus Trust was observed. This was to be used as a reference for completely natural conditions unspoiled by humans. However the troops there were extremely afraid of humans and for this reason and because of the dense vegetation there they were too difficult to observe. So observations on this troop were quickly abandoned.

Data collection

Troop observations started on the 13th of April, the beginning of the long rains period, and ended on the 6th of June, just at the end of this period. A previous study by Donaldson *et al* (Unpublished data, 2003) from January to June, concluded that *Colobus angolensis palliatus* in Diani have two major feeding bouts, one in the morning from around 6am to 9am and one in the evening from around 4pm to 6pm. They also have a smaller feeding bout around 1pm. This was confirmed in my study by full day troop follows prior to the start of data collection. Following this information, troops in my study were observed one at a time in morning and afternoon sessions spanning from 06:20 to 09:00 in the morning and 16:00 to 18:15 in the evening. Visibility conditions were better at 06:20 as the sun had risen, so this was chosen as a start time. For the first week the troops were observed until 9:15am but this did not provide anymore feeding data so 9am was used from then on. Also in the first week the troops were observed until 6pm, but it was noticed that they kept feeding until sun set, so after the first week, the evening observation times were extended to 6:15pm as that was as long as visibility conditions allowed.

In the pilot study scan sampling was tried out in the beginning, but due to the number of individuals per troop and the difficulty in distinguishing between individuals, this method was replaced with focal animal sampling with instantaneous sampling points, which was the method I continued to use for my study. This method is based on those described in (Altmann 1973, Shruhsaker and Leland 1987, and Martin and Bateson 1999). In my study I used two focal animals per sampling period, which lasted 15 minutes each, with data recorded every minute using a stopwatch (Q&Q). A five minute break was taken before the next 15 minute sampling period, which was used to find the next two focal animals. In this way over the morning and afternoon observation sessions, potentially each individual in a troop was observed a number of times. However due to some individuals being more conspicuous than others, it is likely that some individuals were repeated more than others and some individuals were not observed in the morning and/or evening. Half way through the study the individuals in each troop were better known, and an efficient rotation system of individuals was adhered to.

The behaviours recorded for each monkey were those in the ethogram in Table 2. Aside from behaviour, the position of the monkey while carrying out these behaviours was also recorded. Additionally to this the tree species the monkeys were sitting on and foraging from were recorded (appendix, Table 7.) and the food item being consumed (Table 2).

Table 2 Ethogram including behaviour, position of individual and food item

	Behaviour of Individual	**Definition**
Basal behaviours	**Foraging**	Placing of leaves, flowers, fruits etc., into the mouth, also chewing. The search for food using visual scanning in combination with grasping or searching with arms.
	Resting	Lying or sitting when not doing other activities. This includes vigilance.
	Auto grooming	Individual picking through its own fur, including scratching.
	Moving	An individual using its limbs to move from one point to another.
	Drinking	Water ingestion.

Social behaviours	**Social interaction**	Physical interaction with one or more individuals of the same species. Includes copulation. Does not include play.
	Allo grooming	Picking through the fur of another individual.
	Clinging	Infant or juvenile clinging to another individual.
	Playing	One individual is playchasing or being chased by another individual. Also includes two or more individuals wrestling.
	Interspecific interaction	Interaction with another monkey species.
Miscellaneous	**Other**	Behaviours not defined in the ethogram.
	Time out	Individual is out of site or behaviour is not clear.
Position of Individual		**Definition**
Top canopy		10 meters and above.
Mid canopy		Between 5 and 10 meters.
Low canopy		5 meters and below.
Manmade structure		E.g. walls, roofs, bridges etc.
Ground		Ground.
Food item		**Definition**
Flower		Flowers.
Young flower		Flower bud.
Fruit		Fruits.
Young fruit		Unripe fruit.
Seed		Seeds.
Fossil coral		Fossil coral.
Mature leaves		Mature leaves.
Young leaves		Young leaves, including leaf buds.
Unidentified leaves		Unidentified leaves.
Other		E.g. bark, soil, lichen, insects etc., or unidentified food item.

Along with these observations, the GPS location of the focal animals was recorded at the beginning and end of each 15 minute sampling period using a Garmin 550t GPS device (Oregon). Additionally the weather was noted throughout the sampling periods.

For the first half of the study I had a plant expert with me at all troop observation periods. He also took part in observing the monkeys and recording the observations. We took turns throughout the morning and evening periods. He had to return to teaching half way through the study. For the second half of the study a new plant expert was hired but only for the PF troop observations as he was not so good with exotic plant species and the plant species in the pristine forests were more difficult to quickly identify as the forest was much denser there. In the second half of the study I also had an assistant to help with the observations and recordings who was not a plant expert. He had been accompanying us for two days a week for the first half of the study to get experience, and so already knew how to do the work and his observations and recordings

matched ours by the time he was assisting me. For the DF troop observations we collected leaf samples and took pictures of bark if we did not know the plant species. Then every weekend the plant expert from the beginning of the study would drop by and identify the unknowns. At this stage (after six weeks of observations in) we already knew most of the plant species by code name but we were tested by the plant expert who worked with me at the beginning of the study to confirm this.

In total 234 hours of colobus monkey observations were made. This was 47 morning and 50 evening observation periods. CT3 went into private property during an evening observation period and so we could not keep observing them or observe them the next morning. This evening was initially replaced with another evening observation period and a morning observation period. But later in the study the same thing happened. Again the evening was replaced with another evening, but although this time the evening observation period was full, the monkeys went into the private property so could not be observed the next morning. So CT3 was observed for seven morning periods and nine evening periods, as I included the two extra evenings in the analysis to make up for the lost morning.

Data analysis

Statistical analysis

For the data analysis, a morning or an evening was counted as one observation period. The 15 minute focal sampling periods were pooled by these observation periods in excel. In total there were 97 observation periods; 48 PF forest observation periods and 49 DF forest observation periods. The behaviours; social interaction, allogrooming, playing, clinging and interspecific interaction were pooled into a new heading called ″social″ due to low occurrence. The sum of each variable per observation period was calculated in Minitab 15. The percentages of different variables were then calculated from these sums in excel.

For colobus monkey behaviours in Diani Beach, the mean ± the standard error of the mean (SEM) was calculated from the percentages per observation period in Minitab 15. The data was then analysed by ANOVA GLM (General Linear Model) with the level of significance being $p < 0.05$. However before this step, for the sex and age class comparisons the 15 minute sampling periods were pooled by sex and age class and then morning and evening observation periods. I decided to pool all the sub adults into males and females as for the first half of the study the age classes of the monkeys were not totally certain. So only males, females and juveniles were compared. This lead to 273 observation periods for sex/age class, or 96 male, 97 female and 79 juvenile replicates.

For pristine and degraded forest troop comparisons the program R 2.13.0 was used to calculate the mean ± the standard error of the mean (SEM) from the percentages per observation period. R was used here as it was possible with this program to have troop as a random factor to incorporate any within forest type troop differences into the analysis. The data was then analysed in R by ANOVA GLM including troop as a random factor, with the level of significance being $p < 0.05$.

Diet composition and dietary diversity

For the percentage of different plant species in the colobus troops diets, the percentage of foraging behaviour per plant species per observation period was averaged over the three troops in each forest type in Minitab using descriptive statistics. These percentages were then sorted from highest to lowest in excel.

To get the percentage food item per major plant species foraged from, each food item was summed per plant species in excel. And then the percentage of each food item was calculated related to all food items per individual plant species.

The diversity of plant species the pristine and degraded forest troops foraged from per observation period was calculated from the inverse of Simpson's index "D" (Falcao *et al* 2010);

$$D = \frac{1}{\sum_{j=S}^{S} (p_i)^2}$$

where S is the number of plant species, and p_i is the proportional abundance of species *i* foraged from per observation period. The inverse of this index is useful for the comparison of plant species richness per observation period for the pristine and degraded forest troops, as it gives the number of equally used plant species that present the same level of diversity. The value of D increases with the richness of the diet and is not affected by rarely eaten plant species (Falcao *et al* 2010).

GIS analysis

Satellite images of the study sites in Diani beach were taken from Google Earth. These images were georeferenced in ArcGIS 10 with GPS waypoints taken with a Garmin 550t GPS device (Oregon) of landmarks on Diani beach while the study was being conducted. In total 232 – 241 GPS points for each of the six troops were made. Differences in number are due to loosing the monkeys or forgetting to take a GPS location. With these points, shapefiles were made in ArcGIS 10. These shapefiles were used for the further GIS analyses.

Home ranges were calculated using a program called geospatial modeling environment (GME). This links R, Python and statconn to convert shapefiles into output files usable in ArcGIS. Two methods were used with this program to create home ranges; minimum convex polygon (MCP) and kernel density estimator (KDE). MCP is the simplest method used, that creates a convex hull around a set of points. It has been used for a long time to create home ranges, but has some draw backs in that it includes areas not used by the animals (Fashing *et al* 2007, Wartmann *et al* 2010). KDE is a nonparametric method and is considered the best choice for home range analysis. It gives weight to areas containing more points and can also be used to calculate the core use area of the animals within the home range (Worton 1989, Fashing *et al* 2007). The MCP method is still widely used but few studies quote primate home range solely on MCP analysis. They include other methods such as KDE (Wartmann *et al* 2010), which is what I have done in this study. 100% MCP's were calculated by the default setting in GME. This cannot be changed. For the KDE method 97% isoplets were created for the home ranges as 95% did not include all the GPS points. And 50% isoplets were created for the core use areas. Home range areas were then calculated from these polygons in ArcGIS 10.

Home range overlap was calculated by first using the clip tool in Arcgis and including the home ranges of interest and then working out the percentage area of overlap in excel.

Distance travelled by troop for morning and evening observation periods was calculated by turning the GPS points into line features with the points to line tool in ArcGIS 10. This feature is available in GME but was simpler to do in ArcGIS. For distance traveled, 24 morning and 23 evening observation periods were used for the BB forest troops. 22 morning and 24 evening observation periods were used for the CT forest troops. The reason for the differences in observation period number were due to the two extra evening periods and one less morning period for CT2. But also, due to differences in the number of GPS points for other observation periods, some of the observation periods were omitted from the analysis to keep the observation periods used the same length in terms of time.

The GPS points associated with the major food trees for the pristine and degraded forest troops were labeled with each tree species name in ArcGIS 10. The symbology was then changed to unique symbols for each tree species. The KDE home ranges were then displayed with the major food trees inside. As the same tree was recorded being foraged from a number of times, different GPS locations represented the same tree. Therefore clumps of the same symbol will be more often one tree. This method is not ideal, but as tree abundance measures were not taken of Diani Beach in this study, the method used here to visualize tree species abundance is just an aid rather than an accurate representation.

RESULTS

Colobus monkeys in Diani Beach

General behaviours

The colobus monkeys spent most of their time resting and foraging. Other activities were negligible in comparison; e.g. autogrooming, social behaviour and moving (Fig. 2).

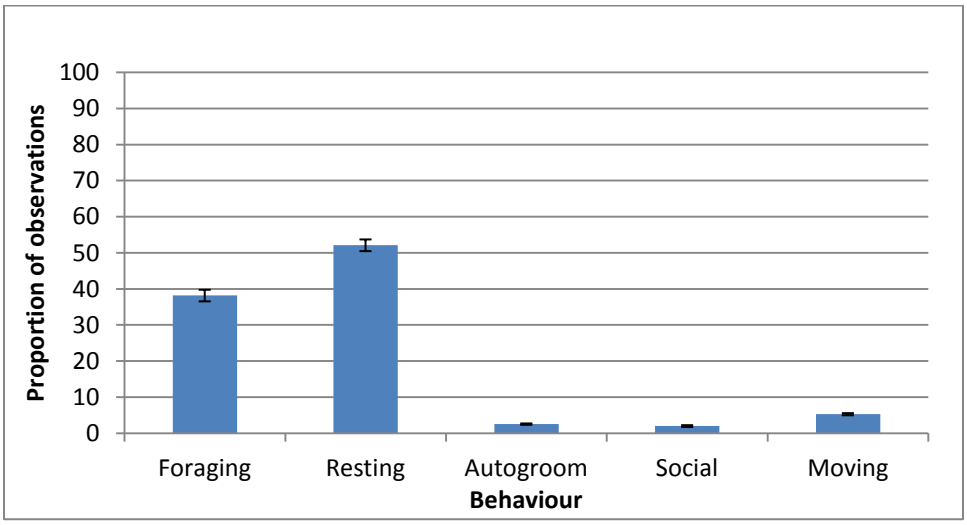

Figure 2. Activity budget in means ± SE (n = 97 observation periods).

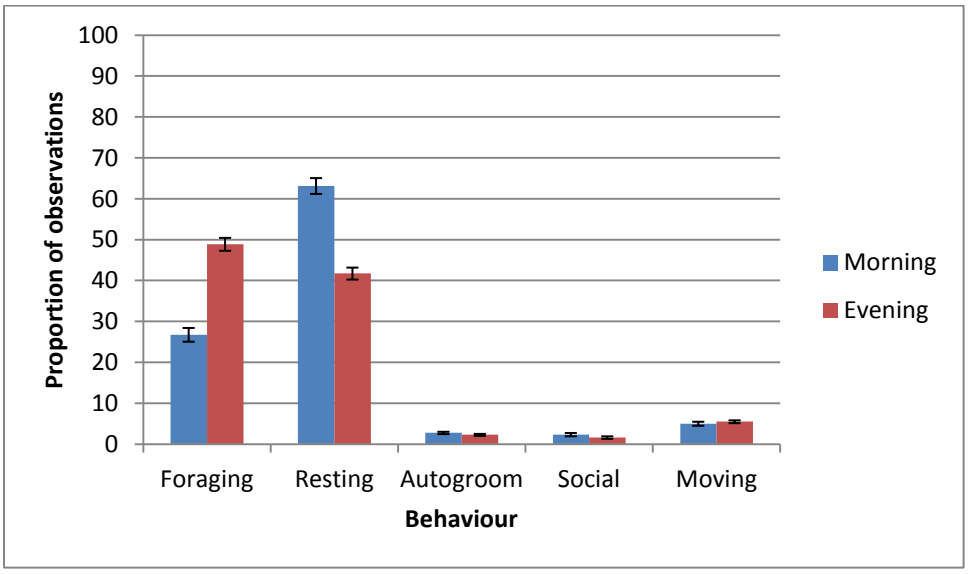

Figure 3. Day time activity budget in means ± SE (n = 47 morning and 50 evening observation periods).

The monkeys spent a higher proportion of time foraging in the evening than the morning (DF = 1, F = 8.6, p = 0.004), and more time resting in the morning than in the evening (DF = 1, F = 6.1, p = 0.015). None of the other recorded behaviours differed significantly between morning and evening observation periods (Fig. 3).

Foraging behaviours

The proportion of time spent foraging for different food items was dominated by foraging for leaves; foraging for mature leaves in particular accounted for the highest proportion of time spent at this activity. The next most foraged for food item was unripe fruits. Other food items were foraged for to a much lesser extent (Fig. 4).

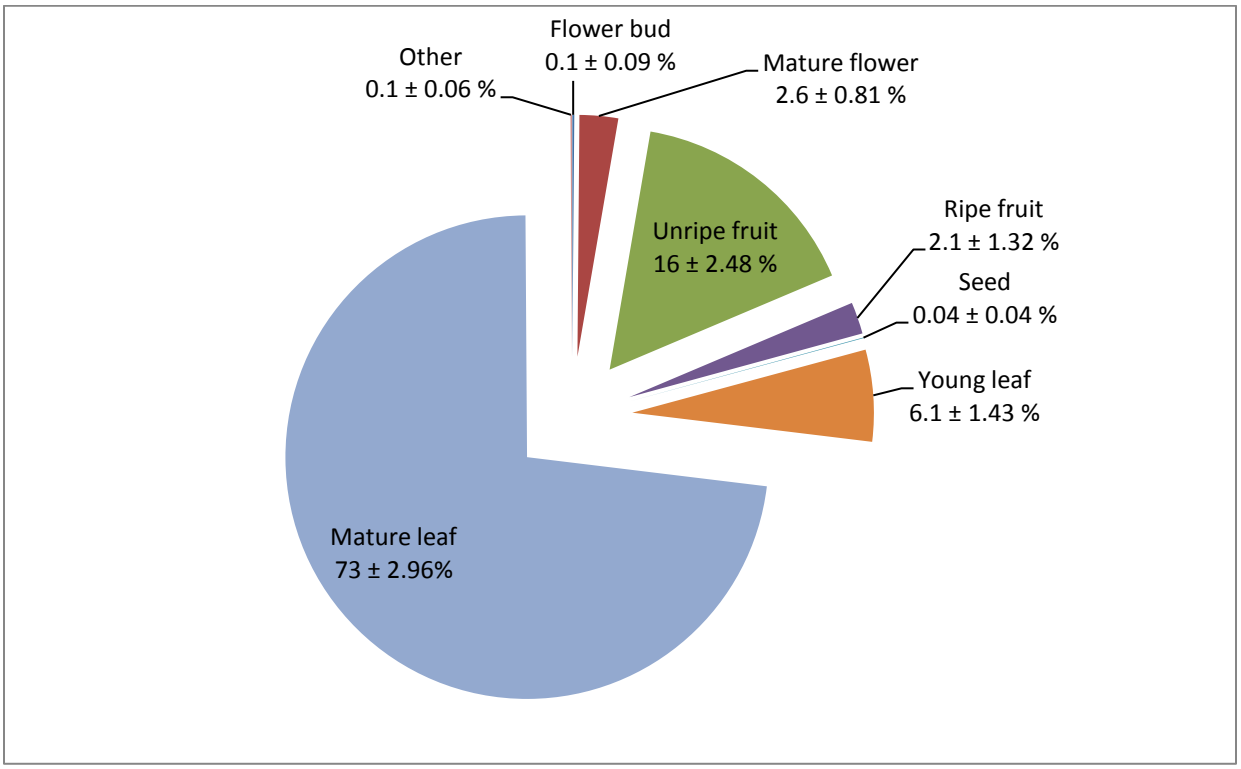

Figure 4. Percentage of time spent foraging for different food items (n = 97 observation periods). Means ± SE.

In total the monkeys foraged for 72 plant species throughout the long rains period; 62 were tree species and the rest were shrubs, climbers and a hemiparasite (see Appendix 1). Sixteen tree species made up more than 75% of the combined foraging observations (Table 3). Two of these (*Delonix regia* and *Adenanthera pavonina*) were exotics.

Table 3. Major food trees making up >75% of *Colobus angolensis palliatus* foraging behaviour in Diani.

Latin name	English name	Local Digo name	Plant type	Native/Exotic	Percentage of time spent foraging
Adansonia digitata	Baobab	mbuyu	Tree	N	19.18
Lecaniodiscus fraxinifolius		mremero	Tree/shrub	N	19.14
Adenanthera pavonina	Sandal wood		Tree	E	7.83
Delonix regia	Flamboyant	msukuku/mjohoro	Tree	E	5.35
Zanthoxylum chalybeum	Prickly ash/ knob wood	mdungu	Tree/shrub	N	5.24
Lannae welwitschii		mchumbu maji	Tree/shrub	N	5.00
Trichilia emetica	Cape mahogoni	munwamadzi	Tree	N	2.24
Majidea zanguebarica		mlanyuni	Tree/shrub	N	2.03
Ficus exasperata		msasa	Tree	N	2.02
Millettia usaramensis		muvamva	Tree/shrub	N	1.67
Milicia exclesa		iroko, mvuli	Tree	N	1.35
Stercularia africana	African star	mugoza	Tree/shrub	N	1.22
Grewia vaughanii		mtsaye	Tree/shrub	N	0.88
Ficus sycomorus	Sycamore fig	mkuyu	Tree	N	0.86
Combretum schumannii		mvia many	Tree/shrub	N	0.84
Grewia plagiophylla		mkone	Tree/shrub/climber	N	0.81
Percentage of Diet					75.66

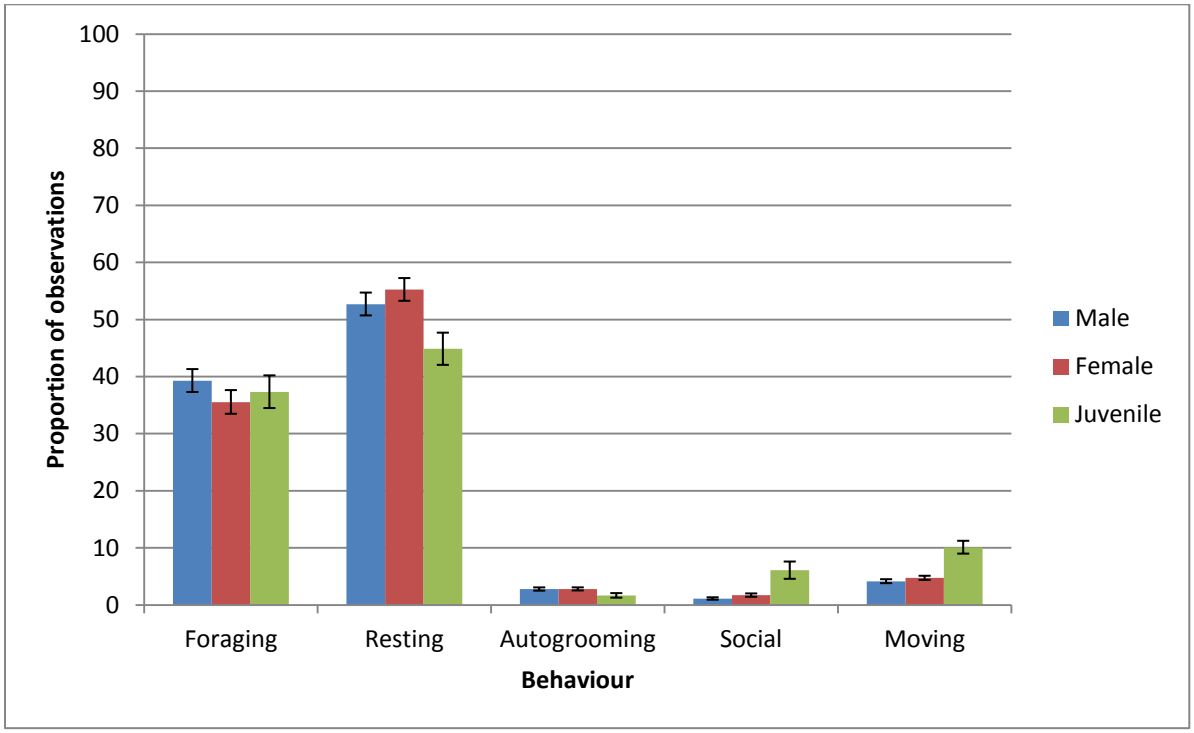

Figure 5. Comparison of activity budgets between males (n = 96 observation periods), females (n = 97 observation periods), and juveniles (n = 79 observation periods). Means ± SE.

Sex & age class comparisons

There were no significant differences in behaviour between males and females. The only significant differences were found between juveniles and adults. This did not include foraging. Juveniles rested less (DF = 2, F = 5.5, p = 0.005), they groomed themselves less (DF = 2, F = 3.9, p = 0.020), they were a lot more social (DF = 2, F = 10.8, p = < 0.001), and they moved a lot more (DF = 2, F = 24.1, p = < 0.001) (Fig. 5).

Comparison of Colobus Troops from Pristine and Degraded Forests

Behaviour

The only significant differences in behaviour between troops for pristine and degraded forest types were for foraging and resting in the morning. DF troops foraged for a longer percentage of the morning observation periods than PF troops (DF = 89, F = 7.2, p = 0.0085). PF troops rested for a higher percentage of the morning observation periods than DF troops (DF = 89, F = 8.8, p = 0.0039) (Fig. 6). All other behaviours did not differ significantly.

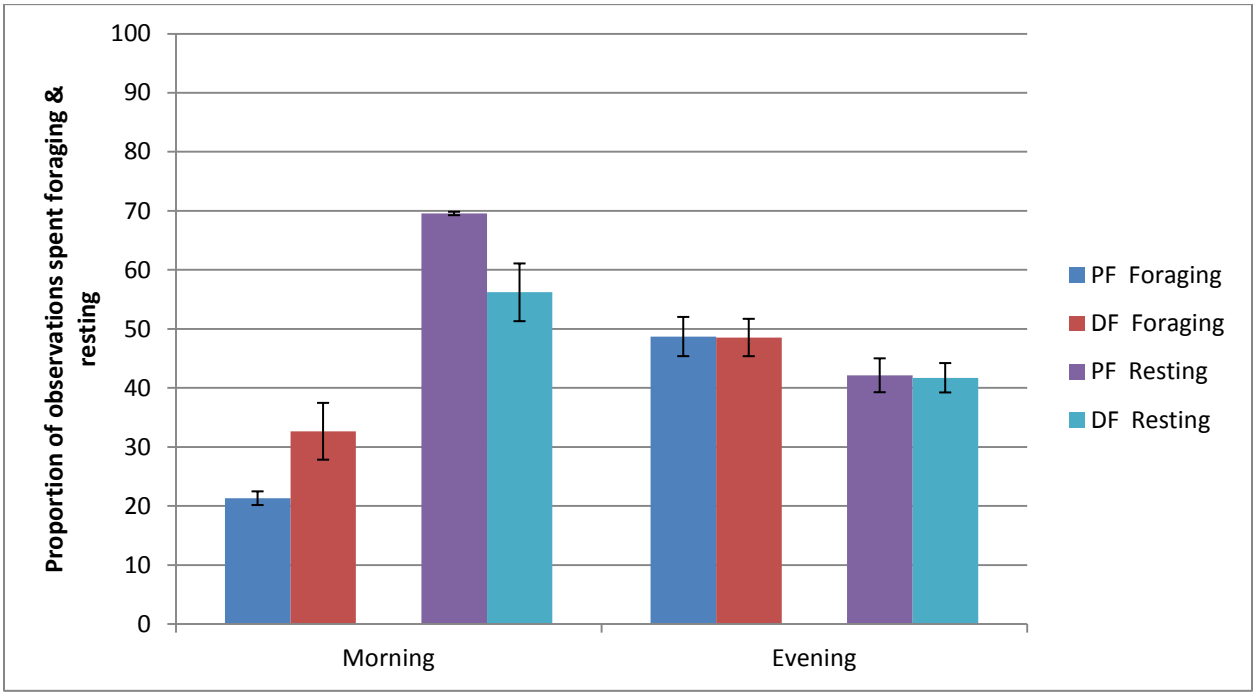

Figure 6. Comparison of foraging activity between PF troops (n = 24 morning and 24 evening observation periods) and DF troops (n = 23 morning and 26 evening observation periods). And Comparison of resting activity between PF troops (n = 24 morning and 24 evening observation periods) and DF troops (n = 23 morning and 26 evening observation periods). Means ± SE.

Food items

There were no significant differences between PF and DF troops regarding the proportion of time spent foraging for different food items. PF troops mainly spent time foraging for mature leaves but also unripe fruits and young leaves; all other items were rarely eaten. Also DF troops used mainly mature leaves, some unripe fruits and young leaves but rarely any other items. There was a tendency that foraging levels for mature flowers were higher in DF than in PF troops (DF = 4, F = 5.6, p = 0.0771) (Fig. 7).

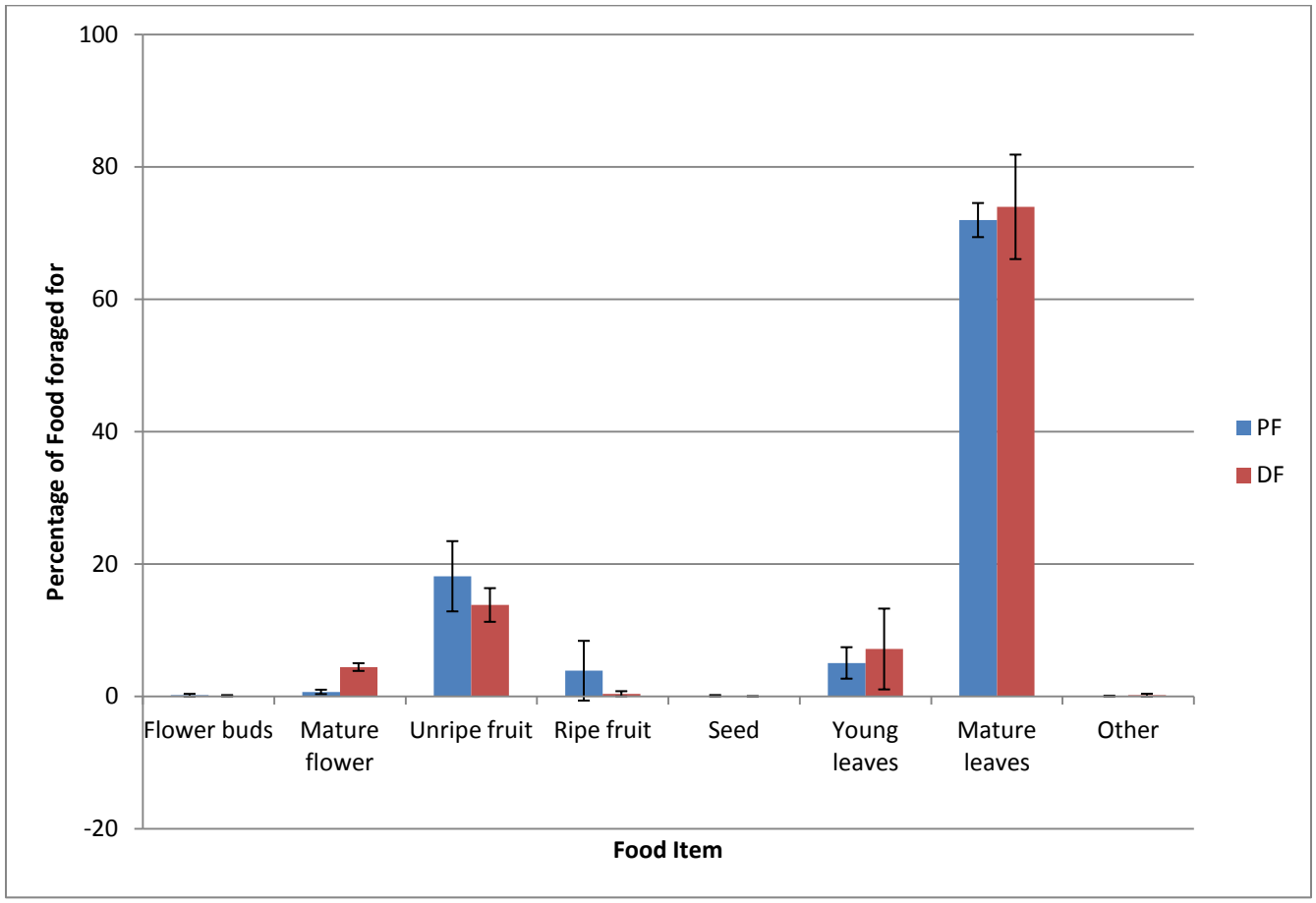

Figure 7. Comparison of the percentage of time that PF troops (n = 48 observation periods) and DF troops (n = 49 observation periods) spent foraging for different types of food. Means ± SE.

PF troops foraged for more food items from native plants than DF troops did (DF = 4, F = 20.5, p = 0.0106). The opposite was observed with DF troops foraging more food items from exotic plants than PF troops (DF = 4, F = 18.2, p = 0.013). No significant differences were found for plants of unknown origin (Fig. 8).

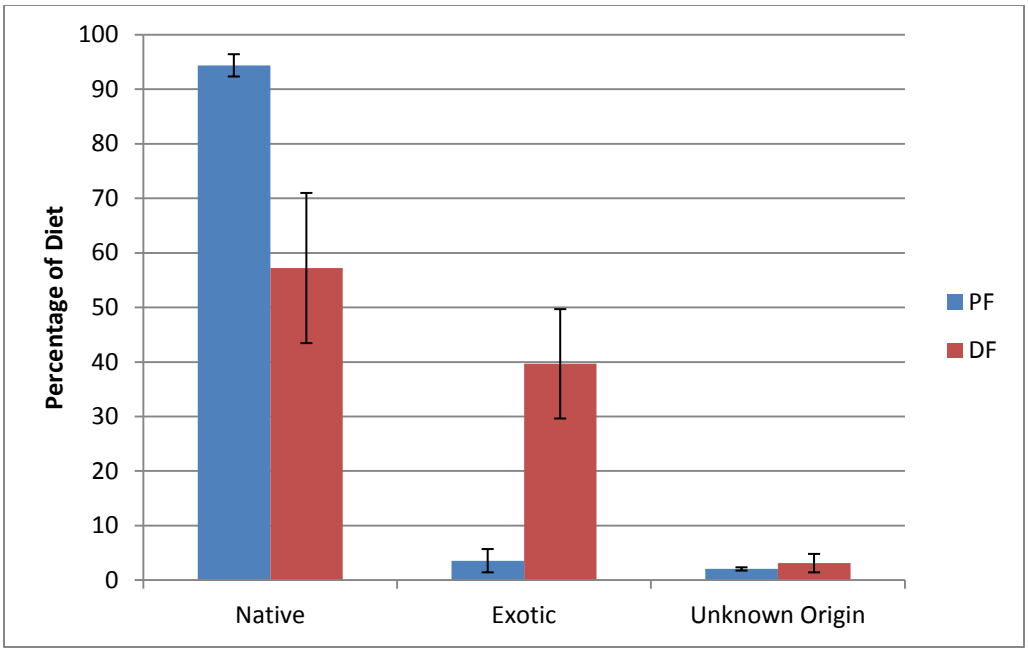

Figure 8. Comparison of the percentage of time that PF troops (n = 48 observation periods) and DF troops (n = 49 observation periods) spent foraging for foods of different origins. Means ± SE.

Combining all foraging observations for the PF troops, food items were mainly foraged from five tree species (Fig. 9); all of them natives. Combining all foraging observations for the DF troops, food items were mainly foraged from eight trees and one shrub/climber (BS) (Fig. 10). Three species ADP, BS & DR are exotics.

For the PF troops, the five trees make up 74, 69 and 70% of the diets of BB1, BB2 & BB3 respectively. With two trees AD and LF accounting for 60, 66 and 40% of their diets. Another 18% of BB3's diet is composed from the tree species LW.

For the DF troops, the seven trees and one shrub/climber make up 71, 86 and 63% of the diets of CT1, CT2 & CT3 respectively. 33% of CT1's diet is composed from one tree; ADP and the rest of the seven range from 1.6 to 7.4%. 24% of CT2's diet is from the shrub/climber BS and 47% is from LF, AD and ADP combined, with the remaining three accounting for 2.5 - 4%. The top tree foraged from in CT3's diet at 19% is ZC, with LF, DR & AD together making up another 39%. BS makes up only 2.6% of CT3's diet. ADP and MZ were not observed being foraged in by CT3. LW is 3% of CT3's diet. Seven other plants and trees are foraged in to about 2 – 3% of the time each in CT3's diet and the rest lower than 2%.

The average dietary diversity per observation period for the three PF troops was 2.41 ± 0.18, which is lower than the average dietary diversity per observation period for the three DF troops at 3.26 ± 0.2 ($DF = 4$, $F = 11.0$, $p = 0.0293$). This means that during morning and evening feeding bouts PF troops foraged from a smaller number of tree species than DF troops.

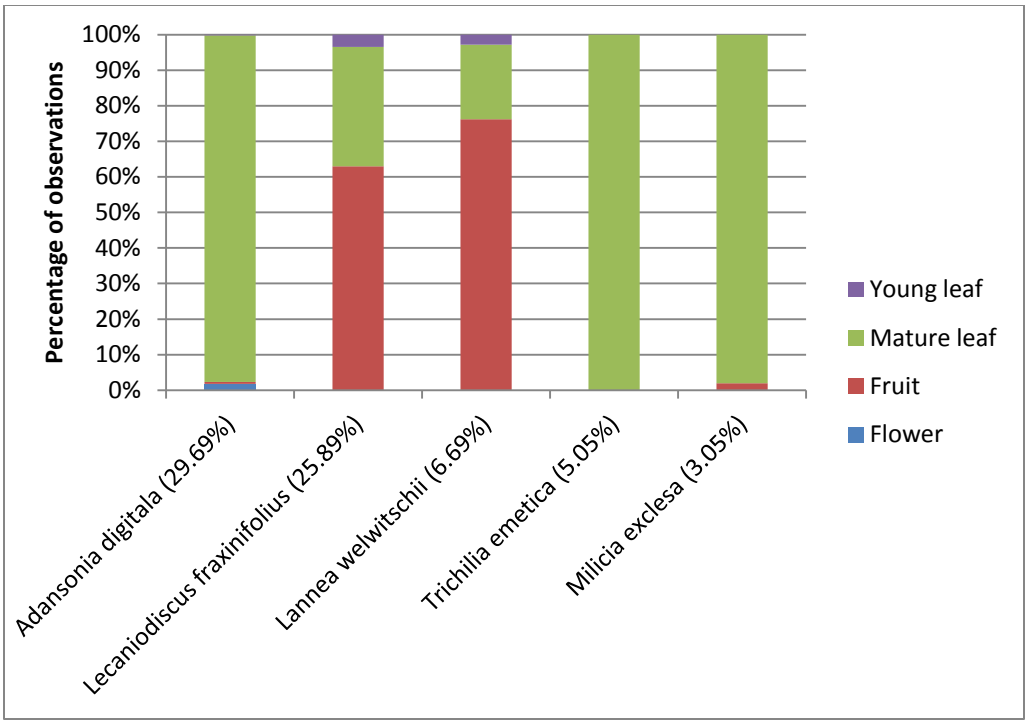

Figure 9. Major plant species foraged by PF troops, totalling 70.4% of diet. Proportions of food items eaten per plant species are illustrated.

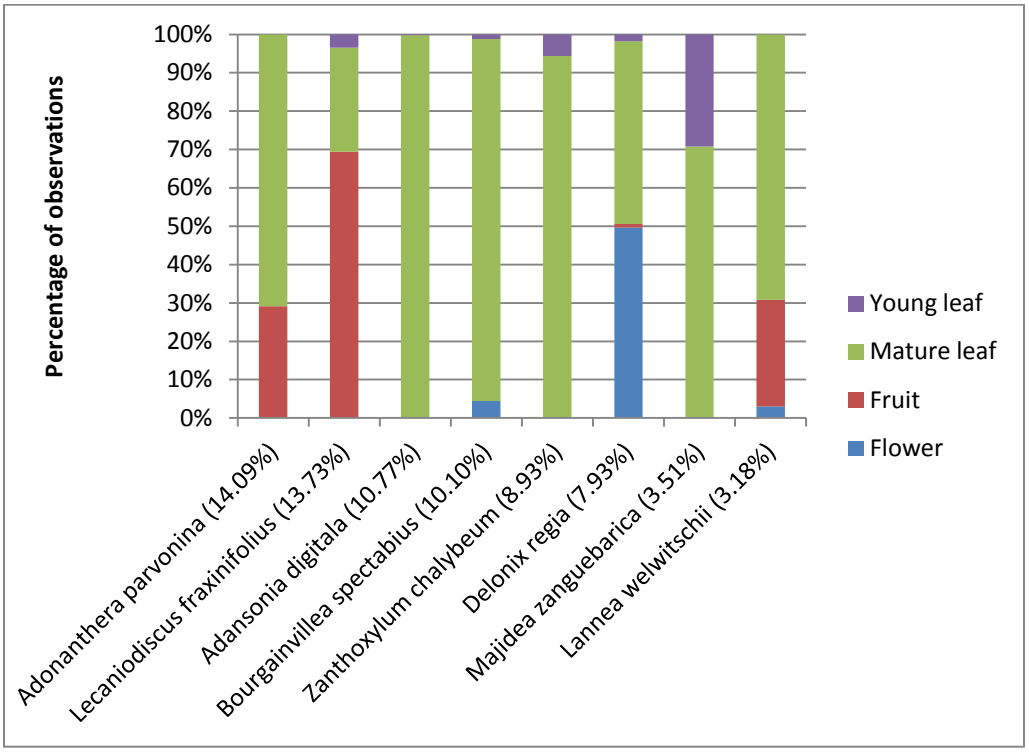

Figure 10. Major plant species foraged by DF troops, totalling 72.2% of diet. Proportions of food items eaten per plant species are illustrated.

Home Range Area

On average home ranges in pristine forests were slightly bigger than in degraded forests, both with 100% MCP and with 97% isoplet KDE analysis (Fig. 11 & 12, table 4).

Core use area is almost identical on average for the pristine and degraded forest type troops (Fig. 12, Table 4.).

The area that the PF troops occupied was 32 ha; for the DF troops 24 ha. I observed at least three other troops using part of the 32 ha enclosing the pristine forest troops. There was most likely a forth, as a big patch of PF was empty of colobus monkeys, but in the pilot study we observed a troop coming from and going in that direction. There was only one other troop using part of the 24 ha enclosing the DF troops, and this only had four individuals in it.

Table 4. Comparison of home range size of PF and DF forest troops using MCP and KDE analysis.

Method	Forest Type	Home range (ha) [a]	GPS Points
MCP	PF	4.7	700
	DF	3.5	712
KDE	PF	6.47	700
	DF	5.96	712
Core	PF	1.2	700
	DF	1.3	712

[a] Average of three troops

Home Range Overlap

Home range overlap is a lot greater for the DF troops with either method (Table 5). Using KDE-made home ranges, home range overlaps accounted for a lot more of the home range for both troops on average. One of the three troops not part of this study in the 32 hectares enclosing the PF troops overlapped with BB2's territory quite a bit. And another one of the three overlapped somewhat with BB3's territory. The troop that isn't included in this study in the 24 hectares enclosing the DF troops home ranges overlapped somewhat with CT3's territory, but only in the forested part.

Table 5. Percentage overlap of PF and DF troops and comparisons of these overlaps by forest type by MCP and KDE analysis.

Method	Forest Type	Troop	% Overlap	GPS Points
MCP	PF	BB1	1.89	236
	PF	BB2	3.03	232
	PF	BB3	0	232
	DF	CT1	52.38	241
	DF	CT2	22.71	233
	DF	CT3	3.58	238
	PF	NA	1.6 [a]	700
	DF	NA	26.22[a]	712
KDE	PF	BB1	6.79	236
	PF	BB2	19.95	232
	PF	BB3	10.71	232
	DF	CT1	73.44	241
	DF	CT2	41.92	233
	DF	CT3	19.75	238
	PF	NA	12.48[a]	700
	DF	NA	45.04[a]	712

[a] Average of three troops

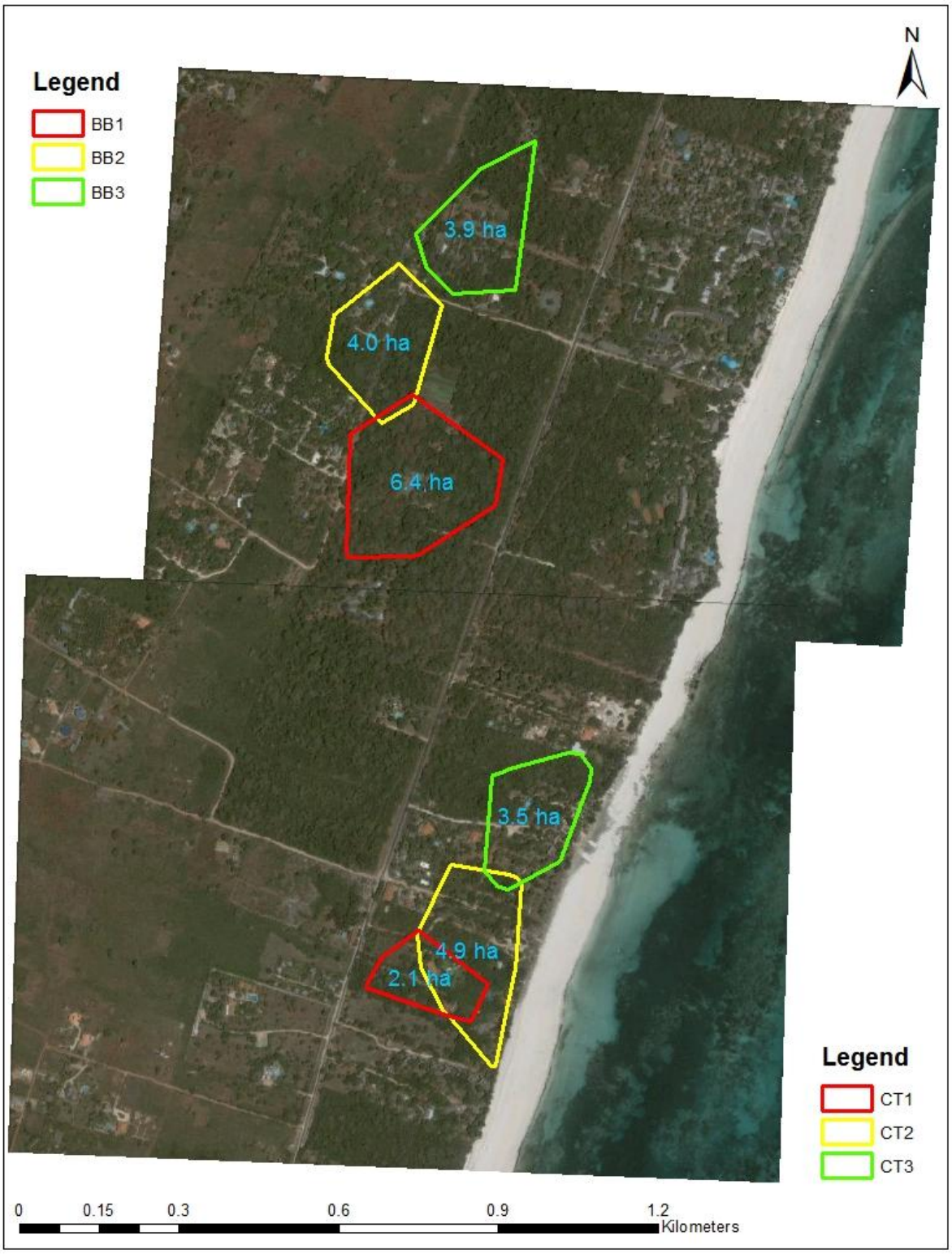

Figure 11. Home ranges of the six colobus troops in hectares (ha); MCP method. See Table 4 for PF & DF troop home range comparisons.

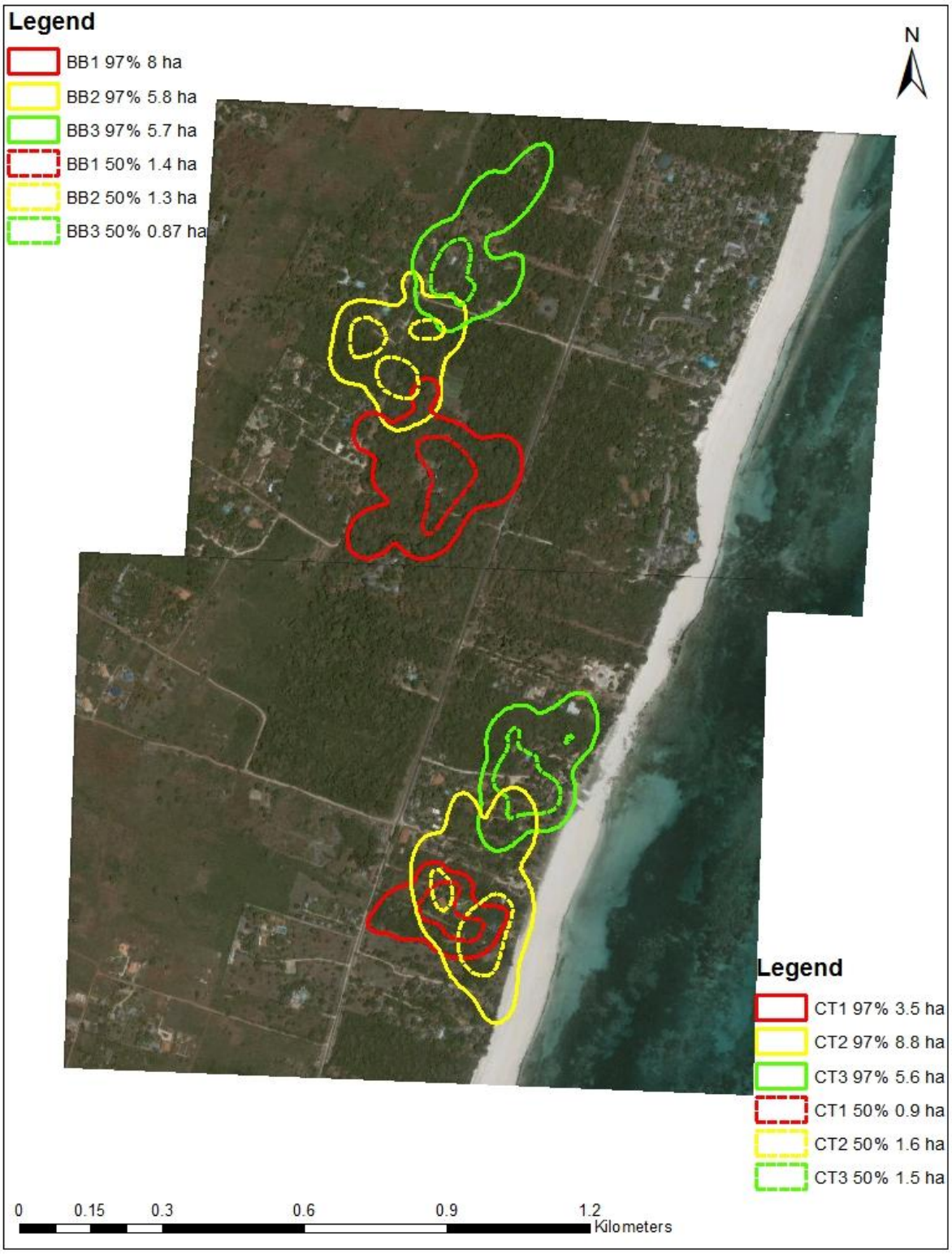

Figure 12. Home ranges of the six colobus troops in hectares (ha); KDE method. 97% = full home range, 50% = core habitat use. See Table 4 for PF & DF troop home range comparisons.

Feeding trees found in respective home ranges

AD, LF and LW appear to be quite common in the home ranges of the PF troops (Fig. 13). These trees also seem to define the boundaries of the respective troops home ranges. Also 50% of the time they use these trees in some way, which can be seen by their core habitats. AD and LF are much less common in the DF home ranges, but LW is seen to a similar extent as in the pristine forests (Fig. 14). All three tree species were much smaller than those found in the pristine forests. There seems to be no particular trees that define the boundaries of the DF home ranges. The core habitats of CT1 & CT2 enclose the same ADP and LF tree and a few AD trees. The core habitat of CT2 seems to be defined by ZC trees and contains the top three trees foraged from by the PF troops; AD, LF & LW.

Rates of Movement

DF troops travelled further than PF troops in the morning and evening (Table 6.). If on average the PF troops travelled at 71 meters per hour in the morning (2 hrs 40 min) and 77 meters per hour (2 hrs 15min) in the evening. And the DF troops travelled at 88 meters per hour in the morning and 88 meters per hour in the evening on average (worked out from table 6.). Then by extrapolation, PF troops would have travelled between 852 meters and 924 meters per day, and DF troops would have travelled 1056 meters per day. Then the DF troops travelled from 132 – 204 meters per day more than the PF troops on average. And from 11 – 17 meters per hour faster than the PF troops on average.

Table 6. Day time comparison of distance travelled by PF and DF troops.

Forest Type	Dist. Travelled (m) [a]	Day Time	Obs. periods
PF	165	Morning	24
DF	204	Morning	23
PF	173	Evening	22
DF	199	Evening	24

[a] Average of three troops

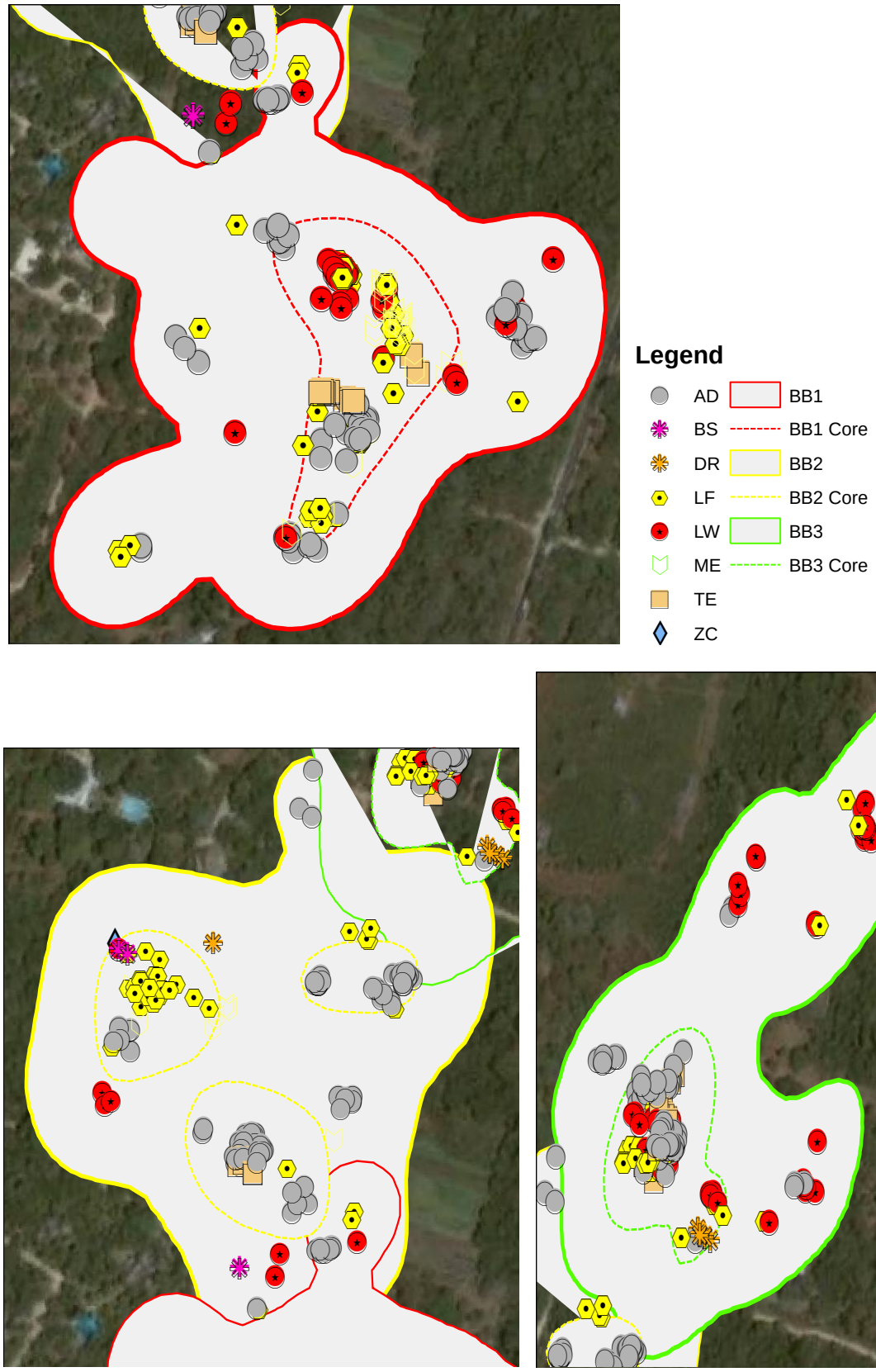

Figure 13. Major plant species distributions inside home ranges for the PF troops. BB1 red, BB2 yellow, BB3 green.

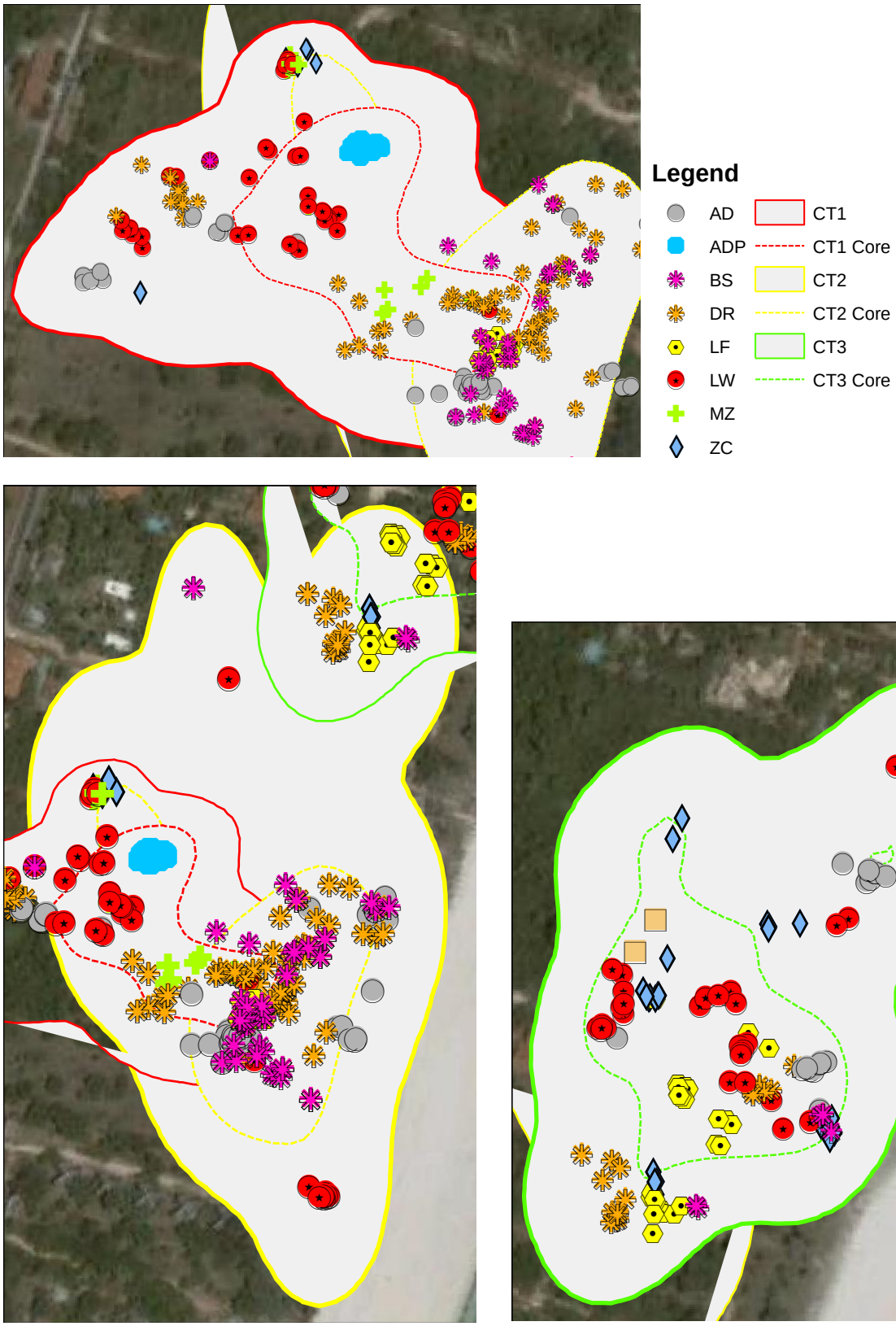

Figure 14. Major plant species distributions inside home ranges for the DF troops. CT1 red, CT2 yellow, CT3 green.

DISCUSSION

Colobus monkeys in Diani Beach

General behaviours & Foraging behaviours

The colobus monkeys in my study spent 52% of their time resting. In other studies species of black-and-white colobus have been found to spend 44 - 64% of their time resting ((*C. polykomos* (55%), *C. guereza* (44 - 64%), *C. sananta* (54%), *C. angolensis* (52%), *C. vellerosus* (58 - 60%). (Teichroeb *et al* 2002)). For *C. angolensis* this is exactly the same as what I found. In my study an explanation for the level of resting may be due to the high percentage of mature leaves in their diet (73%).

Diets that consist of a large amount of low quality food such as mature leaves may lead to more time needed for rest for fermentation to occur. *Colobus guereza* and *Procolobus pennantii* living in forest fragments have been found to eat more mature leaves and spend more time resting than groups in continuous forest with a wider selection of food sources (Chapman *et al* 2007). However, in my study the colobus were recorded as foraging for young leaves only 6% of the time. Colobus monkeys in general rarely include more than 30% mature leaves in their diet unless they are of good quality (Oates and Davies 1994). They eat high quality young leaves and cannot maintain themselves on mature leaves of low quality for long periods (Oates and Davies 1994). Fimbel *et al* (2001) studied *Colobus angolensis* in Nyungwe forest, a high altitude habitat, and observed on average 40% mature leaves and 25% young leaves in their diet, and in some months 61% mature leaves. The authors put this down to the climate and altitude keeping the mature leaves in good quality nutritionally for long periods.

As Diani is at sea level, the reason for 52% resting and high percentage of mature leaves in their diets in my study could be because the troops were observed throughout the whole long rains period where new growths appear and food is plentiful and of better quality than during the dry season. Lowe and Sturrock (1998) compared the diet of a troop of *Colobus angolenis palliatus* at the end of the dry season to their diet at the beginning of the wet season. They found that the troop rested nearly 50% longer during the wet season. Lowe and Sturrock (1998) suggested that the monkeys did not need to feed as much in the wet season to meet their nutritional needs. I think the plant expert in my study may have found it difficult to see the difference in mature and young leaves when the colobus were foraging high in the top canopy. Also when he left I had to identify the leaf age and I was not as good as he was at this. So the colobus monkeys most likely foraged from a lot more young leaves than were recorded. However when they were observed in degraded habitats it was easier to see what the leaf age was, so maybe it was to do with the time of year when they were observed. (We have to discuss this on phone). Saj and Sicotte (2007) found that a troop of *Colobus vellerosus* fed on 46 – 91% mature leaves per month during the wet season. They put this down to other plant parts like flowers being completely absent or less available.

In the literature I have studied the majority of fruits eaten by colobus monkeys were unripe (Shruhsaker and Leland 1987). In my study unripe fruit was the second most foraged for food item at 16% of the observed time; ripe fruit only 2.1% of time. Ripe fruit contains high proportions of simple sugars that can lower forestomach pH in colobus monkeys, leading to

acidosis or even death (Danish *et al* 2006). In many cases the colobus monkeys in my study were observed dropping the fruit out of their mouths and still chewing, with the fruit pulp largely intact minus the seeds on the ground. But they were recorded as foraging for fruit all the same. Forestomach digestion in colobus monkeys readily allows digestion of the main storage carbohydrate in seeds (Kay and Davies 1994). Indeed seed-eating is a major feature of colobus monkeys diets in Africa, with more than 30% of the annual diet of a number of colobus species including *Colobus angolensis* being seeds (Davies *et al* 1999). The fact that less than 1% of the diet of the colobus in my study was composed of seeds is hence strange in this regard. I believe they were eating seeds for many of the times they were recorded as foraging for fruit.

A number of black-and-white colobus species have been observed as having two to three feeding peaks per day; one early in the morning, a peek at mid day and one early in the evening (Teichroeb *et al* 2002, Lowe & Sturrock 1998). In my study they rested a lot more in the morning (63%) than the evening (42%) and foraged much more in the evening (49%) than the morning (26%). On average for the three *C. vellerosus* troops studied by Teichroeb *et al* (2002) resting levels were similar throughout the whole day and there was a only a slight increase in feeding levels in the evening. For the *C. angolensis* troop studied by Lowe & Sturrock (1998) there was no evening peak at all in the wet season. For my study the increase in foraging during the evening may be due to temperatures being hotter during the morning than the in the evening, allowing more activity in cooler periods. Hill *et al* (2003) found that feeding behaviour in baboons increased with temperature but began to decline at a certain level. I did not record the temperature so I cannot prove a difference in terms of day time. However, I do not recall it feeling hotter in the morning or evening observation periods. If the high percentage of mature leaves in the colobus monkey diet in this study is to be taken as fact, feeding for a prolonged period of time in the evenings on mainly mature leaves would require prolonged retention of these leaves for digestion (Kay and Davies 1994), and so the next morning they would still be digesting the food and need to spend more time resting and less time feeding during this time period.

In total colobus monkeys in Diani foraged from 72 plant species. 16 trees made up more than 75% of their foraging observations. Anderson *et al* (2007a) state that colobus monkeys in Diani forage from 116 tree species; 14 of them made up >75% of their diet. Out of the 16 major food trees in my study, 10 were the same as those of the 14 major food trees in Anderson *et al* (2007a). The data from Anderson *et al* (2007a) is a collection of foraging behaviour studies of colobus monkeys at Diani Beach and included whole day observation studies of dry and wet seasons. Therefore a higher number of different plant species foraged from is expected, as plants are of lower nutritional quality during the dry season and so colobus monkeys would have to forage from a greater variety to meet their nutritional needs (Lowe and Sturrock 1998). Also whole day observations would cover much more of the foraging behaviour such as the midday peak (Teichroeb *et al* 2002).

Sex & age class comparisons

There were no significant differences for any of the behaviours between male and female colobus monkeys in Diani Beach or for foraging behaviour for males, females and juveniles. There might be no genuine differences between sexes, or they affected each other and synchronized their activities. Teichroeb *et al* (2002) found no differences in male and female

behaviour for two out of three troops of *Colobus vellerosus* in central Ghana. These troops contained 7-8 and 15-16 individuals, respectively, in the range of the colobus troop sizes in Diani. They did however see male and female behaviour differences in a troop containing 31-33 individuals. This larger troop had a larger number of suckling infants, increasing the nutritional requirements of the females. And the females were observed foraging more than the males, but resting less. In my study only two troops out of six had suckling infants and only one infant per troop, and a number of females per troop to spread the load. The females did rest slightly more than males, but not significantly more, and foraged less, the opposite to Teichroeb *et al* (2002). A lack of an observable increase in female foraging over males in my study, may just then be related to the low number of suckling infants.

Male black-and-white colobus monkeys are known to be involved in intergroup aggression for mate or resource defence (Fashing 2001b). Females do so much less and only for resource defence (Fashing 2001b). Hence, I had expected differences in foraging and resting in adult males and females, as the females would forage while the males kept guard in the presence of a rival troop and attacked them when necessary. This was observed in my study quite often; in most cases the less dominant adult male would be keeping guard. However, as I pooled the sub-adults with the adults, it was not possible to see a difference in adult behaviour. On the other hand juveniles rested less, groomed themselves less, were more social and moved more than adults. As they played and moved around a lot while the adults were resting, they were recorded as more active for these reasons too, as play was pooled into social behaviour. However, immature primates by nature like to explore their environment more and so are more flexible in their behaviours (Poirier and Smith 1974). Also the females groomed the juveniles quite often so the juveniles did not need to do this themselves.

Comparison of Colobus Troops from Pristine and Degraded Forests

General behaviours

While foraging and resting differences in time of day may be due to temperature or fermentation time, these may not explain differences for habitat type, at least where temperature is concerned. PF and DF troops both foraged more in the evening and rested less in the evening, and there is very little difference in percentage of these activities for troops in both forest types in the evening. However the morning period is significantly different for foraging and resting for PF and DF troops. In the morning DF troops foraged ~10% longer than PF troops, and PF troops rested ~13% longer than DF troops. To try and understand these differences in activity levels we have to look more closely at the foraging behaviours of the troops in both habitat types.

Foraging behaviours

Firstly, there were no significant differences in food items foraged for by PF and DF troops. However, there was a tendency that mature flowers were more often foraged for by DF than by PF troops (4.4% vs. 0.7% of the diet, respectively). Flowers are generally high in sugar content, which would give them energy (Wasserman and Chapman 2003). The PF troops foraged for nearly 4% ripe fruit compared with ~0.4% for the DF troops. But this 4% value was accounted for by only one of the PF troops, the other two were not observed foraging for ripe fruit. As colobus monkeys generally do not eat ripe fruit, it may have actually been seeds. I suggest that any differences in food item reflect the availability of these items in the different forest types, rather than different needs of the different troops.

So if differences in food item do not account for the differences in foraging and resting times between habitat type, maybe differences in plant species choice do. The majority of plant species foraged from by PF troops were native plants, and for the DF troops this was nearly 50:50 native:exotic. To examine the differences between these diets, we have to look more closely at the individual plant species involved.
Five major plants accounted for 70% of the combined foraging observations for the PF troops, and eight major food plants accounted for 72% of the combined foraging observations for DF troops. For the most part, the same two to three tree species accounted for a large percentage of each of the PF troops foraging observations. For DF troops, their foraging observations were made up of different combinations of the eight most foraged from trees and plants. Per observation period PF troops mainly foraged from 2.41±0.18 plant species, and DF troops mainly foraged from 3.26 ±0.2 plant species. This difference in dietary diversity is directly connected to habitat quality, as habitat quality plays an important role in determining dietary diversity, with animals living in nutrient poor habitats having higher dietary diversity (Lowe and Sturrock 1998). *Adansonia digitata* or Baobab is a deciduous tree spending only four months of the year in leaf. Its leaves contain proteins and sugars and have a high mineral content (Gebauer *et al* 2002). Lowe and Sturrock (1998) found a nearly fourfold use in *Adansonia digitata* as a feeding tree in the wet season compared to the dry season. They put this down to the fact that a brief period of rain will promote the growth of edible portions of this tree species. Lowe and Sturrock (1998) mentioned that the presence or absence of one species may be responsible for a change in dietary diversity. This seems to be the case in my study, as 29% of the foraging observations for the PF troops were from *Adansonia digitata*, and mainly leaves from this species. Only ~11% of the DF foraging observations were from this tree species. In the DF troops habitats Baobab trees were sparsely distributed and of a much smaller size in comparison to the PF. Hence, it is not surprising that the PF troops foraged highly for Baobab leaves if they are such good quality and are everywhere. *Trichilia emetica* was the fourth most foraged from plant species in the pristine forests at 5.4% of the foraging observations. The reason I mention it after Baobab is that only leaves were foraged for from this tree and only mature leaves. This tree species was not at all part of the DF troops' diets. It is an evergreen tree found all throughout sub-Saharan Africa. Its fruit is quite nutritious and along with its flower buds are eaten by monkeys and baboons. Its leaves are toxic to many animals but are eaten by animals such as nyala and kudu (Komane *et al* 2011). The fact that the colobus monkeys were only eating the leaves of this tree then is quite remarkable. However, fruiting for this plant occurs between January and May (Komane *et al* 2011), and may not have been in fruit throughout my study. Also *Trichilia emetica* was not widely distributed in both habitat types but more common in the pristine forests. I noticed that many places were the monkeys foraged from Baobab trees had *Trichilia emetica* trees close by. It may have just been the proximity to these trees rather than a preference.

For the PF troops the second and third most foraged from plant species were *Lecaniodiscus fraxinifolius* and *Lannae welwitschii*, and mainly fruit was consumed from these trees. Peak fruiting periods of some animal dispersed fleshy-fruited species happen during the rainy season because of the moisture levels needed for fruit production (Chapman *et al* 2005). *Lecaniodiscus fraxinifolius* was fruiting at the end of the dry season and the fruit only started to ripen at the end of my study, so were available to the colobus monkeys throughout. Fruit from *Lannae welwitschii* was available at the end of dry season and into the early wet season, but I did not

notice fruit on these trees for most of the wet season. *Lecaniodiscus fraxinifolius* and *Lannae welwitschii* were widely distributed throughout the PF troops' habitats. *Lecaniodiscus fraxinifolius* was sparsely distributed in the DF troops' habitats, but was still the second most foraged from plant species in this habitat, and again mostly the fruit was consumed. *Lannae welwitschii* was more common in the DF troops habitats, however if it was not fruiting it may not have appealed to the colobus monkeys, which might explain why it was the lowest foraged from of the top eight major food trees/plants for this habitat type in the wet period. But fruit accounted for 28% of the food items foraged for from this tree species. In my pilot study conducted for two weeks at the end of the dry season, *Lannae welwitschii* accounted for nearly 10% of the DF troops' diet, and 50% of the food items foraged from this tree were fruit (data not shown). *Milicia exclesa* was the fifth most foraged from tree species in the foraging observations of the PF troops, and nearly all foraging at this tree was for mature leaves. It is a deciduous tree native to Africa (World Agroforestry Centre 2011) and most likely was foraged in by the colobus monkey for the same reasons as the Baobab leaves.

Adenanthera pavonina, a deciduous tree endemic to southern China and India, was the top foraged in tree in the degraded forests. This was part of the diet of CT1 & CT2 but not CT3. The reason for this is that it was only one tree, an exotic, in between the home ranges of CT1 & CT2. Its seeds are valued as a food source by people as they contain one quarter oil with a high percentage of proteins (Jaromin *et al* 2006). The leaves are also quite high in protein content (17-22%), but low in mineral content (World Agroforestry Centre 2011). With such high protein content of both leaves and seeds it is no wonder the DF troops favoured this tree species. DF troops were recorded as foraging for fruit 29% of the time from this tree, the remaining 71% was for mature leaves. However in this particular case I am quite certain it was the seeds they fed from, as the seed pods or "fruit" were dropped empty and undamaged to the ground. However, to be consistent I recorded it as fruit. 33% of CT1's diet was *Adenanthera pavonina* and for CT2 it was 11%. CT1 as a troop contained 9 individuals, two of which were adult males. Compared to the 7 individuals in CT2 and only one adult male, CT1 tended to win the foraging rights for this tree.

The plant species foraged from most in the CT3 troop diet was *Zanthoxylum chalybeum* at 19%, close behind this was *Lecaniodiscus fraxinifolius* at 16.6%. *Zanthoxylum chalybeum* was fifth overall in the foraging observations of the DF troops at 9%. It is a deciduous tree native to Africa. Its leaves are highly aromatic and citrus smelling when crushed which may have attracted the colobus monkeys (World Agroforestry Centre 2011). For all DF troops, 100% leaves were the items foraged for in this tree. As it is a deciduous tree its leaf quality is highest when the rains come (Baranga 1983), which would explain the high levels of leaves from this tree species consumed by the DF troops. Only a few of these trees were found in the DF troops habitats. It was more common in CT3's home range, which explains it being the top foraged from tree by CT3. One *Zanthoxylum chalybeum* actually defined the edge of CT2 and CT3's territories, as CT3 would defend this tree and not let CT2 near it. *Bougainville spectabilis*, and *Delonix regia* number four and six most foraged plants/trees by the DF troops. Both are deciduous ornamental flowering plants not native to Kenya (Ghouse and Hashmi 1982, Adebayo *et al* 2005). In my study flowers were foraged for in both plants. However *Bougainville spectabilis* stopped flowering early in the wet season but *Delonix regia* kept flowering for a large part of the wet season, which reflects the proportions of flowers consumed from these plants/trees in my study.

Both plants/trees were widely spread throughout the degraded habitats, most likely by the people living there, and as they are both deciduous, their leaves would have been of good quality during the wet season (Baranga 1983). The fact that the DF troops still foraged for the remaining flowers of *Delonix regia* suggest the high sugar content of flowers was needed in their diets to make up for something missing. *Majidea zanguebarica* was foraged from 3.51% of the time by the DF troops. It is a tree species native to the coral rag forest of the southern Kenyan coast (Birch 2011). Young leaves made up 29% of the foraging observations for this tree species and so it was most likely used as a protein source.
Overall the PF troops mainly foraged for leaves from the deciduous tree *Adansonia digitata*, which has leaves containing proteins and sugars and minerals during the wet season. They then got their energy and or more likely their main protein source from fruits (most likely seeds) of *Lecaniodiscus fraxinifolius* and *Lannae welwitschii*; the latter more so at the beginning of the wet season.
Overall the DF troops probably got most of their sugars and minerals from five plants; *Bougainville spectabilis*, *Adansonia digitata*, *Delonix regia*, *Zanthoxylum chalybeum*, and *Majidea zanguebarica*. Their main protein sources were most likely from the leaves and fruit of *Adenanthera pavonina*, the leaves of *Majidea zanguebarica*, and the fruit (most likely seeds) of *Lecaniodiscus fraxinifolius* and *Lannae welwitschii*. Once again the latter was consumed more so at the beginning of the wet season.

Home range analysis
Quite a number of studies have been carried out on colobus monkey home range size. Some have been recorded as having home ranges as small as 1.5 hectares, while others were much higher in the 100s of hectares. Many of the studies are listed in Fashing (2001) and Fashing *et al* (2007). MCP and KDE analysis have been used in many different ways by researchers for home range estimation. One studying a 300 large troop of black-and-white colobus monkeys used both MCP and KDE and got similar results for both methods (20 & 24 kilometers). With the KDE made home range being only slightly larger (Fashing *et al* 2007). The size of this troop meant that they had to travel much further to feed each member. Harris and Chapman (2007) studied eight troops of black-and-white colobus monkeys and also used both methods to calculate home ranges. The MCP method gave home ranges slightly bigger to twice the size of the KDE method home ranges in their study. They used the MCP home ranges as total home range size and the KDE home ranges as the feeding range of the troops. But in this study the GPS points they used were only of the feeding trees. Wartmann *et al* (2010) are another group who compared MCP and KDE when estimating home range size, in this case for individual orangutans. They found that both methods are comparable across studies but that range increased for MCP with increasing sample size. In this study the KDE method gave higher values for the home ranges.
I used the same or a very similar number of GPS points for each of my troops, so sample size is not an issue in my study for using the MCP method. Also, although I only studied each troop for one day a week, I believe for at least in my study, the MCP method is more accurate than the KDE method, as the borders of my troops territories were usually sharply defined by a feeding tree or a wall or road. Also BB3 was only once seen near the territory of BB2 and not during an observation period. So I do not think their territories overlap. For these reasons for the discussion on the PF and DF troops home ranges I will focus on MCP analysis. But I will also mention the 50% core use area created by KDE analysis as I think this is very useful. Additionally, in the above mentioned studies the researchers studied their troops for more consecutive days and

across more seasons than I did. However, I think that even though my troops were studied only once a week each, the fact that there was only a few days between each troop observation, makes the comparisons more valid than many of the above studies.

The home ranges of two of the PF troops BB2 & BB3 are similar in size. BB1's home range is about 50% larger than the other two. But BB2 had 2-3 more individuals than the other two so may have needed to travel more to feed all nine monkeys. However it appears that home range and core habitat use areas of all the PF troops are defined largely by three of the top feeding trees in the PF troops foraging observations. With the three troops spending a large portion of their time where these three trees are clumped. With the exception of CT1, home range sizes of the DF troops were similar to the PF troops. Here home range size and core habitat use areas do not appear to be defined by a small number of tree species, but seem to be determined by what trees and plants are available there and are the best quality. CT1 had the smallest home range size of all six troops at 2.1 hectares, and its core habitat use area was a large part of this, yet it had one of the largest troop sizes at 9 individuals. This troop had access to a number of different food trees and had no competition from another troop other than CT2 as far as I could tell. It also occupied the land around the Colobus Trust. The Colobus Trust created a nature trail for visitors to watch the colobus monkeys, and this is where CT1 spent a lot of their time. There may have been high quality plants in there, and including AD, LF & LW, they also had ADP, ZC and BS in their home range, so did not have had far to travel to meet their nutritional needs. CT2 had the largest home range of the DF troops. But its core area was only a fraction of this. Their home range was heavily degraded and only sparsely contained feeding trees. They were surrounded by two large troops CT1 & CT3, each with nine individuals, for which they had to compete for the best feeding trees. Harris (2006) says that troop size does not affect the outcome in inter group competition for feeding trees, and that group rank is more important. Indeed CT2 did win the feeding rights for the ADP tree over CT1 a number of times. But with scarce resources and at least 25 monkeys to feed in 24 hectares, there was always a queue for the best feeding trees, for which CT2 seemed to be at the back of more often than not. CT3 had the second largest home range of the three DF troops, and like CT1 its core habitat use area was a large portion of this. CT3's home range appears to be defined by many different food trees, but its core area appears to be largely defined by ZC trees. CT3's home range contained the most ZC trees from what I could tell.

You might expect the home ranges of the DF troops to be bigger than the PF troops as their food sources are more spread out, but this does not appear to be the case. All the main predators in Diani are long gone, but there are still many baboons living there (Kanga and Heidi 1999). I have witnessed them chasing after all the monkey species in Diani including colobus monkeys. Studies have shown that predators cause their prey to disperse from their main food sources (Fourrier *et al* 2008). In this paper they use chimpanzees and red colobus monkeys as an example. I have only seen baboons in pursuit of the three PF troops and in the forested areas, but not the DF troops. It's possible that they need cover to stalk their prey. This may explain the slightly larger home ranges of the PF troops. In fact BB1 generally stayed within the Baobab forest until pursued by a troop of baboons. They were forced further south than I had seen them before. They then regularly frequented this area afterwards as there were AD & LF trees there. Also there were large vervet and sykes's troops in the DF areas as well as human food to distract the baboons away from the colobus monkeys.

In terms of home range overlap, BB1 overlapped only slightly with BB2. When they met in the forest they were quite aggressive to each other. But outside the forest they seemed to be more

tolerant. BB3 did not overlap with the other two troops. All three DF troops overlapped with one or more of the three troops. Greater than 50% of CT1's home range is overlapped by CT2, and CT1 & CT2 share core areas. Both troops repeatedly fought over the ADP tree and an LF tree in both of their home ranges. Also CT3 regularly went out of their way to prevent CT2 from going any further than just before the ZC tree on the edge of CT3's home range. However for the most part the DF troops foraged next to each other with no fights. They only fought over the top food trees. CT3 had a number of territorial fights with the other troop in the small forest beside its home range. It seems that fights were more common in forests, possibly because it's hard to know where the other troop is going. Whereas out in the open it may be possible that the troops can tell what the intentions of another troop are fairly early on. I conducted my study during the wet season when food is plentiful. In times of scarce food resources the DF troops would most likely have a hard time, especially CT2. Leading to increased aggressive behaviours and more stress, and with it the onset of illnesses (Mbora and McPeek 2009).

27 studies on colobus monkey troops have shown that they travel from 307 to 1068 meters per day on average (Fashing 2001c). Studies on black-and-white colobus monkeys have shown they can travel from 26 to 141 meters per hour (Fashing *et al* 2007). In my study I did not do whole day observations so I cannot say daily path length per troop without extrapolating. On average the PF troops travelled at 71 meters per hour in the morning and 77 meters per hour in the evening. DF troops travelled at 88 meters per hour in the morning and 88 meters per hour in the evening on average. By extrapolation, the PF troops travelled between 852 meters and 924 meters per day, and DF troops travelled 1056 meters per day. This is somewhere in the middle of the black-and-white colobus monkey studies for meters per hour, but on the high end for daily path length for colobus monkeys. However the DF troops travelled from 132 – 204 meters per day more than the PF troops on average. In terms of meters per hour DF troops travelled 11 – 17 meters per hour faster than the PF troops on average. Fashing (2001c) studying five troops of *Colobus guerezas* found that the largest troop (21 individuals) had the longest daily path length. They put this down to the group needing more resources due to its size. While I did not notice a pattern of troop size and path length per observation period in my study, the longer path length per observation period or higher meters per hour for the DF troops would imply that they have to travel more to find enough food to meet their nutritional needs in a degraded habitat.

Reflections

The data collection method used in this study was focal animal sampling with instantaneous sample points, and I only studied the colobus monkeys in morning and evening periods. Most researchers conducting behavioural studies on primates in the field use scan sampling. Also, most other studies cover whole days, but since my focus was on foraging behaviour I observed the animals during the time of the day when they were expected to be most active. For this reason my results are difficult to compare with other studies.

As in most studies in behavioural ecology, it is desirable to follow the animals over a long period of time. Considering the huge differences between seasons and from year to year, a period of three years would have given a much more general picture of the monkey's behaviour. For the same reasons, I would also have liked to include more troops in the study. To accurately determine the diet and behaviour of the colobus monkeys, whole day studies should be conducted and for multiple seasons. All this is obviously not possible in a master thesis but I still think that my study reveals major differences of the monkeys' behaviour between the two forest types.

Along with the method used I should have included the recording of the temperature, as this may have had something to do with the foraging and resting behaviours.
I did not give unique GPS positions to the feeding trees. In a study by Harris and Chapman (2007), they did this and were able to show the positions of the trees foraged in by each troop and the extent of the home range. With this information I could have more accurately stated why the troops spent more time in different parts of their home ranges. In a better study, all trees in the forest, i.e. trees used and ignored by the monkeys, should have been mapped. Another useful piece of information would have been nutritional content of the feeding trees and the food items. In my study I searched the internet for this information and only found detailed information on a few species. A full analysis of the food items would shed a lot of light on why they are favoured by the monkeys. However, given the limited time and funding for my study, we chose to drop this part since it had reduced the behavioural data collection.
Mature leaves were the most foraged for food item in this study. I do not believe this to be entirely true. My plant expert was very good at identifying plant species. However in the time we had to indentify plant species, plant part, canopy height and still be focused on the same two individual monkeys out of up to nine monkeys all interacting, all in less than one minute, it was very hard to tell the difference between young and mature leaves. Even more so over ten meters up in a tree. More experience at this would have been needed before starting a proper study. (Again, we talk on phone about this).
In home range analysis, periods such as week are split up and compared for site fidelity to make sure the overall home range is an accurate representation of the troops' area usage (Harris and Chapman 2007). However, I did not observe single troops for whole weeks or even whole days. Hence, my home ranges may not really represent the actual home ranges of the six troops for the wet season. Whatsoever, as I did the same thing for all six troops it may still be a good method to compare between troops even if they are not the true home ranges of the troops.

The future of Colobus angolensis palliatus in Diani

The forests of Diani hold the second largest population of *Colobus angolensis palliatus* in the Kwale District (Anderson *et al* 2007a), and as such it is a very important area for the continued survival of this subspecies. As can be seen from my study, troops inhabiting the pristine forest patches of Diani appear to be in better shape when compared to the troops inhabiting the degraded forest areas. Overall the colobus monkeys foraged mainly for leaves, and for the most part from trees, showing the importance of forests. They are already showing signs of stress outside of the pristine forest patches and won't be able to adapt like the baboons, sykes's or vervet monkeys have, who have a single stomach and are omnivorous. 75% of these forests have been lost due to the development for tourism since the 70's (Kanga and Heidi 1999). I have no doubt that what remained since that last survey in the year 1997 has been deforested to some extent. When comparing the Google images of the area, which are only a few years old, I observed during my study that there were large chunks out of the most pristine forest patches. This was for either the development of a new hotel, which is only open during the dry season, or a private residence which may be frequented only a few times a year. Although I did see locals poaching wood from the pristine forest patches, they did not clear the forests on such a short time scale and to such a high extent as the hotel and private owners did. Also the local people believe the Baobab trees contain a daemon in them and are afraid to cut them down. As this is such an important food tree to the colobus monkeys, this is not such a bad myth to have around. However, some land developers have no such qualms about daemons in trees. On the other hand,

some of the wealthy people living in Diani are extremely interested in protecting the colobus and actively stand up for their protection and continued survival in the area. Also the Colobus Trust is making some progress with colobridges linking forest fragments, planting their main food trees everywhere and educating the local school children. Only time will tell if this is enough. Populations there are already relatively inbred (Kanga and Heidi 1999). Planning rules are not enforced in Diani, and unless development is halted and the deforested areas given time to regrow, the future is uncertain for *Colobus angolensis palliatus* in Diani Beach.

CONCLUSIONS

During the long rains period colobus monkeys in Diani mainly forage for leaves, and their foraging activities for the most part occur in 16 tree species.
There are very little differences in sex and age class behaviours except for juveniles, suggesting they synchronized their activities. But most of the females were not lactating yet at the time of this study. Juveniles are naturally more active so any differences here are not surprising.
For this period colobus monkeys foraged significantly more in the evening and rested significantly more in the morning. This may be due to differences in temperature or simply that they are still digesting food from the previous evening during the next morning.
Comparing PF and DF troops, the only significant differences in behaviour were for foraging and resting during the morning period. The DF troops foraged significantly more than the PF troops in the morning and the PF troops rested significantly more than the DF troops in the morning. The PF troops mainly foraged from 2-3 native tree species. But the DF troops foraged in different amounts from eight main feeding plants, which were a mixture of native and exotic species. The DF troops also foraged in a significantly higher number of species per observation period than the PF troops did, which is an indicator of poor habitat quality.
The PF troops home ranges were slightly bigger than the DF troops home ranges, which is most likely partly due to the presence of predators.
Home range over lap was a lot higher in the DF troops' home ranges, further highlighting that lower resource levels may lead to greater chances of inter troop conflicts.
The fact that the DF troops have to travel further each day as indicated by their daily path length, again shows that their resources are either of low quality or are more widely spaced out, making troop conflicts more likely to happen.

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APPENDIX

Table 7. List of 72 trees and plants fed on by the six colobus troops

Code	Latin name	Digo Name	Common name	Native	Exotic
Ad	*Adansonia digitala*	mbuyu	Baobab	X	
Adsp	*Adenia species*			X	
Adp	*Adonanthera parvonina*		Sandal wood		X
Ai	*Azadrachtica indica*	mklifi	Neem		X
Al	*Alcornea laxiflora*	mvunja jembe		X	
At	*Antaris toxicaria*	mnguon guo	False mvule	X	
Bc	*Bridelia carthatica*	mkala kala		X	
Bs	*Bourgainvillea spectabius*	mboga nvilla			X
Bw	*Balanites wilsoneana*	mkonga		X	
Ca	*Carpodiptera africana*	mlangalanga		X	
Co	*Cordia monoica*	humbalangulwe	Sandpaper tree	X	
Cp	*Ceiboi pentendra*	msufi			X
Csc	*Combretum schumannii*	mvia many		X	
Csp	*Cassia sp*			X	
Cysp	*Cysphotema species*			X	
Cz	*Cussonia zimmermannii*	mnyapala/mbombamaji	Cabbage tree	X	
Dc	*Dispyros consolatae*			X	
Dr	*Delonix regia*	msukuku/mjohoro	Flamboyant		X
Ds	*Diospyros squarrosa*	mpweke		X	
Dv	*Daibergia vaccinifolius*	humbo langulwe		X	
Em	*Erythroxylum emarginatum*	chifumai		X	
Es	*Erythrina sacleuxii*	mbamba nyoma		X	
Fb	*Ficus benjamina*		Java fig/bejamins fig		X
Fem	*Fernandoa magnificia*	mlalamga zuka		X	
Fl	*Ficus lingua*	mlandaga/kiuzi	Strangling fig	X	
Fs	*Ficus sycomorus*	mkuyu	Sycamore fig	X	
Fsu	*Ficus sur*	mkuyu	Cape fig	X	
Fv	*Flueggea virosa*	mkwamba		X	
Fx	*Ficus exasperata*	msasa		X	
Fz	*Ficus zanzibarica*	mkuyu		X	
Gh	*Grewia holstii*	mbavumbavu		X	
Gp	*Grewia plagiophylla*	mkone		X	
Gv	*Grewia vaughanii*	mtsaye		X	
Ha	*Harrisonia abbisinica*	mkidori		X	
Hi	*Haplocoeleum inoploeum*	mfunga tanzu		X	
Hp	*Hemi parasite*			X	
Hz	*Hunteria zeuanica*	mziwa ziwa		X	
Lf	*Lecaniodiscus fraxinifolius*	mremero		X	
Li	*Lianas*	mbugumbugu		X	

Lsw	*Lannea schwanforthii*	mchumbu		X	
Lw	*Lannea welwitschii*	mchumbu maji		X	
Me	*Milicia exclesa*	iroko, mvuli		X	
Mf	*Monathotaxis fornicata*	mgwene madevu		X	
Mg	*Monodora grandidiera*	mkere		X	
Mi	*Mangifera indica*	mwembe			X
Mkongolo		Mkongolo		X	
Mkz	*Markhamia zanzibarica*	mpalawanda		X	
Mo	*Mallotus oppositifolius*	mvunja jembe		X	
Ms	*Manikara sulcata*	mngambo		X	
Msp	*Manikara species*				
Mt	*Mayena tetraphilla*			X	
Mu	*Millettia usaramensis*	muvamva		X	
Mz	*Magidea zanguebarica*	mlanyuni		X	
Mzera		Mzera		X	
Os	*Oncoba spinosa*	mnyondoya		X	
Pd	*Pathelocelobium dulce*		Madraz thorn		X
Ph	*Premna hilderbrandii*	muusa pungu		X	
Pr	*Plumeria rubra*				X
Sa	*Stercularia africana*	mugoza	African star	X	
Sc	*Spathodea campanulata*				X
Si	*Sideroxylon inerme*	mkoko bara		X	
Sm	*Sorindea madagascarensis*	mkunguma		X	
Te	*Trichilia emetica*	munwamadzi	Cape mahogoni	X	
Tf	*Tapura fischeri*			X	
Tg	*Tictona grandis*	mtiki			X
Tm	*Tamarindus indica*	mkwaju			X
Tn	*Turrae nilotica*	moza mama		X	
To	*Trema orientalis*	mbonobono	Charcoal wood	X	
Tp	*Thervetia peruviuna*	mkodi	Milk bush/yellow oleander		X
Tw	*Turrae wakiefiedii*	muoza nyama		X	
Uva	*Uvaria acuminata*	mnguene chetu		X	
Xp	*Xylopia pavifolia*	mchiza tsaka		X	
Zc	*Zanthoxylum chalybeum*	mdungu	Prickly ash/ knob wood	X	
Un	Species unknown			X	