GASTRO-INTESTINAL PARASITE INFECTIONS IN THE ANGOLAN BLACK AND WHITE COLOBUS MONKEY (*COLOBUS ANGOLENSIS PALLIATUS*) IN SOUTHERN KENYA IN RELATION TO AGE, SEX AND HABITAT INTERFERENCE

BY

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DECLARATION

I hereby declare that this is my original work and has not been presented for the award of a degree in any other University.

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DEDICATION

I dedicate this work to my late beloved Mother and my beloved Father, both of whom have encouraged me with tireless belief and support to reach this stage.

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ABSTRACT

Approximately 2000 black and white Angolan Colobus, (*Colobus angolensis palliatus*) remain in Kenya, Kwale District. The arboreal primate species is threatened by unchecked deforestation for private development currently ongoing in Kwale District, and also countrywide. The aim of this study was to determine the prevalence of gastro-intestinal parasites in *C. angolensis* in Diani in relation to age, sex and habitat disturbance. Parasites of *C. angolensis* were compared to those of *C. Guereza* in Kitale and other non-human primates in Diani. It was viewed as important to establish the gastro-intestinal parasitic fauna of the Angolan Colobus and other Diani non-human primates in the interests of public health, and also to determine whether habitat change influences Colobus parasite patterns. The study was undertaken in collaboration with the Colobus Trust, an organization dedicated to conserving the Angolan Colobus.

The primary study area was Diani Beach, Kwale District. The second area of study (for the sampling of *C. Guereza*) was located near Kitale town, TransNzoia District. Faecal samples were collected from several *C. angolensis* troops with comparative samples collected from Guereza Colobus in Kitale and non-human primates in Diani. Samples were processed using the Formol-Ether concentration technique, the McMaster's floatation technique and the Harada-Mori larval culture technique. Vegetation transects were conducted through Angolan Colobus troop territories to assess the vegetation integrity; three Colobus troops (from areas of varying integrity) were followed to gather behavioural and other data regarding the troops' environment. Angolan Colobus faecal samples had *Entamoeba coli* and *Entamoeba histolytica* cysts, and eggs of *Trichuris spp*, *Strongyloides spp* and *Enterobius vermicularis* nematode species. Guereza Colobus faecal samples exhibited only *E. coli* and *E. histolytica* cysts. *Balantidium coli* cysts were also found, but only in the Baboon samples. Age and sex showed no influence on parasite prevalence or intensity. *E. coli* and *E. histolytica* prevalence was similar in the Angolan and Guereza Colobus and other primates sampled, whereas intensities of *Trichuris* and *Strongyloides* eggs were highest in Baboons. Thirteen out of 29 of the Colobus samples from the Harada-Mori larval culture were positive for *Strongyloides* species. There was less than 10% variation in the prevalence of parasitic fauna found between Angolan Colobus troops from varying habitat types.

Colobus angolensis and *C. Guereza* troops showed similar activity patterns throughout the day, with variations occurring in feeding ($p < 0.05$) and moving ($p < 0.005$) patterns and a significant difference found between mean height above ground ($p < 0.01$), with *C. Guereza* maintaining a higher height above ground.

Ground contact was viewed as the main mode of parasitic infection in the Angolan Colobus. The minimal influence of habitat on parasite prevalence suggests that factors alternative to forest degradation may be responsible for increased ground contact in *C. angolensis*. However diminishing forest cover has negative implications for public health in Diani, bringing human and primate populations into closer proximity and increasing the potential for zoonotic infections. Further observations may reveal more about factors potentially facilitating parasite infection. A policy aimed at preserving the Diani forest and raising awareness to the impacts of deforestation will invariably contribute towards the conservation of Angolan Colobus in Kenya.

1.0 INTRODUCTION

The Angolan Colobus *(Colobus angolensis*) monkey population in Kenya is restricted to the Kwale District of the Coast Province. Diani Beach in Kwale District contains a large population (over 400) of *C. angolensis* (Colobus Trust[1], personal communication), and was the main site for this study. Presently, approximately 2000 Angolan Colobus remain in Kenya (Colobus Trust, pers. comm.).

The forest habitat in Diani is considerably threatened by the constantly expanding human activities that are taking place. Currently, less than 25% remains of the original coastal forest characterising the majority of Diani's habitat (Colobus Trust, pers. comm.).

The environment is an important factor influencing parasitic infection. Primates act as indicators of the degree of change occurring in a habitat, and habitat changes have the potential to affect how they deal with parasitic infection (Mittermeier and Cheney, 1987). As the increasing human population in Diani continues to encroach on and alter the forest habitat of the Angolan Colobus, the primate species is brought into closer proximity with garbage, waste and increased noise levels, which may have an effect on the prevalence levels of parasitic infection in this primate.

Other factors contributing to parasite prevalence include predatory pressure and gut complexity variables, which have been found to strongly correlate with parasite load (Watve and Sukumar, 1995). *Colobus angolensis* has natural predators in the form of leopards and birds of prey (Oates, 1977a), although in Diani it has been reported that

[1] www.Colobustrust.org

dogs have also killed Colobus monkeys on several occasions, and could be classified as contemporary Colobus predators (Colobus Trust, pers. comm.).

This study was undertaken in collaboration with the Colobus Trust, an organization that has played an active role in the conservation of the Angolan Colobus monkey. Gaps in the parasitic data available for this monkey species were identified, and the filling of these gaps formed the basis for this study. Due to the lack of information regarding the parasites of non-human primates in Diani, parasite diversity and distribution within the Colobus population were unknown and it was unclear whether the parasites could pose a problem, not only for the Colobus but also for the human population in Diani. It was therefore important to determine parasite prevalence in the Colobus and other non-human primates in this area, as some parasites in the non-human primate population are likely to be zoonotic, and consequently are relevant in terms of public health. There was also a desire to establish whether the presence and prevalence of parasites in the Diani primate population was related to the changes occurring in the environment in the form of the ongoing degradation of the Diani forest.

Other diurnal primate species in Diani are the sykes monkey (*Cercopithecus albogularis*), the Vervet monkey (*Cercopithecus aethiops*) and the yellow Baboon (*Papio cynocephalus*).

Guereza black and white Colobus monkeys (*Colobus Guereza*) were included in this study for comparison with the Angolan Colobus in terms of the type and diversity of parasite taxa infecting them, and also for some indication of the factors influencing parasitic patterns in Kenyan black and white Colobus populations.

2.0 OBJECTIVES

The main objective of this study was to provide in a non-invasive manner, a database of gastro-intestinal parasites found in the Diani Colobus monkey population. The goal is to contribute to conservation efforts aimed at the Angolan Colobus and its habitat through fulfillment of the following specified objectives:

1. To determine the prevalence of the gastro-intestinal parasites in the *Colobus angolensis* population in Diani Beach.

2. To determine the influence of age and sex of the host on intensity of infection and parasite diversity within the *Colobus angolensis* population in Diani Beach.

3. To provide base-line information on disturbance levels within the Diani habitat of *Colobus angolensis* by investigating the influences of habitat degradation, predator presence and human (noise) disturbance on Colobus parasite profiles.

4. To compare parasitic diversity in *Colobus angolensis* with opportunistically sampled Guereza Colobus monkeys (*Colobus Guereza*) in Kitale (Transnzoia District), yellow Baboons (*Papio cynocephalus*) and lowland sykes (*Cercopithecus albogularis*) monkey species in Diani Beach (Kwale District).

3.0 LITERATURE REVIEW

3.1 TAXONOMY

The word "Colobus" originates from the Greek word "Kolobos" meaning "mutilated one", as colobine monkeys lack a thumb digit (Burton, 1995).

Black and white Colobus monkeys belong to the Old World Monkey family (the Cercopithecidae), and are classified in the Colobinae sub-family. There are five separate species of black and white Colobus in this sub-family: *Colobus polykomos*, *C. satanas*, *C. Guereza*, *C. vellorosus* and *C. angolensis* (Oates and Trocco, 1983). Of these, *C. Guereza* and *C. angolensis* are found in Kenya, with *C. Guereza* occurring in the highlands, Rift Valley province, and *C. angolensis* in the Coast province.

The black and white Angolan Colobus (Plate 1), *C. angolensis* (sub-species *C. angolensis palliatus)* is characterised by white hair on the sides of the face, the throat and the tail tip, while the rest of the body is covered by black hair (Burton, 1995). Infants are born pure white, and obtain black colouring at 3 – 4 months of age. The adult body mass ranges from 6 – 11.4 kilograms and group sizes are normally between 10 – 15 individuals (Colobus Trust Records, 2003).

Plate 1 – ***Colobus angolensis* resting in vegetation**

3.2 ECOLOGY

Other than the Kenyan coast, the Angolan Colobus also occurs in Angola, Burundi, Rwanda, Tanzania, Uganda, Zambia and Zaire. The lack of a thumb in members of the colobinae is an adaptation for climbing, as they are arboreal primates. They rarely come to the ground and most of their feeding and interacting takes place at the canopy level of the forest.

The species occurs in different types of forest and woodland habitat, mainly primary forest and swamp forest (McGraw, 1994), although they have also been seen in secondary or single species forests. They are rare in disturbed forest, or secondary vegetation habitats (Moreno-Black and Maples, 1977).

3.3 DIET

Like other members of the colobinae, *C. angolensis* is mainly a folivorous primate, feeding on both leguminous and non-leguminous leaves (Maisels *et al.*, 1994).

As an adaptation to a folivorous diet, colobinae have a specialised multi-chambered stomach for fermentation. Fermentation of leafy food occurs in the saccus gastricus, with the formation of volatile fatty acids; a mechanism that is similar to the one that occurs in the rumen of ruminants (Kay *et al.*, 1976). Other components in the colobine diet include fruits, flowers and seeds (Tutin *et al.*, 1997). A large proportion of the *C. angolensis* diet consists of seeds; young leaves, immature fruits and flowers are eaten according to seasonal availability.

Plant species with high tannin levels are avoided (Maisels *et al.*, 1994). During the dry season, Angolan Colobus troops increase their dietary diversity, and spend more time feeding (Lowe and Sturrock, 1998).

The dietary range varies with the Colobus monkey species, as each species has its particular method of food procurement, or different additional food types in the diet (Kelley, 1990). Dietary range is also dependent on the seasonality of the food (Clutton-Brock, 1975). Different parts of different plants are eaten, making the diet of Angolan Colobus diverse in components (Maisels *et al.*, 1994).

Colobines have also been observed practicing geophagy (eating soil), particularly clay. The fermentation process in the colobine stomach releases gas and alters the stomach pH, and geophagy may be a method of toxin absorption and pH adjustment of the gut (Mahaney and Krishnamani, 2000), as well as a means of mineral supplementation.

3.4 SOCIAL STRUCTURE AND BEHAVIOUR

Angolan Colobus troops normally consist of an adult male, one or more females and their young. Multi-male groups also occur (Groves, 1973), and temporary gatherings of more than 300 Angolan Colobus have been sighted, but group size tends to be smaller in areas disturbed by deforestation (Kingston, 1971). Colobus have a more spatial distribution than other forest primate species: *C. angolensis* also exhibits higher perching heights in the forest than other arboreal primates (McGraw, 1994).

The species is territorial; territories are only a small part of the home range, which usually covers several square kilometres. Colobine sleeping sites are located in tall trees, near food sources and away from other troops (von Hippel, 1998).

Angolan Colobus monkeys and other colobines have been observed forming mixed species troops (Groves, 1973; Moreno-Black and Maples, 1977). This is thought to increase foraging efficiency, as the different species feed on different types of forage, which decreases inter-specific competition (Gautier *et al.*, 1997). Interaction with other primate species also occurs (via play and grooming) when troops come across each other. Colobus are active in the early morning hours, and late afternoon or dusk. During the hottest times of day, they are usually found at the top of the tree canopy, feeding and sunning themselves (McGraw, 1994).

Communication between individuals is achieved by a repertoire of calls, visual signals or visual displays, each with a distinct meaning (Estes, 1991). Sensory communication is also used, mainly for the purposes of soliciting social grooming (Estes, 1991). Adult male Colobus produce loud calls known as roars and jump from branch to branch when calling, behaviour known as the "jumping-roaring" display (Groves, 1973).

3.5 GASTRO-INTESTINAL PARASITES

3.5.1 COLOBINAE

Information regarding the parasites of *C. angolensis* is limited, as few gastro-intestinal (GIT) parasites have been documented. Due to similarities in diet and lifestyle, it can be assumed that *C. angolensis* is vulnerable to the same parasites affecting other members of the colobinae and other arboreal primate species.

Munene *et al*., (1998) investigated the incidence of GIT parasites in several non – human primate species, including a black and white Colobus, *C. abyssinicus* (also known as *C. Guereza*). The results showed the Colobus to be infected only by *Trichuris* helminth species, compared to the multi-parasitic infections observed in other primate species in the study. Similar findings report the incidence of gastric trichuriasis in a black and white Colobus (Loomis and Wright, 1986).

The death of a captive Guereza black and white Colobus from oesophagostomiasis (*Oesophagostomum spp*) has also been reported at the Institute of Primate Research in Kenya (David Langoi, personal communication).

3.5.2 OTHER NON-HUMAN PRIMATES

The other non-human primates referred to in this context are Baboons and sykes monkeys, diurnal species that share their habitat with the Angolan Colobus in Diani.

A Study carried out by Munene *et al.,* (1998) included the primate species mentioned above, and showed that, in these species *Trichuris spp, Strongyloides fulleborni, Strongyles spp*, and *Schistosoma mansoni* (*S. mansoni* were present only in Baboons) occurred in the gastro-intestinal tract of these non-human primates. Gastro-intestinal protozoan parasites identified in these primates included *Entamoeba coli, Balantidium coli* and *Entamoeba histolytica.*

A recent study (Hahn *et al.,* 2003) has reported the presence of strongylids (*Oesophagostomum, Trichostrongylus, Ternidens*) together with *Streptopharagus*, *Physaloptera*, *Trichuris*, *Enterobius* and *Strongyloides* parasite species in Baboons.

Cyclospora colobi was reported in *C. angolensis* and *C. Guereza* (Njenga *et al.,* 2001). Baboons are also susceptible to *Cryptosporidium* cysts (Suleman *et al.*, 1997).

A basic survey of some individual monkeys in the Diani beach non-human primate population found the following GIT parasites (Obadha, 1999):

Entamoeba coli, Entamoeba histolytica, Balantidium coli, Strongyloides spp, Trichostrongylus spp, Trichuris spp, Oesophagostomum spp and *Enterobius vermicularis*. *E. histolytica, Trichostrongylus spp,* and *E. vermicularis* were not reported in the Angolan Colobus.

4.0 PROJECT JUSTIFICATION

4.1 STATUS OF THE ANGOLAN COLOBUS IN KENYA

The World Conservation Union's (IUCN) African Primates Report (Oates, 1996) classifies the Angolan Colobus as being at risk of becoming vulnerable to extinction. The status of the Angolan Colobus in Diani (and elsewhere in Africa) is mainly due to uncontrolled deforestation. This has been predicted as a long-term threat to the stability of the Colobus population in Diani (Oates, 1977b), because of the species' heavy dependence on mature forests, and because habitat destruction affects a primate's ability to resist hunting or predation (Bernstein *et al.*, 1976). The deforestation rate in Africa is higher than on any other continent (Deutscher Bundestag, 1990), and is cause for great concern. More recently, it was also shown that forest destruction acts as an additional threat to the stability of primate populations (Stocstad, 2004). The current status of the Angolan Colobus habitat and other possible factors affecting the species have not all yet been comprehensively documented, further hampering conservation efforts.

Hunting although banned in Kenya, is nevertheless a more immediate threat in the form of the bushmeat trade, which is occurring unsustainably (Butynski, 1997) all over Africa. Some African tribes eat Colobus monkey meat and covet the skins for making hats, drums and coats out of their striking hair.

4.2 PROJECT SIGNIFICANCE

Further information on the Angolan Colobus is required to contribute towards the species' future conservation. This study aims to provide information on the parasite patterns of Angolan Colobus in Kenya, shed light on infection patterns in the species and other primate species in Diani, and possibly also indicate how infection is occurring. Parasite information obtained from the Colobus and other primates in the area from this study can be used as an indication of infections in other primate populations in Kwale District and also be used in the interests of public health.

Parasitic information regarding the primates in the area is linked to the alteration of the habitat (via deforestation in Diani), as this may have affected parasite prevalence levels. This aspect of parasite prevalence has not previously been investigated in Diani. The decreasing forest area brings primates into closer proximity to humans and to each other, increasing the chances of parasite transmission. Interactions between the Colobus and the other non-human primates also provide an opportunity for transmission (Moreno-Black and Maples, 1977).

5.0 MATERIALS AND METHODS

5.1 STUDY AREAS

5.1.1 DIANI

The primary study area was Diani Beach, a popular tourist destination situated in the Kenyan South Coast, Kwale District, approximately 30 km south of Mombasa (4°15'30" to 4°35'30" S and 39°35'00" to 39°34'30" E) with an altitude at sea level (Fig. 1). The area has a climate typical of the Kenyan coast, with temperatures of up to 35°C during the dry season, which occurs from December to February and from June to August. Milder temperatures of up to 28°C are experienced in the rainy seasons, (from March to May and from September to November); humidity in this area varies between 80-100%.

The Diani forest is an ancient indigenous coastal forest with a coral rag floor covered with soil of erratic depth in different areas. The forest has been degraded into patches and stretches by hotel development and agricultural encroachment (Kahumbu, 1997), as the local authorities have developed no land-use policy.

The forest spans between 0.5 – 1 km in width, and extends over a distance of 12 km along the coast, taking up a total area of 5.72 km^2. Diani is a popular destination for foreign and local tourists, and has a high concentration of hotels and businesses situated along the beachfront. Diani is bisected by a main road, which extends the length of the area (Fig. 1). The road has the effect of bisecting the forest into inland and beachfront patches that vary in terms of size and quality of the forest.

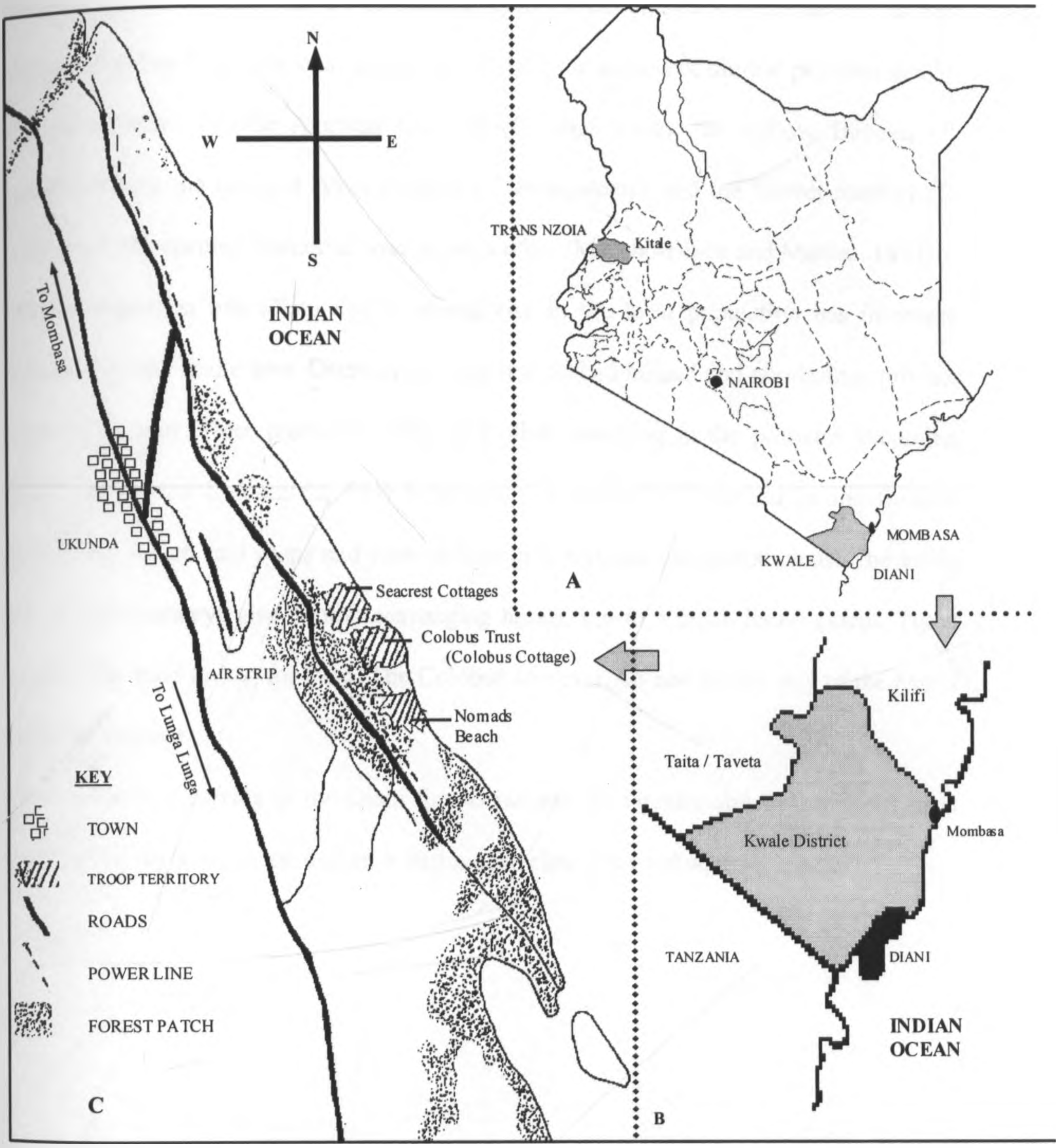


Fig. 1: A- Map of Kenya showing location of study areas (Kwale and Transnzoia districts)

B- Map of Kwale showing location of Diani Beach

C- Map of Diani showing sampling range

Diani is one of the most densely primate-populated areas outside a National Park in East Africa (Colobus Trust, personal communication). Four species of diurnal primates inhabit this area (Plate 2); the Angolan Colobus (*C. angolensis*), the yellow Baboon (*P. cynocephalus*), the lowland sykes monkey (*C. albogularis*), and the Vervet monkey (*C. aethiops*). The species' territories overlap each other (Moreno-Black and Maples, 1977).

Human migration into Diani and a general rise in the local population has increased human intensity in the area. Decreasing space has pushed human and non-human primate populations into closer proximity with each other, resulting in the primates becoming highly habituated to humans. This habituation is particularly marked in the Baboon population, which raid crops and rubbish bins in hotels and residential areas. The sykes and Vervet monkeys also exhibit scavenging habits, but to a much lesser extent. These species also tend to beg for food. The Colobus however, do not exhibit any of the habits mentioned above.

Other wildlife occurring in the Diani forests include the Greater and Lesser bushbabies species, Harvey's red forest duiker, a bushpig species, and a red squirrel species.

Plate 2 – Diurnal primates of Diani

a) The Angolan Colobus monkey

b) The Lowland sykes monkey

c) The Yellow Baboon

5.1.2 THE COLOBUS TRUST

The Colobus Trust (also known as Wakuluzu, friends of the Colobus) is a non-governmental organization based in Diani Beach (Plate 3), dedicated to the conservation of the Angolan Colobus in Kenya, and one that also played a major role in this study.

The Colobus Trust was founded in 1997 by Dr. Paula Kahumbu, who observed the large number of Colobus being run over by cars and electrocuted by uninsulated power cables. As well as being a primate conservation centre, it has expanded in recent years to encompass an educational agenda, with workshops about the Colobus monkey and tours around the Colobus Trust and surrounding forest aimed at educating tourists and locals about the Colobus Trust's work and primate conservation.

The Colobus Trust is also concerned with the protection of the coastal Kaya (sacred) forests. Kayas are significant cultural sites for the coastal Mijikenda tribes, as well as being sites of high biodiversity (Kayas consist mainly of indigenous trees), and significant habitats for the arboreal primates in the area, namely sykes and Colobus.

<u>PLATE 3</u> – Entrance to the Colobus Trust

5.1.3 KITALE

The second area of study (where the Guereza Colobus were observed) is located on the outskirts of Kitale town in TransNzoia District, Rift Valley Province (1°02'481" N and 34°58'765" E), and east of Mount Elgon, which acts as the main water catchment area in Western Kenya. The study area is about 1846 metres above sea level and is located on land belonging to the Kenya Agricultural Research Institute (K.A.R.I).

The area is a patch of indigenous riverine forest spread out along a steep-sided gorge approximately 15m deep and measuring about 1.1 km long by 0.1 km wide; the trees are up to 30m tall, but are widely spaced apart (an average of 10 metres or so apart). Dense tall undergrowth (6-8m in height) occurs on the sides of the ravine. The forest patch has almost been decimated by logging for firewood and burning to make way for agriculture, and is surrounded on both sides by extensive maize plantations (see Plate 4). There is a troop of Guereza Colobus (*C. Guereza*) that are resident in the forest and two troops of Vervet monkeys that frequent the forest.

Constant human-wildlife conflict occurs in and around the forest. Whereas the Colobus stay in the forest, the Vervets raid the surrounding maize plantations regularly. As a result, the forest is patrolled daily by villagers who employ a variety of tactics to chase away both Vervets and Colobus indiscriminately. The Colobus and the Vervet troops are scheduled for translocation to a private game reserve on the slopes of Mount Elgon.

Plate 4 – The forest habitat of the Guereza Colobus troop, Kitale

5.2 COLOBUS STATISTICS

5.2.1 THE ANGOLAN COLOBUS

Information from the Colobus Trust records indicates that there were 64 troops of Colobus, and about 30 solitary individuals in Diani during the period of study. About 436 individuals make up the population and are classified (mainly from size) by the Colobus Trust as adults, sub adults, juveniles and infants, descriptions which are expanded below.

- Infants between 0-3 months old are pure white in colour, after which they turn grey, and by 6 months, have obtained a black and white colouring. At all stages they are dependent on their mothers.
- Juveniles are classified as young Colobus that are being weaned or are no longer suckling. They are distinct from black and white infants by a degree of independence even when still relatively small in size, and will spend a large part of the day away from their mothers.

- Sub-adults are completely independent, but have not yet gained the full size of an adult.
- Adult males are larger than females. Colobus males are marked by a thin white stripe between their legs, while females have a patch of white hair around their vulva. The male to female ratio is 1:1.7 [2] (Colobus Trust, personal communication).

5.3 SAMPLE COLLECTION

The researcher accompanied by three field assistants from the Colobus Trust (who were familiar with the Diani Forest and resident Colobus troops) carried out data collection in Diani beach. No field assistants were involved in data collection in Kitale.

Faecal samples were continuously collected from June to August, which was mainly dry, with occasional rain. Faecal samples were collected from individual members of several troops of Angolan Colobus monkeys. Samples were collected throughout the day, with some troops revisited for a representative sample from a particular age or sex group that was initially missed. Faeces consistency was recorded as:

F = Formed/firm faeces

S = Soft faeces

R = Runny/diarrhea-like faeces

Samples were placed in plastic containers and labelled according to age, sex and area of collection as follows:

[2] Colobus Trust records are updated on an annual basis.

Adult Male = 1 | Adult Female = 2

Sub-adult Male = 3 | Sub-adult Female = 4

Juvenile Male = 5 | Juvenile Female = 6

No labelling for infant samples was done since they could not be distinguished from those of their mothers.

For members of the same troop belonging to the same sex and age groups, faecal samples were collected from all individuals on the same day to avoid future confusion of their samples. Troop members sharing the same age-sex group were coded as follows:

Adult Female 1 = 21

Adult Female 2 = 22

Adult Female 3 = 23

Lone individuals (usually adult males) were coded LoM, or Lo followed by numbers coding their sex-age group.

Troops were distinguished by the location of sample collection (which was normally within the troop's territorial area). The location was labelled with initials to assign each area an identification tag. Time and date of sample collection was recorded on a datasheet, a sample of which is shown in Appendix A1. Each sample was wrapped in the cellophane glove used for its collection, and placed in a cardboard box during transportation in the field. At the laboratory the sample was divided into 3 portions of equal size. The 3 portions were divided as follows.

1. A portion of the sample was put in a 50ml centrifuge tube and preserved in 10% formalin made up to approximately two-thirds of the sample's volume for processing using the Formol-Ether concentration technique.

2. The second portion of the sample was put in a coolbox and kept fresh for processing using the McMaster's faecal floatation technique.

3. The third portion of the sample was processed using the Harada-Mori larval culture technique.

When the sample collected was not large enough for all the processing techniques to be conducted, it was processed using only the Formol-Ether concentration technique. This technique was given priority over the latter two, as it is the most sensitive with regard to the detection of ova and cysts (Ash and Orihel, 1991).

5.3.1 COMPARATIVE SAMPLES

Opportunistic samples were collected from Sykes and Baboons in Diani during the same period as the collection of the Colobus samples. Guereza Colobus samples were collected in Kitale from a troop of 11 Guereza Colobus.

Sample collection for the other primate species was conducted in the same manner as for the Angolan Colobus samples. They were labelled as shown below.

BB1, BB2, BB3 = Baboon samples

SS1, SS2, SS3 = Sykes samples

GG1, GG2, GG3 = Guereza samples

5.4 LABORATORY PROCEDURES

The Formol-Ether concentration technique was carried out at laboratories in the Mombasa Hospital, Mombasa, and at the Institute of Primate Research (IPR), Nairobi respectively. The McMaster's faecal floatation technique was also conducted at the Mombasa Hospital Laboratory. The Harada-Mori larval culture was initially set up and carried out in the Veterinary clinic at the Colobus Trust, and then larvae produced from the cultures were preserved in 10% formalin for identification at IPR.

(1) The Formol-Ether Concentration Technique

The Formol-Ether concentration technique was used to determine the presence of protozoan cysts and nematode ova. The methodology used was adapted from Müller-Graf *et al.*, (1996) and Munene *et al.*, (1998).

1. 1 – 2g of faeces were emulsified with 10% formalin.
2. The solution was strained through a tea strainer into a centrifuge tube to make up 10 ml of solution.
3. 3ml of ether was added; the solution was shaken thoroughly (taking the usual precautions with ether exposed to air).

4. The solution was centrifuged for 10 minutes at 500 r.p.m.
5. The supernatant was poured off.
6. The fatty debris at the interface was loosened with an applicator stick and the supernatant together with the debris poured off, then the sides of the tube were wiped clean.
7. The small deposit at the bottom of the tube was emulsified with the last drop of fluid.
8. A drop was extracted with a pipette, stained with iodine and placed on a slide.
9. The drop was covered with a no.1 coverslip and the concentration of parasite cysts and helminth ova determined at 250x magnification.

During examination, the maximum number of protozoan cysts observed per field of view was recorded, as the number per slide was usually too numerous to count. Helminth ova were counted according to the number seen per slide, as they occurred in considerably lower numbers. Counting was conducted at 250x magnification. A 400x magnification was used to confirm identification of cysts and ova.

(2) The McMaster's Faecal Floatation Technique

The McMaster's faecal floatation technique was employed to count the number of helminth ova present in a fresh faecal sample as described by Aiello (1998).

1. 2g of fresh faeces was added to 28ml of saturated salt solution (about 460g of NaCl / litre distilled water), and mixed thoroughly using an applicator stick.

2. The mixture was strained through a sieve into a beaker and remixed thoroughly.
3. The mixture was loaded into the chambers of a McMaster slide using a pipette, and examined for eggs at 100x magnification. The number of eggs observed for different parasite species per slide was counted and recorded.
4. The number of eggs was multiplied by a factor of 50 for calculating the number of eggs per gram (e.p.g) of faeces.

(3) Harada-Mori Filter Paper Strip Larval Culture Technique

The Harada-Mori technique was used for larval culture in accordance with the method employed by Karere and Munene (2002).

1. A filter paper strip of approximately 13 x 120mm was prepared, with the end tapered to a point. About 0.5-1.0g of fresh faecal material was spread as evenly as possible onto the middle of the filter paper, so that it covered approximately one third of the strip.
2. The strip was inserted into a conical 15ml centrifuge tube so that it reached within several millimeters of the bottom of the tube.
3. Distilled water was carefully added until the water level was slightly below the faecal mass.
4. The tube was kept upright at room temperature for 7-10 days and examined daily to maintain the water level (as some evaporation would occur during the first few days).

5. After 7-10 days the distilled water was removed from the bottom of the tube by means of a pipette and transferred to a petri dish to be examined for larvae. Any larvae seen were preserved in 10% formalin for further examination.

5.5 VEGETATION TRANSECTS

Vegetation transects were conducted through the Colobus troop territories to assess the quality of the area within which a troop was found. A general survey of the area was first carried out noting the site location, the number of rubbish dumps, the number of resident dogs and a rough estimation of the number of people resident in the area. The territory was roughly measured by pacing around the borders (borders were indicated by a field assistant). The area was then divided into strips equal distances apart, and the lines dividing the strips acted as the transect lines.

Each transect in an area was paced through by the researcher and a field assistant; the recording of vegetation features was conducted according to a recommended methodology (Julie Anderson, personal communication). At regular intervals along the transect line (e.g. every 20 or 50 paces), vegetation features such as canopy height and canopy coverage were recorded. The features recorded are shown in the sample of the vegetation datasheet (appendix B1). Vegetation damage was recorded as human or natural. Human damage referred to incidents of logging, whereas natural damage referred to incidents of trees felled by natural (environmental) causes. Damage was ranked as "recent" (less than 6 months), "old" (6 months-one year) or "very old" (more than a year).

Vegetation transects were conducted before the troop behavioural assessments to give information on the troops' territory; each area was given a ranking ranging from I-III, according to the mean value of statistics obtained from the transects, as shown below. A rank of I indicated an area or intact forest of good quality, and a rank of III indicated a degraded or poor quality forest or area.

High human tree damage scores lowered an area's ranking from its previous ranking, as human tree damage was seen as an indicator of human disturbance in an area or forest patch.

% Indigenous species		**% Canopy cover**	
0 - 50%	III	0 – 50%	III
51 - 75%	II	51 – 75%	II
76 - 100%	I	76 – 100%	I
Canopy height (m)		**Nearest tree to transect (m)**	
0 – 1.9	III	4.0 +	III
2.0 – 4.9	II	2.0 – 3.9	II
5.0 +	I	0 – 1.9	I
Area Size (1000 m^2) [3]		**Incidents of Tree damage (human)**	
0 – 10 000	III	6 +	III
10 100 – 20 100	II	3 – 5	II
20 200 +	I	0 - 2	I

[3] Approximate territory size was determined by multiplying the length of the pacer's step (length measured in metres) by the number of paces recorded.

Using the criteria described above, the following categories were generated for habitat types in Diani.

Habitat I – exhibited relatively little disturbance (human tree damage), forest is highly intact, and ranks highly in qualities such as canopy cover, canopy height, percentage of indigenous species and tree distance.

Habitat II – exhibited moderate to heavy disturbance; forest showing signs of degradation, with inconsistency occurring in the qualities mentioned above.

Habitat III – a degraded habitat lacking in qualities such as canopy cover, tree height, indigenous species, and others typical of an intact forest.

5.6 BEHAVIOURAL ASSESSMENT

For the behavioural assessment, three Colobus troops were selected according to the following criteria.

- The troop's habituation to humans (so that they could be followed closely enough to accurately observe their activities)
- The ease with which the troop could be followed through the area (some areas were impenetrable due to thick vegetation).
- Area vegetation quality (each was picked from a different quality area)

Preliminary observations were conducted before detailed observations to assess the range of activities. Data regarding the human disturbance (noise levels) in an area was gathered during the observations as it could be gathered more continuously this way. Noise levels were recorded according to the following key:

1 = Birds/Sea/Natural noises

2 = Faint noises/Background human made noises

3 = Human noises in vicinity (chatter, passing cars)

4 = Loud human made noises (construction, hammering, shouting)

Predator presence (the presence of dogs) and proximity was recorded as it occurred. The troop's reaction to human presence was recorded as "reaction" to give an indication of the troop's habituation to humans.

Reaction was recorded according to the following key:

1 = Intolerant to observation/flee from observation

2 = Wary of observation/react to observer's movements

3 = Tolerant to observation

A sample of the datasheet used for behavioural assessment is given in appendix C.

Data was recorded employing scan sampling and instantaneous recording techniques (Martin and Bateson, 1993) during 6 hour-long observation sessions consisting of 2 mornings and 2 afternoons per troop. Data was recorded every 2 minutes for 10 minutes, followed by a break of 10 minutes before the process was repeated. All behaviour recorded targetted the whole troop to avoid bias. When no troop members were in sight, this was recorded as a time out. The same methods were used for observation of the Guereza Colobus troop.

5.6.1 COLOBUS TROOPS OBSERVED

The three Angolan Colobus troops followed for observation in Diani occurred in different habitat types (section 5.6), which are described in this section. The habitat of the Guereza Colobus troop is also described and compared to the Diani habitats.

Nomads Troop – Habitat I

The Nomads troop (NB troop) had 8 individuals during the observation period; 1 adult male, 2 adult females, 1 sub-adult female, 1 sub-adult male, 2 juvenile females and 1 juvenile male.

The Nomads troop ranged in territory of mainly intact indigenous coral rag forest, with a gap of around 20m of open space between the forest and the beach. The area was approximately 11, 689 m^2 and had a consistent level of canopy coverage and tree height. A power line runs through the forest from North to South (Fig. 1); the area surrounding the line has been cleared. There were about 10-15 people resident within the Nomads troop territory. Three dogs were seen in the range regularly, and were assumed to be resident in the area.

The Colobus troop shared the territory with Vervets, Sykes monkeys and forest duikers.

Colobus Cottage troop – Habitat II

The Colobus Cottage troop (CC troop) had 6 members during the observation period; 1 adult male, 3 adult females, 1 juvenile female and 1 black and white infant. The juvenile female was being weaned at the time of study. Two females in the troop had body parts missing; one female's left hand was amputated from the elbow down and another female's tail was amputated halfway.

The CC troop territory is a mixture of indigenous forest, secondary shrub and patches of open space. The CC troop territory is located between Two Fishes hotel (closed at the time) and Jadini Beach hotel, and the area is approximately 25 406 m^2. The same power line as in the Nomads' area runs through the CC area. There were 10 – 15 people resident in the troop range and two resident dogs.

The troop shares the territory with a Baboon troop, a Vervet troop and several sykes troops.

Seacrest troop – Habitat III

The Seacrest troop (SC troop) had 6 members during the observation period; 1 adult male, 2 adult females, 1 sub-adult male, 1 sub-adult female and 1 juvenile female.

The Seacrest territory has a patch of scrub with a few trees about 50m by 20m in size located in the northwest corner. The rest of the territory consists of open space with tall trees widely spaced apart, and with numerous exotic plant species. The territory spans from within the Two Fishes hotel compound to the compound of the University of Nairobi's Marine studies' campus, and the area is approximately 20 426 m^2. Some of the scrub has been cleared away from the same power line as in the other described troop areas. There were around 30 – 40 people resident in the troop ranging area, 6 resident dogs and numerous chickens and cats.

The troop shares the territory with Baboons, a sykes troop and Vervets.

Guereza troop (Kitale)

The Guereza troop had 10 individuals during the period of observation; 1 adult male, 4 adult females, 1 sub-adult female, 2 juvenile females, 1 black and white infant and 1 unidentified individual.

The Guereza forest habitat (Plate 4) was a strip of forest approximately 0.11 km^2. Despite the degradation responsible for its diminishing size at the time, it was a good quality forest patch, with tall trees and high undergrowth. There were no human residences within or near the forest patch. The troop shared the forest with two Vervet troops. The forest habitat of the Guereza Colobus troop was comparable to a habitat type I forest in Diani.

5.7 DATA MANAGEMENT

5.7.1 FAECAL DATA

Faecal data collected from the Angolan and Guereza Colobus and other non-human primates was recorded for the presence of protozoan cysts and graded as below:

1 – 10 cysts = +

11 – 20 cysts = ++

21 cysts or more = +++

Count results for helminth ova were recorded according to the number observed (i.e. 1, 2, 3, etc). Protozoa and nematode counts were treated separately, as the techniques used to count them varied (section 5.3.3).

Individual records are shown in appendices A2, A3 and A4. The statistical tests Chi-square and the Student's T-test, were used to assess associations and differences observed in parasite patterns, and were also applied to vegetation and behavioural data. Reference tables for statistical tests are taken from Freund and Wilson (1997).

5.7.2 VEGETATION DATA

The data gathered from the vegetation transects was grouped together to generate a set of statistics used to rank each habitat as shown below.

The detailed data from the vegetation transects is given in appendices B2, B3 and B4. The troop areas are abbreviated as shown below.

SC = Seacrest Cottages

CC = Colobus Cottage

WC = Warrandale Cottages

MC = Meditation Centre

VC = Vindigo Cottages

TW = Tradewinds

DH = Diani House

BC = Bramingham Chalets

LB = Leopard Beach

BVC = Bahari Vet Clinic

JH = Jadini Hotel

JW = Jadini West

NB = Nomads Beach

PF = Pig Farm

WR = White Rose Villas

LoM = Lone Adult Male

5.7.3 BEHAVIOURAL DATA

Data gathered from behavioural observations was combined together (e.g. total number of incidents per day) to generate means for the measured parameters.

6.0 RESULTS

6.1 THE ANGOLAN COLOBUS

A total of 79 faecal samples were collected from Angolan Colobus monkeys. The Formol-Ether concentration analysis was conducted on 74, the McMaster's floatation technique on 48 and the Harada-Mori larval culture on 29 samples.

In the Angolan Colobus, the parasite species *Entamoeba coli, Entamoeba histolytica, Trichuris spp, Strongyloides spp* and *Enterobius vermicularis* were observed, with *E. vermicularis* occurring in only one Colobus. Examples of each species are shown in Plates 5 and 6.

6.1.1 SEX

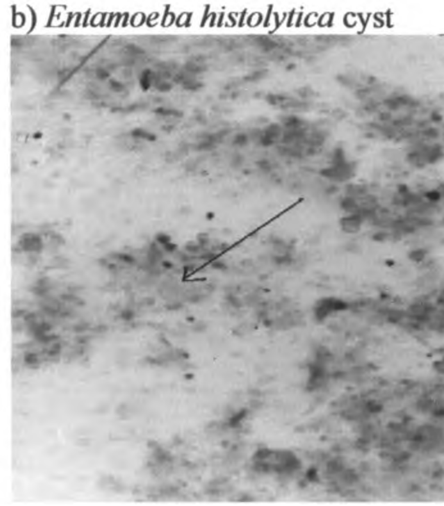
Samples from 32 males and 42 females were analysed using the Formol-Ether concentration analysis. Little difference occurred in the prevalence of parasites between both sexes, which showed similar prevalence figures for *E. coli*, *E. histolytica*, *Strongyloides* and *Trichuris*.

Table 1 shows the number of males and females that were positive for a parasite species in the sampled Angolan Colobus population. Sex had no influence on the prevalence of parasite species or parasite diversity.

Plate 5 – **Protozoan cysts observed from the sampled primate species in the Formol-Ether concentration technique** [4]

a) *Entamoeba coli* cyst

b) *Entamoeba histolytica* cyst



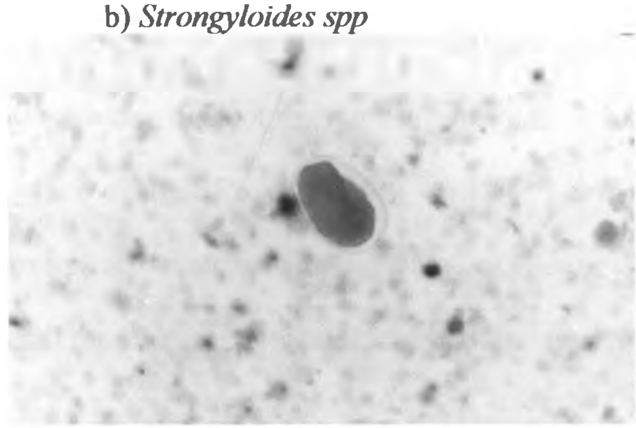
c) *Balantidium coli* cysts

[4] The arrow in picture b) indicates the location of the *Entamoeba histolytica* cyst.

Plate 6 - Nematode ova from the sampled primate species observed in the Formol-Ether concentration technique

a) *Trichuris spp*

b) *Strongyloides spp*



c) *Enterobius vermicularis*

TABLE 1 – Prevalence of parasite species observed in Angolan Colobus according to sex (% in brackets)

SEX	*Entamoeba coli*	*Entamoeba histolytica*	*Strongyloides spp*	*Trichuris spp*
MALES	**31/32** (97)	**31/32** (91)	**3/32** (9)	**3/32** (9)
FEMALES	**41/42** (98)	**37/42** (88)	**4/42** (10)	**4/42** (10)
TOTAL	**72/74** (97)	**68/74** (89)	**7/74** (9)	**7/74** (9)

6.1.2 AGE

Forty-nine (49) adults, 15 sub-adults and 10 juveniles were sampled. Table 2 shows the number of Angolan Colobus in each age group positive for a parasite species. Prevalences for *E. histolytica* and *Strongyloides* did not vary much with age. *E. coli* prevalence was lower in sub-adults, which exhibited a prevalence of 87%. *Trichuris* prevalence also varied noticeably between age groups, with juveniles exhibiting the highest prevalence (30%) infected. Overall the adult age group had the highest number of positive individuals for all parasite species.

TABLE 2 – Prevalence of parasite species observed in Angolan Colobus according to age group (% in brackets)

AGE	*Entamoeba coli*	*Entamoeba histolytica*	*Strongyloides*	*Trichuris*
Adults	**49/49** (100)	**46/49** (92)	**5/49** (10)	**4/49** (8)
Sub-adults	**13/15** (87)	**14/15** (87)	**1/15** (7)	-
Juveniles	**10/10** (100)	**8/10** (80)	**1/10** (10)	**3/10** (30)
TOTAL	**72/74** (97)	**68/74** (89)	**7/74** (9)	**7/74** (9)

Table 3 shows the densities of protozoan cysts observed in the Angolan Colobus. Most of the animals sampled exhibited light (+) infections of *E. coli* and all had light infections of *E. histolytica*.

Egg counts for *Trichuris* and *Strongyloides* observed in the Formol-Ether ranged from 0 – 7 for *Trichuris* and 0 – 6 for *Strongyloides* in the Angolan Colobus.

TABLE 3 – Intensity of protozoan infection in Angolan Colobus (% in brackets)

Intensity of infection	*Entamoeba coli*	*Entamoeba histolytica*
Light (+)	**58/74** (78)	**66/74** (89)
Medium (++)	**6/74** (8)	-
Heavy (+++)	**8/74** (11)	-

KEY

+ = **1-10 cysts**

++ = **11-20 cysts**

+++ = **21 or more cysts**

6.2 OTHER PRIMATE SPECIES

6.2.1 THE GUEREZA COLOBUS

Only the Formol-Ether concentration technique was conducted on the Guereza Colobus samples. In contrast to the Angolan Colobus, the nine Guereza Colobus samples collected exhibited only *E. coli* and *E. histolytica* parasite species. However the prevalences of *E. coli* and *E. histolytica* amongst the sampled Angolan and Guereza Colobus were similar, as shown in Table 4.

6.2.2 BABOONS AND SYKES

The 10 Baboon and 4 sykes opportunistic samples collected exhibited the parasites *Entamoeba coli, Entamoeba histolytica, Balantidium coli, Trichuris spp* and *Strongyloides spp*, with *Balantidium coli* found only in the Baboon samples.

The proportion of Baboon and Sykes individuals positive for *E. coli* and *E. histolytica* were similar to those observed in the Colobine species. Proportions of individuals positive for *Trichuris* and *Strongyloides* in the sampled Baboon and sykes were higher than the proportions observed in the sampled Angolan Colobus (Table 4).

TABLE 4 – Prevalence of various gastro-intestinal parasite species according to primate species sampled (% shown in brackets)

Primate species	*E. coli*	*E. histolytica*	*Strongyloides*	*Trichuris*	*E. vermicularis*	*B. coli*
Angolan Colobus	**72/74** (97)	**66/74** (89)	**7/74** (9)	**7/74** (9)	**1/74** (1)	-
Guereza Colobus	**9/9** (100)	**7/9** (78)	-	-	-	-
Baboons	**10/10** (100)	**10/10** (100)	**5/10** (50)	**7/10** (70)	-	**5/10** (50)
Sykes	**4/4** (100)	**3/4** (75)	**2/4** (50)	**4/4** (100)	-	-

6.3 McMASTER'S FLOATATION TECHNIQUE

Of the 48 samples processed using the McMaster's faecal floatation, only 3 Colobus had *Trichuris* eggs (two with 50 eggs per gram and one with 100 eggs per gram).

One sykes sample was positive for *Trichuris* (50 eggs per gram). The 10 Baboons sampled had *Trichuris* and *Strongyloides* eggs ranging from 0 – 3100 eggs per gram.

6.4 HARADA-MORI LARVAL CULTURE

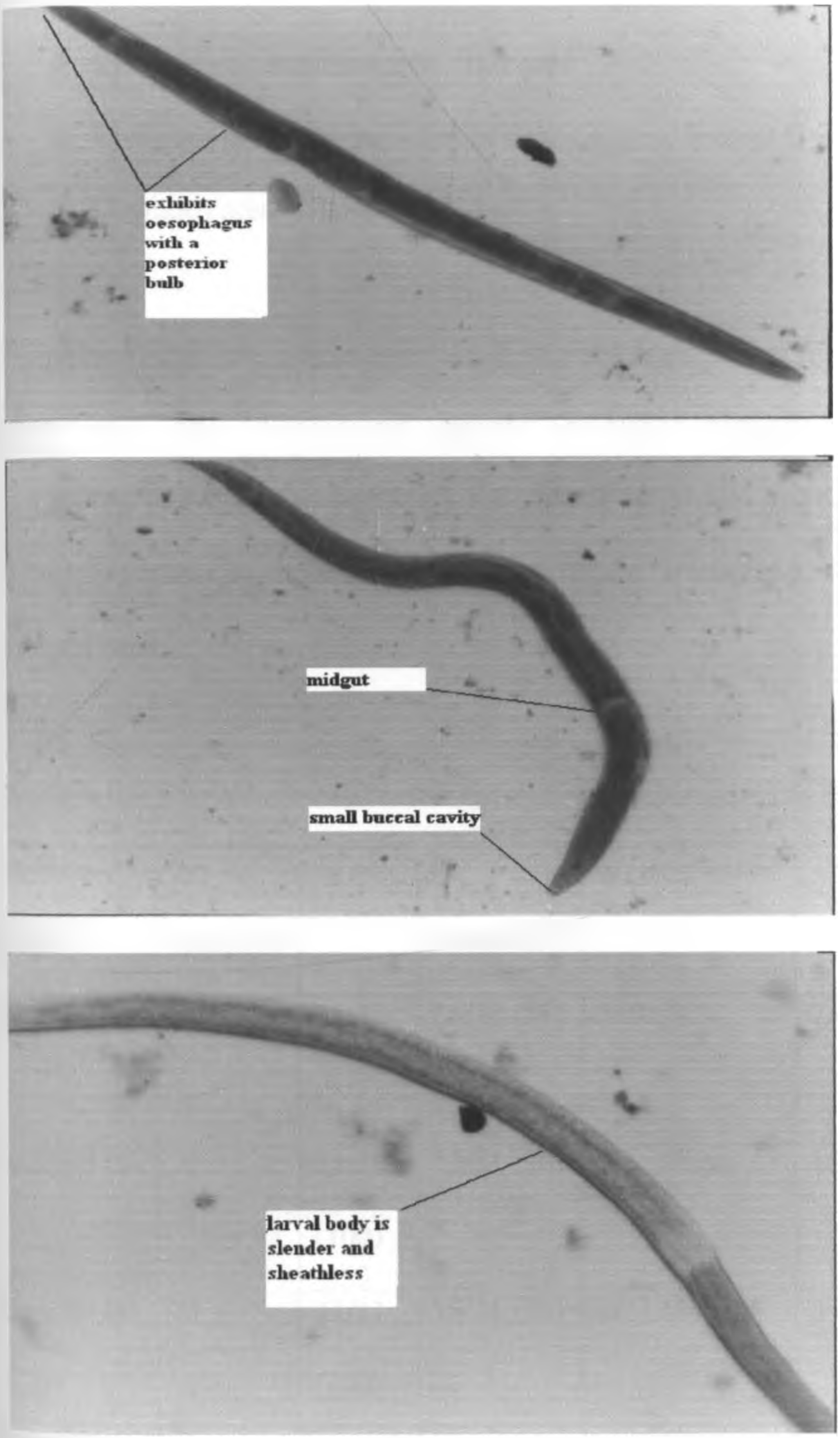
Larvae observed in the Harada-Mori larval culture are shown in Plate 7. Thirteen out of 29 Colobus (45% of the culture samples) were positive for *Strongyloides* larvae in the Harada-Mori larval culture (Tables 5 and 6). Similar prevalence was observed in both sexes (Table 5), where 17% of males and 28% of females were positive for *Strongyloides* larvae. Almost no difference in prevalence occurred within the sex groups. The adults exhibited the highest prevalence between age groups (Table 6), with 20% positive for *Strongyloides* larvae, whilst prevalence within age groups was highest in the juveniles (60% positive).

Seven Baboon samples were positive for *Strongyloides* larvae, with two also having *Trichuris* ova. No larvae were observed in the sykes samples.

TABLE 5 – The prevalence of larval *Strongyloides* in Angolan Colobus according to sex and age using the Harada- Mori larval culture

	Number of positive samples (% in brackets)
SEX	
Males	**5/11** (45)
Females	**8/18** (44)
AGE	
Adults	**7/18** (39)
Sub-adults	**3/6** (50)
Juveniles	**3/5** (60)

Plate 7 – Unidentified stages of development of *Strongyloides* worms obtained by the Harada-Mori technique from Angolan Colobus faeces



6.5 VEGETATION

The Colobus troop territories in which transects were conducted were placed into 3 categories:

- Relatively undisturbed area - Habitat I
- Disturbed area showing signs of degradation – Habitat II
- Degraded area – Habitat III

Examples of the three habitat types are shown in Plate 8.

There was little difference in parasite prevalence between habitats, with similar proportions of individuals positive for *E. coli*, *E. histolytica* and *Strongyloides* (Table 7). A higher number of individuals were positive for *Trichuris* in habitat III compared to habitats I and II.

TABLE 6 – Prevalence of parasite species by habitat type (% in brackets)

Habitat Type	**No. sampled**	***E. coli***	***E. histolytica***	***Strongyloides***	***Trichuris***	***E. vermicularis***
Habitat I	30	**28/30** (93)	**26/30** (87)	**3/30** (10)	**2/30** (7)	-
Habitat II	21	**21/21** (100)	**19/21** (90)	**2/21** (10)	**1/21** (5)	**1/21** (5)
Habitat III	21	**21/21** (100)	**19/21** (90)	**2/21** (10)	**3/21** (14)	-

Plate 8 – **The 3 habitat types of Diani observed in this study**

a) **Boko boko forest – habitat type I**. Vegetation is intact, exhibiting good canopy cover and good canopy height, with little evidence of disturbance.

b) **Colobus Cottage-habitat type II**. Forest shows evidence of disturbance, such as cleared spaces and a generally lower canopy cover.

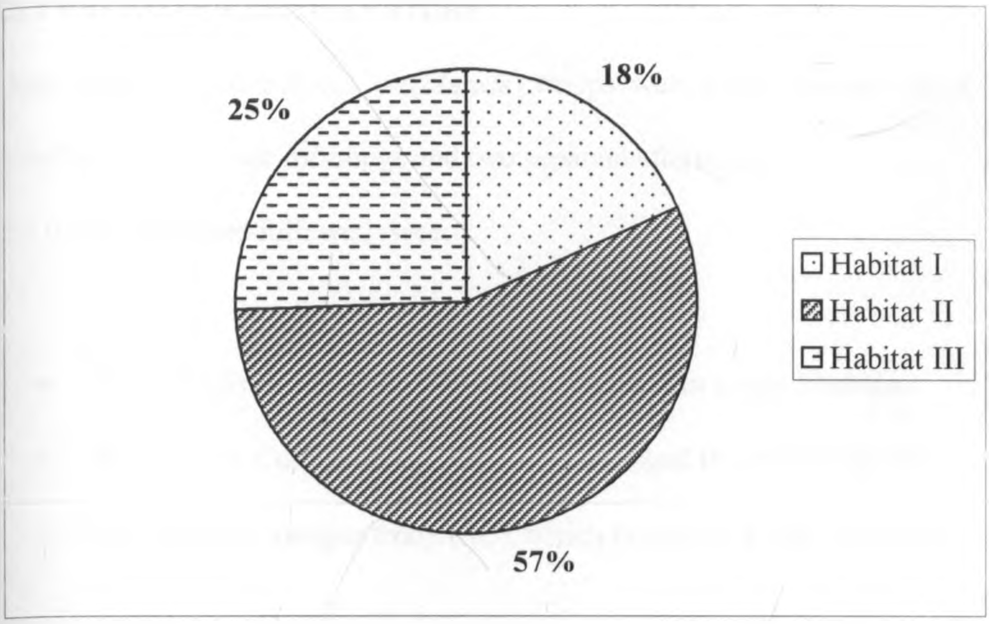
c) **Seacrest Cottages – habitat type III.** Habitat is degraded, with more shrubs occurring than trees, and several large open spaces.

With regard to protozoan parasite intensity, only two Colobus in habitat I had moderate to heavy (++ or +++) *E. coli* counts compared with 4 Colobus in habitat II and 7 Colobus in habitat III. Only light (+) *E. histolytica* counts were recorded for all Colobus. Differences in protozoan parasite intensity between habitats were not statistically significant.

A record was kept of vegetation damage in each habitat. A total of 50 incidents of vegetation damage were recorded, with incidents recorded as either human or natural damage (see section 5.3.4). Fifty-six percent (56%) of observed vegetation damage incidents were human inflicted; from this, 54% of the damage was recent. Human and natural damage incidents in the different habitat types are reflected in Fig. 2. Most human damage was recorded in type II habitats (57% of the incidents), with type I habitats exhibiting the lowest prevalence of incidents (18%). In contrast the highest prevalence of natural damage incidents were recorded in type I habitats (51%), with type III habitats having the lowest prevalence (14%).

Rubbish dumps ranging from 1 to 4 in number were observed in the MC, SC, JW, PF, WR and BC areas.

a - Proportion of human damage in each habitat type



b - Proportion of natural damage in each habitat type

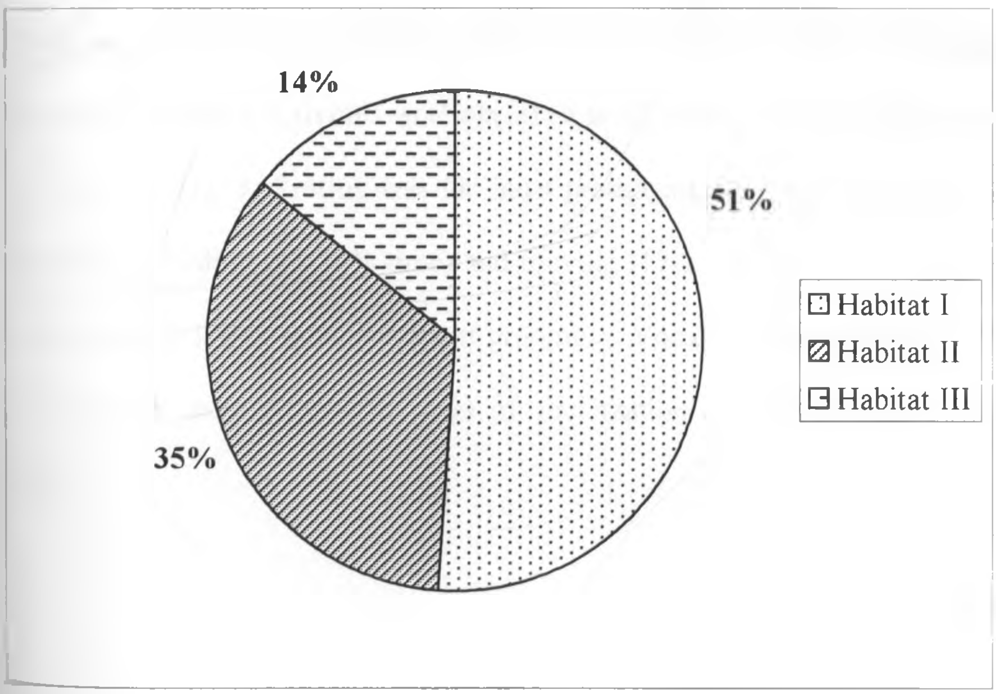


Fig. 2 - Vegetation damage (human and natural) in the different habitat types

6.6 COLOBUS BEHAVIOUR

6.6.1 PROMINENT BEHAVIOURS

Three Angolan Colobus (*C. angolensis*) troops were each followed for a 6 hour-long period on two separate mornings and two separate afternoons.

The troops that were followed were:

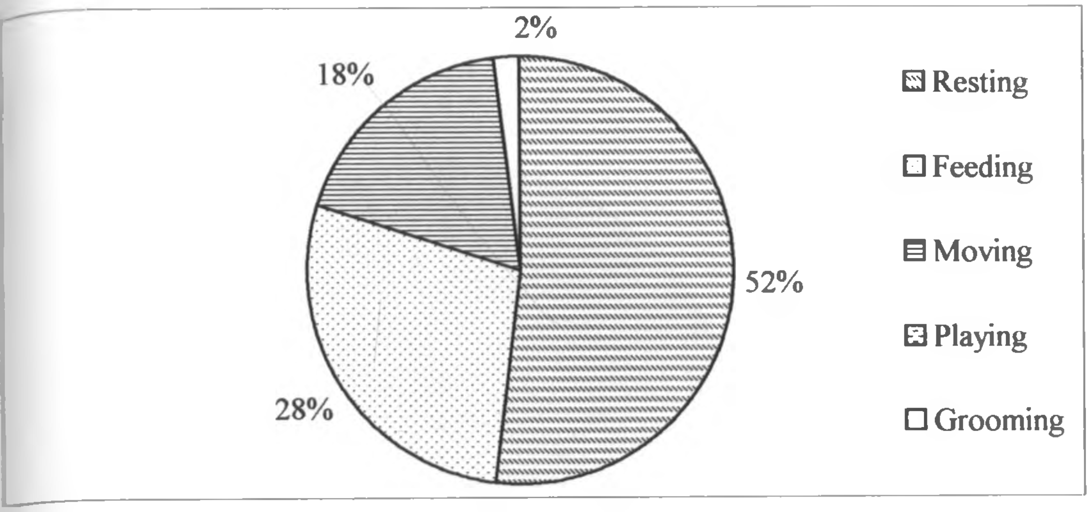
- The Nomads Beach troop (NB), which ranged in a type I habitat
- The Colobus Cottage troop (CC), which ranged in a type II habitat
- The Seacrest Cottages troop (SC), which ranged in a type III habitat

The Guereza Colobus (*C. Guereza*) troop was followed for two mornings and part of one afternoon[5].

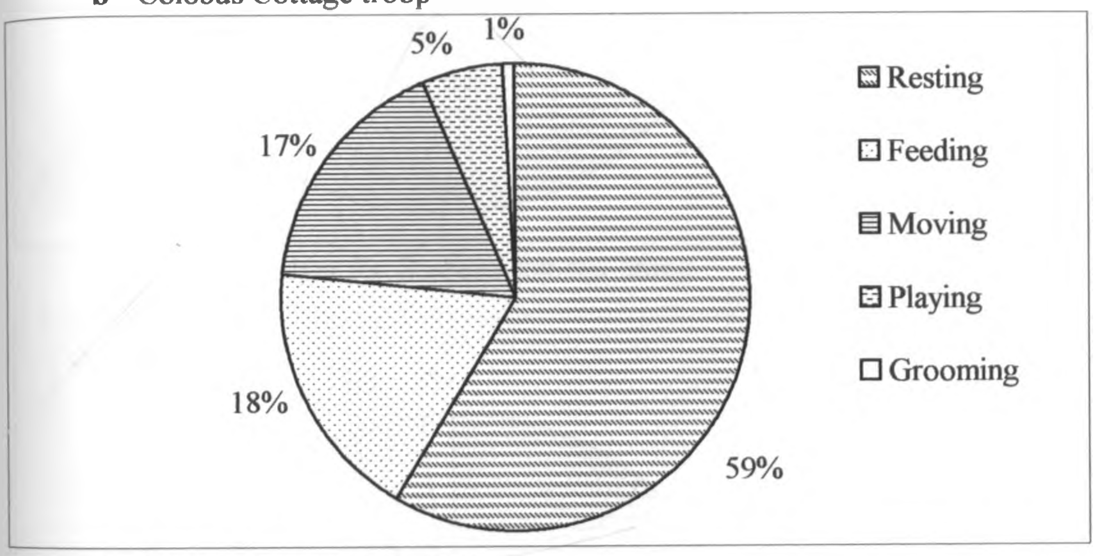
The *C. angolensis* troops followed exhibited similar activity patterns throughout the day. The same prominent activities were observed in all troops; activity budgets for each troop are shown in Fig. 3. Resting was the most prominent activity (taking up 51-59% time), followed by feeding (18-28% time) and moving (17-21% time). 0-5% of time was spent playing, and 0-3% of time was spent grooming. Vocalization was especially frequent in the CC troop, with almost all cases of vocalization coming from the juvenile female (CC6).

[5] Data for the time period 1500-1800 hrs was incomplete and not included

a - Nomads Beach troop



b - Colobus Cottage troop



c - Seacrest Cottages troop

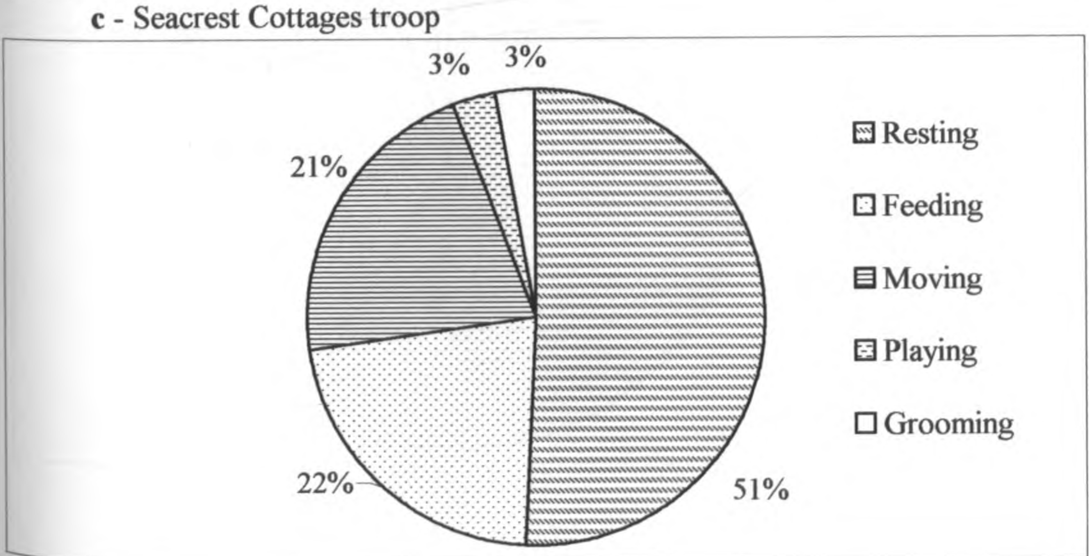
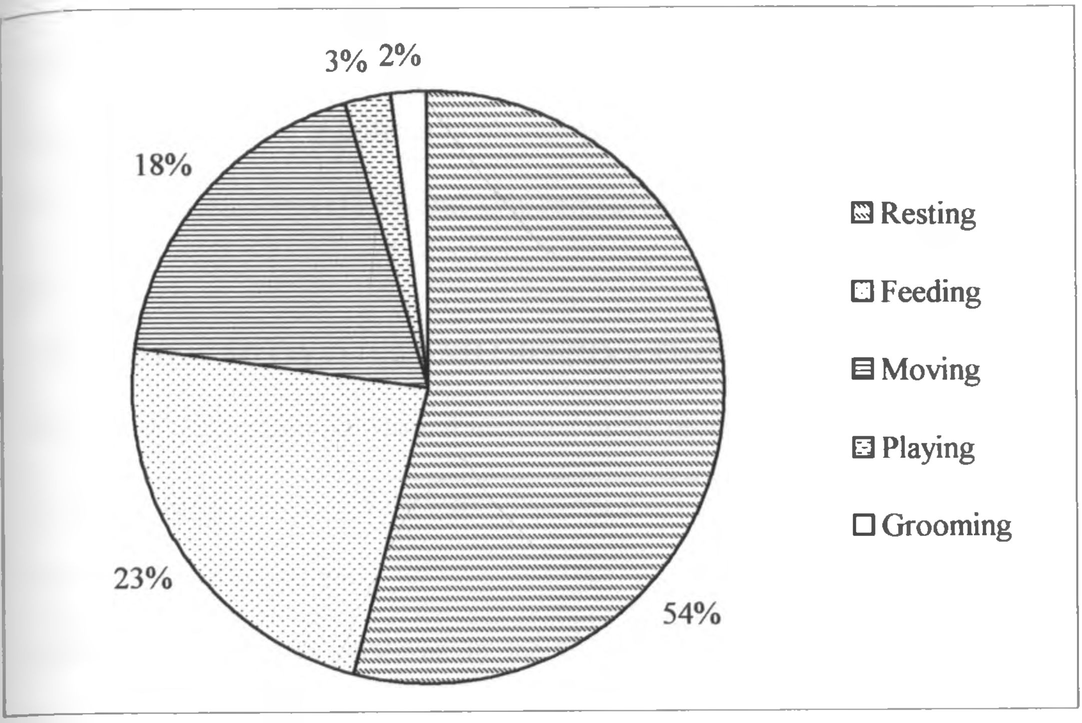


Fig. 3 - Pie charts showing activity patterns of Angolan colobus troops

a - Combined activity budget for Angolan colobus troops



b - Activity budget for Guereza colobus troop

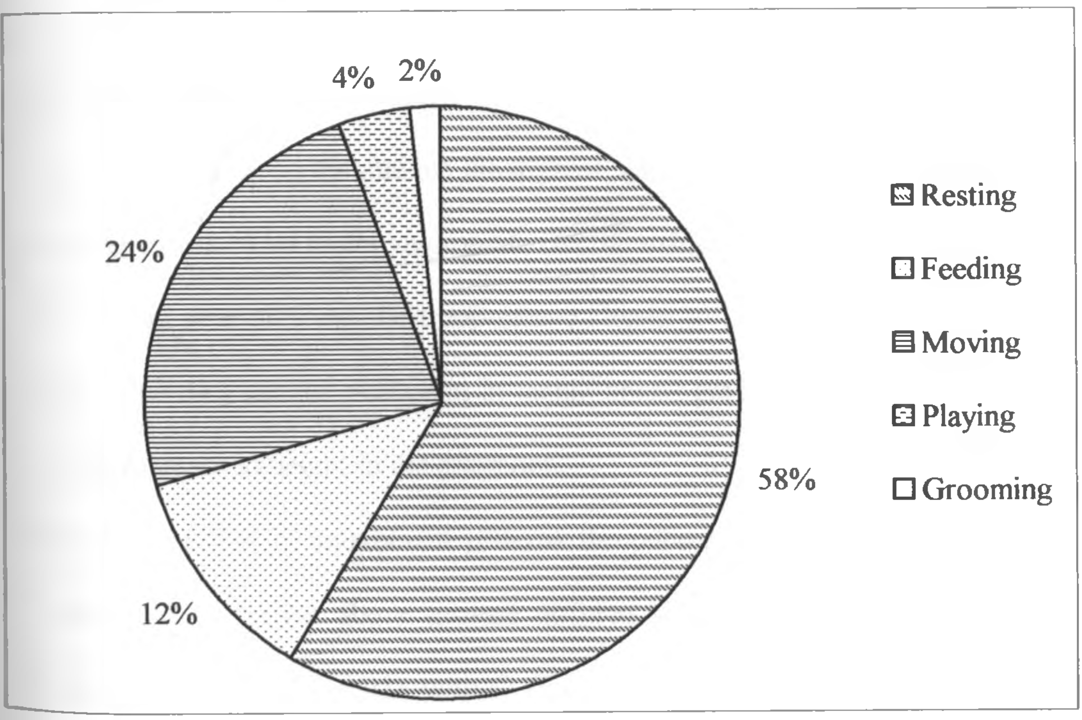


Fig. 4 - Pie charts showing activity patterns of Angolan and Guereza colobus troops

Activity budgets for *C. angolensis* (a combined activity budget) and *C. Guereza* appear in Fig. 4. *C. Guereza* spent more time resting (58% of time) than *C. angolensis* (54% of time) and also more time moving (24% of time) than *C. angolensis* (18% of time). *C. Guereza* also spent a significantly shorter period of time feeding (chi-square = 7.3; $p < 0.05$) than *C. angolensis* (12% and 23% respectively).

6.6.2 OTHER ACTIVITIES AND OBSERVATIONS

Some behaviour observed was not included in the prominent activity categories.

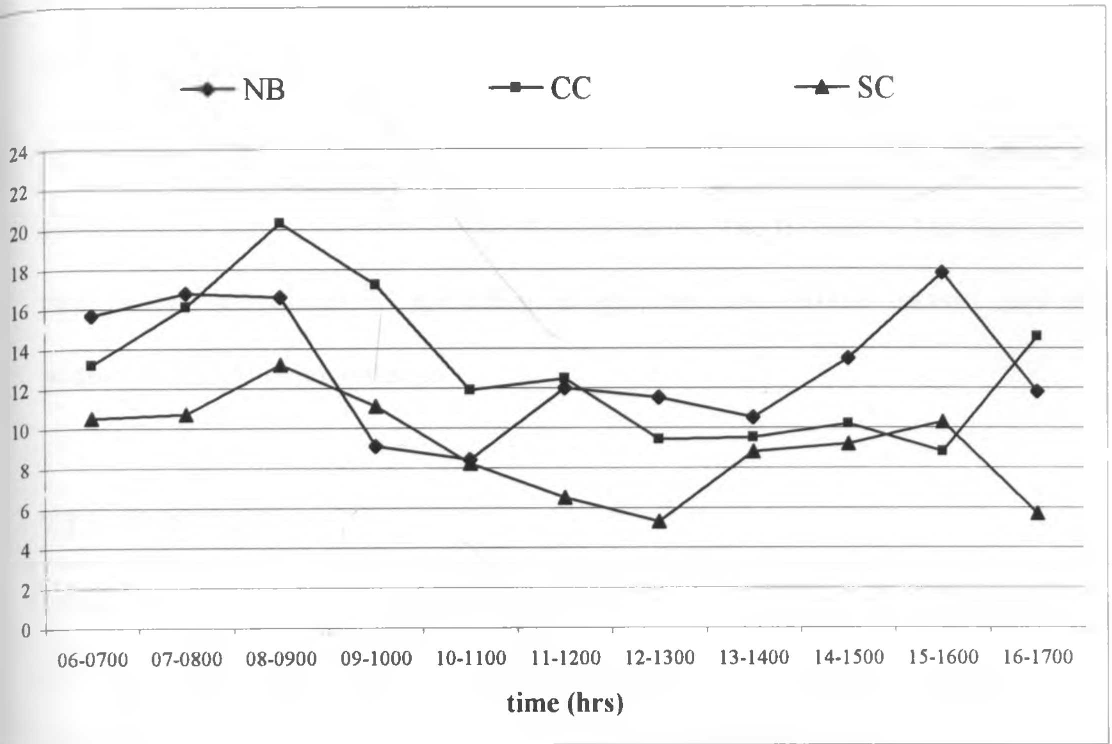
In the NB troop, two Colobus were observed playing with or chewing on pieces of bark on two separate occasions.

Similar behaviour was observed in the CC and SC troops, where Colobus from both troops were observed coming to the ground to chew on pieces of coral.

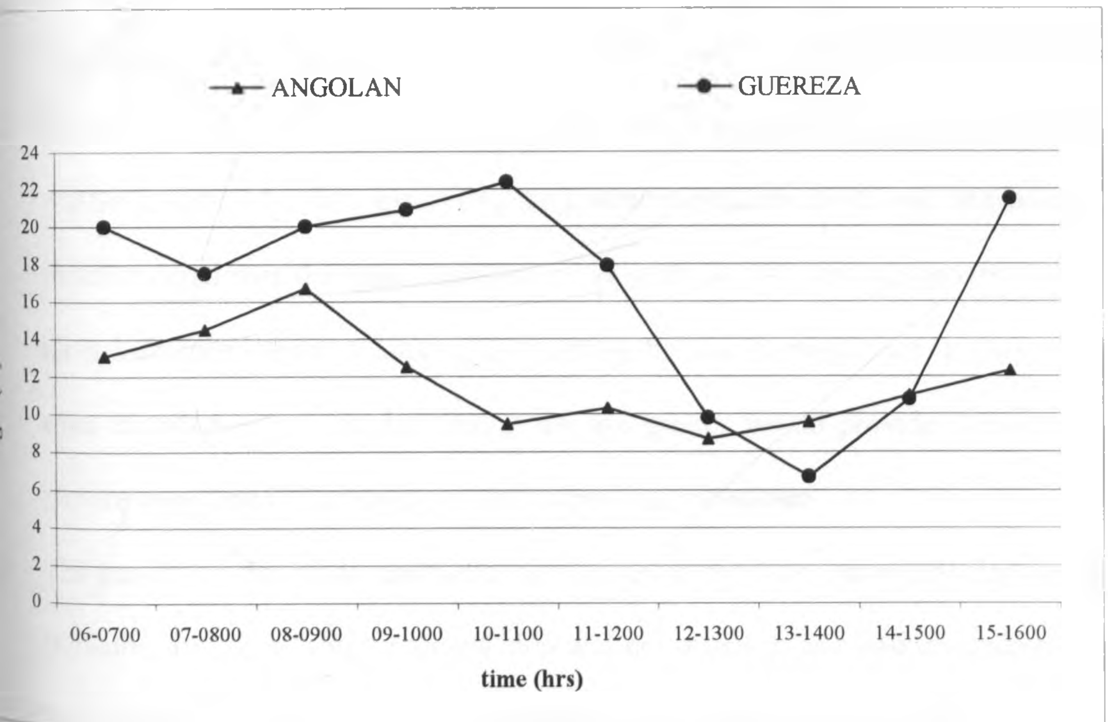
The height above ground of each Colobus troop varied throughout the day as shown in Fig. 5a. The CC troop maintained the highest height above ground for the morning hours, reaching a peak of 20 m above ground. The SC exhibited the lowest height above ground (5.3 m) and generally was the troop placed closest to the ground throughout the day. All troops showed a general reduction in height above ground from the morning to midday, with an increase in height in the afternoon.

Fig. 5b compares the movement patterns throughout the day for *C. angolensis* and *C. Guereza*. Mean height above ground differed significantly between the two Colobus species (t-test = 7.7; $p < 0.01$), with *C. Guereza* maintaining a higher mean height than *C.*

angolensis, and also exhibiting a larger height range (6.7 - 22.3 m; S.D +/- 5.6) than *C. angolensis* (8.7 – 16.7 m; S.D +/- 2.5).



Mean height above ground in 3 Angolan colobus troops in Diani



Mean height above ground between *C. angolensis* and *C. guereza*

Fig. 5 - Mean height above ground during the day for Angolan and guereza colobus troops

7.0 DISCUSSION

7.1 ANGOLAN COLOBUS

In this study, five species of gastro-intestinal parasites (two protozoa and three nematode species) were observed in the faeces of Angolan colobus monkeys. The findings and their implications are discussed according to age, sex and habitat factors, and mainly in relation to the Angolan colobus.

7.1.1 PROTOZOA

The protozoa observed in Angolan colobus faecal samples were *Entamoeba histolytica* and *Entamoeba coli*. In the case of several parasitic infections, age and sex may determine parasite prevalence, as has been demonstrated with *E. histolytica* infections (Faust *et al.,* 1970).

Results in this study indicate that sex did not influence *E. coli* or *E. histolytica* prevalence (Table 1) in the Angolan colobus. Age did show some influence on *E. coli* prevalence ($p < 0.005$), with sub-adults exhibiting the lowest prevalence for *E. coli*. However it should be considered that the small numbers of animals in different age groups sampled may have influenced these results, and regarding further investigations, a larger, and more even distribution of samples among the age groups would provide a more conclusive picture regarding the influence of age on parasite prevalence.

The results of this study contradict the results of previous parasitical findings in Diani (Obadha, 1999), in which *E. histolytica* was not observed in colobus monkeys. However *E. coli* and *E. histolytica* in colobus monkeys has been previously documented (Munene *et al.,* 1998). Observations of ground contact in Diani Angolan colobus (discussed in more detail in sections 7.3 and 7.4) may account for the mode of infection, as both protozoa are soil or water-borne parasites (Soulsby, 1982).

E. coli is non-pathogenic and does not have much significance in terms of its zoonotic potential (Soulsby, 1982).

E. histolytica is pathogenic, with infection potentially leading to amoebic dysentery or colitis. Trophozoites invade the colon mucosa and are passed as cysts in the faeces (Soulsby, 1982), with observed intestinal pathology (Beaver *et al.*, 1988) and invasion of other organs occurring in cases of severe infection (Frenkel *et al.*, 1988).

Angolan colobus sampled in this study exhibited light infections (0 - 10 cysts) of *E. histolytica* (see section 5.4.1), but with a high prevalence (66/74) amongst the Angolan Colobus. A study by Beaver *et al.*, (1988) reported a higher tolerance of *E. histolytica* in Old World monkeys compared to New World monkeys. Similarly, *E. histolytica* strains isolated in primates by Smith and Meerovitch (1985) indicate that Old World monkeys may act as natural hosts for *E. histolytica* - a theory that seems to be supported by the high prevalence of *E. histolytica* in Angolan colobus in this study. Despite this, cases of pathological *E. histolytica* infections in colobus monkeys have been reported, in a study by Verweij *et al.*, (2003), which documented *E. histolytica*-induced diarrhea in *C. guereza*, and Loomis *et al.*, (1983) also reported *E. histolytica* amoebiasis in *C. guereza*. In the latter study the stomach was also affected, indicating that in the colobus the ruminant-like stomach may act as a primary site of infection. In addition, the zoonotic potential of *E. histolytica* was demonstrated, as the person handling the colobus subsequently developed amoebiasis (Loomis *et al.*, 1983). *E. histolytica*'s pathology is dependent upon factors such as the intensity with which the organism occurs, the strain causing infection and the nutritional state of the host (Frenkel *et al.*, 1988). These factors may have had some bearing on the nature of the *E. histolytica* infections observed in this study, which were all light and appeared to be asymptomatic, although the colobus faeces collected showed varying consistency (see Appendix A1). However the finding of *E. histolytica* in Diani Angolan colobus and the zoonotic potential of the protozoa should be taken into account, particularly due to the species' public health importance. Also the true extent of the effect of *E. histolytica* infection in the Diani Angolan colobus with respect to its pathology requires further investigation.

7.1.2 NEMATODES

Very few numbers of nematode ova were observed in Angolan colobus faecal samples, with seven colobus positive for *Strongyloides* and *Trichuris* species, and one colobus positive for *Enterobius vermicularis* in results from the Formol-Ether concentration analysis (see Appendix A2). As with the protozoan parasites, ground contact in the Angolan colobus would seem to be the mode of infection with both *Strongyloides* and *Trichuris* nematodes also being soil and water-borne parasites (Soulsby, 1982). The number of nematode parasites observed was too low for any reliable conclusion to be reached regarding the influence of age or sex on the prevalence of nematode parasites.

Strongyloides nematodes are the cause of Strongyloidiasis, a common infection in Old and New World monkeys (Orihel and Seibold, 1972). *Strongyloides* exhibited a relatively high prevalence (13/29 positive samples) in the Harada-Mori larval culture, with both *Strongyloides* larvae and adult worms observed (Plate 7). Female *Strongyloides* worms are parasitic. Eggs deposited in the tissue of the intestinal mucosa by the females, are passed in the infected host's faeces, and hatch into parasitic or free-living larvae (Soulsby, 1982). Contrasts in *Strongyloides* prevalence in the Formol-Ether concentration analysis and in the Harada-Mori larval culture could be because some of the *Strongyloides* worms observed in the Harada-Mori may not have been hatched from the faecal samples, but were the free-living forms, obtained from contamination of the faecal sample with soil. Additionally, the occasional shedding of *Strongyloides* eggs in faeces (Faust *et al.,* 1970) may have also led to the lower prevalence observed in the Formol-Ether concentration analysis.

Strongyloides species have zoonotic potential, with a case of cross infection from monkey to man having been reported (Wallace *et al.,* 1948). Non-human primates are definitive hosts for the species *Strongyloides fülleborni*, found distributed in equatorial Africa and Papua New Guinea (McCarthy and Moore, 2000).

Trichuris occurs mainly in African monkeys and the chimpanzee (Orihel and Seibold, 1972). It has previously been documented in colobus monkeys (Munene *et al.,* 1998), with death from gastric trichuriasis occurring in one case (Loomis and Wright, 1986).

The isolated case of *E. vermicularis* observed in Angolan colobus in this study may be due to the direct lifecycle of the parasite, which involves autoinfection, making it difficult to detect eggs in the faeces in cases of light infection (Tartakow and Vorperian, 1981).

Most of the Angolan Colobus individuals sampled were asymptomatic and apparently healthy. Although a few individuals did exhibit diarrhoea or runny faeces, the results of their faecal analysis did not support the possibility of infection. However, some of the analysis techniques used may have lacked the necessary sensitivity to detect such signs of infection (Ash and Orihel, 1991).

7.2 OTHER PRIMATES

7.2.1 THE GUEREZA COLOBUS

The Guereza colobus had *E. histolytica* and *E. coli* in similar prevalences to those observed in the Angolan colobus (Table 4). Both *Trichuris* and *Strongyloides* were absent in the guereza colobus sampled in this study, although *Trichuris* has been observed in guereza colobus previously (Munene *et al.,* 1998; Loomis and Wright, 1986). The area geography of the two colobus species may play a part regarding the prevalence levels of *Strongyloides* in their respective environments of the colobine species. *S. stercoralis* is reported to be prevalent in tropical areas or warm, humid climates (Marcial-Rojas, 1971), which may account for *Strongyloides* infection observed in *C. angolensis* sampled in Diani (a climate that suits *Strongyloides* nematodes, described in section 5.1.1) and the absence of infection in *C. guereza* sampled in Kitale, which is cooler and drier (section 5.1.3).

7.2.2 BABOONS AND SYKES

The high infection prevalences of *Strongyloides* and *Trichuris* infections in the sykes and baboons were in agreement with the findings of other studies (Müller-Graf *et al.*, 1996; Munene *et al.*, 1998; Hahn *et al.*, 2003). Higher prevalences of infection in sykes and baboons can be attributed to more frequent ground contact in the two species and additional activities exhibited by baboons, such as scavenging and raiding.

The additional parasite species observed in this study, *Balantidium coli* (the causal organism of balantidiasis) only occurred in the baboon faecal samples, probably because of the intense scavenging habits exhibited by the Diani baboons. *B. coli* is a protozoan with zoonotic potential, transmitted by the consumption of contaminated water or contaminated raw vegetables (Areán and Echevarría, 1971).

All primates sampled in this study had relatively high prevalences of *E. coli* and *E. histolytica*, supporting the case that these protozoa are better tolerated in Old World primates (Smith and Meerovitch, 1985; Beaver *et al.,* 1988). Although only a few samples were collected from baboons and sykes in this study, the results indicate that parasite prevalence and density in these species was heavier than in the colobines, likely because of the terrestrial and semi-terrestrial nature of baboons and sykes respectively.

7.3 VEGETATION

Habitat exerted minimal influence on parasite prevalences (Table 7); prevalence rates for *E. coli* and *E. histolytica* were only slightly lower in habitat I than in habitats II and III. No statistically significant differences occurred in *Strongyloides* prevalence between habitat types, and a very slight variation was observed in *Trichuris* prevalence, which was lowest in habitat II (1/21 colobus infected) and highest in habitat III (3/21 colobus infected).

The similarity in prevalence results between habitats probably indicate that there was no significant difference in the frequency of ground contact between colobus troops occurring in the different habitat types. Alternatively, other troop dynamics such as the tendency of young males to leave the troop to join another troop, or form a new troop, or the tendency of Colobus to disperse during spells of food shortage (Lowe and Sturrock, 1998) could have been responsible for the spread of infection across various habitat types in Diani. The findings also suggest that there may be other reasons as to why the colobus come to the ground, which are not necessarily related to habitat quality in their territories.

Degraded habitats (Plate 8) characteristically consisted of large open spaces, trees spaced far apart, and a lower canopy cover and canopy height. These conditions may have induced the colobus to come to the ground more frequently in order to move long distances, prompting the assumption that prevalence of infection would increase as habitat quality decreases. However the findings of this study suggest that there may not be a large enough margin of difference between the varying habitat types in Diani for the infection prevalence rates of parasites between habitats to have been significantly altered. The lack of difference in prevalence between the habitats may be due to the fact that, historically, all the sampled habitats were once part of one single forest that has been systematically degraded into the present day "micro-habitats" (Colobus Trust Records, 2003). Similarly, the troops may possibly share a source for the parasitic infection, such as a common water source. The overlap observed in several of the troop ranges increases the likelihood of a common infection source.

The most incidents of human tree damage occurred in type II habitats (Fig. 2); in contrast, habitat I exhibited the most incidents of natural tree damage. The trends in vegetation damage served to further illustrate the trend of increasing human disturbance in occurrence as habitat quality decreased. Tree damage was a contributing factor to habitat degradation, but it did not seem to have any direct influence on parasite patterns.

7.4 BEHAVIOUR

Although the three Angolan colobus troops monitored for behavioural observation were ranging in varying habitat types, they did not show significantly different patterns of behaviour, with each troop spending similar amounts of time in each activity (Fig. 3). This indicated that any differences observed in behaviour patterns did not arise from variations in habitat type. There were also similarities between the behaviours of the Angolan and guereza colobus species, with the same activities dominating each species' behaviour most of the time (Fig. 4). This result shows some consistency with other findings, which report behavioural similarities between the two species (Groves, 1973). Both *C. angolensis* and *C. guereza* in this study spent over half of their time resting (54% and 58% respectively); large amounts of time spent resting is characteristic of colobus behaviour, as it allows them to digest bulky foliage (Eley and Kahumbu, 1997). Significant variations occurred in the proportions of time spent feeding and moving, where *C. angolensis* spent a considerably larger percentage of time feeding than *C. guereza* (Fig. 4): similarly, *C. guereza* spent more time moving than *C. angolensis*.

During the observation periods in the forest of the Guereza colobus troop, there were a lot of loud and persistent banging noises throughout most of the day, caused by the local people trying to chase away vervets from the maize plantations around the forest. The human-wildlife conflict in the forest seemed to adversely affect the guereza colobus troop, which was particularly wary of observation, often freezing or fleeing during initial observation. The noise occurring in their environs may also have affected the time they spent feeding which was markedly reduced compared to *C. angolensis* ($p < 0.05$), and likewise, it accounts for the larger proportion of time spent moving by *C. guereza* in comparison to *C. angolensis* ($p < 0.005$).

C. guereza also maintained a higher mean height above ground than *C. angolensis* (Fig. 5). One reason for this may have been an attempt by the guereza troop to put distance between themselves and the sources of noise in the forest. *C. guereza* also exhibited a wider range in height compared to *C. angolensis* mainly due to a sudden dip in height later in the day in the *C. guereza* height pattern (Fig. 5), caused by the *C. guereza* troop descending to investigate the bait cages (section 5.1.3) that had been set out in that particular part of the forest. *C. angolensis* in contrast, were much more habituated and at ease with a lower height above the ground, and did not show much fluctuation in their mean height above ground throughout the day. These observations contradict those of other studies, in which *C. angolensis* was observed to maintain a higher height above ground (McGraw, 1994).

An alternative reason for the differences in height above ground for the two colobine species is their varying habitat types. The height range of the troops could be a reflection of the degradation that has occurred in the *C. angolensis* habitat in general, resulting in a lowered canopy height. The height ranges shown by the three Angolan colobus troops (Fig. 3) seem to reflect the quality of their habitats, where the mean tree height decreases as habitat quality declines (see appendix IIB). Furthermore, the habituation of *C. angolensis* to humans and the degradation of their habitat are other factors facilitating the frequency with which this colobus species came to the ground (movement along the ground was seen several times in this study). *C. angolensis* was also observed on the ground chewing on pieces of coral in this study, and there have been similar observations of colobus in Diani eating soil (Julie Anderson, personal communication), indicating that ground contact could also have been induced by nutritional factors. *C. guereza* in contrast was never seen on the ground.

8.0 CONCLUSION

The influences of age, sex and habitat factors on parasite prevalence in the Angolan colobus were investigated, and it was concluded that none of the investigated factors had any significant influence on parasite prevalence in this primate species. Patterns observed that indicated some influence (such as age and *E. coli* prevalence) were thought to be inconclusive due to the insufficient and unequal sample sizes collected from the age and sex groups.

The main mode of infection by gastro-intestinal parasites in the Angolan colobus (particularly with respect to nematode parasites) is known to be through ground contact. This theory is supported by the absence of nematode parasites in the guereza colobus, and also by the lack of ground contact observed in the guereza colobus. However the influence of climatic factors on the distribution of parasite species such as *Strongyloides* cannot be ruled out (Hinz, 1988), as each colobus species was observed in a different environment. The similar prevalence figures observed for protozoan parasites in both colobus species suggests that the protozoa may occur commensally in these primates, although with regard to *E. histolytica* (which is potentially pathogenic), the commensalism may exist only in cases of light infections (as were observed in this study). The case report documenting amoebiasis in guereza colobus (Loomis *et al.*, 1983) indicated that the stomach was also affected; it can be speculated that the stomach may be the site of commensalism in the colobus. Alternatively, there could be another mode of infection with protozoa, which needs to be further investigated.

The heavier density and higher prevalence of parasites in samples from baboons and sykes is in agreement with the theory of ground contact being the main source of parasitic infection.

The parasite prevalence in Angolan colobus and other primate species occurring in Diani may potentially act as an indicator of the change in the Diani habitat. Although there is a lack of previous studies in this area through which this statement may be supported, current adaptations in the behaviour of primates in Diani seem to be manifestations of such change. Behaviour such as ground contact in Angolan colobus, which is contradictory to reports from other studies (McGraw, 1994), and the scavenging habits of baboons and sykes seems to have evolved from habitat alteration via human activities. Such behaviour also facilitates parasite infection, and the source of the behaviour may bear further investigation.

Deforestation is a major cause of disruption to parasitic lifecycles and vectors. Expanding human populations and immigration result in the introduction of new vegetation types and can also lead to the introduction of new parasites or adaptation of the vectors (Patz *et al.*, 2000) in a habitat type. Deforestation for development threatens the *C. angolensis* populations in Kenya due to their restricted distribution, and also because forest reserves which are too small will be unable to support viable populations (Struhsaker, 1981). Such a threat to the forest habitat will inevitably affect the wildlife species that inhabit it, with the majority of these species being arboreal folivores (Eisenberg *et al*, 1972).

The ongoing tree damage in Diani is highlighted by the Colobus Trust Newsletter (2003) that reported a rise in the incidence of colobus monkeys falling out of trees. Such a report is unusual regarding a primate specially adapted to an arboreal lifestyle. As the gaps between the trees increase, colobus unable or unwilling to come to the ground attempt to cover the distance, but fall, an occurrence that highlights the diminishing forest cover available in Diani.

The time period of this study did not allow for the assessment of time-related trends in the data. Further observations in the future may reveal more about the factors facilitating parasite infection and forest degradation, which if not checked, may lead to irreversible degradation of the environment and the eventual disappearance of the forest together with the inhabitants. There is need to put in place an effective policy that will aid in preserving the Diani forest, which due to the lack of any such protection, is being unsustainably exploited. Investigations into the ability of Angolan colobus to adapt to various levels of forestation will aid in the long-term conservation (Skorupa, 1985) of the species in Diani. and elsewhere also. Similarly efforts should be made towards raising the awareness to the threats of deforestation in terms of exposure to parasitic infection amongst its other negative implications.

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APPENDIX A

APPENDIX A1 - FAECAL DATA COLLECTION SHEET

TIME	DATE	TROOP	MALES	SUBADULT MALES	SUBADULT FEMALES	JUVENILES	OTHER	COMMENTS

APPENDIX A2 - FORMOL ETHER CONCENTRATION RESULTS

1-10 cysts = +
11-20 cysts= ++
21 cysts or more = +++

AM = Adult Male
SAM = Sub-adult Male
JM = Juvenile Male

AF = Adult Female
SAF = Sub-adult Female
JF = Juvenile Female

ID	SEX	*E. coli*	*E.histolytica*	*Trichuris.*	*Strongyloides*	*E. vermicularis*
LB1	AM	(+)	(+)			
BVC1	AM	(++)	(+)		1	
WC1	AM	(+)	(+)			
LoM WC	AM	(+)	(+)			
MC1	AM	(++)	(+)			
VC1	AM	(+)	(+)			
TW1	AM	(+)	(+)			
DH1	AM	(+++)	(+)			
SC1	AM	(++)	(+)			
TF1	AM	(+)	(+)	2		
LoM CC	AM	(+)	(+)			
JH1	AM	(+)	(+)			
JW1	AM	(+)	(+)			
NB1	AM	(+)	(+)			
PF1	AM	(+)	(+)			
WR1	AM	(++)	(+)			
BC1	AM	(+)	(+)			
LB21	AF	(+)	(+)		1	
LB22	AF	(++)	(+)			
BVC21	AF	(+)	(+)	1		
BVC22	AF	(+)	(+)			
WC21	AF	(+)	(+)			
WC22	AF	(+)	(+)			
MC21	AF	(+++)	(+)			
MC22	AF	(+++)	(+)		6	
MC23	AF	(+++)	(+)		4	
VC21	AF	(+)				
TW21	AF	(+)	(+)	2		
TW22	AF	(+)	(+)			
TW23	AF	(+)	(+)			
TW24	AF	(+)	(+)			
DH2	AF	(+)	(+)			
RB2	AF	(+++)	(+)			
SC21	AF	(+)	(+)			
SC22	AF	(+)	(+)			

APPENDIX A2 cont. - FORMOL-ETHER CONCENTRATION RESULTS

1-10 cysts = + | AM = Adult Male | AF = Adult Female
11-20 cysts= ++ | SAM = Sub-adult Male | SAF = Sub-adult Female
21 cysts or more = +++ | JM = Juvenile Male | JF = Juvenile Female

ID	SEX	*E. coli*	*E.histolytica*	*Trichuris*	*Strongyloides*	*E. vermicularis*
CC21	AF	(+)	(+)			
CC22	AF	(+)	(+)			
CC23	AF	(+)	(+)			
JH21	AF	(+)				
JH22	AF	(+)	(+)			
JW2	AF	(+)				
NB2	AF	(+)	(+)		1	
PF21	AF	(+)	(+)			
PF22	AF	(+)	(+)			
PF23	AF	(+)	(+)			
WR21	AF	(+)	(+)			
WR22	AF	(+)	(+)	7		
BC21	AF	(+)	(+)			
BC22	AF	(+)	(+)			
BVC31	SAM	(+++)	(+)			
BVC32	SAM	(+++)	(+)			
BVC33	SAM	(+++)	(+)		1	
MC3	SAM	(+)	(+)			
VC3	SAM	(+)	(+)			
SC31	SAM	(+)	(+)			
SC32	SAM	(+)	(+)			
NB3	SAM		(+)			
WC3	SAM	(+)	(+)			
PF3	SAM	(+)	(+)			
BC3	SAM	(+)	(+)			
LB4	SAF	(+)	(+)			
BVC4	SAF	(++)	(+)			
SC4	SAF	(+)	(+)			
NB4	SAF					
WC5	JM	(+)	(+)	3	1	
NB5	JM	(+)				
PF5	JM	(+)	(+)			
BC5	JM	(+)	(+)	1		

<u>APPENDIX A2 cont.</u> - FORMOL-ETHER CONCENTRATION RESULTS

1-10 cysts = +
11-20 cysts= ++
21 cysts or more = +++

AM = Adult Male
SAM = Sub-adult Male
JM = Juvenile Male

AF = Adult Female
SAF = Sub-adult Female
JF = Juvenile Female

ID	SEX	*E. coli*	*E.histolytica*	*Trichuris*	*Strongyloides*	*E. vermicularis*
BVC6	**JF**	(+)				
VC62	**JF**	(+)	(+)			
CC6	**JF**	(+)	(+)			1
NB6	**JF**	(+)	(+)			
SC6	**JF**	(+)	(+)	1		
PF6	**JF**	(+)	(+)			

FORMOL-ETHER CONCENTRATION RESULTS FOR OTHER PRIMATE SPECIES

ID	N/A	*E. coli*	*E.histolytica*	*Trichuris.*	*Strongyloides*	*B. coli*
G1		(+)				
G2		(+)	(+)			
G3		(+)	(+)			
G4		(+)	(+)			
G5		(+)	(+)			
G6		(+)	(+)			
G7		(+)	(+)			
G8		(++)	(+)			
G9		(+)				
BB1		(+++)	(+)	(+)	(+)	(+)
BB2		(+)	(+)	(+)	(+)	(+)
BB3		(+)	(+)	(+)	(+)	
BB4		(+)	(+)			
BB5		(+)	(+)	(+)		
BB6		(++)	(++)		(+)	
BB7		(+)	(+)	(++)		(+)
BB8		(+)	(+)			
BB9		(+)	(+)	(+)	(+++)	(+)
BB10		(+)	(+)	(+++)		(+)
SS1		(++)	(+)	(+)		
SS2		(+)	(+)	(+)	(+)	
SS3		(+++)	(+)	(+)	(+)	
SS4		(+)		(+)		

APPENDIX A3 - McMASTER'S FLOATATION TECHNIQUE - RESULTS

ID	sample consistency	species	Eggs/gm
TF1	formed	*Trichuris*	50
TW22	formed	*Trichuris*	50
WR22	formed	*Trichuris*	100
SS 2	formed	*Trichuris*	50
BB 1	soft formed	*strongyloides*	450
		Trichuris	900
BB 2	soft formed	*strongyloides*	50
		Trichuris	300
BB 3	soft formed	*strongyloides*	100
BB 4	soft formed	*Trichuris*	150
BB 5	soft formed	*Trichuris*	100
BB 6	soft formed	*strongyloides*	50
		Trichuris	100
BB 7	soft formed	*Trichuris*	650
		strongyloides	50
BB 9	soft formed	*strongyloides*	2900
		Trichuris	200
BB 10	soft formed	*Trichuris*	750

APPENDIX A4 - HARADA - MORI LARVAL CULTURE - RESULTS

ID	SPECIES OF LARVAE PRESENT
VC4	*Strongyloides*
VC1	*Strongyloides*
MC1	*Strongyloides*
CC21	*Strongyloides*
CC22	*Strongyloides*
CC23	*Strongyloides*
CC6	*Strongyloides*
PF21	*Strongyloides*
PF3	*Strongyloides*
PF5	*Strongyloides*
PF6	*Strongyloides*
LB22	*Strongyloides*
WC31	*Strongyloides*
SS1	*Strongyloides*
SS2	*Strongyloides*
BB1	*Strongyloides*
	Trichuris
BB2	*Strongyloides*
	Trichuris
BB3	*Strongyloides*
BB4	*Strongyloides*
BB5	*Strongyloides*
BB6	*Strongyloides*
BB7	*Strongyloides*
	Trichuris

APPENDIX B

APPENDIX B1 - VEGETATION TRANSECT DATA SHEET

DATE: **HABITAT MEASUREMENTS:**

transect no.	indigenous	exotic	tree	damage	seen	% cover	can.ht	tree dist	comments
			natural	human	age				

APPENDIX B2 - VEGETATION TRANSECT STATISTICS FOR EACH TROOP'S AREA

AREA	INDIGENOUS (%)	CANOPY COVER (%)	CANOPY HEIGHT (m	TREE DISTANCE (m	TREE DAMAGE	Size (m2)
Leopard Beach	81.5	74	4.6	3.3	1	14518.1
Bahari Vet Clinic	59	25.7	4.1	5.2	0	2066.1
Warrandale Cottages	83.6	71.7	4.1	3.2	1	6808.9
Meditation Centre	46.8	59.7	6.8	2.7	1	10362.5
Vindigo Cottages	80.9	58.4	3.5	3.2	1	11493.5
Tradewinds	77.5	38.9	4.2	5.1	0	39319.8
Diani House	87.9	76.9	4	3.3	0	7864
Seacrest Cottages	71.8	31.1	3.9	4.4	7	20426.7
Colobus Cottages	74.5	52.3	6.3	2.5	10	25406.6
Jadini Hotel	41.2	58.8	4.9	5	1	3427.9
Jadini West	95.3	64.1	4.9	2.8	3	24803.9
Nomads Beach	91.4	77	8.4	3	0	11689.4
Pig Farm	93.8	80.7	6	3	4	22180.4
White Rose	53.6	43.8	5.2	4.5	3	6208.2
Bramingham Chalets	99.2	85.5	3.6	2.9	4	6247.3

Listed cases of tree damage refer to human tree damage

APPENDIX B3 – **PARASITE PREALENCE FOR COLOBUS TROOPS IN EACH HABITAT TYPE**

HABITAT TYPE	TROOP	No. of samples	*Entamoeba coli*	*Entamoeba histolytica*	*Strongyloides*	*Trichuris*
HABITAT I	LB	4	4	4	1	0
	WC	5	5	5	1	1
	LoM-WC	1	1	1	0	0
	TW	5	5	5	0	1
	DH	2	2	2	0	0
	PF	7	7	7	0	0
	NB	6	4	2	1	0
TOTAL		**30**	**28**	**26**	**3**	**2**
HABITAT II	MC	5	5	5	2	0
	VC	4	4	3	0	0
	CC	4	4	4	0	0
	LoM CC	1	1	1	0	0
	JW	2	2	1	0	0
	BC	5	5	5	0	1
TOTAL		**21**	**21**	**19**	**2**	**1**
HABITAT III	SC	7	7	7	0	1
	BVC	8	8	7	2	1
	JH	3	3	2	0	0
	WR	3	3	3	0	1
TOTAL		**21**	**21**	**19**	**2**	**3**

APPENDIX B4 – TREE DAMAGE IN THE COLOBUS TROOP HABITATS

Habitat Type	Troop Area	Human	Damage	Seen	Natural	Damage	Seen	Total Damage
		Recent	Old	Very Old	Recent	Old	Very Old	
I	LB WC TW DH NB PF	1 1 1	 1	 2			 1 6	1 1 0 0 1 10
Total		**3**	**1**	**2**			7	**13**
II	MC VC BC CC JW	 1 3 2	1 1 3 1 1	 5 			 2 1 2	1 1 6 11 5
Total		**6**	7	**5**			**5**	**24**
III	SC JH BVC WR	3 3	1 1 	3 	1 		 1	8 1 0 4
Total		**6**	**2**	**3**	**1**		**1**	**13**
Grand Total		**15**	**10**	**3**	**1**	**0**	**13**	**50**

APPENDIX C

APPENDIX D

APPENDIX C1 - BEHAVIOURAL DATA SHEET

PERIOD: **TROOP:** **DATE:**

time	activity	noise	predators	distance	Troop spread	reaction	comments
				AG TB			

KEY FOR NOISE

1 = Birds/Sea/Natural noises

2 = Faint/background human made noises

3 = Human made noises in vicinity (chatter, passing cars)

4 = Loud human made noises (construction, hammering, shouting)

AG = Distance of the colobus troop above ground

TB =Distance of observer from base of tree with colobus

KEY FOR REACTION

1 = Intolerant of observation/flee from observation

2 = Wary of observation/alert to observer's movements

3 = Tolerant of observation

APPENDIX D – The guereza colobus (*Colobus guereza*)