BARK STRIPPING BY CHACMA BABOONS (*PAPIO URSINUS*) IN RELATION TO DAILY PATTERNS OF ACTIVITY, FEEDING BEHAVIOUR AND HOME RANGE IN A PINE PLANTATION IN EASTERN ZIMBABWE.

By

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DEDICATION

This project is dedicated to the problem animal control efforts and continued research into the bark-stripping problem by chacma baboons (*Papio hamadryas ursinus*) in pine plantations.

ABSTRACT

This study reports daily activity pattern, home range size, daily travel distances and feeding behaviour for a troop of chacma baboons (*Papio hamadryas ursinus*) inhabiting a pine plantation in Eastern Highlands, Zimbabwe. The amount of time spent foraging is similar to other baboons, *Papio hamadryas* in particular. The minimum home range size and daily travel distance for this troop are smaller than those reported for other troops of chacma, yellow, olive and hamadryas baboons in South Africa, Kenya, Ethiopia, Eritrea and Saudi Arabia. Erin forest baboon densities, however, are much larger than those reported elsewhere for baboons. The high densities may be related to the high concentration of food resources within the pine plantation.

The study also examined the possible underlying causes of bark stripping by chacma baboons. Bark stripping does not appear to be linked to critical limitations in resources such as food, sleeping sites or water. Instead, bark stripping may be a prophylactic or trace nutrient augmentation measure as suggested by a high correlation between coughing by baboons and bark stripping. This possible link between baboon health (as reflected by coughing), parasite loads and trace nutrient requirements and bark stripping merits further investigation.

TABLE OF CONTENTS

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LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

DTD:	daily travel distance
FAO:	food agriculture organisation
GPS:	geographical positioning system
MAR:	mean annual rainfall
MCP:	minimum convex polygon

CHAPTER 1

INTRODUCTION

1.1 Background to the Study

Bark stripping by the chacma baboon, *Papio hamadyas ursinus* has been well documented (Bridgewater *et al,* 1997; *Acacia tortillas* Cumming, personal communication; Katsvanga *et al,* 2006). Bark stripping has also been documented in other primate species, *Celtis africana* by the mangabey (*Cercocebus albigiena*) (Waser, 1977); colobus monkey (Camperio-Ciani *et al*, 2001); barbary macaques (*Maca* sylvanus) (Menard, 2002) and blue monkey (Beeson, 1985; Maganga & Wright, 1991). Baboons damage pine trees by bark stripping, they consume the cambium on the main stem just below the crown (Bridgewater *et al*, 1997).

This results in three principal effects on tree growth. Firstly, the damaged tree is exposed to heavy staining as a result of fungal infection. Secondly, damaged trees are susceptible to stunted or deformed growth. Lastly, mortality occurs from the point of damage upward in cases of ring barking. The major consequence of baboon tree damage is the reduction in stand productivity because of tree mortality and stunted or deformed growth (Bridgewater *et al,* 1997). There is also an increased tree susceptibility to fungal infection.

In South Africa slash pine, *Pinus elliotti* and loblolly pine, *Pinus taeda* are highly susceptible to baboon damage (Bridgewater *et al,* 1997). Similarly in Zimbabwe *Pinus patula* and *P. taeda* are prone to bark stripping by baboons. Trees aged 10 years and above are particularly at high risk but almost all ages of trees are potentially vulnerable. With increasing extensive plantation development, forests now have an

increasingly important role as havens for wildlife (FAO, 1993). Plantations offer shelter from the elements, relative temperature constancy, food and sleeping sites Menard (2002) argues that bark stripping by barbery macaques, *Macaca sylvanus*, in the Middle Atlas could present an adjustment to forest ecosystem modification due to human pressure. It is not yet clear if this could be applied to bark stripping by baboons in pine plantations of the Eastern Highlands, Zimbabwe.

This rise in damage might also be attributed to the effects of exotic species (in this case *Pinus species*) on forest wildlife and wildlife habitat since in some cases exotic species have been shown to reduce forage or cover for wildlife (Campbell, 1997). Exotic species may also change the pattern of plant succession affecting the succession and yield of indigenous plants that provide food to baboons. Practices such as plantation forestry may produce a habitat of poorer food quality than what was previously there, could bark stripping present an adjustment to an altered habitat? This damage is also attributed to the 1991/92 droughts, which left the baboons with little food to forage within their habitats (Mhongwe, 1995).

1.2 Aim

The underlying causes of bark stripping by baboons have not been established and the context in which it occurs has not been previously described. This study aimed to examine bark stripping relation to the daily activity patterns, home range size, daily travel distances and feeding behaviour. The focus was to better understand the context in which bark stripping occurs to identify the causes of bark stripping by baboons. This will enable an understanding of the spatial and temporal distribution of bark stripping in relation to daily activity patterns, feeding behaviour and home range of

baboons in pine plantations allowing for comparison with other savannah dwelling baboons in order to identify the underlying causes of this behaviour.

1.3 **Questions**

More specifically the study examined the following questions:

1. Does time activity budget (feeding, resting, socializing, moving and bark stripping) vary with time (weeks)?
2. Is there a relationship between home range size, daily travel distance and behavioral activities?
3. Are there any variations in home range size between weeks?
4. Are there any relationships between behavioral activities and weather variables (minimum, maximum and mean daily temperatures and humidity)?
5. How is bark stripping related to daily pattern of activity, feeding behaviour, ranging behaviour and use of resources in the home range?

CHAPTER 2

LITERATURE REVIEW

2.1 Study animals

The savannah baboon is *Papio hamadryas* (Linneus, 1758) and is distributed from North Africa to the Cape in South Africa. Some five sub-species are recognised of which the chacma baboon (*Papio hamadryas ursinus*) is one. Savannah baboons occupy a diverse set of habitats including the African woodland savannah and highland grassland. They are found in Angola, Botswana, Mozambique, Zambia and Zimbabwe. Baboons are large group living primates (Altmann, 1980). The chacma baboon (*Papio hamadryas ursinus)* is highly gregarious and social, living in troops of 15-100 individuals.

In areas where aspects of the habitat such as feed and living spaces are patchy, the populations are found in clusters or clumps (Starr & Taggart, 1993). Within a troop, all adult males are dominant over the females a status achieved in their fifth year but there is strict order of rank (Tilde & Tilde, 1997). Baboons are highly terrestrial primates (1980), which make them easy to observe when compared to arboreal primates. An adult male baboon measure 120- 180 cm while the female 100-120 cm. The weight varies between 20-45 kilograms and 12-28 kilograms for adult male and female respectively (Tilde & Tilde, 1997).

2.2 Activity pattern

Activity patterns have been studied in several primate taxa including hominoids: (Goodall, 1986; Watts, 1988; Clutton-Brock, 1977); cercopithecines: (Post, 1981; Van Schaik, *et al*, 1983; Isbell & Young, 1993); colobines: (Struhsaker, 1975). Time is limited for most animals (Dunbar, 1988; 1992). Thus, animals are faced with the challenge of allocating the limited time to different activities. According to the optimality theory, "the amount of time that an organism spends engaged in various activities depends on the cost of the activity relative to the derived benefits in that organism's habitat" (Gessaman, 1973).

The amount of time spent on foraging activities therefore relates to the energy content of the food relative to the costs of obtaining the food plus the cost of all other activities (resting, moving or socialising). Thus, specifically, food availability and energy content are critical determinants of an animals' daily activity pattern. Therefore, factors that influence the availability of food have a strong bearing on time allocation profiles in baboons.

Due to the different costs and benefits of specific activities animals have varying time allocation profiles based on age and sex for certain activities (Johnson & Bock, 2004). Furthermore, since these activities cannot be performed simultaneously some individuals may allocate time between various behaviours better than others (Dunbar, 1988; 1992). The costs and benefits of these activities change with changes in the ecological and social state of the environment as well as the physiological state of the animal.

This gives rise to temporal and spatial variation in individual activity budgets of the animal. Consequently, time allocation profiles vary seasonally in response to changes in the abundance, quality or distribution of important foods (Altman & Muruthi, 1988; Isbell & Young, 1993). This is consistent with evolutionary theory, which predicts that animals should be sensitive to changes in the ecological and social environment and thus should adjust time allocation to suit current conditions. Byrne *et al* (1993) provide evidence of changes in time spent foraging in different seasons with more time spent foraging during winter than both spring and early summer.

Baboons allocate the greater proportion of their time to foraging activities (Altmann & Altmann, 1970; Barton *et al*, 1992; Gaynor, 1994; Bronikowski & Altmann; 1996; Hoffman, 2007). De Hoop and Mkuzi baboon troops spent 69.8 % and 66.5 % of their time foraging respectively (Gaynor, 1994). In a study of Alto, Hook and Lodge baboon groups in Amboseli, Kenya, Bronikowski & Altmann (1996) report them to spend 69.8 %, 75.2 % and 43 % of their time foraging, respectively. The Lodge troop spent relatively less time foraging than Alto and Hook groups.

This was largely because Lodge group has access to human foods, which required less processing and may be high in calorific value. Thus, such food-enhanced troops spend far less time foraging. Byrne *et al* (1993) reported 74 % and 72 % of foraging time for the "High" and "Low" troops of the Drakensberg Mountains, respectively. These large values are highly attributed to the altitudinal gradient of the mountains, which impose nutritional bottlenecks on the animals.

Baboons have been observed to increase foraging time and decrease time spent on other activities in winter. The Tokai baboon troop increased time spent foraging by 11.7 % during winter (Hoffman, 2007). In the Drakensberg Mountains "High" and "Low" groups showed a 4.8 % and 1.6 % increase in time spent foraging respectively (Byrne *et al*, 1993). However, Byrne *et al*, (1993) noted that fewer nutrients are gained from the same time invested in foraging during late winter than the early summer. This was because these troops are already at the limits of the time they could invest in foraging (Whiten *et al*, 1987). Dunbar (1992) found time spent feeding to be a negative function of mean annual temperature and a positive function of day journey length. Consistent with this finding Bronikowski & Altmann (1996) observed that Alto and Hook troops in Amboseli spent more time feeding in years with lower minimum temperatures.

Some studies have observed the social activities of baboons to increase during winter (Hoffman, 2007). Hoffman (2007) further noted social activities to be the second most important activity after foraging. This is because primates, baboons in particular, are social animals, which require time to establish and maintain social relations (Di Fore & Rodman, 2001). This is contrary to Bronikowski & Altmann (1996) who found resting to be the second most important activity in Alto, Hook and Lodge baboon groups. Dunbar (1992) suggested time spent socializing by wild feeding baboons to be abnormally or stressfully low. Bronikowski & Altmann (1996) suggested a minimum of 15 % and 9 % for socialising and resting respectively

Some aspects of individual time budgets also covary with social variables such as group size, for example in primates' time allocated to movement (Clutton-Brock & Harvey, 1977; Wrangham *et al*, 1993) or to foraging (De Ruiter, 1986; Miller, 1996) increases with group size. Interrelations between species ecology and its behaviour are better understood through the analysis of how that particular species allocates time to various activities (Struhsaker & Leland, 1979) under a set of defined conditions.

Weather patterns have both direct and indirect influences on the activity pattern of primates. Rainfall and temperature have pervasive effects on animals (Bronikowski & Altman, 1996) and so influence time allocation patterns both temporally and spatially. The most important effect of weather on primates is indirect in that food availability is strongly influenced by weather conditions. Furthermore, analyses within species have shown variation in time budgets across primate populations to be related to local climatic conditions (Dunbar, 1992). One variable of particular importance is rainfall, which is known to be a reliable predictor of primary productivity in sub-Saharan habitats (Deshmukh, 1984). Since spatial and temporal variations in rainfall affect the distribution of important food resources, baboon time allocation profiles are impacted.

2.3 Home range behaviour

Home range is that area traversed by an individual in its normal activities of food gathering, mating and caring for the young (Burt, 1943). The delineation of the home range differs across studies but the underlying assumption is that an individual will stay within its home range for the majority of its activities (Vincent *et al*, 2005). As Robertson *et al* (1998) said, "for the purpose of analysis, the home range may be identified as an outline enclosing a specified proportion of an animal's trajectory over a specified period, wherein the trajectory is the line of movement through space and

time described by the animal. In some cases a portion or the whole home range will be defended in which case it is known as the territory (Burt, 1943; Grant *et* al, 1992).

A number of factors influence or are determinants of an animals' home range size. These factors include predation (Clarke *et al*, 1993); energetic requirements and body size (Harvey & Clutton-Brock, 1981; Kelt & van Vuren, 1999); resource distribution (Dill *et al*, 1983, Grant, 1997) and intra-specific interactions (Grant *et al*, 1992) and mating systems (McCarthy & Lindemayer, 1998). In many primate species, food availability is an important variable, which influence their spatial movement patterns (Isbell *et al*, 1998; Chapman & Chapman, 2000; Li *et al*, 2000; Gillespie & Chapman, 2001; Kaplin, 2001). It would be expected that where food availability is high home ranges would also be smaller.

A number of studies have been carried out on the home range behaviour of baboons (De Vore & Hall, 1965; Altmann & Altmann, 1970; Sigg & Stolba, 1981; Boug,*et al*, 1994; Swedell, 2002; Hoffman, 2007). Home ranges in hamadryas baboons have been found to range from 9.3 km^2 (Boug *et al*, 1994) to 28 km^2 (Sigg & Stolba, 1981). Home range size for chacma baboons range from 9 km^2 (Hoffman, 2007) to 20.9 km^2 (De Vore & Hall, 1965). Hoffman (2007) reported larger home range size for the Tokai baboon troop in winter and relates this to the abundance and distribution of seasonal foods. This is despite the fact that winters in the cape are wet and thus food availability would be expected to be high.

In most cases, animals do not utilise their home range with equal intensity, certain areas are used more heavily than others are. These are termed *core areas,* described as the area of heaviest use during an observation period. Intensity of use is linked to the distribution of important resources within the home range (Altmann & Altmann, 1970; Barton *et al,* 1992, De Vore & Hall, 1965). Core areas have been reported in chacma baboons (Hoffman, 2007) and mountain gorillas (Robbins & McNeilage, 2005).

As noted in many frugivorous primates, food abundance and its distribution influence daily travel distances and the frequency of habitat use (O'Brien & Kinnaird, 1997; Olupot *et al*, 1997). Other studies have noted larger home range sizes in relation to body size in frugivorous primates (Clutton-Brock & Harvey, 1977). In addition, the distribution of water (Altmann & Altmann, 1970); social interactions (Isbell, 1983); parasite avoidance (Freeland, 1980); weather conditions (Wu & Lin, 1993) and sleeping sites (De Vore & Hall, 1965; Altmann & Altmann, 1970) have also been cited as determinants of ranging and habitat use.

Among primates, group size has a positive relationship with home range size (Clutton-Brock & Harvey, 1977; Swedell, 2002). The ecological constraints model predicts that as group size increase the amount of food needed collectively by the group increases and daily travel distance and home range should expand accordingly (Clutton-Brock & Harvey, 1977; Chapman & Chapman, 2000). Other studies have observed larger home range sizes for smaller group sizes (e.g. Hoffman, 2007). Additionally social factors such as the search for mates or the avoidance of competitors may also influence the ranging pattern of baboons (van Schaik, 1996).

An understanding of the home range and feeding behaviour is useful in quantifying the spatial and ecological needs of social groups (Robbins & McNeilage, 2003). Perry *et al*, (2002) also note that spatial analysis is relevant to the management and conservation of ecological systems. In addition to this, the quantification of baboon spatial patterns (home range size and use and daily travel distances) enables inferences to be made on the possible causation of behaviour (Perry *et al*, 2002).

The Alto and Hook groups travelled farther in years when group size was smaller (Bronikowski & Altmann, 1996). This is contrary to the findings of other studies on baboons (Barton *et al*, 1992; Dunbar, 1992) and macaques (Van Shaik *et al*, 1983). Hall (1962) report long winter day journeys and attributed this to seasonal variation in food availability despite having wet winters in the Cape when food availability is high. This is because seasonal changes in resource availability (Altmann & Altmann, 1970; Whitten *et al*, 1987) affect baboon home range sizes, range occupancy and ranging patterns (Barton *et al*, 1992).

2.4 Bark stripping

Bark stripping has been documented in sheep and feral goats (Scowcroft & Sikai, 1983); red deer (Welch et al, 1987; Welch & Scott, 1998; Verheyden *et al*, 2006;), sika deer (Jiang *et al*, 2005), macaques (Camperio-Ciani *et al*, 2001), blue monkeys (Beeson, 1985; Maganga & Wright, 1991), elephants (Gadd, 2002), rodents (Baxter & Hansson, 2001), grey squirrels (Kenward & Parish, 1986), moose (Miquelle & Van Ballenberghe, 1989) and baboons (Bridgewater *et al*, 1997).

McIntyre (1972) summarizing the more plausible hypotheses to explain why animals strip bark, included:

a) Bark is high in lignin and therefore a good source of necessary roughage
b) Fresh bark during droughts, can be a source of moisture
c) Interaction of animal density and habitat quality is such that as animal density increase or habitat quality decrease bark-stripping increase.

In an analysis of bark stripping by grey squirrels (*Sciurus carolinensis*) (Seymour, 1961) concluded that water shortage was unlikely to be the cause of stripping because trees were even stripped by open water. Contrary to this Camperio-Ciani *et al* (2001) noted that water scarcity and monkey exclusion from available permanent water sources correlated with intense bark stripping behaviour by macaques. Bark stripping might as well be a territory boundary marking behaviour (Taylor, 1966; 1969). However, a study of baboon home range behaviour showed that baboons are not territorial (Altmann & Altmann, 1970). Baboons remove bark from tree stems by biting and pulling instead of gnawing and then consume the soft vascular tissue or cambium, thus this view does not hold (Ndagurwa, personal observation).

Despite the number of alternative possibilities, most authors have agreed that food shortage is the most frequent cause of bark stripping (MacIntyre, 1972**;** Welch *et al*, 1987; Miquelle & Van Ballenberghe, 1989; Gill, 1992**)**. Dietary trace nutrient deficiencies may also be a cause of bark stripping (Mackinnon, 1976). Jiang *et al* (2005) also found stripping by sika deer to overlap with periods of low food availability and poor food nutrition (faecal component index). The findings by Hiroshi *et al* (2002) support this argument as they also found that bark stripping by the

Japanese black bear occurred when food production and nutrient availability in the stands was poor as a result of deep snow cover.

The arguments that bark stripping results from food shortage is consistent with findings by Verheyden *et al* (2006) in bark stripping by red deer. Maganga & Wright (1991) found damage by blue monkeys (*Cercopithecus mitis*) on pine trees (*Pinus patula*) to be 88.7 % of the planted area. In addition, they found damage to increase in the dry season, peaking in June and July (which are periods of low food availability). Bark stripping by moose and deer occurred at places where very little, or no, food was available (Miquelle & Van Ballenberghe, 1989; Welch *et al*, 1987).

Other studies have also shown that more bark stripping occurs in areas where other food resources are less available (Welch *et al*, 1987; Miquelle & Van Ballenberghe, 1989). (Camperio-Ciani *et al*, 2001) hypothesized that bark stripping by primates may be a response to environmental stress such as lack of food and nutrients at ground level or shortage of water. Drucker (1984) suggests that macaques look for water retained by the tree during the dry season when fruits, herbs, and other normally available water resources in the undergrowth have been exhausted.

Kenward & Parish (1986) noted bark stripping by grey squirrels to be consistently correlated with phloem width, with stripped trees having the most phloem. This is consistent with findings that trees most damaged by squirrels and blue monkeys (*Cercopethicas mitis*) tend to be the largest and thus have greater phloem volume (Mackinnon, 1976; Beeson, 1985). Bark stripping was also found to occur when juvenile density was high (Kenward & Parish, 1986). This might be explained as juveniles bark stripping through exploratory feeding. In other cases, animals could eat

bark to compensate for particular mineral deficiencies or because of its anti-parasitic properties (Verheyden *et al*, 2006).

2.5 Damage in pine plantations

Damage in pine plantations results in three principal effects of bark stripping on tree growth; (1). Damage sites increase the likelihood of invasion by harmful insects and disease organisms that could kill trees and reduce their vigour. Pine trees are usually susceptible to heavy staining because of fungal infection; (2) damaged trees are susceptible to stunted or deformed growth, and (3) mortality occurs from the point of damage upwards in cases of ring barking. A combination of such effects within a timber stand can be extremely detrimental to the health and economic value of the timber stand. Damaged timber stands suffer from delayed growth, lengthening the rotation period of that particular timber stand (Nolte & Dykzeul, 2002).

The temporal and spatial scales of forests ensure varied habitats (Nolte & Dykzeul, 2002) that are home to wild animals including baboons. Chacma baboon populations are mostly found in old stands usually 10 years and above. Stands that have undergone improvements such as thinning and pruning are highly vulnerable to damage. Under such a scenario, timber loss is very severe since the most vigorous trees tend to be selected (Nolte and Dykzeul, 2002). Attempts have been made to quantify the levels of damage in pine plantations in Zimbabwe (Katsvanga *et al*, 2006).

2.6 Feeding behaviour

Baboons are dietary generalists consuming a wide range of food items in varying proportions (Codron *et al*, 2005). Baboons are characterised by highly flexible and adaptable foraging strategies, which enable them to extract nutrients from almost all compartments of their environment (Tutin *et al*, 1991). Plants are the most important source of nutrients for baboons (De Vore & Hall, 1965). Invertebrates and vertebrate animals consumed constitute relatively little in calories and protein (Alberts *et al*, 1996).

The dietary diversity of chacma baboons and ability to exploit a wide variety of foods allows them to utilize highly seasonal and modified habitats such as pine plantations where native plant species are patchily distributed. The diet includes a variety of grasses, roots, leaves, flowers, seeds, bark, mushrooms, tubers, lichens and bulbs. Invertebrates that are consumed include grasshoppers, spiders and scorpions (Post, 1982; Norton *et al*, 1987, Byrne *et al*, 1993; Altmann, 1998). Vertebrate prey taken includes lizards, turtles, frogs and young of nesting birds, small rodents and hares.

Baboons are also excellent diggers they can utilise the tubers, bulbs and corms of plants (Post, 1982; Norton *et al*, 1987), the corms are fleshier and have more water content than the tips of the blades (Altmann & Altmann, 1970). Adults are more efficient in the finding, gathering, and preparing of sedge corms and seeds than younger animals. Although even small juveniles and weaned infants are efficient in gathering and preparing them **(**Rhine & Westlund, 1978**)**.

The dietary behaviour of baboons is aimed at maximizing protein intake regardless of their environment (Codron *et al,* 2005). This is indicated by the high faecal nitrogen levels in South African savannah baboons (Codron *et al,* 2005). This is because the foraging strategies of baboons are highly flexible and adaptable enabling the baboons to extract nutrients from a wide range of environments (Clutton-Brock & Harvey, 1980). The foraging behaviour of baboons is also influenced by the trade-offs between their needs to find food, avoid predators and successfully reproduce (Cowlishaw, 1997). Competition and disruption between feeding tend to increase with increase in-group size necessitating increased foraging time.

CHAPTER 3

STUDY AREA AND METHODS

3.1 Study Area

Erin estate occupies 107.4 km^2 in the Eastern Highlands of Zimbabwe, in Nyanga district. It lies 20 km south of Nyanga village along the highway to Mutare and Rusape. Erin is bound by Juliasdale, Claremont to the west, Nyanga National Park mainly bounds it to the east, north, and Nyanga timbers, new resettlement areas, and several small plots bound it to the south. It lies on longitude 32^o 38` and $32^o$ 47` east and latitudes 18^o 16` and $18^o$ 25` south. The plantation is predominantly *Pinus patula* (6589 ha), *Pinus taeda* (5 ha), *Pinus elliotti* (45 ha) and hardwoods (*Eucalyptus species)* (45 ha) (Environmental Management Manual, 2005). *Pinus patula* represents 99 % of the planted area. The riverine areas are mostly dominated by wattle (*Acacia mearnsii*) regenerations.

3.1.1 Rainfall

Rainfall around the Nyanga area is largely orographic due to the mountainous terrain. There is local variation in rainfall pattern in the Juliasdale area due to these orographic effects. The moisture-laden winds from the Indian Ocean precipitate most of their load on the eastern slopes of the Nyanga Mountains. An examination of the rainfall records of the area confirms the absence of a true dry period. Most of the rains are concentrated in the summer months between November and March (Fig 3.1).

Little precipitation occurs between May and September (Appendix 2). This amount in combination with the cooler temperatures that prevail in the area is normally sufficient to maintain moist conditions at least in the subsoil throughout the year.

Juliasdale receives a mean annual rainfall (MAR) of about 1090 mm per year and Nyanga experiment station about 1051 mm per year (Appendix 2; Fig 3.1).

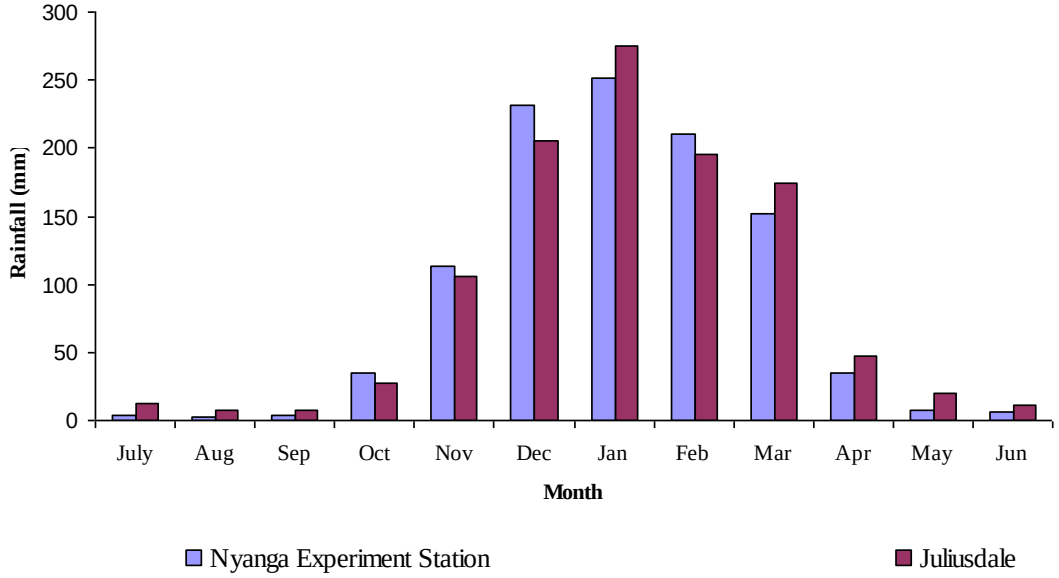

Figure 3.1. Mean monthly rainfall in the study area.

3.1.2 Temperature

Temperature records were obtained for Nyanga experiment station only where the mean annual temperature is approximately 15^{o} C. The coldest months are June and July with a lowest maximum temperature of 18,9^{o} C. The hottest month is October when the highest maximum temperature is 25.8^{o} C. Mean minimum temperatures are lowest in July, 5.2 ^{o} C and highest in January 18.9 ^{o} C.

Frosts are frequent occurring between May and September with the highest incidence in June and July. The rugged and mountainous terrain is the main determinant of frost risk with valleys and vleis that receive and retain cooled night air being especially susceptible. Weekly mean daily temperatures for the 8 weeks of the study differed (T-test for independent means: $t = 3.71$, $df = 6$, $P < 0.01$) but humidity did not (T-test for independent means: $t = 1.54$, $df = 6$, $P = 0.17$).

Table 3.1. Average maximum, minimum and mean daily temperatures and humidity for the study period.

Variable	Mean	Range	Standard deviation
Daily maximum temperature	16.4 ^{o} C	15.1 ^{o} C – 17.8 ^{o} C	1.09 ^{o} C
Daily minimum temperature	12.5 ^{o} C	10.5 ^{o} C – 15.4 ^{o} C	1.60 ^{o} C
Mean daily temperature	14.4 ^{o} C	12.9 ^{o} C – 16.6 ^{o} C	1.31 ^{o} C

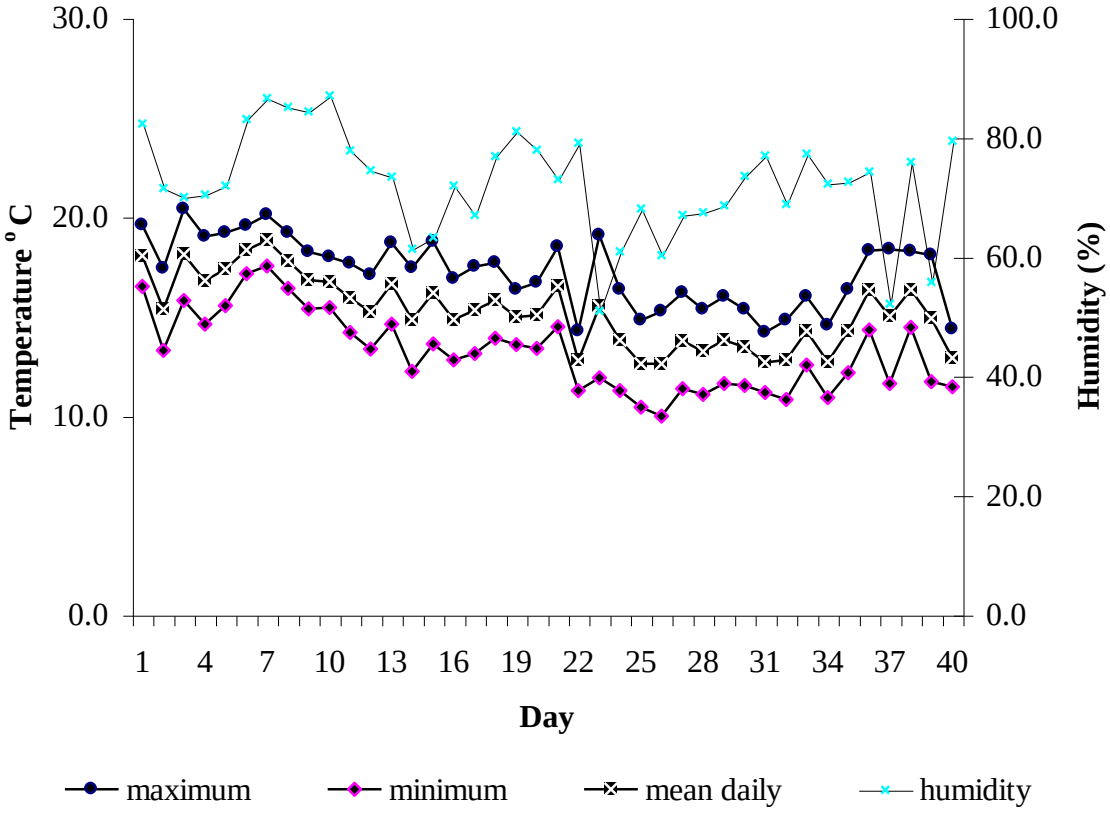

Figure 3.2. Maximum, minimum and mean daily temperatures and percentage humidity during the study period at Erin forest measured in the field on a daily basis using a whirling psychrometer.

3.2 Methods

3.2.1 Study animals

Shatter Troop ranges in the B-block area of the estate and was studied for two months April and May. Group size ranged between 26 and 40 individuals (mean = 30.5). This troop is a bark stripping pine forest ranging troop. This provided an appropriate study troop in which the bark stripping behaviour could be investigated.

3.2.2 Data collection

Before data collection commenced, Shatter Troop was habituated by tracking the troop throughout the day for 10 days. The troop was followed on foot and the same type of clothes was worn each day until the animals were accustomed to the observer. The troops are monitored by forest guards throughout the year, which enabled easy habituation of the baboons to close observations by the observer. Loud noises were avoided since these would disrupt the activities of the baboons. Crossing open areas was a highly specialized operation in this troop, probably because predators often use such areas as hunting points. Therefore, troop follows during such an operation were carried out slowly to avoid disturbing the troop.

Data were collected on Shatter Troop over a period of two months (April and May) 2007. Data were collected on three broad categories activity pattern, feeding behaviour and ranging behaviour. During this period full and part day data were collected but only the data for full days data were used for the analysis. On complete days, the troop was followed from their previous nights' roost to their evening roost. The dataset obtained consist of 21 full days (0700- 1700hrs) and 19 full days (0600hrs-1700hrs) yielding a total of 419 hours of observation and 1 676 behavioural observations. Partial days resulted from the failure to locate the troop and bad

weather. The first 21 days observations began at 0700 hours due to transport constraints 0700 hours was the earliest time the troop could be located.

3.2.2.1 Daily activity patterns and feeding behaviour

Scans of individual behaviour were recorded at 15-minute intervals (Altmann, 1974). A scan is when all the activities of all visible animals are censused at longer time periods or intervals (Clutton-Brock, 1977). Scans were conducted across the troop recording the activity, lasting for more than 5 seconds, of each visible individual. Behaviour categories were categorised as feeding, moving, resting, socialising (Altman, 1980; post, 1981; Dunbar and Dunbar, 1988). Feeding was subdivided into feeding on the ground, bark stripping and digging. The type of food, species and part eaten were also recorded were possible. Additional categories recorded were coughing and "other activities" (self grooming, scratching, mating, and vocalisation).

The definitions of activity categories followed (Alberts et al, 1996) and are as follows:

Feeding:	When an animal was in manual or oral contact with a food item, except that chewing was excluded; feeding was recorded only as long as the food item was wholly or partly outside the animal's mouth
Moving:	when animal was locomoting and not simultaneously feeding
Social behaviour:	when animal was grooming or being groomed by another individual, or engaged in any other agnostic or affiliative social interaction

Resting: when animal was sedentary and not engaged in feeding or in social interactions; included self-grooming.

Data were also collected at each scan on temperature (minimum and maximum) and humidity. Temperature data were collected using a handheld whirling psychrometer. Humidity was derived from humidity tables using the minimum and maximum temperature recorded from the psychrometer. Altitude, slope and vegetation (Riverine grassland, Riverine forest, Roadside vegetation, and Fire break) were also recorded for each scan sample.

3.2.2.2 Home Range behaviour

The location of the troop was recorded using geographical positioning system (GPS). Geographical positioning system (GPS) data points were recorded as UTM coordinates and spheroid WGS84. These were recorded during each scan sample at 15-minute intervals. The elevation of the area was also recorded in meters and time of recording was noted. GPS points were recorded using a Garmin 12 GPS unit.

3.2.3 Data analysis

3.2.3.1 Activity patterns and feeding behaviour

Time spent on a particular activity was calculated as the number of individuals engaged in that activity in each scan as a proportion of the total number of animals in each scan. These scan budgets were then used as individual data points in calculating overall estimates of time spent on various activities. This method has the advantage that it is easily repeated, simple to record and suitable for comparisons to other studies as it has been used by many authors (for example Altmann, 1974; Chivers, 1977;

Clutton-Brock, 1977; Altmann, 1980; O'Brien & Kinniard, 1997, Iwamoto & Dunbar, 1983).

This method is particularly useful when variable numbers of individuals are seen per scan (Clutton-Brock, 1977; Martin & Bateson, 1993) or when behaviour is synchronized such that the behaviour of a few individuals recorded in each scan can be used to represent the troop's overall behaviour (Clutton-Brock, 1977). Analysis of behavioural categories was limited to feeding, moving, resting and socialising since previous studies have noted them to account for over 95% of a baboons' daily activities (Dunbar, 1992). Other behavioural categories such as coughing were only included in order to highlight interesting observations.

The dataset was proportional data so non-parametric statistical tests were employed (Zar, 1984; Sokal & Rohlf, 1995). Variations in activity pattern and meteorological variables were analysed using Mann-Whitney-U test and Kruskal-Wallis test. Correlations between behaviour and meteorological variables were done using Spearman's Rank correlation analysis (Sokal & Rohlf, 1995) and the procedure followed Bronikowski & Altmann (1996).

3.2.3.2 Home range behaviour

The GPS data points were entered into Microsoft Excel (2000) spreadsheet then exported to Arcview GIS 3.2. Home range size was calculated using the minimum convex polygon (MCP) (Southwood, 1966) on a weekly (week= 5 days) and monthly basis (Fig 3.4). This was calculated using the Home range extension to Arcview GIS 32. The MCP calculates home range area as the area of the polygon that connects the outer most fixes for each animal. The MCP is more accurate when the number of data

points is low, however, peripheral data points may influence home range size (Harris *et al*, 1990) and it cannot deal with fragmented home ranges. Ostro *et al* (1999) found the MCP method to overestimate home range area but was a good estimator for cross study analysis, though the coarseness of the method requires that the results be interpreted with caution.

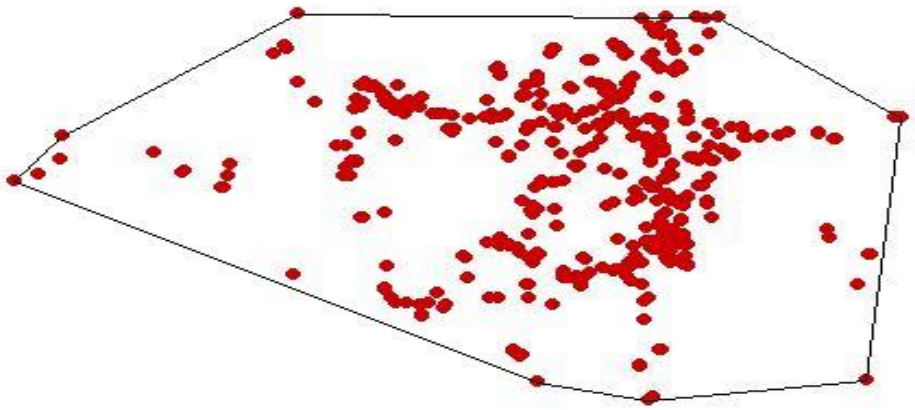

Figure 3.3 Outline represents the home range using the Minimum convex polygon (MCP) method for home range size estimation and shows the distribution of data points within the home range.

3.2.3.3 Home range use and ranging behaviour

This was analysed by calculating a continuous density surface from the data points. This method creates a grid theme as an output. Each cell in the theme contains the number of occurrences per square unit of area surrounding a particular location. 100 m x 100 m cells were used to indicate the utilization of timber stands (per ha). The search radius was considered 51 m to cater for points occurring at overlaps or radius boundary. Density was used in the sense of probability not individuals per unit area (Altmann & Altmann, 1970).

The daily travel distances (DTD) were calculated using the Animal Movement extension (AnimalMovement2.avx) to Arcview GIS 32. DTDs were calculated for each single day and weekly and monthly means were calculated from these figures. The foraging routes were mapped within the home range essentially to show the distribution of foraging effort within the home range.

CHAPTER 4

RESULTS

4.1 Daily activity pattern

The general pattern of activity of the chacma baboons was characterised by most time spent feeding (mean = 49.3 %) (Table 4.1), may be because of foraging in a modified habitat. Social activities (mean = 22.8 %) ranked second to feeding activities during the whole study period. Moving, resting and other activities complete the rest of the activities in descending order according to time spent (Table 4.1). Coughing occurred in 1.3 % of the total activity time. The broad daily pattern was characterised by more time spent feeding throughout the study period

Table 4.1. Amount of time spent on different activities each week by chacma baboons in Erin forest. S.D = Standard deviation

Activity	Time spent (%)			Number of days
	Mean	Range	S. D	
Feeding	49.3	41.80 - 54.70	4.4	40
Moving	19.1	14.90 – 27.00	3.99	40
Resting	10.9	7.30 - 13.30	1.99	40
Socializing	22.8	19.20- 27.30	2.78	40
Coughing	1.3	0.20 - 3.70	1.1	40
Other	5.5	3.40 - 7.40	1.36	40

Feeding constituted a greater percentage of time spent (49.3 %) on various activities. Feeding was low during the 0600 hour and 1700 hour although during the 1700 hour it was slightly higher (Fig 4.1). The number of observations (Fig 4.2) made on feeding activities during these two periods confirms the pattern reflected by proportional analysis shown in Fig 4.1. There was consistency in the feeding pattern during the day 0700 to 1700 hours and there were no clearly defined peaks and lows in feeding time. The feeding pattern reflected no marked relationship between feeding and time of day

(Fig 4.1, 4.2) both in terms of the number of observations on feeding activities and the amount of time spent feeding other than for the first and last hours of the day.

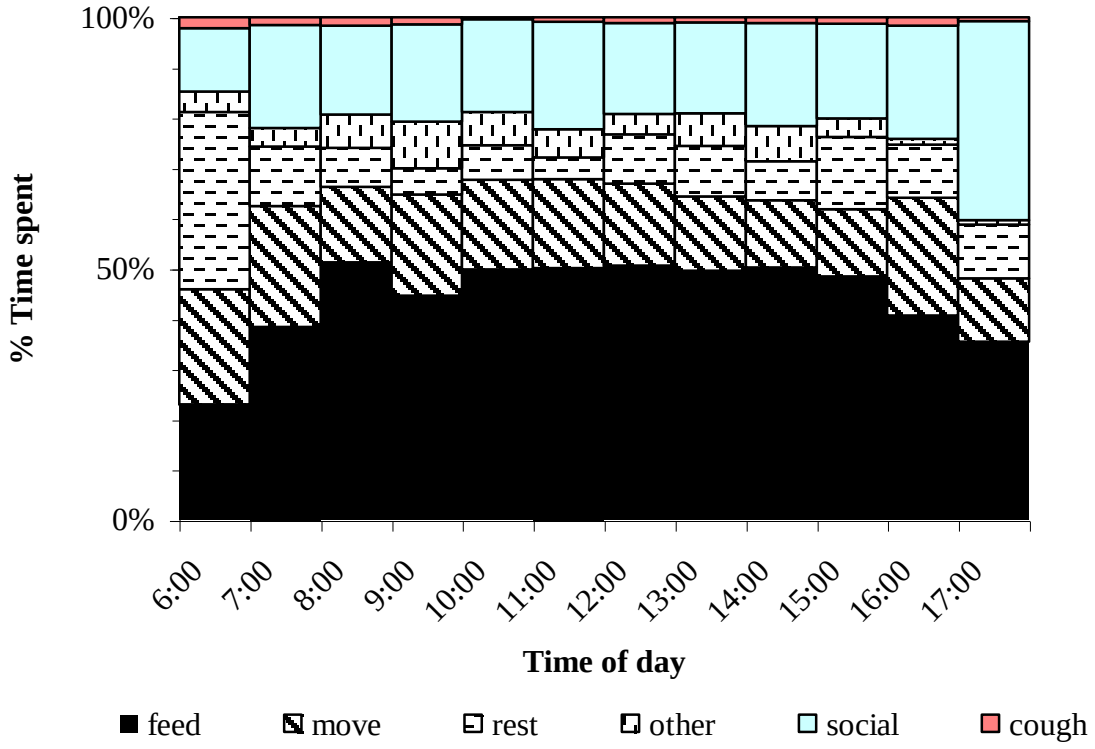

Figure 4.1 Diurnal pattern of activity of bark stripping chacma baboons. The histogram shows the time during each hour spent on various activities. The results for the 06:00 hr are for 19 days only

Socializing was the second most important activity in terms of time spent (22.8 %) which reflects the importance of establishing and maintaining social relations in primate systems (Di Fore & Rodman, 2001). In the early hours of the morning, social activity was low (Fig 4.1), probably because of the low temperatures experienced in the early morning (mean minimum temperature 12.5^{o} C) (Fig 3.2). Between 1500 hours and 1700 hours, there was a peak in social activity before the troop goes to roost.

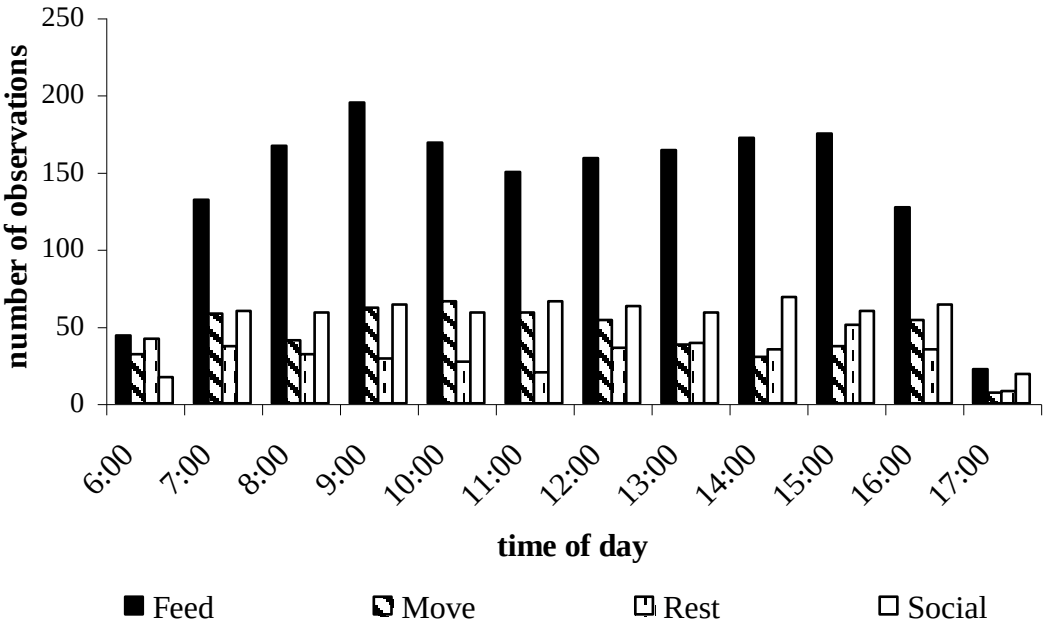

Figure 4.2. Number of observations made on feeding, moving, resting socialising and coughing each hour during the 8 week study period.

Movement, primarily for foraging purposes, was consistent throughout the day with the time spent moving ranging from 14.9 % to 27.0 % (mean 19.1 %). Movement is necessary for finding quality food patches especially in a modified habitat where they could be sparsely distributed. Resting was more pronounced during the early morning, may be due to the pervasive effects of lower morning temperatures as the baboons basked in the sun during the early and late hours of the day. Time spent resting decreased during the mid-morning 900 hours to 1100 hours when feeding began to pick up. As from 1200 to 1700 hours, resting marginally increases. This may be a response to the warmer temperatures of the afternoon and late afternoon periods. Other activities constituted relatively little time (Fig 4.1), with activities confined mainly between 0700 to 1500 hours (Fig 4.1). Coughing occurred mostly during the early morning before declining in the late afternoon (Fig 4.1).

4.2 Trends in activity patterns

Time spent on feeding activities (Fig 4.3) constituted a greater proportion of the daily activity pattern. There was a continuous increase in time spent feeding from the first week of the study to the last. There was a significant difference in time spent feeding among weeks (Kruskal-Wallis test: $H = 14.95$, $P = 0.03$). The baboons spent significantly more time feeding in a week than the previous one. There was also a significant difference in time spent feeding in trees between months (Mann-Whitney-U test: $U = 125.0$, $P = 0.04$).

Time spent socializing decreased during the period spanning week 2 to 8 (Fig 4.3). The decline was also indicated in the number of observations (Fig 4.2), which, may well be linked to the pervasive effects of temperature on time allocation in primates (Bronikowski & Altmann, 1996). Some of the time allocated for these activities was drawn to augment the increased time required for foraging during winter. There were no significant differences in time spent socializing both between weeks and between months ($P > 0.05$).

Time spent moving was on a decline as from week one with a marginal increase in the last week (Fig 4.3). There were differences in time spent moving between weeks (Kruskal-Wallis test: $H = 18.15$, $P = 0.01$). Time spent moving also varied monthly (Mann-Whitney-U test: $U = 67.0$, $P < 0.01$). The baboons spent 22 % and 16 % moving in the first and second month, respectively.

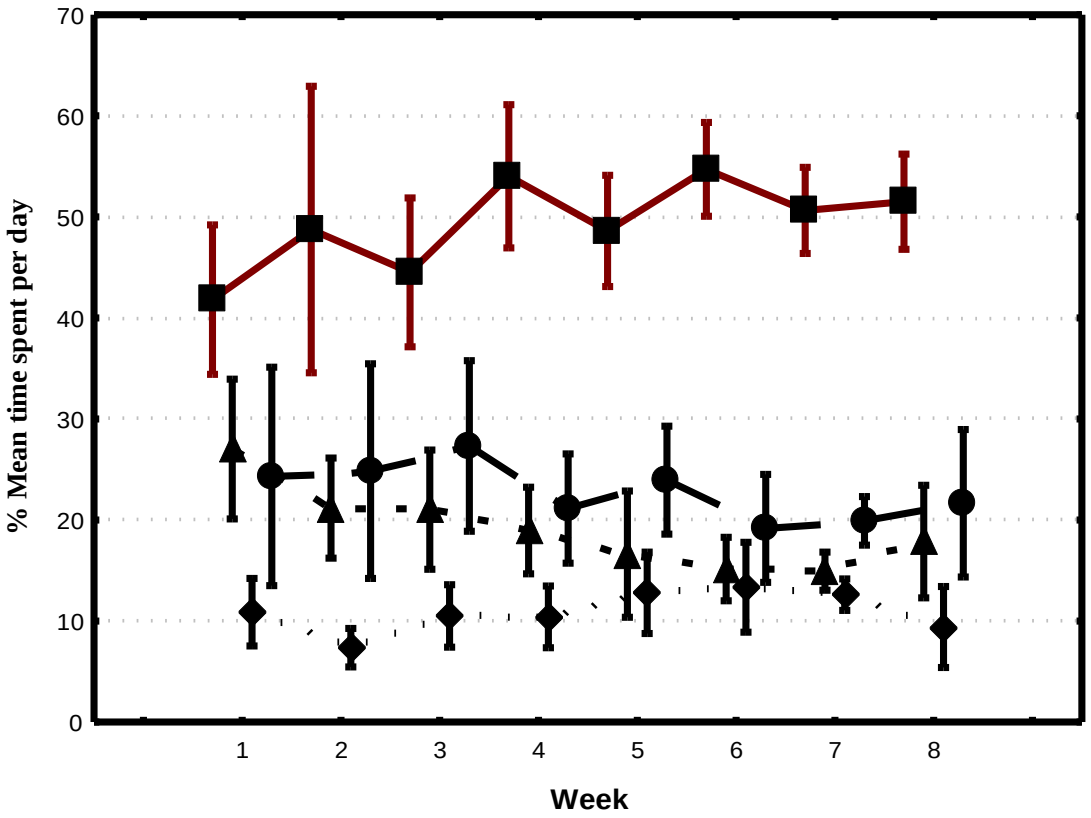

Figure 4.3. Proportion of time spent each week on feeding, moving, resting and socializing by bark stripping chacma baboons. Vertical lines show 95% confidence interval of the daily mean. Feeding ■, Moving ▲, Resting ◆, and Social ●

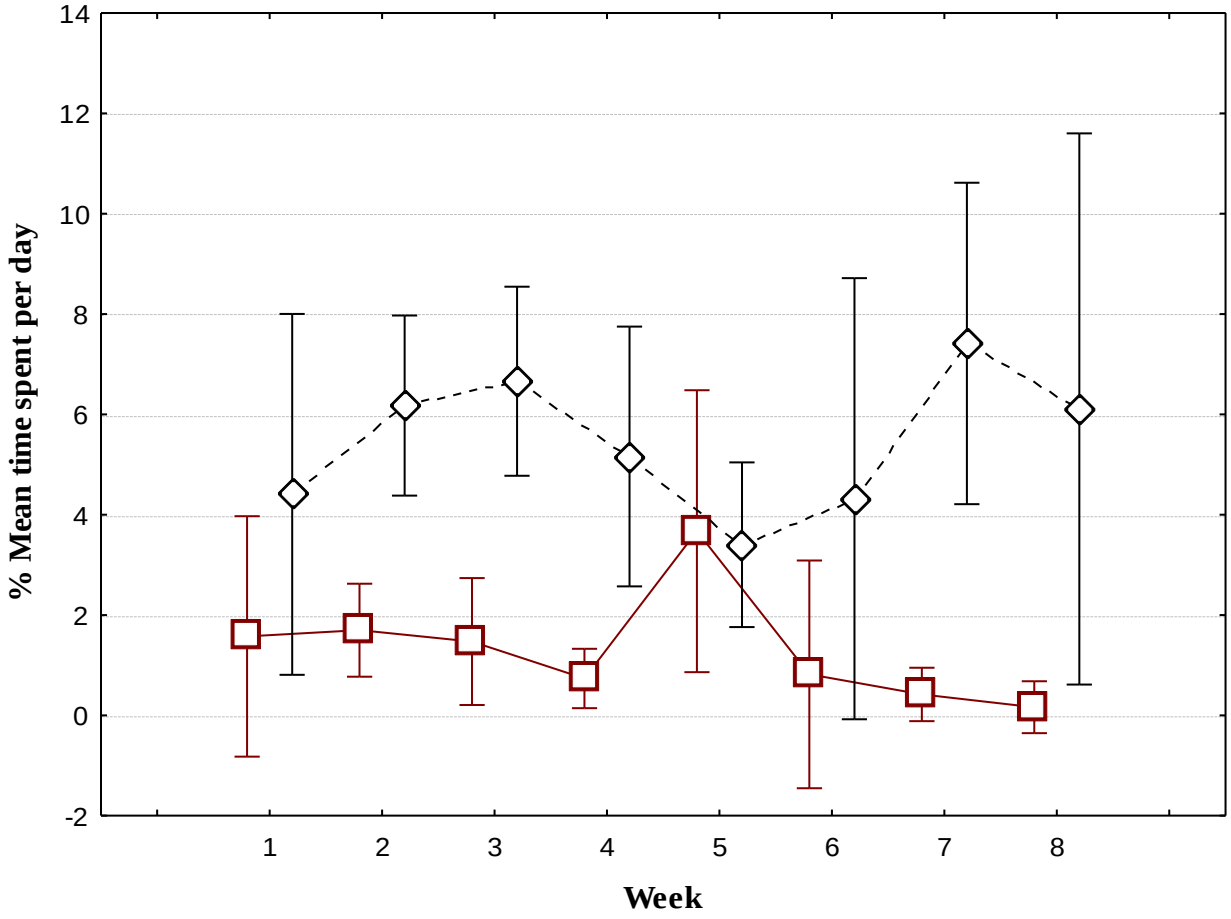

Figure. 4.4. Mean time spent each week on other activities and coughing by bark stripping chacma baboons. Vertical lines show 95% confidence interval of the daily mean. Coughing □and Other activities ◇

Time spent resting increased from week 2 onwards (Fig 6), probably, as energy conservation became a priority during the winter period. Resting time was also declined in the last week. Significant differences in resting time were evident between weeks (Kruskal-Wallis H = 13.98, P = 0.05). Significantly, more time was spent resting in the second month (12 %) than the first (9.8 %) (Mann-Whitney- U test: U = 111, P = 0.02).

Other activities showed alternating increase and decreases at irregular intervals during the study period (Fig 7). Coughing only showed a high during week 5, which is the onset of May. This week coincided with changes in temperature (Fig 2) to lower

winter temperatures. The temporal scale of this study provided a window into the changes in time allocation by baboons during the transition period into winter. The changes in time allocation were directed at increasing feeding time (foraging time= feeding + moving) whilst at the same time reducing the amount of energy lost.

4.3 Time spent feeding

A greater proportion of time spent feeding was spent feeding in trees. It was less than 50 % during the 0600 hour, but constituted greater than 50 % of feeding time during the rest of the day (Fig 4.5). Feeding in trees was high during the 1600 to 1700 hour period when most of the feeding occurred in the sleeping trees. Feeding on the ground occurred mainly between 0800 and 1500 hours. There were significant differences in time spent feeding on the ground between weeks (Kruskal-Wallis test: $H = 17.3$, $P = 0.02$). A few observations of feeding on the ground were made during the early morning and late afternoon hours. This may be the result of predator avoidance during these two periods as most feeding took place in trees (Fig 4.5). Significantly, less time was spent feeding on the ground between months (Mann-Whitney-U test: $U = 106$, $P = 0.01$), 8% and 5.8 % in April and May respectively.

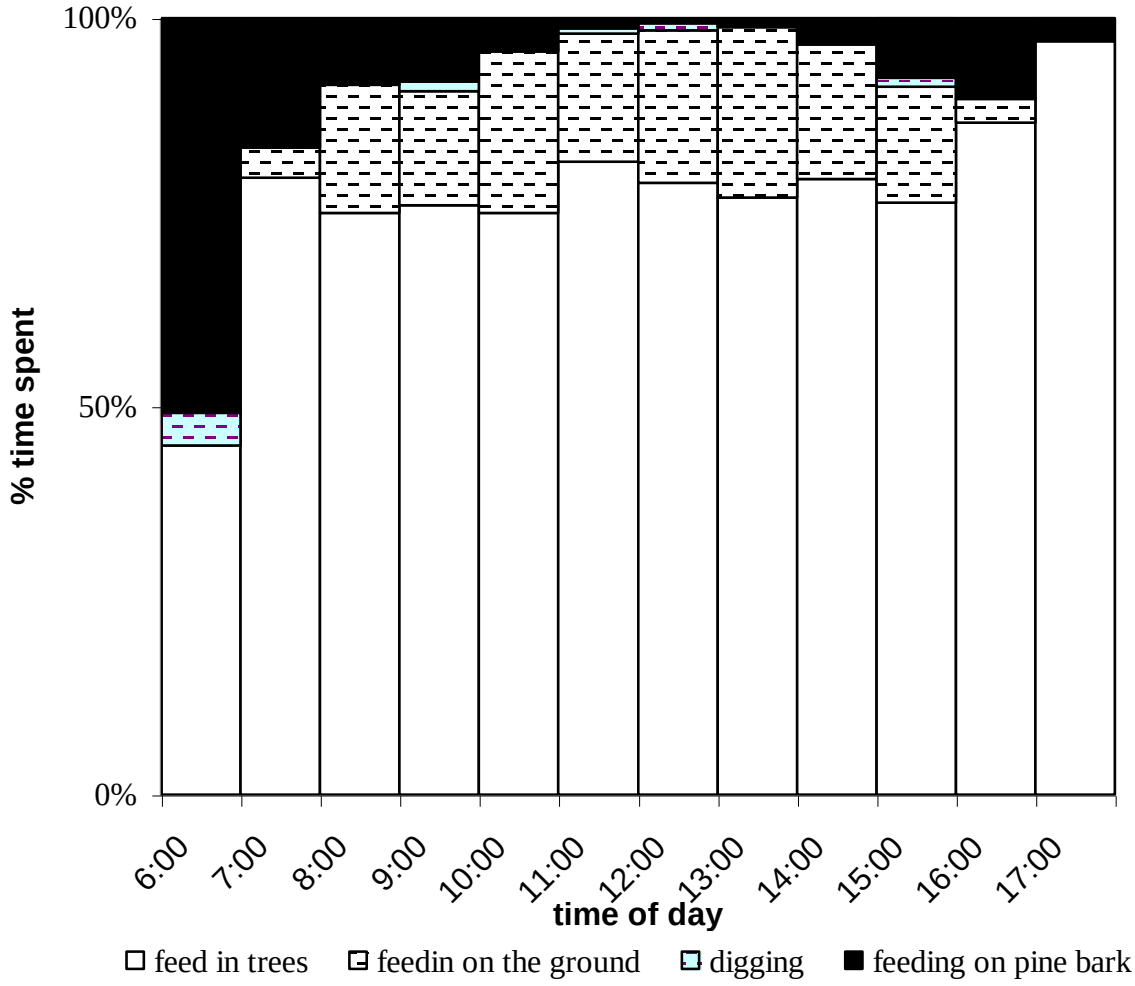

Figure. 4.5. Percentage time spent feeding on the ground, digging, feeding on pine bark and feeding in trees each hour.

Time spent bark stripping was much higher during the early morning when most feeding occurred in trees. A greater proportion of time spent bark stripping occurred during the 0600 hour period declining steadily during the late mid-morning throughout the afternoon. The baboons also spent more time stripping during the late afternoon, 1400 to 1600 hours (Fig 4.5). This coincided with the peak of time spent feeding in trees. Bark stripping showed significant differences between weeks (Kruskal-Wallis test $H = 18.59$, $P < 0.01$). Digging constituted relatively very little in terms of time spent feeding (Fig 4.5).

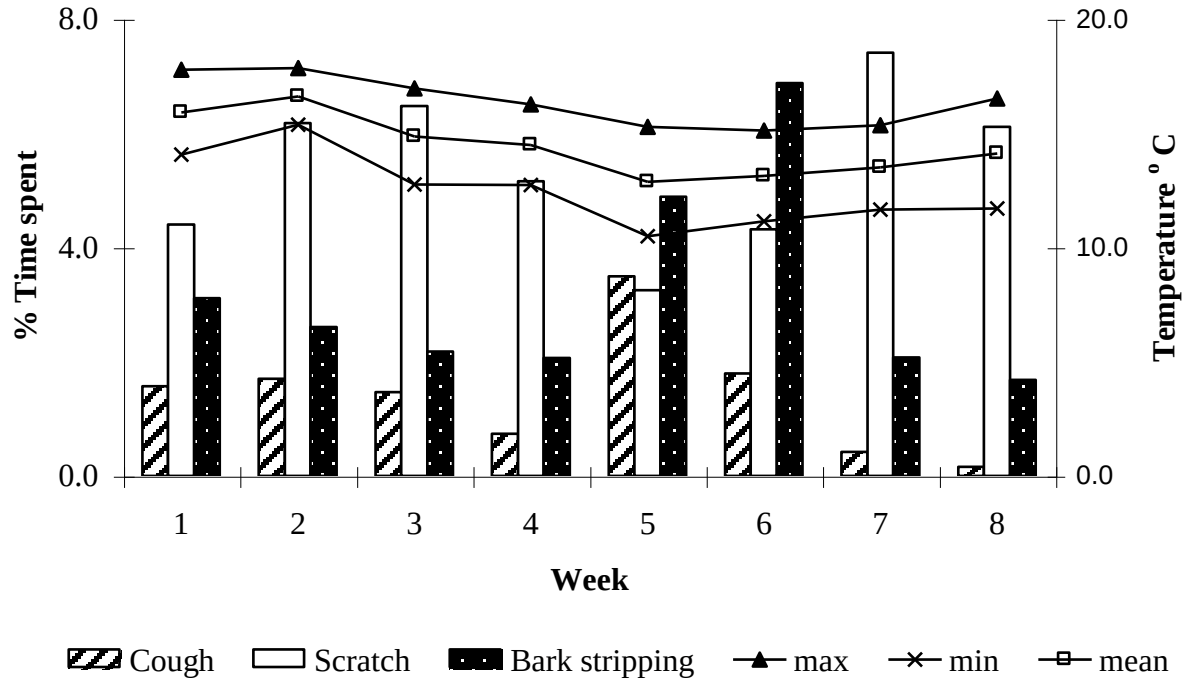

Figure 4.6. Percentage time spent coughing, scratching and bark stripping. The plot also includes the maximum, minimum and mean daily temperature for the 8-week study period.

On a weekly basis, bark stripping was seen to increase during the onset of the winter period (Fig 4.6). Apparently, this period experienced the lowest temperatures (Fig 4.6) with an average minimum temperature of 10.5 ^{o} C and mean daily temperature of 12.9 ^{o} C. Thereafter, bark stripping declined even to lower levels than observed at the onset of the study.

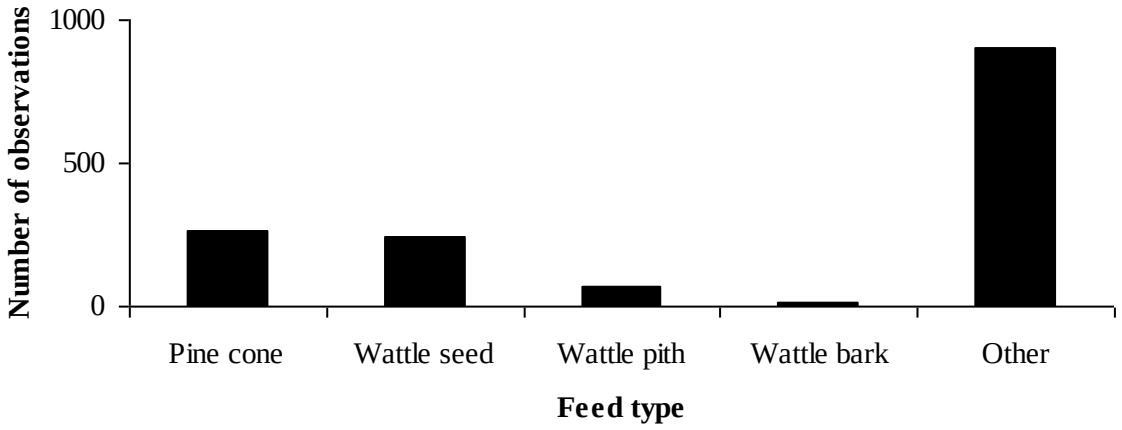

Figure 4.7. Number of observations made of feeding activities on different foods. Other foods include unidentifiable food and invertebrates

4.4 Relationship between activity and environmental variables

Feeding, moving and socializing were interdependent (Table 4.2) either when total feeding (feeding in trees, ground feeding, digging and bark stripping) and feeding other was used in the analysis. In weeks when more time was spent feeding, the baboons always devoted less time to each of these activities. Perhaps, consequently moving and socializing times were related such that more time spent doing one corresponded to less time spent doing the other. Feeding shows a negative correlation with socializing, as feeding increased socializing decreased (Fig 4.3).

Social activities showed a significant correlation with maximum and mean daily temperature ($r = 0.78$, $P = 0.021$) (Table 4.2). As temperatures decreased time spent socializing also declined. This may be because some of the social time is acquired for foraging purposes.

Moving showed correlations with minimum, maximum and mean daily temperature (Table 4.2, 4.3). When feeding activity is considered as separate entities, moving

continued to show a correlation with these variables in addition to digging and socializing (Table 4.3). Moving in primates is primarily for foraging purposes. Therefore, under conditions of low temperatures energy demands are elevated necessitating an increase in time spent moving to meet daily energetic requirements. However, the correlation analysis reflected a positive relationship between moving and temperature (Table 4.2, 4.3).

Time spent resting was also correlated with environmental variables minimum, maximum and mean daily temperature. However, this correlation was negative and might be a reflection of the effects of low temperatures on time spent resting in baboons. When temperatures dropped (Fig 3.2) time spent resting began to increase, may be as an energy conservation strategy. When feeding was considered as separate entities (Table 4.3), resting showed a negative correlation with maximum temperature ($r = -0.76$, $p = 0.03$).

Time spent bark stripping showed a strong positive correlation with coughing ($r = 0.92$, $P = 0.001$) (Table 4.3). When coughing increased there was an increase in bark stripping. However, coughing declined soon after a period of increased bark stripping (Fig 4.6).

Table 4.2. Spearman's Rank Order correlations of time budgets and coughing with meteorological variables. The probability that the correlation is equal to zero is underneath each correlation coefficient. N= 8 weeks. Significant p-values appear in bold

	Activity					Temperature			
	Moving	**Resting**	**Socializing**	**Coughing**	**Other**	**Minimum**	**Maximum**	**Mean daily**	**Humidity**
Feeding total	-0.59	0.07	**-0.81**	-0.59	-0.09	-0.42	-0.57	-0.42	0.33
	0.12	0.87	**0.01**	0.12	0.82	0.28	0.13	0.28	0.41
Moving		-0.59	**0.78**	0.43	0.02	**0.88**	**0.88**	**0.88**	0.14
		0.12	**0.02**	0.29	0.95	**0.004**	**0.004**	**0.004**	0.73
Resting			-0.50	0.14	-0.47	**-0.73**	**-0.78**	**-0.73**	-0.33
			0.21	0.74	0.23	**0.03**	**0.02**	**0.03**	0.41
Socializing				0.57	0.21	0.66	**0.78**	0.66	-0.16
				0.14	0.61	0.07	**0.02**	0.071	0.69
Coughing					-0.43	0.17	0.21	0.16	-0.09
					0.29	0.69	0.61	0.693	0.82
Other						0.42	0.429	0.42	0.38
						0.28	0.28	0.28	0.35

Table 4.3. Spearman's Rank Correlations of behavioral categories and coughing with meteorological variables. The probability that the correlation is equal to zero is underneath each correlation coefficient. N = 8 weeks. Significant P-values appear in bold.

	Ground	Dig	Bark strip	Move	Rest	Social	Cough	Other	Max	Min	Mean daily	Humidity
Feed other	-0.35	-0.19	-0.62	-0.62	0.09	-0.62	-0.61	0.26	0.35	-0.35	-0.37	0.19
	0.38	0.64	0.10	0.10	0.82	0.10	0.10	0.49	0.38	0.38	0.35	0.65
Ground		0.22	0.17	0.28	0.07	0.11	0.26	-0.07	0.07	0.31	0.30	0.43
		0.60	0.69	0.49	0.86	0.77	0.53	0.87	0.87	0.45	0.46	0.29
Digging			-0.44	**0.78**	-0.56	0.22	-0.41	0.02	0.63	0.65	0.69	0.04
			0.28	**0.02**	0.14	0.60	0.30	0.95	0.09	0.07	0.06	0.91
Bark strip				-0.17	0.57	0.02	**0.92**	-0.62	0.28	-0.23	-0.28	-0.12
				0.69	0.13	0.95	**0.001**	0.10	0.49	0.57	0.57	0.78
Move					-0.59	**0.71**	-0.09	0.19	**0.88**	**0.85**	**0.85**	0.05
					0.12	**0.04**	0.82	0.65	**0.004**	**0.007**	**0.007**	0.91
Rest						-0.54	0.33	-0.32	**-0.76**	-0.69	-0.69	-0.21
						0.16	0.42	0.45	**0.03**	0.05	0.06	0.61
Social							0.21	0.16	0.67	0.52	0.52	-0.24
							0.61	0.69	0.07	0.18	0.18	0.57
Cough								-0.67	-0.21	-0.19	-0.19	-0.09
								0.07	0.61	0.65	0.65	0.82
Other									0.42	0.43	0.42	0.38
									0.28	0.29	0.28	0.35

4.5 Home range size and ranging behaviour

Table 4.4. Home range sizes and daily travel distances (DTD) for each week.

Week	Number of days (N)	Home range size (km^2)	Daily travel distance (DTD) (km)
1	5	0.61	1.3
2	5	0.60	1.7
3	5	1.27	1.8
4	6	0.57	1.4
5	5	0.87	1.3
6	5	0.52	1.5
7	5	1.06	2.1
8	4	1.34	2.9

Home range size using the MCP method ranged between 0.60 to 1.34 km^2 (Table 4.4). The mean weekly home range size was 0.86 km^2 during the whole study period. The mean home range size during April and May was 0.76 km^2 and 0.95 km^2 respectively. Although the home range size for May was greater than that for April, the weeks categorized into months were not statistically different in home range size (T-test for independent means: $t = -0.76$, $df = 6$, $P = 0.47$). The home range size calculated for the whole study period was 2.88 km^2.

The daily travel distance ranged between 0.42- 3.7 kilometres (mean = 1.7 km). (Table 4.4). Although mean daily travel distance for May (mean= 1.92, n = 19, s.d. = 0.79) was greater than April (mean = 1.53, n= 21, s.d. = 0.72) there was no significant difference in daily distances travelled between the two months (T-test for independent means: $t = -1.55$, d.f. = 38, $P = 0.13$). Daily travel distances showed no correlation with any of the behavioural categories.

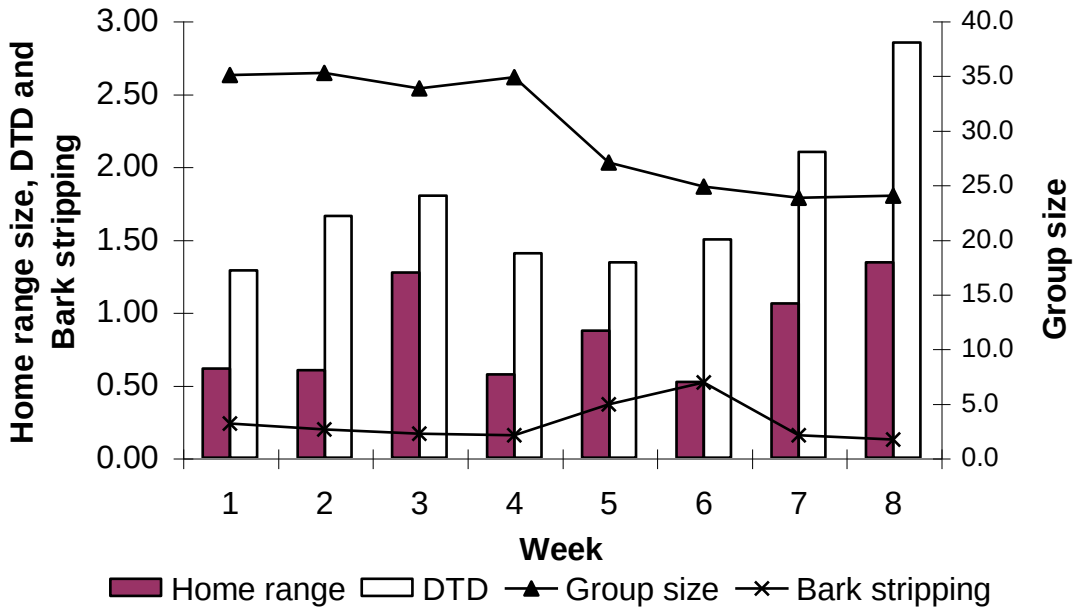

Figure 4.8. Changes in home range, DTD, bark stripping and group size during the study period.

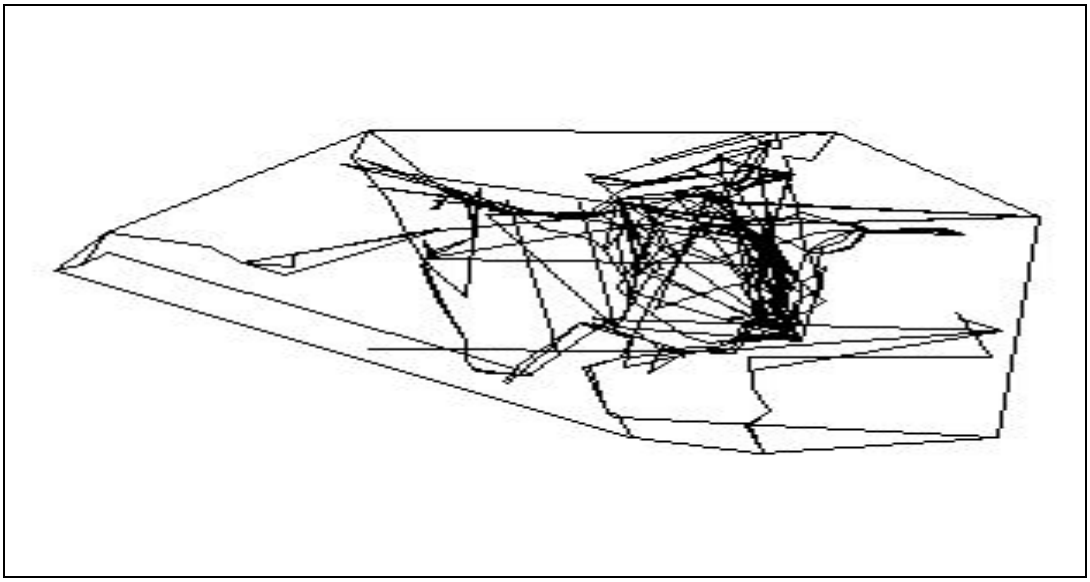

Figure 4.9. Paths of the daily travel distances travelled during the study period. These also indicate the areas of greater foraging effort.

4.6 Home range use

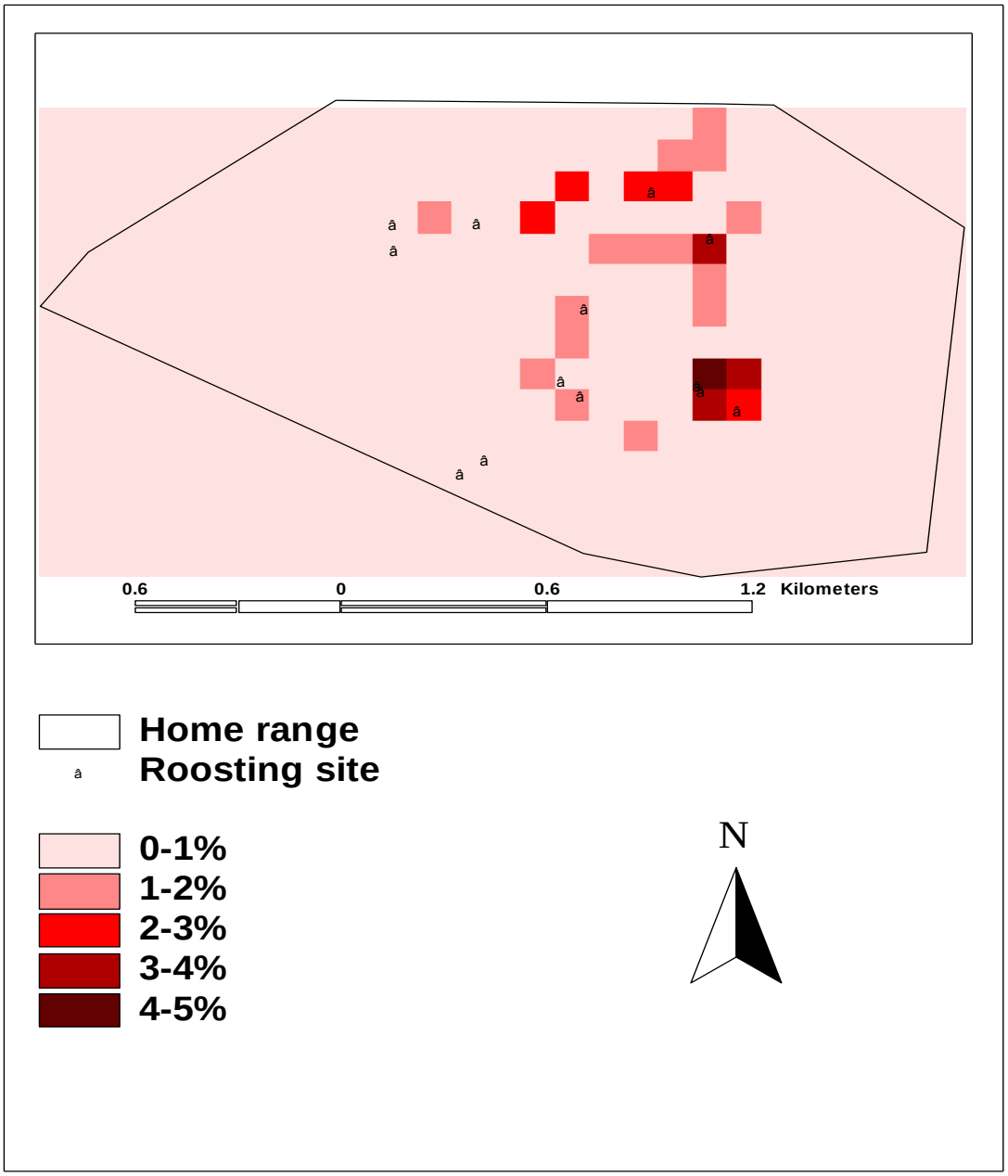

Figure 4.10. Spatial utilization of the home range depicted by the minimum convex polygon (MCP) method for home range size estimation. Also shown is the distribution of roosting sites within the home range.

The spatial utilization showed that a few areas were highly utilized with the greater part of the home range being uniformly utilized. However, some areas were heavily utilised when compared to others (Fig 4.10). Heavily utilised areas are closer to sleeping sites that were used during the study period (Fig 4.10). The dark areas show heavily and frequently used areas.

Table 4.5: Group sizes, home range sizes, baboon density and daily travel distances of Eastern Highlands, Zimbabwe baboons compared to other *Papio hamadryas* baboons.

Species	Site	Home range size (km^2)	Density (baboons/km^2)	DTD (km)	Group size
Papio h. ursinus (this study)	Eastern Highlands, Zimbabwe	2.88	10.6	1.7	30.5
[a]*Papio h. hamadryas**	Filoha, Ethiopia	30	0.22	7.5 (n=27) 13.2 (n=9)	50-220 (mean n.r)
[b]*Papio h. hamadryas**	Erer Gota, Ethiopia	28	0.36	8.6 (band 1 n=57) 10.4 (band 2 n= 13)	62-95 (mean n.r)
[c]*Papio h. ursinus*	Cape peninsula, South Africa	9	12.8	2.67	115.2
[d]*Papio h. hamadrya**	Saudi Arabia	9.31	0.17	1.04-14.3 (mean n.r)	9-102
[e]*Papio ursinus*	Cape reserve, South Africa	N = 5.6 S = 9.2 C = 20.9	0.28 0.26 0.26	n.r	20 35 80
[f]*Papio cynocephalus**	Amboseli, Kenya	24.1	0.44	4.2	5.5

[a] (Swedell, 2002); [b] (Sigg& Stolba, 1981); [c] (Hoffman, 2007); [d] (Boug,*et al*, 1994); [e] (De Vore and Hall, 1965); [f] (Altmann and Altmann, 1970); * densities calculated using the average of the given range, n.r- not recorded

CHAPTER 5

DISCUSSION

5.1 Daily activity pattern

The troop spent proportionally more time foraging during the colder period than during the warmer period. This is consistent with findings from other studies (Dunbar, 1992; Bronikowski & Altmann, 1996; Hill *et al,* 2003). Temperature variations influence time allocation profiles in primates primarily in response to changes in energy requirements. Humidity was not observed to influence any activity during the study period.

The increase in feeding time and reduction in moving and socializing time may also be attributed to the reduction in day length during the second month. Variation in day length represents a significant constraint on time allocation patterns since it restricts the length of the active period. (Hill *et al,* 2003). Baboons perform most of their activities during daylight hours, as they are almost exclusively diurnal. Under such circumstances, they are forced to compress certain activities in order to augment elevated time requirements for other activities (Dunbar, 1992).

Consistent with other studies baboons spent more time foraging (68.4 %), almost half of the active daytime (Altmann & Altmann, 1970; Barton *et al*, 1992; Bronikowski & Altmann, 1996; Altmann, 1998). Gaynor (1994) found baboon troops in De Hoop and Mkuzi to spend 69.8 % and 66.5 % foraging respectively. This is the range of the amount of time spent by Shatter Troop especially the De Hoop results. However, the "High" and "Low" group of the Drakensberg spent 74 % and 72 % of their time foraging, respectively (Byrne *et* al, 1993).

In comparison to *Papio h. cynocephalus* troops in Amboseli, Kenya, (Alto- 69.8 %; Hook- 75.2 % and Lodge- 43 %) (Bronikowski & Altmann, 1998), Shatter Troop spent relatively less time foraging than Hook and Alto groups but more than the Lodge group. This is largely because Shatter Troop occupies a habitat, which receives rainfall almost all year round. While, Hook and Alto groups inhabit a highly seasonal habitat hence they spend more time foraging. Lodge group is found in the same environment as the other two but often has access to human foods hence the low amount of time spent foraging. Dunbar, (1992) reported increased time spent feeding when the diet constitutes a greater proportion of sub-terranean items requiring more processing time. This is contrary to findings of this study where more time is spent feeding in trees (Fig 4.5)

The percentage of time spent on social and movement activities declined from week 4 to week 7 whilst time spent feeding increased. Two possible explanations are offered for this behaviour, 1.Baboons increased time spent feeding to be able to meet their daily nutritional requirements in a modified habitat 2. Time spent moving also declined during this period, as temperatures declined; therefore energy conservation for thermoregulation purposes became a priority. Explanation 2 is consistent with the findings of Bronikowski & Altmann (1996) who found meteorological variables to correlate with behavioural variation with more feeding time during low temperatures.

The baboons exhibited an increase in time spent resting by 2.3 % during the last 4 weeks (Fig 4.3). As expected time spent resting would increase in order to minimise energy expenditure during this period of resource scarcity (dry winter period) when the number of available food options are limited. In other primate species such as the woolly monkeys (*Lagothrix lagotricha*), they adjust time allocation to foraging for and feeding on animal prey (Di Fore & Rodman, 2001). This occurred to Shatter troop

as they shifted their diet to include more pine bark in particular between the 5th and the 6th week which also coincided with the onset and early part of the winter period (Fig 4.6).

In addition to these factors, the increase in feeding time (4.1 %) and decrease in social (3.2 %) and moving (5. 9%) time may be caused by a reduction in day length. The winter period is characterised by shorter days and long nights. Dunbar (1992) noted that were day length varies specific activities may be compressed if the animals are to fulfil their daily nutritional requirements. This is further complicated by the coinciding of the short winter days with lower mean daily temperatures (Fig 3.2), and energy demands may also be elevated due to increased thermoregulatory costs (Hill *et al*, 2003). This confirms the findings by Dunbar (1992) that ambient temperature is one of the most important predictors of variation in the time budgets and day ranges of savannah baboons. Extremes of hot or cold temperatures impose direct energetic costs on baboons. Thus, thermoregulation becomes a priority and consequently time allocation profiles are altered.

Social activities are important in baboon behavioural ecology as they infer certain advantages but also bring with them several disadvantages. This is evident in the results (Fig 4.3), social activity is the second most important activity after feeding. During the whole study period 22.8 % of the baboon's active daytime was spent on social activities. This is quite large than other troops 9.3 %, 8.6 % and 13.3 % for Hook, Alto and Lodge groups respectively (Bronikowski & Altman, 1998). Gaynor (1994) also reports 15.1 % and 12.1 % for Drakensberg and Mkuzi troops respectively.

Shatter Troop relatively spent more time socialising when compared to other troops. Contrary to Dunbar (1992) suggestion that time spent socializing for wild feeding baboons is abnormally or stressfully low. Using Bronikowski & Altmann (1998) minimum of 15 % socialising time, Shatter troop thus has more time for establishing and maintaining social bonds when compared to other troops. However, the reduction in socialising time by 3.2 % in winter is consistent with the findings by Altmann (1980). Altmann (1980) proposed that when baboons are faced with increased foraging demands, individuals reduce social time rather than rest time.,

Some studies have noted that predation is the most important factor in the evolution of sociality in primates (van Schaik, 83; 89; van Hoof & van Schaik, 1992). The study site is frequently traversed by leopards (*Panthera pardus*) and lions (*Panthera leo*) from the adjacent Nyanga National Park. Their presence disrupted data collection on one occasion as the baboons responded to lions wandering in the area by travelling less during that day (0.43 km on the 4^{th} day), compared to the previous day, 2.1 km and 1.2 km on the following day. Predation (or any sign of it) by lions or leopards was never observed during the study period.

The proportion of time spent moving each day was 19.1 % of the total daily activity time. This is lower than the De Hoop and Mkuzi troops which spent 27.1 % and 30.2 % of their time moving respectively. The low proportion of time spent moving is reflected in the shorter daily travel distances of Shatter Troop (Table 4.4) when compared to other troops elsewhere. The relationship with feeding time (Table 4.2) perhaps reflects the trade offs between activities occurring when time is limited. This is because a higher proportion foraging time (defined as feeding + moving) is spent feeding when the time required for foraging is constrained (Henzi *et al*, 1997). These findings are also similar to the findings made by Agetsuma & Nakagawa (1998).

Time spent moving correlated with minimum, maximum and mean daily temperature. Moving was seen to decline with a decline in temperature.

Shatter Troop spent 10.9 % of its time resting. This is low than what Gaynor (1994) found for Drakensberg and Mkuzi troops 13.3 % and 20.6 % respectively. Resting can be important for certain functions for example energy conservation (Dasilva, 1992). With the above comparisons, energy conservation may not be a priority for Shatter Troop. Rather social activities (22.8 %) are more important in comparison to 15.1 % and 12.1 % for the Drakensberg and Mkuzi troops respectively reported by Gaynor (1994). Resting is considered as a reservoir of uncommitted time that can be drawn off for other activities (Dunbar & Sharman, 1984). Contrary with this observation Shatter Troop seem to adjust socialising time than resting time.

In Amboseli, Alto, Hook and Lodge groups spent 21.5%, 16.4 % and 43.8 % resting respectively (Altmann & Altmann, 1970). This further confirms that resting time in Shatter Troop is low. This may be attributed to the relative temperature constancy (Fig 3.2) offered by the pine plantation. Hence, temperature variation does not impose greater thermoregulatory constraints on the baboons. When compared to Bronikowski & Altmann (1996) findings, their troops inhabit a semi-arid environment where mean maximum temperature was 32.6 ^{o} C and mean minimum temperature 14.2 ^{o} C. These temperatures are higher than those experienced in the Eastern Highlands (Table 3.1) and so are likely to impose greater thermoregulatory demands on the baboons hence the more time spent resting.

The relationship between weekly temperature and resting reflects slightly elevated levels of resting at low temperature. This relationship could thus reflect the need to conserve energy during lower temperatures (Dasilva, 1992), although little confidence can be placed in this interpretation. This is because an understanding and identification of the proportion of rest time committed for specific purposes and that, which is uncommitted, is required before solid conclusions could be made.

Other activities and coughing constituted relatively little time spent approximately 6.3 % when combined together. Other activities included scratching which together with coughing were observed to try to ascertain the possibility of bark stripping being a prophylactic response to coughing and scratching. Coughing correlated to bark stripping when feeding was considered as separate entities (feeding other, ground feeding, digging and bark stripping) (Table 4.3).

5.2 Bark stripping

Bark stripping was much higher during the early morning when most feeding occurred in trees (Fig 4.6). The first hypothesis could be that bark consumption is an alternative feed source. This is also supported by the findings by Camperio-Ciani *et al* (2001) who noted that bark stripping might be a response to environmental stress such as lack of food and nutrients at ground level. The baboons also spent more time stripping during the late afternoon. Again, during this period most of the feeding was in trees (Fig 4.6). Bark stripping was seen to increase during the winter, when temperatures were lowest, 10.5^{o} C (Fig 4.6). Hoffman (2007) also observed baboons feeding on pine bark during winter, which is the rainy season in the Cape. This disputes that arguments that bark stripping might be the result of food shortage.

a) The first hypothesis could be that bark stripping might result from food shortage.
b) The second hypothesis could be that bark stripping result from shortages of water
c) The third hypothesis could be that the bark of pine (*Pinus patula*) has medicinal properties.

The findings of this study dispute the first hypothesis that bark stripping might result from food shortage. The baboons maintained smaller home ranges and travelled shorter distances when compared to other wild feeding baboons (Table 4.5). This may be attributed to the concentration of critical resources such as food within their home range. In such a case, bark stripping may not be the result of food shortage. Furthermore, the study period coincides with the end of the rainy season (Fig 3.1) when more food options were expected to be available within the home range during this time. The Eastern Highlands lack a true dry season (Fig 3.1) and the cooler temperatures enable the maintenance of sufficient moisture at least in the sub-soil. This may be able to support plant productivity even during periods of low rainfall (Fig 3.1) although low temperatures may constrain productivity to some extent. Thus, specifically bark stripping is not because of food shortage.

The second hypothesis could be that bark stripping result from shortages of water (Camperio-Ciani *et al*, 2001). This is highly unlikely with this troop since Erin forest receives rainfall almost throughout the year (Fig 3.1) and surface water is available throughout the year within the home range. An analysis of bark stripping by grey squirrels (*Sciurus carolinensis*) (Seymour, 1961) concluded that water shortage to be an unlikely cause of stripping because trees were even stripped by open water. This is

true with Shatter Troop as bark stripping occurred in riverine areas. Therefore, the second hypothesis cannot hold true for the bark stripping behaviour of this troop.

The third hypothesis could be that the bark pine (*Pinus patula*) has medicinal properties. Given that animals can extract secondary compounds from these plants there is a possibility of them being used for protection against parasitism. This is because higher rainfall areas may support greater populations of ecto and endo-parasites (Saunders, 1988). As noted when bark stripping was high coughing and scratching decreased especially the former (Fig 4.6). This is more conspicuous during the 5^{th} and 6^{th} week period (Fig 4.6). However, if the consumption of bark did have any effect on the two it was more effective on coughing than scratching. The baboons may have been consuming the bark to alter their internal environment, rendering it inhospitable to parasites (Lozano, 1991). Lozano (1991) notes that certain foods could be selected because of specific anti-parasitic compounds than might kill or cause the expulsion of parasites already established.

Increase in the stripping of pine bark with a peak during week 5 and 6 may partly be consistent with the views of Lozano (1991). This is because the coughing, which had increased in week 5 immediately, decreased. In another study Phillips-Conroy (1986) noted baboons consuming the leaves and berries of *Balanites aegyptica* a shrub toxic to *Schistosoma cercaria*. He concluded that it was consumed for its prophylactic characteristics, as it might affect the maturation of the adult worm of this parasite. Chimpanzees have also been observed to consume leaves of plants with ethno-medicinal value in a particular manner. They were observed holding the leaves between the tongue and buccal surface for up to 25 seconds before swallowing them (Wrangham & Nishida, 1983; Newton & Nishida, 1990).

Of interest is the consumption of the cambium and resin, which are vital components in the storage and transport of solutes in the tissues of plants. The solutes could be the carriers of the medicinal properties that relieved coughing in baboons. This is because ingestion of such plants could alter the internal environment of the animal particularly the intestinal tract, other tissues though could be affected (Lozano, 1991). It could be a possibility that bark consumption relieved coughing in baboons. On one occasion, an adult male baboon coughed a couple of times and almost immediately consumed pine bark. These observations and the given interpretations cannot lead to concrete conclusions on the nature and causes of bark stripping.

The ingestion of non-nutritional plant parts, such as bark, and some unusual behaviors, like bitter pith chewing and swallowing whole leaves are associated with biological activities of plants consumed (Huffman & Seif, 1989). Janzen (1978) hypothesized that plant secondary compounds actually help animals to combat or control diseases. Huffman, (1997) noted that animals such as primates use plant parts with secondary compounds to increase the comfort of their health. This occurs through altering the internal environment making it inhospitable to parasites.

The evidence provided by Vuorela (2005) supports this argument as he found out that the bark of *Pinus pinnaster* is a rich source of pro-cyanidin oligomers, which are bioactive sources of plant phenolics. These are effective against formation of the pro-inflammatory mediator prostaglandin (E2). Vuorela (2005) showed that pine bark phenolic extracts are safe and bioactive for possible food applications including functional foods intended for health benefits.

5.3 Home range size and ranging behaviour

The mean weekly home range size during the study period was 0.86 km^2 (range 0.61 to 1.34 km^2). The home range calculated for the whole study period was 2.88 km^2. This home range is smaller than what has been found in other habitats (9 km^2 – Hoffman; 7.8- DeVore & Hall, 1965; 24.1 km^2 – Altmann & Altmann, 1970). This might be attributed to the availability of important resources within the home range, since the concentration of important resources (food, water and sleeping sites) is considered the most influential constraint on baboon movement and area residency (DeVore & Hall, 1965; Barton *et* al, 1992).

Another possible explanation to might be the lack of a true dry season in the study area (Fig 3.1). The Eastern Highlands receive a mean MAR of 1051 mm annually and have cooler temperatures (Fig 3.1) which are sufficient to maintain moist conditions at least in the sub-soil throughout the year. The assumption is that there is sufficient primary production to provide a wide selection of foods for the baboons. Furthermore, rainfall is known to be a reliable predictor of primary productivity in sub-Saharan habitats (Deshmukh, 1984). The high rainfall received in this area ensures high primary productivity throughout the year. This is further evidence suggesting that bark stripping is not linked to food shortages. Moreover, the study period coincides with the end of the wet season (Fig 3.1) when more food options are still available. Beeson (1985) also found monkey damage to peak after rainfall, which was noted by (Fahey & Young, 1984) to be linked to an increase the sap volume of the plant.

Clutton-Brock & Harvey (1977) found group size to have a positive relationship with home range size. They found home range sizes to increase with an increase in group-size due to increase in food requirements. This is contrary to the findings of this study, which noted larger home range sizes when group size was smaller (Fig 4.8).

Furthermore, the low temperatures experienced in May may have increased thermoregulatory requirements (Hill *et al*, 2003). Thus, may be the lower temperatures had more influence on home range size than group size through elevated thermoregulatory requirements.

When further compared to other hamadryas baboons (Table 4.5), the home range size of Shatter troop is smaller. This might be due to the presumably semi-arid environments of hamadryas baboons where food sources are scarce (Kummer, 1971) hence have to maintain larger home ranges in order to meet their daily nutritional requirements. Shatter troop thus have a smaller home range considering the method used for home range size calculation. This is because the MCP method, which was used to calculate home range size for this study, tends to overestimate home range area (Ostro *et al*, 1999) through the influence of peripheral data points (Harris *et al*, 1990) (Fig 3.4). This shows that the home range size may be quite smaller than what has been reported. Another possible explanation for the smaller home range size might be the shorter study period

Home range size did not correlate with any of the behavioural activities. This showed that the increase in home range size might well be linked to the elevated thermoregulatory requirements of lower temperatures. This is because ambient temperature is one of the most important predictors of variation in savannah baboon day ranges (Dunbar, 1988; 1992). The smaller home range size of Shatter troop combined with uniform home range use (Fig 4.10) might be the result of homogeneity of the troops home range when compared to other savannah baboons (Table 4.5)

During the study period, the density was 10.6 baboons per km^2. This is smaller than Hoffman (2007) 12. 8 baboons per km^2 for the Tokai troop. However, Shatter troop

density is larger than that found by Whiten *et al (*1987) in the Drakensberg mountains 0.95 baboons/ km^2 and 1.87 baboons/ km^2 for the High and Low groups respectively. This density however, falls within the Eritrean hamadryas baboon population density range 10.2 baboons/km^2 and 23.9 baboons/km^2 and is larger than those reported for Ethiopia 1.84 baboons/km^2 and 3.4 baboons/km^2 (Zinner *et al*, 2001) . This further questions the hypothesis that bark stripping may be the result of food shortage. The high density indicates that critical resources (food, water and sleeping sites) are available and can support high baboon densities when compared to other habitats.

On average Shatter troop travelled 1.7 km per day, this distance is shorter when compared to other *Papio* baboons (savannah, mountain and desert baboons) (Table 4.5). Other studies found daily travel distances of 5.5 km Altmann & Altmann (1970); hamadryas baboons: 8.6 km, 10.4 km- Sigg & Stolba, (1981); 7.5 km- Swedell, (2001). Altmann & Altmann, (1970) report 4.2 km, 6.4 km and 13.2 km for the yellow, olive and hamadryas baboons respectively. The DTD of Shatter Troop is much smaller than that of hamadryas baboons. This might be largely due to the presumable evolution of hamadryas baboons in a semi-arid environment where food resources are scarce (Kummer, 1971). Hamadryas baboons are thus forced to travel longer distances in search of food when compared to Shatter Troop. Therefore, the plantation may offer a variety of food sources, shelter from the elements, relative temperature constancy and abundant sleeping sites

When compared to other chacma baboons (4.2 km- Hall 1962; 8 km Altmann & Altmann, 1970; 2.67 km- Hoffmann) Shatter Troop's DTDs are quite shorter (mean = 1.7 km; range 0.43 – 3.4 km). These shorter daily travel distances may indicate the high concentration of critical resources (such as food, water and sleeping sites) within their home range. This is because DTD is closely related to resource distribution

(Barton *et al, 1992).* Henzi *et al, (*1992*)* showed that day journey length increased with decreasing food availability and further showed a sharp increase in length in late winter on chacma baboons of the Drakensberg.

Although, this study reports longer day journeys during the winter (May) period (Table 4.4), this is not linked to food availability. Instead, lower temperatures might be the influence behind these longer journeys since home ranges during winter remain smaller than other troops elsewhere indicating that food is not limiting. . On average, the DTD for May (mean = 1.92 km) was greater than that for April (mean = 1.53), although there was no significant difference in distance travelled per day during the study period. Thus, DTD were shorter during the warmer period, April, than during the colder period, May. This may be attributed to the elevated energy requirements during low temperature periods.

Furthermore, the baboons spent more time feeding in trees than on the ground (Fig 4.5). Feeding in trees constituted greater than 50 % of time spent feeding during the day. This may explain the shorter DTDs of this troop when compared to other troops (Table 4.5). This is also contrary to the findings by Altman (1980) who found baboons to be highly terrestrial primates. If foraging is confined to feeding in trees and thus limited to food sources above ground, bark will certainly be an integral component of the diet. Bark consumption is not only limited to that of pine trees, the bark of wattle (*Acacia mearnsii)* is also consumed

5.4 Food sources

Pine cones were a favoured food source throughout the study period. *Pinus patula* is serotinous, in the absence of a major disturbance that would cause mass seed release, pine cones offer an abundant and constant supply of food throughout the year. *Pinus*

patula trees were used as sleeping trees; this may be due to a rough bark, which makes ascent and descent easier (Keely & Zeddler, 1998). Foraging efforts also focused on wattle (*Acacia mearnsii)* plant parts namely the seeds, pith and bark (Fig 4.7). Other foods were also exploited and these included unidentifiable food sources from the soil and invertebrates.

Feeding on the ground occurred mainly within timber stands that had undergone improvements. Foraging on the ground was less than 15 % of the time spent feeding. This may be attributed to the lack of skills required to process sub-terranean food items (Johnson & Bock, 2004). However, this interpretation is based on observations that were carried out on a short period and hence should be viewed with caution. In addition to this feeding on the ground may be a function of season were it is expected to be high during the wet season when primary productivity is high in the under storey vegetation.

5.5 Roosting sites

Roosting sites were mainly located closer to the most intensively used areas of the home range (Fig 4.10). Shatter troop slept in trees during the study period. The use of sleeping trees is virtually universal among other monkeys (Altmann & Altmann, 1970. This is in contrast to the sleeping habits of other troops in the Cape peninsula which use cliff faces as sleeping sites (Hall, 1963). However, these findings are consistent with the findings by Hoffman, (2007).

5.6 Conclusions and recommendations

Chacma baboons in Erin forest spent a greater proportion of their time foraging. Socializing was the second most important activity followed by moving and resting. The high social time indicated the importance of social relationships within Shatter

troop. Shatter troop baboons showed behavioural flexibility by adjusting their daily activity patterns under changing conditions in order to meet their daily nutritional requirements. It was also observed that Erin forest baboons spent a greater proportion of their foraging time feeding in trees contrary to observations made by Altmann (1980) in Amboseli where the baboons spent more time on the ground. Home range size was found to be much smaller than those reported for baboon troops elsewhere. Daily travel distances were also found to be shorter than those reported for baboon troops elsewhere.

This study suggests no link between bark stripping and food or water availability. The conclusion that bark stripping in Erin forest is not linked to food or water scarcity is underpinned by the small home range size and short daily travel distances observed for Shatter troop. Small home range and short daily travel distances indicated that food and other critical resources such as water and sleeping sites were not limiting. Instead, bark stripping may be a way of obtaining trace nutrients that might be lacking in the diet nor a prophylactic measure against diseases

However, these interpretations cannot lead to firm conclusions taking into consideration the short study period and lack of fine scale analysis of the nutritive content of pine bark. In addition, there is no data to support the lack of any trace nutrients in the diet of the baboons. Stands that have undergone improvements (thinning and pruning in particular) tend to suffer the most damage as the most vigorous trees are selected. These operations can be timed such that they coincide with periods of food abundance (wet season) for baboons which may reduce pressure on the trees if food availability is partly responsible for bark stripping.

5.7 Further research

This study is based on data obtained during two months. In order to verify the activity pattern, home range size and feeding behaviour further research, needs to be carried out over a full annual cycle to capture seasonal variation. Furthermore, relationships between group sizes, home range size and extent; troop fission and plantation improvements should be established. Activity patterns should also be further researched in the context of variation with age, sex and physiological state. Daily travel distances and home ranges require further research to establish if they remain small throughout the year and to ascertain variation across seasons in the context of inter-group encounters, predation pressure and food requirements.

Bark stripping may be used to obtain trace nutrients and for its prophylactic properties although these interpretations are not yet established. Research should also be carried out on the calorific value gained for the foods that are consumed within this habitat in relation to the nutritional value of pine bark. The nutritional analysis should be investigated across both temporal and spatial scales. Bark stripping needs to be investigated further in terms of tree diameter classes, tree spacing and crown heights that are susceptible to damage.

5.8 Shortcomings of the study

The study period of 2 months was too short to capture the finer details of variation in daily activity pattern, home range size and feeding behaviour on which solid conclusions could be made on the causes of bark stripping. In addition to this, Shatter troop split into two during the second month of data collection. The larger of the two groups was tracked and thus all inferences are based on this group. During the first month, the troop could only be observed from 0700 hours due to logistical constraints. This could have influenced the variation in daily activity pattern, home range size and

feeding behaviour between months. Daily travel distances may be underestimated since the distances travelled between 15 minute GPS records were not captured.

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APPENDICES

Appendix 1: Field Recording Sheet

			Activity												
			Feeding												
Time	**X**	**Y**	**Feed other**	**Bark strip**	**Ground**	**Dig**	**Move**	**Rest**	**Social**	**Max**	**Min**	**Altitude**	**Slope**	**Aspect**	**Vegetation**
06:00															
06:15															
06:30															
06:45															
07:00															
07:15															
07:30															
07:45															
08:00															
08:15															
08:30															
08:45															
09:00															
09:15															
09:30															
09:45															

Appendix 2: Mean monthly precipitation for Juliusdale and Nyanga Experiment Station.

Station	Altitude (m)	No of years	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	MAR
Nyanga Experiment Station	1680	30	4	3	4	35	113	231	251	210	152	35	8	6	1051
Juliusdale	1722	20	13	8	7	27	106	206	275	196	174	47	20	11	1090

Source: Nyanga Experiment Station (2004)

Appendix 3: Mann-Whitney-U test for behavioural and environmental variables between months

	Rank Sum	Rank Sum	U	Z	p-level	Z	p-level	Valid N	Valid N	2*1sided
Feed other	356.0000	464.0000	125.0000	-2.01776	0.043618	-2.01785	0.043608	21	19	0.044172
Move	556.0000	264.0000	74.0000	3.39904	0.000676	3.39904	0.000676	21	19	0.000436
Rest	340.0000	480.0000	109.0000	-2.45110	0.014243	-2.45110	0.014243	21	19	0.013608
Social	475.0000	345.0000	155.0000	1.20524	0.228113	1.20524	0.228113	21	19	0.236259
Cough	464.5000	355.5000	165.5000	0.92085	0.357127	0.93346	0.350582	21	19	0.361123
Other	453.0000	367.0000	177.0000	0.60939	0.542267	0.60939	0.542267	21	19	0.555310
Ground	524.0000	296.0000	106.0000	2.53235	0.011331	2.53235	0.011331	21	19	0.010645
Dig	485.0000	335.0000	145.0000	1.47608	0.139924	2.11261	0.034635	21	19	0.144950
Bark strip	362.0000	458.0000	131.0000	-1.85525	0.063561	-1.85525	0.063561	21	19	0.065094
Max temp	570.0000	250.0000	60.0000	3.77821	0.000158	3.77910	0.000157	21	19	0.000072
Min temp	609.0000	211.0000	21.0000	4.83449	0.000001	4.83517	0.000001	21	19	0.000000
Mean	598.0000	222.0000	32.0000	4.53656	0.000006	4.53742	0.000006	21	19	0.000001
Humidity	516.5000	303.5000	113.5000	2.32922	0.019848	2.32944	0.019836	21	19	0.018644

	Rank Sum	Rank Sum	U	Z	p-level	Z	p-level	Valid N	Valid N	2*1sided
Feed	376.0000	444.0000	145.0000	-1.47608	0.139924	-1.47608	0.139924	21	19	0.144950
Move	563.0000	257.0000	67.0000	3.58863	0.000332	3.58863	0.000332	21	19	0.000184
Rest	342.0000	478.0000	111.0000	-2.39693	0.016534	-2.39693	0.016534	21	19	0.015957
Social	467.0000	353.0000	163.0000	0.98856	0.322877	0.98856	0.322877	21	19	0.333384
Cough	483.0000	337.0000	147.0000	1.42191	0.155054	1.44682	0.147947	21	19	0.160685
Other	455.0000	365.0000	175.0000	0.66356	0.506974	0.66356	0.506974	21	19	0.519832
Max temp	555.0000	265.0000	75.0000	3.37195	0.000746	3.37195	0.000746	21	19	0.000491
Min temp	603.0000	217.0000	27.0000	4.67198	0.000003	4.67220	0.000003	21	19	0.000000
Mean daily	589.0000	231.0000	41.0000	4.29281	0.000018	4.29301	0.000018	21	19	0.000004
Humidity	505.0000	315.0000	125.0000	2.01776	0.043618	2.01776	0.043618	21	19	0.044172

Appendix 5: Kruskal-Wallis ANOVA by Ranks for 8 independent samples for weekly variation in behavioural and environmental variables

Activity	H	P-value	Grouping variable
Feed`	14.95024	0.0366	Week
Mov	18.14927	0.0113	Week
Rest	13.98085	0.0515	Week
Soc	6.243659	0.5116	Week
Cough	14.80644	0.0386	Week
Other	8.695610	0.2753	Week
Maximum temp	19.21695	0.0075	Week
Minimum temp	28.35461	0.0002	Week
Mean daily	26.18490	0.0005	Week
Humidity	16.31427	0.0224	Week
Feed other	14.94177	0.0368	Week
Ground	17.30463	0.0155	Week
Dig	6.970825	0.4319	Week
Bark strip	18.58939	0.0096	Week

Appendix 5: Spearman's rank order correlations on a weekly behavioural and environmental variables

Activity	Valid	Spearman	t(N-2)	p-level
Feed & Move	8	-0.595238	-1.81449	0.119530
Feed & Rest	8	0.071429	0.17541	0.866526
Feed & Social	8	-0.809524	-3.37756	0.014903
Feed & Cough	8	-0.595238	-1.81449	0.119530
Feed & Other	8	-0.095238	-0.23435	0.822505
Feed & maxtemp	8	-0.571429	-1.70561	0.138960
Feed & mintemp	8	-0.428571	-1.16190	0.289403
Feed & mean daily	8	-0.428571	-1.16190	0.289403
Feed & Humidity	8	0.333333	0.86603	0.419753
Feed & Home range	8	-0.404762	-1.08425	0.319889
Feed & DTD	8	0.309524	0.79733	0.455645
Move & Rest	8	-0.595238	-1.81449	0.119530
Move & Social	8	0.785714	3.11127	0.020815
Move & Cough	8	0.428571	1.16190	0.289403
Move & Other	8	0.023810	0.05834	0.955374
Move & maxtemp	8	0.880952	4.56015	0.003850
Move & mintemp	8	0.880952	4.56015	0.003850
Move & mean daily	8	0.880952	4.56015	0.003850
Move & Humidity	8	0.142857	0.35355	0.735765
Move & Home range	8	-0.047619	-0.11677	0.910849
Move & DTD	8	-0.357143	-0.93659	0.385121
Rest & Social	8	-0.500000	-1.41421	0.207031
Rest & Cough	8	0.142857	0.35355	0.735765
Rest & Other	8	-0.476190	-1.32647	0.232936
Rest & maxtemp	8	-0.785714	-3.11127	0.020815

Activity	Valid	Spearman	t(N-2)	p-level
Rest & mintemp	8	-0.738095	-2.67966	0.036553
Rest & mean daily	8	-0.738095	-2.67966	0.036553
Rest & Humidity	8	-0.333333	-0.86603	0.419753
Rest & Home range	8	-0.238095	-0.60048	0.570156
Rest & DTD	8	-0.357143	-0.93659	0.385121
Social & Cough	8	0.571429	1.70561	0.138960
Social & Other	8	0.214286	0.53737	0.610344
Social & maxtemp	8	0.785714	3.11127	0.020815
Social & mintemp	8	0.666667	2.19089	0.070988
Social & mean daily	8	0.666667	2.19089	0.070988
Social & Humidity	8	-0.166667	-0.41404	0.693239
Social & Home range	8	0.357143	0.93659	0.385121
Social & DTD	8	-0.095238	-0.23435	0.822505
Cough & Other	8	-0.428571	-1.16190	0.289403
Cough & maxtemp	8	0.214286	0.53737	0.610344
Cough & mintemp	8	0.166667	0.41404	0.693239
Cough & mean daily	8	0.166667	0.41404	0.693239
Cough & Humidity	8	-0.095238	-0.23435	0.822505
Cough & Home range	8	-0.285714	-0.73030	0.492726
Cough & DTD	8	-0.666667	-2.19089	0.070988
Other & maxtemp	8	0.428571	1.16190	0.289403
Other & mintemp	8	0.428571	1.16190	0.289403
Other & mean daily	8	0.428571	1.16190	0.289403
Other & Humidity	8	0.380952	1.00924	0.351813
Other & Home range	8	0.476190	1.32647	0.232936
Other & DTD	8	0.738095	2.67966	0.036553

Activity	Valid	Spearman	t(N-2)	p-level
Home range & maxtemp	8	0.214286	0.53737	0.610344

Home range & mintemp	8	-0.023810	-0.05834	0.955374
Home range & mean daily	8	-0.023810	-0.05834	0.955374
Home range & Humidity	8	-0.595238	-1.81449	0.119530
Home range & DTD	8	0.595238	1.81449	0.119530
DTD & maxtemp	8	0.047619	0.11677	0.910849
DTD & mintemp	8	-0.023810	-0.05834	0.955374
DTD & mean daily	8	-0.023810	-0.05834	0.955374
DTD & Humidity	8	0.023810	0.05834	0.955374
DTD & Home range	8	0.595238	1.81449	0.119530

Ho: there is no correlation between behavioural variables and environmental variables