Seasonal variation in the behavioural ecology of samango monkeys (*Cercopithecus albogularis schwarzi*) in a southern latitude montane environment

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Abstract

Samango monkeys (*Cercopithecus albogularis schwarzi*) in the Soutpansberg Mountains, South Africa, experience a highly seasonal climate, with relatively cold, dry winters. They must show behavioural flexibility to survive these difficult conditions near the southern limit of the species' distribution and maintain the minimum nutritional intake they require. Through environmental monitoring and behavioural observations of a habituated group of samango monkeys, we explored how they adapted to the highly seasonal climate they experienced in the mountains. Our results indicated that the monkeys varied their foraging behaviours to account for changes in climate and daylight availability. The samangos increased their food intake in colder months, specifically leaves, likely due to an increased need for calories during winter to maintain body temperature. Samango monkeys have anatomical and physiological adaptations for digesting leaves, and these are likely important in explaining their ability to adapt to the broad range of climatic conditions they experience.

Keywords

Blue monkey; Sykes' monkey; activity budget; time budget; guenon; *Cercopithecus mitis erythrarchus*

Introduction

To survive and reproduce, an animal must adapt its behaviour to the environmental conditions it experiences (Krebs and Davies 1993). This adaptation is often expressed in an animal's ability to efficiently vary and sustain its food intake, which can be constrained by a range of factors. One such factor is spatial and temporal variation in climate, which can have important effects on habitat structure, primary productivity and ultimately food availability (Mohamed et al. 2004). All species have limits of tolerance to these factors, which can lower their survival and reproductive success, and so limit their distribution (Graham et al. 1996; Parmesan 2006).

Climate influences primate time budgets across populations (Korstjens et al. 2010; Korstjens et al. 2006; Lehmann et al. 2007; Willems and Hill 2009) and time budget limitations can affect the geographical distribution of a species (Korstjens et al. 2006; Lehmann et al. 2007; Willems and Hill 2009). In confining their activities to daylight, diurnal primates have a finite amount of time each day to complete necessary activities such as foraging (Hill and Dunbar 2002) or resting (Lehman 2004) with local environmental and climatic conditions, resulting in trade-offs in time allocated to different activities (Dunbar et al. 2009). Time budget constraints are predicted to be most acute for populations at the limits of their species' distribution.

The majority of primate species live in tropical regions (Estrada et al. 2017); however, some primates live in locations with relatively cold, dry winters with low primary productivity (Grueter et al. 2009; Hanya et al. 2011; Iwamoto and Dunbar 1983; Parker et al. 2021). There are several potential strategies to increase survival for these species. For example, they may vary in how they use their home range in response to the season. For example, some primates respond to cold conditions by reducing the distance they travel, presumably to reduce energy expenditure (Doran 1997; Hanya 2004; Stanford 1991) or by travelling further to find rarer, higher quality food items (Volampeno et al. 2011; Waser 1977). Day journey length and home range increased in the rainy seasons for blue monkeys (*Cercopithecus mitis*) in Kibale Forest, Uganda (Hijmans et al. 2005; Rudran 1978). Since fruit production in Kibale peaks just after the rainy seasons (Chapman et al. 1999), this suggests a positive relationship between day journey length and fruit availability at that site. In contrast, samango monkeys (*Cercopithecus*

albogularis) in the Eastern Cape, South Africa, which experiences colder, drier winters than Kibale, showed a decrease in day journey length during the wet summer period, compared to the dry winter (Wimberger et al. 2017). This change coincided with a reduction in food availability in native species and a shift to a diet containing more non-native plant species.

Primates may also vary their time budgets seasonally; for example, by feeding more during the more productive wet summer to gain mass for the winter (Hanya et al. 2013), increasing feeding in an attempt to maintain calorie intake (Grueter et al. 2013), decreasing movement (Ni et al. 2015), or increasing resting time to conserve energy (Iwamoto and Dunbar 1983). Seasonal foraging behaviour changes responses can also be driven by food availability; when little fruit is available, frugivorous primates often subsidise their diet with alternative food sources, such as leaves (Cui et al. 2019; Fan et al. 2013; Hanya et al. 2011; Hill 1997; Hladik 1975; Milton 1980; Stanford 1991; Tsuji et al. 2013), seeds (Galetti and Pedroni 1994; Peres 2000), flowers (Galetti and Pedroni 1994), or invertebrates (Garber 1993). Primates may also spend more time searching for food (Garber 1993; Gursky 2000; Hendershott et al. 2016) and resting to reduce energy expenditure (Chaves et al. 2011) when food availability is low.

One other aspect of behaviour to be considered when investigating seasonal behavioural variation, relates to time spent on or near the ground. Many arboreal primates avoid spending time on or near the ground, due to the associated higher risk of predation from terrestrial predators (Emerson et al. 2011; Isbell 1994; Nowak et al. 2014). Nevertheless, a forager seeking more food often follows a more risk-prone strategy than a well-fed animal (Brown and Kotler 2007; Dill and Fraser 1984), and as a consequence arboreal species may descend to the ground for food at times of lower food availability in the upper canopy (Nowak et al. 2017). Terrestrial activity may also increase in response to the availability of some resources. Sichuan snub-nosed monkeys (*Rhinopithecus roxellana*) spent significantly more time terrestrial during the summer due to the availability of the herb heracleum (*Heracleum hemsleyanum*), an important source of protein for that population (Li 2007). There is also evidence that less mature leaves contain more protein and are lower in toxins than mature leaves (Milton 1979),

and these may be more available from smaller, immature plants and herb species, close to the ground.

The samango monkey is a species which experiences cold, dry winter periods in parts of their range. Until recently this species was considered part of a larger species group, including *Cercopithecus mitis*, which contained blue monkeys, golden monkeys and Sykes' monkeys (Kingdon et al. 2008). This highly polytypic group is distributed across much of Africa, from Ethiopia in the north to South Africa in the south. The broad distribution is reflected by a wide variation in the behavioural ecology of these arboreal guenons (Coleman and Hill 2014a), suggesting that their time budgets, diet, group size, home range and day journey length adapt to local ecological conditions. For the remainder of this paper we refer to *C. mitis* as blue monkeys and *C. albogularis* as samango monkeys.

In this study we explore the behavioural responses of a group of samango monkeys in the Soutpansberg Mountains, South Africa, to seasonal variation in environmental conditions. The group inhabits a mountainous environment and forms part of a relatively isolated population near the southerly limit of the species range (Dalton et al. 2015), which experiences the coldest winters of any well studied samango or blue monkey group (Table 1). As a consequence, the group is useful to investigate the extent of behavioural flexibility in a species at the limits of ecological tolerance (Sexton et al. 2009).

The Soutpansberg Mountains have a highly seasonal environment, with summer days characterised by long day lengths, higher temperatures and higher rainfall which leads to significantly greater food availability than in the higher productive summer period (Willems and Hill 2009). Samango monkeys have special digestive adaptations, such as long caecums, large numbers of cellulases and large numbers of cellulose digesting bacteria (Bruorton et al. 1991), allowing them to supplement their diet with relatively large amounts of leaf material for a frugivorous primate species (Cords 1986; Lawes 1991; Rudran 1978; Takahashi et al. 2019). Subsequently, these dietary adaptations may prove advantageous for samango monkeys living in areas with varying fruit availability, allowing them to survive where other more obligate frugiviorous species may not be able.

Based on our understanding of the study species and seasonal climate at the study site, we tested the following hypotheses and predictions:

- Samango monkey ranging will vary with seasonal changes in food availability and weather. Specifically, the monkeys will travel further and expand their range in winter to find more food and increase calorific intake when temperatures and food availability are lowest.
- 2. Behaviour will vary seasonally due to environmental conditions and the monkeys will maximise the time available for foraging and reduce resting during winter when days are short. If foraging increases as a response to increased thermoregulatory pressure in winter, we predict a negative relationship between temperature and time spent foraging. If foraging increases due to a reduction in food availability, we predict a negative relationship between food abundance and time spent foraging.
- 3. Due to their leaf eating adaptations, we predict that during periods where the monkeys increase foraging and supplement their diet, they will do so by increasing time spent feeding on leaves. The increase in leaf feeding will be associated with an increase in terrestrial foraging on smaller ground level plants, as they are more palatable than mature leaves present in the canopy.

Methods

Study site

We conducted our research at Lajuma Research Centre, in the Soutpansberg Mountains, Limpopo Province, South Africa (29°26'05"E, 23°02'23"S). The local climate is classified as temperate/mesothermal, with cool dry winters from April-September and warm to hot, wet summers from October-March (Willems 2007). Substantial local variation in abiotic factors such as elevation and water availability result in various microclimates which support a substantial diversity of both flora and fauna (Brock et al. 2003; Willems 2007). The altitude reaches 1748 m at the top of Mount Letjume, with the study group ranging further down at around 1200 m.

Climate

We collected temperature and rainfall data from a nearby weather station at the Mara Research Station (29°34'12"E, 23°9'0"S) approximately 18 km south-east of the study site and approximately 300 m lower in elevation. We calculated day length using daylight periods extracted from the GPS used in data collection (Garmin GPS 60CSX, Garmin, Olathe, KS, U.S.A.), which gives accurate data on dawn and dusk times. We obtained these times for each follow day and used them to calculate mean monthly day length (Figure 1).

Study species and data collection

Samango monkeys are medium sized, arboreal guenons with a mean adult female mass of 4.4 kg and adult male mass of 7.6 kg (Harvey et al. 1987). Samango monkeys form single-male, multi-female groups of up to 65 individuals (Beeson et al. 1996; Butynski 1990; Lawes et al. 2011). The study group are part of a small, genetically isolated population located in a montane environment recently reclassified as *Cercopithecus albogularis schwarzi* (Dalton et al. 2015). The group is the same as that categorised as *Cercopithecus mitis erythrarchus* in earlier studies (Coleman and Hill 2014a; Coleman and Hill 2014b; Nowak et al. 2014).

We habituated the group of samango monkeys, to observer presence and observed them for 96 days between January 2010 and December 2010 (8 days per month, interspersed as evenly as possible). We considered a successful follow day as following the group from dawn to dusk without losing audio-visual contact for more than a total of 60 minutes. Study days ranged approximately 10.5-13.5 hours depending on day length, with 1292 total contact hours.

Identification of individuals proved difficult; however, counts indicated the group consisted of around 40 individuals, with one adult male and up to 14 adult females. We recorded behavioural data through instantaneous scan sampling (Altmann 1974) of all visible adult individuals every 30 minutes with scans lasting a maximum of five minutes (total n = 6561 samples). Data were collected on a palmtop (Sony Clie SL-10) with behavioural data collection software (Pendragon Forms 4.0; Pendragon Software, Libertyville, IL, U.S.A.), with additional data collected in paper notebooks. We separated activities into six categories: feeding, resting, socialising (including agonistic interactions), moving, eating from cheek pouches and unknown (Table 2). Eating from cheek pouches was kept as a separate behavioural category because it can be conducted away from the food source in safer locations and could be considered an element of both resting and feeding behaviour.

Mean data for each scan sample were calculated, which were used to calculate daily mean data, with daily means used to then calculate the monthly means. We calculated mean monthly proportion of time spent in each activity category from the adult scan data (following the methodology of Hill et al., 2004) and obtained figures for monthly terrestriality by calculating the proportion of time spent on the ground. From these data we calculated annual means. To permit seasonal analysis of activity budgets and terrestriality we converted the monthly percentage data into hours per day spent engaged in these activities, using the mean day length of the follow days (see Hill et al., 2003; Hill et al., 2004) (Table 3, 4). We separated diet composition data into six categories: fruit (young/mature fruits combined, category includes seeds and *Acacia* pods,), leaves, flowers, bark, animal matter (invertebrates) and fungi, and calculated annual diet composition as a mean of monthly figures. To compare seasonal data, we converted the diet data into hours per day feeding on each category (following Hill et al., 2004).

Ranging data

We collected GPS locations from the centre of the group as tracks, and subsequently filtered the data to 10-minute intervals. From the filtered GPS data points, we calculated monthly and annual mean day journey lengths as the total distance travelled from dawn to dusk. We also calculated mean journey speed by dividing day journey length by day length. We estimated home range using adaptive Local Convex Hulls (LoCoH) analysis (Getz et al. 2007; Getz and Wilmers 2004). For adaptive LoCoH analysis it is suggested that the widest point between two locations is used as the value *a* to ensure the correct formation of the 100% isopleths (Getz et al. 2007). To calculate the annual home range

using the full dataset we set *a* to 1329 m, and from this we calculated a 50% isopleth to specify the core area. We also calculated monthly ranging area and monthly core areas (Table 3; see Coleman 2013 for parameters used for monthly calculations). Further details of the methods used for the LoCoH analysis are in Coleman and Hill (2014b).

Fruit availability

As samango monkeys are a predominantly frugivorous species (Coleman and Hill 2014a), we used fruit availability as a measurement to assess food availability. We sampled a minimum of 100, randomly placed 25m² quadrats each month (totalling 1296 across the year). In each quadrat we identified each tree and recorded height and crown size. We combined this information with monthly fruiting data from phenological transects containing 10 marked individuals of 8 of the most eaten fruiting tree species (species were Ficus sur, Acacia ataxacantha, Acacia karroo, Rhoicisusus tomentosa, Rhus chirindensis, Ekebergia capensis, Englerophytum magalismontanum, and a combined category for *Ficus craterostoma* and *Ficus burkei* due to difficulty in differentiating these species). Data collected on each individual included height of tree, crown size and an estimate of number of fruits. These data were then combined with the quadrat data to estimate the number of fruits at each quadrat location per month. To account for varying fruit sizes, fruit availability for each quadrat location was calculated using fruit sizes from Coates-Palgrave (1996) (we assigned *Acacia* pods a nominal thickness of 1 mm) to calculate a fruit availability figure (in cm³ per 25 m²). This gave us a figure for overall fruit availability per 25 m² each month, to be used in further analyses. For more detail on this process see Coleman (2013). Spatial maps of fruit availability are in Coleman and Hill (2014b, Figure 1).

The category "herb" contributed a relatively high proportion of time feeding. This included any small, non-tree species (Coleman 2013), but individual plant species were not specifically identified. Herb species were always found at ground level and the samangos only consumed the leaves of the plants (Figure 2). Therefore, we include time spent feeding on herbs in analyses to ascertain whether it had any effect on terrestriality or time spent feeding on leaves.

Statistical analysis

We used the Kolmogorov-Smirnoff test assess normality for the monthly data. All categories except "unknown" from the activity budgets and "animal" and "flower" in the diet composition were normally distributed (p > 0.05). The deviations were due to small numbers of observations, so we do not include these data in our analyses. We also excluded "fungi" and "bark" from analysis due to small sample size.

We used Pearson's linear correlation analysis to examine the relationships between the behavioural data and underlying ecological conditions. We used Benjamani-Hochberg corrections (Benjamini and Hochberg 1995) to decrease the risk of Type 1 errors. This method decreases the p-value needed to consider a relationship statistically significant within a group. We applied the correction separately for three sets of analyses: ranging behaviours, activity budget variables and diet variables to match our sets of hypotheses and predictions.

Results

Regarding ranging, the home range over the study period was 54.7 ha, with a core (50% isopleth) area of 8.3 ha. Mean day journey length was 1906 m (± SD 264.9 m), with a mean journey speed of 156 m/h (± SD 12.9). There were no significant relationships between ecological variables and neither home range nor core home range (Table 5), which does not support the prediction that the monkeys would range further in the winter. However, there was a significant positive relationship between day journey length and both day length (Figure 3a) and mean monthly temperature (Figure 3b), suggesting the monkeys travel further in warmer months, from a minimum of 1489 m in June, up to a maximum 2373 m in February (Table 3), the opposite pattern to the prediction. There were no significant relationships between any of the ranging variables and fruit availability (Table 5).

Relating to activity budget variables, there was no significant seasonal variation in time spent foraging (Table 6); however, there were significant positive relationships between resting and both day length (Figure 4a) and mean temperature (Figure 4b). There was also a significant positive relationship between time spent moving and mean temperature (Figure 4c) and a significant negative relationship between time spent feeding and time spent moving (Figure 4d). We made predictions relating to food abundance, but there were no significant relationships with any of the time budget variables and availability of fruit (Table 6).

Regarding diet variables, whilst there was no significant seasonal change in time spent feeding (Table 6), there were significant changes in time spent feeding on leaves. Mean temperature and time spent feeding on leaves were significantly negatively related (Table 7, Figure 5a), as were leaf feeding and day length (Table 7). However, there were no significant relationships indicating seasonal variation in fruit feeding, suggesting, as predicted, that when subsidising their diet the monkeys concentrate on eating more leaves, rather than increasing fruit feeding. Feeding on leaves varied from a mean of 0.5 hours per day in March, to a maximum of 3.2 hours per day feeding on leaves in August, with considerable day-to-day variation each month (Table 4).

The results also showed a significant positive relationship between terrestriality and leaf feeding (Table 7, Figure 5b), and also feeding on herbs (Table 7). There was also a significant negative relationship between time spent feeding on herbs and mean temperature (Figure 5c) and a significant positive relationship between time spent feeding on herbs and terrestriality (Figure 5d). Time spent terrestrial ranged from a minimum of 1.4 hours per day spent terrestrial in December, up to a maximum of 4.0 hours per day in August (Table 3), with the monkeys spending 22.4% of their overall time on the ground. It is clear from these results that the monkeys spent more time on the ground in winter to subsidise their diet with less mature leaves on smaller herb species, as predicted.

Discussion

We investigated the effect of seasonal environmental variation on the behavioural ecology of a group of samango monkeys living near the southern limit of their species' distribution. We predicted that the monkeys would range further, spend more time foraging, and spend more time on the ground consuming leaves during winter months than in the summer. We found direct support for the latter two of these predictions, through significant negative correlations with monthly temperature. These results suggest that feeding on leaf material from the herb layer is an important response to colder winter days when day length is short, despite the potential predation risks of terrestrial foraging. In contrast, day journey length increased in the warm, wet summer months, suggesting that the longer summer days permitted greater flexibility to seek out food.

Our results showed no significant change in home range size across the study, but day journey lengths and overall time spent moving increased in the summer months. This may simply be because longer day lengths provide more time for moving, allowing greater ranging and foraging flexibility (Hill et al. 2003), or may be because the monkeys travel less in winter months to reduce energy expenditure (Iwamoto and Dunbar 1983), which is supported by the decrease in time spent moving during the winter. Parker et al (2020) showed for the same samango population that total ranging area and mean monthly daily path length decreased as more indigenous forest was incorporated into the ranging area, with the monkeys using matrix habitat during periods of low productivity. Since the monkeys also fed more on terrestrial herb species in winter, habitat choice related to this resource may have the greatest impact on ranging. Furthermore, to exploit the herb layer, the monkeys probably also paused in their travel, which is normally predominantly arboreal, resulting in lower movement. Arboreal travel may mitigate the risks of encountering terrestrial predators, with high leopard density on site during the study (Chase Grey et al. 2013; Williams et al. 2017), although risk perceptions of terrestrial foraging might have been reduced by the presence of researchers (LaBarge et al. 2020a; Nowak et al. 2014). Nevertheless, foraging on the herb layer is likely to carry greater risk of predation than feeding within the canopy. See Coleman & Hill 2014b for further information on impacts of predation risk on this study group.

The samango monkeys had a mean day journey length of 1906 m, which is approximately a third longer than previously reported for other samango or blue monkey groups (Coleman and Hill 2014a). This difference may be due to different methods used for calculating day journey length by different studies (Butynski 1990; Cords 1986; Kaplin et al. 1998; Schlichte 1978; Tesfaye et al. 2013); for example, our study used GPS points every 10 minutes to calculate day journey length, which will pick up finer scale movements than studies with longer sampling intervals, and older studies also did not have access to GPS. A further potentially important explanation relates to the patchier distribution of indigenous forest in this population compared to many blue monkey groups. The presence of an unused, more open area, in the centre of the monkeys' territory (Figure 6) meant the group travelled around this area to access the eastern edge of their home range, which may have contributed to the higher day journey lengths observed in some months. While the monkeys can use the matrix of habitat, their preference for foraging in the indigenous forest patches (Parker et al. 2020) likely underpins this finding.

Many studies have reported that frugivorous primates use non-fruit items to supplement their diet during times of low fruit availability (Galetti and Pedroni 1994; Garber 1993; Hill 1997; Hladik 1975; Milton 1980; Peres 2000; Stanford 1991). However, we found no significant correlation between time spent feeding on any of the diet components and fruit availability. No significant relationship between fruit availability and ranging was also previously found in Coleman & Hill 2014b, and fruit availability is also known to not be an important driver of group cohesion in this population (LaBarge et al. 2020b). When fruit availability was low, the tree species which contributed most to the fruit diet of the monkeys were large, isolated trees such as Ficus spp. (Coleman 2013). Therefore, whilst overall fruit biomass might be lower during some months, fruit availability may be high in individual patches. This would explain why fruit feeding does not decrease from October to January even though overall fruit availability is lower. This hypothesis is further supported when looking at the adult scan data, which shows that the four months of October to January contained 43% of the total number of 'fig eating' records (n=31 out of 71 in total), which drops to only 7% (n=5) during four months 'peak' of fruit availability in February to May, clearly showing that fig consumption increased during months of lower overall fruit availability (Coleman, B.T. unpublished data). This significance of figs in supporting samango monkeys when other fruit availability is low may offset the reduced probability of germination of *Ficus* seeds following ingestion and gut passage (Stringer et al. 2020), such that samangos are an important disperser of the tree species.

Several previous studies have reported an effect of food availability on activity budgets in primates (Chaves et al. 2011; Doran 1997; Garber 1993; Guo et al. 2007; Gursky 2000; Hill 1997; Wimberger et al. 2017), but we found no such relationships. Nevertheless, we observed an increase in time spent feeding on leaves during winter months, a relationship traditionally explained by a shift from a mostly frugivorous to a more folivorous diet (Beeson et al. 1996; Fairgrieve 1995; Tsuji et al. 2013). Leaves, due to their fibrous nature, are often more difficult to consume and digest and therefore require more time to process (Milton 1981). However, fruit feeding does not decrease consistently in the winter months in our group, with some fruiting trees available in all months (although fruit quality may be lower). Nevertheless, the increase in leaf feeding at this time likely indicates increased energetic requirements during the winter months. Living at such a southerly latitude, and at an altitude of approximately 1200 m, the samangos at Lajuma must survive relatively cold winters compared to other populations of samango or blue monkeys (Table 1), with winter day lengths also shorter than at most other sites. Since fruit tends to be patchily distributed across the study group range during winter, the monkeys appeared to exploit leaf availability to supplement calorific intake.

The increase in time spent resting during summer months may be a result of the high midday temperatures (sometimes exceeding 40°C), as previously observed in baboons (Hill 2006; Pochron 2000; Stelzner and Hausfater 1986) and white-faced capuchins (*Cebus capucinus*) (Campos and Fedigan 2009). Individuals exposed to high temperatures should spend more time resting in shaded areas and the samangos at Lajuma may exhibit similar behaviour. Longer day lengths also permit greater behavioural flexibility in the monkeys' thermoregulatory response (Hill 2005). If the group can satisfy their requirements for food and socialising in the cooler parts of the day, there should still be more time available for resting on longer days (Hill et al. 2003).

Although our results only consider monthly variation in the behavioural ecology of our study population, supplementary studies have highlighted that the ecological constraints on these samangos are best described by broad measures of environmental productivity (Parker et al. 2020; Parker et al. 2021). As a consequence they form an important foundation for more fine scale analyses. The samango monkeys in the Soutpansberg Mountains, South Africa, are an isolated population close to the southerly limit of a large distribution (Coleman and Hill 2014a; Coleman and Hill 2014b; Kingdon et al. 2008; Parker et al 2021). Due to the latitude and altitude, the population experiences a highly seasonal climate with cold, dry winters. While we found that the longer summer day lengths may provide the study group greater opportunity for flexibility in their behaviour, short winter days with increased thermoregulatory requirements represented significant constraints. To survive in these conditions, the study group showed behavioural plasticity through increasing time spent feeding on leaves during winter months, although we found no significant effects of season on fruit feeding. Populations living at the edge of their species range may thus show highly localised behavioural adaptations allowing them to persist in areas at the limits of their ecological tolerance.

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Location	Lowest Temp (°C)	Study
Diani Beach Forest, Kenya	20.4	Moreno-Black & Maples, 1977
Kakamega Forest, Kenya	15.3	Cords, 1986
Kanyawara, Kibale Forest, Uganda	12.7	Rudran, 1978
Cape Vidal Forest, South Africa	11.6	Lawes, 1991
Zomba Plateau, Malawi	9.2	Beeson et al., 1996
Mgahinga Gorilla National Park, D.R.C.	6.4	Twinomugisha et al., 2006
Lajuma, South Africa	3.8	This study

Table 1. Mean lowest temperatures of the coldest months at various samango monkey study sites. Data extracted from Hijmans et al., 2005.

Table 2. Definitions of behaviours recorded

Activity	Definition
Feeding	Consuming or searching for food while stationary
Resting	Stationary and not engaged in any of the other activity types
Moving	Movement and not engaged in any of the other activity types
Eating from cheek pouches	Chewing food stored in cheek pouches
Socialising	Any activity involving another individual
Unknown	Focal individual obscured

	Ranging								
Month (2010)	Rangin g Area (ha)	Core (50%) Area (ha)	Day Journey Length (m)	Journey Speed (m/h)	Terrestria lity (h/d)				
Jan	34.3	4.8	2293 ±382	171 ±29	2.4 ± 2.0				
Feb	26.7	6.3	2373 ±352	184 ±28	2.2 ±1.7				
Mar	16.2	3.2	1951 ±425	158 ±34	1.5 ±1.3				
Apr	24.0	5.2	1951 ±181	170 ±16	2.6 ±1.2				
Мау	22.4	4.1	1730 ±183	158 ±27	2.2 ±1.1				
Jun	25.1	4.7	1489 ±158	139 ±24	3.7 ±1.3				
Jul	27.8	4.2	1609 ±122	148 ±10	3.5 ± 0.8				
Aug	25.1	4.0	1730 ±362	154 ±32	4.0 ±1.3				
Sep	18.7	3.4	1690 ±122	140 ±10	3.0 ±0.9				
Oct	37.1	5.6	1831 ±297	144 ±24	3.0 ±1.3				
Nov	29.8	4.5	2052 ±362	155 ±28	2.3 ±1.4				
Dec	26.1	5.8	2173 ±344	161 ±26	1.4 ±1.3				
Mean	26.0	4.7	1906	157	2.7				

Table 3. Monthly variation in ranging, parameters for the study group (mean + SD).

Table 4. Monthly variation in time budgets and diet composition for the study group (mean +SD). For monthly variation in fruit availability, mean monthly rainfall, mean monthly temperature and day length see Figure 1.

Month			Activity						Diet			
(2010)	Resting (h/d)	Feeding (h/d)	Moving (h/d)	Socialisi ng (h/d)	Eating from cheek pouches (h/d)	Eating fruit (h/d)	Eating leaves (h/d)	Eating bark (h/d)	Eating fungi (h/d)	Eating animals (h/d)	Eating flowers (h/d)	Eating herb spp. (h/d)
Jan	5.4 ±2.0	2.9 ±1.2	3.9 ±2.9	0.7 ±0.6	0.7 ±0.6	2.0 ±1.8	0.9 ±1.2	0	0	0	0	0.2 ± 0.5
Feb	5.2 ±1.5	1.7 ±0.6	4.2 ± 0.8	0.8 ± 0.8	0.6 ±0.6	0.9 ± 0.7	0.8 ± 0.6	0	0	0	0	0.3 ±0.5
Mar	4.4 ±1.4	2.7 ±1.1	3.7 ± 1.0	1.2 ± 1.0	0.3 ±0.5	2.0 ± 1.1	0.5 ± 0.5	0.1 ± 0.3	0.2 ± 0.4	0	0	0.1 ± 0.4
Apr	3.9 ±0.7	3.1 ±0.9	3.6 ±0.6	0.5 ± 0.6	0.4 ± 0.3	1.5 ±0.8	1.2 ± 0.7	0	0.4 ± 0.7	0	0	0.5 ± 0.5
May	3.6 ±0.9	3.1 ±1.1	2.4 ± 0.9	0.7 ± 0.5	1.1 ±0.5	1.7 ±0.9	1.4 ± 1.1	0.1 ± 0.2	0.1 ±0.2	0	0	0.3 ± 0.4
Jun	3.4 ±0.7	4.1 ±1.2	1.8 ±0.9	0.8 ± 0.8	0.7 ±0.8	2.0 ±1.2	2.1 ±1.4	0	0	0	0	1.0 ± 0.3
Jul	3.0 ±0.3	3.8 ±1.3	1.9 ±0.7	1.5 ± 0.6	0.5 ± 0.5	1.2 ± 0.8	2.6 ±0.7	0.1 ±0.2	0.1 ±0.1	0	0	1.6 ±1.0
Aug	3.4 ±0.7	4.4 ±1.2	2.2 ±0.9	0.9 ±0.3	0.4 ± 0.2	1.2 ± 0.8	3.2 ±1.3	0.1 ±0.3	0	0	0	2.0 ±1.6
Sep	5.2 ±1.0	3.6 ±1.1	1.9 ±0.8	1.0 ± 0.7	0.4 ± 0.3	1.6 ±1.4	1.9 ±1.4	0	0	0	0	0.5 ± 0.7
Oct	5.7 ±1.3	3.2 ±1.2	2.6 ±1.1	0.9 ±1.1	0.4 ± 0.4	1.7 ±1.4	1.6 ±1.2	0	0	0	0	0.4 ± 0.7
Nov	5.4 ±0.8	4.0 ±1.5	2.7 ±0.8	0.7 ± 1.0	0.3 ±0.4	2.4 ±1.8	0.8 ± 0.8	0.1 ±0.5	0	0.3 ±0.9	0.2 ± 1.0	0.2 ± 0.4
Dec	5.4 ±1.2	3.6 ±1.1	3.6 ±0.9	0.4 ± 0.5	0.6 ±0.5	2.1 ±1.5	1.3 ±0.8	0	0	0	0	0.2 ± 0.6
Mean	4.5	3.4	2.8	0.8	0.5	1.7	1.5	<0.1	<0.1	<0.1	<0.1	0.7

Table 5. Results of correlation analyses comparing monthly means of ranging behaviours with environmental variables and day journey length. Bold indicates significant correlations following Benjamani-Hochberg corrections. r = Pearson's correlation coefficient.

Variable	r / p	Mean Monthly Temp	Monthly Rainfall	Day Length	Fruit Availab ility	
Mean Day	r	0.856	0.475	0.837	-0.140	
Journey Length	р	<0.001	0.118	0.001	0.664	
Journey	r	0.557	0.474	0.426	0.250	
Speed	р	0.060	0.120	0.167	0.434	
Ranging Area	r	0.197	0.044	0.391	-0.670	
Kunging m cu	р	0.539	0.893	0.208	0.017	
Core (50%)	r	0.365	0.413	0.411	-0.147	
Area	р	0.243	0.182	0.185	0.649	

Table 6. Results of correlation analyses comparing monthly means of time budget variables, along with comparisons with environmental variables. Bold indicates significant correlations following Benjamani-Hochberg corrections. r = Pearson's correlation coefficient.

Variable	r / p	Mean Monthly Temp	Monthly Rainfall	Day Length	Fruit Availa bility	Eating From Pouch es	Feedin g	Movin g	Socialising
Resting	r	0.879	0.213	0.933	-0.444	-0.248	-0.449	0.508	-0.354
Resting	р	<0.001	0.507	<0.001	0.148	0.437	0.143	0.092	0.259
Socialisin	r	-0.329	-0.634	-0.351	0.095	-0.290	0.016	-0.307	
g	р	0.296	0.027	0.263	0.769	0.361	0.960	0.331	
Moving	r	0.804	0.548	0.648	0.195	-0.180	-0.789		-
Moving	р	0.002	0.065	0.023	0.543	0.575	0.002		
Fooding	r	-0.651	-0.111	-0.407	-0.400	-0.054			
recuing	р	0.022	0.732	0.190	0.197	0.868			
Eating	r	-0310	-0.185	-0 308	0 095		-		
From	n	0.326	0.565	0.331	0.760				
Pouches	þ	0.320	0.505	0.551	0.709				

Table 7. Results of correlation analyses comparing monthly means of diet composition variables, along with comparisons with environmental variables and time spent on the ground (terrestriality). Bold indicates significant correlations following Benjamani-Hochberg corrections. r = Pearson's correlation coefficient.

Variable	r / p	Mean Monthl y Temp	Monthly Rainfall	Day Lengt h	Fruit Availab ility	Terrest riality	Eating herb sp.	Eating leaves
Eating	r	0.471	0.084	0.545	-0.334	-0.558	-0.561	-0.510
Fruit	р	0.122	0.795	0.067	0.288	0.059	.058	.091
Eating	r	-0.860	-0.429	-0.686	-0.148	0.884	0.896	
Leaves	р	<0.001	0.164	0.014	0.646	<0.001	<0.001	
Eating	r	-0.831	-0.354	-0.691	-0.039	0.863		
Herb spp.	р	<0.001	0.258	0.031	0.905	<0.001		
Terrestria	r	783	453	637	0830		-	
lity	р	.003	.140	.026	.798			



Fig. 1. Monthly variations in rainfall, mean temperature, fruit availability and day length.

Fig. 2. Adult male samango monkey in typical ground vegetation for the study site. Plants referred to as "herb spp." can be seen in the image.





Fig. 3. Relationships between movement variables and environmental variables. 3a – Positive relationship between day length and day journey length. 3b – Positive relationship between mean temperature and day journey length.



Fig. 4. Relationships between activity budget variables and environmental variables. 4a – Positive relationship between time spent resting and day length. 4b – Positive relationship between time spent resting and mean monthly temperature (Mean temp). 4c – Positive

relationship between time spent moving and mean monthly temperature. 4d – Negative relationship between time spent feeding and time spent moving.



Fig. 5. Relationships between diet variables and environmental variables. 5a – Negating relationship between mean temperature (Mean Temp) and time spent feeding on leaves. 5b – Positive relationship between time terrestrial (Terrestriality) and time spent feeding on

leaves. 5c – Negative relationship between mean temperature and time spend feed on herb spp.. 5d – Positive relationship between terrestriality and time spent feeding on herb spp..



Fig. 6. Home range (54.7 ha) and utilisation distribution of the study group (Coleman and Hill 2014b). Scale bar - highest utilisation 1% isopleth to lowest utilisation 100% isopleth.