Activity Budget and Ranging Patterns of *Colobus vellerosus* in Forest Fragments in Central Ghana

Sarah N.P. Wong  Pascale Sicotte
Department of Anthropology, University of Calgary, Calgary, Alta., Canada

Key Words
Activity budget  *Colobus vellerosus*  Fragmented habitat  Habitat quality  Ranging

Abstract
The forest fragments surrounding the 192-ha Boabeng-Fiema Monkey Sanctuary (BFMS) in central Ghana contain small populations of *Colobus vellerosus*. Data were collected on activity budget, ranging patterns and habitat use of 3 groups living in these small fragments in August–November 2003, and compared to 3 BFMS groups. Fragment groups spent less time moving and more time resting than BFMS groups. Home ranges of fragment groups tended to be smaller than those of BFMS groups. Fragment and BFMS groups used similarly sized trees. Comparisons of activity budget and ranging between fragments and the BFMS suggest that fragment habitat quality was sufficient to sustain current numbers. These behavioral trends are consistent with a concurrent study that we conducted investigating ecological quality in the same fragments.

Introduction

The loss of tropical forests is occurring at a rate of 1.1% per year [FAO, 2000] and has resulted not only in a decline of forest habitat, but also in fragmentation of the landscape. Forest fragmentation may cause local extinctions or a loss of genetic diversity [Lovejoy et al., 1986; Sauer, 1998]. Before local extinctions occur, habitat fragmentation can have other, more subtle effects on the activity and the movements of the animals in their habitat. Many primate species live in what appear to be sub-optimal habitats, yet seem to be able to survive. Documenting how primates fare in these circumstances can contribute to our understanding of what would constitute...
Feeding and Moving indicate the percentage of records spent feeding/moving. The percentage of records represents the percentage of time spent in that activity.

Table 1. Demography, habitat quality and behaviors associated with feeding in Colobus groups in BFMS and smaller fragments

<table>
<thead>
<tr>
<th>Group</th>
<th>Group size</th>
<th>Colobus density, individuals/km²</th>
<th>Total groups in forest</th>
<th>Fragment distance from BFMS, m</th>
<th>Mean DBH of food trees, cm</th>
<th>Density of food trees, indi-</th>
<th>Pioneer species, feeding, %</th>
<th>Feeding, Moving, Home range</th>
</tr>
</thead>
<tbody>
<tr>
<td>AW₁</td>
<td>16</td>
<td>47</td>
<td>1</td>
<td>294</td>
<td>40.5</td>
<td>160</td>
<td>28.9</td>
<td>18.8</td>
</tr>
<tr>
<td>BT₁</td>
<td>17</td>
<td>51</td>
<td>1</td>
<td>1,064</td>
<td>34.5</td>
<td>166</td>
<td>40.0</td>
<td>23.4</td>
</tr>
<tr>
<td>BS₁</td>
<td>8</td>
<td>50</td>
<td>4</td>
<td>1,138</td>
<td>30.4</td>
<td>131</td>
<td>41.7</td>
<td>23.7</td>
</tr>
<tr>
<td>WW</td>
<td>30</td>
<td>119</td>
<td>15</td>
<td>0</td>
<td>37.1</td>
<td>202</td>
<td>17.4</td>
<td>24.3</td>
</tr>
<tr>
<td>B (B1+B2)</td>
<td>23 (8+15)</td>
<td>119</td>
<td>15</td>
<td>0</td>
<td>40.5</td>
<td>180</td>
<td>17.4</td>
<td>23.6</td>
</tr>
</tbody>
</table>

Feeding and Moving indicate the percentage of records spent feeding/moving. The percentage of records represents the percentage of time spent in that activity.

a Data source: Wong and Sicotte [2006].
b Data source: Wong et al. [2006].
c In home range of the groups.
d Indicator of disturbance.

the minimal conditions allowing survival in the short term, and guide conservation decisions regarding investment towards the preservation and possibly enhancement of small forest fragments.

Studies on the behavior and ranging patterns of species in fragments in comparison to larger forest blocks can give an indication of habitat quality (such as food availability, density and distribution) at least in the short term [Menon and Poirier, 1996; Zanette et al., 2000]. For example, the proportion of time spent traveling or feeding may increase if species must spend more time searching for foods or are eating lower-quality foods [Menon and Poirier, 1996; Onderdonk and Chapman, 2000]. An increase in the amount of time spent foraging may result in a decline in social activity [Clarke et al., 2002]. Lower food availability and density may result in longer day journey lengths (DJLs), suggesting that individuals have to travel more to meet their nutritional requirements [Watts, 1991; Gillespie and Chapman, 2001]. Home range size may also increase in lower-quality habitats for the same reason [Dunbar, 1987].

Our goal in this paper is to offer a preliminary assessment of activity budget, home range size, DJL and habitat use of 3 groups of Colobus vellerosus (the ursine colobus) living in the small forest fragments surrounding the 192-ha Boabeng-Fiema Monkey Sanctuary (BFMS) in central Ghana. We compare these groups to 3 groups in the larger forest fragment of the BFMS.

Methods

Study Site and Study Groups

The BFMS is located in the Brong-Ahafo Region of Ghana (7°43' N and 1°42' W). It is a 192-ha dry semideciduous forest fragment, separated from any large forest block (>1,000 ha) by 50 km [Beier et al., 2002]. The BFMS shelters a population of C. vellerosus on which work has been going on since 2000 [Teichroeb et al., 2003; Sicotte and MacIntosh, 2004; Saj et al., 2005; Saj and Sicotte, in press]. Several smaller forest fragments are found within 2 km of the BFMS, and some of them shelter groups of C. vellerosus (fig. 1) [Kankam, 1997; Wong and Sicotte, 2006]. Three focal groups from 3 different forest fragments were studied (Akrudwa Kuma: 34.2
Fig. 1. BFMS and surrounding forest fragments. G = Number of groups in forest [Wong and Sicotte, 2006]. The presence of roads is indicated by lines. Most of the matrix surrounding the fragments is agricultural land. There is a village adjacent to each of the small forest fragments (Akrudwa Kuma, Akrudwa Panyin, Busunya, Bomini and Bonte). The villages of Boabeng and Fiema are adjacent to the BFMS.

ha, Bonte: 33.5 ha, Busunya: 54.1 ha). Three groups from the BFMS were used in the comparisons (WW, B1, B2). The size of the study groups was: WW, 30 individuals; BT, 17; AW, 16; B2, 15; B1, 8, and BS, 8 (table 1).

Ecological surveys of the BFMS and the fragments showed that food abundance tended to be lower in the fragments than in the BFMS. There was also a higher proportion of pioneer species in the fragments than in the BFMS, which suggests that they were more disturbed [Wong et al., 2006].

**Data Collection**

Data from the small forest fragments were collected from August to November 2003 by S.W. and one trained assistant. Data from the BFMS were collected from August to November 2000 (WW and B1) and 2001 (B2) by J. Teichroeb and T. Saj [Teichroeb et al., 2003]. Ideally, comparisons between groups should have been done using data collected during the same year, since comparing data collected in different years may introduce other sources of variation, such as different monthly rainfall. However, this was not possible. For the fragments, comparisons were made between overall activity budgets within specified time blocks by S.W. and the trained assistant and no significant differences were found. No standard interobserver reliability tests were performed between fragment and BFMS researchers, but S.W. and the assistant were trained by T. Saj. Since the behavioral categories were few and simple (see below), we are confident that data were collected reliably.

Full-day follows were conducted from 6.00 to 18.00 h for 3 consecutive days. These 3-day blocks were repeated 5 times for each group, resulting in 15 full-day follows for each group. Scan samples were conducted every 15 min [Fashing, 2001] during which age-sex class and activity (feeding, resting, moving, social; definitions as in Teichroeb et al. [2003]) were recorded for the first 5 individuals spotted in the group (sensu Teichroeb et al. [2003]). Five minutes were allowed for finding the individuals, and the group was circled between scans to get a random selection of individuals. Once an individual was spotted, the observer waited 5 s before recording the behavior to ensure eye-catching behaviors were not overrepresented (sensu Teichroeb et al. [2003]).
All trees being used by the group were also recorded every 15 min during the scan sampling. These trees were identified, given a code and mapped (using the geographical positioning system Trimble Explorer 3.0). A position was only accepted if at least 5 satellites (but usually 6) were used to triangulate the position. In areas of high leaf cover, it was possible to offset the geographical positioning system so that positions could be obtained when the observer was in a clearer view of the sky. The diameter at breast height (DBH) was measured for each mapped tree. The center of the group's location was recorded every half-hour beginning at 6.00 h by walking the periphery of the group. Mapped trees were used as reference points. For a period of 2–4 h each day, the center of the group's location was not collected.

Data Analysis
Activity budgets for the groups in the 3 fragments were calculated by determining the percentage of all records spent in each activity. Results were compared to 3 BFMS groups [Teichroeb et al., 2003].

The minimum convex polygon method (Animal Movement Program [Hooge and Eichenlaub, 2000] extension for the geographical information system ArcView 3.3 was used to calculate home range by constructing a polygon around the outermost trees used by each group [Jenrich and Turner, 1969]. All trees used by the group during the 15 observation days were included.

DJL was calculated on the basis of the center of group location. The location recorded every half-hour was plotted on the geographical information system-generated map and the total distance traveled per day was calculated using measuring tools in the geographical information system. Since DJL data for fragment groups had 2–4 h with missing locations (mean number of hours with data gaps: AWf = 3.27, BTf = 2.77, BSf = 3.03), the shortest distance from the last recorded position to the ensuing position was used [Fashing, 2001]. We calculated DJL using all days, but in order to decrease the potential for error, we also calculated the DJL using only days with gaps of no more than 3 h, which yield a corrected mean DJL. DJLs for BFMS groups were calculated during the same months (August to November) and only days with gaps of no more than 2 h in data collection used.

We calculated the mean DBH of the trees used by our groups for each day, and these daily means were averaged to give an overall mean DBH of trees used (sensu Saj [2005]). Both resting and feeding trees were included in this analysis. The percentage of trees used which were food species was also calculated.

Statistical Analysis
We describe the activity budget by simply presenting percentages of time spent in various activities. We compared activity budget, home range and DJL between two groups of equal size but different habitats using a Mann-Whitney U test (B1 vs. BSf), in an effort to evaluate the effect of habitat quality (presumably higher in B1's range, and lower in BSf's range since habitat quality variables, such as stem density, average DBH and Shannon-Wiener indices, were lower in BSf than in B1 ranges [Wong et al., 2006]) on these dependent variables. Habitat use was explored by conducting paired t tests to determine if there was a difference between DBH of used trees (all trees in which Colobus were found during the 15-min scans) versus DBH of unused trees. All tests were 2-tailed and were significant at p < 0.05, except the test comparing B1 and BSf, where the habitat quality data (reported above) allowed us to formulate a directional hypothesis. Tests were performed using SPSS 11.5.

Results
Activity Budget
A total of 1,754 scans were recorded over 45 days (605 for AWf, 555 for BTf, 594 for BSf). These scans yielded a total of 7,939 records (2,810 for AWf, 2,551 for BTf, 2,578 for BSf). The mean activity budget for the groups in the small fragments was 22.0% feeding, 68.6% resting, 6.8% moving and 2.6% social activities. The values for
BFMS were 23.7, 59.1, 14.6 and 2.6%, respectively [Teichroeb et al., 2003]. The proportion of time spent feeding and in social activity was similar between the small fragments and BFMS, i.e., values were within 2–3% of each other. The groups in the small fragments spent a lower proportion of time moving and a higher proportion of time resting than BFMS groups (fig. 2). The comparison of the two groups of equal size mirrored these trends. They spent similar proportions of time feeding (BSf = 23.7%, B1 = 23.1%), but BSf spent less time moving than B1 (7.5 vs. 14.9%).

**Ranging Patterns and Habitat Use**

AWf had the largest home range and BSf the smallest (fig. 3, table 1). In the 3 small fragments, there appeared to be no relationship between home range size and fragment size; BSf, with the smallest home range, was located in the largest of the 3 fragments. Home range size in relation to the size of the fragment was highest for AWf (57.9%), followed by BTf (18.5%), BSf (7.8%), WW (5.5%), B2 (4.8%) and B1 (4.6%).

WW had the longest mean DJL, whereas BTf had the shortest. No clear trend in DJLs emerged when comparing small-fragment versus BFMS groups (table 2). At equal group size, B1's home range was twice the size of BSf's, yet B1 tended to have
Table 2. DJL of *Colobus* groups in BFMS and small fragments

<table>
<thead>
<tr>
<th>Group</th>
<th>Uncorrected mean DJL ± SD, m</th>
<th>Corrected mean DJL ± SD, m</th>
</tr>
</thead>
<tbody>
<tr>
<td>AK_f</td>
<td>351.8 ± 133.0</td>
<td>366.6 ± 145.0</td>
</tr>
<tr>
<td>BT_f</td>
<td>252.7 ± 120.1</td>
<td>256.9 ± 129.2</td>
</tr>
<tr>
<td>BS_f</td>
<td>341.3 ± 67.9</td>
<td>342.3 ± 54.5</td>
</tr>
<tr>
<td>WW</td>
<td>not available</td>
<td>408.4 ± 109.2</td>
</tr>
<tr>
<td>B1</td>
<td>not available</td>
<td>287.3 ± 71.8</td>
</tr>
<tr>
<td>B2</td>
<td>not available</td>
<td>267.2 ± 49.4</td>
</tr>
</tbody>
</table>

BFMS data source: a subset of data from Saj and Sicotte [in press]. Uncorrected mean DJL uses all days in the calculations; corrected mean DJL uses only days when missing data were 3 h or less for fragment groups (AK_f, BT_f, BS_f) or 2 h or less for BFMS groups (WW, B1, B2). DJLs were calculated using data collected in the same months (August to November).

Table 3. Characteristics of used and unused trees in home ranges of study groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean DBH of all trees used</th>
<th>Mean DBH of all large trees (DBH ≥ 40 cm)</th>
<th>Mean DBH of unused large trees (DBH ≥ 40 cm)</th>
<th>Mean DBH of all trees (DBH ≥ 10 cm)</th>
<th>Mean of trees used which were food trees, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>AK_f</td>
<td>94.9</td>
<td>79.7</td>
<td>75.0</td>
<td>37.1</td>
<td>83.8</td>
</tr>
<tr>
<td>BT_f</td>
<td>92.2</td>
<td>82.0</td>
<td>61.9</td>
<td>29.8</td>
<td>98.9</td>
</tr>
<tr>
<td>BS_f</td>
<td>93.7</td>
<td>77.0</td>
<td>59.7</td>
<td>31.3</td>
<td>85.8</td>
</tr>
<tr>
<td>WW</td>
<td>87.71</td>
<td>96.7</td>
<td>not available</td>
<td>30.3</td>
<td>not assessed</td>
</tr>
<tr>
<td>B (B1+B2)</td>
<td>98.81</td>
<td>84.8</td>
<td>not available</td>
<td>34.0</td>
<td>not assessed</td>
</tr>
</tbody>
</table>

Mean DBH of all trees used included trees with DBH ≥ 10 cm. BFMS data source: Saj [2005].

The mean DBH of all used trees was similar between fragment and BFMS groups (table 3). The DBH of used trees was significantly larger than the DBH of unused trees for the 3 small-fragment groups (AW_f: t = 3.872, d.f. = 542, p < 0.001; BT_f: t = 2.187, d.f. = 75, p = 0.032; BS_f: t = 2.404, d.f. = 129, p = 0.018). Food trees comprised the majority of trees used by the small-fragment groups (mean = 89.5 ± 8.2%).

Discussion

The groups in the small fragments spent the same proportion of time feeding as BFMS groups, but they seemed to move less and rest more. This trend was also found between groups of equal size (BS_f and B1). Other studies have found no difference in
activity budget between fragment groups and those in continuous forests for *Colobus guereza* [Onderdonk and Chapman, 2000] or *Alouatta palliata* [Estrada et al., 1999]. The differences in activity budget between small-fragment and BFMS groups found in our study may be explained by the fact that the small-fragment groups have better-quality food available per capita (fragment groups are at lower densities) than groups in the BFMS. Thus if groups have a good diet, resting time might not be constrained. Studies on the nutritional quality of these food items would be necessary to clarify the situation.

While differences in food availability or quality may explain the differences in activity, we must also consider that there was a lower colobus density in the small fragments compared to the BFMS [Wong and Sicotte, 2006]. No other groups were found in Akrudwa Kuma and Bonte during this study, thus AWf and BTf were not facing between-group competition for food or immediate reproductive competition from extragroup males that might have influenced their movement. There were 4 groups in Busunya, but the population density in this fragment was half of that in the BFMS (50 vs. 119 individuals/km² [Wong and Sicotte, 2006]). This suggests that food availability in these fragments might have been sufficient for the population they supported. Other studies have found higher densities of primates living in forest fragments compared to larger, continuous forests [Schenkel and Schenkel-Hulliger, 1967; Dunbar, 1987; Tutin, 1999; Onderdonk and Chapman, 2000]. The fact that densities were lower in the smaller fragments may illustrate that this forest system has reached an equilibrium as it is relatively old, while the fragments in other studies may represent population decline.

Fragment groups did not consistently have longer DJLs than BFMS groups suggesting that they did not need to increase their foraging effort. This is consistent with the fact that feeding time also did not vary between the groups in the small fragments and those in the BFMS. However, the large standard deviations in DJLs are worth noting. Fragments are not homogeneous in terms of tree distribution. In areas with a good patch of food trees, we can imagine days of relatively short travel, alternated with days of long travel within less optimal food patches. In support of this notion, AWf had the largest home range, which may be reflective of either lower habitat quality [Dunbar, 1987] or a heterogeneous habitat. Comparing the two groups of equal size showed a trend whereby the fragment group (BSf) had a longer DJL than the BFMS group (B1), despite having a home range half its size, suggesting that BSf had to travel farther each day than B1. BSf's standard deviation around the mean DJL was smaller than those of the other groups, suggesting that BSf traveled almost consistently long distances. This would suggest that the rate of revisits to trees was higher in BSf than B1, which might lead to faster food depletion. Rates of revisitations cannot be calculated in the current study, but it is a question that is being examined for future study.

Fragment groups utilized similarly sized trees as groups in the BFMS, the majority of which were food species. DBH is usually correlated with crown size [Barbour et al., 1999], thus larger trees have a higher abundance of leaves than smaller trees of the same species. Since *Colobus* diet comprises mainly leaves, the use of equally large food trees in the fragments suggests that food availability may be similar to that of the BFMS. Food availability in fruiting trees between fragments and BFMS may also be similar since DBH is associated with food availability in fruiting trees [Chapman et al., 1992]. Previous work found similar stem densities [Wong et
Conclusions

Comparisons of activity and ranging patterns of fragments and BFMS are an indirect method of assessing habitat quality and need to be complemented by ecological surveys (e.g. abundance and distribution of food species) and demographics (density and number of neighboring groups). Considering that the smaller fragments contained a lower density and total number of groups than the BFMS, and that small-fragment groups spent similar amounts of time feeding as BFMS groups, it is likely that the food supply in the small fragments was sufficient for the small populations inhabiting these fragments. Our ecological work suggested that food abundance in the fragments was comparable to that of the BFMS; however, the fragments were more disturbed [Wong et al., 2006].

There are trends in our data that are difficult to interpret. For example, BS₁ had the lowest density of food trees and one of the longest mean DJLs, but the smallest home range (table 1). BS₁’s home range also occupied only a small portion of the forest fragment. Also, AW₁ had the highest mean DBH of food trees of the fragments and one of the highest densities of food trees, yet the size of the group’s home range was twice that of the BFMS groups (table 1). Differences in nutritional content of food species between the forest fragments may be a factor influencing the behavior of these groups, since we have shown that the forest fragments differ in species composition [Wong et al., 2006]. If pioneer species have higher-quality leaves, the larger percentage of pioneer species in BS₁ and BT₁’s home range (table 1) might explain their small home ranges. Coley [1983] found that pioneer species had higher nutritional quality, less tough leaves and faster growth rates, which might mean that the home ranges of BS₁ and BT₁ have a high food availability. Pioneer species have lower concentrations of fiber [Coley, 1983], resulting in high protein-to-fiber ratios, which have been shown to correlate with colobine density [Chapman et al., 2002; Wasserman and Chapman, 2003]. Also, we have not considered the distance between food trees or their patchiness. Finally, the pressure from neighboring groups may play a role (e.g. there were 3 other groups in Busunya at the time of data collection, which may explain BS₁’s habitat use), as well as the level of human harassment the monkeys experience in different fragments.

Acknowledgements

We thank the Ghana Wildlife Division, the Management Committee of the Boabeng-Fiema Monkey Sanctuary and the chiefs and residents of Akrudwa Kuma, Akrudwa Panyin, Bonte, Busunya and Bomini for allowing us to conduct research in these forests. Many thanks to Anthony D. Assah for providing invaluable logistical support during the fieldwork. Moses Ampofo assisted in tree identification in the field. Thank you to our field assistants: Adomako Seth, Charles Kodom, Constance Serwa, Effah Boa-Ampomsem, Afia Faustine Boahen. We thank Tania Saj who kindly provided data. Thank you to Dr. Colleen Cassidy St. Clair (University of Alberta) for use of equipment. Funding for this research was primarily provided by...
the Wildlife Conservation Society. We also acknowledge funding from Primate Conservation
Inc., Natural Science and Engineering Research Council of Canada, and the University of Cal-
gary. This study was approved by the Animal Certification Care Committee of the University
of Calgary.

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