Home Range Analysis of *Cercopithecus* Monkeys in Gombe National Park, Tanzania

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Abstract

Home range analysis provides insight into animal behavior and ecology. We documented the home range of a group of hybrid *Cercopithecus* monkeys in Gombe National Park, Tanzania over 40 months (June 2015-September 2018). We analyzed spatial data of monkey movement using ArcGIS software. We measured home range area from the total aggregate range from all years and between seasons in 2016. We found the total home range to be 61.83 ha and the seasonal ranges to be 39.94 ha and 37.04 ha for wet and dry seasons, respectively. Range size was larger than most study groups of the parental species at different sites. Hot spot analysis revealed seasonal differences in intra-range movement with increased utilization of the southeastern part of the range in the wet season and the northwestern section in the dry season. Factors affecting range size are likely linked to food availability and distribution, and group size.

Introduction

A home range consists of the region holding resources, such as food or mates, in which the animal or animals concentrate (Wartmann et al., 2014). Borders of the range may overlap with other neighboring ranges, with “core” areas that exhibit less overlap and greater defense effort (Wrangham et al., 2007). Home range analysis has been utilized as a tool in ecological studies to provide insight into the behavior, abundance, and habitat of animals with regard to seasonal or environmental changes (McLester et al., 2019; Miller et al., 2012).

It is widely used in primatology to examine spatial constraints and habitat preferences related to social and feeding behavior (Cords, 1986; Kaplin, 2001; McLester et al., 2019; Struhsaker, 1980; Wartmann et al., 2014), as well as how spatial constraints relate to morphological and physiological characteristics of primate species (Boinski, 1987; Cords, 1986; Kaplin, 2001; Struhsaker, 1980).

Gombe National Park (GNP) in western Tanzania, alongside the eastern edge of Lake Tanganyika, has been a site of primatology study since the 1960s (Goodall, 1986). Within the park, a rare phenomenon occurs between red-tailed monkeys (*Cercopithecus ascanius schmidti*) and blue monkeys (*Cercopethecus mitis doggetti*). These two *Cercopithecus* species interbreed naturally and produce viable and fertile hybrid offspring (Detwiler, 2002). Documentation of *Cercopithecus* hybridization has been reported for decades, alongside other primate research in GNP (Clutton-Brock, 1975; Detwiler, 2019; Goodall, 1986;). However, further information regarding the ecology and behavior of hybrid monkey social groups is needed (Detwiler, 2019).

In this study, we determined the home range of a habituated hybrid monkey group and investigated patterns of movement between seasons and over multiple years. The study group consisted of *C. ascanius schmidti*, *C. mitis doggetti*, and their hybrids (59 individuals at the end of 2018: 9 *C. mitis*, 37 *C. ascanius*, 13 hybrids). Prior studies have examined the home ranges of the parental species, for example: *C. ascanius* range was documented as 44-65 ha in Ngogo, Kibale National Park, Uganda; 60 ha in Kakamega Forest Reserve, Kenya (Cords, 1986); and 1600 ha in the Issa Valley, western Tanzania (McLester et. al. 2019). *C. mitis* range was documented as 38 ha in Kakamega (Cords, 1986) and 88 ha in Nyungwe National Park, Rwanda (Kaplin, 2001). McLester et al. (2019) found differences in temperature and food availability as factors contributing to variation in the movement of *C. ascanius* groups. However, no previous study has investigated the effect of hybridization on home range and how it may affect range size.

Thus, we established three objectives to build an understanding of GNP's hybrid monkey home range behavior: (1) determine the size of the study group's home range, (2) determine if the study group has seasonal patterns of movement, and (3) determine how the study group's home range size and internal movements compare to those of the parental species from other forests in East Africa (e.g. Cords, 1986; Kaplin, 2001; McLester, 2019).

Methods

Study Site

We conducted the study in Gombe National Park, Tanzania, a forested and hilly region on the eastern edge of Lake Tanganyika. Open and thicket woodlands, including *Brachystegia* woodland, cover the upper and lower slopes with evergreen forests covering valley bottoms (Collins & McGrew, 1988). Grasslands occur at the highest points of the valley ridges (Collins & McGrew, 1988). GNP experiences two major seasons: a dry season from approximately June to October and a wet season from approximately November to May (Goodall, 1986). We defined seasons based on average monthly precipitation. We used spatial data collected from the start of the dry season of 2015 (June) to the end of the dry season in 2018 (September) for a total of 40 months (Table 1).

Data Collection and Formatting

Field assistants collected location data using handheld GPS units which recorded the spatial location of the study group as a GPX file. Each waypoint was documented in a field journal as either "initial contact" with the group, "group scan" every 30 minutes, or "final contact" when the field assistant left the group. Field assistants were typically in contact with the group for approximately 7 hours a day, between 7:00 and 12:00, and then again between 16:00 and 18:00. Due to field assistant schedules and fieldwork conditions, sampling effort varied within hours of the day, days of the month, seasons, and years (Table 1).

In our lab, we transferred the GPX data from the handheld GPS recorder into the DNR GPS program, which transformed the data from GPX files into ArcGIS shapefiles. We set the projection to WGS 1984 UTM Zone 35S. Next, we converted the shapefiles to Excel files (.xlsx), which were consolidated to include only waypoints needed for the study. Once the filtered dataset was created, we imported the information into ArcMap 10.7.1 as XY coordinate data.

Minimum Convex Polygons

We created minimum convex polygons (MCPs) from the XY coordinate datasets for all waypoints and the waypoints from the 2016 wet and dry seasons. We selected 2016 waypoints for seasonal data as it had the most frequent and consistent work effort. In ArcMap, we used the respective XY coordinate data to create a new feature class displaying minimum bounding geometry. We set the geometry type to "Convex hull," resulting in the smallest convex polygon that encompassed the XY data.

Hot spot Analysis

We conducted a hot spot analysis for each dataset using a search radius of 5m and 15m, for the seasonal and total datasets respectively. A hotspot analysis is a spatial analytical technique based on the Getis-Ord Gi* statistic, which facilitates the identification of patterns in the spatial distribution of a dataset. The tool generates p- and z-values, which help the user determine if there is a statistically significant pattern of spatial clustering. We used hot spot analysis to track intra-range movements, thus allowing for a more precise visual of ranging behavior than MCPs. The hot spot analysis accounted for the variation in work effort seen between seasons, as the clusters still indicated areas of frequent use.

Results

Sampling Effort

From the beginning of the dry season in 2015 to the end of the dry season in 2018, we identified 4,155 waypoints from group observational data. Concerning seasonal data, 744 waypoints were from the 2016 wet season (56% of 2016 waypoints), and 573 waypoints were from the 2016 dry season (44% of 2016 waypoints). Over the full course of the study, the average number of waypoints per month was 104 ($\sigma = 43$). We found the average for the 2016 wet season to be 106 waypoints per month ($\sigma = 31$) and 115 waypoints per month for the dry season ($\sigma = 23$).

Minimum Convex Polygons

Using an MCP, the total home range for the group during the study period was 61.84 ha. Seasonally, the MCP for the wet season and dry season were 39.94 ha and 37.04 ha respectively (Figure 2).

Hot spot Analysis

Using hot spot analysis to analyze intra-range movement, we found that the group spread out more in the wet season than in the dry season. We found overall concentration in the wet season to be in the southeast part of their range, whereas in the dry season, the group concentrated in the northwest section (Figure 3).

The overall trend of the full dataset resembled the dry season pattern with a concentration in the northwest section of the range (Figure 4). The results indicate a statistically significant clustering of "hot spots," within the respective radius used in the analysis (orange = $z > 1.65$, $p < 0.1$); red = $z > 1.96$, $p < 0.05$; dark red = $z > 2.58$, $p < 0.01$; Figure 4). The "cold" spots indicate that there is a statistically significant clustering of low values in that area (light blue = $z < -1.65$, $p < 0.1$; blue = $-2.58 < z < -1.96$, $p < 0.05$; Figure 4).

Discussion

The results of our study confirmed the ranging behavior of the hybrid monkey group of *C. ascanius schmidti* and *C. mitis doggetti* to clustering within a defined area. We also were able to locate areas with minimal usage. The cold spots in the range may indicate that the area was lacking in sufficient food sources, covered difficult terrain for the field assistants to traverse, or was in some other way less suitable than the preferred regions. Another factor to consider is areas where home range overlaps between neighboring groups, as such regions are often under-used (Wrangham, 2007).

Seasonal movement was the most obvious trend observed in our study and thus was likely behaviorally motivated. Food availability is cited as a reason for seasonal movement in primates (Cords, 1986; Kaplin, 2001; McLester et al., 2019; Sugiyama, 1976) as seasonal changes in vegetation affect the food sources of primates and consequently lead to the movement of primate groups in a cyclical, temporal manner (Li et al., 2000). Thus, the shift of the study group from the southeast to the northwest may be connected to food resources.

In Nyungwe National Park, *C. mitis* was observed with season-specific behavior, traveling farther in the wet season compared to the dry. At Nyungwe, fruit availability varied with the season, and the monkeys were more prone to travel when the number of fruiting trees diminished, and their diet became more varied (wet season) (Kaplin, 2001). Cords (1986) found the consumption of major diet elements to be seasonally different in Kakamega. Diet likely plays an important role in intra-range movements in our study group as well.

The total aggregate range size of the hybrid monkey group (61.83 ha) was close to the upper end of those previously reported. Our study group had a larger home range than the *C. ascanius* study group in Kakamega, Kenya (Cords, 1986), and all but one of the study groups in Kibale National Park, Uganda (McLester et al., 2019). The hybrid group's range was smaller than the *C. mitis* home range size at Nyungwe National Park, Rwanda, which measured at 87.7 ha (Kaplin, 2001), but *C. mitis* in Kakagmega had a smaller range at 37 ha (Cords, 1986). However, the *C. ascanius* study group's home range size of 1600 ha in Issa Valley in western Tanzania was considerably larger than our study group's home range and the ranges of all other groups reported (McLester et al., 2019).

The longer time scale of the current study resulted in a larger range to encompass all movements from multiple years. As most comparative studies evaluated home range on shorter time scales, the 2016 seasonal range sizes may be more accurate for comparison. Certainly, the seasonal ranges were very similar to the *C. ascanius* range from the Kibale National Park and the *C. mitis* range from Kakamega (Cords, 1986; McLester et al., 2019). A likely factor driving differing range sizes between the hybrid group and parental groups is habitat differences (McLester, 2019). Though all sites include tropical forest (Cords, 1986; Kaplin, 2001; Struhsaker, 1980), GNP's steep valleys allow for diverse terrain shifts from grassland to woodland to forest (Collins & McGrew, 1988).

Additionally, the number of individuals in the reported groups differed, with our hybrid study group having the highest number of individuals compared to the *C. ascanuis* or *C. mitis* groups in the Kibale National Park, Kakamega Forest Reserve, or Nyungwe National Park (Cords, 1986; Kaplin, 2001; McLester et al., 2019). Differences in size between intraspecies groups are common and are likely linked to variances in food availability (McLester et al., 2019). This correlation may indicate that GNP is rich in food resources due to its ability to maintain a group larger than those seen in either parental species without excessive increase in home range size, such as the home range of the Issa Valley group. Hybridization in our study group may also have an impact on range size. Brown (2013) found interspecies interactions a variable in range size due to intergroup conflict. A large group comprised of two species and their hybrids may face less disruption in ranging patterns due to reduced competition, although more research is needed to investigate the impact of hybridization on range size.

Future studies will continue tracking the movement of the hybrid study group and monitoring for shifts in the ranging pattern. Additional data on neighboring groups' ranges would allow for understanding of inter-group relationships, motivations behind range usage and constraints on home range size. One important direction for future work lies in studying the diet of the hybrid study group. Comparing home range data to spatial data on food items would provide information on seasonal patterns of movement. By understanding the distribution and abundance of the foliage and fruits that make up the flora portions of *C. ascanius* and *C. mitis'* diets, we can gain further knowledge on the important factors for home range size, movement, and survival (Boinski, 1987; Wada & Ichiki, 1980).

A technical limitation of our study was that MCPs give an estimate for the maximum home range with a tendency to overestimate total size (Ostro et al., 1999) and thus do not give information regarding core ranges or intra-range movement throughout seasons. We compensated for this by using hot spot analysis which gives a more precise visual of group movement and location. Additionally, it is important to note the periods of the day where most waypoints were recorded (7:00 - 12:00 and 16:00 - 18:00), and the data were not representative of all daylight hours.

Home range studies are important for the evaluation of animal behavior and ecosystem structure, as well as for aid in the conservation of habitats (Li et al., 2000). By studying home range behavior from multiple study groups from different populations, we can understand what factors an animal or group relies on for survival and can monitor for an increase or decrease in the health of their habitat.

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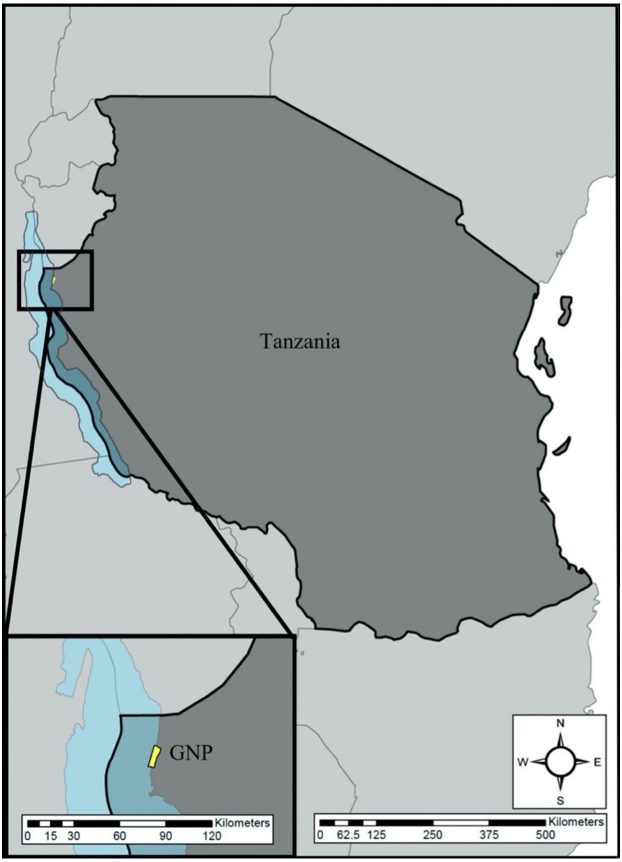
Figure 1

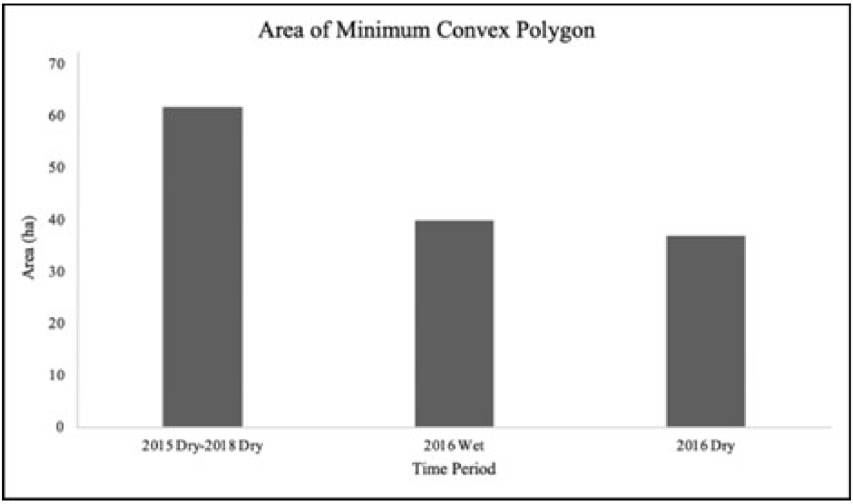
Map of Tanzania



Note. Location of Gombe National Park (GNP) in western Tanzania alongside Lake Tanganyika.

Figure 2

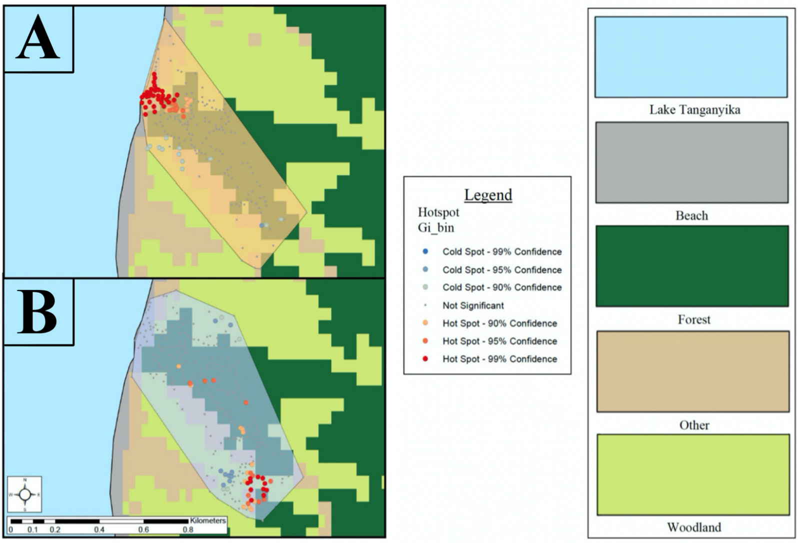
Area of Minimum Convex Polygon



Note. Area of total home range throughout the study (Start of dry season 2015-end of dry season 2018) and range in 2016 wet and dry seasons.

Figure 3

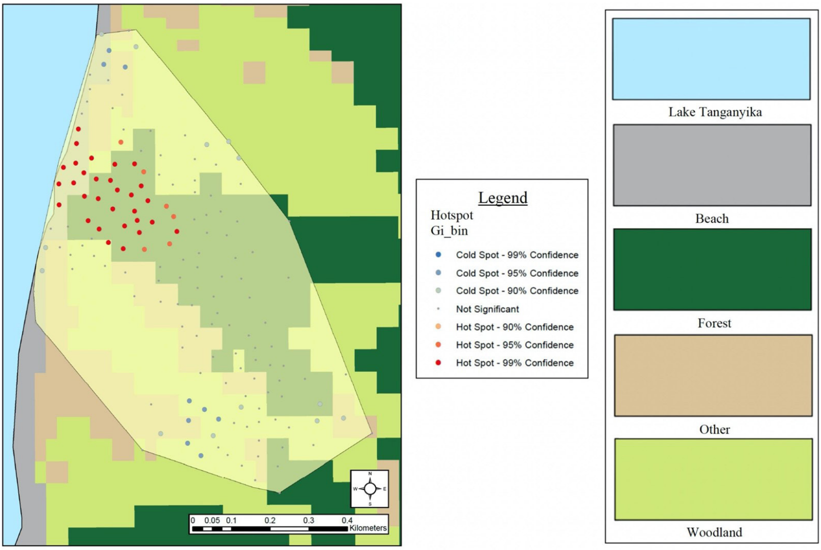
Minimum Convex Polygons of Seasonal Ranges



Note. Minimum Convex Polygons of home range use during 2016 dry (A) and wet (B) seasons combined with results from the hot spot analysis (a cold spot indicates an area that is significantly underused, whereas a hot spot indicates an area that is significantly frequented).

Figure 4

Minimum Convex Polygon of Total Range



Note. Minimum Convex Polygon of total range used throughout the study combined with results from the hot spot analysis (a cold spot indicates an area that is significantly underused, whereas a hot spot indicates an area that is significantly frequented).

Table 1
Total number of waypoints recorded during the study: June 2015-September 2018

Month	2015	2016	2017	2018
Jan		87	92	53
Feb		55	61	26
Mar		155	82	41
Apr		110	136	36
May		124	112	96
Jun	124	109	133	102
Jul	104	106	152	129
Aug	119	156	172	137
Sep	140	98	140	225
Oct	70	104	151	
Nov	46	111	80	
Dec	54	102	25	

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