Use of Space by Black-and-Gold Howler Monkeys (*Alouatta caraya*) in an Urban Environment in Paraguay.

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Research Article

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Abstract

As urbanisation continues to reduce the available habitat for wildlife some species, such as the black-and-gold howler monkey (*Alouatta caraya*) in Pilar, southwest Paraguay, are making their homes in anthropogenic environments. Understanding an animal's home range is an important first step to understanding its ecological needs, an essential requirement for robust conservation plans. In this study we determined the home ranges and core areas of five groups of urban dwelling *A. caraya* using Minimum Convex Polygon (MCP) and Kernel Density Estimation (KDE) Analysis. We used a Spearman's Correlation to explore the relationship between home range size and group size. All five groups had home ranges of less than 10 ha and used core areas of less than 1ha. Group size had no significant relationship to home range size. We provide the first estimates of home range for *A. caraya* in an urban environment in Paraguay. Though the home ranges of the urban *A. caraya* in Pilar, Paraguay fall at the smaller end of the spectrum of range sizes in *Alouatta* they are not abnormal for a species in this genus.

Introduction

Urbanization, the process by which human populations move from rural to urban areas and the subsequent expansion of urban infrastructures (Berry 2008), has been accelerating in recent. Today it is estimated that more than half of the world's population live in an urban environment (Ritchie and Rosen 2018; Corrêa et al. 2018). Urbanization can result in the alteration, fragmentation or destruction of natural habitats (Pauchard et al. 2006; Liu et al. 2016; Šálek et al. 2015). Today 60% of non-human primates (hereafter primates) are threatened with extinction, making it increasingly important to understand the wide-ranging impacts of anthropogenic expansion on the ecology of wild primate populations (Estrada et al. 2017). Urban expansion can negatively impact the survival of primate populations directly and indirectly by decreasing available habitat size and quality (Estrada 2013; Heil et al. 2007; Fernandez-Juricic 2001; Spellerberg 1998), resulting in either dependence on a rapidly disappearing natural habitat or adapting to life in an anthropogenic environment (Mittermeier and Cheney 1987; Janzen 1983). Some primate species appear to have been able to adapt to highly anthropogenically altered areas (Jaman and Huffman 2013; Chaves and Bicca-Marques 2016; Felman et al. 2017; Kane and Smith 2020). Understanding the ecological needs of primates living in urban environments is essential if successful long-term management and conservation (Bicca-Marques et al. 2020).

One important characteristic of a species ecology that the urban environment has the potential to alter significantly is the home range. An animal's home range is considered to be the area that an individual uses during its normal activities (Burt 1943). In natural environments home range size is influenced by many ecological and environmental factors including body size (McNab 1963), food abundance (Hanya et al. 2006; López-Bao et al. 2010), climate and seasonal changes (Kuo and Lee 2012; Osborn 2003; Rautenstrauch and Krausman 1989), mating opportunities (Sugiyama et al. 1965), competition and territoriality (Garneau et al. 2008; Grant et al. 1992) and predation (Hankerson and Dietz 2014). Anthropogenic obstacles present in urban environments can change primate home range, dictating daily path lengths or preventing effective dispersal (Duarte et al. 2011)

The urban environment can impact home range sizes in several ways. Urbanisation can lead to a reduction in availability of natural food resources, while anthropogenic food sources increase, affecting primate diet, activity budgets and ranging patterns (Altmann and Muruthi 1988; Bicca-Marques 2017; Sengupta and Radhakrishna 2018; Thatcher et al. 2018; Back et al. 2019). Urban-dwelling rhesus macaques (*Macaca mulatta*) have significantly smaller home range sizes than their rural counterparts possibly because the urban group was provisioned with high quality food and did not need to cover large distances to satisfy their metabolic requirements (Jaman and Huffman 2013). Long-tailed macaques (*Macaca fascicularis*) in Singapore and Barbary macaques (*Macaca sylvanus*) in Gibraltar that have access to anthropogenic food sources had reduced home range sizes compared with those that did not have access to human provisioning (Klegarth et al. 2017).

The habitat fragmentation caused by the construction of roads, buildings or open gardens can present unique spatial use challenges to wild primates (Stevenson et al. 2015). To move between fragments, arboreal species may have to descend to the ground or incorporate anthropogenic structures such as powerlines into their travel paths (Corrêa et al. 2018; Lokschin 2007). Descending to the ground to travel or using electric cables incurs risks such as electrocutions, traffic accidents or attacks by domestic dogs (*Canis familiaris*) and cats

(*Felis catus*) (Boinski et al. 1998; Loskchin et al. 2006; Ram et al. 2015; Katsis et al. 2018; Balogh et al. 2011) that could impact a species home range through limiting the ability to travel.

The howler monkeys (*Alouatta*) are a widespread genus found from southern Mexico to northern Argentina (Estrada 2015). They can occupy a variety of forest types at varying elevations and show a high degree of behavioural and ecological plasticity, including being able to live in urban areas, tolerating a certain degree of disturbance (Di Fiore 2007; Estrada 2015; Stevenson et al. 2015). Being tolerant to degraded and fragmented habitat allowed them to persist, at least in the short term, in areas of increased urbanisation (Bicca-Marques 2003; Di Fiore 2007; Estrada 2015). The black-and-gold howler monkey (*A. caraya*) is one of the most southernly distributed of the genus, being found throughout Paraguay, Brazil, Bolivia, Argentina, and potentially northwestern Uruguay (Villalba et al. 1995; Jardim et al. 2020). A frugivorous-folivore, this species has been observed to be very adaptable to different habitat types with varying levels of disturbance (Stavis et al. 2019). The aim of this study was to determine the home ranges of five groups of black-and-gold howler monkeys living in the urban centre of Pilar, Néembucú, Paraguay.

Methods

The authors declare no conflicts of interest. This research was approved by the Ministerio del Ambiente y Desarrollo (MADES) and Fundación Para La Tierra. Our research complied with all local laws. We collected data non-invasively and complied with the American Society of Primatologists Code of Best Practices for Field Primatology 2014.

Study Site

We collected data from April to September 2018 in the city of Pilar (26° 52' 04" S 58° 17' 46"W), Ñeembucú Department in southwest Paraguay. Pilar has a population of around 33,000 people. In this area of Paraguay this time period covers the last few weeks of Autumn, the full winter season (May-July) and most of Spring (August and September) (high, low and mean monthly temperatures Table 1). Our data were collected mainly during colder and drier months when howler monkey home ranges are typically smaller due to their energy minimising strategy and for a limited time of five and a half months. Figure 1 shows the location of Pilar and the locations of monkey groups throughout the city (Alesci et al. in press).

Study Subjects

Our study focused on five groups of *A. caraya* living inside the city of Pilar (Table 2).

The population of howler monkeys living inside Pilar consists of between 69-100 individuals living in 15 groups (Para La Tierra unpublished data). Interviews with local people have indicated the population has been residing in the city for over 50 years (Alesci et al. under consideration; Alesci 2018). Immigrations and emigrations between groups have been observed during the four year period that scientists from Fundación Para La Tierra have been monitoring the urban population (Para La Tierra unpublished data).

Data collection

Our team collected data from the 16th April 2018 – 27th September 2018 between 5:45am-10:45am and between 13:45pm-17:45pm six days per week throughout the study period. We used focal animal sampling (Altmann 1974) with each individual during a 45-minute period. At the start of every focal, we recorded the location of each focal individual using a handheld Garmin 64s GPS unit. Our data were collated using the program Garmin BaseCamp Version 4.8.7.

Data analysis

The data were analysed using Quantum GIS 3.14 (QGIS 2020). Kernel density estimation (KDE) analysis (50% and 95%) were conducted using the Heatmap plugin while minimum convex polygon (MCP) analysis was conducted using the Polygonize and Convex-Hull tools. Once a minimum-convex polygon was created for a group, it was manually edited to avoid overestimating home range size editing out roads, open fields, rivers and areas of non-use (such as car parks) that had been confirmed during observations. A 50-metre radius from all data point was used as the furthest estimate of home range.

The percentage of each groups home range that contained trees, and the percentage covered by non-arboreal structures (such as buildings or roads) was calculated using QGIS.

Results

For all groups the MCP analysis resulted in the largest home range estimates, between 1.62 ha. and 7.86ha (Table 3; Figures 2-6). The core areas (50% KDE) for all five groups were less than 1 hectare (Table 3; Figures 2-6).

Our study found that both MCP and KDE analysis resulted in small home range size (all less than 10 ha) for all five of the urban howler monkey groups (Figure 7). The 50% KDE demonstrated that all groups had a core area within their home range of less than 1 ha.

The percentage coverage of trees in the home ranges of the study groups varied from 60.6%–82.3% of the range (Table 4).

Discussion

All of the home ranges for these urban study groups were found to be less than 10 ha. Home range sizes are extremely variable across the genus *Alouatta* and though these ranges are at the lower end of the home range size spectrum, they are not unusual for a species in this genus (Fortes et al. 2015). The ability of these monkeys to survive and reproduce in such small areas may be a contributing factor in their persistence in urban centre of Pilar (Corrêa et al. 2018; Alesci et al. in press; Para La Tierra unpublished data). However, this by no means to say that the situation of *A. caraya* in this environment is ideal or even sustainable over a longer term as the city continues to develop. One potential reason that the Pilar monkeys are able to thrive in such limited spaces may be due to the presence of supplemental food resources – either direct provisioning by humans (observed frequently with the Police Group) or by the abundance of mango and avocado trees providing a lot of high-quality food (Dunn J et al. 2010; Chaves and Bicca-Marques 2016; Back and Bicca-Marques 2019). If these resources were to become unavailable in future, potentially due to anthropogenic modification, it is possible that these groups could struggle in these environments or be forced to change their behaviour (Berry 2008).

All our study groups home ranges included a matrix of roads, buildings and powerlines, several of the groups were observed to include these elements into their daily paths as well as to descend to the ground to move between fragmented sections of their range (Para La Tierra, unpublished data). This behavioural flexibility may have contributed to their persistence in the novel environment. However, studies of the same groups in Pilar have demonstrated that the monkeys are potentially not aware of the risks posed by utilising anthropogenic structures (Wellian and Smith 2021). Other studies have also highlighted the risks to howler monkeys when employing powerlines as crossings or coming to ground to feed (Corrêa et al. 2018; Teixeira et al. 2013).

A potential issue for the long-term survival of Pilar's urban howler monkey population is the disconnected nature of their ranges. Smaller and more disconnected habitat fragments have been demonstrated to make effective dispersal harder for howler monkeys but this has not been well explored in an urban environment (Arroyo-Rodríguez and Dias 2010). In a natural living population of brown howler monkeys (*Alouatta guariba clamitans*) in a fragmented, isolated habitat, group size and population density were large as dispersal was difficult and immigration rarely successful (Fortes and Bicca-Marques 2008). These difficulties led to an increase in inbreeding, a lack of genetic diversity and gave rise to the expression of rare alleles which gave some members of the group an abnormally lightened pelage (Fortes and Bicca-Marques 2008). While the groups in the city do not appear to be completely isolated from one another (both emigrations and immigrations have been observed over the previous five years (Para La Tierra, unpublished data)) there is no guarantee that this situation will not change. In particular, Pilar is currently undergoing major construction

work to build flood defences, that began in 2020, and this as cut off parts of some groups (Factory and Trio) normal routes (Smith Pers. Obs). This study includes only five of more than fifteen groups (Figure 1) it is important to consider that individual persistence can hide issues at a population level (Bicca Marques et al. 2019). One solution that might allow for an expansion of home ranges or dispersal safely, is the construction of rope bridges. Rope bridges across roads may help to limit death due to collisions with traffic and provide an alternative to powerlines (Teixeira et al. 2013). The insulation of power cables could also mitigate some of the deaths of monkeys that use them as crossings, although encouraging use of rope bridges in these areas simultaneously should be considered (Lokschin et al. 2007; Teixeira et al. 2013). The planting of trees to produce a “live fence” or natural canopy bridge has shown to be beneficial and increased home range size for Mexican howler monkeys (*Alouatta palliata mexicana*) living in edge and fragmented habitats (Asensio et al. 2009). It has been found that primates seem to prefer natural canopy bridges to artificial crossings (Lindshield 2016). A simple method of preventing monkeys from utilising powerlines is to clip the trees and hedges that provide access to them (Lindshield 2016), however doing so without providing another means of crossing may force monkeys to use terrestrial means to connect to part of their range, increasing the risk of collision by car or dog attack.

In order to fully understand the what is constraining the home range resource distribution and availability must be understood at a fine scale (Fortes et al. 2015). While this was beyond the scope of this study long-term monitoring of food availability, tree cover and level of human presence will provide insight into if and how home range size of these urban monkeys changes with changing conditions. Previous study have indicated that though howler monkeys can survive in a landscape matrix they are more commonly found in areas with higher canopy and closer to a forest fragment (Pozo-Montuy and Serio-Silva, 2011). In Pilar howler monkeys are not found in areas with no trees at all (Para La Tierra, unpublished data) but further study is required to fully understand what are the most important resources driving the presence of monkeys in the city.

As the human population of Pilar grows it is likely that the city will continue to expand into the surrounding Ñeembucú Wetland Complex, further reducing available habitat. At present it is still unclear to what degree can they adjust to anthropogenic disturbance before their genetic diversity and chances of long-term survival is negatively influenced. By understanding the behaviour and ecology of those monkeys that have currently adapted to life in an anthropogenic environment, we can begin to develop long-term conservation strategies to help safeguard the survival of these unique primates into the future.

Declarations

Funding: The authors did not receive funding for this submitted work.

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Ethics approval: This research was approved by the Ministerio del Ambiente y Desarrollo (MADEs) and Fundación Para La Tierra. The research complied with all local laws. All of our data was collected in a non-invasive manner and complied with the American Society of Primatologists Code of Best Practices for Field Primatology 2014.

Consent for publication: All authors consent to the submission of this work.

Availability of data and material: Data for this study is available at <https://github.com/rebeccasmithPLT2020/Pilar-Howler-Monkeys.git>

Authors' contributions: Xander Duffy – Data analysis, writing; Jake Wellian – Project design, data collection, writing; Rebecca L. Smith – Project design, data collection, data analysis, writing.

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Tables

Table 1: High, Low and Mean Temperatures and Mean Precipitation during the Study Period (www.worldweatheronline.com).

	April	May	June	July	August	September
High °C	33	27	21	20	23	28
Low °C	21	16	11	11	10	17
Mean °C	28	22	16	17	18	24
Precipitation (mm)	14.47	200.10	55.06	30.1	50	106.71

Table 2: Demographics of study groups during study period

Group name	Adult male	Adult female	Subadult male	Subadult female	Juvenile male	Juvenile female	Infant male	Infant Female	Total
Factory	1	2	1				1	1	6
Police	1	2	1	1	1	2-3*	1	1	10-11
New	1	1			1	1*	1		4-5
Crucecita	1	1			1				3
Trio	1	1			1*		1		3-4

* Died during the study period.

Table 3: Home range sizes in hectares for each of the study groups calculated using MCP, 50% KDE and 95% KDE analysis in QGIS.

Group name	MCP Home Range (ha.)	50% KDE (ha.)	95% KDE (ha.)	Figure
Factory	7.86	0.51	3.07	2
Police	1.62	0.09	1.01	3
New	1.89	0.09	0.91	4
Crucecita	6.39	0.44	2.62	5
Trio	2.78	0.03	1.00	6

Table 4: Percentage tree coverage in the home range of each study group.

Group	Trees %	Non-arboreal %
Factory	60.6	39.4
Police	82.3	17.3
Crucesita	67.4	32.6
New Group	75.5	24.5
Trio	64.8	35.2

Figures

Figure 1

Map of location of Pilar, Paraguay and the monkey groups throughout the city.

Figure 2

KDE (50% & 90%) and MCP home range maps of Factory Group Background from GoogleEarth 2020.

Figure 3

KDE (50% & 90%) and MCP home range maps of Police Group Background from GoogleEarth 2020.

Figure 4

KDE (50% & 90%) and MCP home range maps of New Group Background from GoogleEarth 2020.

Figure 5

KDE (50% & 90%) and MCP home range maps of Crucecita Group Background from GoogleEarth 2020.

Figure 6

KDE (50% & 90%) and MCP home range maps of Trio Group. Background from GoogleEarth 2020.

Figure 7

KDE maps of the locations of the five groups in Pilar. Background from GoogleEarth 2020.