

Risk awareness of black-and-gold howler monkeys living in an urban environment in south-west Paraguay

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Abstract

As urbanisation increases, wild primates are exposed to urban environments which come with a distinct and often novel set of risks. Urban habitats can form a matrix of forest fragments and anthropogenic structures, including buildings, electric cables and roads, which can limit movement and force species to live in hazardous areas. We studied five groups of urban black and gold howler monkey (*Alouatta caraya*) in Pilar, Paraguay, to investigate whether the monkeys are aware of anthropogenic risks based on their patterns of self-scratching behaviour, an indicator of stress, and how they used the space available to them. Using a Risk Index created for the study, we ranked the level of risk attributed to different zones of their home range, awarding each zone with a hazard score. Using Quantum GIS and kernel density estimation, we determined the relationship between habitat use and hazard score. Using a Spearman's rank correlation, we found nonsignificant relationships between the hazard score and self-scratching behaviour for four groups, suggesting a lack of awareness. However, there was a significant negative relationship between the hazard score and home range use for four groups, indicating that they spent more time in areas with lower levels of anthropogenic risk.

Key words: *Alouatta caraya*, stress, self-directed behaviour, urban primates, Paraguay

Introduction

More than half of the world's primate species are facing extinction and the loss and fragmentation of their habitats is one of their greatest threats (Estrada et al. 2017). Urbanization is the conversion of land for urban use and is a large contributor to deforestation across the globe (Scheun et al. 2015). Primate species that are unable to adapt to anthropogenic environments risk extirpation and population declines in areas that are rapidly losing their natural spaces to increasing urbanisation (Moore et al. 2010; Estrada et al. 2017; Sinha and Vijaykrishnan 2017). A primate's ability to assess social and environmental

risks is important for determining which locations are the safest and most suitable for survival (Moore et al. 2010; Teixeira et al. 2015; Nowak et al. 2017; Willems and Hill 2009). As human populations increase more primates are being exposed to urban environments, which inherently come with a novel set of risks (Riley et al. 2015; McLennan et al. 2017). Some urban habitats consist of forest remnants, corridors or small wooded areas amidst a matrix of anthropogenic structures, such as buildings and electric cables, limiting animals' movements and making survival in these urbanised areas more challenging (Gordo et al. 2013; Sol et al. 2013).

Some primate species have successfully adapted to urban environments and anthropogenic disturbances (Laundré et al. 2010; Moore et al. 2010; Teixeira et al. 2015). However, spatial conflict between humans and nonhuman primates remains a problem for urban primate populations (Cormier 2002; Sinha and Vijayakrishnan 2017). When food availability is low, urban primates can be more willing to take chances in areas of high risk, raiding crops, houses, shops and garbage heaps (Hockings 2016; Nowak et al. 2017). Human residents can be 'drivers' of conflict and can intensify the problem by injuring primates (Hockings 2016). Even when there is peaceful coexistence, primates can still be at risk from electrocution, road collisions and domestic dog attacks. In some cases, urban primates have been shown to experience elevated stress levels and shorter life expectancies compared to forest-living primates (Teixeira et al. 2007; Moore et al. 2010).

Wild primates' ability to perceive and respond to risks is thought to be dependent on intelligence (Humphrey 1976; Anderson 1982; Arroyo-Rodríguez et al. 2013). Spatial differences in perception of risk create a 'landscape of fear' where a species adapts its home range to minimize exposure to threats and maximize its energy gains (Brown et al. 1999, 2004; Nowak et al. 2016; Willems and Hill 2009). The 'risk-disturbance hypothesis' suggests that the effects of anthropogenic hazards on a species' habitat use and decision-making, parallel that of natural predation risk (Nowak et al. 2016). All primates possess a similar basic cognitive ability to perceive the physical world of objects within a given space (Seed and Tomasello 1999). However, some objects such as electric cables pose a serious threat to primates who may not perceive them as dangerous (Ram et al. 2015; Katsis et al. 2018). A lack of understanding of urban hazards could pose a threat to long-term survival (Coleman and Hill 2014; Coleman and Pierre 2014).

Howler monkeys (Genus *Alouatta*) are a genus of arboreal Central and South American primates which have, in some areas, successfully transitioned to the urban environment (Printes 1999; Lokschin et al. 2007; Kane and Smith 2020). Their highly folivorous diet makes them more tolerant of fragmented forests where other species cannot thrive (Gilbert 2003; Garber et al. 2006; Arroyo-Rodríguez and Dias 2010). Black-and-gold (or Paraguayan) howler monkeys (*Alouatta caraya*) are found throughout Paraguay, Argentina, Bolivia, Brazil and possibly Uruguay (Villalba et al. 1995). The city of Pilar is home to a medium-sized population (~15 groups, Para La Tierra, unpublished data) of these monkeys who are often found in people's gardens or in trees in the streets. Black-and-gold howler monkeys, like many other primates that exploit the urban environment, are vulnerable to electrocution, endoparasites and persecution by humans. Their slow terrestrial mobility can make them vulnerable to domestic dog attacks and vehicle collisions (Mandujano et al. 2004).

Living in such urban environments can cause increased stress (Scheun et al. 2015; Santos et al. 2017; Sinha and Vijayakrishnan 2017). Self-scratching is one of the most commonly reported self-directed behaviours in non-human primates and has been shown to occur more frequently in stressful situations (Maestripieri et al. 1992; Manson and Perry 2000). This leads to the hypothesis that their purpose is to alleviate stress either cognitively by focusing the animal's attention away from the negative stimuli or physiologically.

The study investigates urban black-and-gold howler monkeys' awareness of the anthropogenic risks in their environment using self-scratching as a behavioural indicator of anxiety and as a proxy for their awareness of the danger. Using kernel

density estimation, this study also aims to evaluate whether the howler monkeys adjust use of their home range to avoid higher risk zones.

Methods

The authors declare no conflicts of interest. Permission for this research was provided by the Ministerio del Ambiente y Desarrollo (MADES) and Fundación Para La Tierra. The research complied with all local laws. All data were collected in a non-invasive manner and complied with the American Primatological Society Best Practices.

Study area

The study took place from May to September 2018 in the city of Pilar, Ñeembucú, in south-west Paraguay (26° 52' 04" S 58° 17' 46" W). With a population of around 40 000 people, Pilar is the capital of the Ñeembucú department. The Ñeembucú Wetland Complex surrounds the city, which is situated along the Rio Paraguay and Arroyo Ñeembucú (Contreras et al. 2007). The mean annual temperature is 22.1°C and the annual average precipitation is 1413 mm, with the driest months typically occurring between June and August (Smith 2006).

Study subjects

We studied five groups of black-and-gold howler monkeys living within the city (demographics: Table 1). All five groups had a one-male, multi-female or one-male, one-female social structure, with group sizes ranging from three to eleven individuals.

Data collection

Data were collected from 5:45 to 10:45 and from 13:45 to 17:45 six days per week throughout the study period, using a combination of focal animal sampling and all-occurrence sampling (Altmann 1974). We recorded the number of self-scratches by an individual during a 45-minute period. If the individual moved out of sight for more than 10 minutes, we disregarded the sample. Five hundred seventy-six focal samples, equally distributed between adult and subadult group members [juveniles were not included as they are unlikely to influence group movements (Fernández et al. 2013)] were recorded. At the start of every focal observation, we recorded the location of the individual using a Garmin 64 s GPS unit.

Risk Index, home range mapping and hazard ranking

For each hazard type, we developed a Risk Index, estimating how potentially dangerous a specific area might be on a scale of 1–5: 1—few unnatural dangers, 5—high likelihood of death (Table 2). We developed a hazard score from the Risk Index to quantify the risk associated with an area of the home range. We used Quantum GIS (QGIS) to map out the different hazards within a 20-m radius around each GPS point. To calculate the hazard score of each GPS point, we summed the risk indices of all the hazards within the 20-m radius, and then divided this figure by the number of hazards for each focal. In total, we calculated and mapped 576 hazard scores.

Data analysis

For each group, we performed Spearman rank correlation (r_s) to determine the relationship between the risk index and the

Table 1: Demographic structure of study groups

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 ^a	1	1	10–11
New	1	1	–	–	1	1 ^a	1	–	4–5
Crucesita	1	1	–	–	1	–	–	–	3
Trio	1	1	–	–	1 ^a	–	1	–	3–4

^aDeath during the study period.

Table 2: Hazards and Risk Index

Hazard	Severity	Risk Index
Forest	Provides necessary nutrition, shelter, and the highest- level safety.	1
Barbed wire	Used for travelling when trees are sparse or for entering gardens. Possibility of minor cuts and scratches.	2
Dirt road	Common along the city's outskirts, they are narrow with low traffic density.	2
Normal road	Two-way roads with sidewalks and have medium traffic density. Contact with a vehicle might be lethal.	3
Residential area	Suitable habitat often overlaps in gardens. Residents and domestic dogs pose a threat to howler monkeys.	3
Industrial area	Cotton factory has higher amounts of air, noise and water pollution, which could have potential health implications for howler monkeys. Close contact with workers could pose a threat.	3
Open fields	Howler monkeys are slower during terrestrial travel, making them vulnerable to domestic dogs.	4
Main road	Wide two-way roads, with multiple lanes, and high traffic density. Contact with vehicles is lethal.	4
Electric cables	Used for travelling when trees are sparse. The most frequent cause of death for Pilar's howler monkey population. Use of cables for travel can cause burns, haemorrhage, cardiac arrest, or death (Lokschin et al. 2007)	5

scratch rate per minute (RPM) and the relationship between the risk index and the range use, calculated as:

$$r_s = 1 - \frac{6 \sum d^2}{(n^3 - n)}$$

where n is the number of paired observations and d is the difference between the ranking of each item. The closer the Spearman rank correlation value is to 0, the weaker the relationship.

We calculated home range with QGIS version 2.18 using a 20 m quartic biweight fixed kernel density estimation heatmap (Worton 1989) and we analysed all our data using Microsoft Excel 2016.

Results

Area of use

During the study period, the groups used areas that varied in size from 0.79 to 2.30 hectares, slightly smaller than their total home range (Duffy et al. In review). All groups lived in areas where trees occurred in 60.6%–82.3% of the range. Between 17.3% and 39.4% of the home range was consists of a matrix of residential, industrial and open fields spaces.

Hazard score vs scratching RPM

The Spearman rank correlation (Table 3) indicates that there was a nonsignificant relationship between the hazard score and scratching rate for all groups, except the Police group.

Table 3: Spearman's rank correlation between the hazard score and the scratch RPM

Group name	Spearman r_s	Degrees of freedom (df)	P
Factory	–0.06	118	0.50
Police	0.20	178	0.01
New	0.12	106	0.20
Crucesita	0.03	107	0.77
Trio	0.08	58	0.53

Table 4: Spearman's rank correlation between the hazard score and the range use

Group name	Spearman r_s	Degrees of freedom (df)	P
Factory	–0.29	118	<0.01
Police	–0.76	178	<0.01
New	–0.29	106	<0.01
Crucesita	–0.15	107	0.11
Trio	–0.61	58	<0.01

Hazard score vs range use

The Spearman rank correlation (Table 4) indicated that there was a significant negative relationship between the hazard score and home range use for all groups, except the Crucesita group. Hazard scores and use of home range for each of the five groups are shown in Figures 1–5.

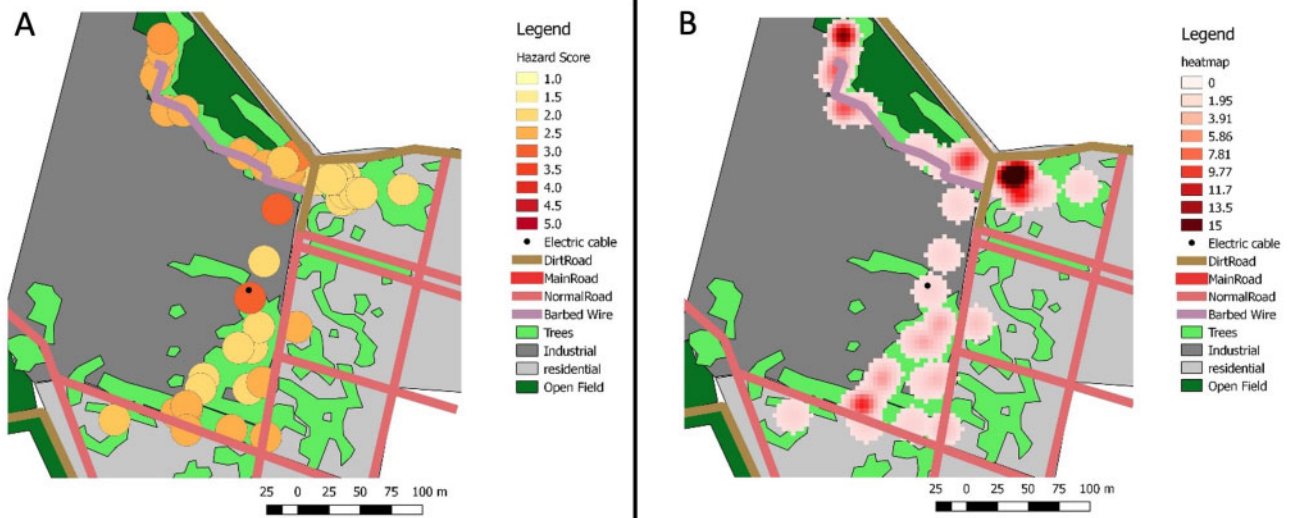


Figure 1: (A) The Factory group's home range showing the hazard scores. (B) The kernel density estimation heatmap of the spatial use of the Factory group during the study period.

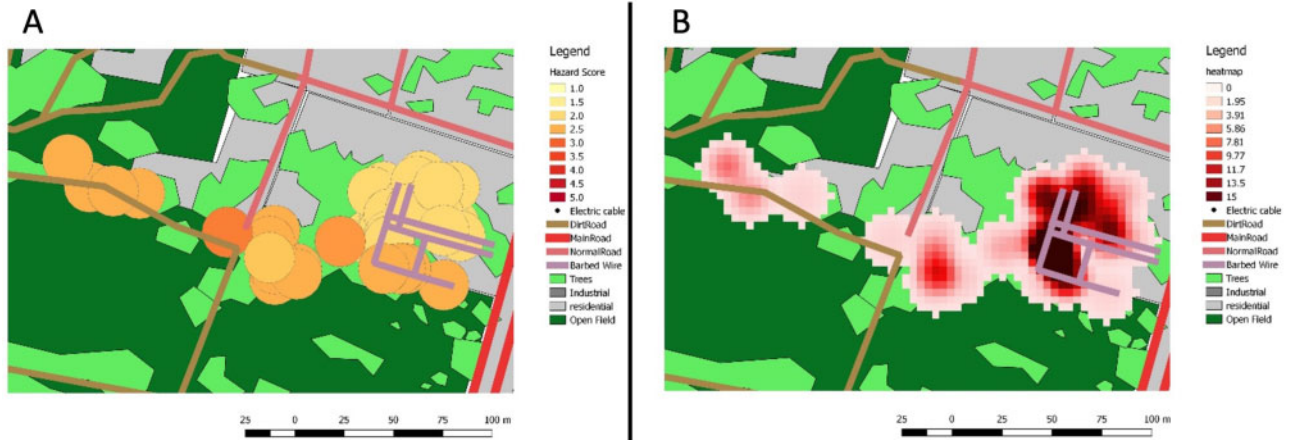


Figure 2: (A) The Police group's home range showing the hazard scores. (B) The kernel density estimation heatmap of the spatial use of the Police group during the study period.

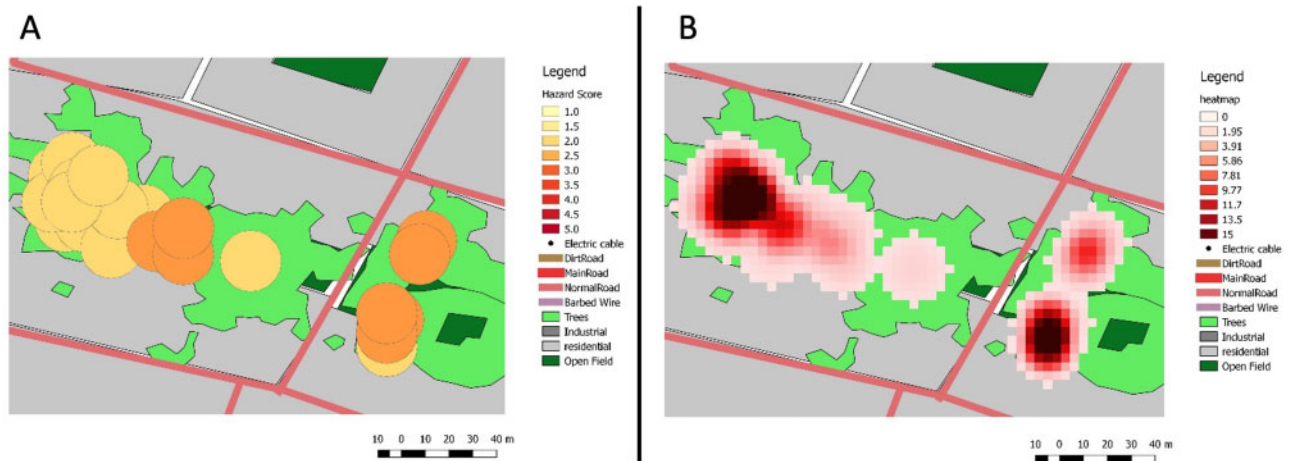


Figure 3: (A) The New group's home range showing the hazard scores. (B) The kernel density estimation heatmap of the spatial use of the New group during the study period.

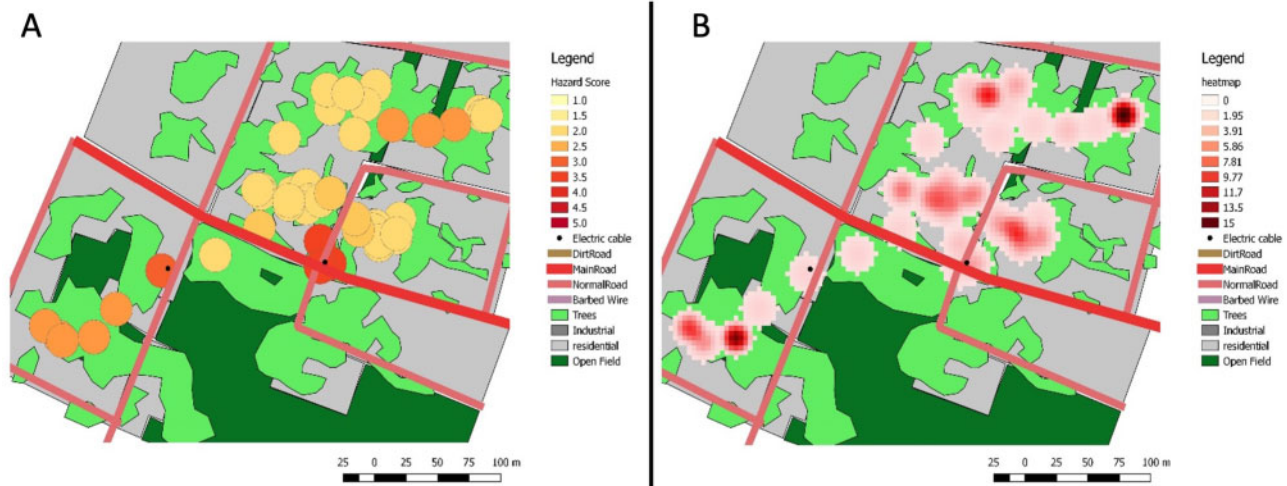


Figure 4: (A) The Crucecita group's home range showing the hazard scores. (B) The kernel density estimation heatmap of the spatial use of the Crucecita group during the study period.

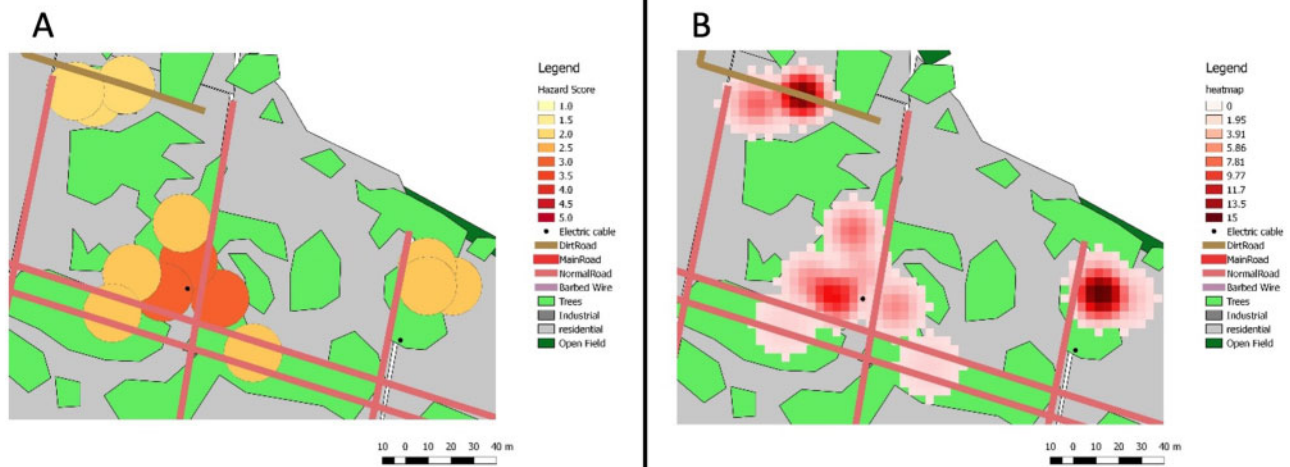


Figure 5: (A) The Trio group's home range showing the hazard scores. (B) The kernel density estimation heatmap of the spatial use of the Trio group during the study period.

Discussion

The results provide evidence that the presence of urban hazards does not cause an increase in self-scratching in the black-and-gold howler monkeys of Pilar, suggesting a lack of awareness of the potential risks. However, when assessing the relationship between hazard score and home range use, it was found that most groups spent less time in areas with fewer hazards, suggesting these groups were potentially more aware of the risks associated with certain zones of their home range.

No correlation was found between frequency of self-scratching and hazard score, except for the Police group, indicating no changes in self-scratching in relation to hazardous areas and a potential lack of awareness. The absence of relationship potentially suggests that other stressors, such as maternal anxiety (Maestriperi 1993a, b), proximity to dominant members (Castles et al. 1999; Kutsukake 2003; Smith 2012), and separation anxiety (Polizzi di Sorrentino et al. 2012), may have influenced

self-scratching behaviour. Self-scratching has previously been observed as a response to ectoparasite bites and movements (Duboscq et al. 2016). In addition, it is possible that increases in self-directed behaviours are a response to social stressors rather than environmental stressors.

Self-directed behaviours as an indicator of stress have not been well studied in platyrrhine primates (Manson and Perry 2000) and, to the best of our knowledge, particularly not in the *Alouatta* genus. While sampling for glucocorticoids is potentially a more reliable gauge for measuring stress in primates (Balestri et al. 2014; Chaves et al. 2019), it was not possible in this study due to financial, logistic and equipment limitations. In addition, this study aimed to develop a methodology that can be replicated by scientists without access to hormone analysis equipment or NGOs that do not have large research budgets. Future studies should, if possible, confirm the effectiveness of using self-directed behaviours as a proxy for increased stress with hormone analysis.

A significant negative relationship between the hazard score and the range use was observed, indicating individuals spent more time in less hazardous zones. Habitat choice is the result of trade-off between potential predation risk and resource richness (Gilliam and Fraser 1987). The densest areas of the studied groups' home range could provide the greatest level of security and the resources, and therefore influence the movement and use of the home range. Folivores need long periods of digestion to break down cellulose and as a result howler monkeys spend large portions of their day resting and digesting (Pavelka and Knopff 2004). This supports the negative nonsignificant relationship between hazard score and home range use, as resting sites were in the 'safest zones'. More hazardous areas were still used, suggesting the resources provided in these areas outweigh the potential costs. White-faced capuchins have been observed demonstrating similar behaviours, heavily utilising the more hazardous peripheral areas of their home ranges to access riper fruits (Tórez-Herrera et al. 2020). As howler monkeys are primarily folivorous and leaves are a widespread food resource, it is possible that food distribution has less impact than it would be on a more frugivorous species such as capuchin monkeys, though further study of the dietary diversity of the urban howler monkeys in Pilar is required to fully address this question.

In the urban environment, electric cables pose one of greatest threats to primates causing burns, haemorrhage, cardiac arrest, and death (Lokschin et al. 2007). While some of the cables in Pilar are insulated, the cables surrounding transformers are not and deaths from electric shocks are common in Pilar, mostly juveniles or subadults (Para La Tierra, unpublished data). Younger individuals were observed resting on and biting cables, suggesting a lack of social learning from adult group members to avoid hazards, such as cables (Custance et al. 2002). It is possible that rather than not being aware of the risks of the cables the monkeys are simply unable to distinguish between 'safe' and 'dangerous' cables and that individual learning is not possible as individual who touch the uninsulated areas do not survive.

The study groups typically avoided human interaction although some individuals did interact with younger children and adults who fed them. Human-primate conflict is rare in Pilar and the local people are proud of their city's howler monkey population (Alesci et al. In review). The howler monkey population is reported to have been thriving in the city for at least 50 years and the high levels of habituation of the monkeys towards humans may also result in lower levels of self-scratching.

Currently, there is no standard method for estimating the risk posed by urban hazards in ecology studies. Determining the risk index for the different observed hazards within the city of Pilar was based on research conducted in urban environments and on previous primatological studies in Pilar. Developing models that quantify the probability of injury or death within a given area could help to promote future studies measuring anxiety in primates.

Overall, this study provides evidence that there was no relationship between levels of self-scratching and hazard score, suggesting a lack of awareness. However, other stressors may influence levels of self-scratching behaviour, making it difficult to determine the level of risk awareness. The negative relationship between hazard score and home range use confirmed that the howler monkeys frequently use safer areas of their home range. Increasing connectivity within the urban environment and provide more green space could reduce the howler monkeys exposure to hazards (Lokschin et al. 2007; Birot et al. 2019).

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Data availability

The data that support this study will be made openly available through Dryad.

Conflict of interest statement. The authors declare that there are no conflicts of interest arising from this work.

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