Assessing the effect of urbanization on tropical forest dwelling teiid lizards

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A B S T R A C T

Urbanization causes marked changes in the landscape usually detrimental for wildlife. There is, thus, a pressing need to understand how wildlife respond to these changes. Here we evaluate the occurrence of large sized teiid lizards (Ameiva ameiva, Tupinambis marianae and Kentropyx calcarata) and the density of K. calcarata inhabiting urban and non-urban forest fragments. We address the question whether urbanization and fragment size influence population persistence and density. We expected that K. calcarata would be found at higher density in smaller fragments due to an abundance of resources and lower predation pressure. We conducted a survey of five urban fragments (range: 5–515 ha) and of one control non-urban fragment (over 1000 ha) of semi-deciduous Atlantic forest in Paraíba, NE Brazil. We surveyed a total of 44 transects and used distance sampling to estimate the density. We recorded a total of 61 K. calcarata with an estimated density of 3.76 ind/ha (95% CI: 3.0–4.65) in the urban fragment and 5.57 ind/ha (95% CI: 3.7–8.3) in the non-urban fragment. Contrary to our expectations, K. calcarata was not observed in the small urban fragments nor were A. ameiva. In non-urban areas K. calcarata respond to fragmentation with a marked increase in abundance. Urban forest fragments are subject to several anthropogenic disturbances that could contributed to the decline and local extinction of teiid lizards. We suggest teiid lizards might be good indicators of environmental health in small urban forest fragments and monitoring of their population might provide information for management and conservation.

1. Introduction

Natural landscapes have been increasingly over exploited and natural areas are rapidly being transformed into cities or fragmented and locked within urban matrices (Saunders et al., 1991; McDonald et al., 2013; Parris, 2016). Habitat fragmentation is the process by which a large expanse of habitat is transformed into smaller patches isolated from each other by a matrix of a non-native habitat (Fahrig, 2003).

At the abrupt boundary between contrasting habitats occurs physical changes (temperature, humidity, luminosity and wind speed) and changes in species abundance and community that are often termed edge effects. For example, the increase in luminosity and desiccation in the forest edge leads to an increase in light-loving vegetation and habitat-generalist species (Laurance et al., 2002). In general, the edge effect is higher in small forest fragments, causing proliferation of secondary vegetation (Murcia, 1995; Laurance et al., 2002) that is associated with marked increases in abundance of a few common species of insects and vertebrates that thrive by exploiting these changes (Fowler et al., 1993; Hue et al., 2017; Laurance et al., 2002). Usually edge effects reduce habitat quality and causes the decline of diverse groups of animals, such as butterflies, understorey birds and large sized primates (Laurance et al., 2002).

Urban development may represent a particularly intense form of fragmentation for many species. Besides the associated edge effects, there is also other compounding impacts such as increased levels of pollution in soil, air and water systems, habitat degradation and alteration in ecosystems process (Grimm et al., 2008; Parris, 2016) that result in loss of biodiversity and declines in abundance (e.g. Aronson et al., 2014; McKinney, 2002). The effects of anthropogenic stressors, e.g. urban lighting and predation by domestic species such as cats, could be more detrimental in small forest fragments due to the edge effect (Godefroid & Koedam, 2003). Most of the native forest remnant in urban area are small sized (Grimm et al., 2008; Parris, 2016), yet even small urban forests can harbour significant biodiversity, despite the shifts in community structure caused by urbanization (Brunbjerga et al., 2018; Melliger et al., 2018). Therefore, monitoring the environmental health of native habitats in urban areas is key for implementation of conservation strategies and to inform decisions for management.

Our understanding, however, on how different species respond to fragmentation suffers from an over representation of some charismatic...
organisms, e.g. birds and mammals, while other groups such as lizards have been neglected despite playing crucial functions in ecosystems (Bonnet et al., 2002; Moura et al., 2015; Fardila et al., 2017; Miranda, 2017). As the pace of urbanization increases with most of the world’s population now living in urban areas (United Nations, 2014; McDonald et al., 2013), there is a pressing need to understand how wildlife respond to urbanization. Although there is little research on how urbanization affects lizards, these studies suggest that there is a negative impact of urbanization on population abundance and only few species are able to thrive in the urban environment (review in French et al., 2018). We also know little about how habitat fragmentation affects lizards in general, and this is particularly true in the Neotropics (e.g. Fardila et al., 2017). Bell and Donnelly (2006) found that lizard density was significantly higher in small fragments (1–7 ha) compared to continuous forest in Costa Rica, but we need more data to understand the long-term impacts of forest fragmentation, particularly within urban landscapes.

Although some reptile species benefit from the effects of fragmentation and urbanization, several species are vulnerable to landscape changes (Jellinek et al., 2004; Brown et al., 2008; French et al., 2018). Studies have shown that the large sized, heliophile and generalist Teiidae species, such as Kentropyx calcarata and Ameiva ameiva, typically respond positively to fragmentation showing a marked increase in abundance (Cosson et al., 1999; Lima et al., 2001; Lion et al., 2016; Palmeirim et al., 2017; Sartorius et al., 1999). These teiids were the most abundant species on the islands formed from construction of the Balbina hydroelectric dam in the central Brazilian Amazonia. In fact, Kentropyx sp were the most abundant species in the artificial archipelago and after 28 year of isolation from the mainland they were still found on islands as small as 0.8 ha (Palmeirim et al., 2017). Reptiles have lower energetic requirements and requires less space, which may favour the persistence of viable populations even in small forest fragments (Pough, 1980; Palmeirim et al., 2017). Recently Lion et al. (2016) found a greater richness and abundance of lizards, chiefly K. calcarata, in small non-urban Atlantic forest fragments and suggested that the absence of predators in smaller fragments released lizards from predation pressure. They further suggest that smaller fragments sustain reduced parasite population, and this might increase the fitness of lizards inhabiting these forest remnants.

Since the understanding of the effects of urbanization on lizards is limited, we evaluate the density of K. calcarata and the occurrence of other larger teiid lizards (A. ameiva and Tupinambis merianae) inhabiting urban forest fragments, varying in patch size and degree of anthropogenic disturbance, and a large non-urban fragment that served as our control. We addressed one specific question: Does urbanization and fragment size influence population persistence and density of teiid lizards?

Many empirical studies have documented increased decline and extinction of predators in small non-urban forest fragments as well an increase in the abundance of lizards (e.g. Lion et al., 2016; Terborgh et al., 2001). We predict that due to ecological release and increased food abundance, that could offset the negative impacts affecting small remnants within an urban matrix, densities would be greater in the small forest fragments when compared to larger habitats.

2. Methods

2.1. Species surveyed

Kentropyx calcarata (Fig. 1) is a South-American teiid lizard with a wide range distribution, occurring in tropical forested habitats east of the Andes (Avila-Pires, 1995). It is a moderate-sized teiid lizard, reaching a maximum snout-vent length (SVL) of 119 mm, it feeds mostly on spiders, orthopterans and cockroaches and is commonly found in disturbed areas including tree falls and riparian habitats (Vitt, 1991; Vitt et al., 2000).

**Fig. 1.** An adult Kentropyx calcarata.

*Ameiva ameiva* is widely distributed in lowland tropical South America. It is a medium sized (maximum SVL of 180 mm), and active lizard that feeds on grasshoppers, roaches, termites, beetles, insect larvae and vertebrate prey (Avila-Pires, 1995; Vitt et al., 2000).

*Tupinambis merianae* is one of the largest lizards in the New World being widespread throughout much of South America. It reaches up to (SVL) 400 mm (Avila-Pires, 1995). They are carnivorous lizards, but also eat fruits (Avila-Pires, 1995).

2.2. Study area

We surveyed a total of 44 transects in urban and rural fragments of semi-deciduous Atlantic forest in Paraiba, NE Brazil (Fig. 2). The urban fragments consisted of four small sized fragments (5–8 ha) located on the campus of the Universidade Federal da Paraíba (UFPB fragments hereafter) and a larger fragment (515 ha), Mata do Buraquinho, located about 400 m from UFPB in the heart of João Pessoa municipality (Fig. 2). The UFPB fragments and Mata do Buraquinho were connected until the 1960’s forming a much larger remnant of Atlantic forest, but are now separated by roads and buildings.

The control rural fragment (Gargau) is located about 18 km north of Mata do Buraquinho (Fig. 2). It is a privately owned conservation area (RPPN) with 1058.62 ha and is surrounded by sugarcane plantation.

The region comprising all studied fragments is warm and wet. The annual mean temperature is 25 °C and shows little variation during the year. The rainy season occurs from March to July and annual rainfall ranges from 1500 to 1700 mm (Lima and Heckendorff, 1985).

2.3. Sampling

In the small UFPB fragments we surveyed a total of 12 trails of different lengths (range 35–60 m) set up within the 4 largest fragments (5–8 ha). In Mata do Buraquinho (hereafter MB), 15 trails (lengths range: 48–56.7 m) were surveyed. In Gargau, 17 trails were surveyed (length range: 47–51 m). The trails in the larger fragments (Gargau and MB) were set up near to the edge of the forest (distance range: 26–215 m). Biodegradable yellow plastic flags were used to signal the beginning and end of the transects. Sampling was carried out from April to August 2017 by Lissa D. Franzini and she walked along the transects between 10:00 and 13:00, when lizards are most active (Vitt, 1991). Each transect was walked at a speed of about 0.8 km/hour and when a lizard was detected the distance to the transect was recorded with a measuring tape.
2.4. Density estimation

We estimated the density of *K. calcarata* using the program DISTANCE (Version 6.2; Thomas et al., 2010). This program fits a detection function to the observed distances and provides an estimate of the number of individuals in the area (see Thomas et al., 2010). Distance sampling has been shown to give accurate and unbiased estimates of population density (Buckland et al., 2001; Thomas et al., 2010).

To increase precision in the density estimates we followed the recommendations of Thomas et al. (2010). We assessed the following combinations of functions and adjustment terms as suggested by Thomas et al. (2010): uniform key function with cosine adjustments; half-normal key with Hermite polynomial adjustments; half-normal with cosine adjustment term and hazard-rate with simple polynomial adjustments.

As we choose the places to establish the transects, we assumed a Poisson distribution with an overdispersion factor set to 0 in the model definition, thus restricting the inferences of density only to the covered region where the transects were laid.

3. Results

We obtained a total of 61 sightings of *K. calcarata* across the larger fragments; this sample size allows accurate estimates of density (Buckland et al., 2001). The models with the uniform key function and cosine adjustment fitted our data the best and resulted in a density of 3.76 lizards/ha in MB and 5.57 lizards/ha in the Gargau fragment (Table 1). *K. calcarata* was not observed in the small forest patches. The other teiid species did not reach a minimum sample size (n ≥ 40) necessary for modelling density. During the surveys *Ameiva ameiva* was sighted only once both in the MB and Gargau fragments. The only teiid lizard observed during the surveys in the UFPB’s fragments was the larger *Tupinambis merianae*. This species occurred in all areas surveyed.

4. Discussion

The density we found for *K. calcarata* in the Atlantic forest is similar to that found for closely related species in non-fragmented Amazonian forest areas: *K. striatus* (6.8 ind/ha: Magnusson et al., 1986) and *K. pelviceps* (5.8 ind/ha: Duellman, 1987). The density of *K. calcarata* in the MB fragment was smaller than that of the larger Gargau fragment.

Contrary to our prediction *K. calcarata* was not observed in the UFPB’s small fragments. Nonetheless, *K. calcarata* was collected in these fragments in the 80’s (M.T. Rodrigues, pers. comm. to ACDA) and one of us (ACDA) observed this lizard in the 90’s. Thus, they may have gone locally extinct, although there has been no systematic or opportunistic sampling in these fragments since the 80’s to document their decline. It is possible that the small UFPB’s fragment size could constrain *K. calcarata* in maintaining viable population due to competition with more generalist species such as *Tropidurus hispidus*. However, this seems improbable: although *T. hispidus* is quite common and may competitively exclude *K. calcarata* in maintaining viable population due to competition with more generalist species such as *Tropidurus hispidus*. However, this seems improbable: although *T. hispidus* is quite common and may competitively exclude *K. calcarata*, it does not venture within the fragment and occurs only in the forest border.

We also did not observe *A. ameiva* in the UFPB’s fragments, despite it being common in the 90’s (ACDA, pers. Obs), particularly in the more open areas. This species was rarely sighted during the surveys in the larger fragments. Unlike *K. calcarata*, *A. ameiva* prefers open habitats, where it reaches densities over ten times higher than in forest habitats (Duellman, 1987; Sartorius et al., 1999). The absence of this species in
UFPB campus, with lots of open habitat, is noteworthy. The larger tegus (Tupinambis merianae) were sighted in all surveyed areas. Their larger size could deter predation by cats and their great vagility (Avila-Pires, 1995) could enabled them to disperse across the more modified areas. The only other larger lizard occurring in the small forest fragments is the canopy dwelling Iguana iguana (Moura et al., 2015).

Native vegetation fragments within an urban matrix, especially those with higher structural complexity such as forests, represent important sanctuaries for diverse groups of the biota and could play a key role in biodiversity conservation (Angold et al., 2006; Aronson et al., 2014; Ives et al., 2016). Our study demonstrates that larger urban forest fragments can play a role in maintaining abundance and diversity of larger tegu lizards somehow comparable to those found in non-urban fragments. Urban forest fragments, however, are intrinsically different from their non-urban counterparts since they are subject to a series of detrimental pressures that could impact wildlife, e.g. habitat degradation, noise, light and chemical pollution, predation by domestic and/or invasive species, among other stressors (Birnie-Gauvin et al., 2016; Grimm et al., 2008). This could explain the lower density of K. calcarata we found at the urban MB fragment when compared to non-urban Gargau fragment. Although the difference was non-significant, it might have substantial ecological implications since common species can have a major effect on ecosystem processes and even small proportional declines in their abundance could result in significant changes in ecosystem structure and function (Gaston and Fuller, 2008; Winfree et al., 2015).

Our study also shows that small sized urban forest fragments (5–8 ha) could not maintain populations of K. calcarata and A. ameiva, despite the proximity to larger fragments. The small fragments we studied suffer from a series of anthropogenic disturbance such as garbage disposal, artificial lights, and noise pollution that could negatively impact the local fauna (de Andrade et al., in review). To pinpoint the stressors that could drive the decline and local extinction of teiid species in urban fragments would need more detailed studies. Domestic cats, which are known globally as a threat to wild animals (Read and Bowen, 2001; Donovan, 2012), have become very abundant in the UFPB campus since the 90 s, and might had played a role in the decline and local extinction of A. ameiva and K. calcarata, which were easily sighted in the 90 s.

Monitoring small urban forest fragments, to inform conservation policy, could be fraught with difficulties due to limited funding, time and qualified personnel to sample larger number of species and areas (e.g. Gardner et al., 2008). One practical way to circumvent these difficulties, reducing time and costs of monitoring, is the use of species easy to identify, with well-known life history, sensitive enough to provide warnings of changes in the environment (see Noss, 1990; Gardner et al., 2008; Thomas, 2005) and the use of distance sampling, that is quick, practical and reliable, could allow robust estimation of population trends over time (Buckland et al., 2001; Isaac et al., 2011).

There are a horde of different organisms, e.g. plants, insects (particularly butterflies), birds and reptiles, that have been suggested as ecological indicators in terrestrial environments (Siddig et al., 2016), but which of them is the best or most appropriate for a specific situation is debatable (see Lindenmayer et al., 2000). For instance, insect groups can have markedly different responses to disturbance (e.g. Talašová et al., 2018) and thus the indicator species approach could be constrained. To the best of our knowledge urban indicators have rarely been developed, except for birds and butterflies. Although butterflies and birds are commonly used as indicators of ecological conditions in urban areas (Dennis et al., 2017; Lizée et al., 2011), they are better dispersers than lizards and could re-recognize forest fragments; hence they could be a less stable indicators of longer-term trends. Given the limited vagility of lizards, smaller spatial requirements (Pough, 1980) and the limited effect posed by habitat fragmentation (e.g. Jellinek et al., 2004; Lion et al., 2016), we believe they could be more useful indicators in urban areas.

Ameiva ameiva and K. calcarata have small home range, have well known life histories (Avila-Pires, 1995; Vitt et al., 2000), are diurnal and relatively easy to monitor for changes in population abundance. Moreover, both species are predators and as such susceptible to the bioaccumulation of environmental pollutants (Aguilera et al., 2012; Gardiner and Harwood, 2017) and, therefore, may be good sentinels of habitat quality. We suggest that A. ameiva and K. calcarata might help monitoring the environmental health of urban forest fragments and also could serve as a good indicator of ecological changes in urban forest remnants. Selecting only one or a few species as indicators might be questionable, however, since co-occurring species can respond markedly different to environmental variation (e.g. Talašová et al., 2018). Nonetheless, the use of a single species has advantages and monitoring single population dynamics is considered to be relatively cost-effective (Siddig et al., 2016).

5. Conclusion

The lizards we studied, particularly K. calcarata, are abundant where they occur, easy to see in the environment, easily identifiable even by lay persons, and no collection is necessary, which reduces the cost of research and help their use as ecological indicators.

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