Revista Brasileira de Ornitologia 26(1): 1–8.
March 2018

ARTICLE

Influence of urbanization on the distribution and defense strategies of the Burrowing Owl *Athene cunicularia* in the city of Uberlândia, southeastern Brazil

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Received on 19 September 2017. Accepted on 19 January 2018.

ABSTRACT: Urbanization causes drastic changes in habitat and species behavior. In birds, these changes influenced the extinction of some species. The Burrowing Owl *Athene cunicularia* (Molina, 1782) (Aves: Strigiformes) has achieved some success in its adaptive process in anthropic environments. The main objective of this study was to measure distribution of this species in urban areas. The specific objectives were to quantify and compare the occurrence of this owl and its satellite burrows among urban biotopes; evaluate the importance of satellite burrows as a defense strategy and compare the depth of burrows in different biotopes. Field activities were carried out from August 2015 to November 2016. Sixty areas were sampled in different urban regions. The species was present in 29 of the 60 sites investigated, totaling 112 individuals, 88 adults, 14 young and 10 chicks; 98 burrows were recorded, from which 22 were refuges, seven nests and 67 satellite burrows. Residential and Urban Green Area biotopes had the highest number of individuals and burrows with a significant difference relative to the Commercial/Industrial biotope. A greater number of individuals were found in areas with a high number of burrows showing a positive linear relationship between these variables. The burrows were deepest, on average, in Urban Green Area biotopes. We conclude that the species has a wide distribution in the city with significantly high numbers in the Residential biotope. This same tendency is verified for the distribution of burrows. In areas with a large number of individuals, the same was observed for the number of satellite burrows. Deeper burrows in the Urban Green Areas are perhaps due to the greater transit of people, one of the main features of this biotope and one of the major threats to the Burrowing Owls.

KEY-WORDS: biotope, habitat, occurrence, satellite burrows, survival.

INTRODUCTION

Urbanization can be defined as a process of anthropic occupation that gradually transforms natural environments and includes the presence of relatively permanent human populations on the site (Marzluff *et al.* 2001). On a global scale, anthropic pressures have influenced the structure and behavior of faunal populations and communities, and also of ecosystems in remnants of natural areas (Bradshaw & Holzapfel 2006, Delibes *et al.* 2011). Human presence can lead to population decline, persistence, or even the expansion of bird distributions (Sih *et al.* 2011). Furthermore, the disturbances caused by anthropic actions seem to be causing changes in the distribution and behavior of birds and might also be leading many species to extinction (Silva & Nakano 2008).

Many birds have adapted to the anthropic environment and their presence is important for pest control, such as predation of rats and insects, besides having an important role in the food chain (Millennium Ecosystem Assessment 2005). In addition, they perform functions like pollination and dispersal of fruits and seeds (Silva & Nakano 2008).

Some of these birds live in urban environments, such as *Athene cunicularia* (Molina, 1782), that is widely distributed throughout the Americas, from Canada to southern Argentina (Poulin *et al.* 2005, 2011). Burrowing Owls have preference for open habitats, foraging and breeding in short, low-density vegetation and mainly grasslands (Rebolo-Ifrán *et al.* 2017). These owls are common in Brazil and known for being urban dwellers, showing behavioral adjustments to anthropic-altered environments (although they are commonly observed in natural areas) (Sick 1997, Motta-Junior & Alho 2000). Some populations are able to exploit human-made habitats with a preference for urban over rural areas (natural grasslands and low-intensive agro-pastoral lands) (Rebolo-Ifrán *et al.* 2017). Main causes of mortality include collisions with vehicles and nest

destruction (Silva 2002). The behavioral responses of Burrowing Owls to threats can be easily recognized, such as the use of deep burrows, use of satellite burrows, flying away in the presence of potential predators, making alarm calls, adopting threat postures and some type of attacks (Coulombe 1971, Thomsen 1971, Fisher *et al.* 2004).

Burrowing Owls are present in many parts of the world and are considered one of the main predator species of rodents in urban areas (Martins & Eagler 1990, Sick 1997, Motta-Junior & Alho 2000). However, the behavior of the species is affected by urbanization and it is reported that the increase in vehicular traffic around the nest produces an increase in the couple's waking time (Plumpton & Lutz 1993). Similarly, populations of Burrowing Owls are under heavy pressure from domestic animals, such as dogs and cats (Dechant *et al.* 2003, Rosenberg & Haley 2004, Moulton *et al.* 2006). These threats determine behavioral responses that include subterranean retreat, deeper burrows, the use of satellite burrows, the issuance of alarm calls, and dive-in-flight attacks (Coulombe 1971, Thomsen 1971, Fisher *et al.* 2004). It has also been described the use of mammalian manure, placed near the entrance of the burrow, to avoid potential predators with bad odor (Martin 1973).

Burrows are the essential component of Burrowing Owl habitat: both natural and artificial burrows provide protection, shelter, and nests (Henny & Blus 1981). Burrowing Owls typically use burrows made by fossorial mammals, but also may use man-made structures, such as cement culverts; cement, asphalt, or wood debris piles; or openings beneath cement or asphalt pavement. Burrowing Owls exhibit high site fidelity, reusing burrows year after year (Rich 1984, Feeney 1992). Once young individuals learn to fly, the family group often moves from one burrow to another (Thomsen 1971).

Declines in populations of this species in North America called the attention of environmentalists (Holroyd *et al.* 2001, Skeel *et al.* 2001, Warnock & Skeel 2004, Conway & Pardieck 2006) and, in Florida, the Burrowing Owl had its status updated to threatened in the state red lists (Florida Fish and Wildlife Conservation Commission 2017). The aim of the present study was to determine the distribution and the abundance of the Burrowing Owl in urban areas of the city of Uberlândia, southeastern Brazil, by (1) evaluating the occurrence and abundance of the species among different urban biotopes; (2) determining the occurrence and distribution of burrows (satellites, nests or refuges) per urban biotopes; (3) evaluating different defense mechanisms, such as the importance of satellite burrows, the relationship between the number of individuals and burrows; and the depth of the burrows in different biotopes, which are fundamental aspects for conservation of the studied species in modified environments.

METHODS

Study area and data collection

The municipality of Uberlândia has about 669,000 habitants (IBGE 2016), with a total area of 4040 km^2 in the state of Minas Gerais (MG), southeastern Brazil, from which 219 km^2 are urban. In areas surrounding the city, the native vegetation was reduced to remnants of less than 15% of the original cover, with evident reduction of the local fauna (Brito & Prudente 2005).

We visited areas with a potential occurrence of the species, typically with short grasses and wide spaces of open areas (Coulombe 1971, Plumpton & Lutz 1993, Marks *et al.* 1999). Field activities were carried out from August 2015 to November 2016, with monthly data collections along the day (from 7:00 h to 18:00 h) with small interruptions, not every day of the month, and totaling 2000 h of observation.

Sixty sites (with areas of about 33 m^2 each) were sampled in different parts of the city, 20 per urban biotope, and visited monthly. The minimum distance between sites was 200 m, in order to guarantee the independence of the samples and considering the territorial behavior of the studied species (Gaston 2003). These sites were selected according to the potential occurrence of the Burrowing Owls with the help of satellite images obtained from the Google image bank of the city of Uberlândia (Google Earth 5.1 2009) and also by direct field observations. All sites were georeferenced by taken a point in the middle using a Global Positioning System (GPS) and a map of the city was made with these GPS points in the software QGIS 2.18.2 (Fig. 1).

Biotope refers to a certain living space distinct from the others, endowed with environmental conditions suitable for specific organisms (Sukopp & Weiler 1988). The selected sites were classified according to the European Method for Mapping Biotopes: Urban Green Areas, Residential and Commercial/Industrial (Sukopp & Weiler 1988, Weber & Bedê 1998). Urban Green Areas include urban parks, squares, sports centers, theaters, universities, schools and airports, all places in which there is a high flow of people and a medium level of urbanization. The residential biotope is characterized by the presence of houses, condominiums and residential buildings, with less evident levels of pollution and environmental disturbances; in addition, this biotope has a lower flow of humans and vehicles (but with constant presence of domestic animals). The Commercial/Industrial biotope includes open areas with short grasses, near places with intense commerce, such as malls, industries or construction sites, with intense traffic of vehicles and high level of urbanization.

Three visits were conducted to each site, totaling 180

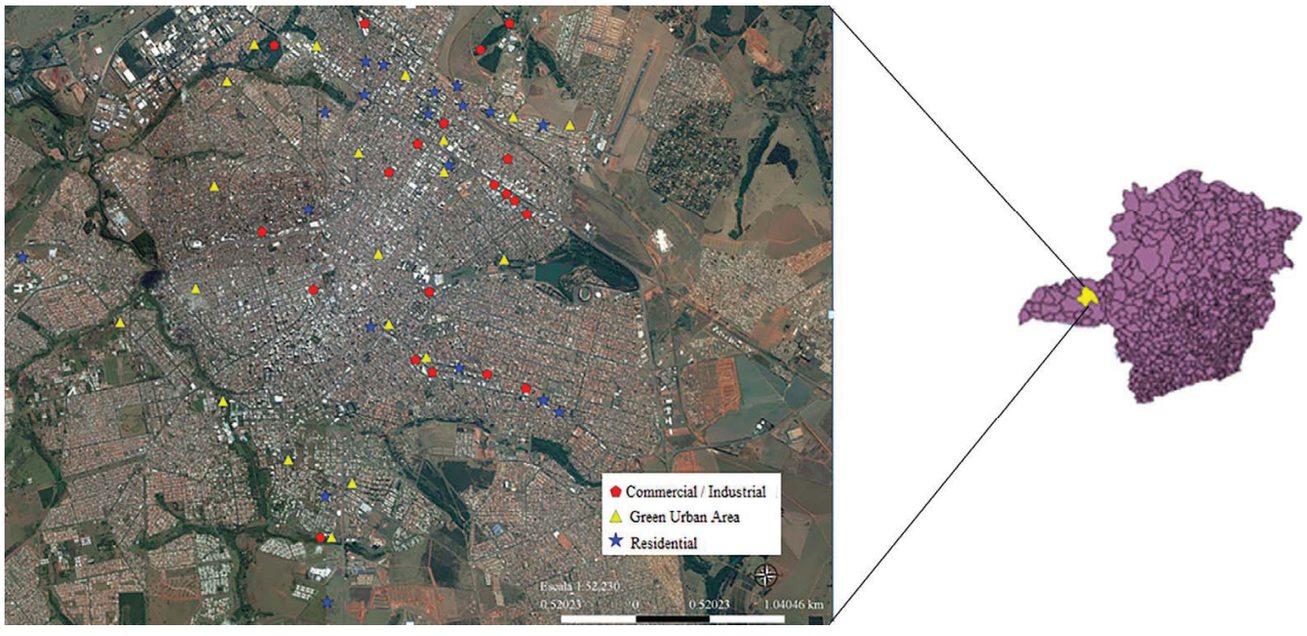

Figure 1. A map of the distribution of the sampled points for the Burrowing Owl occurrence, according to the investigated biotopes (Urban Green Area, Residential or Commercial/Industrial) in the urban area of Uberlândia (MG), Brazil.

visits (60 visits in each biotope investigated). The relative abundance was calculated by counting individuals of the target species per site and the same was done for the burrows. Individuals were classified according to gender (only adults) (Zarn 1974) and age group (adults, chicks and juveniles) (Appendix I). Burrows were classified as main or satellite. Main burrows were subdivided by nests (in which chicks or eggs were present) and refuges (in which only adults were present). Satellite burrows were represented by non-inhabited burrows near the main ones, and are used as a defense mechanism against threats, in which individuals rotate between burrows in order to confuse predators (Henny & Blus 1981, Desmond & Savidge 1999). Some burrows were lost due to human action.

To measure the depth of the burrows we used a digital measuring tape (Bosch GLM30) 5 m long. Only burrows that we could reach without causing stress (absence of individuals) or nests without the presence of chicks, were measured.

Data analysis

Homogeneity tests of variances and normality of the sampled data were performed using a Lilliefors test and by evaluating the data distribution in scatter plots. Sample data transformations (three times in the Variance Analysis, in addition to the Linear Regression) were performed by square rooting values, which were necessary due to the non-normality distribution of the sampling data (Zar 2010). To determine the differences in Burrowing Owl abundance and number of burrows according to urban biotopes we used the ANOVA One-Factor test. Tukey's test was used to determine which factor levels (urban biotope) differed from each other (Zar 2010). Another ANOVA test was used to evaluate the differences in burrow depth by biotope.

To evaluate the correlation between number of individuals and burrows we performed a simple linear regression. Values were square root transformed for normality adjustment (Zar 2010). All statistical analyzes were performed using the Systat 10.2 software, with a significance level of $\alpha = 0.05$ (Zar 2010) and graphs were built using Illustrator 21.1.0.

RESULTS

Distribution, occurrence and abundance

The species was found in 29 out of the 60 sampled sites (48%). In total, 98 burrows were registered, with a mean of 3.14 burrows per point, with 29 main burrows (22 refuges and seven nests) and 69 satellite burrows. We recorded 112 individuals (Table 1).

Distribution and occurrence by biotopes

Residential biotope points showed the highest number of individuals (n = 55) followed by Green Urban Area points (n = 47) and Commercial/Industrial Area points (n = 10). The largest number of individuals found in a single point was recorded in a Residential biotope (n = 8). A mean of three individuals per point were recorded in the

Table 1. Number of individuals of Burrowing Owl, by age group (adults, juveniles and chicks) and gender (male and female) in the biotopes investigated in the urban area of Uberlândia (MG), Brazil.

Biotopes	Adults		Chicks	Juveniles	Total
	Male	Female			
Residential	21	22	9	3	55
Green Urban Area	18	18	4	7	47
Commercial/Industrial	3	6	1	0	10
TOTAL	42	46	14	10	112

Residential biotope, two in Green Urban Area and 0.5 in Commercial/Industrial ($F_{(2,57)}$ = 4.2, P = 0.020, Fig. 2A), with a significant difference between the Residential and Commercial/Industrial biotopes (P < 0.016).

Distribution and occurrence of burrows by biotopes

We found 51 burrows in the Residential biotope, 39 in Green Urban Area and 8 in Commercial/Industrial ($F_{(2,57)}$ = 3.19, P = 0.048, Fig. 2B), with a significant difference between Residential and Commercial/Industrial (Tukey's test; P < 0.040).

Relationship between satellite burrows and number of individuals

In general, large numbers of satellite burrows were found in points with large number of individuals, with a positive linear relationship between the two variables ($F_{(1,58)}$ = 428.89, P < 0.001, R^2 > 0.88) (Fig. 3) (Table 2).

Depths of burrows in the urban biotopes

Thirty-four depths of burrows were measured. The highest mean was observed in the Green Urban Area biotope, reaching a maximum depth of 3.5 m. There was a significant difference between the three biotopes ($F_{(2,17)}$ = 4.05, P < 0.030, Fig. 4), with the greatest depths in the Green Urban Area (P = 0.049).

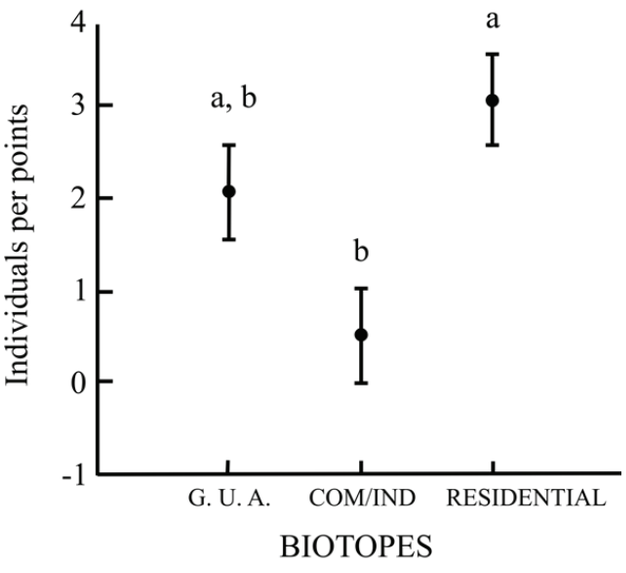

Figure 2. (**A**) Mean of individuals of Burrowing Owl per point distributed according to the biotopes (G.U.A = Green Urban Area; COM/IND = Commercial/Industrial) in Uberlândia (MG), Brazil; (**B**) Mean number of burrows per point, showing a relationship between burrows (refuges, satellites and nests) and biotopes (G.U.A = Green Urban Area; COM/IND = Commercial/Industrial) of the Burrowing Owl in Uberlândia (MG), Brazil. Confidence intervals were considered for P < 0.05.

DISCUSSION

The results obtained corroborated other studies (Haug *et al.* 1993, Holmes 1998, Chipman *et al.* 2008, Berardelli *et al.* 2010), according to which the Burrowing Owl is a common species in cities and tolerant to anthropic environments. Burrowing Owl appears in different bird lists of the Uberlândia (Silveira *et al.* 1989, Pimenta 1993, Franchin & Marçal-Junior 2004, Franchin *et al.* 2004) and, as demonstrated here, the species was able to explore all urban biotopes sampled in this study. Some studies also suggest that Burrowing Owls are easily behaviorally adjusted to humans, being able to colonize different human-altered habitats (Sih *et al.* 2011, Sol *et al.* 2013, Rebolo-Ifrán *et al.* 2017). On the other hand, some studies indicate that urbanization leads to the population decline of Burrowing Owls (Millsap & Bear 2000, Jones & Bock 2002, Chipman *et al.* 2008). This decline is attributed to the loss of habitat to cultivation and other land use activities, predation by domestic animals and human persecution, amongst other factors (Haug *et al.* 1993, Sheffield 1997). Although results of the present study have not demonstrated a negative impact of the urbanization on Burrowing Owls, we cannot disregard that the conservation of the species could be affected by the increase of human pressure, in the future.

The higher frequency of individuals and burrows in residential and green urban biotopes may be associated with a lower likelihood of disturbance in these areas

Table 2. Number of individuals and burrows: main (refuges and nests) and satellite burrows of Burrowing Owl according to biotopes investigated in the urban area of Uberlândia, MG, Brazil. Percentage is the number of each burrow type in relation to the total number of burrows observed (n = 98 burrows).

Biotopes	Main		Satellite Burrows	Individuals
	Refuges	Nests		
Residential	8	6	37	55
Green Urban Area	9	0	30	47
Commercial/Industrial	5	1	2	10
TOTAL	22 (22.4%)	7 (7.1%)	69 (70.5%)	112

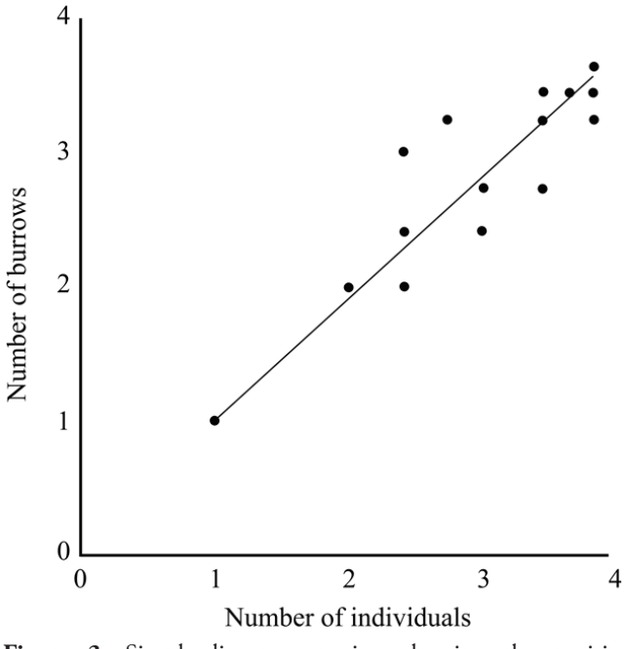

Figure 3. Simple linear regression showing the positive relationship between the number of satellite burrows and the number of individuals of Burrowing Owl, in the city of Uberlândia (MG), Brazil.

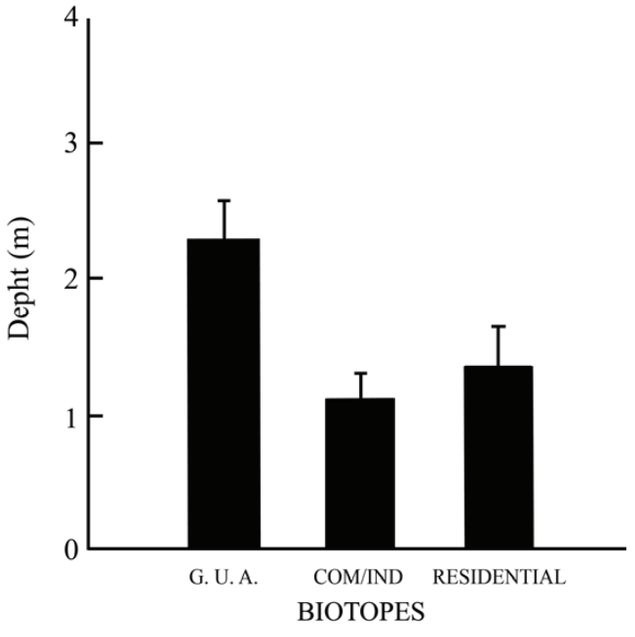

Figure 4. Average depths of burrow of the Burrowing Owl according to biotopes (GUA = Green Urban Area; COM/IND = Commercial/Industrial; RESID = Residential), with a significant difference between the Green Urban and Commercial/Industrial Areas of Uberlândia (MG), Brazil.

compared to the Commercial/Industrial biotope, which had heavy traffic of vehicles and people, as well as low availability of land empty. The flow of vehicles and humans is considered to be the main cause of Burrowing Owl mortality (Silva 2002). On the other hand, the presence of empty lands may have favored the greater occurrence of the species, as these unoccupied spaces present favorable conditions for species survival (Forman & Godron 1986, Blair 1996). It is worth mentioning that these areas present greater availability of food resources due to the intense lighting near burrows, which attracts some beetles and other insects (Chipman *et al.* 2008).

The urban environment has few refuges and places for breeding, feeding, resting and protection against adverse climatic conditions such as rain or wind (Poulin *et al.* 2011). The Burrowing Owl does not dig their own burrows, but takes advantage of previously dug burrows, modifying only their depths and widths (Belthoff & Smith 2003). The availability of burrows affects the choice of habitat: the greater the number of burrows, the greater the probability of Burrowing Owls choosing it (Plumpton & Lutz 1993, Desmond & Savidge 1999, Ronan 2002, Poulin *et al.* 2005, Lantz *et al.* 2007). Burrowing Owls seemed to choose more areas corresponding to the Residential biotope, which presented greater numbers of burrows (main ones and satellites) and, consequently, more individuals, probably because that biotope presented the most favorable characteristics for the species survival, such as short grasses and greater food availability. In this study, deeper burrows were recorded in Residential and Green Urban Areas. Burrows are used for nesting, refuge, to storage food and also may serve as a defense mechanism. Accordingly, Burrowing Owls tend to dig deeper, especially in places with higher degrees of threats (Thomsen 1971). We believe that behavior of digging deeper is related to the type of biotope, like in Residential

and Green Urban Areas, biotopes with a probable higher risk of predation by domestic animals and other potential predators. May be the greater the number of individuals, the greater will be the need for protection against possible threats, such as predators, that can use urban areas as refuge (Griffin *et al*. 2017). This was seen in areas with a large number of satellite burrows, which, associated with the behavior of species individuals to "rotate" among burrows, are used in order to cause a distracting effect on predators (Henny & Blus 1981, Desmond & Savidge 1999). It is known that avoidance of predation is an important determinant of fitness in many animals (Ruxton *et al.* 2004).

Our results show that Burrowing Owls is a species highly adjusted to the human ecosystem, being able to explore different urban biotopes and that its distribution in the municipality of Uberlândia is due to the likelihood of disturbance, as well as the occurrence of empty lands. These aspects can be useful for conservation of the species here and in other cities.

ACKNOWLEDGEMENTS

Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) provided a MSc. scholarship to F.F.F. Special thanks go to Celine de Melo, Rafael de Freitas Juliano, Davi Lee Bang, Diogo Silva Vilela and Dimas Pioli for helping in fieldwork or by reviewing the English version and making valuable suggestions in early drafts of this manuscript.

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Associate Editor: Carla S. Fontana.

APPENDIX I

Classification of Burrowing Owl, *Athene cunicularia*: Adult female (**A**) and male (**B**); Juveniles (**C**) and chick (**D**), in urban environment. Photo authors: Felipe F. Franco (A & B); Phyllis Greenberg (C & D).