Revista Brasileira de Ornitologia 26(2): 77–81.
June 2018

ARTICLE

Behavioral responses of urban birds to human disturbance in urban parks at Curitiba, Paraná (Brazil)

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Received on 13 January 2018. Accepted on 25 May 2018.

ABSTRACT: Proximity to humans can influence behaviors that are essential in birds' life, such as breeding, foraging and flight. In urban parks, which are important natural shelters to birds, human activity varies broadly in time such that attentiveness and escaping behavior of birds may be intensified as humans' density increases. In this study, we tested this hypothesis in six urban parks at Curitiba, southern Brazil, using three common bird species as models, the Rufous Hornero (*Furnarius rufus*), the Southern Lapwing (*Vanellus chilensis*) and the Rufous-bellied Thrush (*Turdus rufiventris*). Specifically, we tested if foraging rate, alert distance (AD), flight initiation distance (FID) and flight distance (FD) were related to human density at birds' surroundings. We found no influence of humans on birds foraging rate, whereas AD, FID and FD decreased with human density in the area. We also found differences in birds escaping strategy; "flying" strategy was associated with higher AD, FID and FD than "walking". Results also indicate that humans' presence temporally affected birds' vigilance and flight responses, evident through their constant foraging rate irrespective of human density, *i.e.* increased tolerance to human proximity. Our study provides evidence of behavioral plasticity of the model species to the intensity of human use of their living area, which also highlights the importance of further efforts in creating refuges within urban parks to minimize negative anthropic impacts on urban species.

KEY-WORDS: approaching experimental trial, escaping strategy, flight initiation distance, foraging rate, human density.

INTRODUCTION

Many bird species are sensitive to environmental change, but several can cope with anthropic activities. Thus, parks and other green areas become important shelter especially to birds in human-altered environments (Fernández-Juricic *et al.* 2001), because ecological and environmental conditions may match with the natural contexts where these species have evolved. However, human use of green areas for leisure or touristic activities can also cause profound impacts in wildlife (Collins-Kreiner *et al.* 2013). For instance, the presence of humans may cause foraging area reduction and increasing stress hormone levels in urban animals that can affect parental care (*e.g.*, *Haematopus ostralegus*, Verhulst *et al.* 2001), hatching success and chick development (*e.g.*, *Opisthocomus hoazin*, Mullner *et al.* 2004 and *Pygoscelis adeliae*, Giese 1996), high mortality rates (Blumstein 2006) and, ultimately, local species extinction. Even though selection has favored agile escape behaviors in birds to overcome potential threats (*e.g.* predators, Ydenberg & Dill 1986), individual habituation to human co-occurrence can be decisive for survival and may represent an important filter selecting individuals and species less sensitive to urbanization.

The escape behavior to human approach reflects a bird innate response to guarantee survival. Individual responses involve an optimal decision-making that maximizes foraging and daily general activities (*e.g.* mating and nesting) while reducing any potential threat (Blumstein *et al.* 2003, Piratelli *et al.* 2015). Three important metrics to assess an individual habituation and risk avoidance agility are the alert distance (AD), flight initiation distance (FID) and flight distance (FD). The first indicates birds' visual and auditory orientation when detecting an approaching threat (Blumstein 2006, Weston *et al.* 2012). Specifically, the alert state in birds is easily recognized through behaviors like head raise (Whitfield *et al.* 2008), continuous surroundings scan (Schlacher *et al.* 2013) and momentarily interruption of activities. The second indicates the distance in relation to a potential threat at which the individual begins to escape by walking or flying away (Cooper-Jr. & Pérez-Mellado 2011), and the third represents the actual distance travelled for escaping.

Optimized alertness and escape responses, measured as AD, FID and FD, may allow birds to accomplish their daily activities in a non-ideal condition for many species. Indeed, birds exposed to human proximity tend to have lower AD, FID and FD, indicating tolerance to human approach likely due to habituation (Miller *et al.* 2001, Ikuta & Blumnstein 2003, Cooper-Jr. & Pérez-Mellado 2011). However, even low levels of human disturbance can be threatening to birds (Bötsch *et al.* 2017). For that reason, these metrics may allow measuring the impacts of the human disturbance in birds living in a given area and how these animals cope with it. To better understand how urban birds deal with human proximity, we experimentally tested the hypothesis that birds respond to humans' presence through shifting AD, FID, FD, and their foraging rate in correlation to the amount of humans that occupy or approach to their foraging areas.

To do so, we had as models three common ground foraging urban species, the Rufous Hornero (*Furnarius rufus*), the Southern Lapwing (*Vanellus chilensis*) and the Rufous-bellied Thrush (*Turdus rufiventris*). Considering urban birds may habituate to humans' presence (Miller *et al.* 2001, Ikuta & Blumnstein 2003, Cooper-Jr. & Pérez-Mellado 2011), in days with denser human population in urban green areas we expected that these birds would thus have lower AD, FID, and FD. In addition, increasing number of people using the green areas would reduce the time window for food search by birds since they would have to spend more time in alert posture than foraging. Therefore, we expected an inverse relationship between foraging rate and human density.

METHODS

Study area

We collected data in 25 sampling days from August to September 2016, in six green areas at Curitiba, the most populous city in Paraná state, south Brazil: Jardim Botânico (25º26'31''S; 49º14'27''W), Parque Barigui (25º25'32''S; 49º18'58''W), Parque São Lourenço (25º23'13''S; 49º16'10''W), Passeio Público (25º25'32''S; 49º16'11''W), Campus Centro Politécnico of the Universidade Federal do Paraná (25º27'6''S; 49º13'55''W) and Fazenda Experimental Canguiri of the Universidade Federal do Paraná (25º27'34''S; 49º15'54''W).

Behavioral observations and approaching experiment

We searched for individuals of the three model-species foraging in each green area. We counted the number of humans within a sampling plot with 20 m radius (1256.64 m^2) around each spotted bird either before and after each observation trial and used their average number to represent human density at each trial in the analyses. We ensured variable human density values across all samples by collecting data both in weekdays and weekends. During five minutes of observation we calculated each individual foraging effort as the number of pecks/min, irrespective of their success in each capturing attempt.

We conducted an approaching experiment by walking towards each bird at a constant walking pace (0.5–1.0 m/s) in a straight trajectory. We then marked and measured with a measuring tape the researcher position when the bird displayed the alert behavior (AD) and when it walked or flew away (FID, Fig. 1). We acquired FD by measuring the distance between the researcher position when the bird initiated its flight and the refuge or landing position (Fig. 1). To standardize all experimental trials, we set the researcher initial distance (ID) to the bird before any approach to be of at least 20 m (Fig. 1) and run all trials in non-rainy days. Since subjects were unmarked, we run the experiments in alternated days and local regions within each green area to avoid sampling each individual repetitively and to prevent birds to get habituated to the experiment. To avoid biases, the same researcher (T.V.P.) made all trials.

Statistical analysis

We tested data for normality using Shapiro-Wilk test and transformed AD, FID, FD and foraging rate to their square root to approximate to a normal distribution. Because AD, FID, and FD were correlated (AD-FID, r = 0.77; AD-FD, r = 0.54, and FID-FD, r = 0.64; P < 0.001 and df = 129 in all cases), we included them in a principal component analysis (PCA) and used the first principal component (PC1, explained variance = 77%) as response variable. Higher PC1 values represented lower values of AD, FID and FD (loadings: -0.40, -0.50 and -0.77, correlations with PC1: -0.77, -0.85 and -0.93, respectively).

We used two Analysis of Covariance (ANCOVA) to test for the relationship between (*i*) PC1 and human density and escape strategy (walking or flying), and (*ii*) between foraging rate and human density. We validated

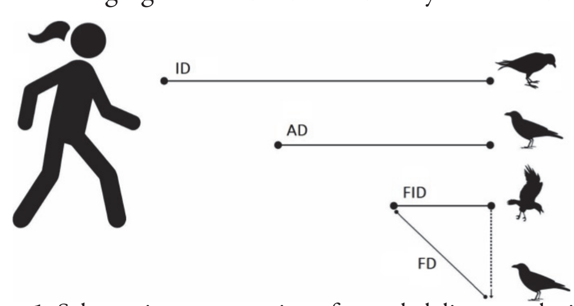

Figure 1. Schematic representation of recorded distances during approaching experiments to the birds. Dashed line indicates bird movement trajectory. ID: researcher initial distance; AD: bird alert distance; FID: flight initiation distance; and FD: flight distance.

Table 1. Foraging rate, alert distance (AD), flight initiation distance (FID) and flight distance (FD) recorded for each bird species in urban parks at Curitiba, Brazil. Values are mean ± SD.

Species	Sample size	Foraging rate (pecks/min)	AD (m)	FID (m)	FD (m)
Rufous Hornero	51	44.6 ± 29.8	4.7 ± 1.98	2.6 ± 1.6	5.6 ± 5.5
Rufous-bellied Thrush	35	24.7 ± 21	6.5 ± 2.4	4.2 ± 2.3	7.9 ± 5.5
Southern Lapwing	45	12.3 ±13.6	7.9 ± 3.3	5.3 ± 3.3	8.3 ± 3.8

the models by plotting residuals versus fitted values. We run all statistical analyses in R 3.4.2 (R Core Team 2016).

RESULTS

We made 133 records of foraging rate and approaching experiments to individuals of the three species: 51 Rufous Horneros, 45 Southern Lapwings and 35 Rufous-bellied Thrushes. Foraging rates were unrelated to human density (β ± SE = -0.009 ± 0.011, n = 131, t = -0.84, P = 0.40), indicating lack of human influence on food-searching behavior by birds (Fig. 2). We found variation in AD, FID and FD between species (Table 1; Fig. 3 left), supporting the inclusion of species as an additional fixed effect term in the models. PC1 was positively related to human density (β ± SE = 0.04 ± 0.01, n = 131, t = 4.09, P < 0.0001, Fig. 3), and indicated that AD, FID and FD reduced as human density increased. In other words, as the number of humans increased on birds surroundings, consequently reducing the area free of people, birds started escaping at shorter distances, but went to closer distances to the observer than in scenarios of low density of humans. PC1 values were smaller when birds flew to escape (β_{flight} ± SE = -1.04 ± 0.16, n = 131, t = -6.46, P < 0.0001) in comparison to the walking escape strategy (Fig. 3). Altogether, this indicates that AD, FID and FD values were higher when birds escaped on the wing, meaning that when humans' density was high, birds preferred walking instead of flying escapes, thus allowing closer approach of the observer and evading to a nearer refuge as opposed to when humans were denser in the area and birds avoided their proximity by flying to a farther refuge.

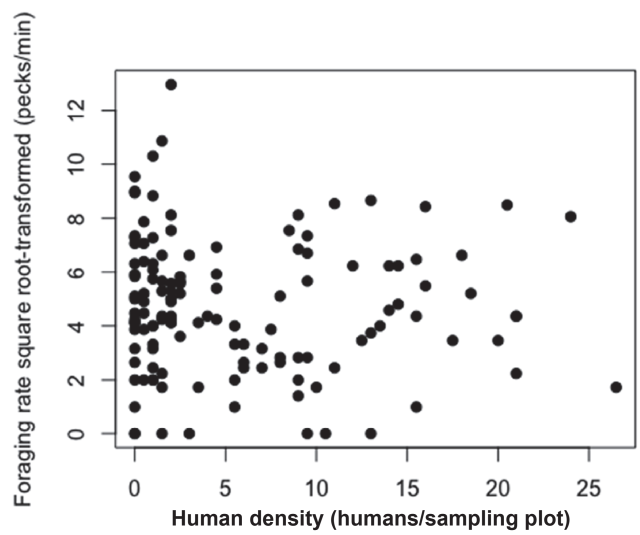

Figure 2. Bird's foraging rate in relation to human density per sampling plot (1256.64 m²) drawn with birds at its center.

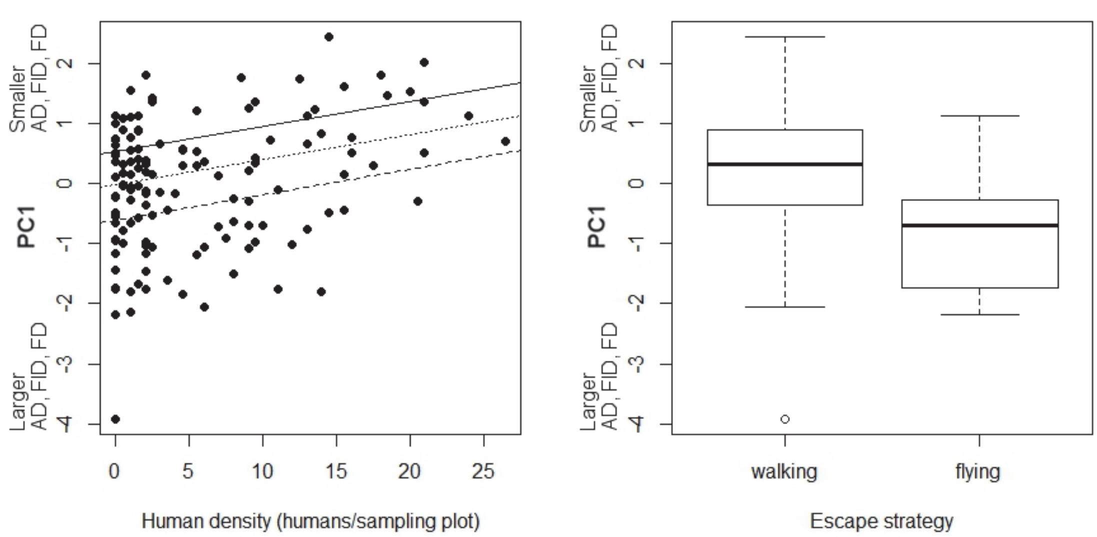

Figure 3. First principal component scores (PC1) of a Principal Component Analyses including AD, FID and FD in relation to humans' density per sampling plot (1256.64 m²; left; Rufous Hornero: solid line; Southern Lapwing: dashed line; Rufous-bellied Thrush: dotted line) and to escape strategy (right). Higher values of PC1 represents lower AD, FID and FD.

DISCUSSION

In this study we tested the hypothesis that individuals of Rufous Horneros, Southern Lapwings and Rufous-bellied Thrushes in urban parks would adjust their foraging and escaping behavior according to the number of humans on their proximity. We showed that birds of the three studied species kept foraging at the same rate irrespective of humans' density. Nevertheless, AD, FID and FD were shorter when more humans were at bird's surroundings, situation in which birds allowed a closer approach of the observer and flew to a closer safe-distance in the approaching experimental trials.

The unpredicted result of human density unaffecting birds' foraging rate reveals a few plausible strategies birds adopt to survive in urban environments. Bird hunting and trapping are illegal activities in Brazil (Brasil 1967), therefore urban birds could have been associating humans' approximation as a non-threatening behavior (*e.g.* Blumstein 2006, Weston *et al.* 2012, Guay *et al.* 2013), ultimately leading to steady foraging rate. Furthermore, the reduction on their adverse reactions to humans may result from a foraging strategy optimized for ensuring proper spatial and temporal exploration of resources in human populated habitats. When high number of humans occupy the parks, foraging may be hampered by the restricted amount of unoccupied foraging areas. To overcome this problem, our data suggest that urban birds maximize their foraging efforts by keep searching for food despite of increased human proximity. This coincides to previous findings that birds become more tolerant to people when human encounter events are more frequent (Samia *et al.* 2015), but our results add that this occur even when the variation of encounter rates occurs within the same location. In other words, birds sustain constant foraging rates through shifting AD and FID to their minimum when human's density increases, thus expressing a finer trade-off equilibrium between energy intake and safety, extending to at least these three tropical species such strategy already reported for some temperate birds (Prieto *et al.* 2009, Lin *et al.* 2012, Jimenez *et al.* 2013) and even other taxa (*e.g.* lizards, Cooper-Jr. 2010).

Interestingly, our results contradict previous findings from temperate region studies, where foraging activity of urban- and seabirds was negatively related to the presence of humans (*e.g.* Fernández-Juricic & Tellería 2000, Velando & Munilla 2011). It is plausible that the increased diversity, and thus abundance of food, at our tropical study sites (Brown 2014) allows birds to sustain foraging rates even in a more confined area. Besides resource availability, future investigations should also include a wider timeframe, thus allowing assessments of individual variation across time and the adaptive value of this response.

Escaping from an imminent threat requires prompt muscular response. In birds, flying is the fastest way of moving away, but also more energy demanding than running (Harrison & Roberts 2000). For this reason, birds should use flight over running for escaping solely when the risk is higher, thus allowing a faster response and reaching the farthest safe distances from the threat, as supported by our results.

Survival in urban habitats requires that birds cope with frequent interactions with humans, which ultimately lead to birds becoming more tolerant to that. Despite of that, our results show that syntopy with humans ultimately affects birds' foraging strategy and always result in birds escaping using a plastic response that varies according to human's density in the surrounding areas. By that, it is obvious that living in urban parks causes inherent stress responses in birds (*e.g.* raised heart rate, and escaping flight, Steven *et al.* 2011), which may ultimately affect individual fitness and population survival. Therefore, we highlight that to improve the chances of native urban-inhabitant bird species conservation it is important to ensure that parks have human-free areas, in which birds could find refuge for foraging and resting especially in days when the density of visitors increases such as during weekends.

ACKNOWLEDGEMENTS

Authors thank a grant by CNPq to L.T.M. (455908/2014-1), CAPES for a post-doctoral fellowship to A.C.G. (PNPD-1459754), and volunteer field assistants.

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Associate Editor: Carla S. Fontana.