On the lookout for danger: House Sparrow alert distance in three cities

Ian MacGregor-Fors[1], Javier Quesada[2], Jeffrey G.-H. Lee[3], Pamela J. Yeh[3,*]

[1]Red de Ambiente y Sustentabilidad, Instituto de Ecología, A.C. (INECOL), Antigua carretera a Coatepec 351, El Haya, 91070 Xalapa, Veracruz, Mexico

[2]Chordates Department, Natural Sciences Museum of Barcelona, Passeig Picasso s/n, 08003 Barcelona, Catalonia, Spain

[3]Department of Ecology and Evolutionary Biology, University of California, Los Angeles, 621 Charles E. Young Drive South, 90095 Los Angeles, California, United States

* Author for correspondence: pamelayeh@ucla.edu

Abstract The House Sparrow *Passer domesticus*, closely associated with human presence along urban–agricultural landscapes and widely distributed species outside its native range, has shown great morphological and physiological variations, with its plasticity linked to its invasiveness. Yet, there is a dearth of knowledge on the escape behavior of this sparrow along its North American invasion range. We here assessed House Sparrows alert distances in Los Angeles and Mexico City, but also in Barcelona as a control within its native distribution, considering 'city', 'sex/age' (adult males vs. adult females and immatures), and 'flock size' as alert distance predictors. Through a linear model and a classification and regression tree, we identified that House Sparrow alert distances in Barcelona were significantly larger when compared to both studied North American cities (Los Angeles, Mexico City). Given that alert distances were also significantly larger in Los Angeles when contrasted with those from Mexico City, where it has

been recently shown to be hyper-abundant, our results also suggest that its boldness could be related not only to an origin (native/non-native) driver, but also to a density-dependent process.

Keywords Barcelona, flushing distance, Los Angeles, Mexico City, *Passer domesticus*, urban ecology.

Introduction

The establishment or growth of an urban system goes beyond the often simplistic view of the replacement of pre-existing land-uses. Instead urbanization processes represent severe physical and ecological changes associated with fulfilling modern urban needs (Eldredge and Horenstein 2014). Although urbanization filters regional avian species pools, limiting the presence of an important proportion of species in cities (Aronson et al. 2014), there is growing evidence of changes to wildlife associated with adaptive responses to urbanization by those species able to overcome urban hazards and able to use the novel array of resources, which can ultimately drive adaptation and evolution (Díaz et al. 2013; McDonnell and Hahs 2015; Johnson and Munshi-South 2017; Samia et al. 2017). In the light of an increasingly urbanized planet, there is a pressing need to understand wildlife responses to urbanization (McDonnell and Hahs 2015; McDonnell and MacGregor-Fors 2016).

Fischer et al. (2015) suggested three types of urban wildlife species categories based on their population response to urbanization: (1) 'avoiders,' (2) 'utilizers,' and (3) 'dwellers.' Among urban 'dwellers,' some species can experience population explosions, which Blair (1996) coined as 'exploiters.' Avian urban exploiters have been widely studied in the search of the traits related to the successful species facing such a dramatic environmental scenario as the urban one (e.g., Kark et al. 2006; Vincze et al. 2015). Exploiters have also received attention in regards to their potential negative effects with native urban avifauna (MacGregor-Fors et al. 2010, González-Oreja et al. 2018). Among the most frequent cosmopolitan bird species, the Rock Dove *Columba livia* and House Sparrow *Passer domesticus* head the list, with both of them considered urban exploiters in many regions of the globe (Aronson et al. 2014).

The House Sparrow, which has been a human commensal species known to live in Eurasia before modern times (Lowther and Cink 2006), has been subject to study for decades due to its impressive range-expanding invasive capacity in several regions worldwide (Aronson et al. 2014). Currently, the House Sparrow has populations in most of Europe, a large proportion of Western, South-Central, and South-Eastern Asia, South-East Oceania, Southern Africa, most North America (except North-Central Canada and Greenland), Central America, and South America (except the Amazon Basin and the Caribbean region) (Summers-Smith et al. 2018). Specifically for North America, the House Sparrow was introduced in the New England area in at least 16 independent events from 1850–1881 (Brown and Wilson 1975). After colonizing most of the United States, it is presumed that the House Sparrow arrived to Mexico City by the 1930s (Wagner 1959), only 49–80 years after its initial introduction. Studies focused on House Sparrow morphological differences have found great variation across its North American range, generally regarding its adaptation to contrastingly different environmental and climatic scenarios in the face of the contrasting environmental heterogeneity of the regions it has successfully invaded (Johnston and Selander 1964, 1971; Lowther 1977).

House Sparrows have been extensively studied along their North American invasion range (mostly in Northern North America) for many decades now, including evidence of morphological differences along their northern invasion range, as well as their physiology (Johnston and Selander 1964, 1973; Kendeigh 1976, Lowther 1977, Martin et al. 2004). Yet, there is an important dearth of knowledge on the behavior of this species, essentially circumscribed to urban–agricultural landscapes throughout its North American invasion distribution. Recently, a study focused on House Sparrow densities in three urban–agricultural landscapes related to three cities (i.e., Barcelona, Los Angeles, Mexico City) showed differing

74 results among and within landscapes (MacGregor-Fors et al. 2017). Briefly, this study reports
75 higher densities in the studied landscape including Mexico City and lower densities in those of
76 Los Angeles and Barcelona, showing that their densities are not dependent from the origin of
77 their populations (i.e., native, exotic).

78 In this study, we assessed House Sparrow escape distances in the same three cities
79 considered in the aforementioned study (i.e., Barcelona, Los Angeles, Mexico City). We focused
80 on escape distances as they have shown to be a robust way to assess predation risk, specifically
81 the reaction to an approaching potential predator (Ydenberg and Dill 1986). In particular, alert
82 distance (i.e., distance at which birds become aware of a threat) has been used as an indicator of
83 the ability of birds to detect potential predators (Fernández-Juricic et al. 2001, Blumstein et al.
84 2004). Thus, escape distances have been long considered as useful approximations of how the
85 boldness or shyness of individuals (Wilson et al. 1994).

86 We had two mutually exclusive predictions related to a behavioral response (i.e., alert
87 distances) of House Sparrow and their population densities: (1) if their invasiveness is related
88 with their boldness, we then predicted individuals from Los Angeles and Mexico City (which are
89 part of the North American invasion population) to be less wary about human approaches than
90 those from Barcelona (which is part of the distribution range considered to be native for the
91 species), resulting in shorter alert distances in these two cities, and (2) if their densities are
92 related to their boldness, we then expected individuals in the city where higher densities were
93 recorded (i.e., Mexico City: average density during the breeding season: 11.6–21.7 ind/ha;
94 MacGregor-Fors et al. 2017) to be less wary about human approaches than those from lower
95 density cities (i.e., Barcelona: average density during the breeding season: 4.5–5.7 ind/ha; Los
96 Angeles: average density during the breeding season: 1.2–2.5 ind/ha; MacGregor-Fors et al.

2017), resulting in shorter alert distances in Mexico City when compared with Barcelona and Los Angeles.

Methods

Study area

We conducted this study in three cities where the House Sparrow is present: Barcelona (Catalonia, Spain), Los Angeles (California, United States) and Mexico City (Mexico). Barcelona is located in the south-eastern region of the Iberian Peninsula (41°23'30" N, 2°10'25" E; ~16 m above sea level), surrounded by the Mediterranean Sea and confined by a mountainous system. It is the second most populated city in Spain (~1.6 million inhabitants), with its metropolitan area housing 4.7 million residents (Demographia 2017). Los Angeles is located in the south-western coast of the United States (34°3'4" N, 118°14'37" W; ~86 m above sea level) (USCB 2012). The Los Angeles-Long Beach-Anaheim metropolitan area has approximately 12.1 million inhabitants. Finally, Mexico City is located in the Valley of Mexico, as part of the Transverse Volcanic Axis (19°25'56" N, 99° 7' 59" W; ~2200 m above sea level). According to the National Institute of Statistics and Geography of Mexico (INEGI 2010), the Metropolitan area has ~20 million inhabitants.

Fieldwork

We assessed House Sparrows alert distances by walking toward House Sparrows at different sectors of the studied cities during June and early July of 2016 (Barcelona: June 15–29; Los Angeles: June 8–July 7; Mexico City June 1–23). In Barcelona, El Poblenou, Eixample, Sant Pere, La Barceloneta, Sant Marti, Les Corts, Les Tres Torres, Sarrià-Sant Gervasi, Santa Eulàlia,

and Gornal; in Los Angeles, Fashion District, Flower District, Koreatown, Hollywood, Inglewood, Hawthorne, and El Pueblo; in Mexico City, Pedregal de Santa Úrsula, El Caracol, Villa Panamericana, and Pedregal de la Zorra. Given that after noticing our presence, House Sparrows tend to hop a few meters away from its initial position and can take several repetitions of such behavior before fleeing (often hoping under a car or fenced area) in some of our study areas, we did not measure flight initiation distances per se, a variable that has been widely studied for birds in the past (Cooke 1980; Erwin 1989; Fernández-Juricic 2000; Blumstein 2003, 2006; Anderson 2006). Thus, the response variable that was comparable among cities was the moment in which sparrows were wary of our presence (i.e., alert distance). Upon encountering a House Sparrow, one observer walked towards the targeted individual at a consistent pace (~2 km/h) to elicit a behavioral response. We recorded the following information when spotting a House Sparrow: (1) 'sex/age' (i.e., adult males vs. adult females and immatures), (2) 'flock size' (number of sparrows grouped in distances <2 m with the targeted individual), and (3) distance at which the individual evidently reacted to our presence approaching it (m), recorded using laser rangefinders (Bushnell Yardage Pro Sport 450). We note that the sampling sites were selected based previous knowledge regarding the presence of House Sparrows, as well as the accessibility to conduct the surveys.

Statistical analyses

To test differences in the alert distances of House Sparrows at the three studied cities, we performed a linear model (LM). Due to the lack of homogeneity of variance in ADs by city, we log-transformed (log(x+1)) ADs. We included 'city' (i.e., Barcelona, Los Angeles, Mexico City), 'sex/age', and 'flock size' as independent variables for the LM. In order to perform contrasts

among the three cities, we used the 'gmodels' package for R (function 'estimable'; Warnes et al. 2018). Based on the variables shown to be significantly related with our independent variable in the LM, we performed classification and regression trees (CARTs). This method uses binary recursive partitioning to identify independent variables that best explain variations in the dependent variable. CARTs consider deviance, which is analogous to the residuals of sum of squares in multiple regressions (used in a similar fashion to the forward procedure of independent variable selection) (Crawley 2013). To run CARTs, we used the 'rpart' package for R (Therneau et al. 2018). One of the particularities of 'rpart' is that it used ANOVAs to split the dataset into two mutually exclusive subsets based on an identified threshold for the independent variable explaining most variance of the dependent one at any given step. As the method is hierarchical, sample size deceases toward the terminal, furthest down node, given by the loss of deviance. Due to its procedure based in ANOVAs, 'rpart' is better than other ways of constructing CARTs at anticipating the results of model simplification, reason why there it no need to prune them. In its graphic representation, CARTs provide the mean value of the dependent variable at the terminal node of all identified scenarios. Thus, CARTs are a robust procedure to identify the scenarios under which the dependent variable changes in a dichotomous and hierarchical manner as a result of variations of the related independent variables at each step (Crawley, 2013). All statistical analyses were run in R (R Development Core Team, 2018).

Results

We gathered a total of 208 House Sparrow alert distance records in the studied cities. Specifically, we recorded the response of 106 individuals in Barcelona, 50 in Los Angeles, and 52 in Mexico City. House Sparrow 'flock sizes' ranged from 1 to 10 individuals (mean ± SD;

Barcelona = 1.5 ± 0.8 individuals, Los Angeles = 2.3 ± 1.9 individuals, Mexico City = 1.8 ± 1.7 individuals). House Sparrow alert differences were shorter for Mexico City (2.0 ± 2.7 m; max. 12 m), than those from the other two cities: Barcelona (8.5 ± 4.0 m; max. 20.8 m), Los Angeles (7.2 ± 5.2 m; max. 23.4 m).

The LM showed that only 'city' showed a significant relationship with House Sparrow ADs, while 'sex/age' indicated a non-significant trend ($F_{1,203} = 3.12$, $P = 0.07$), with adult males being less bold than adult females and juveniles (Table 1). ADs at all three cities showed to be significantly different (i.e., Barcelona–Los Angeles contrast: $t_{203} = 2.95$, $P = 0.003$; Barcelona–Mexico City contrast: $t_{203} = -12.83$, $P < 0.001$; Los Angeles–Mexico City contrast: $t_{203} = 8.10$, $P < 0.001$).

Considering 'city' and 'sex/age' (variables that showed a significant and a non-significant trend in the LM), the CART untangled their relationship with House Sparrow alert distances. Above all, it corroborated the hierarchical importance of 'city' in explaining recorded variations in House Sparrow alert distances at the studied cities. First, alert distances were shorter in Mexico City (average = 2 m), regardless of 'sex/age', when compared to any of the four scenarios identified for Los Angeles and Barcelona. Next, the CART subsequently splits Los Angeles and Barcelona, with 'sex/age' splitting variations in Barcelona, with adult male House Sparrow exhibiting 20% larger average alert distances (9.6 m) when compared to adult females and juveniles (7.9 m) (Figure 1).

Discussion

The ability to colonize and thrive in urban conditions is a key factor that facilitates the successful invasion of species (Møller et al. 2015; González-Lagos and Quesada 2017). In this study, we

found that House Sparrows from Mexico City were significantly bolder in terms of alert distances than those from Barcelona and Los Angeles (with also differed significantly among them), with 'sex/age' representing an important variables Barcelona. Given that alert distances were significantly higher in Barcelona when compared to those from Mexico City and Los Angeles, our findings support our first hypothesis (relation between House Sparrow invasiveness and boldness). Yet, due to the fact that alert distances were significantly lower in Mexico City when contrasted to those recorded at Los Angeles, our results are also in agreement with our second prediction, showing a positive association between alert distances and House sparrow densities, at least in cities where it is non-native and invasive (see MacGregor-Fors et al. 2017). Although it is impossible with our current dataset to determine if the sparrow boldness in Mexico City is associated with its large population density in the city or if its boldness allowed it to become highly successful (Nocedal 1987; Ortega-Álvarez and MacGregor-Fors 2009), our results suggest that this behavior could be tied to a density-dependent process.

Although our results clearly show that 'city' was the most important variable associated with shifts in House Sparrow alert distances, we also found a non-significant trend in the LM with 'sex/age'. These results were confirmed and explained by the CART, relating 'sex/age' only with Barcelona. In this case, the analysis shows that alert distances of adult males are longer than those for adult females and juveniles. Although we could not distinguish females from immature males in the field, this particular finding seems counter-intuitive in the light of the behavior of male House Sparrows, which have complex intra-sexual status signals and aggressive interactions (e.g., bib size, wingbars; Bókony et al. 2006), and they have been shown to be more resilient to certain stressors than females (Ensminger and Westneat 2012). Yet, this result could also be related to differences in the dominant status of the studied House Sparrows, which have

been documented to adopt different behavioral strategies in urban conditions (Lendvai et al. 2006). Indeed, the directional survival selection of the smaller intra-sexual status signals, which are positively related with boldness, has been recorded in urban passerine males in Barcelona, complimenting the reasons behind male boldness in comparison to females or immatures (Senar et al. 2014). Moreover, given that our study does not only consider sex, but also has an age component. Age has been shown to play an important role in avian flushing distances (Dhindsa and Boag 1989), and we suggest that future studies use field marks (e.g., extent of black around the eye, bib size; Nakagawa and Burke 2008) and survey over specified time-windows before the long breeding season of this species. In our case here, January seems to be the best option (*sensu* Summers-Smith et al. 2018) to untangle the relative role of these potential drivers on House Sparrow escape distances. Careful attention should be paid to local breeding periods, as this species has irregular and multiple breeding events across tropical and subtropical regions (Anderson 2006).

Regarding 'flock size', it was not found to be significantly related with House Sparrow alert distances by the LM, and thus were not included in the CART. A previous study performed in wooded parks of Madrid provided evidence that House Sparrows increase buffer distances with the number of conspecifics (Fernández-Juricic et al. 2002). Yet, other studies have shown that this sparrow can behave differently in heavily-urbanized sites when compared to other less-developed conditions (Vincze et al. 2015). Although we did not find 'flock size' to relate with alert distances, it is important to underline that most of our records were from birds in singles, pairs, or triples (overall 1.80 ± 1.43 individuals/flock; see Results for details by city). Although these numbers may seem low, they are in line with the 'flock sizes' reported for House Sparrows in several European cities (average 'flock size' 1.95 individuals; Samia et al. 2017).

Previous studies have shown that the response of wildlife species to human approach is species-specific (Blumstein 2003, 2006); yet, most studies focus on single locations, without comparing populations of the same species in which their densities differ. We recognize that our study considers only three cities during one field season, and therefore acknowledge the limitations of the generalization of our findings. Additionally, we are aware that we only tested one of the potential drivers of House Sparrow boldness, measured through alert distances; yet, there are many other factors, including confounding ones, that could also be behind our findings, including –but not only– habituation to humans (Møller 2008, Díaz et al. 2015), as well as human density (Møller and Díaz in press; Samia et al. 2017; Vincze et al. 2015), geographical differences (e.g., latitudinal behavioral responses; Díaz et al. 2013), and neuroendocrine traits (Chávez-Zichinelli et al. 2010; Liebl and Martin 2012). Nevertheless, our results clearly show that House Sparrow alert distances in one city located within the region where we consider it native (i.e., Barcelona) were significantly larger when compared to both studied North American cities. Given that alert distances were significantly larger in Los Angeles when contrasted with those from Mexico City (where it is hyper-abundant; MacGregor-Fors et al. 2017), our results also suggest that its boldness could be related to density-dependent processes. Based on our results and others in the literature, we suggest that future studies could add evidence to or refute this phenomenon by including a wider array of cities, testing hypotheses related to the familiarization to humans, geographical variations, as well as the physiology of House Sparrows, and including scenarios in which House Sparrows are hyper-abundant, as well as scarce, and finding strategies to sex and age all of the assessed individuals.

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401 Table 1. LM considering relationships between ‘city,’ ‘sex/age’ (i.e., adult males vs. adult
402 females and immatures), and ‘flock size’ with House Sparrow alert distances.
403

404	Variable	F	df	P
405	‘City’	83.11	2	< 0.001
406	‘Sex/Age’	3.12	1	0.079
407	‘Flock size’	1.80	1	0.181

Figure 1. Classification and regression tree (CART) relating ‘city’ and ‘sex/age’ with House Sparrow alert distances in the three studied cities. Numbers displayed at the bottom of the CART represent average alert distances under the ‘city’ and ‘sex/age’ scenarios. * ‘S/A’ = ‘sex/age’.