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Scientific note

Does habitat suitability affect flight-initiation distance in Burrowing owls?

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Fleeing from predators might save individual's life, however, being vigilant or fleeing consumes time, energy and decreases chances for feeding, mating, and protecting the nest. Thus, escaping preferentially occurs when the costs of fleeing is higher than remaining (Blumstein 2006, Cooper & Frederick 2007, Bateman & Fleming 2011). Additionally, there is a trade-off between foraging and being vigilant, influencing the decision-making process of staying or fleeing. This trade-off directly influences an animal's decision to remain and/or establish itself in different locations (Bateman & Fleming 2011). For example, in urban environments, the number of pedestrians reduced bird's abundance, and remaining individuals increased vigilance, reducing foraging, being this effect more intense in large animals (Fernández-Juricic *et al.* 2002). However, other factors may favor the individual's decision to flee, such as a menacing predator and the lack of shelter, contributing for the complex interactions leading to the fleeing decision (Price 2008, Dowling & Bonier 2018).

Here we evaluated, within an urban landscape, the influence of environmental suitability in the flight distance relative to possible predators. Environmental suitability is related to the species occurrence likelihood (Johnson 2007, Hirzel & Le Lay 2008, Wang *et al.* 2008). Modeling techniques using environmental suitability have been widely employed in areas such as conservation planning and trajectories studies (Rushton *et al*. 2004, Johnson 2007). Even though this idea was proposed almost 20 years ago (Frid & Dill 2002), as far as we are concerned, no study has ever adopted this approach towards the study of flight-initiation distance. We hypothesize that, in suitable environments, animals are more tolerant to predators' proximity because of the high benefits of permanence. In this context, the predation risk (directly associated with the predator proximity) would be balanced by the benefits of remaining in a suitable environment (Fig. 1A). To test this hypothesis, we used burrowing owls (*Athene cunicularia*) as model organisms. We chose this species because it is well-studied across its broad distribution in the Americas (see Lincer *et al.* 2018) and has a clear preference for open habitats occurring in disturbed environments (Rebolo-Ifrán *et al.* 2015, Baladrón *et al.* 2016, Cavalli *et al.* 2018, Conway 2018, Poulin *et al.* 2020).

We obtained the data during the non-breeding season, from July to September 2019, in the Federal District, Brazil (Figure 1B, 15°52'11.87"S,

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47°55'17.13"W), located in the Cerrado biome (Eiten 1972, Ribeiro & Walter 1998). The study area comprises a mosaic of urbanized areas (103.31 to 1.08 residents per hectare), agriculture, and conserved green areas covered by grassland, woodlands, and forests along streams and rivers (Eiten 1972, Ribeiro & Walter, 1998). The 2,827.4 km^2 studied area was previously characterized by an environmental suitability spatial model, developed to predict flight trajectories for the species, where we used a glm function with binomial family associating species presence data and eight land use and cover variables (for further details, see Figure S1 and Santos *et al.* 2021).

We measured the owl tolerance to a possible predator using the "Flight Initiation Distance" (FID), a widespread and well-established method (Fig. 1C, for more details, see Stankowich & Blumstein 2005, Price 2008, Møller 2010, Tätte *et al.* 2018, Pettit *et al.* 2021). We thoroughly searched for owl nests within the study area (~70 hours) and, at each nest found, one of the authors (C.O.D.) began to walk towards it at a steady pace (starting point of circa 150 m from the nest). Whenever an escaping behavior occurred, C.O.D stopped, and we measured the remaining, distance between the researcher and the nest with a 50 m tape measure, thus obtaining FID for each observation. We sampled 40 nests found in open green areas and, to ensure observation independence, we considered only the reaction of the first animal to fly in each nest sampled (for original data see Table S1). Since burrowing owls are territorial animals (Green & Anthony 1989, Haug & Oliphant 1990, Gervais *et al.* 2003, Moulton *et al.* 2004, Rosenberg & Haley 2004, Valdez-Gómez *et al.* 2018, Poulin *et al.* 2020), we can ensure that each owl was sampled only once.

We tested the influence of habitat suitability on FID considering two spatial scales: burrow adjacency and home range. We used average values of environmental suitability around each burrow (buffer) for a 50m buffer (representing the environmental suitability directly adjacent to the burrow) and a 600m buffer (representing the environmental suitability of the owls' home range – Green & Anthony 1989, Haug & Oliphant 1990, Moulton *et al.* 2004, Rosenberg & Haley 2004, Valdez-Gómez *et al.* 2018, Poulin *et al.* 2020). Each spatial scale buffer was extracted from the suitability raster using the *raster* package (Hijmans 2017). Next, we manually measured nest distance to the nearest pedestrian causeway (walkways, paths, trails) using a google earth satellite image (www.earth.google.com/web/) to control the effect of habituation towards pedestrians (Cavalli *et al.* 2016, Franco & Marçal-Junior 2018). Then, we adjusted a linear model (GLM) relating the suitability at 50m, the suitability at 600m, and the distance to the nearest pedestrian causeway (predictor variables) with the log-transformed FID values (response variable). We rejected the hypothesis of spatial autocorrelation among nests calculating the Moran's I test using model residuals as the input variable (Anselin 1995), using the distance matrix as an associated weight ($I = -0.063 \pm 0.07$, $P = 0.59$) (Gittleman & Kot 1990). We performed the analyses, using the function Moran.I, of package *ape* (Paradis and Schliep 2018). We checked for multicollinearity using the package *car* applying a VIF (variance inflation factor) threshold of 3 (Zuur *et al.* 2010). We used the R software in all analyses and visually evaluated model residuals.

We did not find significant relationship between FID and the environmental suitability (in both scales used) or pedestrian flow (Table 1, FID:

mean = 18.51, SD = 8.65; Suitability: 50m: mean = 25.70, SD = 1.76; 600m: mean = 25.62, SD = 1.46). Thus, we did not corroborate our hypothesis that predator tolerance, measured by the FID, would be inversely related to the environmental suitability (see Fig. 1A).

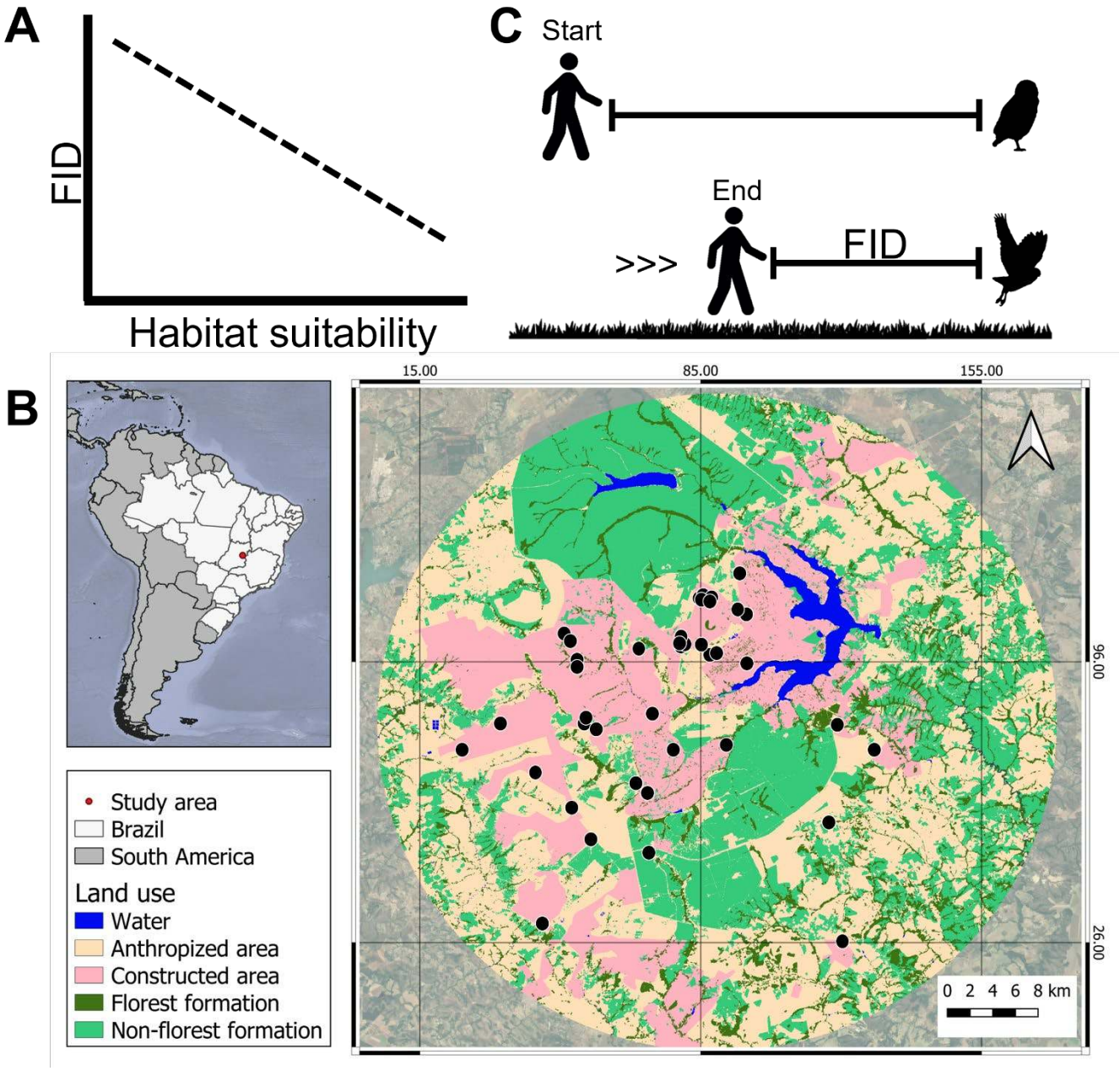


Figure 1. A) Hypothesis addressed in this study relating Flight Initiation Distance (FID) and habitat suitability; B) Study area showing the main land cover classes. Black dots represent our data collection locations. C) Flight-Initiation Distance (FID) used to measure the response of the owls to a potential predator.

Previous study has detected the influence of habitat suitability on burrowing owls' spatial occupation (Uhmann *et al.* 2001). Nevertheless, we did not observe the habitat suitability influence on the FID of burrowing owls in our study area. Indeed, our results showed that neither the suitability of the area directly adjacent to the nest nor the suitability of the individual's home range area influences the tolerance of human approximation.

The absence of the environmental suitability effect suggests that other aspects not investigated here, such as ecological filters, the presence of predators, and spatial scale, might be relevant in future investigations. Initially, urbanization filters

can dilute the environmental suitability effect (e. g. Cavalli *et al.* 2016, Franco & Marçal-Junior 2018). Although our study area is not strictly urban, it is an urban-influenced landscape presenting a gradient of human impact composed of noise, fire, agriculture, and human presence even within the green spaces. For burrowing owls, for example, urbanization is a relevant filter towards tolerant/bold animals, directly influencing the occupation of areas under the human influence (Carrete & Tella 2013). However, this does not seem to explain our results since we did not detect a significant response for proximity to pedestrian causeways and therefore there is no evidence that human presence favor bold animals within the explored range.

Table 1. Description to GLM results between FID (response variable) and habitat suitability at 50 m, 600 m, and pedestrian causeways distance (explanatory variables).

Predictors	**Coeficiente**	**Std. Error**	***t*-value**	***P*-value**	**Imp.**	**VIF**
(Intercept)	4.90	2.33				1.87
Habitat suitability 50 m	0.11	0.10	1.13	0.27	1.13	1.87
Habitat suitability 600 m	-0.20	0.12	-1.75	0.09	1.75	1.87
Pedestrian distance	0.00	0.00	-0.43	0.67	0.43	1.15

Notes: **VIF:** variance inflation factor; **Std. Error:** Standard error; **Imp.:** Importance. Residual standard error: 0.34; Adjusted R2: 2%; F-statistic: 1.20; p-value: 0.32.

Alternatively, human presence leads to predator reduction; and it has been detected that species occurring in urban-influenced environments get more abundant and simultaneously habituated to humans (Bateman & Fleming 2011, Stracey & Robinson 2012, Díaz *et al.* 2013, Rodriguez-Martínez *et al*. 2014, Rebolo-Ifrán *et al.* 2017). Future studies using additional predator models, such as dogs and taxidermized predators would be an alternative approach to disentangle human habituation and predator response (e.g. Carrete & Tella 2017).

Lastly, we did not find owls occupying locations with lower habitat suitability values in our extensive searches within the study area (see Table S1). Suitability values ranged from 1 to 32 and all nests were detected in areas with values above 20. Thus, it is possible that within our study area, owls choose places that do not differ sufficiently to influence flight distance. If this is the case, we must consider that future studies may detect different results if they adopt a broader geographic extension.

Moreover, negative scientific results are usually considered unpublishable and deemed "non-important" (Price 2008). Thus, we believe that our results (despite being negative) are relevant and bring light to the impacts on animal behavior that arise from changes in their habitats. In summary, our study provides evidence that, the environmental suitability does not affect the predator-induced flight response of burrowing owls.

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AUTHORS' CONTRIBUTIONS

EGS**: c**onceptualization, methodology, formal analysis, writing - original draft, visualization, investigation, writing - review & editing. COS: methodology, formal analysis, writing. HCW: supervision, writing - review & editing. All the authors actively participated in the discussion of the

results, they reviewed and approved the final version of the paper.

APPENDIX 1. Supplementary material

Supplementary data associated with this correspondence can be found at 10.6084/m9.figshare.18337721.

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