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Cover Photograph: A Cottontail Rabbit in an urban reserve (represents the study location). Illustration by Daniela Aimee Parra Campos.

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Sofia Abisag Montes-Rodríguez[1], Yury Glebskiy[1,2]*, and Zenón Cano-Santana[1]

Abstract: Fragmentation is a very common process in today's ecosystems, and understanding its effect on species is key to their management. In this particular case, we concentrate on the effect of a natural-urban edge on Eastern Cottontail population density. To estimate this, we measured Eastern Cottontail density using fecal pellet count on 21 transects drawn inwards from the edge of an urban reserve. A GLIM analysis was applied to the data and showed that Eastern Cottontail density was smaller at the edges of the reserve. Our result differs from previous studies and the common assumption that Eastern Cottontails benefit from the edges. This may be because previous studies concentrated on the natural-agricultural edge, which is generally softer and divides two areas that can provide certain resources for the Eastern Cottontail, whereas we studied a natural-urban border, which is more abrupt. Therefore, we propose incorporating buffer areas into the design of urban reserves.

Introduction

Habitat fragmentation is one of the major ecological threats to animals since it can isolate populations or divide natural areas into fragments too small to host certain species, although this rule is not universal (Betts et al. 2019). At the same time, fragmentation brings another challenge for conservation: the edge effect (Betts et al. 2019). The conditions at the edges could be beneficial for certain species or detrimental for others, thus reducing the effective area of conservation. However, it has to be noticed that the same species could respond differently to edges between different vegetation types (Ries and Sisk 2010), and understanding the effect of these edges is key to conservation efforts since these responses determine how much fragmentation a species can endure and the optimal design of a protected area.

In this case, we aim to understand the effect of the edge on *Sylvilagus floridanus* (Allen, 1890) (Eastern Cottontail). There is a fair amount of information on how edges affect this rabbit (Bertolino et al. 2011a, b, Morgan & Gates 1983, Pierse et al. 2011, Roseberry 1998), and from it, we can draw a general conclusion that this species benefits from the edges. However, the aforementioned studies concentrate on the edge between natural vegetation and agricultural fields, which is a softer transition between two vegetation types, both of which can provide cottontails with some resources. In our study, we concentrate on a much sharper edge between natural vegetation and an urban area. In this case, the disturbance by humans and vehicles presence is much higher and the resources provided by the urban area are lower. At the same time, this type of edges is less studied, at least for this species (although there are reports for the genus suggesting that the urban edge has little effect on *S. aquaticus*; Stevens et al. 2023). Therefore, the objective of this study is to understand the effect of an urban-natural edge on the density of Eastern Cottontails.

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Materials and Methods

Study location

For this study, we chose El Pedregal de San Angel natural reserve (henceforth El Pedregal), Mexico City, Mexico. This reserve has a surface area of 237 ha and is divided into 18 fragments surrounded and separated by the urban areas of Mexico City (SEREPSA 2022). The vegetation of El Pedregal consists of well-preserved xerophytic shrubs (Lot and Camarena 2009) that are separated from the urban areas by fences (Zambrano et al. 2016). This makes a perfect location for studying the edges between natural and urban areas. The Eastern Cottontail is the main herbivore in the area (Glebskiy 2016) that increases vegetation diversity (Fortis-Fernandez 2023), and is distributed in 4 El Pedregal fragments (Dorantes-Villalobos 2017). For this study, we excluded the smallest one (the buffer zone called "A8-Biológicas", since it is too small, consists entirely of edge area, and it is not clear if the population there is resident or Eastern Cottontails are visitors from a bigger area). The areas we chose for this study are 23.8, 53.7, and 114.4 ha, and are dominated by well-preserved natural vegetation. The three areas are surrounded by fences that separate them from the urban areas, and in most cases, there is no vegetation buffer between the reserve and urban infrastructure (roads and buildings). Fences prevent Eastern Cottontails from exiting the reserve and protect them from vehicular collisions and direct contact with humans, but there is no infrastructure that prevents them from approaching the fences, and they offer limited protection against sound and light from the urban area. For the purposes of this study, those fences were considered to be the border between natural and urban areas.

Method

We used fecal pellets count as an indirect measure of Eastern Cottontail density; previous studies have proven that this is an efficient method to estimate rabbit populations (Palomares 2001), and since the rugged terrain and vegetation of our study area prevent the use of direct observation technics, this method has been commonly used in the area (Dorantes-Villalobos 2017, Fortis-Fernandez 2023, Glebskiy et al. 2018). Previous studies show that Eastern Cottontail density is greatly influenced by terrain ruggedness (Glebskiy et al. 2018); therefore, this factor was also included in the analysis. We measured fecal pellet density between February and March 2018 using 21 lines 51 m long; each line consisted of 34 quadrants of 1.5 by 1.5 m (Fig. 1). All lines run from the edge fence inwards into the natural area; the distance between lines was at least 150 m. Pellet density was measured by meticulously inspecting the ground in 0.5 by 0.5 m quadrants. Terrain ruggedness was estimated using by dropping a measuring tape on the terrain and dividing the resulting length by the linear distance, similar to the method presented in Risk (1972) and Aronson and Swanson (1997); however, in our case, we measured the ruggedness of each quadrant independently.

Statistical analysis

Lines that contained no fecal pellets were excluded from the analysis, since those lines provide no information on Eastern Cottontails. We used a GLIM (Generalized Linear Model) with Poisson distribution to analyze the data. The response variable is the number of pellets per 0.5 by 0.5 quadrant, and the distance from the edge and terrain ruggedness are independent variables. To evaluate the contribution of each of the predictors, we evaluated the GLIM model using a step Akaike information criteria analysis.

Results

A total of 13 lines and 442 quadrants were used for this analysis (8 lines were excluded since they did not contain pellets). The average pellet density was 22.8 per m^2 (range: 0–628). The GLIM analysis showed an intercept of 1.723 and estimates of 0.0297 for distance from edge and -2.8419 for terrain heterogeneity index ($p < 0.001$ in all cases). The best model, according to the AIC, contained both predictors and scored 8535.6; the model using only distance to the border scored 9875.4; and only terrain ruggedness scored 9008.9.

Discussion

Our results show that both terrain heterogeneity and distance from edge affected Eastern Cottontail density. As previously reported (Glebskiy et al. 2018), Eastern Cottontails preferred plain terrains. The interesting result here is that Eastern Cottontail density is higher away from the edge, suggesting that the natural-urban edge is not suitable for Eastern Cottontails. This conclusion differs from most previous studies that show that Eastern Cottontails are tolerant to edges and are common in the natural-agricultural edges (Bertolino et al. 2011a, b; Morgan and Gates 1983; Pierse et al. 2011; Roseberry 1998). Therefore, we can conclude that urban areas surpass the ability of Eastern Cottontails to withstand disturbance. However, it is not clear what stops Eastern Cottontails from using edge zones in El Pedregal and two main hypotheses can be proposed: 1) the direct human disturbance such as light, sounds, smells, and trash thrown into the reserve scare Eastern Cottontails (although these factors had no impact on Swamp rabbit; Stevens et al. 2023), or 2) the vegetation associated with the edge is less suitable for their activities. In the last case, it is known that in the edges

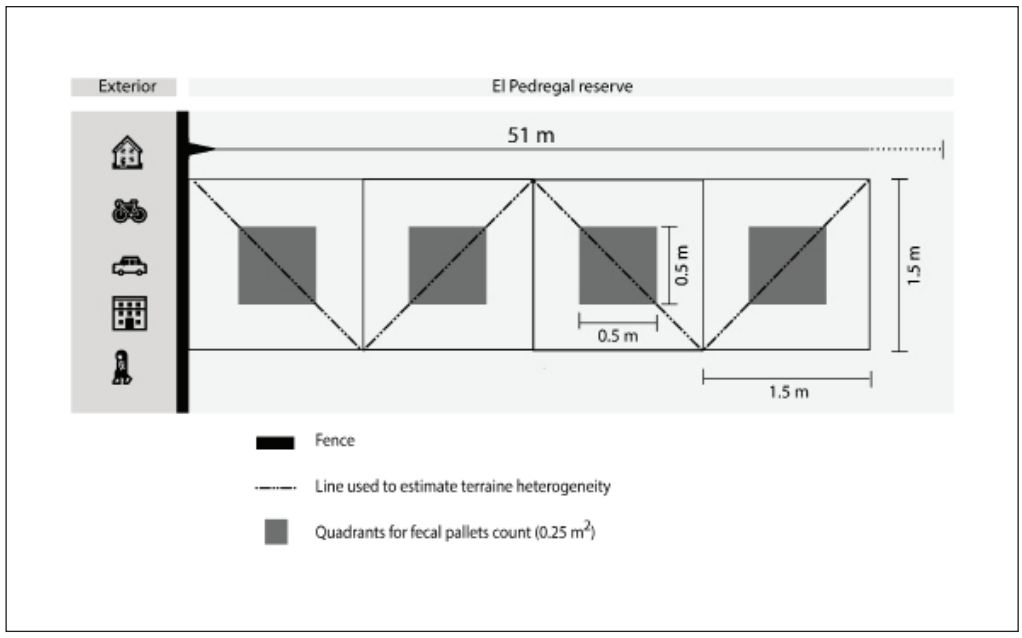

Figure 1. Schematic of the data collection lines. Data from each 1.5 by 1.5 quadrant was used for the GLIM analysis.

of El Pedregal exotics plants dominate the landscape (Noguez-Ledesma and Cano-Santana 2020) and some exotic vegetation has been shown to decrease the Eastern Cottontail population (Glebskiy et al. 2018). We consider that it is unlikely that the fences by themselves affect Eastern Cottontails since in previous studies we placed fences to exclude Eastern Cottontails from fragments of El Pedregal (Fortiz-Fernandez 2023, Glebskiy 2019) and those fences (between natural vegetation) had no effect on Eastern Cottontails.

This suggests that for Eastern Cottontails, the effective conservation area in urban reserves is smaller than the geographical area, this is important since many lagomorphs are sensible to fragmentation (Barbour and Litvaitis 1993) and cannot inhabit most urban reserves (Mora et al. 2020, Stevens et al. 2023, Verde-Aregoitia et al. 2015). Therefore, the ecological functions of lagomorphs (vegetation consumption, seed dispersal, prey for many carnivores, among others; Chapman et al. 1980, Glebskiy 2016, Glebskiy 2019) could be lost. And because of that, conservation of this species (including *S. floridanus*) becomes essential to the ecosystems' functions. Currently, the Eastern Cottontail is not an endangered species (Nielsen and Lanier 2019), however we consider that its conservation is important since losing this species even on a local level could affect other trophic levels for example, in our location Fortiz-Fernandez (2023) proved that in absence of Eastern Cottontails, plant diversity is diminished.

At the same time, given this species' endurance to edges in several other habitats (Bertolino et al. 2011a, b, Morgan and Gates 1983, Pierse et al. 2011, Roseberry 1998) it can be hypothesized that some other species could be even more affected by edges inside urban reserves, although more research is needed in this area. Therefore, we propose that the implementation of buffer areas around urban reserves must be considered, probably in a form of parks or gardens that soften the transition between the urbanized and strict protection areas.

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