CORNFIELD EFFECTS ON BREEDING AND ABUNDANCE OF *Oligoryzomys nigripes* (RODENTIA: SIGMODONTINAE)

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**ABSTRACT.** Small rodents rely on resource gathering during the breeding season to support their reproductive output and offspring survival. Since croplands may provide complementary food sources, we evaluated the influence of the presence of cornfield on the forest edge in *Oligoryzomys nigripes* (Olfers, 1818) abundance and breeding. We found that abundance, proportion of reproductive females and males, as well as the number of juveniles were higher in the cornfield-forest edges, with no seasonality, a pattern divergent from the seasonal reproduction described for the species. Therefore, our results supported the hypothesis of cornfields benefiting *O. nigripes* abundance and breeding success.

**RESUMO.** Efeitos do milharal na reprodução e abundância de *Oligoryzomys nigripes* (Rodentia: Sigmodontinae). Pequenos roedores dependem da aquisição de recursos para sustentar a reprodução e a sobrevivência da ninhada. Uma vez que plantações podem servir como fonte complementar de alimento, nós avaliamos a influência da presença de plantações de milho na borda da floresta sobre a abundância e a reprodução de *Oligoryzomys nigripes* (Olfers, 1818). Constatamos que a abundância, a proporção de indivíduos reprodutivos, assim como o número de juvenis foram maiores nas bordas dos campos de milharal, sem sazonalidade, um padrão divergente da reprodução sazonal descrita para a espécie. Nossos resultados suportam a hipótese de que as plantações de milho beneficiam a abundância e a atividade reprodutiva de *O. nigripes*.

**Key words:** agriculture impact, Cricetidae, edge effect, reproduction, rodents.

**Palavras-chaves:** impacto agrícola, Cricetidae, efeito de borda, reprodução, roedores.
Thus, in this study, we evaluated the influence of populations of rodents that feed on these crops (Bekele 1997; Makundi et al. 2003; Jacob et al. 2014). Populations of small rodents respond quickly to variations in the environment because their life-history traits can fit crop seasonality. These traits comprise a short life span, short gestation time, early reproduction and weaning, and large litter sizes with altricial young (Gaillard et al. 1989; Read & Harvey 1989). Additionally, rodents rely on resource gathering during the breeding season (income breeders) to support the reproductive output and offspring survival (Bonnet et al. 1998). Therefore, although food shortage in forests can limit rodent fitness (Prevedello et al. 2013), croplands might provide supplementary food sources to boost rodents’ reproduction (Ries & Sisk 2004).

In some cases, increase in reproduction could be a problem since rodents are natural reservoirs of zoonosis of human concern, and high population densities of rodents are often related to disease outbreaks (for review of rodent-borne diseases see Meerburg et al. 2009). Additionally, some rodent species are considered agricultural pests (Stenseth et al. 2003). With frequent human-rodent contact in cropland areas, understanding how croplands influence rodent populations is important not only for natural history purposes but also to develop strategies to deal with disease prevalence and rodent population management.

Oligoryzomys nigripes is a common granivore rodent with health implications as a nematode and virus reservoir (Figueiredo et al. 2001; Robles & Navone 2007; Meerburg et al. 2009; Souza et al. 2009). It presents high abundance in the Atlantic Rainforest, especially in edges near croplands in which it prefers to eat corn over natural food (Braga et al. 2015). Therefore, it is an optimal model to study croplands effects on rodents’ populations. Considering the frequent consumption of corn in food preference tests and the numerical dominance of this rodent in cornfield-forest areas (Braga et al. 2015), one could expect that an energetic surplus provided by the corn would influence O. nigripes populations. Thus, in this study, we evaluated the influence of cornfield-forest edges in breeding and abundance of O. nigripes. We hypothesize that both breeding and abundance vary between treatments and are higher in forest-cornfield edges due to the additional food supply provided by the cropland. We evaluate this hypothesis for over a year since food availability is seasonal for both forests and cornfields.

Fieldwork was conducted near the limits of the Parque Estadual Serra do Ouro Branco, located in Minas Gerais state, southeastern Brazil, between January and December 2010. This natural reserve is in an ecotone between two biodiversity hotspots: the Atlantic Forest and the Cerrado. Elevation varied between 900 and 1600 m, and the predominant vegetation is classified as Seasonal Semideciduous Forest, with Rocky Grasslands (“Campos Rupestres”) in higher elevations. Farm buildings and several croplands of corn and coffee surround this reserve (see map in Braga et al. 2015).

We collected individuals of O. nigripes in three sites (hereafter, “blocks”) at 1 to 2.8 km apart using a random-block sampling design. In each of these three blocks, we marked three sampling areas (hereafter, “treatments”): i) forest-cornfield edge, ii) forest-road edge, and iii) forest interior. The forest-cornfield edge has the target edge-effect of crop resources, while forest interior was a control for edge effect and forest-road edge was a control for the presence of crop resource (i.e., corn). With this design, we seek to disentangle resource and edge effects of cropland-forest edges. Habitat structure is very similar among treatments (Braga et al. 2015), reducing the interference of habitat variation on the cornfield edge effect. Corn is planted in October and harvested at the beginning of July for block I and in March for blocks II and III.

Rodent traps were placed in three adjacent Y-shape transects at 25 m apart in each treatment area. In each transect, we installed four pitfall traps consisting of partially buried 60 l buckets connected by 5 m long and 70 cm high drift fences. In total, we used 12 buckets in each treatment, 36 per block, thus 108 for the three blocks altogether. Pitfalls were opened for four nights per month over 12 months, from January to December of 2010. The total sampling effort comprised of 5 184 trap-nights, 1 728 in each block.

Rodents were ear-tagged (Rosaminas 1005-1), measured, and released at the same point of capture. We collected the first five individuals to confirm species identification by cytotgenetic analysis (Weksl & Bonvicino 2005) and they were deposited in the Taxonomic Collections of the Universidade Federal de Ouro Preto, Brazil. Fieldwork activities were licensed by Brazilian environmental institutions (Instituto Chico Mendes de Conservação da Biodiversidade, license number 21543-1).
Female reproductive status was classified into two categories: 1) pregnant: based on belly shape and size, and/or leaking milk. However, the number of reproductive females is likely to be underestimated, since pregnancy is clearly recognizable only at the end of the gestation period. Male reproductive status could also be underestimated because it is classified based on testicles development, and this evaluation is not very precise either (Cerqueira 2005).

Absolute and relative monthly frequencies of specimens, as well as their reproductive condition, were tabulated for each sex. Monthly abundance was calculated as the total number of first captures in each month. Capture success was calculated as the total number of captures divided by sampling effort. Sex ratio (SxR) was calculated dividing the number of females by the number of individuals in each treatment of each block (SxR=0.5: the same number of males and females, SxD=0.5: female-biased, and SxD<0.5: male-biased). The sex ratio is expected to be 0.5 in natural populations (Fisher 1930).

Monthly abundance values obtained in all pitfall traps were summed for each treatment in each block. To evaluate the effects of cornfield-edges on the *O. nigripes*’ population, we performed generalized linear mixed models (glmm) using abundance as a response to the treatments (corn, road, and interior), season (dry or wet), and the interaction between them as fixed factors. Blocks (I, II, and III) and months were random factors. We selected the best model based on the Wald test simplifying from the beyond optimal model to the simplest model, according to Zuur et al. (2009). We used the same approach to test cornfield-forest effects on female and male abundances as response variables. To address the reproduction consequences of cornfield-edge effects, we considered as dependent variables the proportion of reproductive males over adult males, the proportion of reproductive females over adult females, and the abundance of juveniles. Abundance data (for adults and juveniles) followed negative binomial distribution. Proportional data (for sexual deviation and proportion of reproductive male and females) followed Tweedie distribution. Models were built using package “glmmTMB” (Brooks et al. 2017), assumptions of the models (zero inflation, under- and overdispersion, temporal autocorrelation in residuals) were tested in the ”DHARMa” package (Hartig 2017). All analyses were run in software R v3.6.0. Details of the analysis protocol are available in the supplementary material S1.

Sampling resulted in 198 captures, of which 179 were first captures, resulting in a capture success of 3.8%. All recaptures were at the same place of the original tagged. There were 107 total captures (capture success: 6.2%) for the cornfield-edges, 43 (capture success: 2.5%) for the road-edges, and 48 (capture success: 2.8%) for the forest interior. The number of captures also varied between blocks, being 118 in block I, 34 in block II, and 46 in block III.

*Oligoryzomys nigripes* was more abundant in cornfield-edges, followed by road-edges, and forest interiors. The fluctuation pattern indicates that the population increased during the wet season and ceased growth in the dry season (Fig. 1). When *O. nigripes* abundance data are clumped by block, it reveals a high abundance between October and March, reaching its highest peak in November, and a period of low abundance between May and August. However, the model that best explained abundance includes treatment effect (Table 1) but did not detect a seasonal effect, possibly due to the great variability among blocks. For instance, block II is a cornfield plantation inserted inside a forest patch and does not present the traditional edge condition like blocks I and III, and *Oligoryzomys* is a species usually favored by edge-effects (Umetsu & Pardini 2007).

Sexual deviations did not vary between treatments or seasons (Table 1). We captured reproductive females throughout the year in all treatments, but the higher proportion was in the cornfields (Table 1, Fig. 2). As a result, the model that best explained variation in the proportion of reproductive females included only treatments, but not seasons. As for the proportion of reproductive males, it varied greatly. Reproductive males were more frequent in the cornfields, but no seasonality was detected in this treatment (Table 1, Fig. 2). In the interior, we detected reproductive males in a single month (September, wet season), whilst in the road, most of the males were reproductive throughout the whole wet season (September to February) and none in the dry season. The model for the proportion of reproductive males included treatments, season, and the interaction between these two.

We captured juveniles over the year in the cornfields, indicating that reproduction is continuous in this treatment, but their distributions in other treatments were less clear, what could be related to their smaller capture success. Hence, the variation in juvenile capture was explained by treatments (higher in the cornfield) but not by season (Table 1).
Table 1
Model selection for generalized linear mixed models (glmm) on *Oligoryzomys nigripes* population parameters in response to season and treatments (cornfield, forest interior, and road-edge). Fixed and random factors, and deviance results for the selected models (χ², d.f. – degrees of freedom). Beta values, and standard error (±SE) for each fixed factor. B: block; Mo: month; TA: total abundance; MA: male abundance; FA: female abundance; JA: juvenile abundance; PRF: proportion of reproductive females; PRM: proportion of reproductive males; SR: sex ratio; T: treatment; S: season; I: interior; R: road; W: wet.

| Response variable | Factors | Deviance Analysis | Treatment |
|-------------------|---------|-------------------|-----------|
|                   | Fixed   | Random            | β₀        | β₁ (±SE) | β₂ (±SE) | S          | S:T        |
| TA                | T (1B) + (1Mo) | 2               | 0.91 (±0.37)** | -0.82 (±0.24)** | -1.11 (±0.28)** | - | - | - |
| MA                | T (1B) + (1Mo) | 2               | 0.2 (±0.39) | -0.72 (±0.28)** | -0.89 (±0.30)** | - | - | - |
| FA                | T (1B) + (1Mo) | 2               | 0.13 (±0.38) | -0.94 (±0.31)** | -1.21 (±0.36)** | - | - | - |
| JA                | T (1B) + (1Mo) | 2               | -0.70 (±0.50) | -0.99 (±0.44)** | -0.99 (±0.45)** | - | - | - |
| PRF*              | T none   | 2               | -1.13 (±0.30)** | -0.85 (±0.53) | -1.47 (±0.64)** | - | - | - |
| PRM*              | T*S      | 5               | -2.22 (±0.56)** | -0.83 (±0.85) | -0.67 (±0.91) | 0.55 (±0.71) | 26.25 (±18.38) | 0.83 (±1.11) |
| SR                | none     | 1               | 1.51 | - | - | - | - | - |

*Proportion of reproductive individuals over non-reproductive individuals for males and females.

Details on the model selection results are presented in Supplementary Material.

Fig. 1. Monthly abundance of *Oligoryzomys nigripes* during the year 2010 in each treatment (Cornfield, Interior and Road) in the Serra do Ouro Branco (Minas Gerais, Brazil): A) three blocks clumped; B) Block I; C) Block II; and D) Block III.
**Fig. 2.** Relative frequency of reproductive and non-reproductive individuals throughout the year in the three treatments in the Serra do Ouro Branco.
a predominance of non-reproductive males during the winter, which is equivalent to the dry season in our study. The authors attributed this decrease to the higher recruitment in this period, but this is not the case in the present study, since the number of juveniles did not vary significantly between seasons and tend to be smaller in absolute numbers during winter. As proposed by previous studies, temporal variation in resource availability is the more probable explanation (Antunes et al. 2009; Galiano et al. 2013).

An extensive review of the literature showed that food supplementation boosts population growth of small mammals by increasing reproductive output and elevating the immigration rate (Prevedello et al. 2013). The continuous breeding, as performed by *O. nigripes* in the present study, has been considered as energetically expensive by Streilein (1982), since rodents are income breeders. Therefore, the extra resources obtained from corn are probably invested in reproduction, which explains the higher proportion of pregnant females and the number of juveniles in cornfield edges during the whole year.

The effect of food supply provided by cornfields may be similar to that observed in mast seeding episodes. Years with mast seeding production usually boosts rodent populations, often generating population outbreaks (Wolff 1996). The impact of cornfields on reproduction of *O. nigripes* may be higher than we detected here, since food supplementation provided by corn may affect other bionomic aspects not evaluated by us, such as litter size and weight (e.g., Karels et al. 2000).

The results found in this study are evidence of the complex effects of croplands in small mammal populations. Specifically, we highlight the positive effect of cornfields in rodent species, particularly regarding their recruitment. Although the patterns of abundance, reproduction, and the number of juveniles are strongly explained by treatment in all models, there is also variation among blocks that is not explained by models (Fig. 1). Then, there are other important factors affecting *O. nigripes* population not evaluated in this study that needs further investigation.

In a time when agriculture borders are expanding yearly, local adaptations of native fauna to the use of crop resources might be crucial to overcoming habitat loss and anthropic disturbances. Here we highlight the importance of understanding the positive effects of changes in land use on native fauna, which could shape future forest biodiversity, with potential economic and health impacts. We stress the importance of evaluating how crops can induce positive effects on rodent population size, including measurements not addressed in this study. In the specific case of *O. nigripes*, understanding cropland effects are even more critical, since this species carries human diseases, and croplands could favor epidemic outbreaks.

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