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POPULATION DENSITY OF *Crypturellus noctivagus noctivagus* (AVES, TINAMIDAE) IN THE PAMPA BIOME, SOUTHERN BRAZIL

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Abstract: *Crypturellus noctivagus noctivagus* is a forest bird endemic to Brazil. In the state of Rio Grande do Sul, the species is considered Critically Endangered, and is known for one relictual population in Pampa Biome. In this study, we estimated the population density of this relictual population using the Distance Sampling method. Samplings occurred from September to February, thus comprising three reproductive periods of the species (2012 to 2017). In total, 58 contacts were recorded with *C. n. noctivagus* individuals in the three reproductive periods. In each reproductive period 81.600 m were covered in trails. We found a density of 0.04 individuals/km², with an average probability of 18 adult individuals. Our results represent the first efforts for density estimation of this relictual population of *C. n. noctivagus*, which we suggest is composed by the last individuals in the state of Rio Grande do Sul, highlighting the need of local conservation.

Keywords: Distance Sampling; Relictual population; Tinamiformes; Yellow-legged Tinamou.

The Yellow-legged Tinamou *Crypturellus noctivagus* (Wied, 1820) (Tinamidae: Tinamiformes) is a land (terrestrial) bird, endemic from Brazil (Cabot 1992, Piacentini *et al.* 2015). This species occurs mainly in the residual forest areas of the Atlantic Forest, along the coastal area, primarily in well-conserved forest environments. However, it can be found in adjacent secondary habitats that still meet their trophic requirements (Cabot 1992, Sick 1997, Corrêa *et al.* 2019). There are two known subspecies: *Crypturellus noctivagus zabele* (Spix, 1825) and *Crypturellus noctivagus noctivagus* (Wied, 1820) (Cabot 1992, Sick 1997, Piacentini *et al.* 2015). In the state of Rio Grande do Sul, at the southern portion of the Brazilian territory, *C. n. noctivagus* was considered presumably extinct (Bencke *et al.* 2003). However, these authors warned of the importance of investigating the existence of *C. n. noctivagus* in forest remnants of the state, along the historical distribution areas of the species. Recently, a relictual population was rediscovered in the Pampa Biome (Corrêa *et al.* 2010), changing the current regional status to Critically Endangered (Rio Grande do Sul 2014).

This relictual population of *C. n. noctivagus* is known to be completely isolated in the region (Corrêa *et al.* 2010, Corrêa & Petry 2019), where the nearest population is recorded for the city of Praia

Grande, state of Santa Catarina (Corrêa *et al.* 2019). In the Pampa biome, some bioecological information has been already reported for *C. n. noctivagus* (Corrêa *et al.* 2010, Corrêa & Petry 2018, 2019). However, studies on the structure and dynamics of this relictual population of the Yellow-legged Tinamou are fundamental to propose measures for their conservation (Corrêa *et al.* 2010, Corrêa & Petry 2018, Corrêa *et al.* 2019). The objective of this study was to evaluate the population density of a *C. n. noctivagus* relictual population in Rio Grande do Sul, using the Distance Sampling method and to verify if there were differences in the number of contacts with the species along three reproductive periods.

This study was conducted in a forest fragment of approximately 450 hectares, in a private property located between the cities of São Sepé and Formigueiro, Rio Grande do Sul, not inserted in any Conservation Unit (30°05´35,3" S 53°36´22,9" W, Figure 1) (Corrêa *et al.* 2010). The vegetation in the fragment belongs to the Deciduous Seasonal Forest domain (IBGE 2004). The region presents a temperate climate, with an annual average temperature of 19 °C and an annual average precipitation of 1.750 mm (Alvares *et al.* 2013).

Five transects were delimited in the forest fragment covering a representative part of the total area, with the following dimensions: 500 m, 600 m, 700 m (two transects) and 900 m. The minimum distance between each transect was 300 m. Vegetation in a secondary succession stage composed the surroundings of the transects. Considering that the breeding period of *C. n. noctivagus* occurs during spring and summer, the sampling efforts in this study were therefore conducted during the months of September and February, comprising three breeding periods of the species: from 2012 to 2013, from 2015 to 2016 and from 2016 to 2017.

Samples were conducted biweekly in each transect and occurred at two times throughout the day: beginning after sunrise (6 am), traversing all transects in this period and second effort on

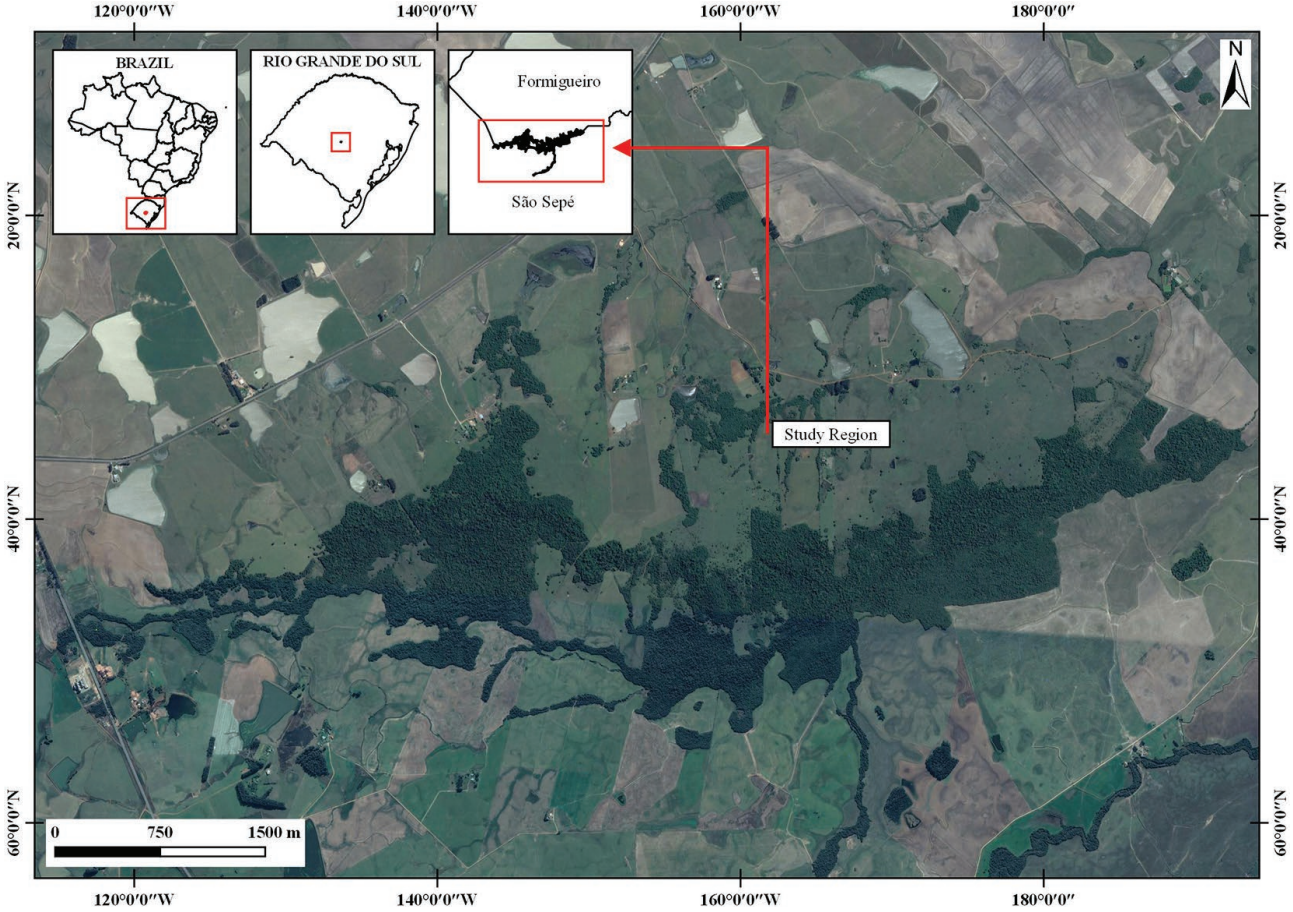

Figure 1. Study area located between the cities of São Sepé and Formigueiro, state of Rio Grande do Sul, Brazil.

the same date, beginning at 13 pm respectively. Transects were traveled by one researcher, at slow speed, avoiding sudden movements and noises during the displacement. In each biweekly survey, a total of 6.800 m was traveled. In each evaluated breeding period, each trail was traveled 24 times. We used the Distance Sampling method (by linear transect), following the basic premises, by measuring distances between the bird and the trail using a measuring tape (Thomas *et al.* 2006, Anjos *et al.* 2010). The detection radius was stablished at 0 to 50 meters (Figure 2).

Using Distance 7.0 software, we applied standard functions (Thomas *et al.* 2006), in order to obtain only the target-species density (we did not use functions of detection probability). We used all the collected data to perform the analysis: length of each transect, distance between each recorded bird and the respective transect, or absence of contact with the target-species, also including the total study area (in hectares) for the analysis. Simulations and adjusts available in the software were also used to improve the analysis, by defining the most suitable functions, considering the lower Akaike Information Criterion (AIC) value (*see details in:* Buckland *et al.* 2001, Thomas *et al.* 2006, 2010). Among the models available in Distance Sampling, we used the Half-normal/cosine adjustment function (AIC = 467.85), (IC = 95 %), (CV = 15 %), and standard. error (0.65). According to Buckland *et al.* (2001) in order to present accurate estimates using Distance Sampling, the coefficient of variation (CV) must not exceed 20 %. Thus indicating in our study an accurate estimate. In order to verify if there were differences in the number of contacts between the reproductive periods and months evaluated, a Kruskal-Wallis test was performed. Statistical tests were performed using BioEstat Software, assuming a significance level at $p < 0.05$ (Ayres *et al.* 2007).

In total, 58 contacts were recorded with *C. n. noctivagus* individuals in the three reproductive periods. In each reproductive period 81.600 m were covered in trails. The results indicate that the relictual population of *C. n. noctivagus* presents a density of 0.04 individuals/km² (with an average probability of 18 adult individuals). We recorded 18 contacts during the breeding period of 2012/13, 21 contacts during the breeding period of 2015/16 and 19 contacts during the breeding period 2016/17. However, we found no differences in the number of contacts among sampled breeding periods (Kruskal-Wallis, H = 2.0942, gl = 2, p = 0.35).

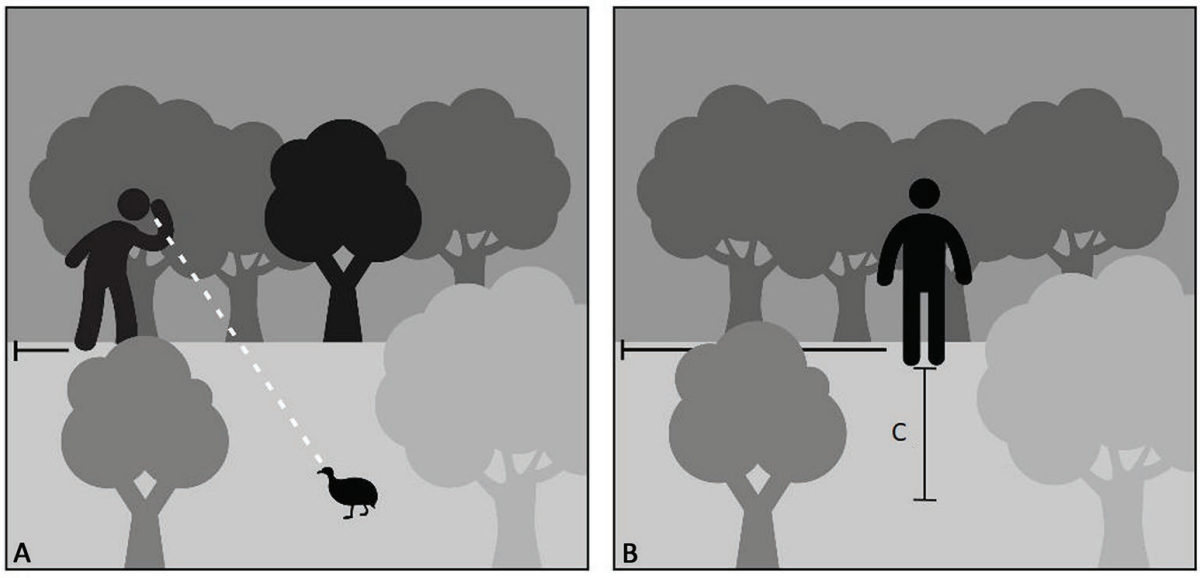

Figure 2. Graphic representation of the Distance Sampling method. (A) Researcher traveling a transect in a forest environment, observing a *Crypturellus noctivagus noctivagus* individual near the transect. (B) Researcher verifying the exact location of the contact with the bird. (C) Distance from the researcher to the trail, in meters (bird-trail distance).

Table I. Contacts per month with *Crypturellus noctivagus noctivagus* individuals, considering three reproductive periods. (N) = total number of contacts.

Period	Sep	Oct	Nov	Dec	Jan	Feb	N
2012/13	05	07	02	01	03	0	18
2015/16	03	04	05	06	01	02	21
2016/17	03	05	06	02	02	01	19
Total	**11**	**16**	**13**	**09**	**06**	**03**	**58**

When compared the number of contacts between months, October (n = 16) showed the highest number of contacts (Kruskal-Wallis, H = 21.0337, gl = 5, p = 0.01), indicating that Yellow-legged Tinamous are more conspicuous during this period in the region. February was the month in which the lower number of contacts occurred (n = 3, Table I). All contacts registered were from adult individuals, with no record of young individuals and/or adults with offspring.

The population data on the Yellow-legged Tinamou are scarce in the literature and this is the first study using Distance Sampling method to estimate the density of *C. n. noctivagus* in Brazil. Few studies have used this method for estimating forest tinamous species' population density (São Bernardo 2004, Negret *et al.* 2015, Ferreguetti *et al.* 2018). In the Alto Fragua Indi Wasi National Park, Colombia, Negret *et al.* (2015) estimated the density of the Black-tinamou *Tinamus osgoodi* in 13.47 individuals/km². In Brazil, São Bernardo (2004) estimated a density of 1.2 individuals/km² for the Solitary Tinamou *Tinamus solitarius* in a protected forest area in the state of São Paulo, while in the Espírito Santo state, the evaluated population of *T. solitarius* was estimated at 9 individuals/km² (Ferreguetti *et al.* 2018). These studies showed that Distance Sampling is a good method for obtaining field population data for forest tinamous' species.

According to previous information available at Birdlife International (2014), it is likely that in some large areas located within Conservation Unities (UCs), Yellow-legged Tinamou populations present about 30 adult individuals each, and it is suspected that the species is in a moderately fast and continuous population decline.

The present study revealed the existence of a small population of *C. n. noctivagus* in Rio Grande do Sul state (18 adult individuals), which is already under threat because of the isolation and vulnerability to human actions (Bencke *et al.* 2003, Corrêa *et al.* 2010). Areas with environmental suitability and which still have forest remnants in the region were predicted by Corrêa *et al.* (2019) for the occurrence of Yellow-legged Tinamou. In this way, long term monitoring of *C. n. noctivagus* in our study area is fundamental to evaluate population trends, as well as for obtaining information on reproduction, sexual ratio and habitat use of the species locally. This study represents important ecological information to support future conservation strategies.

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