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Article

Population density estimates for three endangered bird taxa from the Pernambuco Endemism Center, northeastern Brazil

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Abstract: Determining the relative risks of extinction of declining taxa is important to delineate conservation priorities and to guide the investments in conservation. Brazil concentrates the greatest number of endangered avian taxa on Earth, yet demographic information is lacking for most of them. Here we present distance-sampling population density estimates for three endangered bird taxa endemic to the Pernambuco Endemism Center (PEC), the most critically disturbed Atlantic Forest region. The analyzed taxa were the White-shouldered Antshrike *Thamnophilus aetiops distans* (Endangered), the Brown-winged Mourner *Schiffornis turdina intermedia* (Vulnerable), and the White-bellied Tody-tyrant *Hemitriccus griseipectus naumburgae* (Vulnerable). The estimated numbers of individuals/ha in an approximately 1,000 ha forest fragment were 0.21, 0.14, and 0.73, respectively. Our findings corroborated the premise that even taxa classified in similar threat categories based on habitat characteristics alone can have different population densities and consequently, divergent risks of extinction. Although population densities can vary among fragments, the extrapolation of our data to the whole PEC confirmed the Vulnerable status of the Brown-winged Mourner, and indicated the Vulnerable and Least Concern categories for the White-shouldered Antshrike and for the White-bellied Tody-tyrant, suggesting that for the two later taxa, the current classifications (Endangered and Vulnerable) based on their Areas of Occupancy must prevail.
Keywords: *Aves; Census; Distance sampling; Tropical forest; Atlantic Forest.*

Estimativas de densidade populacional em três táxons de aves ameaçados de extinção do Centro de Endemismo Pernambuco, nordeste do Brasil

Resumo: A determinação dos riscos relativos de extinção dos táxons ameaçados é importante para o delineamento de ações de recuperação e para o direcionamento dos investimentos em conservação. O Brasil é o país que possui o maior número de táxons ameaçados de aves, no entanto, informações sobre aspectos demográficos são inexistentes para a maioria deles. Neste trabalho são apresentadas estimativas de densidades populacionais, baseadas no método de amostragem por distância, para três táxons ameaçados de extinção endêmicos do Centro de Endemismo Pernambuco (CEP), a região mais degradada de toda a Mata Atlântica. Os táxons analisados foram a choca-lisa *Thamnophilus aetiops distans* (Ameaçada), o flautim-marrom *Schiffornis turdina intermedia* (Vulnerável) e a maria-de-barriga-branca *Hemitriccus griseipectus naumburgae* (Vulnerável). Os números de indivíduos/ha estimados para um fragmento de floresta de aproximadamente 1000 ha foram respectivamente 0,21, 0,14 e 0,73. Com isto, foi possível confirmar a premissa de que mesmo táxons classificados em uma mesma categoria de ameaça com base apenas em informações de hábitats podem possuir densidades populacionais bastante divergentes e portanto diferentes graus de riscos de extinção. Embora as densidades populacionais possam variar entre fragmentos, a extrapolação destes dados para toda a área do CEP confirmou a classificação de Vulnerável para o flautim-marrom e indicou as categorias Vulnerável e Pouco Preocupante para a choca-lisa e para a maria-de-barriga-branca, sugerindo que para as duas últimas, as classificações atuais baseadas nos tamanhos das suas Áreas de Ocupação (Ameaçada e Vulnerável) devem prevalecer.

Palavras-chave: *Aves; Censo; Amostragem por distância; Floresta tropical; Mata Atlântica.*

Introduction

Determining the relative risks of extinction of declining taxa is essential to indicate conservation priorities, and to optimize the investments in conservation (Rodrigues et al. 2006, Bennun et al. 2018). Red lists are predicted to provide this information to conservation managers, but a species assessment relies on a set of demographic information that are often unavailable (Bachman et al. 2019, Santini et al. 2019). Then, criteria related to habitat conservation and distribution, such as former and current habitat extension, reduction tendencies, and levels of fragmentation have been the most frequent parameters used for the categorization of many species (see ICMBio 2018, Santini et al. 2019). Although these criteria have been sufficient to include a relevant number of taxa in red lists, knowledge on demographic aspects is important for at least three main reasons: first, species vary naturally in population densities within target habitats (Gottschalk & Huettmann 2011), in such a way that in a same geographic region different species can have highly divergent population sizes; second, species sharing the same endangered habitats may respond differently to the effects of habitat disturbances, meaning that their risks of extinction are not uniform (Powell et al. 2015), and third, the determinants of the demographic parameters of many taxa may not be related only to habitat amount and quality, but also to other anthropogenic effects such as poaching and trapping (Bernardo et al. 2011, Alves et al. 2017). Then, censuses are essential to address the relative risks of extinction of endangered taxa, and their publications in the form of scientific articles, with detailed methodological descriptions, permit their reproducibility and the monitoring of future population tendencies (Alves et al. 2017, Tonetti & Pizo 2016).

Brazil is the richest country in the world in number of bird species, but it also concentrates the greatest number of endangered taxa (BirdLife 2021). Species inhabiting the Atlantic Forest are of special concern because this is where 120 (51%) of the 234 Brazilian endangered taxa, including subspecies, can be found (ICMBio 2018). Although the destruction and unsustainable exploitation of the Atlantic Forest has the potential for causing a catastrophic wave of global bird extinctions, censuses estimates are available only for very few taxa (see Alves et al. 2017, Tonetti & Pizo 2016).

The Pernambuco Endemism Center (hereafter PEC) is the portion of the Atlantic Forest distributed in northeastern Brazil, northern from São Francisco River, in the states of Alagoas, Pernambuco, and Paraíba. While it shelters a unique biota, with elevated levels of endemism (Tabarelli et al. 2006, Pontes et al. 2016), this is the most fragmented and degraded of the Atlantic Forest regions, with only about 12% of the forested areas remaining, all in small fragments (Ribeiro et al. 2009). This region has alarmed conservation practitioners because three bird species endemic to the PEC were recently recognized as globally extinct: the Pernambuco Pygmy-owl (*Glaucidium mooreorum*), the Cryptic Treehunter (*Cichlocolaptes mazarbarnetti*), and the Alagoas Foliage-gleaner (*Philydor novaesi*), and many others are on the verge of extinction (Pereira et al. 2014, ICMBio 2018). Paradoxically, demographic information needed to give raise to conservation plans is unavailable for most of them.

Here we provide distance sampling population density estimates for three endangered bird taxa endemic to the PEC, the White-shouldered Antshrike *Thamnophilus aetiops distans* (Endangered), the Brown-winged Mourner *Schiffornis turdina intermedia* (Vulnerable), and the White-bellied Tody-tyrant *Hemitriccus griseipectus naumburgae* (Vulnerable), from an Atlantic Forest fragment from the state of Alagoas, Brazil. Our findings were consistent with the premise that taxa classified in similar threat categories for inhabiting the same threatened habitats can have different population densities and likely divergent risks of extinction. It reinforced the fact that demographic information is urgently needed to improve the conservation planning of Atlantic Forest birds.

Material and Methods

1. *Study area*

Censuses estimates were performed in a 978-ha Private Natural Heritage Reserve (PNHR Mata do Cedro; 9°31'23.82"S; 35°55'6.53"O; altitude 120 m), at the municipality of Rio Largo, Alagoas state, northeastern Brazil (Figure 1). The area is surrounded by sugar cane plantations and the vegetation is classified as open ombrophilous forest (Roda & Santos 2005). Despite the selective logging occurred in the decades of 1970 and 1980 in most PEC fragments, tall forests with open understory can be found in slopes, and level areas are currently composed of tracts of habitats in middle and late regeneration stages, with tangled understory and emergent trees already present, e.g. *Parkia* and *Attalea* palms (Silveira et al. 2003, Roda & Santos 2005, Pereira et al. 2014, 2016). The climate is AS', following Köppen classification: tropical with a well-defined dry season from October through January, and a long rainy season corresponding to the months of the autumn and winter. Average annual rainfall is 1600–1700 mm, and average minimum and maximum temperatures range from 21–22°C, and 30–31°C, respectively (Roda & Santos 2005, Barros et al. 2012).

2. *Studied taxa*

The White-shouldered Antshrike *Thamnophilus aetiops distans* (Thamnophilidae) is an insectivorous passerine that occur in the understory of mature or secondary forests in late generation stages (ICMBio 2018). It forages near the ground and can follow army-ants to capture invertebrates, not rarely being a component of mixed-species flocks (Zimmer & Isler 2020). The species is known to occur in only 25 forest fragments from Alagoas, Pernambuco, and Paraíba states and it was classified as endangered (EN) due to an estimated occupancy area of only 244 km^2, (24.400 ha) that is highly fragmented and still experience severe threats (ICMBio 2018).

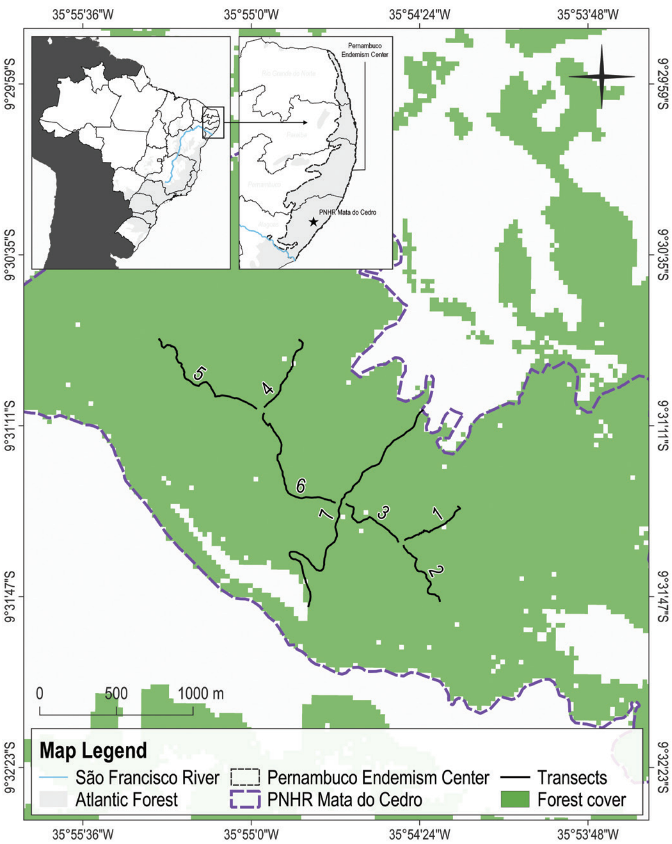

Figure 1. Pernambuco Endemism Center (PEC) in northeastern Brazil, and PNHR Mata do Cedro, located at the municipality of Rio Largo, state of Alagoas. The seven transects used for Distance-sampling population density estimates are represented by the numbered black lines.

The White-bellied Tody-tyrant *Hemitriccus griseipectus naumburgae* (Tyrannidae) is a small flycatcher that occurs in the understory and midstory of forested areas, where they are commonly seen capturing insects (Schulenberg 2020). Considering that the entire PEC is estimated to preserve 2.200 km^2 of Atlantic Forest (ICMBio 2018), and that the White-bellied Tody-tyrant avoids small fragments, the occupancy area of the species was estimated to be about 2000 km^2 by the Red List committee, reason why it was classified as Vulnerable (VU) (ICMBio 2018).

The Brown-winged Mourner *Schiffornis turdina intermedia* (Tityridae) is also restricted to the forested areas of the PEC. It inhabits forest mid-strata and feeds on fruits and insects (Snow & Kirwan 2020). It was classified as VU for the same reason of the White-bellied Tody-tyrant. Even in the absence of censuses, the population was estimated to be about 10,000 individuals, distributed in highly fragmented areas that cannot hold more than 1,000 individuals each, which, however, is still to be confirmed. All of these subspecies are endemic to the PEC; are geographically isolated from other subspecies and present diagnostic characteristics that led them to be classified as different forms (Schulenberg 2020, Snow & Kirwan 2020, Zimmer & Isler 2020). Taxonomic reviews, however, are still needed to confirm if they could receive the status of full species (ICMBio 2018).

3. *Population density estimates*

To estimate population densities of the three taxa, we used a line-transect distance sampling approach (Buckland et al. 1993, 2001). We established seven line-transects, with lengths varying from 0.5 to 2.17 km, that were distributed in forest interior and totaled 6.36 km. To avoid pseudoreplications, these transects were at least 100 m apart in the portions in which they were closest to each other (Figure 1). Field work was performed from October 2019 to January 2020, corresponding to the summer, when the days are longer and birds vocalize intensely, mainly in the morning, easing the detection by this method. Transects were walked 10 times by a single trained observer (LCP), with at least 10 days intervals, from 4:30–9:00 am, at an average speed of 1.5–2 km/h. The order of the transects walked in a day, as well as their directions were always previously assorted. For each bird detected visually or audibly, the perpendicular distance between the initial detection point and the transect line was sampled using a laser measuring tool (Stanley tlm100 – 30 mt) to improve data accuracy. To minimize potential detection errors related to unrecognized vocalizations performed by the studied taxa, the observer accumulated at least 5 hr of observations for each taxa before the start of the population density surveys to become familiar with their sounds. We did not establish truncation distances, we sampled both sides of the transects, and individuals of all ages and sex were considered. In total, we accumulated 140 hr of field work, distributed across 31 days. We have not performed surveys during rainy or windy days to avoid detection problems, and we never used playbacks to stimulate bird responses.

4. *Statistical analyses*

Population densities were estimated using the model selection procedure of the software Distance 7.0 (Thomas et al. 2010), by which pre-defined detection functions (uniform, hazard-rate, half-normal, and negative exponential key functions) are applied to model how detection probability decreases across perpendicular distance classes, generating corrected population density estimates (Buckland et al. 1993, 2001, Thomas et al. 2010). Since each of the four detection functions can be associated to cosine, hermite polynomial, and simple polynomial adjustments, we exploited a total of 12 different models for each taxon. To select the model that best fitted the data, we used Akaike's Information Criteria (AIC), the goodness-of-fit test of Kolmogorov-Smirnov, and the visual analyses of quantile-quantile plots (Q-q plots). To reach the minimum number of 50 records necessary for Distance efficient modeling (Buckland et al. 1993, 2001, Thomas et al. 2010), the set of transects was treated as a unique longer transect for the statistical analyses, and the records obtained in the different transects were pooled together (see also Bernardo et al. 2011). Then, the obtained number of individuals per hectare was subdivided by the number of replicates (n = 10) to generate the actual population density estimates. We used the analytical approach, with default parameters settings, to estimate the coefficients of variation (dCV) and lower and upper 95% confidence intervals associated to population density data. For comparative purposes, we also used Distance 7.0 to estimate the average probabilities of detection (PD) of the individuals of the different taxa, as well as their associated lower (LCL) and upper 95% confidence limits (UCL), and coefficients of variation (pdCV).

Results

In total, considering the 10 transect replicates, we obtained 105 records for the White-shouldered Antshrike, with perpendicular distances varying from 2.1 to 70 m (25.33 ± 18.01); 110 records for the Brown-winged Mourner, with perpendicular distances varying from

Table 1. Results of the model selection procedures used to estimate population densities (D) for the White-shouldered Antshrike (*Thamnophilus aetiops distans*), the Brown-winged Mourner (*Schiffornis turdina intermedia*), and the White-bellied Tody-tyrant (*Hemitriccus griseipectus naumburgae*) using distance sampling approach. Models were selected based on AIC Criteria, and the ΔAIC indicated their relative importance. Estimates of lower (LCL) and upper 95% confidence limits (UCL), coefficient of variation (dCV), and probability of the Kolmogorov-Smirnov goodness-of-fit test (P) are provided for the density estimates, which were calculated by pooling 10 transect replicates together. The Probabilities of Detection (PD) of the individuals of the different taxa, as well as their associated lower (LCL) and upper 95% confidence limits (UCL), and coefficients of variation (pdCV) were also estimated.

	AIC	ΔAIC	D (LCL–UCL)	dCV	P	PD (LCL–UCL)	pdCV
White-shouldered Antshrike							
Uniform Cosine	862.41	0.00	2.39 (1.90–3.01)	0.12	0.008	0.49 (0.39–0.62)	0.12
Half-Normal Cosine	868.79	6.38	1.95 (1.69–2.24)	0.07	0.009	0.61 (0.53–0.70)	0.07
Hazard-Rate Cosine	**863.13**	**0.72**	**2.06 (1.60–2.64)**	**1.28**	**0.070**	**0.57 (0.45–0.74)**	**0.13**
Neg. Exponential Cosine	864.41	2.00	2.39 (1.90–3.01)	0.12	0.008	0.49 (0.39–0.62)	0.12
Brown-winged Mourner							
Uniform Cosine	**930.24**	**0.00**	**1.30 (0.90–1.88)**	**0.19**	**0.098**	**0.83 (0.57–1.00)**	**0.19**
Half-Normal Cosine	937.07	6.83	1.49 (0.83–2.65)	0.30	0.027	0.73 (0.41–1.00)	0.30
Hazard-Rate Cosine	932.20	1.96	1.36 (1.28–1.46)	0.03	0.085	0.79 (0.74–0.85)	0.03
Neg. Exponential Cosine	937.45	7.21	1.48 (0.95–2.29)	0.22	0.030	0.73(0.47–1.00)	0.22
White-bellied Tody-tyrant							
Uniform Cosine	2572.44	7.40	7.33 (6.19–8.68)	0.09	0.023	0.51 (0.43–0.60)	0.09
Half-Normal Cosine	2571.80	6.76	7.45 (6.24–8.89)	0.09	0.045	0.50 (0.42–0.59)	0.09
Hazard-Rate Cosine	**2565.04**	**0.00**	**7.26 (6.69–7.87)**	**0.04**	**0.231**	**0.51 (0.47–0.55)**	**0.04**
Neg. Exponential Cosine	2574.44	9.40	7.33 (6.19–8.68)	0.09	0.023	0.51 (0.43–0.60)	0.09

0.5 to 80 m (32.37 ± 16.57), and 330 records for the White-bellied Tody-tyrant, with perpendicular distances varying from 1.0 to 70 m (20.16 ± 13.07).

Because cosine, hermite polynomial, and simple polynomial adjustments resulted in only slight variations in modeling results, only the results of each key detection function with cosine adjustments were used for population density estimates and were shown in Table 1. For the White-shouldered Antshrike, although the key detection function with the lower ΔAIC value was Uniform Cosine, the Kolmogorov-Sminov goodness-of-fit test was significant for this model, indicating a poor model fit, which was corroborated by a relatively high CV (Table 1). On the other hand, the Hazard-Rate detection function was the only presenting non-significant goodness-of-fit test and had only slightly bigger AIC value compared to the best model based on ΔAIC (Uniform Cosine) (Table 1). Further, the plot of detection probabilities across perpendicular distances, and the Q-q plots demonstrated no relevant deviations (Figures S1A and S1B).

For the Brown-winged Mourner, the key detection function with lower ΔAIC was Uniform Cosine, and its adherence to the data was confirmed by the non-significant goodness-of-fit test (Table 1). Although the Hazard-Rate model also had non-significant goodness-of-fit test, the graphic depicting the detection probabilities distributed according to perpendicular distances and the Q-q plots visually evidenced the best fit of the Uniform Cosine model (Figures S1C and S1D).

For the White-bellied Tody-tyrant the Hazard-Rate Cosine detection function returned the lowest ΔAIC, and it was the only model with non-significant goodness-of-fit test (Table 1). The graphic of detection probability versus perpendicular distance and the Q-q plot did not evidence remarkable deviations and also provided a visual evidence that this model was well-fitted (Figures S1E and S1F).

In Table 1 we present population density estimates (D) obtained by pooling together the 10 transect replicates. After correcting the data (subdividing by 10), the resulted numbers of individuals per hectare estimated with the selected models were 0.21 for the White-shouldered Antshrike, 0.14 for the Brown-winged Mourner, and 0.73 for the White-bellied Tody-tyrant. Then, the expected numbers of individuals of the three taxa in our study area of 978 ha were 205, 137, and 714, respectively. The probabilities of detection (PD) were 0.57 for the White-shouldered Antshrike, 0.83 for the Brown-winged Mourner, and 0.51 for the White-bellied Tody-tyrant.

Discussion

1. *Population density estimates*

Distance-sampling population density data are scarce for Neotropical forest passerines. For the EN Black-cheeked Ant-tanager, *Habia atrimaxillaris* (Thraupidae), densities across Costa Rican populations varied from 0.24 to 0.27 individuals/ha (Cornils et al. 2015), and for the Near Threatened (NT) Atlantic Forest endemic Southern Bristle-Tyrant, *Phylloscartes eximius* (Tyrannidae) it was 0.13 individuals/ha (Tonetti & Pizo 2016). These data are close to our findings for the White-shouldered Antshrike (0.21 individuals/ha) and for the Brown-winged Mourner (0.14 individuals/ha), respectively, while for the White-bellied Tody-tyrant population density was much higher (0.73 individuals/ha).

An important assumption of the distance-sampling method is that all birds in the first perpendicular distance band should be detected (Bernardo et al. 2011, Cornils et al. 2015), and violations to this assumption could mean that birds are avoiding the trails, or that they have moved before being detected by the observer (Buckland et al. 1993, 2001, Thomas et al. 2010, Bernardo et al. 2011, Cornils et al. 2015). Our plots of detection probabilities across perpendicular distance bands indicated that this assumption was violated to some level for all of the analyzed taxa, an effect that was more drastic for the Brown-winged Mourner. A way to avoid this type of error is using point-counts instead of transect-based distance-sampling methods (see for instance Tonetti & Pizo 2016) because point-counting is independent of the use of trails, which reduces the effects of observer displacement. Here, point-counting was tested but it was inefficient due to the low number of records, which could compromise model fit (see also Buckland et al. 1993, 2001, Thomas et al. 2010). Despite the potential residual variances introduced in our estimates by this sampling artifact, other procedures used to address model fitting, i.e. the goodness-of-fit tests, the Q-q plots, density confidence limits and variation coefficients returned satisfactory results, suggesting that our estimates are still good proxies of the population densities of the analyzed taxa. Average probabilities of detection (PD) were high for the three studied taxa, when compared, for instance, with the Southern Bristle-Tyrant (0.08 to 0.14) (Tonetti & Pizo 2016). The values we obtained (all above 0.5) were comparable to those reported for large tropical forest game-birds, such as curassows (Alves et al. 2017), suggesting that the lower population density estimates found for the Brown-winged Mourner, for example, may not be associated with potential detectability problems.

Behavioral differences between sexes can be another important source of bias in distance-sampling analyses (Alves et al. 2017). For passerine birds, for instance, divergent vocalization patterns between males and females can affect detectability, misleading population density estimates, especially when males have louder territorial songs (Bibby et al. 2000). Among our study species, this seemed not to be a problem for the White-shouldered Antshrike and for the White-bellied Tody-tyrant, that were more often detected by visual cues or by their short calls likely emitted by both sexes. On the other hand, Brown-winged Mourners were rarely seen, and they were detected mainly when they displayed their main songs. We are unaware, however, if females also display the main songs; if males could vocalize more frequently, or even if sex biased densities can occur. Due to the lack of sexual dimorphism in this taxon, correct multipliers could be generated only by the observation of marked, molecularly-sexed individuals, which should be in the scope of future studies. It is worth noting that population densities of the studied taxa may vary across the studied fragment due to habitat heterogeneity. However, because our transects have covered large portions of the fragment we are confident that we have provided good overall estimates of population densities for the area.

2. *Importance for conservation*

Population densities can differ across fragments of habitats due to varying environmental conditions (Magrach et al. 2011, Kattan et al. 2014), meaning that our data, collected in only one area, could be used to generate only rough approximations of the global population sizes of the studied taxa. However, because no other demographic information exists for the addressed taxa, below we present preliminary inferences about their conservation status. During the elaboration of the Brazilian Red List of Endangered Bird Species, members of the assessment committee estimated the Area of Occupancy (AOO) for some of the taxa from the PEC, being AOO the area of suitable habitat effectively occupied by a taxon (IUCN 2019). For the White-shouldered Antshrike, AOO was calculated as the summation of 4 km^2 grids in which the species was known to occur, which resulted in an area of approximately 244 km^2. Then, this taxon was listed as EN based on the criteria B2ab(ii,iii) from IUCN (AOO is <500 km^2) (ICMBio 2018, IUCN 2019). The multiplication of the estimated AOO by the population density we found resulted in a global population of 5,124 individuals, which according to the IUCN population size criteria (criteria C) would place this taxon in the VU category (population of mature individuals between 2,500 and 10,000) (IUCN 2019), confirming that it is threatened, and evidencing that its current EN status based on its limited AOO must prevail.

For the Brown-winged Mourner AOO was not provided, but despite the lack of censuses data the global population was estimated to be about 10,000 individuals, with no subpopulations presenting more than 1,000 reproductive animals (ICMBio 2018). Then, this taxon was listed as VU based on criteria C2a(i), which means that the number of mature individuals in each subpopulation should be 250–1,000 (IUCN 2019). The Brown-winged Mourner presented the lowest population density estimate (0.14 individuals/ha). With such a low population density, an area of approximately 7,143 ha would be necessary for keeping a subpopulation of 1,000 individuals, but in a thorough mapping work, the biggest PEC fragment had approximately 3,500 ha (Pontes et al. 2016), which based on our data could retain ~490 individuals. These extrapolations are obviously problematic, but in the absence of further data we suggest that the decision of the Brazilian Red List committee to include this taxon in the VU category due to the limited sizes of the individual subpopulations should be maintained.

The White-bellied Tody-tyrant, on the other hand, was considered by the Red List committee as a frequent taxon, for which AOO was assumed to be an approximation of the total amount of Atlantic Forest from the PEC fragments (~2,000 km^2). Then, the latter was listed as VU based on the IUCN criteria B2ab(iii), i.e. AOO is less than 2,000 km^2, with areas that are fragmented and still declining (ICMBio 2018, IUCN 2019). Of the three addressed taxa, the White-bellied Tody-tyrant was the one of least conservation concern under a demographic perspective. Considering the C2a(i) criteria, the number of 1,000 birds per subpopulation needed to reach the Least Concern (LC) category could be reached in areas above 1,370 ha, which are scarce, but still occur in the PEC. Further, if the AOO estimate of 2,000 km^2 presented in Brazilian Red List for this taxon is true, the global population of the White-bellied Tody-tyrant could be around 146,000 individuals, which is highly above the 10,000 individuals necessary to reach the LC category based on the population size criteria of IUCN (C criteria) (IUCN 2019).

Our findings corroborated the premise that demographic information is important to indicate conservation priorities and to optimize the investments in conservation (Rodrigues et al. 2006, Bennun et al. 2018), as taxa listed in the same categories based on habitat parameters only, proved to have highly variable population densities and likely divergent risks of extinction. Future studies may address population densities in other areas to improve censuses estimates, and may focus on the generation of more precise habitat availability data for each of the taxa. It is surprising that red lists in the country with the higher concentration of endangered bird taxa are almost entirely devoid of demographic information, providing only rough information to direct the use of the scarce resources available for the implementation of conservation actions. It is worth noting that the taxa we studied are among the most frequent passerines from PEC fragments (Lobo-Araújo et al. 2013), and our preliminary population size extrapolations confirmed that two of these taxa are facing some level of threat also under a demographic perspective. It means that demographic studies on many other less frequent taxa, i.e. large frugivorous and birds of prey, are urgently needed.

Supplementary Material

The following online material is available for this article:

Figure S1 – Detection probabilities at different perpendicular distances, and Q-q plots obtained respectively for the White-shouldered Antshrike (A and B), the Brown-winged Mourner (C and D), and the White-bellied Tody-tyrant (E and F).

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Author Contributions

Luiza Carvalho Prado: work delineation; data collection; data analyses; manuscript preparation.

Thiago da Costa Dias: work delineation; data analyses; manuscript preparation.

Lahert Willian Lobo-Araújo: work delineation; data analyses.

Luís F. Silveira: work delineation; data analyses; manuscript preparation.

Mercival R. Francisco: work delineation; data analyses; manuscript preparation.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Data Availability

The datasets generated during and/or analyzed during the current study are available at: https://doi.org/10.48331/scielodata.T3U4P5

References

ALVES, F., LÓPEZ-IBORRA, G.M. & SILVEIRA, L.F. 2017. Population size assessment of the Endangered Red-billed Curassow *Crax blumenbachii*: accounting for variation in detectability and sex-biased estimates. Oryx 51:137–145.

BACHMAN, S.P., FIELD, R., READER, T., RAIMONDO, D., DONALDSON, J., SCHATZ, G.E. & LUGHADHA, E.N. 2019. Progress, challenges and opportunities for Red Listing. Biol. Conserv. 234:45–55.

BARROS, A.H.C., ARAÚJO FILHO, J.C., SILVA, A.B. & SANTIAGO, G.A.C.F. 2012. Climatologia do estado de Alagoas. Boletín de pesquisa e desenvolvimento 211. Embrapa, PE, Brasil.

BENNUN, L., REGAN, E.C., BIRD, J., VAN BOCHOVE, J.W., KATARIYA, V., LIVINGSTONE, S., MITCHELL, R., SAVY, C., STARKEY, M., TEMPLE, H. & PILGRIM, J.D. 2018. The Value of the IUCN Red List for business decision-making. Conserv. Lett. 11:1–8.

BERNARDO, C.S.S., RUBIN, P., BUENO, R.S., BEGOTTI, R.A., MEIRELLES, F., DONATTI, C., DENZIN, C., STEFFLER, C.E., MARQUES, R.M., BOVENDORP, R.S., GOBBO, S.K. & GALETTI, M. 2011. Density estimates of the Black-fronted Piping Guan in the Brazilian Atlantic rainforest. Wilson J. Ornithol. 123:690–698.

BIBBY, C.J., BURGESS, N.D., HILL, D.A. & MUSTOE, S.H. 2000. Birds census techniques. Academic Press, USA.

BIRDLIFE INTERNATIONAL. 2021. Country profile: Brazil. Search available at: http://www.birdlife.org/datazone/country/brazil (last access in 25/02/2021).

BUCKLAND, S.T., ANDERSON, D.R., BURNHAM, K.P. & LAAKE, J.L. 1993. Distance Sampling: Estimating abundance of biological populations. Chapman and Hall, London.

BUCKLAND, S.T., ANDERSON, D.R., BURNHAM, K.P., LAAKE, J.L., BOCHERS, D.L. & THOMAS, L. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press. New York

CORNILS, J.S., RIEDL, I., FRICKE, J., KATZ, M. & SCHULZE, C.H. 2015. Population density and habitat preferences of the Black-cheeked Ant-tanager *Habia atrimaxillaris*. Bird Conserv. Int. 25:306–321.

GOTTSCHALK, T.K. & HUETTMANN, F. 2011. Comparison of distance sampling and territory mapping methods for birds in four different habitats. J. Ornithol. 152:421–429.

ICMBio 2018. Livro vermelho da fauna brasileira ameaçada de extinção: Volume III – Aves, 1.ed. ICMBio/MMA, Brasília, DF.

IUCN 2019. IUCN Standards and petitions committee. Guidelines for using the IUCN Red List categories and criteria. Version 14.

KATTAN, G.H., RONCANCIO, N., BANGUERA, Y., KESSLER-RIOS, M., LONDOÑO, G.A., MARÍN, O.H. & MUÑOZ, M.C. 2014. Spatial variation in population density of an endemic and endangered bird, the Cauca Guan (*Penelope perspicax*). Trop. Conserv. Sci. 7:161–170.

LOBO-ARAÚJO, L.W., TOLEDO, M.T.F., EFE, M.A., MALHADO, A.C.M., VITAL, M.V.C., TOLEDO-LIMA, G.S., MACARIO, P., SANTOS, J.G. & LADLE, R.J. 2013. Bird communities in three forest types in the Pernambuco Centre of Endemism, Alagoas, Brazil. Iheringia Ser. Zool. 103:85–96.

MAGRACH, A., LARRINAGA, A.R. & SANTAMARÍA, L. 2011. Changes in patch features may exacerbate or compensate for the effect of habitat loss on forest bird populations. PLoS ONE 6(6):e21596.

PEREIRA, G.A., ARAÚJO, H.F.P. & AZEVEDO-JÚNIOR, S.M. 2016. Distribution and conservation of three important bird groups of the Atlantic Forest in north-east Brazil. Braz. J. Biol. 76:1004–1020.

PEREIRA, G.A., DANTAS, S.M., SILVEIRA, L.F., RODA, A.S., ALBANO, C., SONNTAG, F.A., LEAL, S., PERIQUITO, M.C., MALACCO, G.B. & LEES, A.C. 2014. Status of the globally threatened forest birds of northeast Brazil. Pap. Av. Zool. 54:177–194.

PONTES, A.R.M., BELTRÃO, A.C.M., NORMAN, I.C., MALTA JR., A.D., SILVA JÚNIOR, A.P.D. & SANTOS, A.M.M. 2016. Mass extinction and the disappearance of unknown mammal species: Scenario and perspectives of a biodiversity hotspot's hotspot. PLoS ONE 11(5):e0150887.

POWELL, L.L., CORDEIRO, N.J. & STRATFORD, J.A. 2015. Ecology and conservation of avian insectivores of the rainforest understory: A pantropical perspective. Biol. Conserv. 188:1–10.

RIBEIRO, M.C., METZGER, J.P., MARTENSEN, A.C., PONZONI, F.J. & HIROTA, M.M. 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. Biol. Conserv. 142:1141–1153.

RODA, S.A. & SANTOS, A.M.M. 2005. Avaliação de fragmentos florestais para uma possível reintrodução do mutum-de-alagoas em seu ambiente natural. Centro de Pesquisas Ambientais do Nordeste – CEPAN.

RODRIGUES, A.S.L., PILGRIM, J.D., LAMOREUX, J.F., HOFFMANN, M. & BROOKS, T.M. 2006. The value of IUCN Red List for conservation. Trends Ecol. Evol. 21:71–76.

SANTINI, L., BUTCHART, S.H.M., RONDININI, C., BENÍTEZ-LÓPEZ, A., HILBERS, J.P., SCHIPPER, A.M., CENGIC, M., TOBIAS, J.A. & HUIJBREGTS, M.A.J. 2019. Applying habitat and population-density models to land-cover time series to inform IUCN Red List assessments. Conserv. Biol. 33:1084–1093.

SCHULENBERG, T.S. 2020. White-bellied Tody-Tyrant (*Hemitriccus griseipectus*), version 1.0. In Birds of the World (T. S. Schulenberg, Ed.). Cornell Lab of Ornithology, Ithaca, NY, USA.

SILVEIRA, L.F., OLMOS, F. & LONG, A.J. 2003. Birds in Atlantic Forest fragments in north-east Brazil. Cotinga 20:32–46.

SNOW, D. & KIRWAN, G.M. 2020. Brown-winged Schiffornis (*Schiffornis turdina*), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie & E. de Juana, eds). Cornell Lab of Ornithology, Ithaca, NY, USA.

TABARELLI, M., SIQUEIRA-FILHO, J.A. & SANTOS, A.M.M. 2006. Conservação da Floresta Atlântica ao norte do rio São Francisco. In Biodiversidade biológica e conservação da Floresta Atlântica ao norte do rio São Francisco (K.C. Pôrto, J.S. Almeida-Cortez, M. Tabarelli eds) Brasília: Ministério do Meio Ambiente. Pp. 41–48.

THOMAS, L., BUCKLAND, S.T., REXSTAD, E.A., LAAKE, J.L., STRINDBERG, S., HEDLEY, S.L., BISHOP, J.R.B., MARQUES, T.A. & BURNHAM, K.P. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. J. Appl. Ecol. 47:5–14.

TONETTI, V.R. & PIZO, M.A. 2016. Density and microhabitat preference of the Southern Bristle-Tyrant (*Phylloscartes eximius*): Conservation policy implications. Condor 118:791–803.

ZIMMER, K. & ISLER, M.L. 2020. White-shouldered Antshrike (*Thamnophilus aethiops*), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie & E. de Juana, eds). Cornell Lab of Ornithology, Ithaca, NY, USA.

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