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HABITAT ASSOCIATIONS OF LAND BIRDS IN FERNANDO DE NORONHA, BRAZIL

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ABSTRACT Fernando de Noronha is one of few archipelagos of Brazil. These islands harbor five species of land birds: two introduced species (House Sparrow, *Passer domesticus*, and Cattle Egret, *Bubulcus ibis*), one widespread dove (Eared Dove, *Zenaida auriculata*) and two endemic passerines. The two endemic species, Noronha Vireo (*Vireo gracilirostris*) and Noronha Elaenia (*Elaenia ridleyana*), have been classified as 'Near Threatened' and 'Vulnerable', respectively. Here, we quantified the abundance of land birds and correlated it to habitat features to assess potential habitat preferences. We carried out 120 five-minute point counts in October 2009, and correlated bird abundance with percentages of woodland, bushes, low herbs, bare ground, and man-made habitats in each sample. The abundance of Noronha Vireo and Noronha Elaenia was positively correlated with woodland and bushes cover. The Eared Dove was associated to sites with bare ground, the House Sparrow with man-made habitats, and the Cattle Egret with low vegetation sites. Abundances of Noronha Vireo and Noronha Elaenia were significantly higher in sites with natural vegetation than in human-influenced areas. The association between these species and areas with high native vegetation cover highlights their potential vulnerability to human disturbance.

RESUMO · Associações entre os ambientes e as aves terrestres de Fernando de Noronha, Brasil
Fernando de Noronha é um dos poucos arquipélagos do Brasil. Estas ilhas abrigam cinco espécies de aves terrestres: duas espécies introduzidas (*Passer domesticus* e *Bubulcus ibis*), uma pomba com ampla distribuição (*Zenaida auriculata*) e duas espécies de passeriformes endêmicos (*Vireo gracilirostris* e *Elaenia ridleyana*). Estas duas espécies são classificadas como "quase ameaçada" (*V. gracilirostris*) e "vulnerável" (*E. ridleyana*). Neste estudo, quantificamos a abundancia das aves terrestres e correlacionamos com as características de habitat do arquipélago de Fernando de Noronha. Fizemos 120 pontos de escuta de cinco minutos em outubro de 2009, comparamos a abundancia de aves com a porcentagem de ambientes contendo vegetação árvobórea, arbustos, vegetação rasteira, solo aberto e construções amostradas em um raio de 25m. A abundancia de *V. gracilirostris* e de *E. ridleyana* é positivamente correlacionada com porcentagem de cobertura de árvores e arbustos. A abundancia de *Z. auriculata* está positivamente correlacionada com a porcentagem de solo aberto, a abundancia de *P. domesticus* com construções e de *B. ibis* com a porcentagem de vegetação rasteira. As abundancias de *V. gracilirostris* e *E. ridleyana* são significativamente maiores em locais com vegetação conservada, distante das vilas. As associações entre as espécies endêmicas e a porcentagem de cobertura vegetal enfatiza a vulnerabilidade destas aves a ocupação humana.

KEY WORDS Abundance · Brazil · *Bubulcus ibis* · *Elaenia ridleyana* · Fernando de Noronha · Habitat preference · *Passer domesticus* · *Vireo gracilirostris* · *Zenaida auriculata*

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INTRODUCTION

Environmental changes endanger bird species by replacing natural habitat with modified environments that often do not provide essential resources (McKinney 2002). Consequently, native species richness tends to decrease while introduced species generally increase in abundance and richness in these modified environments (Crooks & Soulé 1999, McKinney 2002). For these reasons, many bird species are declining to unsustainable populations levels as their habitat is changed, fragmented and impacted by human activities (Zedler et al. 2001).

The consequences of habitat change are amplified in isolated sites, such as islands, since bird communities and habitat structure are relatively constant and less complex than continents (Yu & Lei 2001). Island birds are, at least, 40 times more susceptible to extinction than continental populations (Trevino et al. 2007, Martin & Blackburn 2012). Fewer than 20% of all birds are endemic to islands, yet 39% of all threatened bird species are island dwellers (Johnson & Stattersfield 1990). Avian extinction in these isolated sites is primarily caused by habitat destruction, limited range and introduced species (Johnson & Stattersfield 1990, Blackburn et al. 2005). Consequently, defining the habitat requirements of island species are important actions proposed for the protection of endangered island birds (BirdLife International 2012).

Fernando de Noronha is one of the few archipelagos in the Northeastern Brazilian coast. These islands shelter the richest marine bird community in the country, and consequently are classified internationally as an important area for bird conservation in the world (IBA BR062) (Vooren & Brusque 1999, BirdLife International 2014). Most of the published work on Noronha birds deals with marine species (e.g., Murphy 1915; Oren 1982, 1984; Nacinovic & Teixeira 1989; Antas et al. 1990a, 1990c, 1991; Schulz 1995, 2004; Mestre et al. 2009). However, these islands also harbor terrestrial birds (hereafter land birds).

The land birds in Fernando de Noronha include the two endemic terrestrial passerines Noronha Vireo (*Vireo gracilirostris*) and Noronha Elaenia (*Elaenia ridleyana*), a non-endemic species of the Eared Dove (subspecies *Zenaida auriculata noronhae*, which is also found in the continent), and two introduced species, Cattle Egret (*Bubulcus ibis*) and House Sparrow (*Passer domesticus*). The endemic passerine species are classified as 'Near threatened' (Noronha Vireo) and 'Vulnerable' (Noronha Elaenia) (BirdLife International 2012a, 2012b). Habitat change due to tourism and village expansion, together with land clearing and predation by exotic species are the major threats for the endemic species (BirdLife International 2012).

The endemic avifauna of Fernando de Noronha is of high conservation significance, but remains poorly studied. Given the current land use and the potential degradation of habitats (imposed by tourism and village expansion permitted in some parts of the island), it is important to understand the habitat preferences of land birds of Noronha to assist conservation actions (Oren 1982, 1984; Olson 1994, Ridgely & Tudor 1994, Schulz 2004, Oppel et al. 2004, BirdLife International 2014). Therefore, our paper will focus on defining habitat associations of land birds by comparing bird abundance in different sites with different habitat characteristics, helping to identify key areas for conservation in the Archipelago of Fernando de Noronha.

METHODS

This study was conducted in the main island (Ilha Principal) of Fernando de Noronha Archipelago located 345 km from the northeastern Brazilian coast (3°52'00"S, 32°26'00"W). The group of volcanic islands (26 km^2) is composed of a main island (17 km^2) and 15 small islets (IBAMA 1990, Figure 1). The main island is about 10 km long and 3 km wide, and it is the only one inhabited by humans, with about 3000 permanent residents and receiving around 70,000 tourists per year (Oren 1982, IBGE 2010). The vegetation was strongly degraded in the past, and the main island was a prison for 201 years, until 1957 (IBAMA 1990). Islands with natural vegetation (mostly the main island) are covered by a secondary dry vegetation dominated by vines and shrubs (e.g., *Capparis cynophallophora*, Capparaceae; *Cassia* sp., Fabaceae; *Sapium sceleratum,* Euphorbiaceae), sometimes grading into open woodland with some emergent trees reaching 20 m in height (e.g., *Bumelia sartorum*, Sapotaceae; *Spondias* spp., Anacardiaceae; *Ficus noronhae*, Moraceae; *Erythrina velutina aurantiaca*, Fabaceae), low herbs (e.g., *Hypomoea* sp., Convolvulaceae; *Merremia* sp., Convolvulaceae), and open areas (IBAMA 1990). Human colonization brought invasive animals, such as exotic birds, lizards, rodents, cats, goats and cows, affecting the endemic flora and fauna (Olson 1981, Oren 1984). Fernando de Noronha is officially protected, with 70% of the area classified as a National Park and 30% as Environmental Protection Area (IUCN Category V, Área de Proteção Ambiental –APA, IBAMA 1990). The Environmental Protection Area permits regulated land use and colonization (IBAMA 1990).

The main island is considered to be the core habitat of the land birds of Noronha (Oren 1982, Olson 1994). Most of the natural vegetation cover of the archipelago is found there, supporting the populations of five resident bird species: Noronha Vireo, Noronha Elaenia, Eared Dove, House Sparrow, and Cattle Egret. The two endemics Noronha Vireo and Noronha Elaenia inhabit shrubs, woodlands, and gardens of the archipelago, and can persist in secondary habitats (Oren 1982, Olson 1994). The Eared Dove is

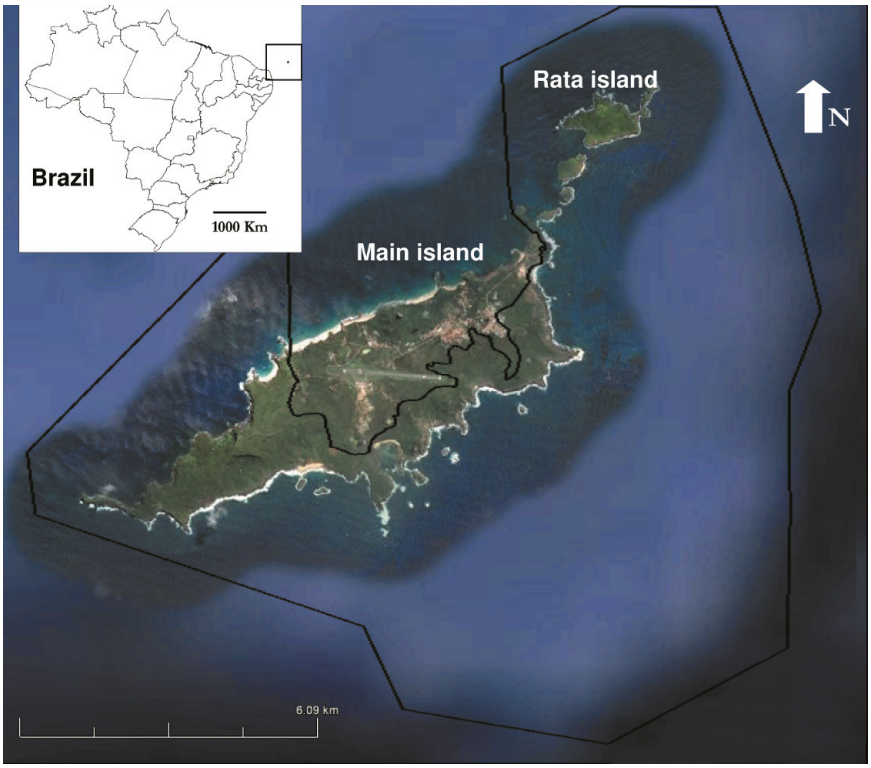

Figure 1. Map of Fernando de Noronha Archipelago, showing the National Park border represented as a solid line. Environmental Protection Area (Área de Proteção Ambiental) and villages are outside the polygon in Main Island (adapted from "Fernando de Noronha," 3°50'46.36"S 32°24'48.34"O. 20/04/14. Google Earth, Image 2016 Digital Globe). Insert indicates location of archipelago (grey dot in square).

the most abundant terrestrial bird in these islands, and belongs to a widespread subspecies (also occurring in the Brazilian States of Maranhão, Piauí and Bahia) (Schulz 2004). The exotic House Sparrow was probably introduced recently (no records until the 1980's but increasingly encountered since the 1990's; Oren 1982, Schulz 2004), and the Cattle Egret was first reported in the 1980s (Oren 1982, Schulz 2004, Nunes et al. 2010). Sporadically, other terrestrial exotic birds have been observed in the archipelago (i.e., *Aratinga solstitialis*, *Paroaria dominicana*, *Sporophila leucoptera*, *Sicalis flaveola*) but do not constitute stable populations (Oren 1984, Schulz 2004).

We carried out 120 five-minute point counts (within a 25 m radius, excluding flying birds) separated by at least 150 m (to avoid counting the same individuals twice) along almost all available trails of the main island (we recorded coordinates of each point using a GPS unit). Surveys were conducted from 20 to 28 October 2009, during the morning between 05:30 h and 09:00 h. We compared the abundances between species using ANOVA tests (followed by Tukey pots-hoc tests). We estimated percentages of each habitat feature in each point count. We used percentages of five classes of features within the 25 m radius. We divided habitat features in 1) "woodland" (vegetation with more than 5 m high, with thicker and lignified trunks), 2) "bushes" (or shrubs, plants with small diameter and few lignified branches between 0.5–5 m), 3) "low herbs" (short plants between 0–0.5 m high, including vines and herbs), 4) "bare ground" (open land, rocks, sand, or open trails), and 5) "man-made" habitats (including roads, houses, and other man-made installations; see examples of sites in Figure 2). We compared the percentages of each feature to the bird abundance in each point count by Principal Component Analysis (PCA), using correlation matrix, and correlating PCA scores with the abundance of each species. We also tested for correlations between the percentages of habitats and abundance of each species and within species using Spearman rank correlations implemented in Past Software (Hammer et al. 2001). To compare the abundances of each species in sites classified as anthropic or conserved, we selected point counts in the villages and in isolated trails. We classified as anthropic the 16 points performed in the in human influenced areas in the villages (not on the roads), characterized with more than 40% of man-made habitats, only in the Environmental Protection Area (in human occupation permitted sites). Additionally, we used 19 points to represent the conserved areas, performed exclusively in non-occupied sites in the core area of the National Park, without man-made influenced habitats and far from the villages. We com-

Figure 2. Examples of the most representative habitats in Fernando de Noronha, Brazil. A) Woodland; B) Shrub vegetation (left) with low herbs (right); C) Woodland (left), bare ground, and man-made (right; borders and unpaved roads); D) Man-made habitats (sidewalks, streets), bare-ground (on left near sidewalks). Photographs by Andreza Amaral and Juliana Rechetelo.

pared these points with non-parametric Two-Sample Permutation tests. Bird abundances were plotted and compared graphically in DIVA 7.5 Software (Hijmans et al. 2012) and figures adapted from Google Earth (Version 7.1.2.2041).

RESULTS

We counted a total of 1251 land birds including 361 Eared Doves (mean = 3.00, SE = 0.43), 354 Noronha Elaenias (mean = 2.95, SE = 0.23), 304 Noronha Vireos (mean = 2.53, SE = 0.19), 192 House Sparrows (mean = 1.6, SE = 0.29), and 40 Cattle Egrets (mean = 0.33, SE = 0.07). Overall, we found significant differences in the abundance of the five species (ANOVA, $F = 17$, $df = 4$, $p < 0.0001$). Relative abundances of Eared Dove, House Sparrow, Noronha Elaenia, and Noronha Vireo were not statistically different (Tukey, all $Q < 3.4$, $p > 0.1$), but House Sparrow abundance was significantly lower than Eared Dove and Noronha Elaenia abundance (Tukey, all $Q > 4$, $p < 0.05$), and Cattle Egret abundance was significantly lower than that of the other species (Tukey, all $Q > 4$, $p < 0.05$). We found strong correlations between bird abundance and habitats. The PCA analyses and Spearman rank correlations revealed strong correlations between Noronha Vireo and Noronha Elaenia abundances and the percentage of woodland and bushes, while Eared Dove and House Sparrow were associated with sites with higher percentage of bare ground and man-made habitat, and Cattle Egrets with low-herb habitats (Figure 3, Table 1).

We found significantly higher abundances of Noronha Vireo and Noronha Elaenia in point counts made in the non-occupied part of the main island (National Park) when compared to the points performed in the villages, in the Environmental Protection Area (Noronha Vireo: mean in National Park sites = 4.52, SE = 0.52, n = 19, mean in villages = 0.56, SE = 0.22, n = 16; 2-sample Permutation test, $p = 0.0001$; Noronha Elaenia: mean in National Park sites = 5.21, SE = 0.64, n = 19, mean in villages = 1.87, SE = 0.56, n = 16; 2-sample Permutation test, $p = 0.0009$). On the other hand, we observed higher numbers of Eared Dove in villages (Eared Dove: mean in National Park sites = 2.52, SE = 0.46, n = 19, mean in villages = 5.37, SE = 1.56, n = 16; 2-sample Permutation test, $p = 0.047$). One Cattle Egret and no House Sparrows were counted in the non-occupied part of the main island, and hence no tests were done. Visual comparisons of maps with three classes of abundances (Figure 4) showed higher abundances of Noronha Vireo and

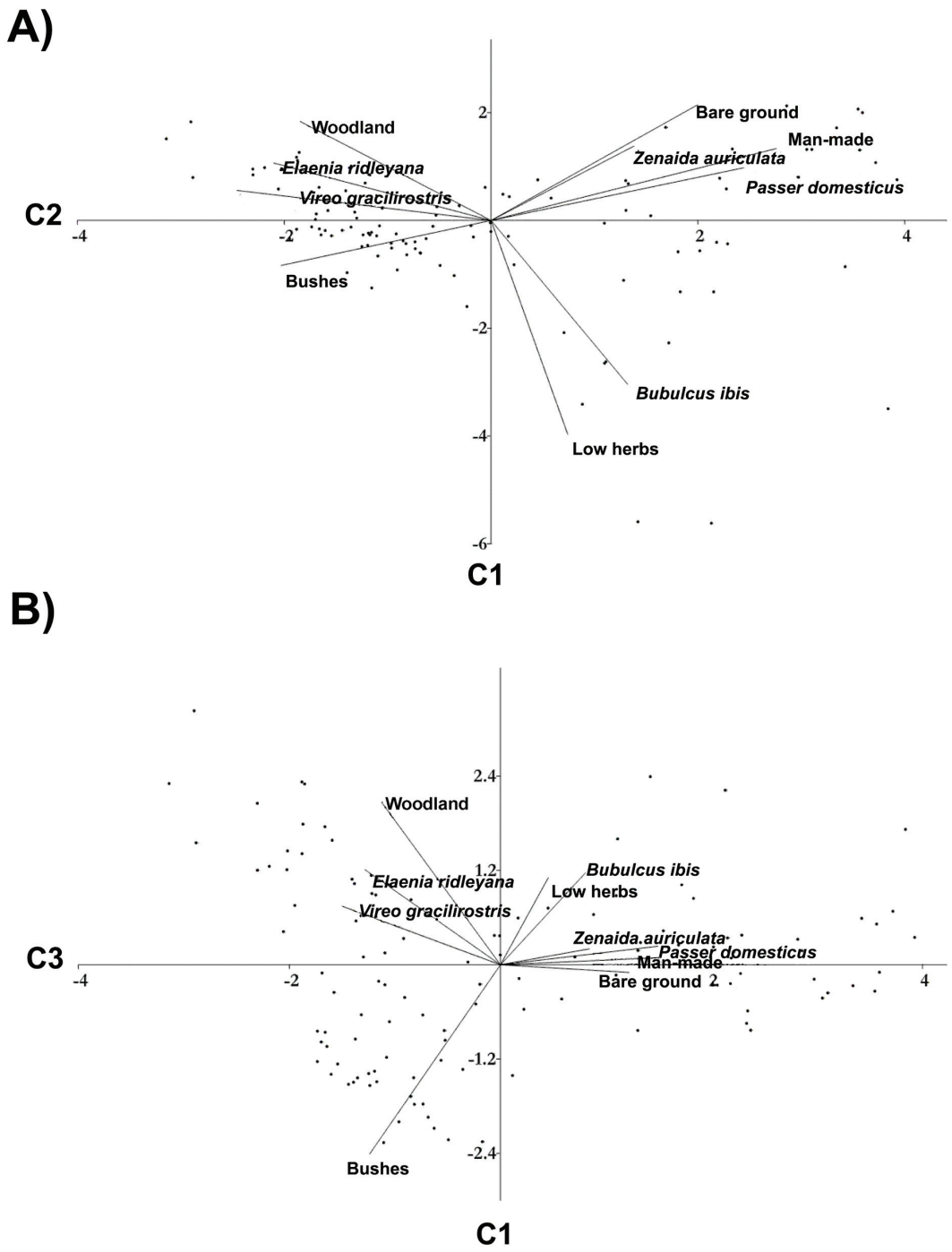

Figure 3. Principal Component Analysis scatterplot based on terrestrial bird abundance and percentage of habitat cover observed in Noronha Archipelago, Brazil. A) Principal Component 1 "C1" (34.36% of variance) against Principal Component 2 "C2" (16.62%). B) Principal Component 1 "C1" against Principal Component 3 "C3" (13.35%).

Noronha Elaenia occurring in protected sites (mostly in the National Park area) and higher abundances of Eared Dove, House Sparrow, and Cattle Egret near villages and in man-made habitats (in the Environmental Protection Area).

DISCUSSION

The results presented here show that at the study site Noronha Vireo and Noronha Elaenia are preferably associated with bushy and forested habitats, indicating that they rely on vegetated sites to persist. Previous information on the abundance of land birds on the island is based on studies carried out between the 1970s and the 1990s (Ridgely & Tudor 1994; Schulz 1995, Schulz 2004; BirdLife International 2012a, 2012b). Those studies showed the Eared Dove to be the most numerous land bird species in the archipelago, with a population around 17,000 individuals (Schulz 2004), followed by House Sparrows with

Table 1. Principal Component Analysis performed with the abundances of the five species of land birds and the percentages of habitat characteristics in each point count carried out in Fernando de Noronha, Brazil. The table shows percentages of variance explained, eigenvalues, and loadings of the three most informative principal components (PC1, PC2, and PC3).

	PC 1	PC 2	PC 3
% Variance	**34.36**	**16.63**	**13.35**
Eigenvalues	**3.44**	**1.66**	**1.34**
Man Made	0.81	0.27	0.03
Bare Ground	0.59	0.44	-0.03
Low Herbs	0.22	-0.81	0.33
Bushes	-0.60	-0.17	-0.72
Trees	-0.54	0.38	0.62
Bubulcus ibis	0.39	-0.62	0.35
Elaenia ridleyana	-0.62	0.22	0.36
Passer domesticus	0.72	0.20	0.07
Vireo gracilirostris	-0.72	0.11	0.22
Zenaida auriculata	0.41	0.28	0.06

around 2000 birds (Schulz 1995). These studies also reported estimated numbers of Noronha Vireo (c. 750 ind.) and Noronha Elaenia (c. 1000 ind.), respectively (BirdLife International 2012a, 2012b). Another study estimated around 600 Cattle Egrets living in the islands in 2009, but this population possibly decreased after control measures initiated by the Park and airport management to prevent bird strikes (Nunes et al. 2010, ICMBio internal report). Our data show that the Eared Dove is still the most abundant species on the main island. However, we found similar abundances of Noronha Elaenia and Noronha Vireo populations. House Sparrow and Cattle Egret were less abundant in our records but they are restricted to some areas, as mentioned in previous studies (Schulz 1995, Nunes et al. 2010).

Differences in methods and seasons make detailed comparisons between the present and past abundances of endemics difficult. Olson counted 93 Noronha Vireos along a 2 km trail on 18 July 1973 from Morro Dois Abraços to the lighthouse Morro da Bandeira (Olson, 1994). We made 11 point counts on this trail and counted 63 Noronha Vireos (26 October 2009). These sites are still the best conserved in the island and also shelter larger numbers of Noronha Vireos in comparison to villages. We found fewer individuals than Olson in 1973 (Olson, 1994), which could suggest a decrease over time. Although the differences in methodologies do not really permit accurate comparisons, our results indicate higher abundances of the endemics in protected sites as well (also stated by Oren 1984).

It has been suggested that the abundance of the two endemics on the island was higher before human-induced vegetation clearance (Olson 1981, Olson 1994). However, the fact that both species still persist in the island may also indicate a certain degree of resilience to habitat degradation (historically all large trees were cut since the beginning of human colonization after 1503; Olson 1981, IBAMA 1990). The positive and strong correlation of both Noronha Vireo and Noronha Elaenia with sites with well-conserved vegetation areas suggests that there may be limits to this resilience. Indeed, we often found that the two endemic birds were associated to large mulungu trees (*Erythrina velutina*). In some sites, we registered more than five individuals (especially of Noronha Vireo) perched and foraging on the branches and flowers of this tree. Other authors have also noted this association (Olson 1994, Schulz 2004) and the possible ecological interdependence of these species; the trees provide shelter and food, including nectar, and the birds contribute to pollination and seed dispersal. We also registered Eared Dove feeding on mulungu flowers (possibly taking nectar as well). These associations can also be an important reason for the higher abundance of Noronha Vireo and Noronha Elaenia at protected sites. Therefore we propose that the potential associations of birds and trees in Noronha should be addressed in future ecological studies.

Noronha Vireo and Noronha Elaenia are considered as 'Near threatened' and 'Vulnerable' respectively, based on their low abundance, restricted range, and sensitivity to introduced fauna (IUCN 2013, MMA 2014). We suggest that the observed associations between these species and sites with well-conserved native vegetation can also be an important reason for their sensitivity, and should be considered in future conservation planning. Moreover, these data highlight the importance of protected areas in the National Park for the conservation of the two endemic species. We thus recommend stronger land-use restrictions in the Environmental Protection Area (Área de Proteção Ambiental) than at present, emphasizing the conservation of the remaining natural vegetation. In addition, it is important to carry out long-term surveys to determine population trends of land birds. The proposals for further development of tourism, which would favor the construction of additional buildings in the villages, and increase the imminent impact of introduced species and the risk of fire, could cause yet greater damage to habitat and populations of endemic birds (IBAMA 1990, Didham et al. 2005, Birdlife International 2014). Consequently, future policies and educational mea-

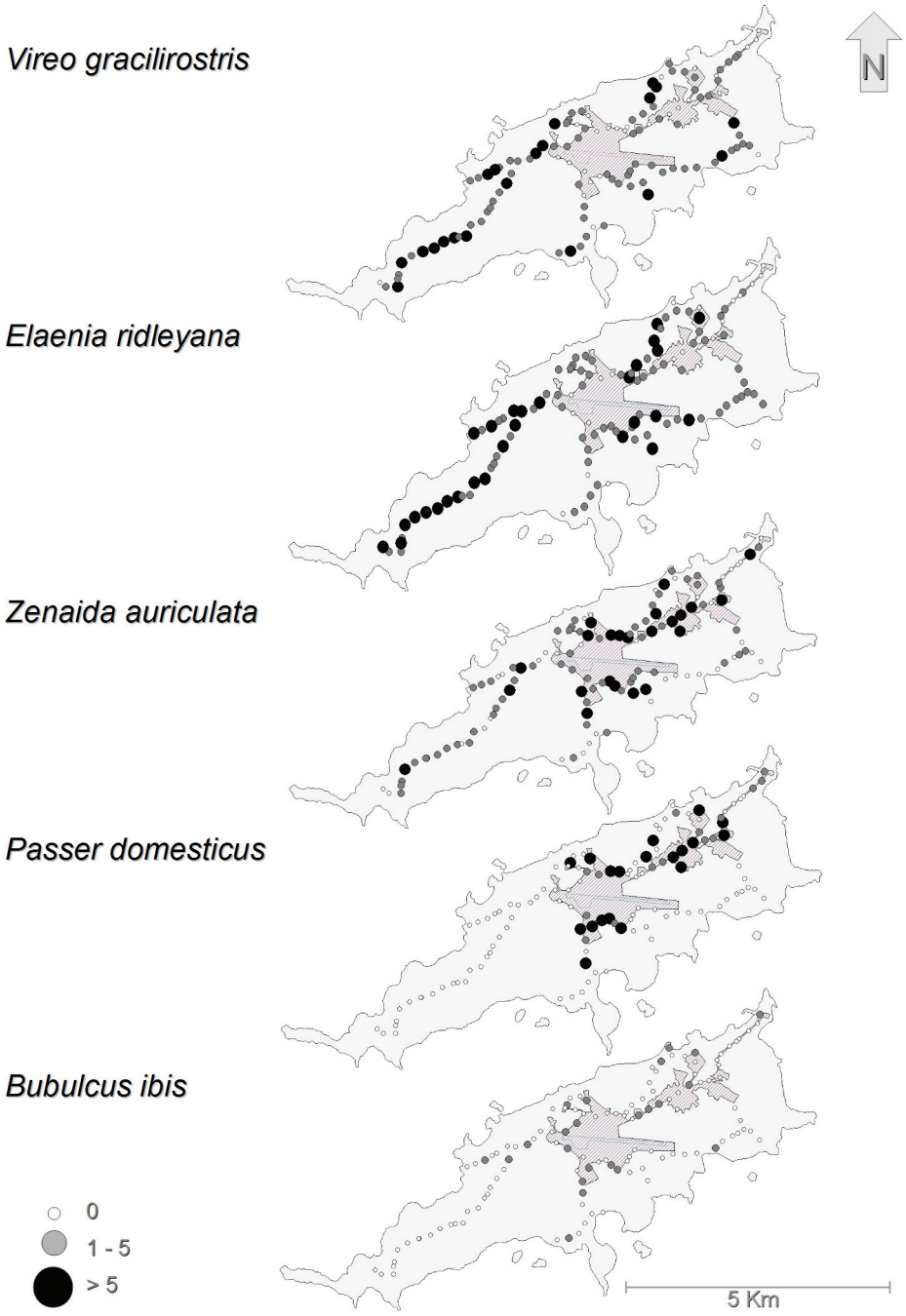

Figure 4. Maps of the main island of Noronha, Brazil, depicting the abundance of each species of landbird per point count (small white circle = 0 individuals, medium grey circle = 1–5 individuals, large black circle = more than 5 individuals). The grey shaded area indicates villages and human influenced landscapes.

sures in the archipelago should use the unique representatives of the avifauna as flag-ship species in order to protect the natural habitats of the land birds of Fernando de Noronha.

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