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HOME-RANGE SIZE OF CHESTNUT-BACKED ANTBIRD (*MYRMECIZA EXSUL*) IN FRAGMENTED LANDSCAPES IN SOUTHWESTERN COSTA RICA

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Resumen. – Tamaño de rango de hogar del Hormiguero dorsicastaño (*Myrmeciza exsul*) en paisajes fragmentados en el suroeste de Costa Rica. – Las aves insectívoras de sotobosque son sensibles a la fragmentación debido a sus limitadas habilidades de dispersión. Esta sensibilidad a la dispersión hace de estas especies un grupo importante para conservar la conectividad del paisaje. A través de métodos de telemetría, individuos marcados, técnicas de captura-recaptura y observaciones visuales, nosotros evaluamos al Hormiguero dorsicastaño (*Myrmeciza exsul*, una especie insectívora común de sotobosque no migratoria con baja movilidad y especialista de bosque), para determinar su rango de hogar en dos paisajes fragmentados en el suroccidente de Costa Rica. Adicionalmente, registramos datos de vegetación en las áreas de hogar detectadas. Nosotros registramos diferencias significativas entre paisajes con respecto al tamaño del rango de hogar ($t = -3.52$, $P = 0.002$) (1.02–2.76 ha en Paisaje Los Cusingos [LCL, $N = 19$] y 0.77–1.80 ha en Paisaje Boruca [BOL, $N = 19$]). Además, las áreas núcleo promedio fueron estimadas entre 0.14 y 1.08 ha en LCL y entre 0.05 y 0.52 ha en BOL. Nosotros concluimos que los tamaños de rango de hogar de *M. exsul* están influenciados por variables de vegetación como área basal y densidad de árboles, mientras que el área núcleo está afectada por el tipo de paisaje.

Abstract. – Understory insectivorous birds are sensitive to fragmentation due to their limited dispersal abilities. This limited dispersal makes these species an important group for conserving the landscape connectivity. Through telemetry methods, banding individuals, capture-recapture techniques, and visual observations, we evaluated Chestnut-backed Antbird individuals (*Myrmeciza exsul*, a common non-migratory understory insectivorous and forest specialist with low mobility), to determine the home-range size in two fragmented landscapes in southwestern Costa Rica. Additionally, we recorded vegetation data in each one detected home area. We found significant differences ($t = -3.52$, $P = 0.002$) between landscapes regarding home-range sizes (1.02–2.76 ha at Los Cusingos Landscape [LCL, $N = 19$] and 0.77–1.80 at Boruca Landscape [BOL, $N = 19$]). Additionally, average core areas were estimated

between 0.14 and 1.08 ha at LCL and between 0.05 and 0.52 ha at BOL. We concluded that Chestnut-backed Antbird home-range size was influenced by vegetation variables such as basal area and tree density, whereas core area was affected by landscape type. *Accepted 8 April 2014.*

Key words: Chestnut-backed Antbird, *Myrmeciza exsul*, agroecosystem, fragmented landscapes, home range, insectivory.

INTRODUCTION

Recently, the effects of habitat fragmentation on species dispersal have received increased attention with the aim of maintaining connectivity among animal populations (Hannon & Schmiegelow 2002, Cullen *et al.* 2004, Frankman 2006, Paquet *et al.* 2006, Marra *et al.* 2006, Ruiz-Gutiérrez *et al.* 2008) and the provision of ecosystem services (Pearce & Mourato 2004, Ricketts *et al.* 2006) to enhance the persistence of animal populations. Further basic information on territory size, density, and microhabitat requirements for animal species in fragmented landscapes is necessary (Stouffer & Bierregaard 1995, Renjifo 2001, Bierregaard *et al.* 2001) and this information can contribute to predictions about how specific species can use a fragment of a specific size or secondary vegetation of a given structure.

In addition, estimates of either territory or home-range sizes are important to bird conservation in fragmented landscapes and some researchers have suggested that these variables are possible indices of habitat quality for management issues (Yosef 1993, Atwood *et al.* 1998, Linkhart *et al.* 1998). According to Myers *et al.* (1979), individuals establish territories that contain adequate resources to meet their energetic needs and they will defend as large of an area as they can when constrained by competition with other individuals. However, these hypotheses do not include the influence of matrix types on the species territory size in fragmented landscapes—a factor that has been studied very little.

The Chestnut-backed Antbird (*Myrmeciza exsul*) is a common non-migratory

understory insectivore that ranges from eastern Nicaragua to western Ecuador, has low mobility, prefers treefall tangles as nest sites (Willis & Oniki 1972, Sieving & Karr 1997, Zimmer & Isler 2003), and can be found throughout the year (Stiles 1983). The species is found in lowland forests, forest edges, and older secondary forests throughout its range to about 1000 m elevation (Skutch 1969, Willis & Oniki 1972, Zimmer & Isler 2003, Losada-Prado *pers. obs.*). *M. exsul* is categorized as Ap4acd (A = abundant, many can be recorded daily; p = permanent resident, breeds in the area, can be seen at any time of year; 4 = wooded habitats; a = forest interior; c = forest edge, including light gaps of various types; d = old second growth, with a more or less distinct “canopy” stratum (Stiles 1983)). Clutch size is two eggs, and mated pairs remain paired year-round; also, *M. exsul* can produce up to three successful broods per year (Skutch 1960, Willis & Oniki 1972). Little is known about its home-range sizes and movements (Barnett *et al.* 2007), particularly in fragmented agricultural landscapes. Willis & Oniki (1972) estimated a male’s territory size at ~2.5 ha in mature forest at Barro Colorado Island, whereas Stutchbury *et al.* (2005) registered territories of 1 ha at the same site for the same species. Sigel *et al.* (2006) found that *M. exsul* decreased in abundance in continuous forest at La Selva Biological Station (Costa Rica), together with other insectivorous species, possibly due to multiple ecological factors. Unfortunately, these researchers were unable to test

interactions among factors. However, Roberts (2007) evaluated the presence of *M. exsul* in forest fragments (~ 10 ha) surrounded by pastures around La Selva Biological Station and found that abundance was influenced by the interaction of fragment area and forest cover. However, they neither demonstrate movements among nor within forest patches. None of these studies estimated both home-range sizes and movements of *M. exsul* in fragmented landscapes with different agricultural matrices.

We examined the home-range size of *M. exsul* in two fragmented landscapes in southwestern Costa Rica with different forest fragment sizes and agricultural matrices (Los Cusingos Landscape LCL and Boruca Landscape BOL) and compared the home-range size using radio telemetry and colored leg bands. Our first hypothesis is that home-range size of *M. exsul* are smaller in landscapes with degraded pastures matrices (BOL) than in landscapes with shaded coffee/sun-grown coffee matrices (LCL). Also, our second hypothesis is that home-range size of *M. exsul* in forest patches > 100 ha are larger than in forest fragments ≤ 10 ha. Finally, the third hypothesis is that home-range size determined for birds with radio transmitters and birds with colored leg bands is similar.

METHODS

Study sites. We conducted the study in two fragmented landscapes in southwestern Costa Rica: (a) Los Cusingos Landscape (LCL, ~ 700 m a.s.l.) in the Alexander Skutch Biological Corridor, which included the Los Cusingos Natural Reserve; and (b) Boruca Landscape (BOL, ~ 680 m a.s.l.) in the proposed AMISTOSA Biological Corridor, which included the Boruca Indigenous Reserve (Fig. 1, Table 1). In Los Cusingos Landscape, the most representative life zones

according to Holdridge Life Zone classification system (Holdridge 1978) are Premontane wet forest (P-wf) and Premontane rain forest (P-rf). The average annual temperature is 24° C and annual precipitation averages 3237.8 mm (Canet 2005). BOL is in the Boruca Indigenous Reserve (~680 masl) in the Buenos Aires Canton, Puntarenas Providence. This reserve is the second most important in the AMISTOSA Biological Corridor, and includes undisturbed high priority habitats within the structural connectivity network proposed by Céspedes (2005). The most representative life zones are premontane wet forest (P-wf) and tropical moist forest (T-mf), premontane belt transition. Data for this study were gathered during both dry and rainy seasons from April 2008 to March 2009 in both landscapes. There is almost no rain from November to December, and there is less rain in the middle of the year than in the months just before or after July–August or August–September. Similarly, a main dry and hot season on the Pacific occurs between December and May. Peak annual rainfall occurs in September and October (Coen 1983).

Forest fragments (≤ 10 ha) and forests sites (> 100 ha) selection. In LCL we selected three forest sites >100 ha in continuous forest and five forest fragments ≤ 10 ha (0.16, 1.5, 2.5, 3.0, and 10.0 ha) surrounded by either shaded coffee or sun-grown coffee. In BOL, three forest sites were selected using the former criterion (> 100 ha) and three forest fragments ≤ 10 ha (2.0, 2.5, and 5.0 ha) surrounded by pastures. In each landscape the forest sites > 100 ha were separated from each other by ~ 1 km and the same criterion was used among forest fragments, so we compared home-range sizes of *M. exsul* between landscapes with different matrices and forest fragments. With these criteria we only found five forest fragment in LCL and three in BOL.

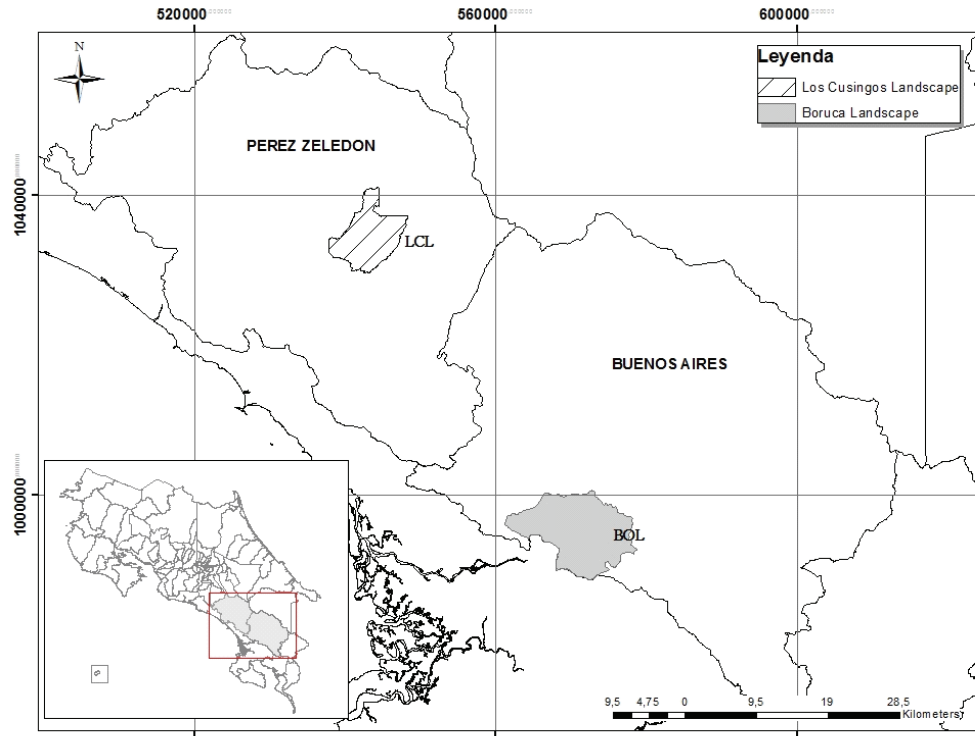


FIG. 1. Geographic location of studied landscapes, Los Cusingos Landscape (LCL) and Boruca Landscape (BOL), in southwestern Costa Rica.

Chestnut-backed Antbird's locations in forest sites and forest fragments. We marked four individuals with radio transmitters and 26 individuals with colored leg bands in forest sites >100 ha (19 males and 11 females). Additionally, eight individuals (four males and four females) were radio-marked in forest fragments ≤ 10 ha surrounded by agricultural matrix and pastures in both landscapes. Radio-marked individuals were fitted with a TXB-003B (TELENAX, Mexico) radio transmitter. Radio transmitters were attached using a figure-eight harness (Rappole & Tipton 1991) made of lightweight cotton embroidery floss. We monitored each individual daily over three weeks, using a RA-14K hand-held antenna (TELONICS, Arizona, USA) and a TR-4 radio receiver (TELONICS, Arizona, USA) to

locate radio-marked birds. When the experiment concluded the radio-marked individuals were recaptured and radio transmitters were removed.

The sites for each marked individual were recorded on a grid system (25×25 m) using a GPS (Garmin *eTrex*), a compass, a metric tape measure, and by spending the time necessary to improve the accuracy of the location records at each site (Verner & Ritter 1988, Bibby *et al.* 1992, Buckland *et al.* 2004, Stouffer 2007). With this technique birds can be placed within an area of 0.25 ha and it is considered an adequate sampling method for terrestrial insectivores (Stouffer 2007). Also, following Stouffer (2007), each individual was located at least 63 times over three weeks with a mean of 21 locations per week.

TABLE 1. Percentage of land cover types both in Los Cusingos Landscape (LCL) and Boruca Landscape (BOL) according to Canet (2005) and Céspedes (2006).

| Land use type | LCL (Canet 2005) | BOL (Céspedes 2006) |
|---|------------------|---------------------|
| Forest | 56.0 | 31.0 |
| Permanent crops | 23.6 | 3.1 |
| Annual crops | - | 3.9 |
| Pastures | 17.9 | 23.2 |
| Pastures with woody plants | - | 5.5 |
| Secondary shrublands | 2.1 | 20.5 |
| Different uses (e.g., transitory plantations, infrastructure) | 8.4 | - |
| Others | 0.6 | 8.4 |

Birds were monitored from 06:00–10:00 and 16:00–18:00h every day. In addition, we recorded locations at intervals of no less than 20 min (Swihart & Slate 1985, Atwood *et al.* 1998) to ensure that observations were independent. We located each individual at least eight times per day during a three-hour period and took bearings from at least three points.

Vegetation structure. We analyzed habitat variables through temporary sampling-plots at each site following Finegan *et al.* (2004) for estimating horizontal and vertical structure of the habitat. We established two 110-m-transects with at least 50 m from one other. Each transect had four sampling-plots of 20 x 20 m for a total of 8 sampling-plots by site. Horizontal structure was measured through variables such as density (#/ha), basal area ($G = m^2/ha$), diameter at breast height ≥ 10 cm (DBH), and canopy cover (Table 2). Transects were located at the same area where *M. exsul* individuals were captured, and we first confirmed *M. exsul*'s presence in the sites. We quantified the vertical structure of the forest according to Thiollay (1992) by estimating the average foliage cover within each of the five layers from understory to canopy (0–2 m, 2–9 m, 10–20 m, 20–30 m, and > 30 m).

Statistical analyses. We estimated the kernel home-range size of *M. exsul* using the utilization distribution function (Worton 1987, 1989) in Arcview GIS version 3.3, Animal Movement extension (USGS 1998), and Distances and Bearings between Matched Features extensions (Jenness 2007). The home range size was estimated as a 95% probability polygon (with default smoothing parameter), which includes the location points to delineate home range boundaries and a 50% probability to represent core areas within each home range (UGSD 1998, Bennett & Bloom 2005). Home-range size and core area are reported as mean \pm SD. Normal distribution and homogeneity variance were analyzed for home-range size (Zar 1996). We did not find a correlation between home-range sizes and the number of locations ($R = 0.02$, $N = 30$); therefore home-range size was not affected by the number of locations for each individual. Overall, statistical tests were evaluated with a significance level of 0.05. A *t*-test (Zar 1996) was used to determine if home-range sizes differed between landscapes in the forest sites >100 ha and forest fragments ≤ 10 ha and home-range sizes between males and females. Also, data from radio-telemetry and color-banding methods were transformed ($\log_{10} X + 1$) to analyze this data set together between landscapes. Additionally, the home-range size

TABLE 2. Vegetation variables at Los Cusingos landscape (LCL) and Boruca landscape (BOL) in south-western Costa Rica. Density = number of trees ≥ 10 DBH/ha). Values given are means \pm SD. ^a Vertical structure = mean of foliage covers among the five layers.

| Landscapes | Sites | Density (#/ha) | Basal area (m ² /ha) | Canopy cover (%) | Vertical structure ^a | Mean DBH |
|------------|--------------|---------------------|------------------------------------|---------------------|------------------------------------|------------------|
| LCL | | 702.34 \pm 145.27 | 28.05 \pm 7.53 | 76.16 \pm 9.11 | 1.18 \pm 0.25 | 19.83 \pm 2.29 |
| | Los Cusingos | 670.31 \pm 109.25 | 28.32 \pm 9.26 | 70.62 \pm 4.76 | 1.26 \pm 0.26 | 19.64 \pm 2.83 |
| | La Escondida | 809.38 \pm 178.75 | 29.90 \pm 6.70 | 74.87 \pm 8.37 | 1.25 \pm 0.14 | 19.63 \pm 1.51 |
| | Chober | 659.38 \pm 135.58 | 25.67 \pm 3.47 | 88.53 \pm 1.45 | 0.93 \pm 0.10 | 20.42 \pm 1.81 |
| BOL | | 404.17 \pm 224.42 | 15.19 \pm 9.01 | 81.13 \pm 4.72 | 0.63 \pm 0.25 | 19.02 \pm 3.83 |
| | Kantan | 640.63 \pm 220.77 | 19.79 \pm 8.54 | 83.95 \pm 6.97 | 0.53 \pm 0.18 | 17.91 \pm 1.78 |
| | San Joaquín | 215.63 \pm 74.33 | 6.85 \pm 4.87 | 79.34 \pm 2.39 | 0.50 \pm 0.19 | 16.86 \pm 3.75 |
| | Changuina | 356.25 \pm 63.74 | 18.92 \pm 7.13 | 80.09 \pm 2.21 | 0.88 \pm 0.21 | 22.30 \pm 3.48 |

was analyzed with vegetation variables through General Lineal Models (GLM). These analyses were run with InfoStat version 2009 (Di Rienzo *et al.* 2009) and R-Program (R Development Core Team 2008).

RESULTS

Home-range sizes in forest sites > 100 ha. We registered 5236 locations (2895 from LCL and 2341 from BOL) to obtain the mean home-range size of *M. exsul* in forest sites > 100 ha. Of these locations, 4277 were obtained from observations of color-marked individuals and 959 were from radio-marked individuals (481 from LCL and 478 from BOL). Overall, we estimated 30 home-range sizes, 15 from LCL and 15 from BOL, of which four were from radio-marked individuals. Each individual averaged 175 locations with eight locations / day. Overall sampling effort was 1890 h and a mean of 63 h/individual. A third radio-marked individual in BOL was lost early (3 days) in the study and the individual was removed from the analysis.

The home-range sizes were significantly different ($t = -3.52$, $P = 0.002$) between landscapes with color-marked individuals, and home-range sizes were higher at LCL than at BOL (Table 3). Also, we observed significant

differences ($t = -5.13$, $P = 0.036$) between landscapes with radio-marked individuals with home-range sizes greater at LCL than at BOL. Data from radio-marked individuals showed less variance (LCL = 0.005, BOL = 0.0005) than color-marked individuals (LCL = 0.39, BOL = 0.14) for both landscapes. However, home-range sizes between color-marked individuals and radio-marked individuals were not significantly different in LCL ($t = 0.60$, $P = 0.559$) nor in BOL ($t = -0.67$, $P = 0.513$). This supports the notion that the color leg banding method provides the same results as the telemetry method for this species. Additionally, home-range sizes between males and females did not show significant difference in LCL ($t = -0.41$, $P = 0.690$) nor in BOL ($t = 0.48$, $P = 0.640$) (Table 4).

Core areas in forest sites > 100 ha. Core areas were significantly different ($t = -4.13$, $P = 0.001$) between landscapes with color-marked individuals, but radio-marked individuals showed no significant differences ($t = -3.02$, $P = 0.094$) between landscapes. Core areas were always higher in LCL than in BOL. For males, the core areas were significantly different ($t = -2.74$, $P = 0.023$) between landscapes with color-marked individuals and the same was recorded for females ($t = -2.78$, $P = 0.027$).

TABLE 3. Home-range sizes (HR) and core areas (CA) in ha (mean \pm SD) of color-marked and radio-tracked Chestnut-backed Antbirds (*Myrmeciza exsul*) in forest fragments (≤ 10 ha) and forest sites (> 100 ha) in two fragmented landscapes in Costa Rica, 2008–2009. LCL: Los Cusingos Landscape; BOL: Boruca landscape; N: number of individuals; HR: 95% home range; CA: 50% core area. ^a: color-marked individuals; ^b: radio-tracked individuals.

| Landscape | Sites | N | HR | CA |
|-----------|-------------------------------|-----------------|-----------------|-----------------|
| LCL | Forest sites > 100 ha | 13 ^a | 1.88 \pm 0.62 | 0.53 \pm 0.27 |
| | Forest fragments ≤ 10 ha | 2 ^b | 1.61 \pm 0.07 | 0.93 \pm 0.16 |
| BOL | Forest sites > 100 ha | 4 ^b | 1.95 \pm 0.78 | 0.28 \pm 0.07 |
| | Forest sites > 100 ha | 13 ^a | 1.18 \pm 0.37 | 0.19 \pm 0.12 |
| | Forest fragments ≤ 10 ha | 2 ^b | 1.36 \pm 0.02 | 0.39 \pm 0.20 |
| | Forest fragments ≤ 10 ha | 4 ^b | 1.38 \pm 0.42 | 0.40 \pm 0.27 |

Home-range sizes in forest fragments ≤ 10 ha. We recorded 1939 locations in forest fragments (973 locations at LCL and 966 locations at BOL) surrounded by agricultural matrix (shaded-coffee at LCL and pastures at BOL). The home-range sizes were not significantly different ($t = -1.28$, $P = 0.248$) between landscapes with different matrices, even though the values were the highest in LCL (Table 4). Likewise, core areas were not significantly different ($t = 0.90$, $P = 0.436$) between landscapes. We did not find a correlation between forest fragment sizes and home-range sizes ($R = -0.01$, $N = 8$). Furthermore, home-range size was not different between forest sites ≤ 10 ha and forest fragments > 100 ha in each landscape (LCL: $t = -0.28$, $P = 0.7810$; BOL: $t = -0.88$, $P = 0.3913$), but core area was significantly different in LCL between forest sites and forest fragments ($t = 3.72$, $P = 0.0016$).

Home-range size and vegetation structure. By using GLM, home-range size was influenced by basal area and tree density ($Y_{\text{hr}} = 4.50273 + 0.09004_{\text{g}} - 0.00232_{\text{den}}$), whereas core area was affected by landscape type ($Y_{\text{ca}} = 0.92822 - 0.3498_{\text{landscape}}$).

DISCUSSION

Our home-range sizes were close to those reported by Willis & Oniki (1972) and Stutch-

bury *et al.* (2005) in mature forests at Barro Colorado Island (2.5 and 1.0 ha, respectively). However, home-range size data from LCL (the less fragmented landscape) were closer to Willis & Oniki's (1972) value than were BOL home-range sizes. The differences between home-range sizes on Barro Colorado Island were not specified by Stutchbury *et al.* (2005), but could be related to habitat variations. Additionally, in our study, core areas were not higher than 0.90 ha, indicating that *M. exsul* might use small habitat areas, although its persistence in fragments of this area could not be guaranteed over long periods of time. This was observed with two radio-marked individuals at LCL, which for five days remained in a 0.16 ha forest fragment, and with two color-banded individuals who stayed four days in the same forest fragment.

For congeneric species, Fedy & Stutchbury (2004) found that home-range sizes of the White-bellied Antbird (*Myrmeciza longipes*), a common species in second growth and edge habitat, ranged from 0.7 to 2.3 ha in Soberania National Park, Panama. Studies carried out with other species have found much larger home-range sizes; e.g., Willson (2004), who estimated a home-range size of 15.4 ha for the Sooty Antbird (*Myrmeciza fortis*), an obligate army-ant-following bird, in lowland rain forest of Manu National Park, Perú. Stouffer (2007), in lowland rainforest of Manaus,

TABLE 4. Home-range sizes (HR) and core areas (CA) in hectares (mean \pm SD) of color-marked and radio-tracked Chestnut-backed Antbirds (*Myrmeciza exsul*) by sex in forest sites > 100 ha in two fragmented landscapes in Costa Rica, 2008–2009. LCL: Los Cusingos Landscape, BOL: Boruca landscape, N: number of individuals, HR: 95% home range, CA: 50% core area. ^a: color-marked individuals. ^b: radio-tracked individuals.

| Landscape | Sex | N | HR | CA |
|-----------|---------|----------------|-----------------|-----------------|
| LCL | Males | 8 ^a | 1.94 \pm 0.60 | 0.50 \pm 0.29 |
| | | 1 ^b | 1.56 | 0.82 |
| | Females | 5 ^a | 1.79 \pm 0.71 | 0.58 \pm 0.27 |
| | | 1 ^b | 1.66 | 1.04 |
| BOL | Males | 9 ^a | 1.14 \pm 0.35 | 0.20 \pm 0.12 |
| | | 1 ^b | 1.38 | 0.24 |
| | Females | 4 ^a | 1.25 \pm 0.46 | 0.16 \pm 0.14 |
| | | 1 ^b | 1.34 | 0.52 |

Brazil, reported a home-range size of 6.62 ha for the Ferruginous-backed Antbird (*Myrmeciza ferruginea*), a species of small gaps and undisturbed forest. Stouffer (2007) also recorded small home ranges for other terrestrial insectivores, such as Rufous-capped Antthrush (*Formicarius colma*, 6.58 ha), Chestnut-belted Gnateater (*Conopophaga aurita*, 6.28 ha), and Ringed Antpipit (*Corythopsis torquatus*, 6.00 ha). Although the home-range sizes could depend on body mass in terrestrial insectivorous birds, Willson (2004) found no support for this hypothesis. In a literature review, we were unable to find direct relation ($R^2 = 0.03$, $N = 27$) between home-range sizes and body mass for 25 terrestrial insectivores species (Losada-Prado 2009). Therefore, our data indicated that *M. exsul* has smaller home-range sizes than similar-sized species (between 20 and 30 g) living in Amazonian forests, with the exceptions of Variable Antshrike (*Thamnophilus caeruleus*) and White-shouldered Fire-eye (*Pyriglena leucoptera*) (Duca et al. 2006). In Nicaragua, the Rufous-and-white Wren (*Thryothorus rufalbus*) seems to have similar home-range sizes from 0.33 to 1.58 ha (Martinez 2008). Regarding our results about *M. exsul* at BOL, which share fragmented landscape and degraded pastures,

we can point out that they could indicate an effect of the landscape type on home-range sizes of a forest-specialist bird. However, that effect would be influenced by tree density and basal area, and structural features of the patch, whereas core area was influenced by landscape type, where degraded matrices have direct effects on forest patches.

We concluded that the home-range size of *M. exsul* is influenced by tree density and basal area. Our data suggest that habitat disturbances (e.g., anthropogenic use, abiotic factors [Becker et al. 1991, Brosi et al. 2008]) are affecting the home-range size as a consequence of habitat fragmentation. In addition, core area affected by landscape type could demonstrate that this variable can affect habitat conditions for forest-specialist species. Thus, our results could motivate farmers and policymakers to establish forest fragments with at least 1 ha in agricultural matrices with both shaded coffee and pastures for cattle. Such a decision would increase forest habitats in fragmented landscapes.

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