Movements of neotropical understory passerines affected by anthropogenic forest edges in the Brazilian Atlantic rainforest

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ABSTRACT

Edge effects are suggested to have great impact on the persistence of species in fragmented landscapes. We tested edge avoidance by forest understory passerines in the Brazilian Atlantic Rainforest and also compared their mobility and movement patterns in contiguous and fragmented landscapes to assess whether movements would increase in the fragmented landscape. Between 2003 and 2005, 96 Chiroxiphia caudata, 38 Pyriglena leucoptera and 27 Sclerurus scansor were radio-tracked. The most strictly forest species C. caudata and S. scansor avoided forest edges, while P. leucoptera showed affinities for the edge. Both sensitive species showed larger mean step length and maximal observed daily distance in the fragmented forest versus the unfragmented forest. P. leucoptera did not show any significant difference. There were no significant differences in proportional daily home range use for any of the three species. Our results suggested that fragmentation and the consequent increase in edge areas do influence movement behavior of sensitive forest understory birds that avoided the use of edges and increased the speed and distance they covered daily. For the most restricted forest species, it would be advisable to protect larger patches of forest instead of many small or medium fragments connected by narrow corridors. However, by comparing our data with that obtained earlier, we concluded that movement behavior of resident birds differs from that of dispersing birds and might not allow to infer functional connectivity or landscape-scale sensitivity to fragmentation; a fact that should be taken into consideration when suggesting conservation strategies.

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1. Introduction

Edge effects, i.e., adverse influences of the surrounding matrix on a patch of habitat, play a key role in the ecology of species living in fragmented forests (Saunders et al., 1991; Murcia, 1995; Debinski and Holt, 2000), and thus are avoided by strictly forest organisms (Wiens et al., 1993b). There is no consistent evidence about how far the edge zone stretches into the forest, but small fragments of only a few hectares most likely consist exclusively of edge area (Kapos, 1989), and will therefore lose edge sensitive forest species (Levenson, 1981). Consequently, edge effects are a major distinctly different from those in the original forest (Saunders et al., 1991; Murcia, 1995; Debinski and Holt, 2000), and thus are avoided by strictly forest organisms (Wiens et al., 1993b).
concern in biodiversity conservation, because sensitivity to edges and extinction vulnerability of a species can be closely correlated (Lehtinen et al., 2003).

Movement behavior is one of the keys to understanding the ecology of animal populations in fragmented landscapes (With and Crist, 1995; Goodwin and Fahrig, 2002), because in fragmented landscapes, species persistence is generally dependent on gene flow and metapopulation connectivity (Hanski, 1999). In such landscapes, the permeability of forest edges is essential, because an edge may be the first barrier to be crossed when movement is towards other forest patches (Rittenhouse and Semlitsch, 2006). Hence, the movement characteristics of a species and the spatial relationships between landscape components are among the most decisive factors affecting the survival of the species (Fahrig and Merriam, 1994). For a better understanding of the spatial ecology of animals in fragmented landscapes and towards edges, fine-scale movement patterns are essential (Pither and Taylor, 1998; Ricketts, 2001; Goodwin and Fahrig, 2002).

Forest understory birds are suitable model organisms for studying fragmentation and edge effects on movement patterns (Castellón and Sieving, 2005). They depend on forest structures, but generally are physically capable of crossing the matrix between forest patches. Yet, some species refuse to move through the matrix or even to approach the forest edge, and movements remain confined to core areas of forest islands (Sieving et al., 1996; Desrochers and Hannon, 1997; Develey and Stouffer, 2001; Laurance et al., 2004). Contrary to former literature (Stotz et al., 1996; Sieving et al., 1996; Sodhi et al., 2004) a study in the Amazon showed that some tropical understory forest bird species are capable of moving longer distances and crossing large gaps (Van Houtan et al., 2007). Those species, however, that move larger distances in contiguous forests are more prone to extinction after fragmentation (Van Houtan et al., 2007).

In the other Brazilian rainforest biome, the Atlantic Rainforest, it is also known that understory bird species differ in their susceptibility to forest fragmentation (Stotz et al., 1996; Uezu et al., 2005; Develey and Metzger, 2006). Nevertheless forest birds are good indicators of environmental changes, because they are closely associated with forest structures and easy to sample (Laurance et al., 2004).

The Atlantic Rainforest in Brazil is one of the top biodiversity hotspots (Fonseca, 1985; Myers et al., 2000) in the world. It already has been reduced to small fragments that account for less than eight percent of the original area coverage (Ministério do Meio Ambiente, 2000; Fundação SOS Mata Atlântica e Instituto Nacional de Pesquisas Espaciais, 2002), and as late as 2004 was still being cut and fragmented at rates of millions of hectares per year (Oppel et al., 2004). The remaining forest patches, however, comprise high biological diversity and endemism (Fonseca, 1985).

In this study, we (1) tested the edge avoidance by endemic forest understory birds and (2) compared their movement behaviors in a fragmented forest landscape with those in a contiguous forest (Fig. 1). We used radio-telemetry on three endemic forest bird species of the Atlantic Rainforest in

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**Fig. 1** – Location of study area (after Uezu, 2002). The black dots demarcate the two study sites within the reserve and the five sites in the fragmented landscape.
South-eastern Brazil: Chiroxiphia caudata, Pyrigena leucoptera, and Sclerurus scisor. The birds do not only differ in feeding habits and breeding strategies (Skutch, 1996; Sick, 1997), but also in landscape perception (Hansbauer, 2007). Thus, we (1) expected that the study species would avoid edges when compared to forest interiors, because conditions such as temperature, humidity, or food availability are different at forest edges (Sievig et al., 1996; Desrochers and Hannon, 1997; Restrepo and Gomez, 1997; Develey and Stouffer, 2001; Laurance et al., 2004). However, interspecific variation in response to edges might be expected in relation to life-history and foraging strategies (Lovejoy et al., 1986; Develey and Metzger, 2006; Van Houtan et al., 2007) and hence avoidance might be most pronounced in the species most strongly restricted to old forest, i.e., S. scisor (Develey and Metzger, 2006).

We tested this hypothesis based on habitat preferences of radio-tagged individuals in relation to distance from an edge. We further (2) expected that birds would move longer distances in the fragmented than in the contiguous forest landscape because resources might be heterogeneously distributed in the fragmented forest (Stouffer and Bierregaard, 1995; Bierregaard and Stouffer, 1997; Van Houtan et al., 2007). We based our analyses on mean step lengths (distances between foraging locations), daily home ranges, and daily maximal observed movement distances of radio-tagged individuals in both breeding and non-breeding season.

2. Methods

2.1. Study area

The study area was located on the Atlantic Plateau of Ibiúna in South-eastern Brazil, about 40 km west of the city of São Paulo (23°35′-50′ S; 46°45′-47°15′ W) at altitudes of 800–1050 m above sea level. Birds were captured and radio-tracked in two sites of a non-fragmented forest of about 10,000 ha (Reserve of Morro Grande), structurally connected to the forest of the Paranapiacaba Serra (~760,000 ha), and at several sites in an adjacent fragmented landscape where the forest only remained as patches of <1–280 ha (Fig. 1). Both contiguous forest and forest fragments were composed predominantly of intermediate to old secondary-growth forest (Silva et al., 2007). The forest fragments were embedded in a matrix of agricultural fields, Eucalyptus or Pinus plantations, horticulture, and urban settlements (Uezu et al., 2005). The climate was determined by a marked dry season between June and August (SABESP, 1997) with mean annual rainfalls of 1400 mm and average temperatures between 11 °C (July) and 27 °C (February). For more detailed description of the study area see also Uezu et al. (2005), Pardini et al. (2005) and Metzger et al. (2006).

2.2. Study species

Our study species were C. caudata (15 cm, 25 g), P. leucoptera (18 cm, 30 g) and S. scisor (18.5 cm, 39 g). All three species are endemic to the Atlantic Rainforest (Ridgely and Tudor, 1994; Stotz et al., 1996; Sick, 1997), and we selected them according to their feeding strategies (Willis, 1979; Stotz et al., 1996; Sick, 1997), supposed sensitivity to forest fragmentation (Stotz et al., 1996; Develey and Metzger, 2006), and presumed ease of capture (Uezu, 2002; Boscolo et al., 2006).

2.3. Radio tracking

In total, 86 individuals of C. caudata, 2 individuals of P. leucoptera, and 21 individuals of S. scisor were caught with mist-nets between February 2003 and February 2005.

Birds were equipped with 0.43–0.64 g radio transmitters (<2.9% of body mass; PIP2 and PIP3, Biotrack Ltd., Dorset, United Kingdom; life expectancies of 3–5 weeks). To fix the transmitter on the bird we either used a backpack harness (Hill, 1998, modified), a back mount using cyanoacrylate glue (Bowman et al., 2002, modified), a tail-mount (Wikander et al., 2001), or back mounts based on two types of eye-lash glue (Raim, 1978, modified). Birds were located for 3–5 weeks at least once a day (maximum 24 points per day) by triangulation (Kenward, 2001) using an H-Adcock hand-held antenna. The accuracy of the located bird position was influenced by several factors including topography deflecting the signal, deviation of GPS signal in terms of receiver location, or movements of the bird. Radio tags that had fallen off the bird were relocated and only 2 of 16 cases of triangulation bearings departed for more than 20 m (max 25.5 m) from the GPS position taken after recovering the tag. We therefore assumed that most radio locations were within 20 m of real bird positions.

2.4. Response to edge

Because of our relatively great radio location error (<20 m, see above), we focused our attention on the relative differences among the three species in their responses to edge, rather than absolute distances of bird locations from edges. We assumed species-specific differences in response to edge not to be biased by location precision because (1) location precision was the same for all three species and (2) telemetry errors occurred independently of distance to edges.

To assess whether a species avoided forest edges, we divided the forest fragments into 20 m-wide concentric zones in relation to distance from the forest edge: 0–20 m, 20–40 m, etc. In the largest fragment, 14 zones (0–20 m to 260–280 m) were distinguished.

We calculated a preference index for each of these zones with the 0–20 m zone as reference class (i.e., index value = 0). In order to exclude areas not available to the radio-tagged individuals, we defined available habitat as an area defined by two times the observed mean home range diameter of the tracked animals and centered on mist net locations. This procedure was applied because the larger forest fragments exceeded the sizes of individual home ranges, and radio-tagged bird locations were aggregated around mist net locations. The directly adjacent matrix areas consisted of agricultural fields and scrub land. Analyses included the individuals captured in the fragmented forest area: 24 C. caudata, 7 P. leucoptera, and 8 S. scisor. Calculations were the same as for the habitat preference index described below.
2.5. Mean step lengths and daily movements

Our expectation was that the birds would move longer distances per unit time in the fragmented than the unfragmented forest. To quantify the distances covered by the birds we calculated mean step lengths (m/min; Wiens et al., 1993a). Although this is a measure of speed, it is often used to describe the average distance moved during 1 min (Wiens et al., 1993a; Schooley and Wiens, 2004). We calculated it for each bird for which we had obtained pairs of consecutive relocations 2–90 min apart (C. caudata, n = 56; P. leucoptera, n = 16; S. scansor, n = 20). We developed a General Linear Model (GLM) with log transformed data of mean step length as the dependent variable. The variables landscape pattern (contiguous/fragmented forest), season (wet/dry), and sex were set as factors; as covariates we added size and habitat preference of the individual home ranges (Mean Convex Polygons, MCP).

Habitat preference was evaluated comparing the use of different habitat classes (old forest, young forest, scrub, eucalypt plantation, agricultural field, and human settlement) in a previous analysis of the radio-tracked bird’s movement (Hansbauer, 2007). Aebischer et al. (1993) had developed a preference ranking of habitat classes based on Aitchison’s statistics of compositional data (Aitchison, 1982). This approach was extended to quantify preference indices for each habitat class relative to a reference class (ref). For each individual (i) and each habitat class (j) it was calculated

\[ \text{p}_{ij} = \log \left( \frac{u_{ij}}{u_{a ij}} \right) - \log \left( \frac{u_j}{u_{a ref}} \right) \]

based on use (uij), the proportion of an individual’s radio location, and availability (a) of habitat. Available habitat was delineated at the capture site level as a MCP drawn around the outermost bird locations (radio-marked individuals pooled by species) of each site with a buffer extension equal to the longest diameter of the largest individual MCP per species. As reference habitat class (Aitchison, 1982) “old forest” was used. The resulting \( P_{ij} \) was weighted by the square root of the number of locations, and averaged over all individuals of each species and for each habitat class, resulting in a species-specific habitat preference index \( I_{HPr} \) for each habitat class. \( I_{HPr} \) was then used to calculate mean habitat preference indices \( I_{HPr} \) for each individual MCP.

To allow insights into daily foraging patterns we tracked individuals between sunrise and sunset over 6–8 h, starting at different times, at intervals of 30–90 min. For the analyses we considered a minimum of seven consecutive positions at intervals of <90 min. We compared the sizes of these 6–8 h home ranges (below termed as daily home ranges) with the 3–5-week home ranges (below termed as total home ranges) of the respective individual. Additionally we analyzed maximal observed daily distances (m) to gain information on general mobility of the three species. We measured it as the distance between the furthest two points within the collection of points from a given day for the respective individual.

Sample sizes of C. caudata (n = 36 males/25 females) allowed the development of a GLM to analyze the proportional daily home range use. The respective data were square root transformed to achieve normality and used as dependent variable, whereas sex, season (wet/dry), and landscape pattern (contiguous/fragmented) were used as factor variables; total MCP size and total minutes between first and last location determining the daily MCP became covariates. For S. scansor (n = 12 males/9 females/7 unsexed) and for P. leucoptera (n = 13 males/2 females) we conducted Mann-Whitney-U-tests to see whether the landscape pattern (fragmented/unfragmented) had an influence on their proportional daily home range use. Spearman rank correlations were performed to analyze total MCP size and total minutes.

Maximal observed daily distance data of C. caudata were log transformed and used as the dependent variable in a GLM. Sex, season (wet/dry), and landscape pattern (contiguous/fragmented) were used as factor variables; total MCP size and habitat preference indices of total MCPs were covariates. To analyze influences of landscape pattern and total MCPs habitat preference indices on the maximal observed daily distances of S. scansor and P. leucoptera we applied Mann-Whitney-U-tests and Spearman rank correlations, respectively.

3. Results

3.1. Response to edge

We found a clear trend of edge avoidance in C. caudata (2 = 0.650, p = 0.029; Fig. 2A) and S. scansor (2 = 0.966, p < 0.001; Fig. 2B), whereas in contrast P. leucoptera (2 = 0.644, p = 0.030; Fig. 2C) showed affinities to forest edges. Sample sizes of C. caudata were large enough to separately analyze two differently sized old forest fragments (28 ha and 53 ha); in both, edge zones were clearly avoided (A: \( r^2 = 0.712, p = 0.002; B: r^2 = 0.762, p = 0.053 \) (Fig. 3).

3.2. Mean step lengths and daily movements

The mean step lengths varied significantly between the three study species (Kruskal Wallis: \( \chi^2 \)-approximation = 11.29, p = 0.004), with C. caudata and P. leucoptera having rather similar values (mean ± SD = 3.5 ± 0.20 m/min and 3.7 ± 3.1 m/min, respectively) and S. scansor moving less (mean ± SD = 1.56 ± 1.13 m/min).

For S. scansor landscape pattern (contiguous/fragmented) had significant influence on mean step length. In the fragmented landscape the mean step length was larger (mean ± SD = 2.3 ± 1.3 m/min) than in the contiguous forest (mean ± SD = 1.1 ± 0.7 m/min; GLM, p = 0.009; \( r^2 = 0.319 \); Table 1). P. leucoptera showed no significant changes in mobility between the two landscape patterns. For C. caudata, males (mean ± SD = 4.3 ± 3.2 m/min) moved faster than females (mean ± SD = 1.9 ± 1.1 m/min), independently of all other variables examined (GLM, p < 0.001; \( r^2 = 0.381 \)). We thus divided the data set into males (n = 34) and females (n = 22) (Table 1). In males none of the factors or covariates was linked to mean step length (p > 0.05 for all cases), and in females only home range size was linked to mean step length (p = 0.002; \( r^2 = 0.645 \)). Although C. caudata generally moved just a few meters per minute, and remained confined to areas of a few hectares (see Table 2), we occasionally observed highly mobile individuals. During October–November 2004 (beginning of wet
season) we tracked one female for 27 days during which she covered an area of at least 460 ha. During 82 min she managed to fly at least 1740.4 m (Euclidian distance), equivalent to a mean step length of 21.2 m/min, thereby leaving one patch of old forest and entering at least one other patch. At another occasion she covered a distance of 460 m in 32 min (i.e., 14.4 m/min) and crossed 65 m of open agricultural land (pers. obs.). In *P. leucoptera* none of the factors had significant influence on the mean step length (GLM, *p* > 0.05, *r*² = 0.145).

The average mean step length was 3.7 ± 3.1 m/min (mean ± SD), but radio-tracked individuals often covered long distances within a short period of time (e.g., 477 m in 57 min).

The proportional daily home range use of *C. caudata* did not differ significantly between contiguous and fragmented forests; neither in the wet nor the dry season, and neither for males nor for females (GLM, *p* > 0.05; Table 2). U-tests revealed that for *S. scansor* none of the factors had a significant influence on daily home range proportions (*p* > 0.05 for all cases; Table 2). In *P. leucoptera* daily home range sizes varied from 0.6 ha to 8.7 ha (5.6–39.6%). However, the U-test did not show significant differences between contiguous and fragmented landscape (*p* > 0.05), but sample size of the contiguous forest was very small (*n* = 3). Neither total MCP size, nor total minutes were significantly correlated with daily home range proportions of both, *S. scansor* and *P. leucoptera* (Spearman rank correlation, *p* > 0.05, *r* < 0.352 for all cases).

The maximal observed daily distance of *C. caudata* was significantly larger in the fragmented (mean ± SD = 333.3 ± 201.4 m) compared to the contiguous forest (mean ± SD = 150.4 ± 53.3 m) (GLM, *p* < 0.001; *r*² = 0.475). In *S. scansor* the maximal observed daily distance in the fragmented landscape (mean ± SD = 279.9 ± 189.2 m) was significantly larger as compared to contiguous forest (mean ± SD = 140.5 ± 59.7 m; *p* = 0.028). The Spearman rank correlation showed that the habitat preference index significantly influenced the maximal observed daily distance: the better the index the smaller the maximal observed daily distance (*p* = 0.002, *r*² = −0.564; Fig. 4). The maximal observed daily distance of *P. leucoptera* ranged between 351.3 m and 498.1 m; but again,
significances could be revealed neither between the two landscape patterns nor for a correlation with the habitat preference index \((p > 0.05, r < 0.187\) for all cases).

4. Discussion

4.1. Response to edge

Bird species of tropical forests have evolved in, and therefore are often believed to depend on stable and contiguous forest habitats. As conditions may change towards forest edges, it is further assumed that forest birds avoid edges (Sieving et al., 1996; Laurance et al., 2004). Nevertheless, the permeability of forest edges is an important feature of functional connectivity of a fragmented landscape (Rittenhouse and Semlitsch, 2006), because organisms have to approach the edge before leaving the forest. *S. scansor* and *C. caudata* indeed avoided the areas near edges; this also conforms to findings of Canaday (1997) and Develey and Metzger (2006) who had analyzed species occurrence data, achieved by point counts and mist-netting, in relation to disturbance through human impact, patch size, and isolation. We applied the Core-Area Model (Laurance and Yensen, 1991) on the largest fragment in the study landscape (274 ha, perimeter = 35.3 m).

If edge effects extended into the forest, as indicated by our data for *S. scansor* and *C. caudata* (Figs. 2 and 3), none of the studied forest patches we studied would have a core area unaffected by edge effects. If the shape of a forest fragment is isodiametric, a patch would have to be 23 ha in area to have 50% of unaffected core area.

**Table 1 – Mean step lengths (m/min) of *C. caudata* by sex, landscape pattern (contiguous/fragmented) and season (dry/wet), and of *S. scansor* by landscape pattern (contiguous/fragmented)**

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**Table 2 – Total and daily home range sizes (ha) and proportions (%) of *C. caudata* and *S. scansor* by landscape pattern (contiguous/fragmented) and season (wet/dry)**

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Movements are necessary for an organism to find food or mates, to explore new areas, or to escape from predators. In an undisturbed, contiguous habitat, movements are usually unconstrained. In a fragmented landscape, however, even within patches of original habitat, movements might change, as space is limited by the surrounding matrix and edge areas. Abiotic factors as well as density of individuals might be different compared to the original habitat. We hypothesized that in a fragmented landscape movements of birds would increase because resources are heterogeneously distributed. As expected, total home ranges of C. caudata were significantly larger in the fragmented forest landscape compared to the contiguous forest. Their daily movements covered similar proportions of their total home ranges, and accordingly, the maximal observed daily distance was larger in the fragmented than in the contiguous forest. Our data on between-patch movements remained anecdotal. Yet, we were able to document C. caudata traversing distances of at least 1700 m in less than 1.5 h. If we assume juvenile dispersal distances of at least a similar order of magnitude as adult movements documented in this study, we may infer that dispersers may reach even the distant most forest fragments, and thus, movement capabilities of the species still maintain functional connectivity across our study landscape. This speculation is supported by the fact that the species occurs throughout the study landscape (Uezu et al., 2005; Martensen et al., in press). Apparently, despite avoidance of edges during breeding and non-breeding seasons (this study), dispersers readily cross the study landscape and the distribution of C. caudata is neither limited by patch size nor isolation (Uezu et al., 2005; Martensen et al., in press). However, studies of C. caudata dispersal are needed to clarify if gene flow among patches across the landscape indeed is unaffected by forest fragmentation.

Movements of S. scansor were almost exclusively recorded in patches of old forest. This matches with common statements about ground dwelling insectivores regarded as most vulnerable to forest fragmentation (Willis, 1979; Johns, 1991; Stouffer and Bierregaard, 1995; Thiollay, 1992; Canaday, 1997; Sekercioglu et al., 2002; Ribon et al., 2003; Develey and Metzger, 2006). Mean step length and maximal observed daily distance of S. scansor were larger in the fragmented than in the contiguous forest, although proportional daily home range use was about the same. This indicates that daily foraging might be less efficient in the fragmented landscape; small scale habitat structures, like vegetation and hence, food composition might be less favorable. The fact that maximal observed daily distance became significantly smaller with better habitat preference index values supports this suggestion.

Maximal observed daily distances and mean step lengths of P. leucoptera were the same in the fragmented and the contiguous forest. Daily use of their home range was similar in both fragmented and contiguous forest. As no differences became obvious, P. leucoptera appeared to be the least affected by forest fragmentation when compared to the two other study species. This strengthens the notion that this species is the least tightly associated with old forest of the three studied species (Hansbauer, 2007).

We hypothesized that forest understory birds would move differently in fragmented compared to contiguous habitats. This was confirmed for two of the studied species (i.e., S. scansor and C. caudata), whereas in contrast to expectation, P. leucoptera moved similarly in fragmented and contiguous forest. Our results suggest that this species may even be favored by an increase in foraging sites in edge habitats, and thus can adapt more easily to fragmentation as compared to the other two study species, as also had been suggested by Develey and Metzger (2006).

Other studies in the Atlantic Rainforest, however, have concluded that P. leucoptera was more sensitive to fragmentation than C. caudata (Uezu et al., 2005). These seemingly conflicting results indicate that adult habitat preferences (Hansbauer, 2007) and movement behavior (our study) may not sufficiently reflect the prerequisites for species occurrence and persistence across the landscape (Uezu et al.,
2005). Adult spatial behavior, as documented in our study, is probably resource driven. Foraging *P. leucoptera* follow ant raids into edge habitats; however, this does not allow any inferences concerning the landscape-level habitat relationships of the species. Uezu et al. (2005) found that *P. leucoptera* was less abundant in more isolated forest fragments of the study landscape; however, crossing of open areas up to 60 m was observed (Uezu et al., 2005).

Possibly, factors such as dispersal costs to distant fragments or a lack of ant raids, and thus food, in more isolated fragments, may restrict the occurrence of *P. leucoptera* at larger landscape extents. Our study illustrates that although a species may not be able to persist in more isolated forest patches, as shown by Uezu et al. (2005) for *P. leucoptera*, it may still prefer edge habitats.

5. Conclusions

Because edge effects often reach far into the forest, the area of unaffected forest interior is widely reduced (Laurance, 2000). Accordingly, in fragmented habitats not only the matrix, but also large areas of the remaining forest may be of lower habitat quality for forest organisms. The Atlantic Rainforest is still under strong pressure, and the amount of forest edge is increasing. Edge effects vary broadly, thus, different species will respond differently (Bissonette et al., 1997; Debinski and Holt, 2000; Bissonette and Storch, 2002). For more sensitive species such as *S. scansor* only the larger patches of old forest may remain suitable, and thus, are vital to ensure survival.

Understanding the responses of forest-dependent organisms to fragmentation in the Atlantic Rainforest is important for managing and therefore mitigating the impacts of landscape changes in this biodiversity hotspot. As also illustrated by our daily movement data, bird movements generally intensify in fragmented landscapes (Van Houtan et al., 2007) as availability of food, nesting or lekking places, and mates are decreasing (Stouffer and Bierregaard, 1995; Bierregaard and Stouffer, 1997). Increased movements may involve increased costs, such as higher energy expenses and exposure to predators. Reduced reproduction success and increased mortality, and thus, reduced fitness, may be the consequences. These results reinforce the necessity of large remnant habitat areas for the conservation of species sensitive to edge effect. In this case, it would be advisable to protect larger patches of forest instead of many small or medium fragments connected by narrow corridors.

The most important lesson learned from our study is that conclusions regarding the sensitivity of bird species to forest fragmentation may greatly depend on the domain and scale of study (Bissonette, 1997). Our fine-scale behavioral study of bird movements in relation to edges suggested *P. leucoptera* to prefer edges and thus, to be favored by fragmentation, whereas a landscape-scale study showed occurrence of the same species to be negatively related to patch size (Uezu et al., 2005) and fragmentation. Seemingly contrasting results like these may be perceived as little helpful for conservation decision makers, who are interested in clear management recommendations. However, if interpreted in context of each other, the two studies (Uezu et al., 2005; this study) may provide an excellent case example illustrating that fragmentation effects are generally multicausal and complex (Bissonette and Storch, 2002), and more specifically, that adult habitat preferences (Hansbauer, 2007) and movement behavior (our study) may not sufficiently reflect the prerequisites for species occurrence and persistence across the landscape (Uezu et al., 2005).

In telemetry studies, data on range use and movements are often biased towards resident individuals, whereas information on dispersers remains anecdotal. However, juvenile dispersers, and not residents, are likely to drive functional connectivity between fragments and across a landscape. Conclusions about a species’ susceptibility to fragmentation have to be drawn cautiously when available information is limited to resident bird habitat use, as in our study. Similarly, limitation to landscape-scale research on species occurrence in relation to fragmentation, such as the study of Uezu et al. (2005), may fail to recognize fine-scale habitat preferences of individuals. Conservationists are well advised to consider all available information, and ideally include studies at different scales, when planning for optimizing population and community preservation in fragmented landscapes.

To verify functional connectivity of a fragmented landscape for forest bird species, movement behavior of dispersing individuals should be studied more thoroughly.

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