Importance of Interhabitat Gaps and Stepping-Stones for Lesser Woodcreepers (*Xiphorhynchus fuscus)* in the Atlantic Forest, Brazil

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ABSTRACT

Translocation experiments showed that a woodcreeper bird species is able to move between isolated forest fragments, but this ability is limited by increasing interpatch distances. Larger distances (> 100 m) were overcome by using small stepping-stones (isolated trees), which enhance connectivity and are useful for the species conservation in fragmented landscapes.

Abstract in Portuguese is available at http://www.blackwell-synergy.com/loi/btp.

Key words: Atlantic plateau; Dendrocolaptidae; fragmented forests; functional connectivity; radiotelemetry; translocations.

HABITAT PATCHES IN FRAGMENTED LANDSCAPES ARE COMMONLY ISO-LATED FROM EACH OTHER BY a matrix environment not suitable for several bird species (Hobbs 1993, Wiens 1995, Metzger 1998, Debinski & Holt 2000). As habitat is lost, interpatch distances tend to increase. This may reduce habitat connectivity (Fahrig 2003), leading to unsuccessful recolonization events and increased extinction rates (Hanski 1994, Brooker & Brooker 2001). These processes are directly linked to the ability of dispersing individuals to move between patches and overcome the matrix. One way to assess the aptitude of birds to move through such an environment is to make use of individuals' translocation experiments (Bélisle *et al.* 2001). Due to territoriality, such a method tends to induce birds to move through the landscape back to their home territories, providing fine indication of individuals' moving abilities, and especially useful information on their spacing behavior in fragmented landscapes. Several studies revealed that the existence of small nonhabitat gaps between habitat fragments can reduce the ability of birds to return to their home territories after being translocated to structurally isolated habitat patches (St Clair *et al.* 1998, Bélisle *et al.* 2001, Gobeil & Villard 2002). Translocation experiments can also indicate how individuals might use several landscape elements and are fundamental to enhance our understanding of the effects of fragmentation on birds, aiding in their conservation (Bélisle 2005).

Our aim in this study was to test the effect of interhabitat gap widths on the homing behavior of the lesser woodcreeper (*Xiphorhynchus fuscus* Dendrocolaptidae) among remaining patches of the Brazilian Atlantic forest, an extremely endangered woodland, with only about 7 percent of its original extent left (Fundação SOS Mata Atlântica & INPE 1998).

This species is a resident insectivorous bird that inhabits mature and second-growth Atlantic forests (Goerck 1999, Melo-Júnior *et al.* 2001, del Hoyo *et al.* 2003). It weights 15.5–25 g and presents no apparent sexual dimorphism (del Hoyo *et al.* 2003). It lands only on upright logs and trees, being unable to perch on horizontal branches or on the ground (Brooke 1983). Hence, it is probably reluctant to cross large areas of open fields, which should therefore be crossed in a single flight. This suggests reduced dispersal abilities in landscapes with structurally isolated fragments. However, although this species is recognized to be negatively affected by habitat fragmentation and isolation (dos Anjos & Boçon 1999, Maldonado-Coelho & Marini 2000), no information on its gap-crossing skills is known.

We conducted this study at the fragmented agricultural landscape between Piedade and Tapirai municipalities (23°48′ S; 47°57′ W), SE Brazil, which was originally covered by 'dense montane ombrophylous forests' (Oliveira-Filho & Fontes 2000), but nowadays presents only about 45 percent of second-growth forest in advanced successional state. The interhabitat matrix is composed mainly by pasture and open field vegetable plantations. In this landscape we selected six study sites (Table 1), each one composed by two isolated forest patches, one large (> 20 ha) and one small (< 7 ha), with similar vegetation structure.

We evaluated the ability of *X. fuscus* to overcome interpatch matrices through individuals' translocations. We tracked them by Radiotelemetry, registering their homing time and, when possible, landscape elements that they used. The birds were captured with single lines of seven mist nets (2 × 12 m, 36 mm mesh size) inside the largest patch of each site at about 20 m from the forest edge. The nets were opened right after sunrise and closed by 1200 h to standardize the release time of all birds before 1400 h. Captured birds were marked with unique numbered aluminum bands and tagged with Biotrack® PIP3 micro radio transmitters (no more than 5% of the birds' weight), attached to their lower back using neutral eyelash glue, allowing the free movement of wings and feathers (Kenward 2001).

We captured two individuals at each site. One of these birds was translocated to the smaller isolated fragment, stimulating it to cross the open field matrix to return to its origin patch (gap treatment).

TABLE 1. *Tracking time of each bird until the end of the experiment and description of the six selected study sites in terms of the capture and release patch sizes, the interpatch field matrix distances (interpatch), the largest matrix distance to be crossed considering the use of stepping-stones (MaxSs), and the interior translocation distance. The time is expressed in hours after release.* [R]: *birds with observed return event;* [NR]: *birds which did not return after 3 d of tracking (right censored);* [TL]: *birds that lost the transmitter (right censored).*

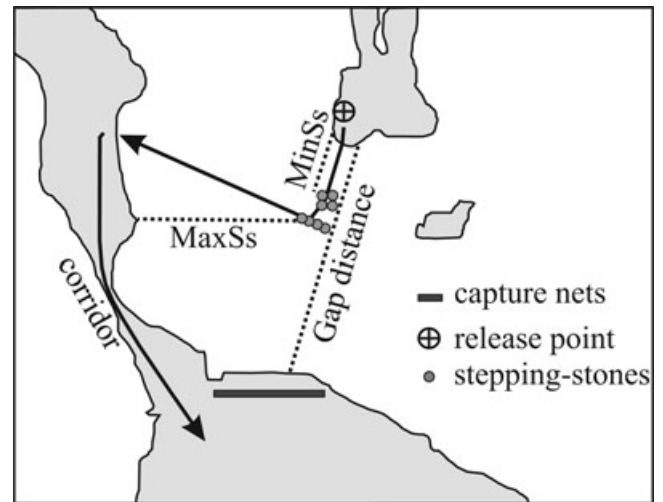|	Size (ha)		Gap distance (m)		Gap tracking time (h)	Interior distance (m)	Interior tracking time (h)
Site	Capture patch	Release patch	Interpatch	MaxSs			
1	20.6	1.0	32	32	5.53 [R]	50	2.66 [R]
2	27.5	1.4	75	40	2.08 [R]	75	3.45 [R]
3	21.2	6.7	100	95	72.0 [NR]	100	2.83 [R]
4	21.2	0.6	180	100	50.83 [R]	180	0.33 [R]
5	174.1	1.0	230	145	28.93 [R]	230	4.75 [R]
6	37.1	5.6	260	90	26.0 [TL]	260	72.0 [NR]

FIGURE 1. Example of return path (continuous line, arrows indicate the direction of movement) for the individual translocated 230 m (gap distance) across the matrix, evidencing the use of isolated trees as 'stepping-stones' and a forest corridor connected to the origin patch. At this given case, the largest matrix distance to be crossed considering the use of stepping-stones (MaxSs) is 145 m, and the shortest distance between a stepping-stone and the tested patches (MinSs) is 30 m. Shaded areas correspond to forest and light areas to open matrix.

The second bird was released within the capture fragment (interior treatment) at a distance equivalent to the interpatch gap. Because our aim was to test the gap-crossing ability of the birds, the distances from the nets to the forest edges were ignored in the data analysis. Since this species tends to disappear in our landscape from patches isolated by more than 120 m (Boscolo 2007) and was not expected to travel more than a few hundred meters, we selected interpatch distances varying from 32 to 260 m (Table 1). Because stepping-stones (*e.g.*, any isolated or small group of trees in the matrix between patches) were rather frequent, which could reduce the maximum distance to be crossed in a single flight, we also measured the largest distance between either the release or origin patches to a stepping-stone (Fig. 1).

We determined the position of each bird every 50–70 min from 0600 to 1830 h using a two-element directional antenna linked to a Telonics® TR-2 radio receiver. The birds were not tracked at night, when they were not expected to move. We estimated birds' positions from compass bearings toward the strongest transmitter signal taken from three different stand-points within walking distance from each other. A return event was recorded when we observed the birds back at their origin patch, what meant they were able to overcome the interpatch matrix (gap treatment), or back at their capture site (interior treatment). For both treatments, if no return was detected after 3 d from the release time, the experiment was finished and the bird recorded as not returned.

Homing times were compared using a one-tailed *t*-test and a Cox Proportional Hazards survival analysis (Cox 1972). The regressions explanatory variables were either the interior treatment distances vs. gap distances, or the interior treatment distances vs. the largest distance from a patch to a stepping-stone. Birds that did not return after three tracking days or lost the transmitter were considered as right censored (incomplete) data (Cox 1972). All statistical analyses were conducted using Statistica© 6.0 (StatSoft 2001).

Of all 12 captured birds, six for each treatment, only the individual taken to the patch isolated by 260 m lost its transmitter (Table 1). Birds of the gap treatment took generally longer to return if compared to the interior group (Fig. S1). The mean homing time of the interior birds (2.8 ± 1.4 h, $N = 5$) was significantly shorter ($t = -1.96$; df $= 7$; $P < 0.046$) than of gap birds (13.4 ± 10.5 h, $N = 4$). The maximum translocation distance with detected return was 230 m for both treatments. None of the two Cox regressions showed significant overall effects of distance, regardless of the pair of distance types considered ($P > 0.1$; Table S1). However, if the distance to a stepping-stone was included, there was a significant difference between the interior and gap treatments ($\chi^2 = 3.98$; $P < 0.046$; Table S1).

For both treatments, translocations up to 230 m were not enough to prevent the birds from returning to their source locations. The individuals translocated within the forest had no apparent problem with moving back to their site of capture, presenting no clear effect of the translocation distances. This reflects their ability to move through their own breeding and feeding habitat, as observed for other species in boreal forests (Gobeil & Villard 2002). Inside the forest, there are sufficient vertical trunks to provide the birds with plenty of landing places, making it possible for them to fly between trees with low risk and effort, since this is their common movement pattern (Brooke 1983, Soares & dos Anjos 1999).

However, the disruption of forest increased the difficulty of bird movement through the landscape and consequently their homing time. Similar patterns were also observed for other forest birds in

Amazonia (Laurance & Gomez 2005). Castellón and Sieving (2006) stated that translocated Chilean Chucao Tapaculos (*Scelorchilus rubecula*) seemed gradually more reluctant to cross interhabitat gaps with increasing width, a trend also verified for other species in different habitats (Gobeil & Villard 2002, Bosschieter & Goedhart 2005). The same seems to be true of *X. fuscus*, which returned quickly when translocated to 32 and 75 m across the matrix, but took much longer when interpatch distances were > 100 m (Table 1). This is probably linked to a natural avoidance of the species to make lengthy flights. According to Bélisle (2005), forest birds that venture in open habitats are exposed to higher costs, including physical stress and increased predation risks, hindering, or at least delaying, their decision to face the matrix.

Nevertheless, gaps of up to 75 m, did not seem to hinder the daily movements of *X. fuscus*, since the bird taken this distance was observed habitually shifting between both studied patches and a third nearby patch isolated by no more than 55 m from the other two. This could be a bias of the translocation procedure, which may modify the displaced individual's behavior, but can also indicate that these birds might actually assume the risks of daily crossing small areas of matrix, expanding their territories to include more than one nearby patch in it. However, even though the species home range is not larger than a few hectares in continuous forests (Develey 1997), its size is not known for fragmented landscapes. This behavior may function to fulfill their resource requirements when patches are too small or have low habitat quality (Dunning *et al.* 1992). Birds living in such conditions probably do not perceive their habitat as exceedingly fragmented when patches are close enough because they would, in principle, perceive them as functionally connected. Also, short-range movement is strongly related to the within home range exploratory behavior and has little effect on interpopulation dispersal (Dyck & Baguette 2005).

Another important fact observed in our study was the use of stepping-stones, reducing the distance to be flown without landing, which facilitates interpatch movements. The importance of having stepping-stones in the matrix can be inferred by the Cox regressions, which could significantly discriminate the return times of one treatment compared to the other only if the distances to stepping-stones were included in the model. The use of such landscape elements was confirmed in field in the case of the bird taken 230 m across the matrix. This bird did not overcome the interpatch gap in a single flight, being observed to land on isolated trees, and to use thin habitat corridors on the way back to its origin patch (Fig. 1). This behavior reduced the maximum open matrix distance crossed by this individual in a single flight to about 145 m (MaxSs).

Even though the other gap individuals were not observed using stepping-stones, this does not mean that they did not or were unable to. Previous studies have already showed that *X. fuscus* is able to make use of forest corridors or even abandoned Eucalyptus plantations with dense understory to move between patches (Dario & Almeida 2000). Similar behavior has been recorded for other bird species in fragmented habitats (Price *et al.* 1999). The existence of nearby corridors or even isolated trees might ease the movement of these individuals as it probably increases matrix permeability (Gobeil & Villard 2002, Castellón & Sieving 2006).

Our work records important information on the gap-crossing abilities of *X. fuscus* in fragmented landscapes dominated by open field matrices. We showed that habitat gaps of increasing width can modify the path and pace at which birds move through the landscape, a behavioral pattern associated with cost/benefit evaluations of single individuals (Bélisle 2005). The implementation of stepping-stones in the open matrix may enhance the functional connectivity for this species and can contribute to its conservation in sparsely forested landscapes.

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SUPPLEMENTARY MATERIAL

The following supplementary material for this article is available online at: www.blackwell-synergy.com/loi/btp

TABLE S1. *Relationships between bird homing times and gap/interior treatments.*

FIGURE S1. Kaplan–Meier plot of cumulative proportion of bird return for each of the two treatments.

LITERATURE CITED

Bélisle, M. 2005. Measuring landscape connectivity: The challenge of behavioral landscape ecology. Ecology 86: 1988–1995.

Bélisle, M., A. Desrochers, and M.-J. Fortin. 2001. Influence of forest cover on the movements of forest birds: A homing experiment. Ecology 82: 1893–1904.

Boscolo, D. 2007. Influência da estrutura da paisagem sobre a persistência de três espécies de aves em paisagens fragmentadas da Mata Atlântica. PhD Dissertation, University of São Paulo, Brazil. http://www.teses.usp.br/teses/disponiveis/41/41134/tde-13022008-180423/.

Bosschieter, L., and P. W. Goedhart. 2005. Gap crossing decisions by reed warblers (*Acrocephalus scirpaceus*) in agricultural landscapes. Landscape Ecol. 20: 455–468.

Brooke, M. L. 1983. Ecological segregation of woodcreepers (Dendrocolaptidae) in the state of Rio de Janeiro, Brasil. Ibis 125: 562–567.

Brooker, M., and L. Brooker. 2001. Breeding biology, reproductive success and survival of blue-breasted fairy-wrens in fragmented habitat in the western Australian wheatbelt. Wildl. Res. 28: 205–214.

Castellón, T. D., and K. E. Sieving. 2006. An experimental test of matrix permeability and corridor use by an endemic understory bird. Conserv. Biol. 20: 135–145.

Cox, D. R. 1972. Regression models and life-tables. J. R. Stat. Soc. 34: 187–220.

Dario, F. R., and A. F. Almeida. 2000. Influence of forest corridor on avifauna of the Atlantic Forest. Scientia Florestalis 58: 99–109.

Debinski, D. M., and R. D. Holt. 2000. A survey and overview of habitat fragmentation experiments. Conserv. Biol. 14: 342–355.

Del Hoyo, J., A. Elliott, and D. A. Christie. 2003. Handbook of the birds of the world. Vol. 8. Broadbills to Tapaculos. Lynx Edicions, Barcelona, Spain.

DEVELEY, P. F. 1997. Ecologia de bandos mistos de aves de Mata Atlântica na estação Ecológica Juréia Itatins. MSc Dissertation, University of São Paulo, Brazil.

DOS ANJOS, L., AND R. BOÇON. 1999. Bird communities in natural forest patches in southern Brazil. Willson Bull. 111: 397–414.

DUNNING, J. B., B. J. DANIELSON, AND H. R. PULLIAM. 1992. Ecological processes that affect populations in complex landscapes. Oikos 65: 169–175.

DYCK, H. V., AND M. BAGUETTE. 2005. Ecological processes that affect populations in complex landscapes. Basic Appl. Ecol. 6: 535–545.

FAHRIG, L. 2003. Effects of habitat fragmentation on biodiversity. Annu. Rev. Ecol. Evol. Syst. 34: 487–515.

FUNDAÇÃO SOS MATA ATLÂNTICA, AND INPE. 1998. Atlas da evolução dos remanescentes florestais e ecossistemas associados no Domínio da Mata Atlântica no período de 1990–1995. Fundação SOS Mata Atlântica, São Paulo, SP, Brazil.

GOBEIL, J. F., AND M. A. VILLARD. 2002. Permeability of three boreal forest landscape types to bird movements as determined from experimental translocations. Oikos 98: 447–458.

GOERCK, J. M. 1999. Distribution of birds along an elevational gradient in the Atlantic forest of Brazil: Implications for the conservation of endemic and endangered species. Bird Conserv. Int. 9: 235–253.

HANSKI, I. 1994. A practical model of metapopulation dynamics. J. Anim. Ecol. 63: 151–162.

HOBBS R. J. 1993. Landscape ecology. CSIRO, Division of Wildlife & Ecology, Australia.

KENWARD R. E. 2001. A manual for wildlife radio tagging. Academic Press, London, UK.

LAURANCE, S. G. W., AND M. S. GOMEZ. 2005. Clearing width and movements of understory rainforest birds. Biotropica 37: 149–152.

MALDONADO-COELHO, M., AND M. Â. MARINI. 2000. Effects of forest fragment size and successional stage on mixed-species bird flocks in southeastern Brazil. Condor 102: 585–594.

MELO-JÚNIOR, T. A., M. F. VASCONCELOS, W. FERNANDES, AND M. Â. MARINI. 2001. Bird species distribution and conservation in Serra do Cipó, Minas Gerais, Brazil. Bird Life Int. 11: 189–204.

METZGER, J. P. 1998. Estrutura da paisagem e fragmentação: análise bibliográfica. Anais da Academia Brasileira de Ciências 71: 445–463.

OLIVEIRA-FILHO, A. T., AND M. A. L. FONTES. 2000. Patterns of floristic differentiation among Atlantic Forests in southeastern Brazil and influence of climate. Biotropica 32: 793–810.

PRICE, O. F., J. C. Z. WOINARSKI, AND D. ROBINSON. 1999. Very large requirements for frugivorous birds in monsoon rainforests of the Northern Territory, Australia. Biol. Conserv. 91: 169–180.

SOARES, E. S., AND L. DOS ANJOS. 1999. Efeito da fragmentação florestal sobre aves escaladoras de tronco e galho na região de Londrina, norte do estado do Paraná, Brasil. Ornitologia Neotrop. 10: 61–68.

STATSOFT, INC. 2001. STATISTICA (data analysis software system), version 6. http://www.statsoft.com.

ST CLAIR, C. C., M. BÉLISLE, A. DESROCHERS, AND S. HANNON. 1998. Winter responses of forest birds to habitat corridors and gaps. Conserv. Ecol. 2: 13. http://www.consecol.org/vol2/iss2/art13/.

WIENS, J. A. 1995. Habitat fragmentation: island v landscape perspectives on bird conservation. Ibis 137: 97–104.