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The Potential Role of Migratory Birds in the Expansion of Araucaria Forest

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Abstract

The present study assessed the variation in bird species composition, and in the proportion of frugivorous and migratory individuals between areas of continuous forest and patches of Araucaria forests in natural grassland areas of southern Brazil. In the grassland-forest mosaic, 703 individuals of 83 bird species were recorded. The proportion of frugivorous and migratory individuals was significantly higher in forest patches and in the interior of continuous forest, compared to forest edges. We suggest that migratory birds are important for the dispersal of seeds from forest interiors to forest patches within the grassland, highlighting the importance of regional processes for the maintenance of local processes, for ecosystem conservation.

Key words: Forest-Grassland Mosaic, Seed Dispersal, Forest Interior, Forest Edge.

Introduction

Birds perform many ecosystem services, and are important seed-dispersal agents (Whelan *et al.* 2008). This mutualistic relationship (particularly endozoochoric dispersal) is diffuse, because generally the seeds of a plant species are dispersed by many animal species (McDiarmid *et al.* 1977). Seed dispersal through seed dispersers' activity is also an important process influencing the distribution of plant species in the environment (Schupp 1993). Moreover, seed dispersal may exert selective pressures on plants, and these pressures directly affect their reproductive success (Thompson & Wilson 1979). In spite of the potential of intensifying interspecific competition, synchronicity in the fruiting of many plant species may attract more-efficient dispersers, which show temporal patterns of abundance distribution, thus enhancing the dispersal of the plants' offspring (Poulin *et al.* 1999).

In temperate regions, the climate is markedly seasonal and the production of ornithochoric fruits tends to coincide with the presence of migratory birds, which creates an evolutionary temporal and spatial synchronicity in the animal-plant seed dispersal relationship (Thompson & Wilson 1979). This process was also described for altitudinal gradients in tropical regions (Loiselle & Blake 1991). The role that migratory species play in seed dispersal is well documented; however, their contribution to forest expansion over grassland areas has not been elucidated. We may infer that scale-dependent processes (forest patches at the local scale, and movements through the landscape at the regional scale) should be interconnected and interdependent in order to conserve and increase forest areas. Recent studies have highlighted the importance of migratory species for the forest-restoration process (Leighton Reid *et al.* 2008; Lindell *et al.* 2012, among others).

Araucaria Forest on southern Brazil's highland plateaus is frequently interspersed with grassland, forming a landscape mosaic that is one of the most endangered ecosystems in the country (Carlucci *et al.* 2011). In this physiognomy, the historical expansion of forest over the grasslands is well documented by palynological studies (e.g. Behling *et al.* 2004). The forest spreads naturally in suitable environmental conditions, such as a humid climate and low levels of perturbation by fire and cattle (Duarte *et al.* 2006). According to Duarte *et al.* (2011), the forest species involved in the early stages of Araucaria Forest patch formation in grassland areas tend to produce small red to black diaspores, which indicates that their arrival at appropriate nursery sites is dependent on the activity of vertebrate dispersers, mainly birds.

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Some bird species occurring in the highlands of southern Brazil (locally termed the *Campos de Cima da Serra*) perform latitudinal migrations (Belton 1994) and migrate to lower latitudes during austral winter. Although knowledge of the seasonal movements of bird species of the *Campos de Cima da Serra* is sparse, all or part of the populations of some species leave the high plateaus during the winter. Therefore, these populations also perform altitudinal migrations or even inter-habitat movements (Bencke & Kindel 1999). What might be the potential role of these species in the expansion of Araucaria Forest over the grasslands? If they are important in the process, we may assume that they would utilize the early forest patches as well as the continuous forest, which is the source of propagules. In this regard, bird species that potentially disperse forest seeds must be frugivores inhabiting the forest-grassland ecotone.

Our purpose was to evaluate the contribution of migratory bird species to the seed-dispersal potential of the bird community in the highlands of southern Brazil. Specifically, we asked "Do the composition and proportion of frugivorous migratory birds differ between forest areas and the grassland-forest ecotone?"

Material and Methods

Study site

The study was performed at the Pró-Mata Research and Nature Conservation Center (CPCN, 29° 12' 80" S and 50° 11' 30" W), located in São Francisco de Paula, State of Rio Grande do Sul, Southern Brazil. The regional climate is classified according to the Köppen system as Cfb, with an annual mean temperature of ca. 15.1 °C and annual mean rainfall of 2086 mm, equally distributed through the year (Duarte *et al.* 2007). The study site consisted of ca. 78 ha of Campos grassland surrounded by a continuous matrix of thousands of hectares of Araucaria forest, situated on a plateau at ca. 900 m a.s.l. In the grassland are small forest nuclei showing different degrees of development (Duarte *et al.* 2007). Cattle grazing and burning practices were stopped in 1993, allowing regeneration in the forest, and more biomass accumulation and woody-plant establishment in the grassland. These conditions generated a grassland matrix composed of tall dense caespitose grasses and shrubs. The plant composition of the forest patches was described by Duarte *et al.* (2006).

Sampling methods

Avian fauna was detected visually within a 25 m radius, by counting points for 15 minutes, during the two hours after sunrise and the two hours before sunset. Samples were taken on six days/month in october and December 2007, periods of migrant species activity. The counting points were set at least 150 m apart at the forest edge and inside the continuous forest (300 m from the edge).

Three sites of continuous forest were sampled. At each site, three points were located at the edge and three in the forest interior, totaling 18 counting points. Birds in the forest patches were also sampled by counting points. Because of the small size of the patches (mean 200 m^2), only one point was sampled in order to maintain the independence between points (150 m). In total, 11 forest patches were sampled, totaling 29 points in each month. Distance between patches and the edge of the continuous forest ranged between 85 and 1000 m.

Besides the abundance of each species (maximum number of individuals recorded in shifts and months), the birds were also classified as frugivorous (binary – yes/no) and migratory (binary – yes/no) based on the literature (Belton 1994, Bencke & Kindel 1999, Bencke 2001). The partial migratory species (part of the populations leave the region) were classified as migratory, because the maintenance of populations also depends on the migratory movements.

Data analysis

We performed a permutational MANOVA on the abundance matrix of bird species (double adjusted) to test for differences in the composition of birds among the three habitats (edge, interior and patch). We controlled for temporal variation by using the months as blocks. The Euclidean distance among sampling units was used as the dissimilarity measure. We used the sum of squares between groups (Qb statistic) as the test criterion (Pillar & Orlócci 1996). A PCoA ordination was performed to explore the relationship between the species and the three habitat types.

After the composition analysis, a matrix of species attributes was constructed (frugivorous and migratory). This matrix was multiplied by the bird abundance matrix, which generated a matrix of attributes by sites. Using this matrix, we calculated the proportion of frugivorous and migratory individuals at each site, and used a permutational ANOVA to test for differences among the three habitats, using the Euclidean distance as the dissimilarity measurement. The analyses were performed 1) with each attribute alone, and 2) with the two attributes simultaneously. Additionally, we performed a PCoA to explore the relationship among the three habitats and the attributes of migratory species. All analyses were performed on MULTIV 2.74b software (by V. Pillar, available at http://ecoqua.ecologia.ufrgs.br/ecoqua/software.html, user's guide included.).

Results

A total of 703 individuals were observed, representing 83 bird species (see Additional Supporting Information, available at www.abeco.org.br). Sixteen species were migratory and 39 were frugivorous. The forest interior showed the highest richness (S = 59), followed by the forest edge (S = 46) and forest patches (S = 41). Taking into account all the

counting points, means of 9 ± 3.3 (SD) bird species and 12.1 ± 4.8 individuals per counting point were recorded.

The bird compositions differed significantly among the three habitats (Table 1). The PCoA showed a clear compositional gradient from the forest interior to the forest patches (Figure 1). The first ordination axis was significantly stable ($p < 0.1$) after bootstrap resampling (1000 permutations).

The proportion of frugivorous birds was significantly smaller in the forest interior compared to the forest edges and patches (Table 2, Figure 2). On the other hand, the proportions of migratory and frugivorous/migratory birds were higher in the forest interior and in the patches (Table 2, Figure 2). The ordination of samples based only on migratory birds was not stable ($p > 0.1$). Therefore, there was no clear pattern of habitat use by migratory species.

Discussion

The importance of a migratory bird species to forest expansion must rely both on its frugivorous habit and on its capacity to cross the grasslands in order to disperse the forest seeds, provided that gut passage time of seeds is adequate to enable efficient dispersal (Traveset 1998). Our results indicate that bird species showing both ecological features (frugivory and migration) occurred more frequently in the forest interior and in the patches. Levey & Stiles (1992), authors of the evolutionary precursor hypothesis, proposed that the migratory habit would have evolved in bird lineages occupying open habitats, such as the canopy and the edge of forests. Boyle & Conway (2007) tested the hypothesis on tyrannid species by evaluating the interaction between habitat and diet on migratory behavior, and found that the migratory habit was more related to the habitats than to frugivory. We found a higher proportion of frugivorous birds at the forest edge and in the patches, indicating that resident species may also disperse seeds to forest patches within the grassland. We may infer that migratory and resident bird species disperse particular sets of seeds from the forest interior or edge. Indeed, previous studies in the same region revealed that the sizes of the diaspores increase in larger forest patches, showing the presence of specific plant genera such as *Cabralea*, *Annona* and *Ocotea* (Duarte *et al.* 2006, 2007, 2011). Therefore, bird species occurring at the edge and in the forest interior may disperse particular types of diaspores, which partly explains the gradient observed in the attributes of diaspores of plant species that colonize forest patches in open areas (Duarte *et al.* 2006, 2007, 2011).

The role that migratory birds play in seed dispersal has been widely documented in temperate and tropical regions

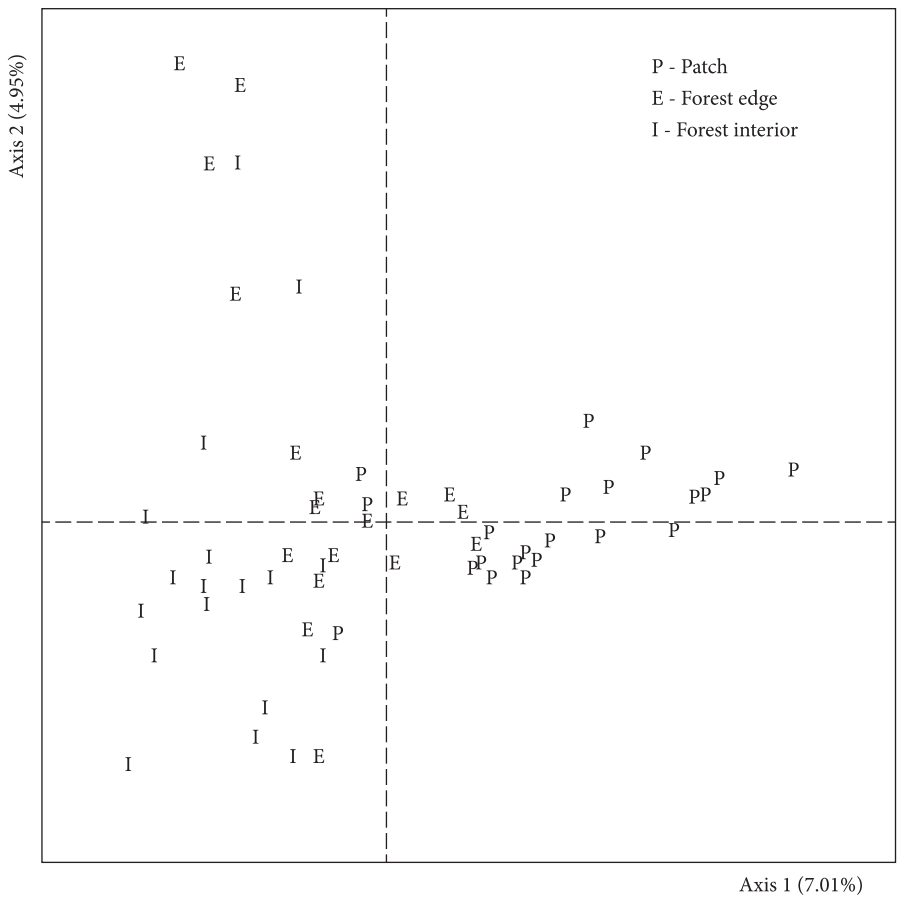

Figure 1. PCoA ordination of bird communities in different habitat types in the southern Brazilian highlands.

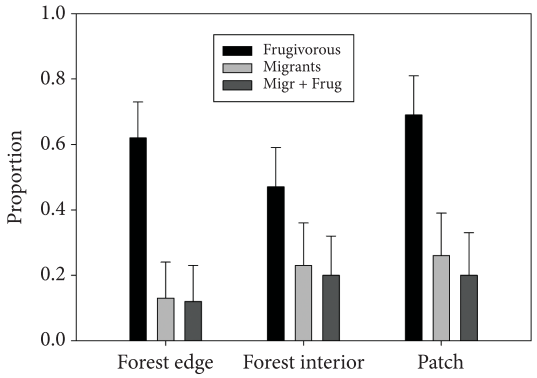

Figure 2. Proportion of frugivorous and/or migratory birds in different habitat types in the southern Brazilian highlands.

Table 1. Permutational MANOVA comparing bird species composition in three different forest habitats.

Source of variation	Q	p-value
Between groups	0.668	0.0001
Edge × Patches	0.287	0.0001
Edge × Interior	0.259	0.0001
Interior × Patches	0.448	0.0001
Within groups	7.271	

Q = sum of squares; p-values generated after 10 000 iterations.

Table 2. Permutational ANOVA comparing the proportion of frugivorous birds, migratory birds, and frugivorous-migratory birds in three different forest habitats.

Proportion of frugivores	Q	p-value
Between groups	0.5290	0.0001
Edge × Interior	0.2110	0.0004
Edge × Patches	0.0570	0.0546
Interior × Patches	0.5200	0.0001
Within groups	0.7260	
Proportion of migratory species		
Between groups	0.1650	0.0054
Edge × Interior	0.0850	0.0192
Edge × Patches	0.1550	0.0021
Interior × Patches	0.0008	0.4918
Within groups	0.7750	
Proportion of frugivorous and migratory		
Between groups	0.0740	0.0727
Edge × Interior	0.0560	0.0366
Edge × Patches	0.0570	0.0482
Interior × Patches	0.0009	0.9425
Within groups	0.7390	

Q = sum of squares; p-values generated after 10 000 iterations.

(Loiselle & Blake 1991). We were able to show that this bird assemblage is also important for the potential dispersal of seeds in the Araucaria Forest region of southern Brazil, in spite of the low proportion of migratory birds (~20%). The assemblage was sampled during only one season of the year, but we infer that the proportion of resident and migratory species must vary little, because the region has a regular annual climate variation. This pattern was described by Jones & Cresswell (2010) as the phenology mismatch hypothesis, in which several migratory bird populations showed phenological inertia during the period of migration, relative to global climatic changes. However, some recent studies have found some plasticity in the time of arrival for some migratory species, mainly short-distance migratory birds (Hulbert & Liang 2012).

The higher proportion of frugivorous and migratory birds found in the forest interior and in the forest patches was due to higher abundances of certain species. *Elaenia mesoleuca* showed the highest abundance. In spite of the lack of reliable information about migratory routes, we do know that *E. mesoleuca* individuals belong to the austral-breeding species group (Sick 1997), which breed in southern and southeastern Brazil and migrate to midwestern and northern Brazil during austral winter. In Cerrado regions, *E. mesoleuca* was found only in denser forest areas (Piratelli & Blake 2006).

Migratory birds are considered to have a lower risk of extinction compared to residents, because they show a wide tolerance to diverse habitats (Loiselle & Blake, 1991). However migrants that overwinter in central Brazil such as species of *Elaenia* merit special attention because this ecosystem has suffered intense pressure from human activities (Alves 2007). The same concern applies to altitudinal migratory species, since lowlands are subjected to severe deforestation (Stotz *et al.* 1996). Even though seed dispersal is a diffuse process, it can be severely affected by disperser losses. The migratory bird species acting as seed dispersers play an important role at the local bird-assemblage scale, as well as at regional landscape-scale processes such as forest expansion. The continuous process of habitat fragmentation exerts a negative effect on the disperser assemblage, which can endanger the maintenance of the landscape process of forest expansion (Gómez-Montes & Bayly 2010). The results of the present study suggest that the migratory bird species participate in the process of forest expansion mainly by dispersing plant species from the forest interior to the forest patches. Other studies have demonstrated the need for maintaining a matrix of different interconnected patch types, for the conservation of migratory bird species (Tellería *et al.* 2005; Gómez-Montes & Bayly 2010). Therefore, actions aiming for the conservation of seed-dispersal processes and the Araucaria Forest ecosystem must be applied at local as well as regional scales, in order to conserve the key migratory routes that maintain the assemblage of disperser birds in this ecosystem.

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