

Avian responses to fragmentation of the Maulino Forest in central Chile

Pablo M. Vergara and Javier A. Simonetti

Abstract Depending on the mosaic of habitats that is created, forest fragmentation can reduce the abundance and diversity of forest birds. Temperate deciduous forests in South America are rapidly being replaced by pine plantations, causing changes in habitats for both breeding and migrant birds. We examined differences in avian species richness and abundance in three areas: a reserve with continuous tracts of native forest, forest fragments and pine plantations. Four species were negatively affected by fragmentation, with their abundance declining from continuous forest to pine plantations. Fourteen species were not affected by fragmentation and eight had significantly increased abundance in pine

plantations compared to continuous forest. Overall abundance in pooled and ground/understorey birds was higher in forest fragments and pine plantations compared to continuous forest. The abundance of granivorous species was higher in the pine plantations than in the forest reserve, but the abundance of insectivorous species was higher in the forest reserve and in forest fragments than in pine plantations. Thus, forest fragmentation affects birds differentially according to their feeding ecology.

Keywords Birds, Chile, forest fragmentation, granivores, insectivores, Maulino forest, *Pinus radiata*.

Introduction

Forest fragmentation triggers a reduction in the number of forest bird species (Boulinier *et al.*, 1998), and the creation of pine plantations involves both disturbance and fragmentation of habitats for birds (Díaz *et al.*, 1998). Landscapes fragmented and dominated by such plantations may be unsuitable habitats for birds (Armstrong *et al.*, 1996) because reproductive success is affected (Rosenfield *et al.*, 2000). Forest specialists, frugivorous species, woodpeckers and other cavity-nesters are particularly vulnerable to such fragmentation (Clout & Gaze, 1984; Mitra & Sheldon, 1993; Hayes & Samad, 1998). In some cases, however, pine plantations and small forest fragments may be used as foraging or breeding habitats (Estades & Temple, 1999; Renjifo, 2001), and some pine plantations have a mosaic of heterogeneous vegetation that can support large numbers and a high diversity of bird species (Hanowski *et al.*, 1997; Shochat *et al.*, 2001), depending on the initial site conditions,

rotation ages and management intensity (Dickson *et al.*, 1993; Summers *et al.*, 1993). Maintenance of the understorey in pine plantations may increase bird diversity and also improve habitat quality for forest bird species (López & Moro, 1997). Furthermore, some species can benefit from pine plantations that provide a source of seeds (Marquiss & Rae, 1994) or insects (Kleintjes & Dahlsten, 1994).

Deciduous forests in the coastal range of central Chile have been severely fragmented over the last 100 years by agricultural practices, and are now only found in some areas of the Cordillera de la Costa, from Altos de Licantén (35° 55' S) to the Itata River (36° 20' S) (Donoso, 1996). Afforestation with Monterrey pine *Pinus radiata* is changing the landscape, with both croplands and native forests converted into large pine plantations (Donoso & Lara, 1996).

The fragmentation of continuous deciduous forest into small fragments enclosed by extensive pine plantations has triggered important changes in the original habitat mosaic for breeding birds. However, such habitat transformations do not affect all forest birds in the same way because pine plantations and small forest fragments constitute a habitat mosaic of differing quality (Estades & Temple, 1999). Understorey cover, a variable associated with understorey bird abundance (Sieving *et al.*, 2000; Vergara, 2002), has increased in some pine plantations and secondary growth forest fragments (Acosta-Jamett & Simonetti, 2004), but there has been a reduction in

Pablo M. Vergara Departamento de Ciencias Ecológicas, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile, and Departamento de Ecología, Pontificia Universidad Católica de Chile, Alameda 340, C.P. 6513677, Casilla 114-D, Santiago, Chile.

Javier A. Simonetti (Corresponding author) Departamento de Ciencias Ecológicas, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile. E-mail jsimonet@uchile.cl

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canopy cover, an important influence on the abundance of canopy foliage birds (Estades, 1997a), from continuous forest to forest fragments and pine plantations. There are more ground insects, which are an important food for some understory birds, in both pine plantations and forest fragments compared to continuous forest (Grez *et al.*, 2003). Furthermore, some birds, such as finches, may take advantage of the larger amount of seeds (e.g. pine seeds) in plantations (Donoso *et al.*, 2003). Therefore, fragmentation of continuous forest could differentially affect forest bird species. Here we report a study of changes in the abundance and habitat-use categories of forest birds in a deciduous forest within pine plantations in central Chile.

Study site

We studied a 16 km² area in the Cordillera de la Costa of central Chile (Fig. 1). This area comprises part of the Los Queules National Reserve (a 145 ha reserve that is part of 600 ha of continuous native forest) and also includes Monterey pine *Pinus radiata* plantations and fragments of native forest. Pine plantations, covering c. 865 ha, are regarded as the matrix that surrounds the native forest remnants. These plantations are on former agricultural fields, and are at least 20–40 years old. Consequently, most forest fragments are older than 40 years. The predominant habitat within the Reserve is a mature mixed forest composed principally of hualo *Nothofagus*

glauca, roble *N. obliqua* and evergreen sclerophyllous tree species. Pine plantations comprised 54% of the total area, fragments and corridors 24%, and continuous forest 22% (Acosta-Jamett & Simonetti, 2004). Forest fragments included both isolated fragments and corridors of native vegetation. Isolated fragments were *Nothofagus* forest and native thicket <7 ha in area and separated by ≥ 50 m. Native vegetation corridors included small creeks that support dense native vegetation and were <140 m wide.

Methods

During the avian breeding season (October–November 2000) we located 50 survey points at random within an area of c. 16 km², including the Reserve, pine plantations and forest fragments. Sampling points were ≥ 320 m apart; 28 points were in pine plantations, 11 in forest fragments and 11 in the continuous forest of the Reserve. The number of survey points reflected our capacity to sample them all within a given day. We surveyed species abundance at each point using 50 m fixed-radius point counts of 10 minutes duration (Reynolds *et al.*, 1980; Dawson, 1981; Fuller & Langslow, 1984; Jiménez, 2000). Each point was visited five times during the breeding season to increase the probability of detecting elusive or rare birds (Raphl *et al.*, 1993). Surveys were always in the morning (05.20–11.30) and 2 minutes after arrival at the station. The 50 m fixed-radius was chosen to reduce

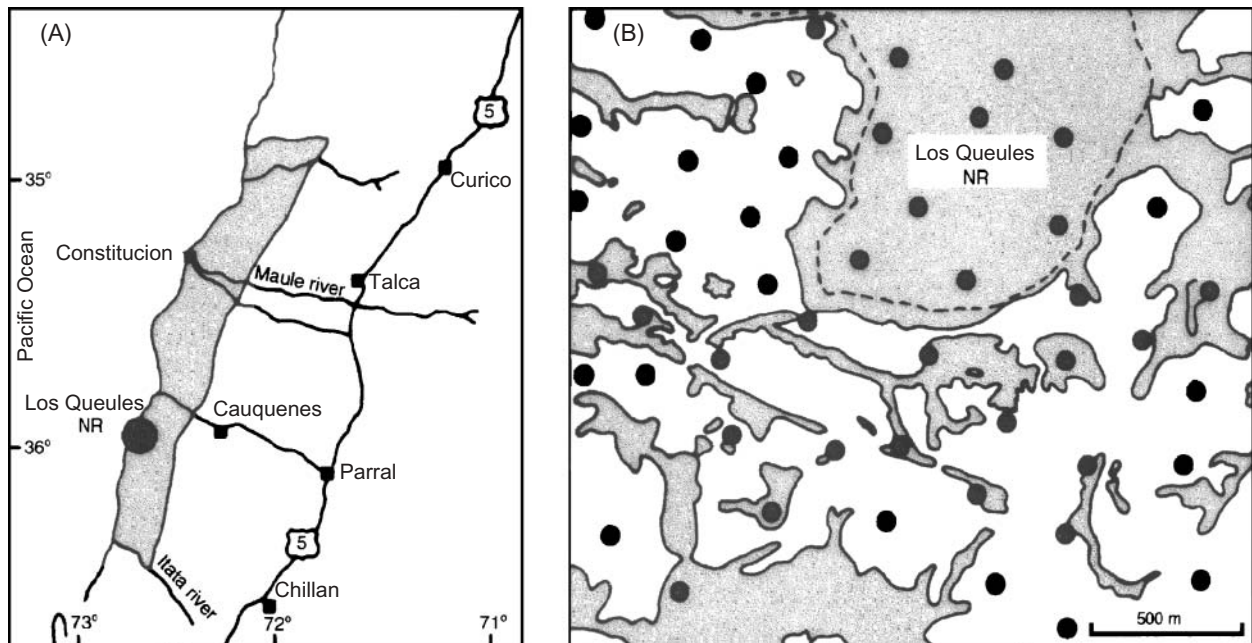


Fig. 1 (A) Geographical distribution of the coastal Maulino forest (shaded) and location of the study site at Los Queules National Reserve (filled circle). (B) Study site, depicting the continuous forest of the Reserve and adjacent fragments (shaded) and pine plantations (unshaded). The dashed line denotes the limits of the Reserve, and filled circles the sampling sites.

the effect of variation in the effective radius of detection among observers (Nichols *et al.*, 2000) and to avoid pseudo-replication between neighbouring points.

We estimated abundance, as individuals per ha, by averaging the number of birds in the five counts at each point. Bird species richness was estimated at each sampling point (Gutzwiller, 1991; Drapeau *et al.*, 1999). We used an *a priori* classification of bird habitat use and trophic categories (Wiens, 1992). Categories were not mutually exclusive in species composition. We pooled bird abundance into the following categories (Johnson, 1967; Araya *et al.*, 1995; Rozzi *et al.*, 1996): resident and migratory, cavity and open nesters, granivorous, frugivorous, nectarivorous, insectivorous, ground and understorey insectivorous, foliage insectivorous, and trunk and branch insectivorous. Differences in abundance and species richness in the Reserve, forest fragments and pine plantations were tested using a non-parametric Kruskal-Wallis ANOVA.

We also measured habitat and landscape variables at each sampling point: % cover, diameter at breast height (DBH), density (trees ha⁻¹), tree height (m), age (in years for pine plantations) within the 50 m radius of the sampling point, size of native forest fragment (ha), and distance from the sampling point to the nearest creek or native forest patch. These variables were used to determine the best predictors of avian richness and pooled abundance using stepwise regression analysis.

Results

We recorded 32 bird species during our surveys (Table 1). Twenty-four (75%) were recorded in the Reserve, 28 (88%) in forest fragments and 29 (91%) in pine plantations. Species richness was not significantly different between the Reserve (mean \pm SE, 8.5 \pm 0.84), forest fragments (11.0 \pm 0.88) and pine plantations (10.2 \pm 0.51) (Kruskal-Wallis $H_{2,50} = 5.42$, $P = 0.07$). Pooled abundance was greater in pine plantations and forest fragments than in the Reserve (Table 2). Five species were negatively affected by fragmentation. Of these, four species (thorn-tailed rayadito *Aphrastura spinicauda*, Chilean pigeon *Columba araucana*, Chilean swallow *Tachycineta meyeni* and Austral pygmy-owl *Glacidium nanum*) were more abundant in the Reserve and forest fragments than in the pine plantations, and only one species (white-throated treerunner *Pygarrhichas albogularis*) was more abundant in the Reserve than in the pine plantations (Table 1).

The abundance of 12 species did not differ significantly between the Reserve, forest fragments and pine plantations (Table 1). Eight species were significantly more abundant in forest fragments and pine plantations than in the Reserve (Table 1). The other seven species were

uncommon and it was not therefore possible to make any statistical comparisons. The abundance of granivorous species was greater in the pine plantations than in the Reserve, but did not differ between pine plantations and forest fragments (Table 1). The abundance of ground-understorey insectivores was significantly greater in forest fragments and pine plantations than in the Reserve, and the abundance of trunk-branch insectivores was greater in the Reserve and in forest fragments than in pine plantations (Table 2).

Regression models accounted for little of the variation in avian richness and pooled abundance (Table 3). Understorey cover was the only significant predictor of avian richness (Table 3), and understorey cover and native forest fragment size were the only significant predictors of pooled abundance (Table 3).

Discussion

Habitat fragmentation often increases the probability of local extinction of forest bird species because it may reduce and isolate available habitats (Turner, 1996). In the first 50 years after isolation even large tropical forest fragments (i.e. 1,000 ha) suffer *c.* 50% of the total number of extinctions they are likely to experience (Brooks *et al.*, 1999). Given the small size of forest fragments in the Maulino forest and the long time since they were created, these remnants should have already lost a significant number of species. However, the number of species is similar in forest fragments and continuous forest, suggesting that birds are responding to factors other than area alone. Bird responses to fragmentation may depend on their ecological and biological attributes (Karr, 1990; Kattan *et al.*, 1994) and the way the birds perceive the habitat mosaic (Roldstad, 1991). Forest fragmentation in Chile is caused mostly by clearing for pastures, substitution of native forests with exotic pines, urban development and logging (Bustamante & Castor, 1998). On Chiloé Island, southern Chile, where forest is fragmented by pastures, forest birds only use forest fragments because the pasture is unsuitable (Willson *et al.*, 1994). On the other hand, in landscapes dominated by pines, plantations could be beneficial to some bird species, depending on the characteristics of the vegetation in the understorey (Estades, 1994; Estades & Temple, 1999; Vergara, 2002). Many bird species commonly nest in pine plantations (Estades, 1997b,c). Furthermore, birds associated with temperate forests, including nocturnal raptors such as rufous-legged owl *Strix rufipes* and understorey birds such as chestnut-throated huet-huet *Pteroptochos castaneus*, also nest in pine plantations (C.F. Estades, pers. comm.; Vergara, 2002).

Fragmentation of deciduous forests might have increased rather than decreased bird species abundance.

Table 1 Abundance of breeding birds (individuals per ha \pm SE) in the continuous forest of Los Queules National Reserve, forest fragments and pine plantations (species with 1–2 individuals overall are depicted by P (present) and their abundances were not compared statistically), with results of a Kruskal-Wallis ANOVA for comparisons of abundance between the three forest types; different superscripted letters indicate significant differences.

| Species | Landscape component (no. of plots) | | | Kruskal-Wallis ANOVA | |
|---|------------------------------------|--------------------------------|------------------------------|----------------------|---------|
| | Reserve (28) | Forest fragments (11) | Pine plantations (11) | H ₂ * | P |
| Thorn-tailed ryadito <i>Aphrastura spinicauda</i> | 1.62 \pm 0.16 ^a | 1.37 \pm 0.17 ^a | 0.62 \pm 0.11 ^a | 36.6 | < 0.001 |
| White-crested eania <i>Elaenia albiceps</i> | 1.57 \pm 0.11 | 1.43 \pm 0.17 | 1.40 \pm 0.12 | 0.7 | 0.72 |
| Austral thrush <i>Turdus falklandii</i> | 0.71 \pm 0.14 | 0.50 \pm 0.05 | 0.63 \pm 0.06 | 3.1 | 0.21 |
| White-throated treerunner <i>Pygarrhichas albogularis</i> | 0.64 \pm 0.15 ^a | 0.39 \pm 0.08 ^{a,b} | 0.17 \pm 0.05 ^b | 27.7 | < 0.001 |
| Chilean swallow <i>Tachycineta meyeni</i> | 0.55 \pm 0.09 ^a | 0.45 \pm 0.06 ^{a,b} | 0.32 \pm 0.10 ^b | 7.1 | 0.05 |
| Chestnut-throated huet-huet <i>Pteroptochos castaneus</i> | 0.29 \pm 0.16 | 0.42 \pm 0.19 | 0.23 \pm 0.04 | 5.8 | 0.55 |
| Chilean pigeon <i>Columba araucana</i> | 0.26 \pm 0.11 ^a | 0.07 \pm 0.00 ^a | 0 ^b | 20.5 | < 0.001 |
| Patagonian sierra-finch <i>Phrygilus patagonicus</i> | 0.25 \pm 0.07 | 0.19 \pm 0.04 | 0.24 \pm 0.02 | 1.2 | 0.55 |
| Black-chinned siskin <i>Carduelis barbata</i> | 0.22 \pm 0.08 | 0.33 \pm 0.10 | 0.36 \pm 0.12 | 4.7 | 0.86 |
| Ochre-flanked tapaculo <i>Eugralla paradoxa</i> | 0.19 \pm 0.08 ^a | 0.84 \pm 0.05 ^b | 0.75 \pm 0.08 ^b | 23.7 | < 0.001 |
| House wren <i>Troglodytes aedon</i> | 0.17 \pm 0.02 ^a | 1.02 \pm 0.11 ^b | 1.18 \pm 0.12 ^b | 26.7 | < 0.001 |
| Des Murs's wiretail <i>Sylviorthorhynchus desmursii</i> | 0.14 \pm 0.09 ^a | 0.78 \pm 0.16 ^b | 0.69 \pm 0.06 ^b | 24.0 | < 0.001 |
| Fire-eyed diucon <i>Xolmis pyrope</i> | 0.13 \pm 0.00 | 0.24 \pm 0.00 | 0.21 \pm 0.11 | 1.6 | 0.44 |
| Austral blackbird <i>Curaeus curaeus</i> | 0.12 \pm 0.01 ^a | 0.52 \pm 0.19 ^{a,b} | 0.80 \pm 0.10 ^b | 35.1 | < 0.001 |
| Tufted tit-tyrant <i>Anairetes parulus</i> | 0.12 \pm 0.00 | 0.18 \pm 0.02 | 0.14 \pm 0.01 | 3.3 | 0.19 |
| Chimango caracara <i>Milvago chimango</i> | 0.12 \pm 0.051 | 0.18 \pm 0.11 | 0.13 \pm 0.05 | 0.2 | 0.93 |
| Austral pygmy-owl <i>Glacidium nanum</i> | 0.09 \pm 0.00 ^a | 0.19 \pm 0.18 ^a | 0 ^b | 8.7 | 0.01 |
| Striped woodpecker <i>Picoides lignarius</i> | 0.09 \pm 0.00 | 0.12 \pm 0.00 | 0.07 \pm 0.00 | 2.0 | 0.38 |
| Rufous-legged owl <i>Strix rufipes</i> | 0.09 \pm 0.03 | 0.03 \pm 0.00 | 0.07 \pm 0.02 ^b | 1.7 | 0.42 |
| Andean tapaculo <i>Scytalopus magellanicus</i> | 0.06 \pm 0.00 ^a | 0.47 \pm 0.16 ^b | 0.75 \pm 0.05 ^b | 32.3 | < 0.001 |
| Rufous-collared sparrow <i>Zonotrichia capensis</i> | 0.06 ^a \pm 0.00 | 0.18 \pm 0.00 ^b | 0.22 \pm 0.04 ^b | 6.4 | 0.04 |
| Chilean flicker <i>Colaptes pitius</i> | 0.06 \pm 0.00 | 0.06 \pm 0.00 | 0.07 \pm 0.00 | 0.60 | 0.76 |
| Plain-mantled tit-spinetail <i>Leptasthenura aegitaloides</i> | 0.03 \pm 0.00 | 0.03 \pm 0.00 | 0.05 \pm 0.02 | 0.1 | 0.96 |
| Green-backed firecrown <i>Sephanoides galeritus</i> | P | 0 | P | – | – |
| Great shrike-tyrant <i>Agrionis livida</i> | 0 | P | 0 | – | – |
| Red-backed hawk <i>Buteo polysoma</i> | 0 | 0 | P | – | – |
| California quail <i>Callipepla californica</i> | 0 ^a | 0.22 \pm 0.11 ^b | 0.20 \pm 0.03 ^b | 5.7 | 0.04 |
| Common diuca-finch <i>Diuca diuca</i> | 0 ^a | 0.04 \pm 0.00 ^b | 0.29 \pm 0.09 ^b | 7.1 | 0.03 |
| American kestrel <i>Falco sparverius</i> | 0 | 0 | P | – | – |
| Chilean tinamou <i>Nothoprocta perdicaria</i> | 0 | P | P | – | – |
| Giant hummingbird <i>Patagona gigas</i> | 0 | 0 | P | – | – |
| Chuca tapaculo <i>Scelorchilus rubecula</i> | 0 | P | P | – | – |

Table 2 Pooled abundance and abundance of habitat use categories (individuals per ha \pm SE) of birds in continuous forest in the Los Queules National Reserve, forest fragments and pine plantations, with results of a Kruskal-Wallis ANOVA for comparisons of abundance between the three forest types; different superscripted letters indicate significant differences.

| Category (no. of species) | Reserve | Forest fragments | Pine plantations | Kruskal-Wallis ANOVA | |
|--|------------------------------|--------------------------------|------------------------------|----------------------|--------|
| | | | | H _{2,50} | P |
| Pooled (32) | 7.66 \pm 0.64 ^a | 9.82 \pm 0.52 ^b | 9.53 \pm 0.38 ^b | 8.16 | 0.02 |
| Resident (18) | 5.35 \pm 0.37 | 7.33 \pm 0.52 | 6.47 \pm 0.27 | 6.14 | 0.06 |
| Migratory (14) | 2.20 \pm 0.26 | 2.45 \pm 0.17 | 3.06 \pm 0.25 | 0.83 | 0.61 |
| Cavity nesting (13) | 3.85 \pm 0.47 | 4.65 \pm 0.23 | 4.15 \pm 0.25 | 0.98 | 0.50 |
| Open nesting (19) | 3.67 \pm 0.37 | 4.86 \pm 0.41 | 5.38 \pm 0.29 | 4.26 | 0.11 |
| Granivorous (6) | 0.36 \pm 0.15 ^a | 0.81 \pm 0.12 ^{a,b} | 1.31 \pm 0.12 ^b | 7.41 | 0.03 |
| Frugivorous (2) | 0.97 \pm 0.48 | 0.57 \pm 0.18 | 0.63 \pm 0.11 | 5.21 | 0.09 |
| Nectarivorous (7) | 2.71 \pm 0.19 | 2.76 \pm 0.15 | 3.04 \pm 0.21 | 1.98 | 0.44 |
| Insectivorous (24) | 5.46 \pm 0.58 | 5.54 \pm 0.53 | 4.88 \pm 0.39 | 2.18 | 0.33 |
| Ground & understorey insectivorous (6) | 0.92 \pm 0.31 ^a | 3.53 \pm 0.35 ^b | 3.62 \pm 0.21 ^b | 33.73 | <0.001 |
| Foliage insectivorous (10) | 4.49 \pm 0.32 | 4.52 \pm 0.29 | 3.68 \pm 0.24 | 3.28 | 0.27 |
| Trunk & branch insectivorous (5) | 2.44 \pm 0.24 ^a | 1.97 \pm 0.29 ^a | 0.96 \pm 0.13 ^b | 24.77 | <0.001 |

Table 3 Multiple regression models of avian richness and pooled abundance, using habitat and landscape variables (see text for details), indicating the variables included in the final model.

| | Variables in the model | r ² | df | F | P |
|------------------|---|----------------|------|------|-------|
| Avian richness | Understorey cover | 0.14 | 1,48 | 7.7 | 0.008 |
| Pooled abundance | Understorey cover & native forest fragment size | 0.24 | 2,47 | 11.9 | 0.003 |

Insectivorous birds that forage in the understorey are more abundant in pine plantations and forest fragments, possibly due to an increased number of ground insects (Grez *et al.*, 2003). The understorey of pine plantations and forest fragments has complex, dense vegetation, which is important in determining understorey bird abundance (Sieving *et al.*, 2000; Vergara, 2002). Thus plantations with a more heterogeneous understorey could support more birds (Hanowski, 1997; López & Moro, 1997), although management activities such as herbicide application, removal of the stumps and roots of native trees, and other soil disturbance may reduce habitat quality for these birds. Plantations of Monterey pine in their native California serve as an important foraging resource for certain birds during the breeding season (Kleintjes & Dahlsten, 1994).

The forest of the Reserve has a less complex understorey than the pine plantations and native forest fragments. However, in this habitat the thorn-tailed rayadito and the white-throated treerunner are forest-specialist species (Vuilleumier, 1985) that forage mostly on boles and occasionally on the ground (R.P. Schlatter & P.M. Vergara, unpubl. data). Thus, insectivorous specialists amongst the trunks and branches could be sensitive to land cover change because disturbance of continuous forest degrades canopy structure, including large and decayed tree branches. The Chilean pigeon and the Austral pygmy-owl are also forest specialist species, the former feeds on seeds and forest fruits and the latter nests in tree hollows. Fragmentation may reduce fruit availability and nesting structures. The abundance of the Chilean pigeon, categorized as Vulnerable on the national IUCN Red List (Glade, 1988) is lower in forest fragments than in the Reserve, and the species is absent in pine plantations. Finally, forest disturbance could have significant effects on birds that exploit trunk resources such as bark insects and holes in which to nest. These structures are more available in continuous forest than in pine plantations.

Maintenance of suitable bird habitats is possible within the context of a heavily managed plantation system (Houseman & Anderson, 2002). Conservation programmes for deciduous forest birds should focus on species that depend on specific forest structures that become less available when pine plantations replace the original forests. Therefore, forest managers should

consider maintaining patches of mature forest rather than fragments of native secondary growth forests.

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Biographical sketches

Pablo Vergara is a forester interested in avian ecology and conservation. Currently he is studying the ecology of birds in forest fragments in relict forests in northern Chile.

Javier A. Simonetti is interested in the ecology and conservation of Latin American biodiversity. His research focuses on plant-animal interactions in fragmented forests and the role of the habitat matrix for species survival.