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Effects of Patagonian pine forestry on native breeding birds

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Abstract

Aim of the study: The objective is to assess the influences of the tree stand age and other forestry management practices on species richness, composition, and distribution of the Patagonian pine plantation bird assemblages.

Area of study: The work was carried out in forested plots of Ponderosa pine located at the Lanín National Park (Patagonia, Argentina).

Material and methods: Birds were sampled using 25 m fixed radius point counts, at four plots varying in age, management, and forest structure.

Main results: A total of 2090 individuals belonging to 34 bird species were observed, their numbers vary significantly depending on the different modes of plantation management. The population density of the 14 most abundant bird species was compared among the four plantation plots and ten species don't show statistically significant differences in their population density among the different forest plots. The California Quail, the White-Crested Elaenia and the Southern House Wren showed higher densities in pine plantations with lower tree densities and fewer cutting treatments. The Diuca Finch had high densities in the younger plantations not subjected to any treatment.

Research highlights: Most of these bird species are opportunistic and a few are found more regularly in these non-native woods than in other native forested or afforested areas. Our data suggest that a mixed scenario based on a mosaic of plantation with patches of native deciduous forest may help maximize the bird diversity in the management of northwestern Patagonian plantation landscapes.

Key words: bird population; diversity; exotic plantations; Patagonia; tree-age.

Introduction

Biodiversity in forest ecosystems is determined and influenced by climatic and soil conditions, evolution, changes in species' geographical ranges, population and community processes, and natural or human-related disturbances. Ecological processes and biodiversity change with time as ecosystems recover from natural or human-related disturbances. Such disturbances may either increase or decrease biological diversity, depending on the scales and measures considered. The highest levels of biodiversity are found in forests that have previously been subjected to intermediate frequencies, scales, and intensities of disturbance (Kimmins, 2000).

It is widely believed that plantation forests are on average less favourable as habitat for a wide range of animal taxa. This is particularly so in the case of even-aged, single-species stands involving exotic species (Hartley, 2002; Hunter & Hunter, 2003). In support of that hypothesis, it has been pointed out that the avifauna of single-species plantation forests tends to have lesser species diversity than that in natural or semi-natural forests (Disney & Stokes, 1976; Baguette *et al.,* 1994; Fisher & Goldney, 1998). However, the effect of forest plantations on biodiversity depends on the type of plantation, the natural structure of the surrounding native forests, and on regional characteristics (Luck & Korodaj, 2008).

Additionally, such findings cannot be generalised, thus in some cases, wildlife or other biota within plantation forests may be as abundant or more than in their populations in natural forests; although biological integrity is lower than in the latter. For instance, the species richness of indigenous birds in New Zealand is only slightly lower in pine plantation forests than in native forests (Clout & Gaze, 1984), and in some ca-

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ses bird counts in these plantations exceeded those of the most naturally preserved forests (Brockie, 1992).

Furthermore, an analysis of the impact of plantation forestry on species diversity based simply on comparisons with natural forests in the same area is not always appropriate. While the conversion of ecosystems with full up biological integrity such as old-growth forests, native grasslands or other natural ecosystems to plantation forests is generally undesirable from the point of view of species diversity; the economic pressure for planted forests that often replace other land uses is pervasive. However, where plantations have been established on abandoned pastures or degraded land, they can be more beneficial to species diversity than the modified agricultural areas they replace (Avery & Leslie, 1990; Tubelis *et al.,* 2007).

The structure of older-growth plantation stands is eventually modified by the application of silvicultural treatments, such as regeneration cuts and thinning prescriptions (Lencinas *et al.,* 2005; Du Bus De Warnaffe & Deconchat, 2008). Modifications in forest structure can elicit a significant impact on bird communities, including relatively common avian species (Clout and Gaze, 1984; Loyn, 1985). Such species benefit from the additional habitat provided by plantations if these forests have replaced a less suitable native habitat. Plantation forests can also accommodate edge-specialist bird species and generalist forest species that would theoretically benefit from a mix array of forest types (Christian *et al.,* 1998; Du Bus De Warnaffe & Deconchat, 2008).

Plantations are most likely to be used by the breeding birds of native forests as feeding areas or dispersal corridors (MacDonald, 2003). Thus, the different elements of a land mosaic can be viewed as integral parts of a complex landscape composed of habitat patches with different qualities. The capacity of different species to use patches of modified habitat can define a gradient of habitat use that is more complex than a simple classification as “habitat” or “non-habitat”, particularly in the case of birds (Barbaro *et al.,* 2005). The role of native forest patches in the conservation of bird species can be improved by promoting the existence of more suitable matrix types surrounding landscape remnants. For example, in Australia the maintenance of bands of pine forest adjacent to patches of native eucalyptus forest benefits several species inhabiting such native patches (Tubelis *et al.,* 2007).

Plantation forests, also called planted forests, are cultivated forest ecosystems established by planting or seeding for afforestation and reforestation. Such undertakings are primarily for wood biomass production, but also for soil and water conservation and wind protection. Because of its rapid growth, the Ponderosa pine —*Pinus ponderosa* (Dougl.)— is one of the conifer species most widely employed to afforest vast areas of the Patagonian Andean region (Andenmatten and Letourneau, 1997). In Patagonia, individual trees of this species often exhibit significantly greater growth rates than those achieved in North America (Markstrom *et al.,* 1983). Some local studies have reported that the substitution of native *Nothofagus* forests by exotic conifer plantations has had a significant effect on bird assemblages, diminishing their species richness, abundance, diversity, and evenness (Deferrari *et al.,* 2001; Lantschner & Rush, 2007; Paritsis & Aizen, 2008). Currently, the Patagonian region of Argentina has approximately 80,000 ha planted with this species, with some stands found in their first thinning and pruning stage, whereas others are close to their final cut (Jovanovski *et al.,* 2002).

The aim of the present work is to assess the influences of the tree stand age and other forestry management practices on species richness, composition, and distribution of the Patagonian pine plantation bird assemblages.

Material and methods

Study Area

The study was carried out in forested plots of Ponderosa pine located in the Meliquina Valley (40.3° S, 71.1° W at 800-860 m in altitude) in the Lanín National Park, Patagonia, Argentina. According to Köppen-Geiger classification it is a dry-summer subtropical climate, it has cold wet winters and hot, dry summers. Average annual rainfall (1978-1999 period) at the site was 684 ± 283.1 mm (with approx. 579 mm in autumn and winter and 105 mm in spring and summer). Maximum and minimum average annual temperatures are 17.1 ± 0.5 and 4 ± 2.1°C, respectively (data from the “Autoridad interjurisdiccional de las Cuencas de los Ríos Limay, Neuquén y Negro”).

The characteristics of the forest plots are described in Table 1. All plots were separated by at least 600-800 m from each other, and were interconnected by non-asphalted forestry roads. In plot A, small remnants of native southern beech forest of *Nothofagus obliqua*,

Table 1. Structural characteristics of the pine plantations surveyed at Lanín National Park (Patagonia, Argentina)

Type	Age (years)	Distance to river (m)	Plant density (pines ha^{-1})	Silvicultural treatment	Average height (m)	Average DBH (cm)	Size (ha)
Plot A	15-18	0-200	350	Limited clear-cutting and pruning height	8.5	22	61.4
Plot B	16-18	400-800	350	Limited clear-cutting and pruning height	8.5	22	77.9
Plot C	15-18	400-800	250	Extensive clear cutting and pruning height	8.0	22.4	81.6
Plot D	10-11	1,000-1,200	500	None	4.0	10	54.2

N. antarctica,N. dombeyi coexist whereas Chilean cypress (*Austrocedrus chilensis*) grows at the edges of the plot.

Bird sampling

We used 25 m fixed radius point counts-measured by a laser rangefinder- (Bibby *et al.,* 2000) to sample the plantation's breeding bird communities. Surveys were performed in November 2005 and December 2006, from 06:30 to 10:30 h, and only with favourable weather conditions (*i.e.,* no precipitation and no mist or strong wind).A total of 155 point counts were made at plot A (76 in 2005 and 79 in 2006); 141 at plot B (69 in 2005, 72 in 2006); 156 at plot C (75 and 79, in 2005 and 2006, respectively), and 159 at plot D, 78 in 2005 and 81 in 2006. These points were at least 200 m apart to avoid double counting. However, such a distance does not guarantee the statistical independence of the samples; moreover, despite of the fact that there is controversy among authors —200 *versus* 300 m— (Buckland *et al*., 2008) the protocol for our point counts was kept in the average of methodological standards. During each survey, all birds seen or heard during a 10 minute period and within each sampling point were recorded. The fixed circular-plot method (Marsden, 1999; Shiu and Lee, 2003) was used to calculate density estimates (individuals per 10 ha) for the bird species inside the forest.

Statistical analyses

Analysis of variance (ANOVA) was performed to assess: 1) the differences in the number of species recorded at each plot, 2) total bird densities among the different pine plantation plots, 3) mean bird densities along the two years of study according to the different types of plots, and 4) density of the 14 most abundant species separately and by each type of plot. In all cases, *post-hoc* confidence comparisons for testing differences among means were carried out using the Scheffé test (Sokal & Rohlf, 1994).

The species accumulation curves for each plot were built in order to gauge the completeness of the sampling and gain an estimation of their species richness (Colwell & Coddington, 1994). These curves enabled us to establish a compromise among the different plot surveys, since if they had been made exclusively from the values of the number of species observed, with no reference to the effort invested, false results would have been obtained (Gotelli & Colwell, 2001). The number of point counts was taken as a measure of the sampling effort and was randomized 100 times in order to build smoothed curves. The functions of the curves were calculated by adjusting Clench's equation to the accumulation curves (Soberón and Llorente, 1993). The function has an asymptote, which estimates the total (maximum) number of species expected.

Results

As a result of the sampling, 24 bird species were observed at plot A; 16 at plot B; 22 at plot C, and 25 at plot D (Table 2). The expected species accumulation curve reached the asymptote in 26 species at plot A; 16 species at plot B; 22 at plot C, and 25 at plot D (Fig. 1), and significant differences were found ($F = 5.517$, $df = 3,610$, $p = 0.015$) between plots, with *post-hoc* comparisons between plot A and plot B, and between plot B and plot D.

No statistically significant differences were observed in total bird density between years ($F = 1.138$, $df = 3,610$, $p = 0.30$). An average of 17.64 birds 10 ha^{-1} was recorded for plot A; 12.94 birds 10 ha^{-1} for plot B; 16.77 birds 10 ha^{-1} for plot C, and 17.66 birds 10 ha^{-1} for plot D (Table 2). Statistically significant differences were observed in the bird population ($F = 5.063$,

Table 2. Average density (birds 10 ha^{-1}) by years of species recorded at the different sampling plots at Meliquina Valley, Argentina. Species less than 4 individuals are indicated as P (Present) and their densities were not calculated

English name	Scientific name	Plot A		Plot B		Plot C		Plot D	
		2005	2006	2005	2006	2005	2006	2005	2006
Ashy-headed goose	*Cloephaga poliocephala*		P						
Speckled teal	*Anas flavirostris*		0.31						
Red-backed hawk	*Buteo polyosoma*							P	
Chimango caracara	*Milvago chimango*	0.30	0.25	0.25	0.50	0.31	0.70	0.13	0.10
Crested caracara	*Polyborus plancus*							P	
Spot-winged falconet	*Spiziapteryx circumcinctus*								P
Austral pigmy owl	*Glaucidium nanum*					P			
California quail	*Callipepla californica*	0.40	0.62	0.90	1.01	1.04	1.31	0.56	0.39
Chilean eared dove	*Zenaida auriculata*			0.34	0.14	0.89	0.41	0.24	0.31
Ringed kingfisher	*Megaceryle torquata*	P	P						
Chilean flicker	*Colaptes pitius*	P		P					
Scale-throated earthcreeper	*Upucerthia dumetaria*							0.24	
Dark-bellied cinclodes	*Cinclodes patagonicus*	P	0.22			P			
White throated tree-runner	*Pygarrichas albogularis*		P			P			
Des Murs's wiretail	*Sylviorthorhynchus desmursii*		P						
Thorn-tailed rayadito	*Aphrastura spinicauda*	0.30	0.63	0.36	0.20	0.42	0.24	0.31	0.44
Plain-mantled tit-spinetail	*Leptasthenura aegithaloides*	P						0.44	0.23
Sharp-billed canastero	*Asthenes pyrrholeuca*	0.40	0.34	0.19	0.45	0.35	0.25	0.41	0.65
Chucao tapaculo	*Scelorchilus rubecula*		P				P		
Magellanic tapaculo	*Scytalopus magellanicus*		P						
Patagonian tyrant	*Colorhamphus parvirostris*					0.13			P
Patagonian mockingbird	*Mimus patagonicus*		P			P		0.13	
Fire-eyed diucon	*Xolmis pyrope*	0.12					0.11	0.61	0.53
White-crested elaenia	*Elaenia albiceps*	0.31	1.46	0.56	1.69	2.02	2.47	0.22	0.81
Tufted tit-tyrant	*Anairetes parulus*	0.50	0.45	0.11	0.42	0.76	0.72	0.54	0.76
Chilean swallow	*Tachycineta meyeni*	3.25	0.78	0.34	0.20	1.10	0.35	2.07	0.38
Southern house wren	*Troglodytes aedon*	2.03	1.94	2.36	1.41	4.44	2.50	2.00	1.99
Austral thrush	*Turdus falklandii*	0.20	1.38	0.19	0.14		0.28	0.24	0.68
Austral blackbird	*Curaeus curaeus*					P		P	
Long-tailed meadowlark	*Sturnella loyca*	P							0.21
Patagonian sierra finch	*Phrygilus patagonicus*	2.54	1.06	0.89	0.98	2.02	1.56	1.38	0.99
Common diuca finch	*Diuca diuca*	1.93	2.50	3.18	1.86	1.57	1.37	4.64	3.86
Rufous-collared sparrow	*Zonotrichia capensis*	2.54	1.36	1.52	0.98	2.54	1.48	2.00	2.28
Black-chinned siskin	*Carduelis barbata*	3.11	3.00	3.41	2.53	2.61	2.33	1.17	3.68
Total density		15.43	18.44	14.40	12.12	18.71	15.59	17.82	18.18

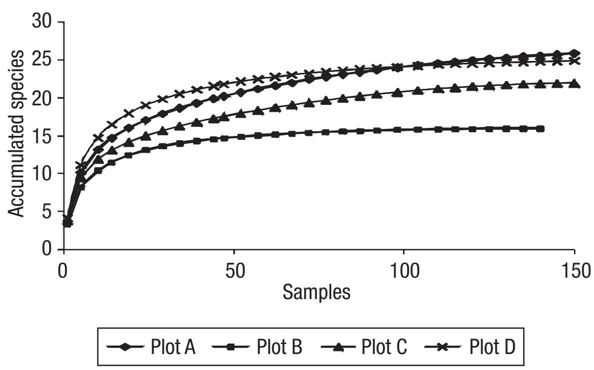

Figure 1. Bird species richness accumulation curves of the different sampling plots at Meliquina Valley, Argentina.

df = 3,610, $p = 0.002$) at plot B as compared with the other plots. Regardless of this, no statistically significant differences were found in densities between plot A, plot C, and plot D.

The population densities of the 14 most abundant species were compared between years and no statistically significant results were found, with the exception of *Tachycineta meyeni* (F = 7.187, df = 1,76, $p = 0.025$). For this species, the density was higher in 2005 than in 2006 (Table 2). Morever, each of the fourteen species was analysed separately according to its density per plot, and in 10 of them no statistically significant differences were observed (Fig. 2).

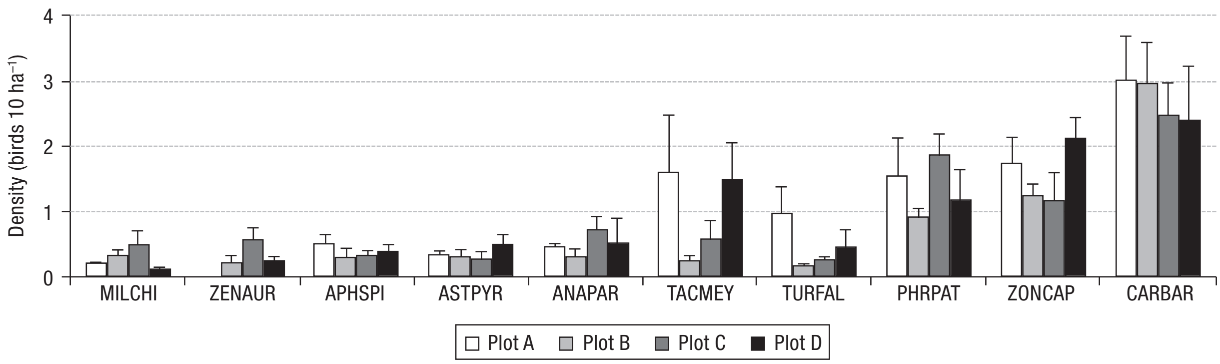

Figure 2. Average density (birds 10 ha^{-1}) at each plot at Meliquina Valley, Argentina: MILCHI, Milvago chimango; ZENAUR, *Zenaida auriculata;* APHSPI, *Aphrastura spinicauda;* ASTPYR, *Asthenes pyrrholeuca;* ANAPAR, *Anairetes parulus;* TACMEY, *Tachycineta meyeni;* TURFAL, *Turdus falklandii;* PHRPAT, *Phrygilus patagonicus;* ZONCAP, *Zonotrichia capensis;* CARBAR, *Carduelis barbata.* Vertical T-bars represent Standard Error (SE).

However, statistically significant differences were observed for *Callipepla californica* ($F = 5.525$, $df = 3,84$, $p = 0.035$) and *Elaenia albiceps* ($F = 4.283$, $df = 3,212$, $p = 0.048$). The breeding density values of these species were higher for plot C than for plot D, but with no differences between plots A and B (Fig. 3).

The density of *Troglodytes aedon* had statistically significant differences ($F = 4.485$, $df = 3,190$, $p = 0.030$) between plot B and plot C, but not for the rest of plots (Fig. 3). The *Diuca diuca* breeding population densities showed statistically significant differences ($F = 8.344$, $df = 3,157$, $p = 0.008$) between plot D and plot C and also between plot D and plot B, but not for the other combinations (Fig. 3).

Discussion

Previous studies have shown that bird richness, abundance and diversity are generally low within native sub-Antarctic forests; that is, between 16 to 28 species in *Nothofagus* native forest (Erazo, 1984; Vergara & Simonetti, 2004; Becerra & Grigera, 2005; Lantschner & Rush, 2007; Lantschner *et al.,* 2008; Paritsis & Aizen, 2008). The hypothesized reasons for these low values include geological and paleoclimatic processes, the Andean orogeny and the quaternary glaciations. We found similarly a low bird species numbers in the exotic pine plantations; between 16 to 25 species.

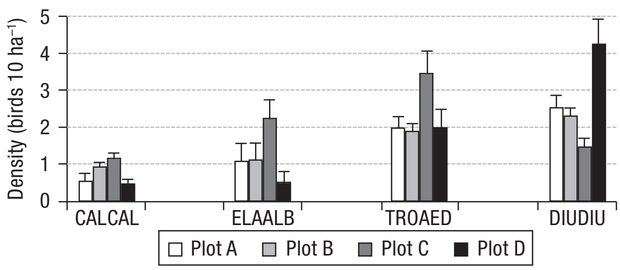

Figure 3. Average density (birds 10 ha^{-1}) at each plot at Meliquina Valley, Argenttina: CALCAL, *Callipepla californica;* ELAALB, *Elaenia albiceps;* TROAED, *Troglodytes aedon;* DIUDIU, *Diuca diuca.* Vertical T-bars represent Standard Error (SE).

Bird species composition at Patagonian pine plantations follows the naturally low diversity of the region, but their numbers could be further reduced by the poor bird species diversity usually observed at plantations worldwide (Messersmith, 1963; Tubelis *et al.,* 2007; Du Bus De Warnaffe & Deconchat, 2008; Lantschner *et al.,* 2008; Luck & Korodaj, 2008; Paritsis & Aizen, 2008). However, our results show that only for some bird species richness tend to decrease with the increase in the age of the plantation. Generally, silvicultural management in exotic pine forests lead to drastic habitat alterations that affect bird communities (Szaro & Balda, 1979; Luck & Korodaj, 2008). In some studies of exotic pine plantations, breeding-bird density and bird diversity are initially high in rapidly-growing young stands, with forbs and shrubs; they then decrease in middle-aged pine stands as the pine canopies close and shade out other plants, but, later on, they again increase to the highest diversity of structurally diverse older stands, with several layers of foliage (Dickson *et al.,* 1995). In contrast, other studies show that mature and old thinned stands contain more bird species than young and old un-thinned stands. Thinning treatment might be an indirect factor of the species richness increase; probably because thinning allows the understory vegetation grow, which is a key factor in increasing the use of pine stands by birds (Luck & Korodaj, 2008).

In our study, birds surveyed at plots A and D had the highest abundance of birds. Both had a very well development of shrub layer, whose suppression in the forests has been associated worldwide with decreasing abundances of the birds. According to Dickson *et al.* (1995), bird abundance increases consistently until plantations reach an age of 7-9 years, after which it declines as the pine canopy closes and shades out lower vegetation. Although a long-term monitoring on plots would be needed to compare plantation age and bird species, there seems to be an overall decline in bird numbers at forests as from 11years. In our case, the youngest plantation plot was only 10 years old, but a decrease in species numbers was recorded from only one year to the next. This could be explained in terms of the growth of tree foliage, which robbed open space and prevented the development of other plant species on the ground (Dickson *et al.,* 1995). Thus, in our study some open-nest species such as *Upucerthia dumetaria* and *Mimus patagonicus* had disappeared when the pine coverage had increased with age.

Another complicating factor in Patagonian pine plantations is the presence of patches of native deciduous woodland that can support higher species richness and diversity (Becerra & Grigera, 2005; Lantschner & Rush, 2007; Lantschner *et al.,* 2008; Paritsis & Aizen, 2008). Moreover, mixed woodlands with their higher structural heterogeneity have a greater availability of nesting sites, a reduced risk of nest predation, and offer a higher food abundance (Vergara and Simonetti, 2004; Barbaro *et al.,* 2005; Lantschner *et al.,* 2008; Paritsis & Aizen, 2008).

Within our study plantation plots, bird species were most abundant where tree density was low. Among forest species, canopy birds accounted for most of the records and were most common where tree density was low. Birds used clear-cuts as habitats in managed forests such as pine plantations, and hence clear-cutting may enhance avian diversity at landscape scale by continuous replacement of old growth plantations by young ones (Lantschner *et al.,* 2008; Paritsis & Aizen, 2008). Additionally, some bird species, which usually occur in forest borders, river margins, open areas, bogs or *N. antarctica* forests were detected at the harvested stands (Deferrari *et al.,* 2001; Lantschner & Rush, 2007). Thinning pine plantations allows greater penetration of light to the forest floor, which enhances tree growth, development of larger crowns, and often results in an accumulation of coarse woody debris. Subsequently, native (and/or introduced) over-storey and under-storey plants grow; consequently the habitat structure becomes more diverse (Luck & Korodaj, 2008). This is probably a key factor in the increased use of pines by bird species. Our study supports the view that the effect of clear-cutting and thinning is a management process that slightly enhances species richness and abundance.

The bird density recorded in our pine plantation plots was similar to that reported for native *Nothofagus* forest (Erazo, 1984; Becerra & Grigera, 2005; Lantschner & Rush, 2007; Lantschner *et al.,* 2008), with an average of 27.05 birds 10 ha^{-1} and 21.08 birds 10 ha^{-1}, respectively. However, studies in Chilean pine plantations have reported higher bird densities than those for Argentina, probably due to the increased number of ground insects observed in the former (Chile) (Vergara & Simonetti, 2004). Differences in bird diversity may also be partly due to rain. Annual rainfall in the Chilean forest is close to 2,000 mm year^{-1}; whereas Argentinean pine plantations do not receive more than 700 mm year^{-1}.

Two of the species detected in all the study plots were Patagonian endemics: the Thorn-tailed Rayadito (*Aphrastura spinicauda*) and the Patagonian Sierra-Finch (*Phrygilus patagonicus*). Both are eclectic species living in a broad spectrum of environments that are well represented in several protected areas of Argentina and Chile throughout the Patagonian region (Deferrari *et al.,* 2001; Lencinas *et al.,* 2005; Lantschner & Rush, 2007). The different population densities recorded in the first year of the study for the Chilean Swallow (*T. meyeni*) were likely due to an unusually cold spring in November.

Also, the proximity of the Meliquina river probably exerted an effect because several species from riparian/water environments were recorded at the plantations, such as the Ringed Kingfisher *Megaceryle torquata*, the Ashy-headed goose *Cloephaga poliocephala* and the Speckled teal *Anas flavirostris*, although the latter two were also detected in grasslands and open areas. The breeding habitat of the introduced California quail (*C. californica*) comprises shrubby areas and open woodlands, and hence the density of this species is higher in pine plantations with a lower tree density with respect to plantations without thinning and pruning treatments. The White-crested elaenia (*E. albiceps*) has a similar density pattern; its breeding habitat is shrubby areas and open woodlands. This species is common in the pine forests (Smith-Ramírez & Armesto, 2003).

The habitat of the Southern House Wren (*T. aedon*) is a mixture of open areas with shrubby woodlands, small wood lots and forest edges. The species forages small terrestrial insects in the woodland sub-canopy, in shrubs, and among the herbaceous ground cover (Deferrari *et al.,* 2001). This behaviour could explain the differences observed between the two managed pine plantations because trees allow the entrance of light, and hence understory growth.

The Common Diuca Finch (*D. diuca*) is prevalent throughout the region on farmland, forest edges, and gardens. This species is also one of the most abundant ones, and was particularly observed in large numbers on unmanaged plantations. The preference of Diuca finches for this habitat could be related to the avoidance of predation in closed vegetation.

Accordingly, we suggest that the presence of even small, isolated native woodland patches in the pine plantation landscape enhances species richness and abundance; moreover, we found no statistical differences in bird numbers between pine plantation and native forest. Species such as, *Carduelis barbata* and *T. aedon* have larger populations in pine plantations, while others, namely *A. spinicauda*, *Enicognathus ferrugineus* and *Pygarrhinchas albogularis,* have larger populations in native forest. Further studies are needed to determine if these patches of native forest act as refuge and source habitats for birds, at least for some of their habitat requirements, such as foraging or breeding support.

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