



Conservation of temperate forest birds in Chile: implications from the study of an isolated forest relict

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Abstract. We characterize the bird assemblage of an isolated relict temperate rainforest (Santa Inés) in terms of its structure, composition and dynamics. The relict character and long-term isolation of this forest remnant, immersed in a matrix of semiarid scrub, provide a natural experiment to assess the consequences of long-term isolation and forest area reduction for temperate bird species. Bird surveys were conducted in a forest fragment and the surrounding scrub matrix between April 1999 (austral autumn) and October 2000 (austral spring) on a seasonal basis. Within the forest fragment we distinguished two microhabitat types: creeks and areas far from creeks (i.e. slopes). A total of 36 species were recorded in the study site, of which 21 were inside the relict forest. Highest bird abundance and richness were recorded during winter and spring, and these were always higher in creek plots rather than slope plots. Comparisons between this assemblage and those distributed in the continuous temperate forest (located more than 900 km southwards) indicate that this bird assemblage shares more similarities, with regard to bird species composition, to southern temperate forest localities and to other relict forests, than to nearer scrub habitats. However, there are eight species, endemic to temperate forests in southern South America, missing from our system. In this regard, our analyses indicate that these eight endemic species should be of great conservation concern and will likely be the ones that will go extinct first if the fragmentation of the temperate forest continues.

Introduction

South American temperate rain forests are considered to be a biodiversity world reserve (Armesto et al. 1996a; Arroyo et al. 1996). In Chile, the temperate rainforest exhibits a high diversity of species, a remarkably high proportion of endemics (many of which are presently endangered), and an enormous heterogeneity of forest types, soils, and perturbation regimes (Armesto et al. 1996a). However, human encroachment, fire use, agriculture, and commercial logging have caused its degradation and fragmentation, which is manifested in an accelerated rate of loss in forest area (Armesto et al. 1994; Bustamante and Grez 1995; Lara et al. 1996). This degradation has been so acute that this ecosystem type is currently recognized as

being of high priority for conservation (Armesto et al. 1992, 1998; Dinerstein 1995). The loss and degradation of this forest ecosystem are even more dramatic if one considers its insular character, with high endemism, due to glaciation episodes (Vuilleumier 1985) and fragility due to its strong dependence on biological mechanisms of nutrient uptake and storage, which means that even minor clearcuts could cause enormous damage, through major losses of nutrients (Armesto et al. 1996b). Although 29% of the land in this region is protected, most of it (>90%) is concentrated at high latitudes, outside the most important areas for biodiversity (Armesto et al. 1998). Thus, in light of the accelerated rates of degradation they sustain and the lack of representation of biodiversity hotspots in protected areas, South American temperate forests represent an ecosystem in peril.

Temperate rain forests span a wide latitudinal range between 35 and 55° S, forming an almost continuous habitat type all along southern Chile. Interestingly, several Pleistocene remnants of Valdivian Temperate rain forest exist more than 900 km north of its present distribution, restricted to the sea-facing slopes of the coastal range in a fog-induced microclimate in semiarid Chile (Troncoso et al. 1980; Villagrán and Armesto 1980; Pérez and Villagrán 1985, 1994). Several studies have shown that these relict forests, notwithstanding their insular character, resemble the continuous southern temperate forest in terms of floristic composition, relative abundance of tree species and soil chemistry (Villagrán and Armesto 1980; Pérez and Villagrán 1985, 1994). One of the largest relict forests is that of Santa Inés, first described in 1961 (Kummerow et al. 1961).

In this paper we analyze the structure, composition, and dynamics of the bird species assemblage found in the relict forest of Santa Inés. The relict character and long-term isolation of this forest remnant, immersed in a matrix where the predominant vegetation is semiarid scrub, represents a natural experiment to assess the consequences of long-term isolation and forest area reduction for temperate bird species and, at the same time, a great opportunity to derive important lessons for the conservation of birds in temperate forests.

Considering that up to now no bird studies exist in this forest, our first objective is to characterize the structure, composition, and seasonal dynamics of the bird assemblage inhabiting the relict forest at Santa Inés. Secondly, we assess the hypothesis that the bird species assemblage present in the relict forest at Santa Inés is more similar to the bird assemblages documented for the continuous temperate forest (located more than 900 km to the south) than to the bird assemblages present in the surrounding scrub matrix (i.e. the relict forest at Santa Inés would represent a temperate forest island). Finally, we assess the conservation value of this relict forest and infer the potential impact of long-term isolation and area reduction upon temperate forest birds.

Methods

Study site

The Santa Inés relict forest (32°10' S, 71°30' W), located 1 km east of the town of

Pichidangui, lies on the west-facing slope of the coastal mountain range (400–680 m elevation) (Figure 1). The forest is composed of several connected habitat fragments that vary in shape and size, with a total estimated area of 68.2 ha. The climate is Mediterranean-arid, with dry hot summers and cool and rainy winters (Di Castri and Hajek 1976). Mean average precipitation is 312 mm and mean temperature is 15 °C (Gajardo et al. 1987). The forest lies within the property of a private stakeholder, in the ‘Lomas de Huaquen’ farm. Predominant land uses are livestock pasture, wood harvest and tourism (Gajardo et al. 1987).

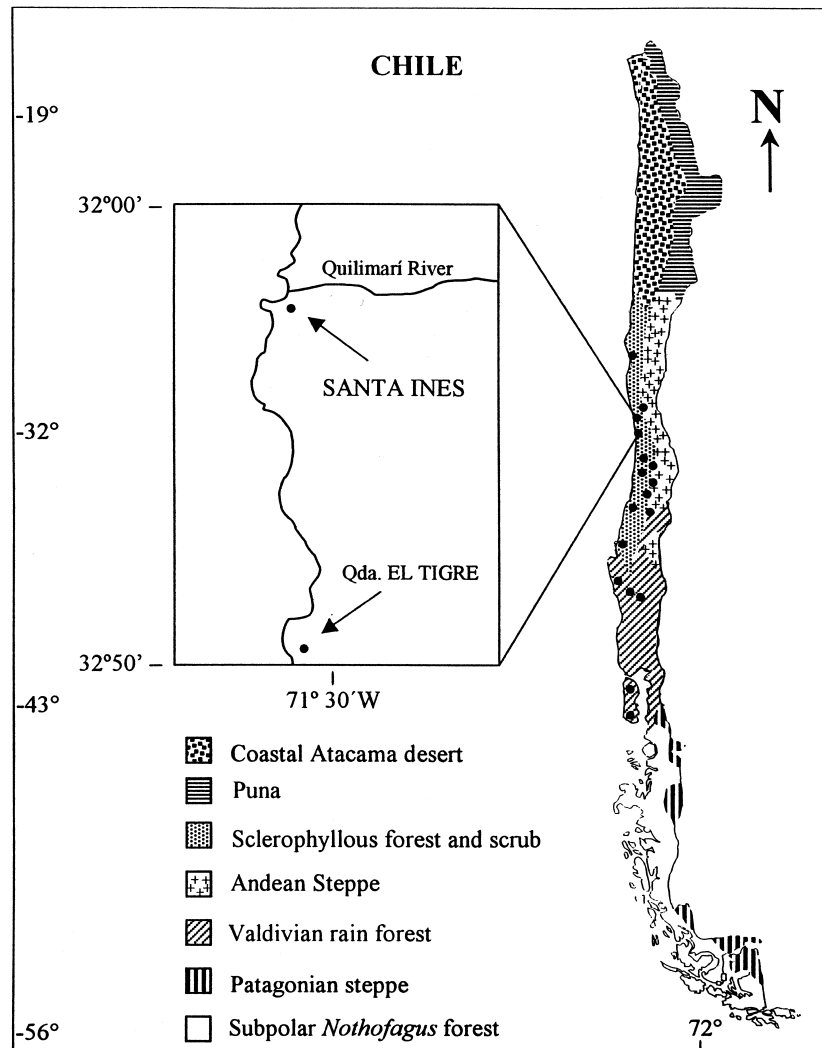


Figure 1. The Santa Inés relict forest remnant in north central Chile and the distribution of major ecoregions in Chile (modified from Cofré and Marquet 1999). Black dots denote the localities used in the cluster analysis.

The floristic composition of the Santa Inés relict forest corresponds to a more xeric version of the one described for the relict forest in Fray Jorge (located on the coastal mountain range 160 km to the north), with *Aextoxicon punctatum*–*Myrceugenia correifolia* (Olivillo–Petrillo) being the dominant tree association (Kummerow et al. 1961). Other dominant forest species are *Raphitamnus spinosus*, *Peumus boldus*, *Citronella mucronata*, *Chusquea cumingii*, *Senecio yegua*, *Aristolochia chilensis*, *Azara microphylla*, *Mitraria coccinea* and several ferns in the *Blechnum* genus (see Villagrán and Armesto (1980) and Pérez and Villagrán (1985) for a discussion of plant diversity in this forest). The surrounding matrix corresponds to the Coastal Stepparian Matorral of Coquimbo (Araya et al. 1992; Gajardo 1993), dominated by species such as *Baccharis concava*, *Chorizanthe vaginata*, *Puya berteroaana*, *P. chilensis*, *Margyricarpus pinnatus* and *Fuchsia lycioides* (Pérez and Villagrán 1985).

Bird surveys

A total of six point counts (plots) were established in a large forest fragment of 21.2 ha. Three plots were located within creeks, in creek valleys (creek plots hereafter) and three in a steep slope (slope plots hereafter) 300 m away and 100 m higher than the creek plots. Bird surveys followed the point-count method used by Willson et al. (1994), described in Ralph et al. (1993). Plots were at least 200 m apart to minimize the risk of counting the same individual twice, as suggested by Hutto et al. (1986). In each plot we spent 8 min and registered all seen and/or heard birds within an area of a fixed radius of 25 m (i.e. 0.2 ha). Bird surveys were done during each season from April 1999 (i.e. austral autumn) to October 2000 (i.e. austral spring), and were conducted during three consecutive days, from 8 to 11 h. This methodology allowed us to obtain the relative abundance of birds calculated as number of birds per point per day. Species richness was calculated as number of species per point per day (Willson et al. 1994; Cornelius et al. 2000). However, to document forest bird species richness we included all species seen inside the forest, regardless of their presence/absence during the 8 min point counts.

In the surrounding scrub matrix, we carried out surveys of species along three linear transects, located at least 3 km away from the forest at 420 m elevation. Transects were 100 m long and 30 m wide on each side, with stations distributed 20 m apart within each transect (Bibby et al. 1992). Transects were separated from one another by at least 1000 m in order to treat all transects as independent replicates. To document bird species richness in all the surrounding scrub matrix, we included all species seen in this type of habitat regardless of their presence/absence in the observation stations within transects. As bird surveys were carried out differently in the forest fragments and the surrounding scrub matrix, we do not make quantitative comparisons of bird abundance or richness between these habitats, but instead focus on trends.

Even though nocturnal species (*Caprimulgus longirostris*) and most raptors (*Bubo virginianus*, *Buteo polyosoma*, *Geranoaetus melanoleucus* and *Falco* sp.) were not included in the surveys, as suggested by Cornelius et al. (2000), we did include two

raptor species, *Cathartes aura* and *Accipiter bicolor*, as they were observed actually using the vegetation of the forest for nesting sites.

Habitat measures

To characterize each plot, the following vegetation variables were recorded: tree species richness, density of trees, diameter at breast height (dbh > 10 cm), number of logs (diameter >20 m), canopy height, canopy cover and vertical foliage heterogeneity. Tree density was measured by using the point-centered-quarter method (Bonham 1989). This was done by establishing two 50-m long transects perpendicular to each other, centered in the plot and oriented along cardinal points. We then determined five points on these transects (one in the center and the other four in each of the four cardinal points). At each point we measured the distance and dbh of the four closest trees to the point. At the same points, we counted the number of logs within a 5-m radius area, estimated canopy height (using a 6-m pole) and measured vertical foliage heterogeneity as number of plant segments intersecting the 6-m pole. Canopy cover was estimated by taking 100 densitometer measures along transects.

Data analyses

To assess if the bird assemblage in the relict forest at Santa Inés is more similar in composition to the bird assemblage documented for the continuous temperate forest than to nearby semiarid habitat types, data on bird species composition (i.e. presence and absence) in the forest and the surrounding scrub matrix in Santa Inés were compared with similar forest sites in southern Chile and nearby semiarid sites. The comparison was done by performing a cluster analysis using the complete linkage (furthest neighbor) method. Dissimilarity between sites was calculated using the percent disagreement between sites. Data for sites other than Santa Inés were taken from published data: Cody (1970; sites Temuco, Cañete, Puchuncaví and Melipilla), Riveros and López-Calleja (1990; site Ocoa), Cornelius et al. (2000; site Fray Jorge), Estades and Temple (1999; site Constitución), Willson et al. (1994; site Chiloé fragments), Rozzi et al. (1996a; Chiloé continuous), Jaksic and Lazo (1999; site Aucó), López-Calleja (1990; site Quebrada de la Plata), and Lazo and Anabalón (1992; site Tilti). The statistical significance of the observed clusters was assessed by a bootstrap analysis (Jaksic and Medel 1990).

In order to assess temporal changes in bird species abundance and richness between creek and slope plots we used two-way repeated measures ANOVA.

Results

Habitat measures

Creek plots were characterized by steep-sided valleys, a well-developed understory

Table 1. Vegetation variables associated with creek and slope plots in the relict forest of Santa Inés.

Vegetation variables	Habitat		P
	Creeks	Slopes	
Density (trees/ha)	601.54 ± 340.5	945.21 ± 583.49	0.079
Dbh (cm)	39.15 ± 5.51	27.17 ± 7.33	0.001
Logs	13.04 ± 4.03	9.18 ± 4.36	0.029
Canopy cover (%)	83.33 ± 7.5	95.33 ± 3.78	0.069
Canopy height (m)	14.57 ± 1.32	12.46 ± 3.07	0.017
Vertical heterogeneity	4.52 ± 1.77	4.48 ± 1.06	0.971

dominated by *A. punctatum*, *M. correifolia* and *R. spinosus* seedlings and saplings and several patches of bamboo cover (*C. cumingii*), a more open and higher canopy, bigger trees and a higher number of >20 cm diameter logs in comparison to slope plots (see Table 1). Slope plots were devoid of an understory; instead 5 cm of leaf litter covered the ground. Plots were significantly different in dbh, number of logs and canopy height, but differences in tree density and canopy cover were marginally significant ($P = 0.079$ and 0.069 , respectively).

Composition and structure of the bird assemblage in Santa Inés

A total of 36 bird species were recorded in both forest fragments and matrix scrub habitats (Table 2). Of these, 23 species were observed in the relict forest, belonging to the orders Tinamiformes (1), Falconiformes (2), Columbiformes (1), Apodiformes (1), Piciformes (2) and Passeriformes (16). However, of the 23 species recorded in the forest, eight were exclusively observed in this habitat, while the remaining 15 were also observed in the surrounding scrub matrix. The total number of bird species recorded in the scrub matrix habitat was 28, of which 13 were exclusively observed in this habitat (Table 2).

In general, the most abundant species year round were *Sephanoides galeritus* and *Aphrastura spinicauda*. However, in spring the species with highest abundance were *Elaenia albiceps* (30%) and *A. spinicauda* (21%); in summer *A. spinicauda* (27%), *S. galeritus* (26%) and *E. albiceps* (13%), in autumn *S. galeritus* (34%), *Anairetes parulus* (20%) and *A. spinicauda* (17.5%) and, finally, in winter *S. galeritus* (34%), *Phrygilus gayi* (24%) and *A. spinicauda* (17%) presented highest abundance. Most of the species recorded in the forest, but not *E. albiceps* and *Colorhamphus parvirostris*, were year-round residents. On the other hand, only two matrix species (*Patagona gigas* and *Geositta cucularia*) were migrants (Table 2). We recorded four endemic species to southern South American temperate forests, *Ap. spinicauda*, *Co. parvirostris*, *Pygarrhichas albogularis* and *Sylviorthorhynchus desmursii* (Rozzi et al. 1996b). The sighting of *Py. albogularis* and *Sy. desmursii* in this forest represents the most northern record to date for these species. Finally, we observed two raptor species, *Ca. aura* and *Ac. bicolor* (in two of the three creek plots) nesting in the forest.

Table 2. Bird species list in the forest fragment (F) and scrub areas (S) in Santa Inés.

Family	Species	Common name	Habitat	Status ^a	Diet		Nest	
					Type ^b	Place ^c	Type ^d	Place ^e
Cathartidae	<i>Cathartes aura</i>	Jote de cabeza colorada	F, S	R	C	g	O	t
Accipitridae	<i>Accipiter bicolor</i>	Pequito	F	R	C	g	O	t
Tinamidae	<i>Nothoprocta perdicaria</i>	Perdiz chilena	F, S	R	I/H	g	O	g
Phasianidae	<i>Callipepla californica</i>	Codorniz	S	R	G	g	O	g
Columbidae	<i>Columba araucana</i>	Torcaza	F	R	F/G	f/g	O	t
Trochilidae	<i>Patagona gigas</i>	Picaflor gigante	S	S	N/I	f/a	O	s/t
	<i>Sephanoides galeritus</i>	Picaflor	F, S	R	N/I	f/a	O	s
Picidae	<i>Colaptes pitius</i>	Pitío	F, S	R	I	s/g	C	t/g
	<i>Picoides lignarius</i>	Carpinterito	F, S	R	I	s	C	t
Furnariidae	<i>Geositta cunicularia</i>	Minero	S	W	I/G	g	S	g
	<i>Sylviorthorhynchus desmursii</i>	Colilarga	F	R	I	f	O/S	s
	<i>Aphrastura spinicauda</i>	Rayadito	F	R	I	f/s	C	t
	<i>Leptasthenura aegithaloides</i>	Tijeral	F, S	R	I	f	C/S	s/t
	<i>Asthenes humicola</i>	Canastero	S	R	I	f	S	s/t
	<i>Pygarrhichas albogularis</i>	Comesebo grande	F	R	I	s	C	t
Rhinocryptidae	<i>Pteroptochos megapodius</i>	Turca	S	R	I	g	S	g
	<i>Scelorchilus albicollis</i>	Tapaculo	S	R	I	g	C/S	g
	<i>Scytalopus fuscus</i>	Churrín	F	R	I	f/g	C/S	g
Tyrannidae	<i>Agriornis livida</i>	Mero	S	R	I	f/a	O	s
	<i>Xolmis pyrope</i>	Diucón	F, S	R	I/F	f/a	O	s/t
	<i>Elaenia albiceps</i>	Fío-fío	F, S	S	I/F	f/a	O	s/t
	<i>Anairetes parulus</i>	Cachudito	F, S	R	I/G	f	O	s
	<i>Colorhamphus parvirostris</i>	Viudita	F, S	W	I	a/f	O	s/t
Hirundinidae	<i>Tachycineta meyeni</i>	Golondrina chilena	F, S	R	I	a	C	t
Troglodytidae	<i>Troglodytes aedon</i>	Chercán	F, S	R	I	f	C/S	s/t
Turdidae	<i>Turdus falcklandii</i>	Zorzal	F	R	I/F	g/f	O	s/t
Mimidae	<i>Mimus thenca</i>	Tenca	S	R	I/F	g/f	O	s/t
Emberizidae								
Emberizinae ^f	<i>Zonotrichia capensis</i>	Chincol	F, S	R	G/I	g/s	O	s/g
	<i>Sicalis luteiventris</i>	Chirihue	S	R	G	g	O	s/g
Icterinae ^f	<i>Curaeus curaeus</i>	Tordo	F, S	R	I/H	g/f	O	s
	<i>Sturnella loyca</i>	Loica	S	R	I/G	g	O	g
Fringillidae	<i>Phrygilus gayi</i>	Cometocino de Gay	F, S	R	G/H	g/f	O	s/g
	<i>P. fruticeti</i>	Yal	S	R	G	g	O	g
	<i>P. alaudinus</i>	Platero	S	R	G	g	O	g
	<i>Diuca diuca</i>	Diuca	S	R	G	g	O	s/t
	<i>Carduelis barbata</i>	Jilguero	F	R	G/H	g/t	O	s/g

Habitat and status according to field observations. Diet and nest data collected from published studies (Johnson 1967; Fjeldså and Krabbe 1990; Ridley and Tudor 1994). ^aR – resident; S – summer migrant; W – winter migrant. ^bC – carnivores; I – insectivores; H – herbivores; G – granivores; F – frugivores; N – nectarivores. ^cg – ground; f – foliage; a – air; s – stems. ^dC – cavity; O – open nest; S – closed structure. ^eg – ground; s – shrubs; t – trees. ^fSubfamilies.

Bird dynamics in time and space

In the forest, bird abundance varied according to season and plot type (repeated measures ANOVA $F_{1,4} = 99.34$, $P = 0.001$, $F_{4,4} = 7.91$, $P = 0.001$, respectively).

The highest bird abundances were recorded in the spring and winter seasons and higher abundances were always found in creek plots than in slope plots (Figure 2a). Similarly, species richness was also affected by both plot type and season (repeated measures ANOVA $F_{1,4} = 44.58$, $P = 0.003$, $F_{4,4} = 6.78$, $P = 0.002$, respectively). Species richness was higher in the spring and winter seasons and always higher in creek than in slope plots (Figure 2b).

With regard to the bird abundance in the surrounding matrix, a similar temporal pattern can be observed; season had a significant effect on bird abundance (repeated measures ANOVA $F_{4,8} = 3.06$, $P = 0.036$) and species richness (repeated measures ANOVA $F_{4,8} = 5.73$, $P = 0.002$) and both were higher during spring and winter (Figure 3a and b).

Comparison with other bird assemblages

The cluster analysis showed three significant clusters differing by 64 and 43%, respectively in their species composition (Figure 4). The bootstrapping analysis yielded a critical value for the linkage distance of 0.3729, so that clusters that differed by more than this value were considered significantly different ($P \leq 0.05$). The first cluster pooled forest bird assemblages, including both temperate forests (e.g., Chiloé, Temuco) and relicts (i.e. Fray Jorge, Ocoa and Santa Inés). The second cluster was composed of bird assemblages of three scrub habitats: Santa Inés, Fray Jorge and Aucó. And the third cluster pooled bird assemblages in both scrub and sclerophyllous forest habitats (e.g., Melipilla, Tiltil). Thus, the bird assemblage found in the relict forest of Santa Inés shares more similarities, with regard to bird species composition, to southern temperate forest localities and to other relict forests than to nearer scrub habitats.

Discussion

The forest bird assemblage

We found significant seasonal and spatial changes in total species abundance and richness in the census plots. With regard to seasonal changes, abundance tended to be higher during winter and spring seasons as a consequence of the increased abundance of the species *P. gayi* and *S. galeritus* in winter. This latter species increases in abundance as a consequence of the arrival of individuals from southern populations (Fjeldså and Krabbe 1990). During spring, the increase in abundance is a consequence of the arrival of the migratory species *E. albiceps*. The seasonal changes in species richness follow a similar trend, and are accounted for by the arrival of migratory species (*E. albiceps* in spring and *C. parvirostris* in winter) as well as by the non-migratory species (*Columba araucana* and *Picoides lignarius*) that likely move from nearby habitat patches within the landscape. Interestingly, the matrix habitat followed a similar seasonal trend in abundance and richness. This is in part a reflection of the large fraction of species shared between these two habitat

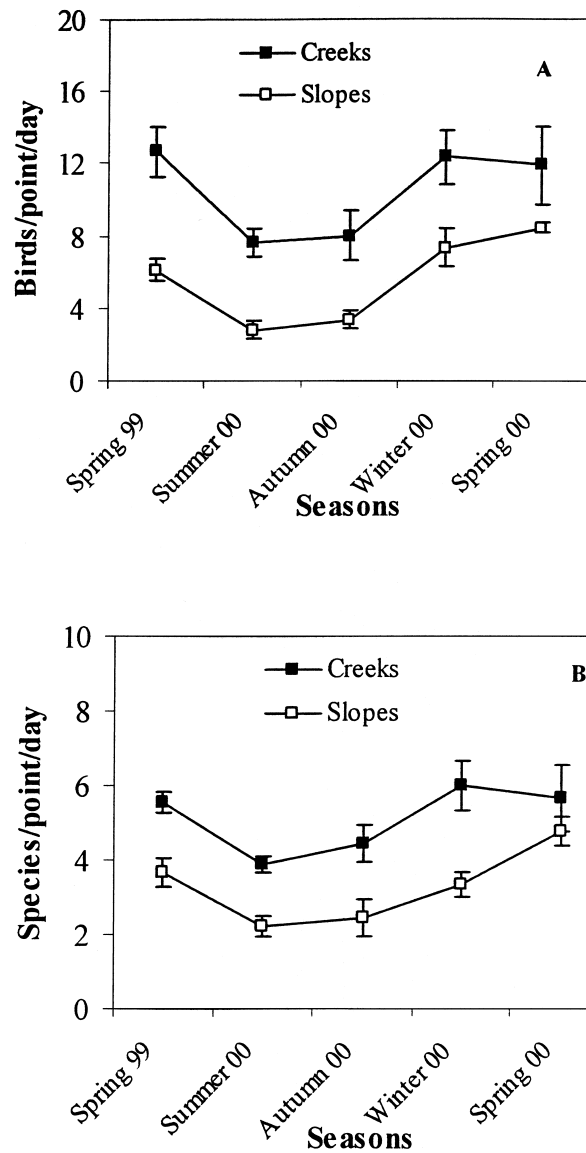


Figure 2. Seasonal variability in (A) abundance (birds/point/day) and (B) number of species (species/point/day) inhabiting creek and slope plots at the Santa Inés relict forest.

types (54% of the species found in the matrix are also found in the forest habitat), especially those that can reach large abundances such as *S. galeritus*, *A. parulus* and *Xolmis pyrope*, which showed correlated trends in abundance between both habitat types (S. Reid, personal observation).

We found striking differences between slope and creek plots with regard to

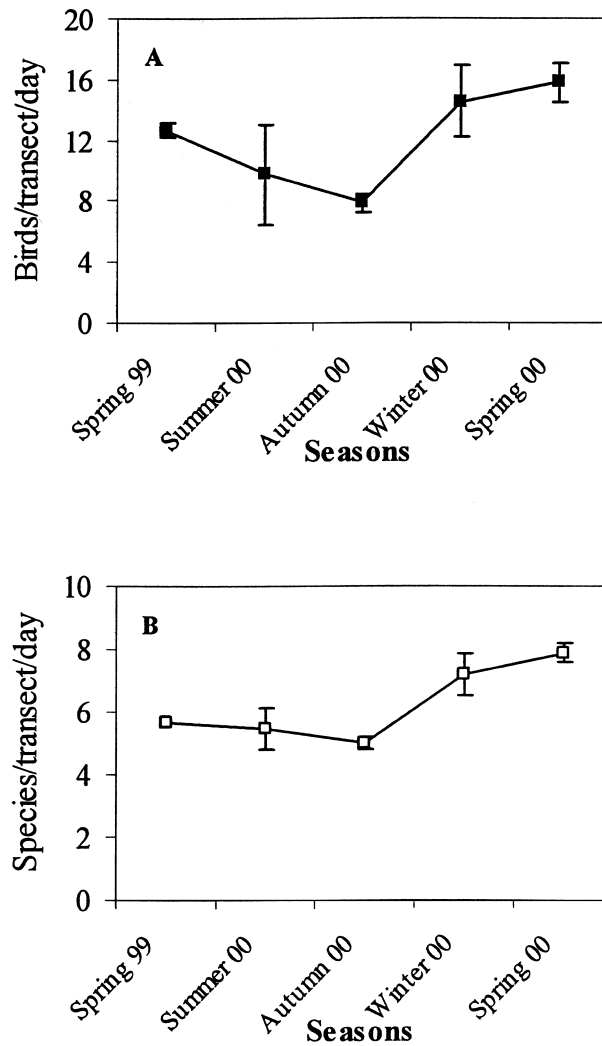


Figure 3. Seasonal variability in (A) abundance (birds/point/day) and (B) number of species (species/point/day) inhabiting the surrounding scrub matrix at Santa Inés.

average abundance and richness; both were higher in creek than in slope plots. Differences in abundance can be explained largely as the result of two species (*A. spinicauda* and *S. galeritus*) that reach large numbers in creeks. On the other hand, differences in richness can be explained by the occurrence of several species that are mostly restricted to creeks, such as *Colaptes pitius*, *Scytalopus fuscus*, *P. lignarius* and *S. desmursii*. Ultimately, these different species responses are associated with the observed dissimilarity in forest structure between creek and slope plots (Table 1). For example, creek plots have bigger trees and a higher number of fallen logs, which are important nesting and feeding sites for several species, *C. pitius*,

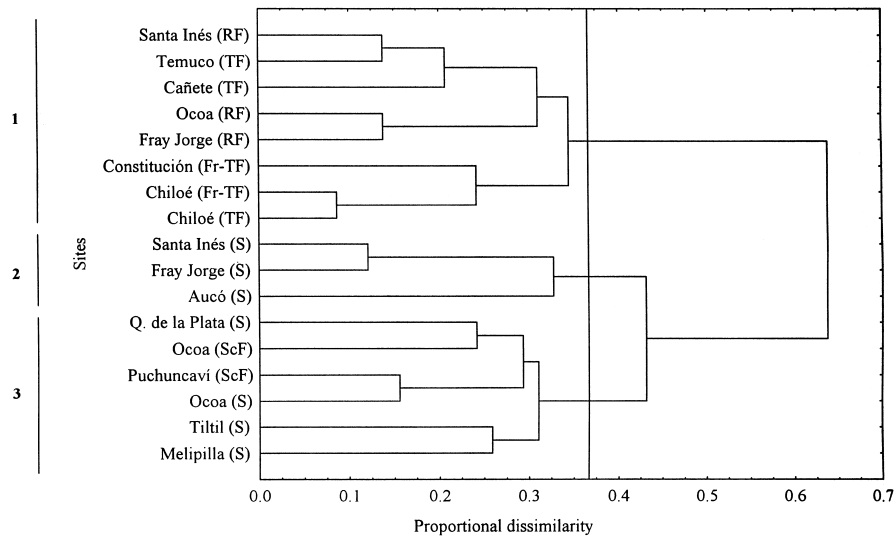


Figure 4. Cluster analysis of different habitat types based on bird species composition (presence/absence). Habitat types: relict (RF), temperate (TF), fragmented temperate (Fr-TF), and sclerophyllous (ScF) forests and scrubs (S). Vertical line indicates critical value of proportional dissimilarity. Site locations: Santa Inés 32°10' S, 71°30' W, Temuco 38°44' S, 72°35' W, Cañete 37°14' S, 73°19' W, Ocoa 32°55' S, 71°38' W, Fray Jorge 30°39' S, 71°40' W, Constitución 35°20' S, 71°24' W, Chiloé 40°55' S, 73°35' W, Aucó 31°31' S, 71°06' W, Quebrada de la Plata 33°31' S, 70°50' W, Puchuncaví 32°41' S, 71°25' W, Tiltil 32°58' S, 70°50' W and Melipilla 33°41' S, 71°13' W. Numbers identify significant clusters.

Tachycineta meyeni, *P. lignarius*, *A. spinicauda*, and *Pygarrhichas albogularis*, and logs are important nesting sites for *S. fuscus* and *Troglodytes aedon* (Willson et al. 1994; Franklin and Armesto 1996). Interestingly, all these species were always more abundant in creek than in slope plots, and this is verified in a positive and significant relationship between total relative abundance and richness across census plots and time vs. number of fallen logs ($F_{1,40} = 6.03$, $P = 0.019$ and $F_{1,40} = 4.28$, $P = 0.045$, respectively). Further, a stepwise regression analysis (forward procedure, P to enter = 0.15) points out that 46% of the variability in total relative abundance across plots and time is accounted for by the positive effect of the variable dbh and the negative effect of canopy cover. Dbh increases from slope to creek habitat, while the opposite happens with canopy cover. Similarly, 38% of the variability in number of species is accounted for by the negative effect of canopy cover and vertical foliage heterogeneity. However, although these regression statistics are significant, they should be interpreted with caution given that seasonal censuses are not completely independent in time, because it is likely that the same individuals of resident species are included in each census.

It has been widely recognized (e.g., Cody 1970; Wiens 1989; Wenny et al. 1993; Faaborg et al. 1998) that differences in habitat structure can be of paramount importance in affecting bird abundance, diversity, and distribution. In this regard,

the bird species assemblages of temperate forests in the southern hemisphere are not an exception (see also Estades 1997). In Chile, creeks have been considered a microhabitat that significantly affects the composition of bird communities in forest-dwelling species (Estades and Temple 1999). These authors document a significant increase in bird species richness and abundance with proximity to creeks in native *Nothofagus glauca* forests and exotic pine plantations in central Chile. Thus, our results concur with those of Estades and Temple (1999) in identifying creek habitats as being of critical importance for the conservation of temperate forest bird species, and therefore should be preserved and enhanced.

Missing species

Southern South American temperate forests have been described to hold a bird assemblage of 31 non-raptor species (Rozzi et al. 1996b). Cornelius et al. (2000) found 17 of these species in the most northern relict forest, Fray Jorge. In Santa Inés, we found 19 of these species, with *P. albogularis* and *S. desmursii* being the two missing species in Fray Jorge.

If we analyze the distribution of the 12 species that are missing in Santa Inés, eight are endemic to southern South American temperate forests, these being *Enicognathus ferrugineus* and *E. leptorhynchus* (Psittaciformes), *Campephilus magellanicus* (Piciformes), *P. patagonicus* (Fringillidae), *Eugralla paradoxa*, *Pteroptochos castaneus/tarnii* and *Scelorchilus rubecula* (Rhinocryptidae). The four remaining species, *Theristicus melanopsis* (Threskiornithidae), *P. gigas* (Trochilidae), *Phytotoma rara* (Phytotomidae) and *Pygochelidon cyanoleuca* (Hirundinidae), have wider distributions than the temperate forest itself and use other habitat types, such as open country or forest clearings (Johnson 1967; Fjeldså and Krabbe 1990); therefore the absence of these latter species in the Santa Inés forest should not be taken as a reflection of their inability to persist in forest fragments, but rather a selection of other habitat types (Cornelius et al. 2000). In contrast, the absence of the eight endemic species pointed out above more likely is an indication of their great sensitivity to habitat fragmentation and the long-term isolation of the Santa Inés forest. In fact, Willson et al. (1994) and Sieving et al. (1996, 2000) show that the four species of the family Rhinocryptidae mentioned above are among the most sensitive to habitat fragmentation in southern Chilean temperate forests. According to these results, these eight endemic species should be of great conservation concern (see also Cofré 1999; Cornelius et al. 2000) and will likely be the ones that will go extinct first if the fragmentation of the temperate forest continues.

Long-term isolation and area reduction

Using a reported species–area relationship for the non-raptor species in the relict forest fragments of Fray Jorge (Cornelius et al. 2000), we estimate the number of species expected in Santa Inés to be 16 (95% CI 12.38–19.47). This value is significantly different from the observed number (21) of non-raptor species in Santa Inés (Table 2). If we perform the same exercise but this time with the species–area relationship derived from continuous temperate forest sites in Chiloé Island (Will-

son et al. 1994), the expected number of species for Santa Inés increases to 20 (95% CI 16.05–23.54), which is not significantly different from the observed value. We take this result as reflecting the greater isolation of Fray Jorge (Cornelius et al. 2000) and the closer resemblance and connectivity between Santa Inés and the bird assemblages of southern South American temperate forests. This is in agreement with the results of the cluster analysis (Figure 2), whereby Santa Inés is shown to exhibit great similarities with temperate forest bird assemblages distributed more than 900 km to the south.

Conservation value

In 1996 Chile's National System of Wild Protected Areas recognized the forest at Santa Inés as an important site for conservation, assigning it with 'priority 2', which means that it is important to conserve (Muñoz et al. 1996); however, to date no conservation plans exist. On the contrary, direct human encroachment (exemplified by the setup of telecommunication antennas and unregulated touristic and recreational activities) and indirect effects (exemplified by the impact of domestic livestock such as goats, cows, and horses) have increased. Interestingly, the effect of livestock is especially acute in the slope habitat, which further reinforces the importance of creeks. The observation of *A. bicolor*, a rare species (Glade 1988), and *C. araucana*, a vulnerable species (Glade 1988; Vásquez and Simonetti 1999), reinforces its importance for biodiversity. Further, the Santa Inés forest contains peripheral populations of several species (*P. albogularis*, *S. desmursii* and *A. spinicauda*) and is rich in ecotone habitats, characteristics which may be of great importance for maintaining overall levels of genetic diversity (Lande and Barrowclough 1987; Ehrlich 1988; Howe et al. 1991; Lesica and Allendorf 1995; Smith et al. 1997).

This relict forest represents a temperate forest island immersed in a semiarid scrub matrix. There are only two other relict forest patches of *A. punctatum* near Santa Inés; Fray Jorge-Talinay (located 160 km to the north) and Quebrada El Tigre (60 km to the south) (Figure 1). Thus its preservation may be essential in maintaining connectivity at the landscape level, especially for species with limited dispersal abilities such as *S. desmursii*, *P. albogularis* and *A. spinicauda* (Sieving et al. 1996; Estades and Temple 1999).

Further studies aimed at assessing the importance of Santa Inés for landscape connectivity and for the persistence of species populations are required, but in the meantime this and other similar habitat patches should be protected in order to impede further human-driven degradation and to improve the reduced protection and representation that natural habitats in central Chile receive from the Chilean National System of Wild Protected Areas currently in place (Armesto et al. 1998).

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