Abundance and movement of understory birds in a Maulino forest fragmented by pine plantations

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Abstract. Understory birds are especially vulnerable to habitat fragmentation because of the reduction in habitat quality and bird movement. We study the separate effects of understory, overstory and landscape on four understory birds (tapaculos), in Central Chile, comprising a landscape mosaic of pine (*Pinus radiata* D. Don) plantations and native Maulino forest fragments. We also determined whether habitats with poor understory could be barrier to tapaculos movements. Abundance was measured using stationary playbacks and habitat barrier through playbacks. Understory structure was the main factor that predicted tapaculos presence and abundance. Two species, the Andean Tapaculo (*Scytalopus magellanicus fuscus* Gmelin) and the Ochre-flanked Tapaculo (*Eugralla paradoxa* Kittlitz), were positively associated with dead pine branches and negatively to forest fragment size. Tapaculos were less abundant in mature native forest, but appeared willing to cross between different habitat types. However, the Chestnut-throated Huet-huet (*Pteroptochos castaneus* Philippi and Landbeck), did not move from forest fragments to pine with poor understory. Overall, tapaculos species varied in their response to fragmentation depending on their habitat selection and movement capacities.

Introduction

Understory forest birds are particularly sensitive to habitat fragmentation. Forest fragmentation not only reduces both the quantity and quality of remaining habitat but also isolates remnant populations. Usually, the matrix surrounding fragments is structurally less complex than the original forest, rendering it an unsuitable habitat. Matrix then, might act as a barrier for understory birds, precluding their movements between fragments (Stouffer and Bierregaard 1995; Sekercioglu et al. 2002).

Tapaculos (Rhynocriptidae) are understory insectivorous birds widespread across western South America and eastern Brazil (Krabbe and Schulenberg 2003). In forests fragmented by pasture in Chiloé Island, southern Chile, tapaculos perceive these open areas as barriers, dispersing between fragments through forested corridors but avoiding open terrain (Sieving et al. 1996, 2000). Isolation precludes male dispersal and pair formation of tapaculos,

reducing fitness hence increasing the likelihood of disappearance of isolated populations (Willson 2004).

In central Chile, remnants of temperate forests are surrounded by commercial plantations of *Pinus radiata* rather than pasture (San Martín and Donoso 1995). As a matrix, pine plantations are a mosaic of heterogeneous understory vegetation (Vergara and Simonetti 2003; Estades and Escobar 2005). Such dense understory might improve habitat quality for forest birds in pine plantations (López and Moro 1997; Lindenmayer and Hobbs 2004). In fact, in the Maulino forest of central Chile, the abundance of two tapaculo species, the Ochre-flanked Tapaculo (*Eugralla paradoxa*) and the Andean Tapaculo (*Scytalopus magellanicus*) increases in pine plantations and forest fragments compared to the continuous forest, while the Chestnut-throated Huet-huet (*Pteroptochos castaneus*) attains similar abundance in fragments, plantations and continuous forest (Vergara and Simonetti 2004a). This response might be accounted for by an increased offer of nesting sites and food (ground insects) associated to a dense understory in forest fragments and pine plantations (Grez et al. 2003; Vergara and Simonetti 2004a, b; Grez 2005; see also Reid et al. 2004). Therefore, pine plantations might not be a completely unsuitable matrix for tapaculos if they have a dense understory (Vergara and Simonetti 2004a).

Currently, pine plantations cover over 413,336 ha of the regional native forests in the Maulino forest region of central Chile, as opposed to 370,329 ha of native forests, of which only 1.5% is under protection (Lara et al. 2002). Furthermore, native forests are replaced by plantations at a high rate. For instance, 8,282 ha were replaced between 1994 and 1999. Therefore, if plantations could be used, at least partially, as habitat by tapaculos, it could mitigate the detrimental effects of forest fragmentation (Simonetti et al. 2002). On this regard, our aim is twofold. First, we unravel if presence and abundance of tapaculos is related to understory cover and other habitat and landscape features at pine plantations, forest fragments and the continuous forest in the Maulino region. Second, we experimentally assess if tapaculos are willing to move from habitats with high understory cover to habitats with a scarce one, as these plantations with poorly developed understory could be a barrier to tapaculo's movement among fragments.

Methods

Study area

The study area is located in the Cordillera de la Costa of central Chile (35°59′ S, 72°41′ W; Figure 1), and comprised Los Queules National Reserve (a 145 ha native forest tract embedded in 600 ha of continuous native forest), extensive pine (*P. radiata*) plantations and forest fragments scattered
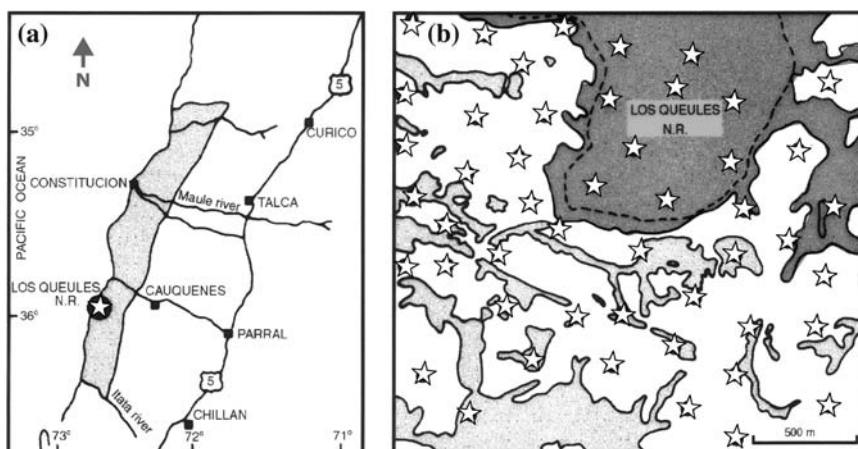
Figure 1. (a) Geographic distribution of the Maulino forest in coastal Central Chile and location of the study site (star). (b) Study site showing the continuous forest, (including the Los Queules National Reserve; dark gray), neighboring forest fragments (light gray areas) and pine plantations (white areas). Stars are sampling sites.

throughout the landscape, acting as a matrix. Pine plantations comprise 54% of the study area, forest fragments 26% and the continuous forest 20% (Acosta-Jamett and Simonetti 2004).

The predominant habitat within the continuous forest is a mature, mixed forest (*Nothofagus glauca*, *N. obliqua* and evergreen tree species) interspersed with bamboo (*Chusquea quila*) in canopy gaps and ravines. Pine plantations ($n = 13$) include stands with a dense understory cover and others with a scarcely developed understory if developed at all. Plantations ranged from 3 to 40 ha in area. Plantations with poor understory tend to be older than those with a well developed understory. Forest fragments ($n = 9$) were both isolated remnants and strips of native vegetation along creeks. Isolated fragments were *Nothofagus* forests and native thicket ranging from 1 to 12 ha. Native strips included some small creeks with banks covered by native thicket and were <140 m wide.

Bird sampling

Four species of tapaculos inhabit the coastal range forests of Chile: Chestnut-throated Huet-huet (*P. castaneus*), an endemic species to central Chile; Chucao Tapaculo (*Scelorchilus rubecula*); Andean Tapaculo (*S. magellanicus fuscus*) and the Ochre-flanked Tapaculo (*E. paradoxa*), all endemic to Chile and Argentina (Johnson 1967). These species were sampled by direct observations using playbacks.

We randomly positioned 50 survey points within an area of about 16 km^2. Sampling points were ≥320 m apart. We measured the presence and abundance of each tapaculo species at the beginning of the reproductive season (October 2000). In order to detect tapaculos, we used stationary tape-song playback surveys using recordings of territorial songs broadcast from two 5 W speakers (Falls 1981).

Surveys started at dawn (05:45 h) and continued until 11:30 h. In the evening, we repeated surveys between 16:00 and 17:00 h. In each survey, we spent about 20 min per sampling point. For the smaller Andean and Ochre-flanked tapaculos, we recorded only the individuals that were 20 m or less from the observer. For the larger and more mobile Chucao and Chestnut-throated Huet-huet, we recorded individuals ≤ 30 m distant from the observer. Using only those records, we reduced the risk of detecting individuals from neighbouring habitats and thus overestimating abundance. During each visit, we run playbacks three times: first, the observer stayed 5 min in a central point (2 min to playback and 3 min to detect birds), then he moved up to 15 m away from the central point, where he again broadcasted a 2 min playback, repeating the procedure towards the opposite side from the central point. Many times, this center point was within a bird's territory and birds from adjacent territories did not approach the observer. We estimated bird's abundance as the mean number of individuals recorded during the four times we sampled each point.

Habitat measures

We measured habitat variables around each sampling point, in 60 m radius plots. Overall, we measured 24 habitat variables related to the structure and composition of the under- and overstory, including plant species that are conspicuous elements in the landscape and change the understory structure among plots (*Chusquea quila*, *Aristotelia chilensis*, *Rubus ulmifolius*, *Teline montpessulana*, herbs and vines; Table 1).Within each plot, understory cover was measured using 30 m line-intercept transects and canopy cover by 0.1 ha circular plots (Higgins et al. 1996). For each point, we also included nine landscape variables that could affect tapaculos: fragment size (ha), pine plantation size (ha), distance to nearest native fragment (m), distance to nearest creek (m), slope (%) and aspect (N = 0, NW and NE = 1, SW and SE = 2, S = 3).

To determine the habitat-landscape variables that best account tapaculo's presence, we used a stepwise logistic regression. The best models were selected by backward elimination, excluding redundant variables to reduce multico-linearity (Hosmer and Lemeshow 1998). We also correlated the abundance of each tapaculo species and their pooled abundance, which were normally distributed, on habitat and landscape variables. Ridge multiple linear regressions selecting models by backward elimination were used (*F*-to-remove; Bare and Hann 1981).

Table 1. Differences in habitat variables (Table 1) from four different habitat types in Los Queules National Reserve.

Habitat variable	Habitat types			
	Forest fragments	Pine with poor understory	Pine with dense understory	Continuous forest
Understory retated variables				
Chusquea quila cover (%)	14.5 ± 6.2a	0.2 ± 0.8b	9.3 ± 5.1a	5.4 ± 3.2a
Aristotelia chilensis cover (%)	28.2 ± 6.6a	4.8 ± 2.6b	29.4 ± 6.4a	7.9 ± 3.9b
Rubus ulmifolius cover (%)	21.0 ± 8.2a	9.3 ± 6.2ba	26.2 ± 7.5a	1.9 ± 2.4b
Total understory cover (%)	60.0 ± 4.6a	22.3 ± 2.7 b	56.2 ± 5.1a	34.9 ± 4.2c
Ground dead branch cover (%)	39.3 ± 4.6a	41.9 ± 5.1a	53.2 ± 4a	17 ± 2.3b
Herbaceous cover (%)	1.9 ± 1.2	1.2 ± 1.1	3.7 ± 1.4	0.9 ± 0.8
Teline montpessulana cover (%)	6.5 ± 8.2a	4.3 ± 1.2a	8.2 ± 2.5a	0.9 ± 1.4b
Vine cover (%)	4.5 ± 1.1a	0.3 ± 0.8b	1.1 ± 1.5b	3.7 ± 1.1a
Rock cover (%)	0.9 ± 1.2	1.1 ± 0.9	1.7 ± 1.4	1.2 ± 0.8
Percentage of pine leafs (% in litter)	2.5 ± 1.3a	99 ± 0.1b	94.2 ± 4.3b	0
Litter depth (cm)	3.1 ± 1.0a	9.4 ± 1.3b	7.1 ± 2.4b	3.9 ± 0.8a
Overstory retated variables				
Nothofagus glauca cover (%)	7.9 ± 3.2a	0.2 ± 0.9b	2.3 ± 3.1b	17.4 ± 3.2c
Woody species richness	19.7 ± 2.4a	10.5 ± 2.9b	15.5 ± 3.3c	17.3 ± 3.6a,b
Snag density (snag ha^{-1})	4.4 ± 2.2a	0.9 ± 1.8 b	3.3 ± 1.6a	8.7 ± 1.1c
Log density (logs ha^{-1})	8.4 ± 2.3a	1.5 ± 1.2b	10.9 ± 2.5a	8.5 ± 3.2a
Pine canopy cover (%)	6.4 ± 6.3a	91.1 ± 6.1b	80.9 ± 7.8b	0
Pine density (trees/ha)	11 ± 4.4a	634 ± 69b	893 ± 85c	0
Pine dbh (cm)	9.2 ± 11.1a	46 ± 3.1b	32.0 ± 9.2b	0
Pine height (m)	7.9 ± 3.2a	21.0 ± 4.8b	15.0 ± 3.8c	0
Age of pine stand (years)	0	15.0 ± 0.5a	9.0 ± 1.5b	0
Native forest canopy cover (%)	54.5 ± 10.3a	1.2 ± 1.1b	7.9 ± 5.3c	75.8 ± 7.3d
Native forest dbh (cm)	10.8 ± 2.1a	5.1 ± 2.4b	7.5 ± 9.3b	24.1 ± 4.8c
Native forest height (m)	7.5 ± 1.6a	2.8 ± 3.8b	2.9 ± 3.9b	14.1 ± 4.3c
Native forest density (trees/ha)	2680 ± 54.4a	8.0 ± 4.5b	64 ± 32.1c	1690.0 ± 110.3d

Values are means ± standard error. Significant differences by ANOVA and Tukey test are showed by different letters.

Bird movements

We used tape-song playback to test whether birds cross from a given habitat to another in response to territorial songs (Sieving et al. 1996). Habitat trials were conducted in four habitat types: forest fragments, pine with dense understory stands, pine with poor understory stands and continuous native forests. As a large number of birds were initially recorded within forest fragments and dense understory pine stands, we attracted them from those habitats to other habitats with lower tapaculo abundance, such as pine stands with a poor understory and continuous forests. During each trial, we played territorial songs at the juncture between two habitat types for 3 min until one bird arrived there (at

least to 20 m from the observer; St Clair et al. 1998). Then, the observer moved about 20 m into the destination habitat and played a territorial song for another 5 min (Sieving et al. 2000). If the bird entered into the destination habitat, speakers were moved 40 m further into the destination habitat, and a new 5 min playback was displayed. We scored trials as positive when an individual moved into the destination habitat. It was regarded as negative, if animal was reluctant to cross habitat edges. Similarly, we measured bird movements within the same habitat type as controls, moving speakers about 60 m within of this habitat (using the same protocol). Trials were ≥250 m, in order to avoid recording the reaction of the same individual more than once. We compared trials done in the same habitats and those done in different through the Fisher exact test (one-tailed).

Results

Habitat features

Habitat features varied significantly at the landscape level. Pine with poor and dense understory, forest fragments and the continuous forest differed in all habitat variables except for herbaceous and rock cover (Table 1). Regarding understory variables, pine plantations with poor understory had a lower cover of *C. quila* and *A. chilensis* than plantations with dense cover. Regarding the overstory, pine with poor understory was less diverse in plant composition and had a lower cover of native trees, snags and logs (Table 1). Further, pine trees in plantations with poor undestory are older, higher and stands have a lower pine density than plantations with a dense understory (Table 1). Cover of dead ground branches (including fallen timber logs < 0.3 m of diameter) was low in the continuous forest, and forest canopy was larger in continuous forest and forest fragments (Table 1).

Habitat and landscape effects

Tapaculo's presence and abundance was associated to both under and overstory as well as landscape-level variables. Understory cover was the primary predictor of the presence of Chestnut-throated Huet-huet, Andean and Ochre-flanked tapaculos. Furthermore, their presence was predicted by different habitat and landscape variables (Table 2). Presence of Ochre-flanked and Andean tapaculos was negatively associated to fragment size and positively associated to pine and ground dead cover. Presence of Chestnut-throated Huet-huet was also predicted by woody species richness (Table 2). Habitat variables correctly classified over 65% of cases in logistic models.

  The abundance of each tapaculo species and that of tapaculos as a whole was also explained by understory cover (Table 3). Abundance of the Ochre-flanked and the Andean tapaculos was related to dead branch cover. The

Table 2. Fitted logistic regression models for Rhinocryptid incidence using habitat-landscape variables.

Species	Variables in the model	d.f.	χ^2	p	% Correctly classified (n)		
					Presence	Absence	Overall
Ochre-flanked Tapaculo	Total understory + pine canopy – fragments size	3	19.5	0.0011	81 (42)	100 (8)	84
Andean Tapaculo	Ground dead branches + pine canopy – fragment size	3	25.3	0.0007	65.7 (35)	86.7 (15)	72
Chestnut-throated Huet-huet	Total understory + woody species richness	2	8.6	0.0064	50 (28)	72.7 (22)	62

Table 3. Fitted multiple regression models for Rhinocryptid abundance using habitat-landscape variables.

Species	Variables in the model	r^2	d.f.	F	p
Ochre-flanked Tapaculo	Total understory + *A. chilensis* + ground dead branches	0.57	3.46	20.5	< 0.0001
Andean Tapaculo	Total understory + ground dead branches – native canopy	0.66	3.46	22.1	< 0.0001
Chestnut-throated Huet-huet	Total understory + woody richness – creek distance	0.38	3.46	9.53	< 0.0001
Pooled	Total understory + ground dead branches	0.63	2.47	41.14	< 0.0001

abundance of the Ochre-flanked Tapaculo was also related to the cover of *Aristotelia chilensis*, but the abundance of the Andean Tapaculo was negatively related to native canopy cover. The Chestnut-throated Huet-huet abundance decreased with the distance to creeks (Table 3).

Bird movements

In general, individuals of all species crossed between habitat types when they were motivated by playback songs. The proportion of the Ochre-flanked and the Andean tapaculos that crossed from forest fragments to pine with poor understory did not differ from the proportion that moved within forest fragments (Table 4). The proportion of the Chestnut-throated Huet-huet individ-

Table 4. Habitat trial results indicating the ratio (c/n) between the number of times that individuals of a particular species crossed from an origin to a destination habitat (c) and the total number of taped song playback experiments (n).

Species	From	To*				
		Forest fragments	Pine with poor understory	Pine with dense understory	Reserve	Fisher (p)
Chestnut-throated Huet-huet	Forest fragments	9/10	–	–	3/7	0.31
Chestnut-throated Huet-huet	Forest fragments	9/10	0/9	–	–	0.01*
Chestnut-throated Huet-huet	Pine with dense understory	–	4/5	5/5	–	0.59
Ochre-flanked Tapaculo	Pine with dense understory	7/8	6/8	–	–	0.56
Andean Tapaculo	Forest fragments	6/6	6/7	–	–	0.58

Difference in proportions between individuals moving between habitat and controls (see text) are tested by Fisher exact test (* indicates a significant difference). Blank cells mean that no trials were done.

uals that moved from pine with dense understory to pine with poor understory and from forest fragments to mature native forest was not different from the proportion that moved within pine with dense understory and forest fragments, respectively (Table 4). However, Chestnut-throated Huet-huet individuals crossed less often from forest fragments to pine with poor understory than individuals that moved within forest fragments (Table 4).

Discussion

The potential use of plantations as habitat for forest organisms could mitigate the detrimental effects of forest fragmentation (Simonetti et al. 2002). In the fragmented Maulino forest, the pine plantation matrix is a heterogeneous habitat. Such heterogeneity at the habitat and landscape-level determine tapaculo's distribution in these fragmented forests (Vergara and Simonetti 2003; Estades and Escobar 2005). As tapaculos are understory cover-dependent, pine stands with dense understory could be a suitable habitat, albeit a surrogate of native ones. These stands tend to be younger and managed mostly for cellulose or a mixed production of cellulose and timber wood. Management includes thinning, which allows light entrance and understory growth (Estades and Escobar 2005). As long as management allows understory development, plantations can temporarily mitigate habitat loss for tapaculos and other ground dwelling species, such as coleopterans (e.g., Grez et al. 2003).

Mobile species may have a higher incidence than relatively sedentary species in fragmented landscapes (Wiens 1990). Furthermore, local landscape features may be important determinants of inter-patch movement and habitat utilization in a native patch-pine matrix system (Lindenmayer and Lacy 1995). As in other fragmented forests (Sieving et al. 1996), the Andean Tapaculo was the most mobile of all species, and thus its higher incidence together with the Ochre-flanked Tapaculo, may reflect high mobility among habitats. Although Chestnut-throated Huet-huet individuals were able to move between two structural different habitats, some individuals did not cross from forest fragment to pine with poor understory. This behavior could reduce individual movements among habitats, affecting its distribution as the landscapes become more fragmented by pine with poor understories.

Deciduous forest of central Chile, a landscape dominated by pine plantations, comprises a mosaic of different habitats for forest birds (Estades and Escobar 2005). Many bird species may profit from forest fragmentation, increasing their abundance in pine matrix and in the smaller forest fragments due to increased understory complexity (Estades and Escobar 2005; Vergara and Simonetti 2004a). In fact, habitat use by tapaculos is related mainly to availability of understory structures in both pine matrix and forest fragments. On the other hand, forest fragmentation for pasture, like in Chiloé Island (Willson et al. 1994; Sieving et al. 1996, 2000), where an open matrix encloses native fragments and corridors, could impose more severe problems for

tapaculo persistence because of the lack of a cover like that found in the plantations and fragments in the Maulino forest. In Chiloé, bird territories would be more isolated and packed than in forest fragmented by pine, and therefore individual movements could be more limited among fragments (Willson et al. 1994). Therefore, native fragments enclosed by pine plantations could be a less restrictive landscape to tapaculos than a forest fragmented by pasture.

Acknowledgments

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