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Habitat selection of endemic birds in temperate forests in a biodiversity "Hotspot"

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Abstract

Aim of study: Our objective was to find habitat associations at a microhabitat level for two endemic birds in a Chilean temperate forest (biodiversity "hotspots"), in order to integrate biodiversity into forest planning.

Area of study: Nahuelbuta Range, Chile.

Material and methods: The two birds studied were *Scelorchilus rubecula* (Chucao Tapaculo) and *Scytalopus magellanicus* (Magellanic Tapaculo), both belonging to the *Rhinocryptidae* family. Presence or absence of the two species was sampled in 57 census spots. Habitat was categorized according to presence/absence results. We assessed the influence of abiotic variables (altitude, exposure, slope) and vegetation structure (percentage of understory cover, number of strata) using a statistical cluster analysis.

Main results: The two bird species selected the habitat. Most frequent presence was detected at a range of 600-1100 masl, but Magellanic Tapaculo was associated to more protected sites in terms of vegetation structure (50-75% for understory cover and 2-3 strata). Slope was the most relevant abiotic variable in habitat selection due to its linkage to vegetation traits in this area.

Research highlights: Our results can help managers to integrate biodiversity (endemic fauna species) into forest planning by preserving certain traits of the vegetation as part of a habitat (at a microhabitat level) selected by the fauna species. That planning should be implemented with both an adequate wood harvesting cuts system and specific silvicultural treatments.

Key words: Chile; nahuelbuta; rhinocryptidae; cluster analysis; forest planning; vegetation structure.

Introduction

Biodiversity management research usually focuses on key species and forest characteristics (Saura and Pascual-Hortal, 2007; Rubio *et al.,* 2012). In Chile, a diversity of temperate bioclimatic forest types exists along with groups of species that have adapted to these ecosystems and habitats (Simonetti and Armesto, 1991). Simultaneously, there has been an increase in the fragmentation of natural ecosystems with the corresponding decrease of quality and size of habitats for many plant and animal species of high ecological value, placing a large number of them at risk.

A place that meets all the requirements of a species is called habitat, and provides the conditions needed for the reproduction and survival of its populations (Boyce and McDonald, 1999). The occupation of a place by a species leads to habitat use (Bustamante and Grez, 1995; Estades, 1997; Jones, 2001). Habitat selection implies a discriminate use of an area by the species. Habitat use studies point out the importance of knowing the limiting factors for their conservation (Luck, 2002; Oppel *et al*., 2004, McFarland *et al*., 2012), specially for threatened species or with a high degree of habitat specialization that requires a more specific scale analysis rather than a general habitat scale (Cahill and Matthysen, 2007).

The birds chosen for this study are two endemic species of South America, belonging to the *Rhinocryptidae* family (Moreno *et al*., 2011): the Chucao

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Abbreviations used: S.A. is the Spanish abbreviation for Limited Liability Company.

Tapaculo *(Scelorchilus rubecula)* and the Magellanic Tapaculo *(Scytalopus magellanicus),* both being typical and permanent resident species of temperate South American forests (Rozzi *et al.,* 1996; Sieving *et al.,* 2000; Amico *et al.,* 2008). Being endemic species, they are relevant constituents of the biodiversity of the area under study.

These birds are extremely sensitive to habitat fragmentation (Willson *et al.,* 1994). However, as Estades pointed out (1997), the habitat characteristics of a species depend on the scale of analysis. In this way, the area with which an animal routinely interacts can be defined as its local habitat (Hall *et al*., 1997), whereas concrete points or sites used by the species can be termed microhabitat.

Our research was conducted at the microhabitat level. The two small birds are found mainly at the lowest forest stratum (Diaz *et al*., 2005). Information about their food is scarce and imprecise, but they have been categorized as insectivores or omnivores (Rozzi *et al*., 1996).

Despite the various studies of these birds, there is little information on its habitat selection and use, and the available ones usually are based on extremely broad spatial scales (Estades, 1997; Estades and Temple, 1999; Brotons *et al*., 2007; Rodriguez *et al*., 2007). Other studies focused on their response to habitat fragmentation (Cornelius *et al*., 2000; Sieving *et al*., 2000; Castellón and Sieving, 2007). Only few studies have tried to specify variables associated with habitat selection (Moreno, 2003; Reid *et al*., 2004; Amico *et al*., 2008; Moreno *et al*., 2011). This confirms the lack of information available regarding the environmental needs of these birds.

The variables used in this study considered both abiotic and vegetation characteristics, all of them identified by several authors (Hall *et al*., 1997; Estades 1999) as being responsible for animal habitat use and/or selection. This study includes geographic characteristics (slope, altitude and land use) that are commonly used in research for determining potential wildlife habitats (Bustamante *et al*., 1997; Nogues and Agirre 2006; Costa *et al*., 2010), as well as two vegetation variables: percentage of understory cover and number of strata.

Our study aimed to evaluate the association between some site characteristics and the presence of the two above mentioned bird species (Reid *et al*., 2004; Amico *et al*., 2008), and how this may have influence on forest planning.

Material and methods

Study area

The study was conducted in the Nahuelbuta Mountain Range (Cordillera Nahuelbuta), which is part of the Chilean coastal mountain chain, located south of the Bio-Bio River (37° 11' S) and north of the Imperial River (38° 45' S). It crosses the VIII and IX regions of Chile. The study area is approximately 1564 km^2. Data collection centered around the sectors of Trongol, Caramavida and the environs of Angol, which include the Nahuelbuta National Park (Fig. 1), and several forest holdings of the Arauco, S.A. Company.

The Nahuelbuta Mountain Range was declared, nationally and internationally, as a priority for ecological protection (Teneb, 2006). Thus, both the upper basin of the Caramavida River and the native forests adjacent to Nahuelbuta National Park have been proposed by the Chilean Environment Ministry as prime sites for local biodiversity conservation (CONAMA, 2003). Additionally, the Nahuelbuta area has been globally designated as a main conservation *eco-region,* "hotspot" of biodiversity (Myers *et al.,* 2000).

In the far north, the Nahuelbuta Mountain Range has a peak of 1500 masl (Mardones, 2005) while the southern border, in contrast, does not exceed 720 masl (Quintanilla, 1983). Eighty percent of the rainfall occurs during autumn and winter (March-August). There are two gradients in precipitation: a latitudinal increase from north to south, and a longitudinal increase from east to west. This creates a transition between a warm, sub-humid Mediterranean climate and a humid, rainy temperate one (Di Castri and Hajek, 1976). Data from the Nahuelbuta National Park meteorological station showed a 1,491 mm annual average, a temperature that ranges from 5 to 26°C, and an average annual temperature of 13.4°C (Bonilla *et al*., 2002).

Because of its biogeographic history, the Nahuelbuta area contains a high number of endemic plant species (Cavieres *et al.,* 2005; Smith-Ramírez, 2004). Currently, the natural vegetation is characterized by ecotones ranging, chiefly, between deciduous and temperate evergreen forests (Teneb, 2006). This condition explains why it is one of the world's floristically richest areas (Myers *et al.,* 2000), with 38.4% of the

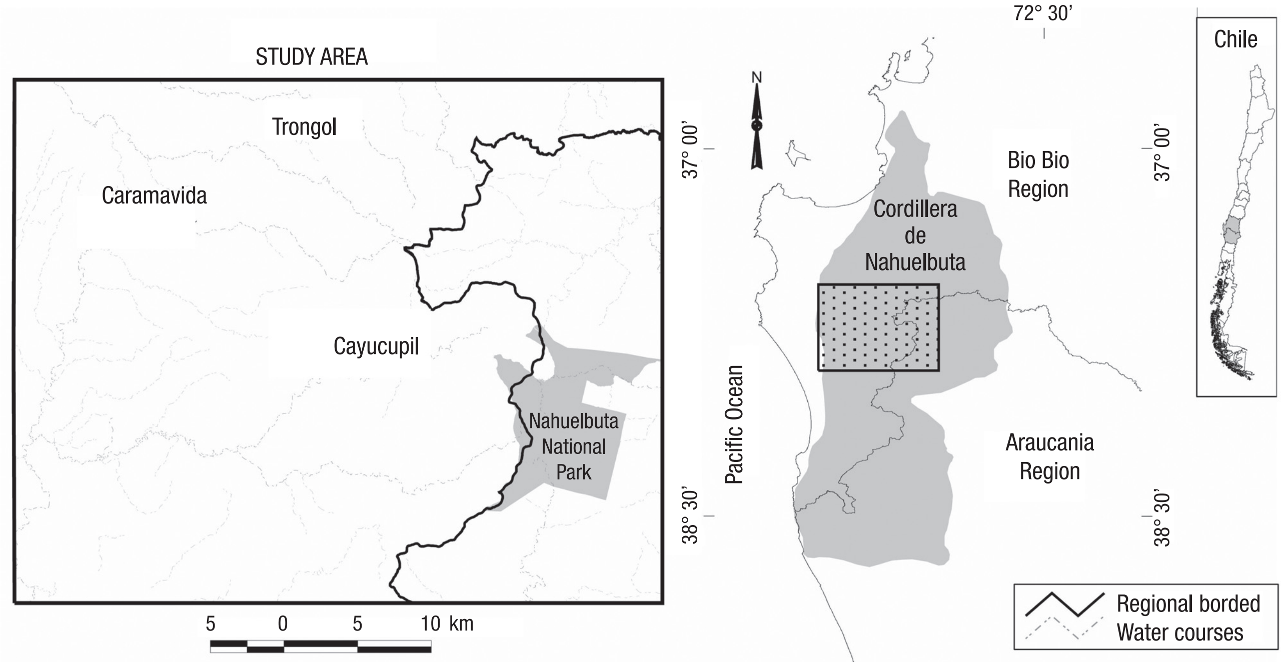

Figure 1. Map of study area at Nahuelbuta Mountain Range.

native species being endemic to Chile (Cavieres *et al.,* 2005).

Bird surveys

To survey the birds under study, we used a method based on Blondel *et al.* (1981), which consisted of recording all birds seen and heard at 20-m fixed censusing spots or stations (CS). The bird field guide by Araya and Millie (1986) was used to identify the two species. Four repetitions were carried out at each spot, using the presence of the birds to calculate their frequency (Donazar *et al*., 1993; Bustamante *et al*., 1997). Sampling was conducted in February 2010, since, for the study area, it was easier to detect the presence of the target birds during that month than in any other period.

Sampling was systematic; it consisted of 57 CS´s with the first one randomly placed. In order to avoid recording the same individual twice, each CS was 300-500 meters apart from any other CS along existing paths, following Bibby *et al.* (1992). Moreover, each CS was placed 30-35 meters away from the paths inside the forest (Fig. 2).

Each record was carried out as it follows: once the person making the sampling was at each CS, he let a five-minute silent period to go by before starting with the sampling, to avoid disturbances on the detection by the noise effects caused by his transit through the forest. Birds (sounds and sightings) were then recorded for other five-minute period (Blondel *et al.,* 1981).

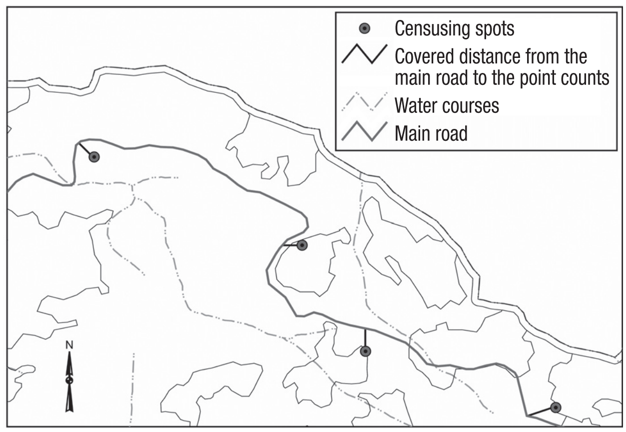

Figure 2. Distribution of some of the censusing spots.

To coincide with peak bird activity hours, repetitions took place, on non-consecutive days, between 8 to 12 am and 2 to 6 pm (Rozzi *et al.,* 1996).

For each of the two species, a 1 value was assigned to the CS point where the species was detected (*presence*). Otherwise, a 0 value (*absence*) was assigned to the CS point.

Habitat characterization

Our approach was at the microhabitat level in order to better characterize the forest site conditions in which the presence of each species was detected. This implies focusing on specific vegetation structures (North and Reynolds, 1996; Moreno, 2003; Brottons *et al*., 2007).

For our purpose, the microhabitat was categorized, according to the relative frequency of each species detection after the four repetitions made at each CS, in: 0 = Microhabitat with no association, 1 = Microhabitat with association and 2 = Microhabitat with relevant association (Table 1). Once the Microhabitat was so categorized, it was included as another variable in the cluster analysis made.

Other analyzed variables were categorized as shown in Tables 2 and 3.

Structural traits of the vegetation which could influence the presence of the two studied bird species were counted at each CS. The variables evaluated were *understory cover* (assumed to be as the percentage of ground covered by shrubbery less than 3 meters height), and *number of strata* (different vegetation layers distinguished) (Table 3).

The abiotic variables selected for this study were slope, exposure and altitude. These biophysical features were assessed by means of a digital elevation model generated by NASA´s Shuttle Radar Topography Mission (SRTM) 2003 program with a spatial resolution of 90 m. It was transformed to Datum PSAD56 UTM 18 South at a spatial resolution of 30 × 30 m. Such resolution has been used in land use analysis (Burrough *et al*., 2000; Aldana and Bosque, 2008).

The image processing and cartographic coverage were carried out by ENVI 4.5 and Arc GIS 9.2 software. The base map was made using digital information provided both by the Chilean National Forestry Corporation (CONAMA), the IX region of Araucanía, and Arauco, S.A. Forestry Company.

Table 1. Microhabitat types according to bird presence frequency at each CS[1] (no. of detections/no. of repetitions)

Bird Presence Frequency (%)	Category	Microhabitat Type
<25%	0	Microhabitat with no association
25%-75%	1	Microhabitat with association
>75%	2	Microhabitat with relevant association

[1] Censusing spot.

Table 2. Categories for Exposure

Category	Exposure
1	N
2	NE
3	E
4	SE
5	S
6	SO
7	O
8	NO
9	NO EXPOSURE

Table 3. Categories for Variables (except for Exposure)

Category	Variables			
	Number of strata	Understory coverage (%)	Elevation (masl)	Ground slope (%)
1	1	0-25	155-335	0-15
2	2	25-50	335-615	15-30
3	3	50-75	615-895	30-45
4	4	75-100	895-1175	45-60
5	5	—	>1175	>60

Statistical analysis

A cluster method was used, as an exploratory tool, to analyze the data. All values of the variables, including 0, 1 values for absence/presence of birds, were analyzed together. This multivariate technique allowed all the data to be grouped according to their likenesses or similarities (Hair *et al*., 1999). For this study, we used a K-means clustering analysis, fixing three groups according to the distances among all of the variables. This method has been already used in the analysis of environmental variables (Fandiño-Lozano, 1996; Gorsevski *et al.,* 2003; Burrough *et al.,* 2000; Rodriguez *et al*., 2007).

The analysis was implemented using SPSS 8.0 software, after which all cases were linked in three groups or clusters (Tables 4 and 5).

Results

Once the cases were grouped, we analyzed the values and ranges of the variables that most probably

Table 4. Nº of iterations with clusters centre[a] changes

Iteration	Change of clusters centre		
	1	2	3
1	1,657	2,490	1,067
2	,616	,410	,246
3	,320	,136	,472
4	,127	,244	,415
5	,084	,190	,272
6	,000	,182	,122
7	,000	,000	,000

[a] Convergence reached, since no change of clusters centre found, after 7 iterations. Minimum distance among initial centers is 5,292.

Table 5. Number of cases for each cluster

Cluster	1	28,000
	2	12,000
	3	17,000
Valids		57,000
No valids		,000

affected the different degrees of bird presence in the selected area for each species (Tables 6 and 7).

Chucao Tapaculo

Microhabitat variables with relevant association. The presence of this bird was detected more frequently at medium-low altitudes of the area, from 600 to 1100 masl, although its altitudinal range can reach up to 1350 masl. With regard to exposure, this bird was more detected in the northwest, west and southwest, and at slopes from 0 to 30%.

Regarding vegetation variables, the species selected areas with an understory cover of 50 to 75%, and a vertical stratification of two to three strata.

Microhabitat variables with association (see table 1). The altitude range for topographic variables increased between 600 to 1350 masl. North, east and southeast exposures were added to those previously identified in the most used sites, without any restrictions for slope.

For understory cover, the lower range decreased to 25%, with a vertical stratification of two to three strata.

Microhabitat variables with no association. The Chucao Tapaculo species was rarely detected in terrains with less than 15% of slope; this was consistent with its absence in flatlands with little exposure.

Regarding vegetation structure, we noted a low usage of sites with less than 25% of understory cover and just one stratum.

Magellanic Tapaculo

Microhabitat with relevant association. The topographic features selected by this bird were areas with an altitude between 600 to 1100 masl, preferably with a northeastern exposure, and slopes between 15 to 45%.

Regarding structural variables of vegetation, the species selected areas with understory cover between 50 to 75% and a vertical stratification made up of two to three strata.

Microhabitat with association. This case included altitudes ranging from 600 to 1350 masl. Its exposure range expanded to include northeast, east, south, southwest and west to the previously mentioned northeastern exposure. Slopes in sites occupied by the species remained at the same range described above.

Table 6. Categories of variables and habitat association for Chucao Tapaculo (*Scelorchilus rubecula)* after Cluster analysis

Variables	Categories with no habitat association	Categories with habitat association (relevant association included)
Elevation	4	1-3
Exposure	3-5-9	1-7-8
Ground Slope	3-4	1-2
Understory cover	1	2
Nº of strata	1	2-3

Table 7. Categories of variables and habitat association for Magellanic Tapaculo *(Scytalopus magellanicus)* after Cluster analysis

Variables	Categories with no habitat association	Categories with habitat association (relevant association included)
Elevation	4	1
Exposure	1-4-7-8-9	2
Ground slope	4	1
Understory cover	1-4	2
Nº of strata	1	2-3

With relation to understory cover, the species did not show any preference, although there was a greater presence of the species in areas with understory cover from 25 to 75%. Vertical stratification of sites occupied remained at two to three strata.

Microhabitat with no association. For this category, the Magellanic Tapaculo species was not detected at altitudes exceeding 1100 masl. In terms of exposure, it avoided terrain exposed to the north, southeast, northwest as well as land with no exposure at all. This was combined with an absence of the species in areas with slopes of less than 15% and a total absence in those with more than 45%.

Regarding vegetation structure, it can be pointed out that forests with less than 25% or over 75% of understory cover were not used as a habitat by this species. Likewise, one-stratum areas were not used either.

Discussion

This study gives information about vegetation and topographic characteristics that are useful in determining habitat selection of two endemic bird species of Chilean temperate forests. These birds can also be considered as bio-indicators species relating to ecosystems with high biodiversity (Rozzi *et al.,* 1996; Amico *et al.,* 2008). Habitat descriptive techniques, as those shown here, could help to implement wildlife conservation actions in forests of great ecological value that are highly susceptible to degradation and/or fragmentation (Reid *et al.,* 2002, Rodriguez *et al*., 2007; McFarland *et al*., 2012).

Our results complete some information generated by other studies (Reid *et al.,* 2004; Amico *et al.,* 2008; Moreno *et al*. 2011). In this sense, topographical variables, although already used in forest management, have not been applied in Chile until now to determine habitat selection by fauna.

Our results suggest that Chucao Tapaculo might show a greater selectivity in vegetation variables than in topographic ones, selecting medium-high values in understory cover and vertical stratification. This relationship with understory cover confirms the findings of Sieving *et al.* (2000) and Castellón and Sieving (2006) in which its vertical and horizontal protection against predators is provided by the vegetation.

With regard to topographic variables, it is worth noting that although this species reaches relatively high altitudes; its top limit is 1100 masl. Our results also suggest that the changes in vegetation traits that go with the increase of altitude affect its habitat use, *i.e.*, there is less understory cover and number of strata as the altitude increases. Therefore the habitat protection and shelter capacity for the species decrease.

Exposure does not appear to be a problem for this species. This could mean that the light and temperature influences of its habitat come from the aforementioned structural variables of the forest. For the case of slope, the species shows a clear association to areas with medium to high gradients, excluding flatlands and low slope values. The latter may also be explained by the fact that this bird needs protection from potential predators, as suggested by Sieving *et al.* (2000).

For Magellanic Tapaculo, the need for continuous protection provided by the vegetation is confirmed, as indicated by Vuilleumier (1998) and Anderson and Rozzi (2000). Additionally, there was a strong association to NE, E, and S exposures, which made those mountainsides to be partially or fully shaded and, therefore, more humid. No association was found with SE exposures. This could be explained on the basis of avoiding competition with other birds occupying that space or because these places do not meet other selection requirements, such as slope range or understory cover, among others, but further research is needed to prove this.

This species seemed to select rugged terrains with medium to high gradients in slope, along with medium-high values for understory cover and number of strata, confirming that stated by Moreno (2003), namely, that the presence of this bird required a minimum of canopy height and understory cover values. This also suggests that the species uses more frequently well-protected sites with constant, medium-high level of humidity.

As a habitat association assessment, our study confirmed that these two species of the *Rhinocryptidae* family are typical of the temperate forests of southern Chile, in accordance with previous reports (Armesto *et al*., 1996; Rozzi *et al*., 1996; Sieving *et al*., 2000; Reid *et al*., 2004). Additionally, we can corroborate the importance of the understory cover as a key habitat component not only for the two target species, but also for the whole family (Sieving *et al.,* 2000; Moreno, 2003; Reid *et al.,* 2004; Diaz *et al.,* 2005; Castellón and Sieving, 2007). Available literature highlights the importance of these variables as limiting factors for habitat use and/or selection by the species in these forests. Among the topographic variables, our results suggest that slope is the most significant habitat variable, probably due to its relationship with other site conditions (*i.e.*, understory cover, number of strata) in the studied area.

The information provided is useful for biodiversity conservation in forest planning (McFarland *et al.*, 2012). This implies designing adequate harvesting plans that meet the main vegetation structure requirements. In this sense, biodiversity conservation should be included as a main objective in strategic forest plans, along with other objectives such as maximizing the yield of forest products.

Therefore, in a tactical management plan for the conservation of any of these bird species, we recommend that wood selection felling systems should keep 50-75% of understory coverage and 2-3 vegetation strata. Such recommendation implies avoiding clear-cutting methods; shelter-wood and selection-cut systems should be implemented instead. Moreover, any silvicultural system to be applied should manage not only one, but various forest tree species. In this way, thinning regimes should alter neither the understory coverage nor the number of strata. In general, uneven-aged stands are recommendable rather than even-aged stands.

Conclusions

Further research is advisable to improve the management of wildlife biodiversity conservation in South America temperate forests. The habitat selection studies should be focused on fauna species highly associated with singular ecosystems, which is the case of the birds included in the *Rhinocryptidae* taxon and the temperate forests of South America. These birds live in native forests and are sensible to disturbances in such forests, so they can play the role of bio-indicators about habitat quality.

A greater knowledge of habitat-fauna relationships from the scope of biodiversity conservation can be evaluated by both abiotic and biotic variables. Any fauna species showing habitat occupation specificity, like the two ones here studied, requires a microhabitat scale analysis rather than a general habitat scale, so occupation monitoring techniques should be taken into account.

These facts are considered in some conservation protocols, such as the Montreal Protocol on Sustainable Forest Management (Montreal Process, 1995), of which Chile is a signatory.

When implemented on areas with high biodiversity, forest plans should preserve the structure of the vegetation in the habitats selected by endemic species associated to such biodiversity. This can be achieved both at a strategic level considering biodiversity conservation as an explicit objective, and at a tactical level with an adequate design of wood harvest methods and silvicultural treatments.

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