

Effect of connectivity and habitat availability on the occurrence of the Chestnut-throated Huet-Huet (*Pterotochos castaneus*, Rhinocryptidae) in fragmented landscapes of central Chile

Matías G. Castillo · H. Jaime Hernández · Cristián F. Estades

Received: 31 March 2017 / Accepted: 17 May 2018 / Published online: 24 May 2018
© Springer Science+Business Media B.V., part of Springer Nature 2018

Abstract

Context Although small isolated habitat patches may not be able to maintain a minimum viable population, small patches that are structurally isolated may be functionally connected if individuals can cross the gaps between them, in which case, their areas could be added to form a larger habitat patch, eventually surpassing the size threshold for holding a viable population.

Objectives We studied whether models based on the size and isolation of habitat patches could be used to predict the distribution of the Chestnut-throated Huet-Huet (*Pterotochos castaneus*) in fragmented landscapes of the coastal range of the Maule region, central Chile.

Methods We selected seven 10,000-ha landscapes (8.4–70.7% forest cover). For each habitat patch we

made 18 predictions of the presence of the species based on the combination of two thresholds: three critical patch sizes for maintaining a viable population (62.5, 125 and 250 ha) and six critical isolation distances between patches (0, 10, 50, 100, 150 and 200 m). We used playbacks in 59 sampling points to estimate the species' presence/absence. We used logistic regressions to test whether the output of the patch-matrix models could explain part of the variation in the presence of *Pterotochos castaneus*.

Results The best predictions for the presence of *P. castaneus* were obtained with the most conservative scenarios (125–250 ha to 0–10 m), including a positive effect of the understory cover and a lack of effect of the forest type (native or exotic).

Conclusions Our findings suggest that the long term persistence of *P. castaneus* may depend on the existence of large and/or very connected forest tracts.

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s10980-018-0649-5>) contains supplementary material, which is available to authorized users.

M. G. Castillo (✉) · C. F. Estades
Wildlife Ecology Laboratory, School of Forest Sciences
and Nature Conservation, University of Chile, Santa Rosa
Avenue 11315, Santiago, Chile
e-mail: mattcastilloa@gmail.com

H. Jaime Hernández
Geomatics and Landscape Ecology Laboratory, School of
Forest Sciences and Nature Conservation, University of
Chile, Santa Rosa Avenue 11315, Santiago, Chile

Keywords Habitat fragmentation · Functional connectivity · Ground-dwelling forest birds · *Pterotochos castaneus* · Central Chile

Introduction

Habitat loss and fragmentation are considered major threats to biodiversity conservation throughout the world (Fahrig 2003). One of the main mechanisms of the latter is the reduced viability of populations living

in fragmented landscapes (Saunders et al. 1991). Several studies have documented a reduced persistence of species in smaller and more isolated habitat fragments (Lens et al. 2002; Nanin et al. 2015; Zaiden et al. 2015). Thus, if an isolated habitat patch is smaller than the area required to maintain the minimum viable population, it is expected that the population should decline to extinction (With and King 1999).

The importance of landscape connectivity on species persistence at the landscape level has been widely stressed in the literature (e.g. Alderman et al. 2005; Crooks and Sanjayan 2006; Stevens and Baguette 2008). Connectivity can be split into two main domains: structural and functional. Structural connectivity describes the topological relationships among habitat patches without any consideration to the specific attributes of the target organism (Kadoya 2009), while functional connectivity describes the ease with which individuals can move through the landscape, but explicitly considering the organism's behavioral response to landscape elements and their spatial configuration (Kindlmann and Burel 2008).

An implication of the latter difference is that if some small habitat patches are structurally isolated (i.e. there is a gap between them) but functionally connected (i.e. individuals can cross the gap), then their areas could be summed up to form a larger habitat patch, eventually surpassing the size threshold for holding a viable population (Saura and Rubio 2010). Therefore, modelling the effect of landscape fragmentation on a species' population persistence will require both a representation of the landscape configuration (e.g. patch size, shape, isolation, etc.) and the relevant behavioral traits that describe the ways in which the species interact with such landscape (e.g. habitat selection, movement patterns, etc.).

A prediction of such models—supported by empirical evidence—is that less mobile species, or species that are reluctant to move into non-habitat areas, will be more affected by landscape fragmentation (Tomasevic and Estades 2008). Among birds, large ground-dwelling forest species are particularly sensitive to habitat fragmentation (Thorton et al. 2012).

The coastal range of central Chile is dominated by exotic Monterey pine (*Pinus radiata*) plantations and scattered native forests fragments cover no more than 10% of the landscape (Estades and Temple 1999; Echeverría et al. 2006). Throughout this region, total forest cover (native and exotic) ranges from less than

10 to more than 80%, usually contrasting with open land uses such as prairies and crops. The use of clearcutting for harvesting plantations exacerbates the high contrast between forested areas and the landscape matrix. The discrete nature of most land cover types in this region makes size and distance landscape metrics a potentially useful approach for the analysis of the effects of landscape structure on biotic populations (Wang et al. 2014).

The Chestnut-throated Huet-Huet (*Pteroptochos castaneus*) is an endemic, ground-dwelling forest bird of central Chile. It is found in both native forests and pine plantations (Estades and Temple 1999), but actively avoids open areas (Vergara and Simonetti 2003; Tomasevic and Estades 2008). Although the species is not considered as threatened, it has been used as a model for the study of the response of ground-dwelling forest birds to landscape interventions by the forestry industry (Vergara and Simonetti 2003; Tomasevic and Estades 2008, Ramírez-Collio et al. 2017). In this article we report on a study aimed at analyzing the effect of landscape configuration on the occurrence of Chestnut-throated Huet-Huets in a region dominated by industrial pine plantations. Specifically, we tested the hypothesis that a model based on the size and isolation of forest (native or exotic) patches can successfully predict the occurrence of Chestnut throated Huet-Huets in landscapes of Central Chile.

Methods

Study region

The study was conducted in the eastern slope of the coastal range of the Maule Region, in Central Chile (Fig. 1). This slope has a drier climate than the side that faces the ocean and, thus, has a more patchy forest cover. Also natural forests have a lower proportion of *Nothofagus* trees and a higher cover of sclerophyllous species such as *Lithraea caustica*, *Peumus boldus*, and *Quillaja saponaria*, among others. We considered these forests, plus pine and eucalypt plantations as potential habitat for the species, as we have observed its occurrence in all of these environments in the past (Estades and Temple 1999; Tomasevic and Estades 2008; authors' unpublished observations). On the other hand, we defined the landscape “matrix” (sensu

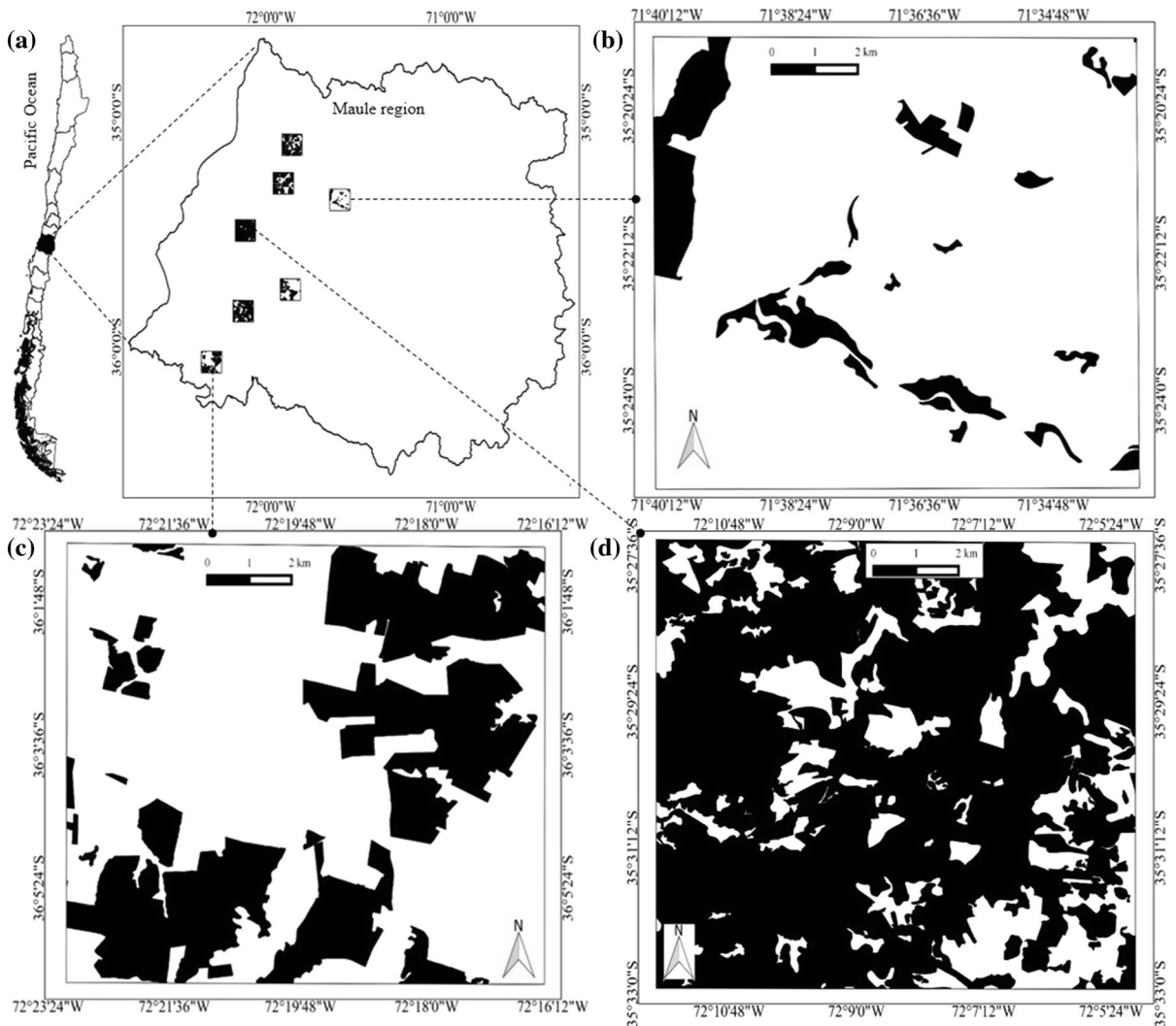


Fig. 1 Maule region, Central Chile, showing the location of the seven studied landscapes and a detail of the configuration of three of them (habitat patches in black)

Forman 1995) as all “open” land covers, including prairies, sparse *Acacia* savannas, wetlands and agricultural fields.

Patch-matrix models

Within the study region we selected seven 10,000-ha landscapes (Fig. 1) trying to include in our sample a wide range of percentages of habitat cover (8.4–70.7%) along with differences in landscape configuration (patch sizes and isolation). This design allowed us to cover a wide geographical range and, at the same time, to be able to test for simultaneous patch

and landscape effects. We obtained the land use data from the “Catastro y Evaluación de los Recursos Vegetacionales Nativos de Chile” (CONAF et al. 1999), updated in 2011 (available in <http://www.conaf.cl>). This data source contains vector information on major forest types for Chile, derived from photo-interpretation and ground truthing.

For each habitat patch in the studied landscapes we predicted the occurrence of the species based on two thresholds: a critical patch size for maintaining a viable population and a critical isolation distance that determines which patches are functionally connected

and, therefore, whose areas can be added as a larger patch.

Sieving et al. (2000) estimated that the densities of *Pteroptochos tarnii*, a similar species of southern Chile, ranged approximately from 0.2 to 1.2 ind/ha. Our own unpublished point count estimates indicate that the densities of *P. castaneus* in the study region hardly reach 0.8 ind/ha of forested habitats (average (SD) density = 0.42 (0.17), $n = 70$). In order to account for the uncertainty in the species population density we analyzed scenarios with different values for this parameter. Thus, considering a number of 50 individuals as a minimum viable population size (Franklin 1980), we used three different critical habitat patch sizes: 62.5, 125 and 250 ha, associated to densities of 0.8, 0.4 and 0.2 ind/ha, respectively. The latter range includes the lowest known population density for the sister species and the highest recorded local population density for our study subject.

In a playback study, Tomasevic and Estades (2008) showed that, when stimulated, territorial *P. castaneus* made very few (35% of trials) intrusions into clearcut areas, and those birds who did enter the open sites, moved an average of only 16.4 m (max 35 m) before returning to the forest. However, these authors argued that these results might underestimate the capacity of the species to cross gaps in the forest cover as non-territorial juveniles might move larger distances. Because of the uncertainty regarding the movement capacity of the latter individuals, we considered different scenarios covering a wide range of values for the critical isolation distance: 0 (complete reluctance to cross gaps), 10, 50, 100, 150 and 200 m.

By combining the three critical habitat patch sizes with the six critical isolation distances, we produced 18 different models with their corresponding predictions for the presence of *P. castaneus* in the different habitat patches. For that purposes we geoprocessed the habitat maps in Qgis 2.4, with the help of Conefor plugin, and we developed spatially explicit models of structural connectivity between the edge of habitat patches (Saura and Torné 2009) at each landscape to determine connectivity and habitat availability. The procedure for the latter began with the identification of isolated patches (i.e. distance to the nearest patch $>$ critical isolation distance). Then, if the size of the isolated patch \geq critical habitat patch size, the polygon was assigned a value of 1 (predicted presence of the species). Otherwise, it was assigned a value of 0

(predicted absence of the species). For non-isolated patches, the algorithm identified clusters of patches “functionally” connected (i.e. all patches that can be reached by crossing gaps $<$ critical isolation distance). All polygons in a patch cluster whose total area \geq critical habitat patch size were, then, assigned a value of 1 (predicted presence), whereas the rest were assigned a 0 (predicted absence). These binary prediction maps were later used as predictors of the actual occurrence of the species in the landscape (see “Statistical analysis”).

Field work

During February (Austral summer) 2015, we randomly distributed 59 sampling points within habitat patches in the seven studied landscapes, with an average of 8.4 (range 8–10) points per landscape. Although we originally tried to sample 10 points per landscape, access constraints prevented us from reaching that number. The average (range) distance between closest points within a landscape was 2681 (226–6707) m. We sampled a wide range of habitat patch sizes (2.4–9392.8 ha, median = 253.6 ha). All sampling points were located at a minimum distance of 50 m from the forest/plantation edge. At each point we used playbacks to estimate the presence/absence of the species (Boscolo et al. 2006). We obtained a 1-min recording of the species’ vocalizations from the site www.xeno-canto.org (Xeno-canto 2015). We reproduced this recording with the help of an 8w speaker using the following protocol: after arriving to the plot and waiting for a moment, we played the 1-min recording, followed by a 2-min wait and, then, by another 1-m of playback. We finished our assessment of the site with a 5-min wait. After that time we recorded the presence of the species if one or more individuals responded to the call, either vocally or by approaching to us. If no responses were detected we recorded the absence of the species in the site. Previous experience with *P. castaneus* (Tomasevic and Estades 2008, authors’ own unpublished data) suggests that the used protocol provides a reasonable estimate of the presence of this highly territorial bird. Each point was visited once during the study.

At each point we also recorded some habitat variables such as the forest type (native or exotic) and the cover (%) of the herbaceous (0–0.30 m), understory (0.3–2 m) and canopy (2 m +) layers. For

the latter we applied a visual assessment protocol used by us in previous studies in the region in both native forests and plantations (e.g. see Estades and Temple 1999; Tomasevic and Estades 2006).

Statistical analysis

Using a logistic regression (Hosmer and Lemeshow 2000) we tested whether the output of our patch-matrix models would successfully explain part of the variation in the occurrence of *P. castaneus* estimated in the field. Logistic regression models have been successfully used to assess the effects of habitat area and isolation on fragmented animal populations (Prugh et al. 2008; Zarrì et al. 2008). For each of the 18 models we obtained the prediction (presence or absence) for the coordinates in which we conducted the playback study. Then, we used these numbers as an independent variable in the regression, along with covariates, such as the site's vegetation attributes, the total amount of habitat in the landscape, and the geographic coordinates of each sampling point.

We tested the effect of the different patch-matrix models separately, and compared their contribution using the AICc criterion (Buckland et al. 1997). Logistic regressions were conducted using the GLM module of the r-project system (R Core Team 2013).

Results

We recorded the presence of *P. castaneus* in 20 of the 59 sampled points. Figure 2a shows the global accuracy (% true positives + true negatives) of the different tested models, which tends to increase with lower isolation distances and greater critical habitat patch sizes.

Although most of the tried models showed a significant positive effect on the occurrence of the species, the three that had the best performance were based on a critical patch size of 250 ha and a critical isolation distance of 0 and 10 m ($p = 0.005$), and a critical patch size of 125 ha and a critical isolation distance of 0 m ($p = 0.005$), all with AICc = 65.8. They also included a positive effect of the understory cover ($p = 0.03$), Fig. 2B shows the AICc for all the regressions including one of the 18 patch-matrix models plus the effect of the understory cover.

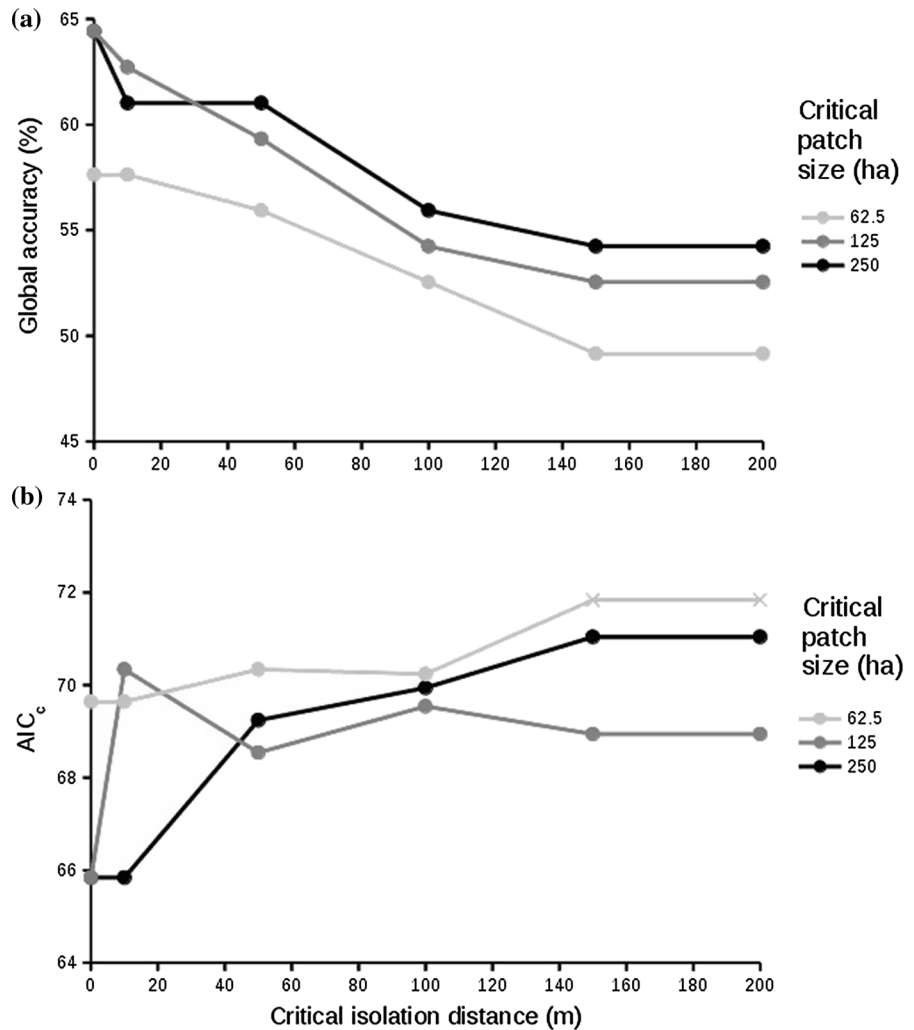
The model including only the understory cover was also statistically significant ($p = 0.03$, AICc = 74.9) with a positive effect, as was the one including a positive effect of the understory cover ($p = 0.02$) and a positive effect of the total amount of habitat in the landscape ($p = 0.05$), with AICc = 73.1. None of the other covariates had a significant effect as predictors of the presence of the species.

Discussion

Most available evidence would predict that a medium-sized (24 cm, 130 g, authors' data), ground-dwelling, insectivorous forest bird, such as *P. castaneus*, might be particularly sensitive to habitat fragmentation (e.g. see Thornton et al. 2012; Powell et al. 2015). Our observations seem to support this expectation. Thus, our results show that the presence of *P. castaneus* at a given point can be successfully predicted using information about the patch's size and isolation. And although most of the tested models had a significant effect on the presence of the species, the best predictions were obtained when using the most conservative scenarios, assuming that large (125–250 ha) patches may be required to sustain viable *P. castaneus* populations. The best models also assume that if patches are smaller than the critical size, they can act as a larger one only if they are very close to each other (10 m of isolation). The fact that three models (125 ha–0 m, 250 ha–0 m and 250 ha–10 m) made the same predictions (and, thus, had identical effects as independent variables) is likely related to the lack of all possible parameter combinations in the studied landscapes that we sampled. For instance, in the case of 0-m critical distance the sampled patches > 125 ha were also larger than 250 ha.

Predation risk might force large, conspicuous birds to be more conservative when crossing forest gaps (Belisle and Desrochers 2002). Previous observations indicated a clear reluctance of territorial individuals on *P. castaneus* to leave forested areas, likely as a predation avoidance behavior (Tomasevic and Estades 2008). We cannot claim that 0 or 10 m are “real” critical isolation distances for the species, because these value are indirectly tied to an arbitrary definition of a minimum viable population size of 50 individuals, and also because we only tried a limited set values for the studied parameters. Also, 10 m may well be under

Fig. 2 **a** Global accuracy (% true positives + true negatives) of different patch-matrix models in predicting presence of Chestnut-throated Huet-Huets in fragmented landscapes of Central Chile. **b** AIC_c of different logistic regression models including the effect of the referred patch-matrix model plus the effect of the understory cover. In all cases shown with a circle the effect of the patch-matrix model was statistically significant ($p < 0.05$), as opposed to the ones with a cross ($p > 0.05$)



the precision level of the database used to build our models. Thus, we interpret our results qualitatively only as a clear indication that *P. castaneus* may require very large and/or very connected habitat patches to persist in the landscape. The latter is in agreement with the notion that PVA-derived models might be better at producing relative than absolute predictions (Ball et al. 2003).

Awade et al. (2012) conducted a similar study with a ground-dwelling bird (*Pyriglena leucoptera*) of the Brazilian Atlantic forest. They concluded that using a probabilistic approach to gap crossing events was better to analyze the effects of fragmentation on these birds than using a binary model such as the one used by us. However, we consider our simpler approach more in accordance with the nature of the data available to

us. Because natal dispersal may be an important mechanism in determining the distribution of birds in fragmented landscapes (Witter and Berggren 2007) and we did not possess information on such factor (neither did Awade et al. 2012, as they explicitly acknowledged), we opted for a more conservative qualitative approach to the problem, comparing a wide range of movement capacities.

Besides the mentioned limitations of our study, there are other factors that prevent us from deriving precise management recommendations. We can identify at least two. First, there might be differences in the actual sizes and shapes of some of patches we used in our analyses, as we worked with a land use database from 2011, and, also, some of the plantation stands might have been clearcut during the time of our field

study, rendering a smaller effective forested area. The second source of “noise” in our model comes from the fact that the presence of individuals in some of our sample sites may not be evidence of a viable population but a case of extinction debt (sensu Tilman et al. 1994). Thus, some local extinctions might still be in process in the less favorable conditions, which would likely exacerbate the observed pattern in the future.

The observed general pattern is consistent with the finding of a positive effect of the percentage of habitat cover at the 10,000-ha landscape level on the occurrence of the species in a sampling plot. The amount of remaining habitat in the landscape has a negative association with the degree of isolation between habitat patches and a positive relationship with the average patch size (Fahrig 2003, 2013) and, consequently, has been shown to have a significant effect on the persistence of forest birds in fragmented landscapes (Fahrig 2002; Radford et al. 2005; Betts et al. 2007).

Other interesting result was the fact that *P. castaneus* did not seem to discriminate among forest types, as suggested by the lack of a statistical effect of this factor on the presence of the species. This agrees with previous observations that indicate that the species can use artificial vegetation (e.g. pine plantations) if it has a sufficient tree cover (Estades and Temple 1999; Tomasevic and Estades 2008). In our case we also detected the species in an eucalypt stand and even in some partially burned pine plantations.

A third clear pattern was the positive effect of the understory cover on the probability of recording the species in a given site. This result is also in agreement with several studies that have shown that the abundance of Rhinocryptids, including *P. castaneus*, is positively related to the density of the understory (Estades 1997; Estades and Temple 1999; Reid et al. 2002; Vergara and Simonetti 2003; Díaz et al. 2005; Tomasevic and Estades 2008, Ramírez-Collio et al. 2017). A complex, dense understory provides with many resources for this species, including habitat for the insects that constitute its main food item and protection against predators (Tomasevic and Estades 2008).

Our results clearly suggest that the long term persistence of a ground-dwelling bird such as the Chestnut-throated Huet-Huet may depend on the existence of large and very connected forest tracts

(native or not), ideally with well-developed understoreys. Although the latter conditions are relatively common in most of the Maule coastal range, while we were writing a first draft of this paper, a large portion of this region was burnt by the worst forest fires ever recorded in Chile (CONAF 2017). Sadly, not only these fires may have destroyed a large proportion of the habitat of the species, but also raised public concern about the dangers that large continuous tracts of forest may pose for the spread of fire. Hopefully the redesign of a firebreak system in this region will take into account the biology of fragmentation-sensitive species.

Acknowledgements This study was partially funded by a Fondecyt (1120314) grant to C.F. Estades. The School of Forest Science and Nature Conservation of the University of Chile provided important logistical support during the field work. Three anonymous reviewers made important observations on the first version of this work that helped us improve the quality of our study.

References

- Alderman J, McCollin D, Hinsley SA, Bellamy PE, Picton P, Crockett R (2005) Modelling the effects of dispersal and landscape configuration on population distribution and viability in fragmented habitat. *Landscape Ecol* 20:857–870
- Awade M, Boscolo D, Metzger JP (2012) Using binary and probabilistic habitat availability indices derived from graph theory to model bird occurrence in fragmented forests. *Landscape Ecol* 27:185–198
- Ball SJ, Lindenmayer DB, Possingham HP (2003) The predictive accuracy of population viability analysis: a test using data from two small mammal species in a fragmented landscape. *Biodivers Conserv* 12:2393–2413
- Belisle M, Desrochers A (2002) Gap-crossing decisions by forest birds: an empirical basis for parameterizing spatially-explicit, individual-based models. *Landscape Ecol* 17:219–231
- Betts MG, Forbes GJ, Diamond AW (2007) Thresholds in songbird occurrence in relation to landscape structure. *Conserv Biol* 21:1046–1058
- Boscolo D, Metzger JP, Vielliard JME (2006) Efficiency of playback for assessing the occurrence of five bird species in Brazilian Atlantic Forest fragments. *An Acad Bras Cienc* 78:629–644
- Buckland ST, Burnham KP, Augustin NH (1997) Model selection: an integral part of inference. *Biometrics* 53:603–618
- CONAF (2017) Situación diaria de incendios forestales. <http://www.conaf.cl/situacion-nacional-de-incendios-forestales/>. Accessed Jan 2017

- CONAF, CONAMA, BIRF, Universidad Austral de Chile, Pontificia Universidad Católica de Chile and Universidad Católica de Temuco (1999) Catastro y evaluación de los recursos vegetacionales nativos de Chile. Informe nacional con variables ambientales, Santiago
- Crooks KR, Sanjayan M (eds) (2006) Connectivity conservation. Cambridge University Press, New York
- Díaz IA, Armesto JJ, Reid S, Sieving KE, Willson MF (2005) Linking forest structure and composition: avian diversity in successional forests of Chiloe Island, Chile. *Biol Conserv* 123:91–101
- Echeverría C, Coomes D, Salas J, Rey-Benayas JM, Lara A, Newton A (2006) Rapid deforestation and fragmentation of Chilean Temperate Forests. *Biol Conserv* 130:481–494
- Estades CF (1997) Bird-habitat relationships in a vegetational gradient in the Andes of central Chile. *Condor* 99:719–727
- Estades CF, Temple S (1999) Deciduous-forest bird communities in a fragmented landscape dominated by exotic pine plantations. *Ecol Appl* 9:573–585
- Fahrig L (2002) Effect of habitat fragmentation on the extinction threshold: a synthesis. *Ecol Appl* 12:346–353
- Fahrig L (2003) Effects of habitat fragmentation on biodiversity. *Annu Rev Ecol Evol Syst* 34:487–515
- Fahrig L (2013) Rethinking patch size and isolation effects: the habitat amount hypothesis. *J Biogeogr* 40:1649–1663
- Forman RTT (1995) Land mosaics: the ecology of landscapes and regions. Cambridge University Press, New York
- Franklin IA (1980) Evolutionary change in small populations. In: Soulé ME, Wilcox BA (eds) Conservation biology: an evolutionary-ecological perspective. Sinauer Associates, Sunderland, pp 135–149
- Hosmer DW, Lemeshow S (2000) Applied logistic regression, 2nd edn. Wiley, New York
- Kadoya T (2009) Assessing functional connectivity using empirical data. *Popul Ecol* 51:5–15
- Kindlmann P, Burel F (2008) Connectivity measures: a review. *Landscape Ecol* 23:879–890
- Lens L, Van Dongen S, Norris K, Githiru M, Matthysen E (2002) Avian persistence in fragmented rainforest. *Science* 298:1236–1238
- Nanin M, Palomares F, Brito D (2015) The jaguar's patches: viability of jaguar populations in fragmented landscapes. *J Nat Conserv* 23:90–97
- Powell LL, Cordeiro NJ, Stratford JA (2015) Ecology and conservation of avian insectivores of the rainforest understory: a pantropical perspective. *Biol Conserv* 188:1–10
- Prugh LR, Hodges KE, Sinclair AR, Brashares JS (2008) Effect of habitat area and isolation on fragmented animal populations. *Proc Natl Acad Sci USA* 105(52):20770–20775
- R Core Team (2013) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. <http://www.R-project.org/>
- Radford JQ, Bennett AF, Cheers GJ (2005) Landscape-level thresholds of habitat cover for woodland-dependent birds. *Biol Conserv* 124:317–337
- Ramírez-Collío K, Vergara PM, Simonetti JA (2017) Converting clear cutting into a less hostile habitat: the importance of understory for the abundance and movement of the Chestnut-throated Huet-Huet (*Pteroptochos castaneus*: rhinocryptidae). *Forest Ecol Manag* 384:279–286
- Reid S, Cornelius C, Barbosa O, Meynard C, Silva-García C, Marquet P (2002) Conservation of temperate forest birds in Chile: implications from the study of an isolated forest relict. *Biodivers Conserv* 11:1975–1990
- Saunders DA, Hobbs RJ, Margules CR (1991) Biological consequences of ecosystem fragmentation: a review. *Conserv Biol* 5:18–32
- Saura S, Rubio L (2010) A common currency for the different ways in which patches and links can contribute to habitat availability and connectivity in the landscape. *Ecography* 33:523–537
- Saura S, Torné J (2009) Conefor Sensinode 2.2: a software package for quantifying the importance of habitat patches for landscape connectivity. *Environ Model Softw* 24:135–139
- Sieving K, Willson M, de Santo T (2000) Defining corridor functions for endemic birds in fragmented south-temperate rainforest. *Conserv Biol* 14:1120–1132
- Stevens VN, Bagnette M (2008) Importance of habitat quality and landscape connectivity for the persistence of endangered Natterjack Toads. *Conserv Biol* 22:1194–1204
- Thorton DH, Branch LC, Sunquist ME (2012) Response of large galliforms and tinamous (Cracidae, Phasianidae, Tinamidae) to habitat loss and fragmentation in northern Guatemala. *Oryx* 46:567–576
- Tilman D, May RM, Lehman CL, Nowak MA (1994) Habitat destruction and the extinction debt. *Nature* 371:65–66
- Tomasevic J, Estades CF (2006) Stand attributes and the abundance of secondary cavity-nesting birds in southern beech (*Nothofagus*) forests in south-central Chile. *Ornitol Neotrop* 17:1–14
- Tomasevic J, Estades CF (2008) Effects of the structure of pine plantations on their “softness” as barriers for ground-dwelling forest birds in south-central Chile. *Forest Ecol Manag* 255:810–816
- Vergara P, Simonetti J (2003) Forest fragmentation and rhinocryptid nest predation in central Chile. *Acta Oecol* 24:285–288
- Wang X, Blanche FG, Koper N (2014) Measuring habitat fragmentation: an evaluation of landscape pattern metrics. *Methods Ecol Evol* 5(7):634–646
- With KA, King AW (1999) Extinction thresholds for species in fractal landscapes. *Conserv Biol* 13:314–326
- Witter AK, Berggren (2007) Natal dispersal in the North Island Robin (*Petroica longipes*): the importance of connectivity in fragmented habitats. *Avian Conserv Ecol* 2:2. <http://www.ace-eco.org/vol2/iss2/art2/>
- Xeno-canto (2015) <http://www.xeno-canto.org/species/Pteroptochos-castaneus>. Accessed Jan 2015
- Zaiden T, Marques FC, Medeiros HR, dos Anjos L (2015) Decadal persistence of frugivorous birds in tropical forest fragments of northern Parana. *Biota Neotrop*. <https://doi.org/10.1590/1676-06032015008414>
- Zarri AA, Rahmani AR, Singh A, Kushwaha SPS (2008) Habitat suitability assessment for the endangered Nilgiri Laughingthrush: a multiple logistic regression approach. *Curr Sci* 94(11):1487–1494