Published by Associazione Teriologica Italiana
Hystrix, the Italian Journal of Mammalogy
Volume 32 (2): 37–40, 2020
OPEN ACCESS
Available online at:
http://www.italian-journal-of-mammalogy.it
doi:10.4404/hystrix-00399-2020

Research Article

Enhancing habitat quality for small mammals at young pine plantations after clearcutting

Matías Barceló[1,2,*], André V. Rubio[3], Javier Andrés Simonetti[1]

[1] *Laboratorio de Conservación Biológica, Departamento de Ciencias Ecológicas, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile*
[2] *Center of Applied Ecology and Sustainability (CAPES), Departamento de Ecología, Pontificia Universidad Católica de Chile, Santiago, Chile*
[3] *Departamento de Ciencias Biológicas Animales, Facultad de Ciencias Veterinarias y Pecuarias, Universidad de Chile, Av. Santa Rosa 11735, Santiago, Chile*

Keywords:
rodents
Chile
clearcut
Pinus radiata
rewilding

Article history:
Received: 10 November 2020
Accepted: 28 January 2021

Acknowledgements
This study was supported by FONDECYT 3160037 and 1140657. MB was supported by CONICYT-PCHA, Magister Nacional, 2015-22151445. AVR is supported by ANID + PAI No. PAI77180009. MB thanks the Centre of Applied Ecology and Sustainability CAPES CONICYT PIA/BASAL FB0002. We are grateful to C. Reyes, J. Veloso, I. Kraft, C. Ugarte, A. Arzabe, R. Almuna and H. Mendoza for their help during field work. We also thank R. Zúñiga for logisitical support and C. Veloso for the loan of traps. We also thank Forestal Masisa S.A. and Corporación Nacional Forestal for allowing us to work on their properties. Finally, the authors would like to thank the constructive comments of the reviewers.

Abstract

Monoculture plantations of exotic Monterey pine (*Pinus radiata*) is a widespread practice which reduces richness and abundance of native species. The presence of shrub vegetation in mature pine plantations confers structural complexity, enabling the presence of native wildlife, and potentially mitigating the impacts of these plantations. However, little is known about the effect of shrub cover in young pine plantations after clearcutting. We assessed if shrub vegetation cover contributes to enhancing habitat quality for small mammals by assessing the abundance and composition of small mammal assemblages in young pine plantations (15 years), and in the native temperate forest in central Chile. We found that a high development of shrub vegetation in young pine plantation increased both the abundance of small mammals, and the similarity of small mammal assemblages among habitat types. These findings support maintaining developed shrub vegetation in Monterey pine plantations as a conservation strategy that could help reduce the negative impact of this monoculture and the impact of clearcutting.

Introduction

The replacement of native habitat by forestry plantations is a widespread practice that can impact biodiversity (Newbold et al., 2015). As demand for wood products is increasing worldwide (FAO 2012), the Convention on Biological Diversity (CBD) through its Strategic Plan for Biodiversity 2011–2020, states that forestry plantations ought to be managed to ensure conservation of biodiversity. One management practice to achieve this goal is the occurrence of a developed understory or multiple vegetation strata within plantations, which can increase the richness and abundance of a variety of wildlife species (McFadden and Dirzo, 2018; Nájera and Simonetti, 2010; Ramírez and Simonetti, 2011). Implementation of this practice in Monterey pine plantations (*Pinus radiata*) would contribute to satisfying CBD's target, as pine plantations account for 32% of productive plantations worldwide (Mead, 2013). The presence of understory vegetation in mature Monterey pine plantations confers structural complexity, allowing the presence of native wildlife, including some endangered ones (e.g. Estades et al., 2012; Simonetti et al., 2013; Cerda et al., 2015. However, similar to other forestry plantations, Monterey pine plantations are harvested under a clearcutting system that impacts small mammals via mortality due to trampling by machinery and other operational aspects (Escobar et al., 2015), and also producing immediate change in habitat attributes, including structural, compositional and microclimate changes, that modify small mammals assemblages (Chen et al., 1995; Niklitschek, 2015; Roberts and Zhu, 2002). Clearcutting can generate a decrease in abundance (Knapp et al., 2003; Williams et al., 2001) and a change in species composition among forest-dwelling wildlife (Hansson, 1994; Niemelä et al., 1993). Despite numerous studies on clearcutting, only 3% of these studies focus on the effects of clearcutting on biodiversity and even fewer studies focus on small mammals and their recovery after plantations are harvested and replanted (Simonetti and Estades, 2015).

In Chile, Monterey pine plantations are one of the most important land-use changes in south-central regions of the country, covering approximately 1.9 million ha and accounting for 68% of forestry plantations in Chile (Nahuelhual et al., 2012). Clearcutting activities of Monterey plantations generate a high mortality of rodents (Escobar et al., 2015), and information about rewilding on young pine plantations is necessary to achieve a sustainable forestry at an early stage. Current evidence indicates that young Monterey pine plantations with higher shrub vegetation growing after harvesting facilitates rewilding (i.e. wildlife recolonization of disturbed areas), and use of these plantations as secondary habitat for some ground-dwelling wildlife such as tapaculo birds and ground beetles (Ramírez-Collío et al., 2017; Russek et al., 2017). However, information on other wildlife such as small mammals is still needed.

In this context, we aim to assess the importance of shrub cover on composition and abundance of small mammals at young pine plantations, assessing if accompanying shrub vegetation enhances the rewilding of small mammals in new plantations after clearcutting. We expect a higher abundance of native small mammals in young plantations with well-developed shrub vegetation in relation to young pine plantations with low shrub vegetation, and also, that increased shrub cover in young pine plantations will increase small mammal similarity compared to native forest or mature pine plantations.

*Corresponding author
Email address: barcelo.matias@gmail.com ORCID:0000-0002-8754-1517 (Matías Barceló)

Methods

We conducted our study at Tregualemu (72°43′55.59″ W–35°59′37.12″ S to 72°40′46.34″ W–35°58′5.27″ S), an area located in the coastal range of Maule region in central Chile. The landscape contains extensive Monterey pine stands of different ages (covering 54% of the total area) and interspersed remnants of native temperate deciduous forests, including the Los Queules National Reserve (Grez et al., 2006).

Twelve sampling plots interspersed in the landscape were placed in four dominant habitats (three plots per habitat): (1) native forest, (2) mature pine plantations (>15 years), (3) young pine plantations with high shrub cover (<3 years and more than 10% of shrub vegetation cover) and young pine plantations with low shrub cover (<3 years and less than 5% of shrub vegetation cover). Shrub vegetation cover at each sampling plot was measured twice, before the first small mammal sampling and after the last sampling. To assess vegetation cover, we used a 50 m transect per plot, quantifying the transect proportion covered by shrub vegetation (Higgins et al., 19966).

Vegetation cover was different between the first (i.e. 2016) and final (i.e. 2017) measurement only for young pine plantations (ANOVA: $F=5.72$, $p=0.04$; Tukey test: $p<0.05$, Supplementary Material Fig. S1).

Small mammals were sampled seasonally during 2016 and 2017, totalling eight sampling periods. To assess small mammal assemblage, at each sampling plot, a 7×10 grid consisting of 70 Sherman traps set at 10m intervals were placed during four consecutive nights. Traps were baited with rolled oats and vanilla essence and checked daily at dawn. After capture, animals were identified to species and marked with uniquely numbered ear tags (National Band and Tag Co., Newport, KY). After handling, animals were released at their site of capture.

All procedures for trapping and handling rodents followed the American Society of Mammologists' guidelines for the use of wild mammals in research (Sikes, 2016). Sampling procedures were authorized by the Servicio Agrícola y Ganadero (License No. 6831/2015) and the Ethics Committee of the Facultad de Ciencias, Universidad de Chile.

To compare small mammal abundance of each species between habitat types, we used GLM models with Poisson distribution or Negative Binomial distribution to account for overdispersion. Tukey *post hoc* test were applied to assess differences between habitats using the minimum number of individuals known to be alive (MNKA) as an index of population abundance (Lancia et al., 1994), and habitat type as predictor. To assess the response of small mammals to vegetation cover through time, we compared the response ratio of small mammal abundance between years as ln (average MNKA in 2017 / average MNKA in 2016), since we observed a rapid growing of shrub vegetation in young pine plantations. If the response ratio is positive, it means that abundance is higher at the end of the study. The statistical significance was established with a Monte Carlo permutation test, using 9999 random permutations between MNKA 2016 and MNKA2017.

Finally, the Jaccard index based on relative presence/absence was used to compare the level of similarity between small mammal assemblages for each habitat and year. A dendrogram of habitat similarity was created using UPGMA clustering of Jaccard similarity values in Past software (Paleontological Stat). All other analyses and test were performed with software R version 3.5.2 (R Core Team, 2018).

Results

We captured 1962 individuals for a total of 2335 captures, representing an 8.7% of trapping success. Eight species were captured: Long-haired field mouse (*Abrothrix longipilis*), Olivaceous field mouse (*Abrothrix olivaceus*), Chilean arboreal-rat (*Irenomys tarsalis*), Bridges's degu (*Octodon bridgesi*), Long-tailed rice mice (*Oligoryzomys longicaudatus*), Darwin's leaf-eared mouse (*Phyllotis darwini*), Llaca mouse-opossum (*Thylamys elegans*), and the introduced Black rat (*Rattus rattus*).

Total abundance of species varied between habitat types (Fig. 1). Species such as Long-tailed rice mice and Black rat showed higher abundances at native forest compared to other habitats ($p<0.05$). In contrast, total abundances of Long-haired field mouse and Olivaceous field mouse were higher at mature pine and both young pine plantations, respectively ($p<0.05$, Fig. 1, Table S2). On the other hand, Bridge's degu, Darwin's leaf-eared mouse and Llaca mouse-opossum were not present in all habitats (Fig. 1). Only one individual of the strictly arboreal (Kelt, 1993) Chilean arboreal-rat was captured in the native forest. Therefore, we excluded from further abundance analysis because the trapping method used here underestimates its presence and abundance.

The abundance of Long-haired field mouse, Black rat, Bridges's degu and Llaca mouse-opossum did not change between years ($p>0.10$; Fig. 2). However, the abundance of Olivaceous field mouse was higher when shrub cover was higher at the end of study in young pine plantations with low shrub cover ($p=0.05$; Fig. 2), while there was no change of abundance in other habitats for this rodent ($p>0.15$; Fig. 2). Long-tailed rice mice showed higher abundance in 2017 at young pine plantation with low shrub cover ($p=0.046$), but there was no change in other habitats ($p>0.25$; Fig. 2). For Darwin's leaf-eared mouse, abundance was higher at young pine plantations with low shrub cover in 2016 ($p=0.05$).

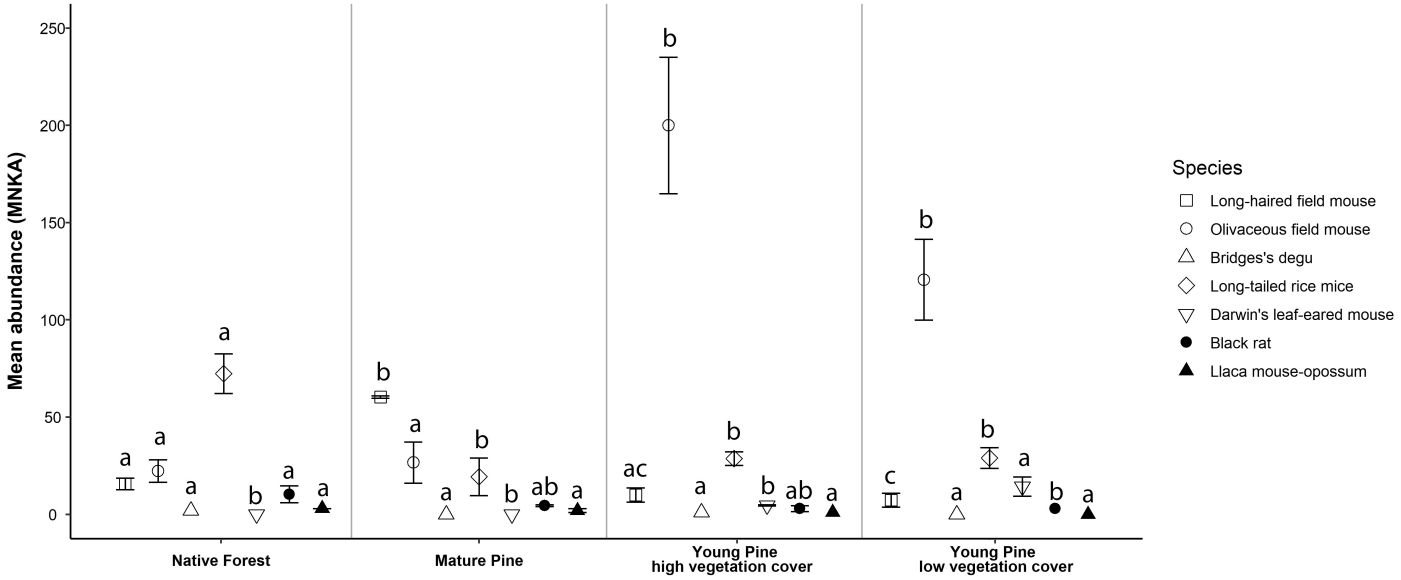

Figure 1 – Abundance expressed as minimum number known alive (MNKA) of each small mammal in all habitats. Species are identified in the legend. Different letters indicate statistical significance between habitats for each species based on Tukey test ($p<0.05$).

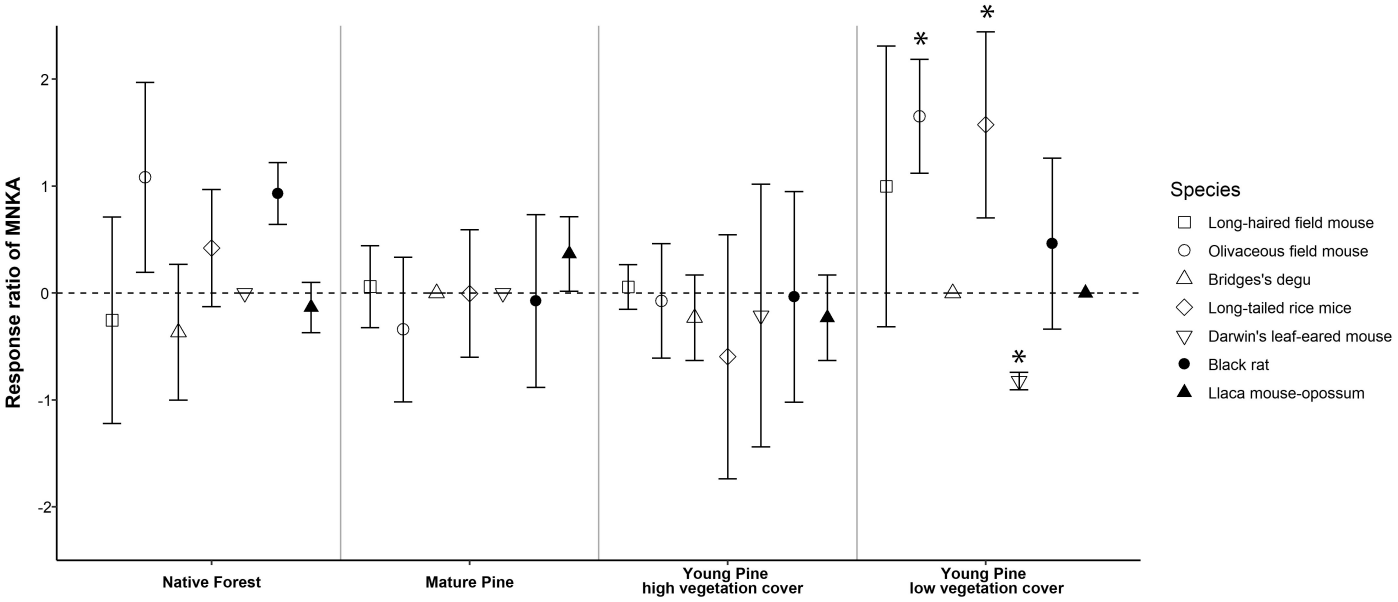

Figure 2 – Response ratio of the minimum number known to be alive (ln of average MNKA 2016 / ln of average MNKA 2017) of each small mammal in all habitats. Species are identified in the legend. If response ratio is different to zero, it means that abundance changed between the beginning of study relation to the end of study. A positive value means higher abundance at the end of study, on the other hand, a negative value means slower abundance at the end of study. * Indicates statistical significance based on permutation test ($p \leq 0.05$).

Similarity between small mammal assemblages during the first year showed two different clusters: one small mammal assemblages in young pine plantations with low shrub cover and the other cluster of small mammal assemblages in young pine plantations with high shrub cover, mature plantations and native forest (Fig. 3a). The similarity of small mammal assemblages between clusters was 47% and within the last cluster, ranged between 72–75% (Fig. 3a). Species similarity in the last year also showed two clusters: one cluster of small mammal assemblages in young pine plantations and another cluster of small mammal assemblages in mature plantation and native forest. Similarity index was 63% between clusters and from 83–98% within clusters (Fig. 3b).

Discussion

Rewilding of small mammal species in young pine plantations is influenced by the increased shrub vegetation cover, and small mammals' response depends on different requirements of each species. For example, after clearcutting, young pine plantations increased the abundance of Olivaceous field mouse abruptly, and the occurrence of Darwin's leaf-eared mouse, which was not present in native forest or mature pine. Both species are often abundant in sclerophyllous shrublands of central Chile (Simonetti, 1989), a more open habitat than the temperate forest, a feature that is also shared with the young pine plantations. These results may indicate that species from surrounding open environments

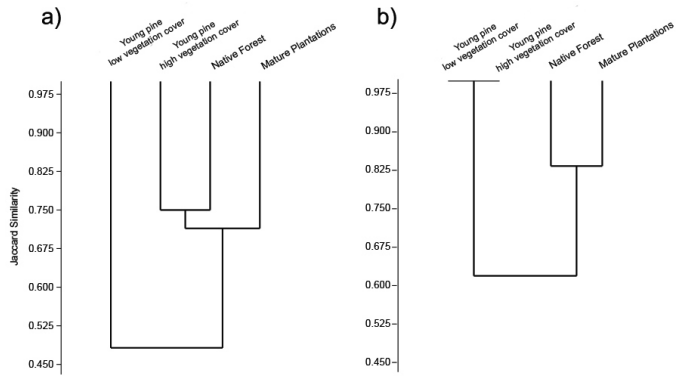

Figure 3 – Jaccard similarity index between small mammals' assemblages in different habitats. a) indicates similarity index in the first year of trapping (2016) and b) indicates similarity index at final year of trapping (2017).

move into and are favoured by the dynamics of landscape change associated with pine plantations which dominate this landscape.

Increasing shrub cover at young pine plantations improves habitat quality for some ground-dwelling birds and insects (Ramírez-Collío et al., 2017; Russek et al., 2017). This seems a general phenomenon as our findings indicate that small mammals also increased their abundance when shrub vegetation cover increased. Specifically, the most abundant species in young plantations (Olivaceous field mouse) significantly increased their abundance in the second year. The response ratio of the Long-haired field mouse and the Long-tailed rice mouse reached higher abundance when shrub vegetation was more developed. In fact, the Long-haired field mouse, moves more often from native forest or mature plantations to young pine plantations when there is a high level of shrub vegetation (Barceló and Simonetti, 2020). Similarly, birds and insects' movement behaviour in the study area is modulated by the presence of vegetation cover within pine plantations (Ramírez-Collío et al., 2017; Russek et al., 2017). The increment of shrub cover within young pine plantations increased the similarity of small mammal composition with respect to native forest and mature pine plantations, which may help reduce the impact of clearcutting.

Mature stands of pine plantations are harvested every 12–15 years. Thus, the possibility of species to persist in a highly dynamic landscape will depend on the structure of habitats that allow to cross boundaries between landscape units (Barceló and Simonetti, 2020; Diekötter et al., 2014). Shrub vegetation confers structural complexity and may be improving the quality of habitats after clearcutting. The presence of shrub vegetation in young pine plantations will decrease native species' resistance to move through the landscape (Pliscoff et al., 2020). Therefore, small mammals would be willing to use these sites and persist in these heterogeneous landscapes.

Pine plantations are widespread worldwide, therefore, their management to contribute to the maintenance of local animal populations in dynamic landscapes is needed. Management of young pine plantations, through developed shrubs would be necessary to maintain species diversity along this heterogeneous habitat, since young pine plantations without shrub vegetation cover seem to be an inadequate habitat for forest species. Lack of shrub vegetation in young pine plantations will reduce connectivity between different habitats. Since young pine plantations are early managed to enhance the productivity of plantations (Wagner et al., 2006), we recommend adopting practices such as reducing the use of herbicides to allow the growth of shrub vegetation. Simultaneously, forestry practices need to adopt the use of coarse woody

debris in the first 3-4 years, which allows a significant increase in small mammals (Sullivan et al., 2012). As small mammals are important prey for several predators such as carnivores and raptors, higher abundance of small mammals in young pine plantations can facilitate the use of these habitats by large wildlife that usually require larger areas and are commonly affected by the replacement of native forests by exotic monoculture plantations which account for 32% of productive plantations worldwide (Mead, 2013). These results contribute to a better understanding of the conservation of wildlife in forestry landscapes if the recommended measures are adopted.

References

Barceló M., Simonetti J.A., 2020. Rewilding clearcuts: shrub vegetation as a facilitator of movement of a forest specialist. Eur. J. Wildl. Res. 66: 1–4. doi:10.1007/s10344-020-01391-0

Cerda Y., Grez A.A., Simonetti J.A., 2015. The role of the understory on the abundance, movement and survival of *Ceroglossus chilensis* in pine plantations: an experimental test. J. Insect Conserv. 19(1): 119–127. doi:10.1007/s10841-015-9752-y

Chen J., Franklin J.F., Spies T.A., 1995. Growing-season microclimatic gradients from clearcut edges into old-growth Douglas-fir forests. Ecol. Appl. 5(1): 74–86.

Diekötter T., Speelmans M., Dusoulier F., Van Wingerden W.K.R.E., Malfait J.-P., Crist T.O., Edwards P.J., Dietz H., 2014. Effects of landscape structure on movement patterns of the flightless bush cricket *Pholidoptera griseoaptera*. Environ. Entomol. 36(1): 90–98.

Escobar M.A.H., Uribe S.V., Chiappe R., Estades C.F., 2015. Effect of clearcutting operations on the survival rate of a small mammal. PLoS ONE 10(3): 1–11. doi:10.1371/journal.pone.0118883

Estades C.F., Grez A.A., Simonetti J.A., 2012. Biodiversity in Monterey pine plantations. Biodivers. Conserv. Agrofor. landscapes challenges Oppor. Editor. Univ. Santiago 77–98.

Grez A.A., Simonetti J.A., Bustamante R.O., 2006. Biodiversidad en ambientes fragmentados de Chile: Patrones y procesos a diferentes escalas. Editorial Universitaria Santiago. [in Spanish]

Hansson L., 1994. Vertebrate distributions relative to clear-cut edges in a boreal forest landscape. Landsc. Ecol. 9(2): 105–115. doi:10.1007/BF00124377

Higgins K.F., Oldemeyer J.L., Jenkins K.J., Clambey G.K., Harlow R.F., 1996. Vegetation sampling and measurement. Res. Manag. Tech. Wildl. habitats 5: 567–591.

Kelt D.A., 1993 *Irenomys tarsalis*. Mammalian Species 447:1–3

Knapp S.M., Haas C.A., Harpole D.N., Kirkpatrick R.L., 2003. Initial effects of clearcutting and alternative silvicultural practices on terrestrial salamander abundance. Conserv. Biol. 17(3): 752–762.

Lancia R.A., Nichols J.D., Pollock K.H., 1994. Estimating the number of animals in wildlife populations. Res. Manag. Tech. Wildl. habitats. Wildl. Soc. Bethesda, Maryland, USA. 215–253.

McFadden T.N., Dirzo R., 2018. Opening the silvicultural toolbox: A new framework for conserving biodiversity in Chilean timber plantations. For. Ecol. Manage. 425: 75–84. doi:10.1016/j.foreco.2018.05.028

Mead D.J., 2013. Sustainable management of *Pinus radiata* plantations. Food and agriculture organization of the United nations (FAO).

Nahuelhual L., Carmona A., Lara A., Echeverría C., González M.E., 2012. Land-cover change to forest plantations: Proximate causes and implications for the landscape in south-central Chile. Landsc. Urban Plan. 107(1): 12–20. doi:10.1016/j.landurbplan.2012.04.006

Nájera A., Simonetti J.A., 2010. Enhancing avifauna in commercial plantations: Research note. Conserv. Biol. 24(1): 319–324. doi:10.1111/j.1523-1739.2009.01350.x

Newbold T., Hudson L.N., Hill S.L.L., Contu S., Lysenko I., Senior R.A., Börger L., Bennett D.J., Choimes A., Collen B., Day J., De Palma A., Díaz S., Echeverria-Londoño S., Edgar M.J., Feldman A., Garon M., Harrison M.L.K., Alhusseini T., Ingram D.J., Itescu Y., Kattge J., Kemp V., Kirkpatrick L., Kleyer M., Correia D.L.P., Martin C.D., Meiri S., Novosolov M., Pan Y., Phillips H.R.P., Purves D.W., Robinson A., Simpson J., Tuck S.L., Weiher E., White H.J., Ewers R.M., MacE G.M., Scharlemann J.P.W., Purvis A., 2015. Global effects of land use on local terrestrial biodiversity. Nature 520(7545): 45–50. doi:10.1038/nature14324

Niemelä J., Langor D., Spence J.R., 1993. Effects of clear-cut harvesting on boreal ground-beetle assemblages (Coleoptera: Carabidae) in western Canada. Conserv. Biol. 7(3): 551–561.

Niklitschek M., 2015. El surgimiento de restricciones al tamaño de la tala rasa. Tamaño la tala rasa en plantaciones For. efectos y Regul. Editor. Univ. Santiago, Chile 182. [in Spanish]

Pliscoff P., Simonetti J.A., Grez A.A., Vergara P.M., Barahona-Segovia R.M., 2020. Defining corridors for movement of multiple species in a forest-plantation landscape. Glob. Ecol. Conserv. 23: e01108. doi:10.1016/j.gecco.2020.e01108

R Core Team, 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at https://www.R-project.org/

Ramírez-Collío K., Vergara P.M., Simonetti J.A., 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). For. Ecol. Manage. 384: 279–286. doi:10.1016/j.foreco.2016.11.005

Ramírez P.A., Simonetti J.A., 2011. Conservation opportunities in commercial plantations: The case of mammals. J. Nat. Conserv. 19(6): 351–355. doi:10.1016/j.jnc.2011.06.003

Roberts M.R., Zhu L., 2002. Early response of the herbaceous layer to harvesting in a mixed coniferous-deciduous forest in New Brunswick, Canada. For. Ecol. Manage. 155(1–3): 17–31. doi:10.1016/S0378-1127(01)00544-8

Russek L.A., Mansilla C.L., Crespin S.J., Simonetti J.A., Grez A.A., 2017. Accompanying vegetation in young *Pinus radiata* plantations enhances recolonization by *Ceroglossus chilensis* (Coleoptera: Carabidae) after clearcutting. J. Insect Conserv. 21(5–6): 943–950. doi:10.1007/s10841-017-0033-9

Sikes R.S., 2016. 2016 Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. J. Mammal. 97(3): 663–688.

Simonetti J., 1989. Microhabitat Use by Small Mammals in Central Chile. Oikos 56(3): 309–318.

Simonetti J.A., Estades C.F., 2015. Efectos de la tala rasa sobre la biodiversidad. Tamaño tala rasa en plantaciones For. efectos y Regul. Editor. Univ. Santiago 85–104. [in Spanish]

Simonetti J.A., Grez A.A., Estades C.F., 2013. Providing habitat for native mammals through understory enhancement in forestry plantations. Conserv. Biol. 27(5): 1117–1121. doi:10.1111/cobi.12129

Sullivan T.P., Sullivan D.S., Lindgren P.M.F., Ransome D.B., 2012. If we build habitat, will they come? Woody debris structures and conservation of forest mammals. J. Mammal. 93(6): 1456–1468. doi:10.1644/11-MAMM-A-250.1

Wagner R.G., Little K.M., Richardson B., Mcnabb K., 2006. The role of vegetation management for enhancing productivity of the world's forests. Forestry 79(1): 57–79.

Williams M.R., Abbott I., Liddelow G.L., Vellios C., Wheeler I.B., Mellican A.E., 2001. Recovery of bird populations after clearfelling of tall open eucalypt forest in Western Australia. J. Appl. Ecol. 38(5): 910–920.

Associate Editor: S. Gasperini

Supplemental information

Additional Supplemental Information may be found in the online version of this article:

Figure S1 Vegetation cover in native forest, mature pine and young pine plantations before and after sampling.

Table S2 Summary of GLM results for abundance of species in the study area.