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SHORT COMMUNICATION

Rewilding clearcuts: shrub vegetation as a facilitator of movement of a forest specialist

Matías Barceló [1,2] · Javier A. Simonetti [1]

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Abstract

Replacement of native forests by exotic monoculture plantations is the principal driver of land change in central Chile; it reduces the richness and abundance of native mammals. The presence of shrub vegetation in mature pine plantation enhances habitat quality for small mammals. However, the role of structural complexity of shrub vegetation in young pine plantations after clearcutting remains unknown. Since plantations are managed by clearcutting, young pine plantations act as a barrier to movement of forest species. We tested if shrub vegetation contributes to rewilding harvested areas, assessing the movements of the long-haired field mouse (*Abrothrix longipilis*), a forest rodent, from native forest or mature pine plantations into young pine plantations. We evaluated habitat use at the edge of contrasting habitats, young pine plantations, and native forest or mature pine plantations. Habitat use was higher in young plantations that have shrub vegetation than those that have no shrubs. The long-haired field mouse is willing to use young plantations when shrub vegetation is developed.

Keywords Clearcut · Edge · Forest rodent · *Abrothrix longipilis* · Pine plantations

Introduction

The replacement of native forests by monoculture plantations of exotic species reduces both species richness and abundance of native mammals (Ramírez and Simonetti 2011). Monoculture plantations are usually harvested by clearcutting (Niklitschek 2015), which disturbs the structural properties of the plantation, eliminating cover and creating abrupt edges between harvested areas and adjacent habitats (Roberts and Zhu 2002), which further modify mammalian assemblages (Pawson et al. 2006; Simonetti and Estades 2015). If monoculture plantations have a well-developed structural understory, they can harbor higher richness and abundance of native mammal species (Estades et al. 2012; Simonetti et al. 2013). However, richness and abundance are changed when plantations are harvested by clearcutting, favoring generalists and open-habitat species (Pawson et al. 2006; Bogdziewicz and Zwolak 2014). While the role of understory as an enhancer of native fauna in mature plantations is known, whether it facilitates the rewilding of young plantations planted after clearcutting is yet to be established (Simonetti et al. 2012). Rewilding will advance managerial options toward more sustainable forestry activities as requested by Aichi Target 7, which requests that by 2020, areas under forestry ought to ensure the conservation of biodiversity (Convention on Biological Diversity 2011).

Rewilding clearcuts will depend on how "soft" edges between forested areas and clearcuts are. Higher structural similarity between them will increase softness of edges, facilitating movement from a source stand to a stand to be repopulated by forest species. Species such as the ground-dwelling bird, chestnut-throated huet-huet (*Pteroptochos castaneus*), might be willing to move toward young pine plantations if shrub vegetation is present (Ramírez-Collío et al. 2017), suggesting such vegetation might mitigate the structural habitat changes after clearcutting. Hence, young plantations might be rewilded by forest species.

We tested this hypothesis by assessing the movements of small mammals in Monterey pine (*Pinus radiata*) plantations of central Chile. Pine plantations cover around 1.5 million ha

✉ Matías Barceló
barcelo.matias@gmail.com

[1] Laboratorio de Conservación Biológica, Departamento de Ciencias Ecológicas, Facultad de Ciencias, Universidad de Chile, Casilla 653, Santiago, Chile

[2] Present address: Center of Applied Ecology and Sustainability (CAPES), Departamento de Ecologia, Pontificia Universidad Católica de Chile, Santiago, Chile

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(INFOR 2016); the forestry industry accounts for 3% of Chilean GNP (gross national product). Mature plantations with a well-developed understory do support forest mammals, including endangered species such as the kodkod (*Leopardus guigna*) (Simonetti et al. 2013). Here we test if shrub vegetation contributes to the rewilding of harvested areas, assessing the movements of the long-haired field mouse (*Abrothrix longipilis*), a forest rodent species. The long-haired field mouse inhabits both native forests and mature pine plantations (Saavedra and Simonetti 2005); it is sensitive to clearcutting operations, with at least 40% mortality due just to crushing by machinery during clearfelling (Escobar et al. 2015). In this context, we expect that the presence of shrub vegetation in young pine plantations will promote rodent movement between habitats by increasing edge permeability between contrasting habitat types (i.e., native forest or pine plantation to young pine plantation areas).

Methods

Our study was conducted in Trehualemu, in the Coastal Range of the Maule region, central Chile. The area comprises remnants of native forest immersed in a matrix of monoculture plantations of Monterey pine of different ages. Four habitat types were present: mature pine plantation (> 15 years), native forest, and young pine plantation either with or without shrub vegetation (< 3 years). When developed, such vegetation included species such as the Chilean wineberry (*Aristotelia chilensis*), French broom (*Genista monspessulana*), and elmleaf blackberry (*Rubus ulmifolius*) (Ramírez-Collío et al. 2017). We selected four study sites, with one replicate of each site. Each study site consisted of two habitat types, specifically (1) native forest adjacent to a young pine plantation with shrub cover, (2) native forest adjacent to a young pine plantation without shrub cover, (3) mature pine plantation adjacent to a young pine plantation with shrub cover, and (4) mature pine plantation adjacent to a young pine plantation without shrub cover.

To assess movement patterns of the long-haired field mouse, we live sampled individuals from September, 2016, to March, 2017, at each study site. We radio-tracked five adult individuals (> 40 g) for each study site. Individuals were ear-tagged, equipped with a 2.0 g radio collar (Model BD-2C Holohil Systems Ltd., Carp, Ontario, Canada) and tracked with a portable receiver (R-1000, Communication Specialists, Inc., CA, USA) with a handheld 3-element Yagi antenna (RA-150, Communication Specialists, Inc., CA, USA). Individuals were tracked during four to five consecutive nights, starting radio-telemetry 24 h after individuals were equipped with a collar to avoid bias associated with manipulation. Radio collars were removed at the end of the radio-telemetry study. Locations of individuals were obtained by triangulation using two bearings taken simultaneously by two independent observers at fixed location stations, with 15-min intervals to assess short-term movement. We defined fixed stations (with GPS error < 3 m) where one station was always located in the edge of habitats. All data was collected after sunset. Locations were estimated using LOAS 4.0 software (Ecological Software Solutions, Switzerland). With location coordinates, we estimated a home range of individuals at 50% and 95% isopleths using the minimum convex polygon (MCP) algorithm. Based on home range information and using a GIS layer, we estimated the ratio (proportion) of home range occupying young pine plantations. Minimum convex polygon was chosen over fixed kernel density (FKD) because FKD tends to overestimate home range, and it is not appropriate for data interpretation at abrupt habitat edges (Boyle et al. 2009). Mixed models with individuals as random factor were carried out to compare the ratio of home range (i.e., the proportion of habitat use in young pine plantations with or without shrubs) of rodents. All statistical tests and data analyses were performed in R (R Core Team 2013).

Results and discussion

We obtained a total of 813 fixes (mean = 38.8 ± 2.1 SE per individual). The average 95% home range was 2 times larger in small mammals inhabiting native forests bordering young pine plantations with shrub than home ranges in native forests adjacent to young plantations without such shrub (0.4 ± 0.1 ha vs. 0.2 ± 0.1 ha). In mature pine plantations, average 95% home ranges bordering young pine plantations with shrub were 5 times larger than those bordering young plantations without it (1 ± 0.3 ha vs. 0.21 ± 0.1 ha). Core home range (50%) was 1.8 times larger in native forests bordering young pine plantations with shrubs than bordering young plantations without such vegetation (0.09 ± 0.04 ha vs. 0.05 ± 0.03 ha), while in mature plantations, core home ranges bordering young pine plantations with shrub were 3.5 times larger than those without shrub (0.3 ± 0.1 ha vs. 0.1 ± 0.1 ha).

Regarding the habitat use, the ratio of home range in native forest bordering young pine plantations was 2 times higher in young pine plantations with shrub than without it (50% 0.9 vs. 0.5, $P = 0.1$; 95% 0.8 vs. 0.4, $P = 0.1$; Fig. 1a). In mature plantations bordering young pine plantations, ratio of home range in young pine plantations with shrub was 50% higher than without it (0.1 vs. 0, $P = 0.2$, Fig. 1b) and 95% home range (0.1 vs. 0, $P = 0.6$; Fig. 1b); however, this was not statistically significant.

Despite the low number of replicates, this preliminary study suggests that shrub vegetation could promote the rewilding of areas by this rodent, which are replanted after clearcutting. Long-haired field mouse does use young pine plantations more if shrub vegetation is present (Fig. 1); thus,

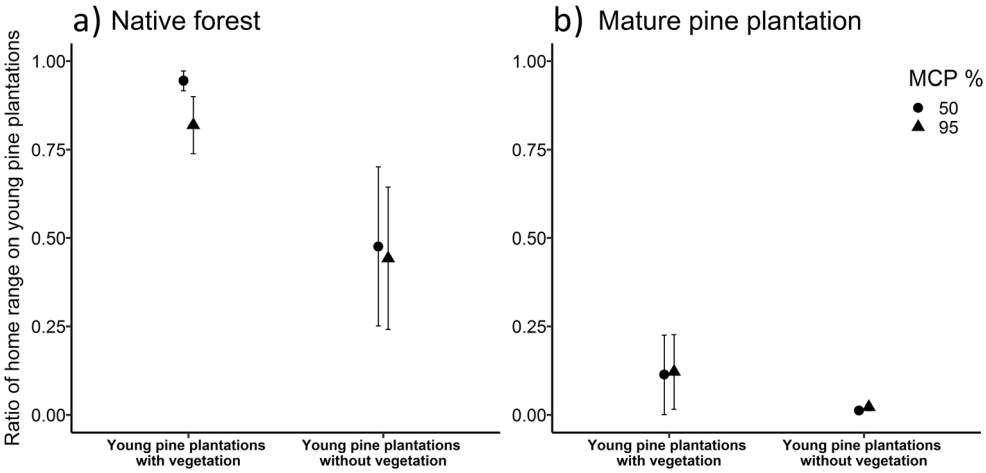

Fig. 1 Ratio of home range (50% and 95%) of *A. longipilis* in young pine plantations at **a** native forest and **b** mature pine plantation. Circle indicates MCP at 50%; triangle indicates MCP at 95%

our hypothesis is preliminarily supported. Further testing with a larger number of sites will be required in a future study. Shrub vegetation confers structural complexity and may be improving the quality of habitats after clearcutting; hence, rodents would be willing to explore these sites. These findings are consistent with the importance of shrub cover in young pine plantations, increasing the willingness of ground dwelling birds and insects to explore from a native forest or mature pine plantation (Ramírez-Collío et al. 2017; Russek et al. 2017). The ability of rodents to cross boundaries and inhabit young plantations will allow their populations to persist in a highly dynamic landscape, where mature stands are harvested every 12–15 years, creating a heterogeneous landscape with suitable and unsuitable habitat patches (Hawkes 2009; Diekötter et al. 2014).

Differences in the ratio of the utilized area between native forest and mature pine sites might be due to the presence of coarse woody debris. We observed a large amount of coarse woody debris in young pine plantations adjacent to native forest, while coarse woody debris was absent in mature pine plantations, which could explain the difference in habitat use. Whether the difference in course woody debris depends on forestry practices is yet to assessed. We do not know the reason for this difference in our study area.

Post-harvested sites with the presence of coarse woody debris can harbor forest rodents, working as small habitat patches (Sullivan et al. 2012). Coarse woody debris along forest clearcut edges may mitigate negative effects on rodent abundance and movement in areas post-harvest (Sullivan and Sullivan 2014). However, most of the coarse woody debris is extracted for energy production after clearcutting, ignoring which is the minimum volume of woody debris necessary to maintain the abundance of small mammals (Sullivan et al. 2012). Therefore, maintaining the negative consequences for species persistence in a heterogeneous landscape (Hiron et al. 2017). In Chile, the minimum volume of woody debris is yet to be determined.

Facing a rapid increase of exotic pine plantations in the world, where pine plantations represent at least 20% of plantations worldwide (Carle et al. 2002), managing post-harvested areas is required to protect biodiversity. Shrub vegetation in young plantations will enhance the habitat quality of young pine plantations to be rewilded. We recommend early management of post-harvested areas by adopting practices such as reducing use of herbicides to allow shrub vegetation to grow (Kogan et al. 2002), maintenance of a minimum volume of woody debris (Nordén et al. 2004; Sullivan et al. 2012), and the presence of green tree retention to enhance the habitat for forest small mammals after clearcutting (Sullivan and Sullivan 2018). We expect that adopting these recommendations would contribute to the maintenance of local animal populations through the movement of individuals and biodiversity persistence in dynamic landscapes where pine plantations are a widespread tendency worldwide.

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