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Research Note

Providing Habitat for Native Mammals through Understory Enhancement in Forestry Plantations

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Abstract: *The Convention on Biological Diversity (CBD) expects forestry plantations to contribute to biodiversity conservation. A well-developed understory in forestry plantations might serve as a surrogate habitat for native species and mitigate the negative effect of plantations on species richness. We experimentally tested this hypothesis by removing the understory in Monterey pine* (Pinus radiata) *plantations in central Chile and assessing changes in species richness and abundance of medium-sized mammals. Frequency of occurrence of mammals, including kodkods* (Leopardus guigna)*, culpeo foxes* (Pseudalopex culpaeus)*, lesser grisons* (Conepatus chinga)*, and Southern pudu deer* (Pudu puda)*, was low in forest stands with little to no understory relative to stands with well-developed undergrowth vegetation. After removing the understory, their frequency of occurrence decreased significantly, whereas in control stands, where understory was not removed, their frequency did not change. This result strongly supports the idea that facilitating the development of undergrowth vegetation may turn forestry stands into secondary habitats as opposed to their containing no habitat for native mammals. This forestry practice could contribute to conservation of biological diversity as it pertains to CBD targets.*

Keywords: Aichi targets, Chile, *Pinus radiata*, understory removal

Proporcionando Hábitat para Mamíferos Nativos Mediante el Mejoramiento del Sotobosque en Plantaciones Forestales

Resumen: *La Convención sobre Diversidad Biológica (CDB) espera que las plantaciones forestales contribuyan a la conservación de la biodiversidad. Un sotobosque bien desarrollado en plantaciones forestales puede servir como hábitat sustituto para especies nativas y mitigar el efecto negativo de las plantaciones sobre la riqueza de especies. Probamos esta hipótesis experimentalmente mediante la remoción del sotobosque en plantaciones de pino (Pinus radiata) en Chile central y evaluando los cambios en la riqueza y abundancia de mamíferos medianos. La frecuencia de ocurrencia de mamíferos, incluyendo* Leopardus guigna, Pseudalopex culpaeus, Conepatus chinga y Pudu puda*, fue baja en bosques con poco o nada de sotobosque. Después de remover el sotobosque, su frecuencia de ocurrencia disminuyó significativamente, mientras que en las plantaciones control, donde no se removió el sotobosque, la frecuencia no cambió. Este resultado soporta sólidamente la idea de que la facilitación del desarrollo de la vegetación de sotobosque puede convertir las parcelas forestales en hábitats secundarios para mamíferos nativos en contraposición a que no los tengan. Esta práctica forestal podría contribuir a la conservación de la diversidad biológica en el contexto de las metas de la CBD.*

Palabras Clave: Chile, metas de Aichi, *Pinus radiata*, remoción de sotobosque

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Introduction

To reduce pressures on biodiversity, the Aichi Targets, agreed to at the 10th Conference of the Parties of the Convention on Biological Diversity (CBD) in 2010, established that by 2020, forestry plantations ought to be managed to ensure conservation of biodiversity (Convention on Biological Diversity 2010). This goal aims to increase wildlife-friendly practices that will provide both goods and services while contributing to conservation of a suite of native species in "production lands" (Fisher et al. 2008). This is a significant challenge because forestry plantations, particularly those based on monoculture plantations of exotic species, reduce species richness and abundance of vertebrates. In fact, plantations are often regarded as "green deserts" (i.e., areas of little or no value for conservation of biological diversity) (Hartley 2002). However, increasing evidence suggests that, throughout the world, forestry plantations, including monocultures of Monterey pine (*Pinus radiata*) and eucalypts (*Eucalyptus* spp.), among others, could support a suite of native species, including some endangered ones (Simonetti et al. 2012).

The occurrence of a developed understory or multiple vegetation strata within a plantation may enhance species richness and abundance in forestry plantations because they may provide food and shelter (e.g., Grez et al. 2003; Lindenmayer & Hobbs 2004). In fact, mammal and bird species richness and abundance are higher in plantations with a developed understory than in stands lacking an understory (Nájera & Simonetti 2010*a*; Ramírez & Simonetti 2011).

Plantations of Monterey pine cover over 4 million ha, mostly in Australia, Chile, and New Zealand, and account for 32% of productive plantations worldwide (FAO 2007). These plantations support native fauna, including the critically endangered ground beetle *Holcapsis brevicula*, the vulnerable long-tailed bat (*Chalanilobus tuberculata*), and kiwis (*Apteryx mantelli* and *Apteryx haasti*) in New Zealand plantations (Pawson et al. 2010). In Chile, vulnerable species such as Bridges's degu (*Octodon bridgesi*), a rodent, and kodkods (*Leopardus guigna*), a carnivore, thrive in plantations, particularly those with complex understories (Simonetti 2006). The presence of a developed understory is presumed to account for their occurrence in pine plantations because the understory provides either food or shelter, but this relation has not been tested experimentally.

To further test whether understory is a key factor in enhancement of the value of forestry plantations for biodiversity conservation, we experimentally assessed the effect of undergrowth on the occurrence of medium-sized mammals in pine plantations in Chile. If undergrowth enhances the use of plantations by mammals, their frequency ought to be higher in plantations with a developed understory than in stands with no or little developed vegetation. Furthermore, their use of plantations should decrease if understory is removed from stands with well-developed undergrowth. Our results should provide information that will help fulfill Aichi's goal regarding species conservation in production-oriented lands.

Methods

Study Area

Surveys were carried out at Trehualemu in the coastal range of central Chile (35°59′S 72°41′W to 35°59′S 72°46′W). The landscape contains extensive stands of Monterey pine and interspersed remnants of Maulino forest, a temperate forest harboring a suite of threatened endemic tree species such as keule (*Gomortega keule*), the single representative of the Gomortegaceae family, ruil (*Nothofagus alessandrii*), which like keules are restricted to the Maulino forests (Smith-Ramírez et al. 2005). Plantations cover 54% of the study area (1095 ha) (Acosta-Jamett & Simonetti 2004). Sixty-five percent of plantations have well-developed understories, and compared with plantations with no undergrowth vegetation, they have 2.2 more woody species, an understory density 4 times higher, and a vegetation volume almost 12 times higher (Table 1). Native tree species, particularly maqui (*Aristotelia chilensis*) and boldo (*Peumus boldus*), account for differences among stands with dense and sparse understory (similarity percentage, Simper index: 69% [Clarke 1993]). The understory also contains 3 introduced shrubs (*Teline monspessulana*, *Rubus ulmifolius*, and *Rosa moschata*) and native trees (*Cryptocarya alba*, *Persea lingue*, *Nothofagus obliqua*, *Lithraea caustica*, *Luma apiculata*, and *Gevuina avellana*). The native trees are all species characteristic of the forests replaced by plantations.

Five medium-sized mammals occur in the area, including kodkods, culpeo foxes (*Pseudalopex culpaeus*), hog-nosed skunks (*Conepatus chinga*), lesser grisons (*Galictis cuja*), and the Southern pudu deer (*Pudu puda*) (Simonetti 2006). Plantations in the study area contain the same number of carnivore species, but their relative abundance is lower compared with native forests and their distribution is heterogeneous. These species are 4 times more frequent in plantations with understory than in plantations without understory (Simonetti 2006).

Sampling

In an area of relatively continuous cover of mature pine plantations, we selected 13 sites with a developed understory and 6 sites with no undergrowth vegetation. The absence of understory in some stands was likely due

Table 1. Structural attributes (mean and SE) of the understory in Monterey pine (*Pinus radiata*) stands in Tregualemu, Chile.[a]

		Understory			
Stand attribute		*dense (SE)*	*scarce (SE)*	*t*	*p*
Woody species richness	(spp./50 m^2)	5.8 (0.5)	2.6 (0.5)	3.9	0.001
Undergrowth density	(individuals/m^2)				
	0.0–0.5 m above ground	1.2 (0.2)	0.3 (0.1)	12.9	0.001
	0.5–1.0 m above ground	0.8 (0.1)	0.2 (0.1)	30.4	0.001
Stereo volume of foliage[b]	(m^3)	25.9 (3.6)	2.2 (0.8)	4.4	<0.01

[a] *Data from Poch and Simonetti (2013).*
[b] *Volume of woody perennial plants in a 3-m radius around each Monterey pine tree (Mills et al. 1991).*

to soil constraints rather than to directed management practices. Plots were at least 300 m apart. Monthly, from October 2009 until July 2012, we deployed one Stealth Cam digital infrared camera (Stealth Cam, Grand Praire, Texas) per plot. Cameras were set at an average height of 30 cm above the ground, operated 24 h/d for 4–5 d. Repeated photographs of a species at a given plot the same night were counted as one occurrence of that species. We estimated the frequency of medium-sized mammals as the number of photographs standardized by the number of hours the cameras operated. No bait or attractant was used to lure animals to the cameras.

Experiment and Data Analyses

We sampled mammals in all plots from October 2009 until February 2011 to establish a baseline with which to compare changes after understory removal. During February 2011, we manually removed the understory from 5 plots. We cut all woody vegetation within 1600 m^2 around each camera. These plots then resembled plots with no vegetation or plots with barely developed undergrowth. We removed debris from the area and disposed of it properly. Subsequent regrowth was removed in February 2012. Fourteen plots remained as controls, 8 with understory and 6 that had not supported understory since the beginning of the study. Sampling continued from March 2011 until July 2012. We pooled data for all mammal species into a single frequency value for each sampling plot so we could compare such frequency before and after understory removal. We compared the response ratio as ln (baseline frequency/postcutting frequency). If the frequency of mammals is related to the presence of a well-developed understory, the response ratio ought to be negative, with lower frequencies after cutting compared with the baseline frequency. In contrast, the ratio ought to be zero if there was no difference in frequency before and after undergrowth removal.

Results

During the baseline survey, we recorded 36 individuals of 4 species, kodkod, culpeo fox, hog-nosed skunk, and Southern pudu, in a total of 28,216 h (equivalent to 1175 camera days). Most animals were recorded (76%) in plots with understory. We excluded from analyses domestic animals such as horses and cows, which occasionally passed by when being moved by their owners through plantations. Foxes were the only species recorded in stands without understory, whereas kodkods, foxes, hog-nosed skunks, and Southern pudus were the only species recorded in stands with understory.

After undergrowth cutting, 33 photographs of 4 species were taken in 35,849 h (equivalent to 1494 camera days). Kodkods, culpeo foxes, Southern pudus, hog-nosed skunks were recorded. The frequency of medium-sized mammals did not differ in control stands, either in those with little understory or those with a well-developed understory (Fig. 1). In contrast, the frequency of medium-sized mammals was 2.5 times lower in stands where undergrowth was removed than in the same stands before understory removal. After cutting, only Southern

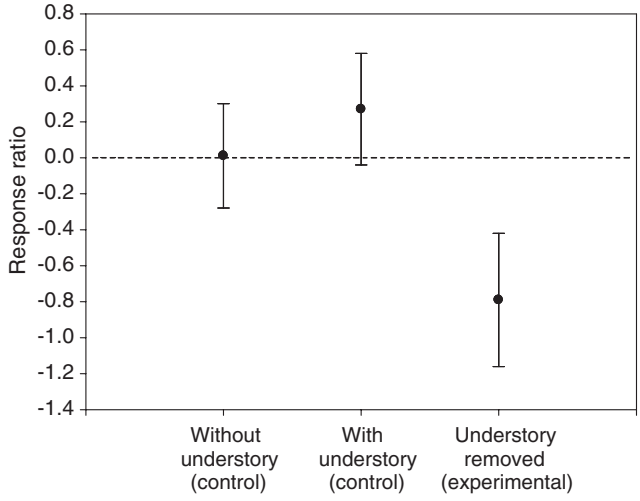

Figure 1. Response ratio of the frequency of medium-sized mammals in Monterey pine plantations. Values are the ln (baseline frequency/frequency after understory removal) (mean and SE). Samples sizes were 6 sites without understory, 8 control sites with understory, and 5 sites with understory removed.

pudus were recorded in stands with undergrowth removed (Fig. 1). Only this response ratio differed significantly from zero, which is the expected value if frequencies were not modified by undergrowth cutting ($t = 2.1$, $p = 0.05$; other comparisons $t < 0.3$, $p > 0.25$).

Discussion

Forestry plantations are expected to contribute to biodiversity conservation, but instead they are often green deserts containing depauperate assemblages of the native fauna (Hartley 2002). To determine the variables that may help plantations become more biodiversity friendly is then a challenge (Puettmann et al. 2009). Forestry plantations of non-native species, such as Monterey pine, are viewed negatively by the public due to their negative environmental effects, including biodiversity loss (e.g., Potton 1994). Furthermore, forestry plantations, which cover over 265 million ha worldwide, are expected to increase by 2% yearly (FAO 2011), underpinning the importance of advancing mechanisms to enhance the value of plantations for biodiversity, as agreed at the 10th Conference of the Parties of the Convention on Biological Diversity.

Understory of plantations seems a key factor that could increase the occurrence of native fauna in plantations. We found that stands of Monterery pine with no or barely developed understory contained fewer species of medium-sized mammals, which is consistent with Nájera and Simonetti's (2010*b*) finding that Guatemalan oil palm plantations with little understory support fewer bird species than stands with a well-developed understory. That the experimental removal of understory reduced the use of such stands by mammals strongly suggests understory enhances the quality of plantations as habitat for native fauna, which in this case includes 2 vulnerable species, kodkod and Southern pudu. Deforestation and the increase in plantations are regarded as significant threats to these species (Acosta & Lucherini 2008; Jiménez & Ramilo 2008). Our results support the hypothesis that plantations with well-developed understories could mitigate these effects by providing substitute habitats for these species.

Undergrowth may provide refuge and food for mammals. For carnivores, for instance, the abundance of prey, such as small mammals and birds, is correlated with the presence of shrub cover in the understory (Vergara & Simonetti 2004; Saavedra & Simonetti 2005; Estades et al. 2012). Furthermore, ground-dwelling beetles, another prey item of foxes and kodkods, are as abundant in plantations as in native forests (Grez et al. 2003). Plantations with well-developed understory may similarly provide resources for the Southern pudu. This deer inhabits temperate forests with thick understory and browses on leaves and shoots of trees and shrubs (Eldridge et al. 1987; Meir & Merino 2007), habitat features present in plantations with a dense undergrowth.

Understory that contains a substantial suite of native species is a common phenomenon in Monterey pine plantations in the Basque Country of northern Spain, New Zealand, and Chile (Ramírez et al. 1984; Brockerhoff et al. 2003; Aturi et al. 2005). Therefore, if managers allow the development of this vegetation, Monterey pine plantations may contribute to the conservation of native mammals. However, such vegetation may compete with pines and thus reduce pine growth and negatively affect plantation productivity (Lindenmayer & Hobbs 2004). Although competition between understory and pines at stages other than seedlings ought to be examined, preliminary evidence suggests undergrowth may have a negligible effect on pines (our unpublished data). Consumers are willing to pay premium prices for forest products coming from biodiversity-friendly plantations. Furthermore, plantations with dense undergrowth have a higher aesthetic value than and are preferred over plantations without understory (Püschel-Hoeneisen & Simonetti 2012). These public preferences suggest that despite the possible costs of leaving understory, consumers are willing to support conserving biodiversity in plantations.

The value of forestry plantations as habitat for native fauna could be enhanced by allowing the development of a dense understory. If adopted as a common practice, planted forests may make more sustainable contributions to biodiversity conservation and fulfill CBD targets.

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