Insectivory in *Pinus radiata* plantations with different degree of structural complexity

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ABSTRACT

Increasing evidence suggests that, depending on the structural complexity of a plantation, it can act as complementary habitat for insectivore birds and mammals. The magnitude of interactions such as insectivory, in turn, have been determined by species' richness and abundance in an ecosystem. Therefore, insectivory can vary in function of the plantation's complexity, and thereby, decrease chance of plantations damage due to herbivorous insects. Through an experimental procedure, the insect larvae mortality risk in pine plantations with different degree of structural complexity was measured, together with the herbivory levels on *Aristotelia chilensis* related to each plantation type.

Attacks to artificial caterpillars were significantly greater and herbivory significantly less in structurally complex plantations, where we found higher woody species richness and abundance and a greater understory development, compared to simple plantations. These results suggest that insectivory does vary in function of the structural complexity within forestry plantations, and it is greater in those with higher species diversity, mediating a trophic cascade effect over vegetation, significantly diminishing herbivory. Therefore, forestry plantations should be managed into more structurally complex ones in order to allow a win–win scenario, where maintaining a greater biodiversity increases the provision of useful ecosystem services for these plantations.

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1. Introduction

Forestry plantations are usually regarded as "biological deserts", mainly because they lack biodiversity in comparison with native forests (Allen et al., 1995; Hartley, 2002). However, increasing evidence suggests that they can act as complementary habitat for birds and mammals, and therefore contribute to sustain some biodiversity (reviewed in Hartley, 2002; Nájera and Simonetti, 2010; Ramírez and Simonetti, 2011). Both richness and abundance of birds in forestry plantations in some cases might be the same or even higher than in native forests (e.g. Estades and Temple, 1999; Vergara and Simonetti, 2004; González-Gómez et al., 2006). Species richness and abundance is likely related to the structural complexity of forestry plantation (e.g. Nájera and Simonetti, 2010), including characteristics such as multiple vegetation strata, well developed understory, high vegetation diversity and native vegetation remnants (Hartley, 2002; Lindenmayer and Hobbs, 2004). In fact, species richness and abundance in complex forestry plantations are larger than in structurally simple plantations, with scarcely developed understory and lower vegetation diversity (Nájera and Simonetti, 2010; Ramírez and Simonetti, 2011). As changes

in the abundance of organisms may lead to concomitant changes in the intensity of the interactions in which they participate (Simonetti et al., 2006), ecosystem services provided by some functional groups might differ between plantations with different structural complexity.

Insectivorous species have significant effects in ecological processes, such as in herbivore-damage to plants (Schmitz et al., 2000). Abundance or richness of birds, or a combination of both, determines the levels of predation upon herbivorous insects (e.g. Marquis and Whelan, 1994; Van Bael & Brawn, 2005; Philpott et al., 2009). Insectivory indirectly decreases foliar damage through reducing the abundance of herbivorous insects, and as a result it may also benefit plant biomass productivity (Mäntylä et al., 2011). If the intensity of ecosystem services is related with insectivorous species richness and abundance, it would be expected that, within commercial forestry plantations, there should be a higher insectivory in structurally complex plantations than in simpler ones, and consequently, herbivore-induced damage might be attenuated and productivity increased in structurally complex plantations. In this study, we tested this hypothesis by experimentally assessing insect mortality risk in structurally simple and complex pine (*Pinus radiata* D. Don) plantations. We also measured levels of herbivory aiming to determine whether there are noticeable trophic cascade effects on foliar damage within the forestry

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plantations. These assessments might unravel the implications for structural complexity on the provision of ecosystem services and the management of forestry plantations.

2. Methods

2.1. Study site

Field work was conducted within *P. radiata* plantations in Tregualemu, VII Región del Maule, Chile, at the northernmost zone of the Southern temperate rainforest (35°59′19″S, 72°41′15″W), which comprises the matrix of scattered native forest fragments, consisting mainly of *Nothofagus glauca*, *Persea lingue*, *Gevuina avellana*, *N. obliqua* and *N. alessandrii* (Bustamante et al., 2005). In total, 25 different study sites within 11 pine stands were selected, eight being structurally simple and 17 structurally complex plantation sites, coinciding with the relative abundance of sites available within the study location. Distance between sites ranged from a minimum of 300 m up to 4.7 km. Undergrowth development could differ between study sites of a single stand. All stands had been subjected to at least one thinning and one pruning process, which are generally done when tree height is between 5 and 7 m (Muñoz, 2008). Structurally simple and complex plantation sites differed only in the degree of undergrowth development, as no significant differences existed regarding stand age (20.4 ± 1.06 vs. 20.6 ± 2.18 years old, respectively; $t = -0.26$, $P = 0.80$), pine tree density (534.9 ± 155.0 vs. 481.2 ± 16.7 trees/ha, respectively; $t = 1.44$, $P = 0.16$), DBH (Diameter at Breast Height) (34.8 ± 4.7 vs. 36.3 ± 2.7 cm, respectively; $t = -1.03$, $P = 0.31$) nor mean tree height (28.4 ± 4.0 vs. 28.8 ± 3.3 m, respectively; $t = -0.27$, $P = 0.79$). Plantations with a well-developed understory hold mainly *Aristotelia chilensis*, *Peumus boldus* and *Rubus ulmifolius*, among other species (see below).

Insectivorous birds present at the study area are mainly Thorn-tailed rayadito (*Aphrastrura spinicauda*), Des Mur's wiretail (*Sylviorthorhynchus desmursii*) and House wren (*Troglodytes aedon*; González-Gómez et al., 2006). Among largely frugivorous and granivorous bird species that could be also feeding on insect prey during reproductive season are Black-chinned Siskin (*Carduelis barbata*), White-crested Elaenia (*Elaenia albiceps*) and Austral thrush (*Turdus falckandii*; González-Gómez et al., 2006).

The study was carried out during the austral spring of 2011 (September through November), coinciding with the reproductive season of most birds (González-Gómez et al., 2006), which also matches with the build-up of herbivorous insect populations and foliar development (Jaña-Prado and Grez, 2004; Vásquez et al., 2007).

2.2. Plantations complexity

Structural complexity within plantation sites was quantitatively assessed through vegetation cover measurements. Three 40 m parallel transects, separated by 15 m, were laid in each plantation site. A 1 m radius-circular plot was established every 10 m within each transect, where vertical plant density measurements by intersection of plant individuals were performed every 0.5 m from the ground up to 3 m high. Plantations were classified as structurally simple when woody plant density 1 m above ground was less than 0.5 individuals/m², and structurally complex when density was above 0.5 individuals/m². Vegetation diversity was computed with statistical analysis software PAST v2.15 (Hammer et al., 2001). Differences in diversity values between plantation types were assessed through a Mann–Whitney's U-test.

2.3. Insectivory

Insect predation was experimentally assessed as birds', mammals' or arthropods' attacks upon plasticine insect larvae, as previously described by González-Gómez et al. (2006). Artificial larvae are valid surrogates of natural ones (González-Gómez et al., 2006). The use of plasticine larvae provide an estimate of relative predation levels across sites (Loiselle and Farji-Brener, 2002; Howe et al., 2009), and they have been successfully used in several previous predation surveys (Loiselle and Farji-Brener, 2002; González-Gómez et al., 2006; Mäntylä et al., 2008; Howe et al., 2009). Plasticine models mimicked *Ormiscodes cinnamomea* (Feisthamel) (Lepidoptera: Saturnidae) larvae, moth feeding on *P. radiata* occurring in the study area (de Ferari and Ramírez, 1998).

During late September, groups of 15 model caterpillars of approximately 5 cm long were placed on 20 randomly selected pine plantation sites (structurally simple plantations sites, $n = 6$; complex plantations sites, $n = 14$), following the methodology described in González-Gómez et al. (2006). Each group of artificial larvae was placed on a twig of a randomly selected *A. chilensis* seedling within plantation sites, at approximately 0.4 m from the ground. Plasticine attached itself to the twigs without the use of wires or glue. Seedlings were preferred over adult trees since González-Gómez et al. (2006) results suggest a greater insect predation on the former. Larvae groups simulated natural aggregations of *Ormiscodes* larvae as clumps on branches, as they naturally occur (Artigas, 1994). During late November, 10 artificial caterpillars were attached individually with staples on a twig of *A. chilensis* seedlings separated by at least 2 m within plantations sites (simple plantations $n = 7$; complex plantations $n = 16$), instead of placing them in clusters. This methodology was used to increase the area covered within each plantation site. After artificial caterpillars were attached, markings left by any predator were recorded every 24 h, until 72 h after the beginning of the study.

The sampling unit was each plantation site. Caterpillar predation data obtained in both months were pooled, and the proportion of sites with larvae predation was estimated out of the total plantation sites for both simple and complex plantations (leading to a simple plantation sites $n = 13$, and a complex plantation sites $n = 30$). Differences between percentages of attacked sites were statistically assessed through z-ratio for two independent groups.

2.4. Herbivory

Herbivory was visually estimated as the percentage of foliar area removed in plant individuals within each plantation site. Logistic prevented us from measuring herbivory in the canopy of *P. radiata*, hence *A. chilensis* individuals were selected, as *Ormiscodes* larvae are a common herbivore naturally feeding upon both *A. chilensis* and *P. radiata* species particularly in pine plantations; also, it is abundant within the pine stands, and it is possible to find it even in structurally simple sites. Most defoliating activity is concentrated in spring and summer and accumulated through time until the end of the growing season (Vásquez et al., 2007), thus herbivory levels were assessed for leaves sampled after the end of the growing season.

During May 2012, 2582 leaves in total where taken from several *A. chilensis* trees within structurally simple and complex plantation sites. Each leaf was assigned to a category of leaf area removed by herbivory: 0 = no damage; 1 = 0–5%; 2 = 5–12%; 3 = 12–25%; 4 = 25–50%; 5 = 50–100% of leaf surface removed. We proceeded to calculate an overall herbivory index (IH) for each plantation site as: $IH = \sum n_i (C_i)/N$, where i was the category of leaf area removed, n_i was the number of leaves in the ith category, C_i was the midpoint of the area removed category (i.e., $C_1 = 2.5\%$, $C_2 = 8.5\%$, $C_3 = 18.5\%$, $C_4 = 37.5\%$, $C_5 = 75\%$, respectively), and N was the total number of