Forest Ecology and Management 269 (2012) 271–278

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Habitat use by carnivores at different spatial scales in a plantation forest landscape in Patagonia, Argentina

María Victoria Lantschner [a,*], Verónica Rusch [a], John P. Hayes [b]

[a] Grupo de Ecología Forestal, INTA EEA Bariloche, CC 277, 8400 Bariloche, Argentina
[b] Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL 32611, USA

ARTICLE INFO

Article history:
Received 4 October 2011
Received in revised form 21 December 2011
Accepted 21 December 2011
Available online 7 February 2012

Keywords:
Biodiversity
Landscape scale
Conifer plantation
Habitat fragmentation
Land use change

ABSTRACT

Forest plantations are an increasingly important source of industrial wood around the world, and the design and management of plantations can greatly influence the relationship with wildlife. The aim of this study was to examine the effects of conversion of native open vegetation to conifer plantations on mammalian carnivore assemblages in NW Patagonia, Argentina. We conducted camera-trap surveys at 69 sites and assessed composition of carnivore assemblages and habitat use in conifer plantations and native vegetation. We also evaluated habitat characteristics at stand and landscape scales related to presence of carnivores. Four species of carnivores were detected: *Lycalopex culpaeus*, *Conepatus chinga*, *Puma concolor*, and *Leopardus geoffroyi*. *L. culpaeus* and *C. chinga* used continuous native vegetation most frequently, but also used dense conifer plantations and tended to be more abundant in firebreaks and sparse plantations than in dense plantations. *L. geoffroyi* was almost fully restricted to continuous native vegetation, but was also detected in firebreaks and native vegetation remnants between plantations; this species was never detected in plantations. *P. concolor* was detected in all habitat types and did not exhibit any preference. The presence of carnivores was associated with understory diversity, tree density, and prey availability at the stand scale, and with amount of area with native vegetation at the landscape scale. Our results suggest that management decisions at the stand and landscape scales can influence habitat quality for wildlife in the region.

1. Introduction

Forest plantations modify the landscape and may alter habitat quality for some species, thereby shifting their distribution and abundance (Hayes et al., 2005; Brockerhoff et al., 2008). Human-modified lands can provide important habitat, offering food, shelter, or climatic conditions, and allowing dispersal and survival of some others (Lindenmayer and Franklin, 2002; Brockerhoff et al., 2008). As a result, management of human-modified lands is an important consideration in conservation, as these lands cover an increasingly large fraction of the globe. To a large extent and in many regions, the future of biodiversity depends on how productive areas are managed (Franklin and Lindenmayer, 2009).

Contemporary conservation strategies recognize that effective conservation of biodiversity must take multiple spatial scales into consideration (Franklin and Lindenmayer, 2009). In modified landscapes, for some species it is important to maintain connectivity through the establishment of corridors that link habitat patches, but also to consider the potential of a permeable matrix to maintain connectivity across a range of scales and habitat types (Hilty and Merenlender, 2004; Fischer et al., 2005; Shepherd and Whittington, 2006).

Forest plantations provide habitat for many species of wildlife (Hartley, 2002; Carnus et al., 2006; Simonetti, 2006; Brockerhoff et al., 2008), and plantation management often has less impact on biodiversity than many other land uses (Brockerhoff et al., 2008). At the stand scale, plantations managed to develop complex structure, and particularly one similar to the region's native vegetation, tend to hold more diverse assemblages than do plantations with more simple vegetative structure (Hartley, 2002; Lindenmayer and Hobbs, 2004; Nájera and Simonetti, 2010). However, managing for increased biodiversity only at stand scale could reduce the economic productivity. Thus, managers often enhance biodiversity in plantation forests by using a landscape-scale strategy, which consists in maintaining a mosaic of diverse habitat types, such as different plantation ages and structural classes, and the retention of remnant patches of native vegetation and corridors (Lindenmayer and Franklin, 2002; Lindenmayer and Hobbs, 2004; Simonetti, 2006).

In Argentinean Patagonia, establishment of exotic conifer plantations is strongly promoted by the state. From the mid-1970's to 2010, this policy resulted in establishment of approximately

* Corresponding author. Tel.: +54 2944 422731; fax: +54 2944 424991.
E-mail addresses: mvlantschner@bariloche.inta.gov.ar (M.V. Lantschner), vrusch@bariloche.inta.gov.ar (V. Rusch), hayesj@ufl.edu (J.P. Hayes).

0378-1127/$ - see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.foreco.2011.12.045

80,000 ha of conifer plantations, and there are still around 800,000 ha of rangeland in the region that are highly suitable to be converted to forest plantations (Loguercio and Deccechis, 2006; CFI-FUNDFAEP, 2009). However, there are few studies that evaluate how the replacement of native vegetation affects biodiversity in the region, including insects (Corley et al., 2006; Paritsis and Aizen, 2008), birds (Lantschner and Rusch, 2007; Lantschner et al., 2008; Paritsis and Aizen, 2008), and small mammals: (Lantschner et al., 2011); and there is almost a complete lack of information on relationships between forestry and carnivores in the region.

Carnivores may be particularly sensitive to landscape change due to their relatively low population densities and requirements for large habitat area (Carrol et al., 2001). This makes carnivores potentially valuable as focal species in regional conservation planning. As a consequence, identification of factors that influence distributions of carnivores can help define management practices at different spatial scales (Noss et al., 1996; Carrol et al., 2001). Studies of carnivores around the world have shown that influences of forest plantations as habitat vary with requirements of each species and the context in which plantations are established (Lindenmayer et al., 1999, 2000; Ferreras, 2001; Acosta-Jamett and Simonetti, 2004; Di Bitetti et al., 2006).

Plantations in Patagonia are established in a very particular landscape context, replacing the forest–steppe ecotone, a narrow zone of transition along the Andes Mountains which is dominated by a gramineous steppe with sparse shrubs and trees. Hence, habitat changes are especially marked, as open ecosystems are transformed to exotic plantations (Allan et al., 1997; Bremer and Farley, 2010). Additionally, these systems have historically been dedicated to extensive sheep and cattle production. Domestic grazing was introduced in Patagonia in the early 20th century (Soriano, 1983). Livestock are present in almost the whole region, and thus conifer plantations do not replace pristine grasslands, but systems that have already been altered (Novaro and Walker, 2005). With the introduction of livestock top carnivores were killed to avoid predation, reducing densities of these species, but apparently without effects on species' distributions (Novaro and Walker, 2005).

The aims of this study were to: (a) assess differences in habitat-use by carnivore species among native open vegetation, dense conifer plantations, and alternative landscape structures like firebreaks, remnants of native vegetation between conifer plantations, and sparse conifer plantations; and (b) identify habitat variables at stand and landscape scale related to presence of carnivores in plantation landscapes.

2. Methods

2.1. Study area

We carried out our study in the Meliquina Valley (41°S, 71°W) in northwest Patagonia, Argentina. Climate is temperate to cold, with maximum and minimum annual average temperatures of 17.1 ± 0.5 and 4 ± 2.1 °C, respectively. Mean annual rainfall ranges between 800 and 1400 mm/year (Barros et al., 1983). Geomorphology consists of two river valleys (Meliquina, Filo-Huaum, and Caleufu rivers), with steep stony mountain slopes, and narrow floodplains.

The vegetation of the basin corresponds to a transition between *Austrocedrus chilensis* forest and arid steppe. It is dominated by bunchgrasses (*Festuca* spp., *Stipa* spp., and *Poa* spp.), low shrubs (*Mulinum* spp., *Berberis* spp., and *Senecio* spp.), and sparse patches of *A. chilensis* woodlands, accompanied by shrubs and other trees, including *Lomatia hirsuta, Aristotelia chilensis, Maytenus boaria*, and *Schinus patagonicus*. In wet microsites and along the borders of creeks, there are patches of shrublands dominated by *Nothofagus antarctica*, a small deciduous tree. This area has been grazed since the beginning of the 20th century. Cattle are typically stocked at a low density and allowed to range freely over extensive areas (Funes et al., 2006). Vegetation structure and composition remains similar to the original ecotonal vegetation, although some areas show a reduction of herbaceous cover and replacement of some herbaceous species (Laclau, 1997; Funes et al., 2006).

Approximately 4350 ha of the basin were replaced with conifer plantations over the last 30 years, mostly of ponderosa pine (*Pinus ponderosa*), and in some cases, lodgepole pine (*Pinus contorta*) and Douglas-fir (*Pseudotsuga menziesii*). Plantations were established along the slopes and bottom of the river valleys (between 800 and 1200 m asl), distributed in stands of ca. 15–25 ha separated from each other by open strips, 30–35 m wide, designed to act as firebreaks. Initial plantation density varied between 2500 and 1111 trees/ha. Almost all plantations were pruned (at ages between 12 and 15 years), and branches were left in the stand, while approximately 60% of the planted area was thinned to densities between 1200 and 500 trees/ha (at ages between 15 and 20 years). Rotation periods are stipulated to be of 35–40 years, but no stand yet reached the harvest period.

Our sampling area was restricted to elevations ranging from 800 to 1200 m asl, corresponding to the range of elevations in the study area where conifer plantations are established. We excluded from our sampling area all human settlements, and a buffer zone of 400 m around them.

2.2. Sampling design

We used camera traps to estimate relative habitat use of carnivores. We determined indices of habitat use for carnivores in five types of habitats: continuous native vegetation, dense conifer plantations, sparse conifer plantations, native vegetation remnants between plantations, and firebreaks. Continuous native vegetation was selected as reference habitat of the ecosystem existing prior to planting conifers. Dense plantation was selected because it is the dominant habitat type in the plantation landscape, and we were interested in studying the main effect of replacement of native vegetation by plantations managed in the traditional way. Sparse plantations were studied to assess the effect of alternative management practices, particularly lower tree densities, which has been documented as an important variable for determining biodiversity in forest plantations. Remnants of native vegetation between pine plantations and firebreaks were selected to assess the role of these alternative landscape structures in providing complementary habitat for carnivore species in plantation landscapes.

We selected 20 sites in dense conifer plantations and 20 sites in continuous native vegetation for sampling, 10 sites in firebreaks, 10 sites in native vegetation remnants, and 9 sites in sparse conifer plantations. Sites were separated by a minimum of 1 km from one another, and we avoided selecting sites within 50 m of roads or other features used for human travel (excepting in firebreak, which are used as forestry roads in some cases).

For the purposes of this study we defined continuous native vegetation as any area >150 ha in size with vegetation composition structurally similar to that which existed prior to planting conifers and managed using traditional cattle grazing. These sites were dominated by vegetation typical of the transition between *A. chilensis* forest and arid steppe with patches of shrublands. Continuous native vegetation sites were randomly sampled from the basin and native vegetation within 500 m of conifer plantations was not sampled. Continuous native vegetation represented approximately 3200 ha in the study area (42% of the study area).

We defined dense conifer plantations as areas planted with conifers, ranging from 20 to 28 years old, with crown closure complete (canopy cover >60%), tree densities between 500 and 1200 trees/