Note

Assessing Productive Lands as Viable Habitat for Huemul in Patagonia

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ABSTRACT The creation of protected areas has been the main strategy to counter loss and fragmentation of habitats for large mammals, but these areas by themselves cannot guarantee species' conservation. Forestry plantations can provide habitat for a large range of species. However, studies assessing the impact of forestry plantations on large mammals are scarce. Our objective was to identify the environmental variables that explained the presence of the endangered huemul deer (*Hippocamelus bisulcus*) in an area with mixed pine plantation and native forest in the Chilean Patagonia. Occupancy models using data collected from camera traps indicated higher occupancy in plantation areas (0.70) than in native forest (0.50). The main variable explaining the presence of the huemul in both forest types was the understory cover between 21 cm and 50 cm in height. By maintaining understory cover, plantations provide a suitable complementary habitat for the forest-dwelling huemul.

KEY WORDS camera traps, conservation, exotic ungulates, forestry plantations, *Hippocamelus bisulcus*, occupancy.

Habitat loss is one of the most important factors affecting the survival of endangered species (Hanski and Ovaskainen 2002, Henle et al. 2004). Since the 1990s, the main strategy used to counter habitat loss has been the creation of protected areas (Norton 1999). This approach assumes that the survival of wildlife is less likely in altered habitats than in unaltered areas (Fischer et al. 2008). Modifications made to the landscape by changes in land use can constitute a threat to biodiversity by diminishing the availability of critical habitat features, and restricting dispersal and the reproductive success of many species, thereby increasing the probability of local extirpation (Fahrig 2003). However, even though it is common to think that areas of altered productive use are of lower ecological value, they can play an important complementary role for the conservation of a wide range of species (Gascon et al. 1999, Daily 2001), even for rare or endangered species (Brockerhoff et al. 2008).

Approximately 265 million ha of forestry plantations exist globally, which represents 7% of all forests, and the area devoted to forestry plantations is expected to grow 2% annually (Food and Agriculture Organization of the United Nations 2011). In some cases, forestry plantations can be a less favorable habitat than original forests, for native flora (Shankar et al. 1998, Humphrey et al. 2002) and fauna (Pomeroy and Dranzoa 1998, Magura et al. 2000). Under the right circumstances, however, plantations can offer food and shelter for a range of species, thus not necessarily fragmenting or degrading wildlife habitats (Hansbauer et al. 2010). Plantations are used as corridors among forest remnants by many species, such as ocelots (*Leopardus pardalis*; Di Bitetti et al. 2006), jaguars (*Panthera onca*), and pumas (*Puma concolor*; De Angelo et al. 2011), and for kodkods (*Leopardus guigna*) the presence of understory in plantations is important (Acosta-Jamett and Simonetti 2004). Nonetheless, studies of habitat use by large mammals in plantation landscapes remain scarce.

The huemul deer (*Hippocamelus bisulcus*) is an endemic deer of southern Chile and Argentina, with a global population estimated to be <2,000 individuals (Vila et al. 2006). It is classified as endangered by the International Union for Conservation of Nature (Jiménez et al. 2008) because of the decline and fragmentation of its populations and a >50% reduction in its historical distribution range (Vila et al. 2006). Habitat loss is possibly the most important factor affecting the recovery of this species (Corti et al. 2010, 2011), but understanding its real impact and importance is still at an early stage.

Information required to achieve a sustainable management of huemul populations in areas modified by humans is practically nonexistent, as it is for many species in human-disturbed ecosystems (Irwin et al. 2010). Most research

Received: 3 November 2014; Accepted: 29 December 2015

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focused on huemul has been centered in protected areas (Vila et al. 2009*a*,*b*; Corti et al. 2010). Thus, studying the ecology and knowing the status of huemul populations in areas subjected to human exploitation is of vital importance because most protected areas exist within a matrix of altered ecosystems (Pimentel et al. 1992). To improve our understanding of the huemul's use of altered habitats, we monitored 2 populations of huemul and compared occupancy between plantations and native forest patches. We also investigated environmental variables that could determine the presence of huemul.

STUDY AREA

We conducted this study in the Aysén District of the Chilean Patagonia on 2 plantation sites located 60 km from each other, both the property of Forestal Mininco S.A.: 1) San Miguel (SM; 45°54′4″ S y 72°03′29″ W; 672–952 m above sea level [asl]) covering 806.89 ha, and 2) La Cascada (LC; 45°21′21″ S y 71°52′37″ W; 700–1,089 m asl) covering 304.72 ha (Fig. 1). Both properties were composed of a mix of native forest (SM: 232.03 ha; LC: 159.39 ha) and pine plantations (SM: 574.86 ha; LC: 145.33 ha), where the native forest was principally lenga beech (*Nothofagus pumilio*); the understory was predominantly composed of prickly heath (*Gaultheria mucronata*), Chilean firetree (*Emobothrium coccineum*), redcurrant (*Ribes sp.*), and bay-leaved barberry (*Berberis microphylla*). The pine plantations were composed of 17–18-year-old stands of introduced ponderosa pine (*Pinus ponderosa*), roughly half way through the approximately 40-year harvesting cycle at this latitude. Huemul deer occurred on both properties during surveys conducted in 2011 (P. Corti, Universidad Austral de Chile, unpublished data).

METHODS

Data Collection

To determine occupancy rates, we used 28 camera traps (8 MP Trophy Cam, Bushnell Outdoors Products, Overland Park, KS, USA) from November 2012 to October 2014: 9 located at the SM site and 19 at the LC site. We positioned the cameras in a grid at a distance of approximately 500 m between cameras to minimize the likelihood of detecting the same individual at different cameras during the same day (Fig. 1) because an individual huemul has a home range size of approximately 350 ha (Corti et al. 2010). No animals were

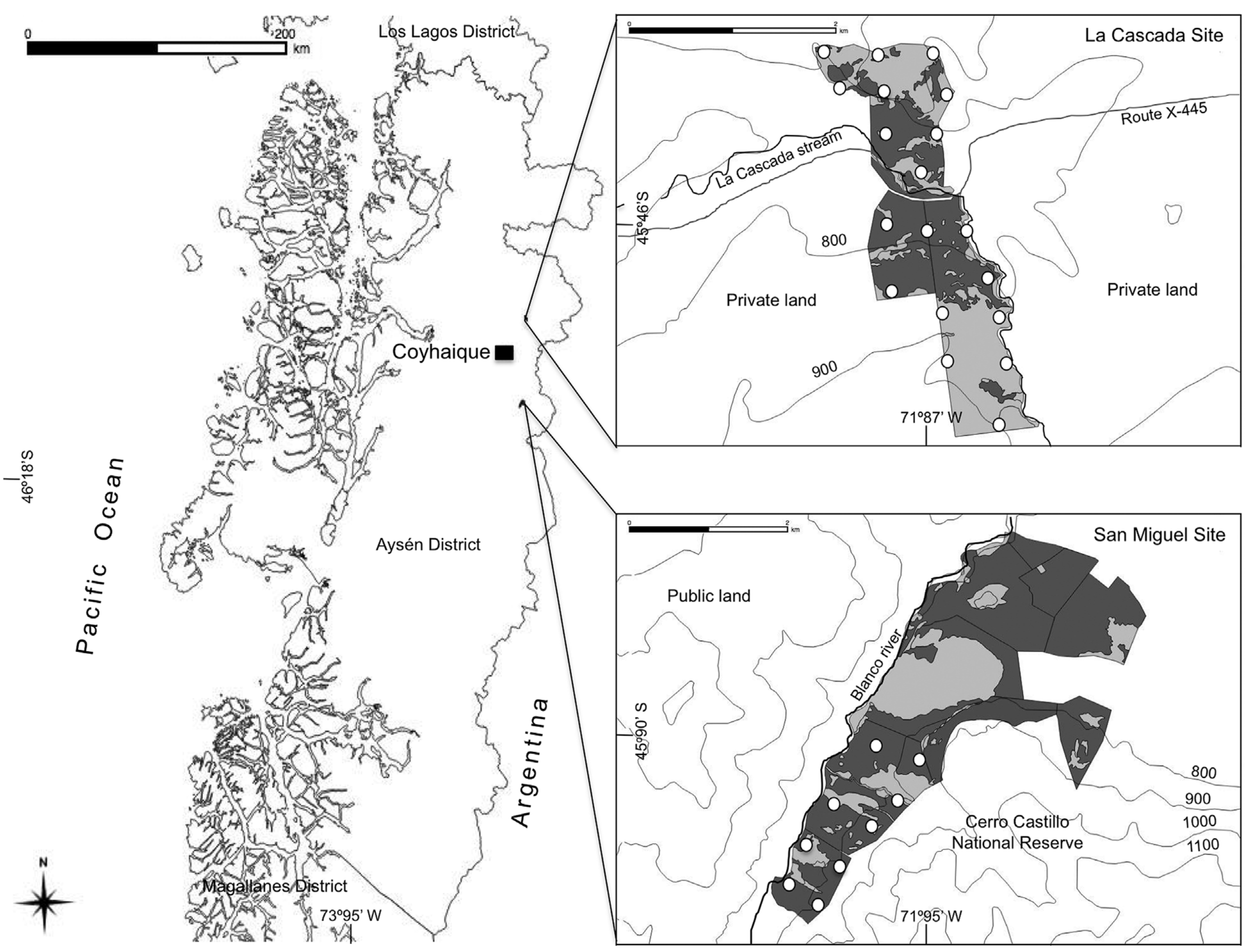

Figure 1. Location of the 2 study sites in the Aysén District, Chile, where we monitored huemul from 2012 to 2014. Dark gray areas represent exotic pine plantations and light gray areas depict native forest. The approximate location of camera traps in the La Cascada and San Miguel sites are shown by white circles. The camera traps were positioned approximately 500 m apart from each other. Main roads, rivers, altitude, and land use of adjacent lands are also indicated.

captured or disturbed during the research, all the procedures were approved by the Universidad Austral de Chile Bioethical Committee.

We placed 10 cameras in native forest, 10 in plantations, and 8 in the ecotone between both habitats. We considered a camera to be in the ecotone when it was in a mix of ponderosa pine and native trees, or if both habitats were <50 m away. For each day of sampling, we measured the presence or absence of huemul. At each camera, we measured 5 variables: slope, understory cover, distance to native forests, distance to pine plantations, and pine density. We visually estimated slope by looking uphill from a point 10 m downhill of each camera site. We measured the understory cover in 100-m^2 (5.64-m radius) plots around each camera by completing a horizontal cover profile in vertical height strata (U.S. Department of Agriculture 1997). We visually estimated the percentage of understory vegetation cover in 4 height strata: 0–20 cm, 21–50 cm, 51–100 cm, and 101–200 cm. We measured plant species that were part of the huemul diet (Vila et al. 2009*a,b*) because they would have more influence on huemul presence than plants that were not consumed. For each height stratum, we also calculated the mean cover for each habitat. We calculated the distance from the cameras to native forest and plantation using the software QGIS (QGIS Development Team, http://qgis.osgeo.org, accessed 18 Jan 2013), where the Euclidian distance between the camera location and the edge of the opposing habitat was measured. When the camera was located in the ecotone, both distances were 0. We obtained pine density (trees/km^2) from the forestry company.

Occupancy and Detectability Estimation

Occupancy is defined as the proportion of an area in which a species is present (MacKenzie et al. 2002) and assumes that the study system is closed to the influx of new individuals and that the entire population is detected (MacKenzie et al. 2002). However, it is necessary to measure the detectability to minimize bias (ρ [the probability of detecting an individual when it is present]; MacKenzie et al. 2006). We constructed detection histories for each camera, in which each sampling occasion was a 5-day period. To construct the occupancy models, we used the methodology described by MacKenzie et al. (2006), implemented in program PRESENCE 5.7 (Hines 2006; Proteus Research and Consulting Ltd., Dunedin, New Zealand). We used a multi-season model (MacKenzie et al. 2002) to account for variation in occupancy across seasons (MacKenzie et al. 2006) and defined seasons in the model as 3-month periods.

Because of the small number of cameras at site SM ($n = 9$), we were not able to obtain results for each site separately; thus, we pooled data from both sites. We evaluated the environmental variables for multicollinearity through a correlation matrix, and removed those with a significant correlation ($P < 0.05$) with $\geq$2 other variables from the analyses (Dormann et al. 2013). We approached model selection by first defining the best-fit detection model, whereby we tested combinations of additive effects of the environmental covariates. We then tested for effects of the environmental covariates on occupancy in combinations of $\leq$2 additive effects because models with 3 covariate parameters were not able to converge. We tested 25 models. We ranked models using Akaike's Information Criterion (<2 ΔAIC) adjusted for small sample size (AIC$_c$), and the Akaike weight (ω; Burnham and Anderson 2002). We obtained parameter estimates (β) for each model, which indicated the magnitude and direction of the relationship of the covariate with the measured occupancy (Burnham and Anderson 2002).

RESULTS

The measured understory vegetation cover within each height stratum varied by forest type. The vegetation cover in the 0–20-cm strata was 37% in native forests, 14% in plantations, and 43% in the ecotone. In the 21–50-cm strata, vegetation cover was 19% in native forests, 25% in plantations, and 31% in the ecotone. We recorded less understory vegetation cover at heights of 51–100 cm (native forest = 6%, plantation = 3%, ecotone = 12%) and 101–200 cm (native forest = 4%, plantation = 7%, ecotone = 6%).

The cameras registered data during 144 sampling occasions of 5 days each ($n = 720$ days). We recorded 152 huemul photographs across the habitats: plantation ($n = 87$), native forest ($n = 36$), ecotone ($n = 29$). The naïve occupancy for each habitat was 0.70 for plantation, 0.50 for native, and 0.63 for ecotone. The naïve occupancy for all sites was 0.64 and detectability was 0.11. The overall estimated probability of occupancy (ψ) was 0.69.

We determined there was collinearity for understory vegetation cover at 0–20 cm, distance to native forests, and pine density with $\geq$2 variables; thus, we excluded them from the models. Detectability was best explained by a constant detection model, rather than by the environmental variables. Model selection results of best-fit model indicated the understory cover between 21 cm and 50 cm ($\beta = 25 \pm 21$) and distance to plantation ($\beta = -5 \pm 4$) were the environmental variables that best explained occupancy (Table 1). A 10% increase in understory cover at the 21–50-cm strata increased probability of occupancy by 0.10. A 10% increase in the distance to plantation decreased probability of occupancy by 0.006. Additionally, 4 other models ranked better than the constant occupancy model but did not receive model support under our model selection criteria (Table 1). All 4 of these models included understory cover between 21 cm and 50 cm with positive effect sizes in all cases ($\beta = 18 \pm 10$, 14 ± 9, 16 ± 11, 13 ± 9 in models 2–5, respectively; Table 1). These models also indicated negative effects of understory cover at heights 101–200 cm ($\beta = -19 \pm 13$; model 2 in Table 1) and 51–100 cm ($\beta = -4 \pm 11$; model 4 in Table 1) and a positive effect of slope ($\beta = 0.5 \pm 2$; model 5 in Table 1).

DISCUSSION

Huemul presence was not negatively related to plantation areas, which might have been expected in a human-altered environment. On the contrary, higher occupancy occurred in the modified forests (0.70) than in native forests (0.50), with

Table 1. Model selection of huemul occupancy (ψ) in mixed pine plantation and native forest in the Aysén District, Chile, from November 2012 to October 2014. We present corrected Akaike's Information Criterion (AIC_c), AIC_c value difference in regards to the best model (ΔAIC_c), AIC_c weight (ω_i), and the number of variables tested in the model (K). Models that presented greater AIC values than the constant occupancy model are not shown. Covariates Cov 21–50, Cov 51–100, and Cov 101–200 are vegetation cover for 3 height strata of 21–50 cm, 51–100 cm, and 101–200 cm, respectively; DPlant is distance from the camera to plantation; and slope is the slope of the terrain at each camera. Gamma is the probability of an unoccupied site becoming occupied, epsilon (eps) is the probability of an occupied site becoming unoccupied, and ρ is the detection probability of a visit to a site (MacKenzie et al. 2006).

Models	AIC_c	ΔAIC_c	ω_i	K
ψ (Cov 21–50 + DPlant), gamma(.), eps(.)ρ()	1,340.56	0.00	0.58	5
ψ (Cov 21–50 + Cov 101–200), gamma(.), eps(.)ρ()	1,342.73	2.17	0.20	5
ψ (Cov 21–50), gamma(.), eps(.)ρ()	1,343.67	3.11	0.12	4
ψ (Cov 21–50 + Cov 51–100), gamma(.), eps(.)ρ()	1,345.51	4.95	0.05	5
ψ (Cov 21–50 + Slope), gamma(.), eps(.)ρ()	1,345.64	5.08	0.05	5
ψ (.), gamma(.), eps(.)ρ()	1,351.42	10.86	0.00	3

intermediate use in ecotone areas (0.63). The use of occupancy models, incorporating environmental variables, allowed us to improve our understanding of key factors influencing the presence of huemul in mixed pine plantation areas.

We were able to identify the importance of the understory cover, especially plant species occupying the 21–50-cm height stratum; this variable was present in all 5 models that performed better than the constant model and was positively associated with huemul occupancy. The most abundant species in this stratum were prickly heath, redcurrant, bay-leafed barberry, and Chilean firetree and all were important food items for huemul (Vila et al. 2009*a*, *b*). Our findings suggest the importance of the lower understory cover in terms of food availability rather than cover against predation because we focused our attention on species that compromise the huemul diet, unlike other studies that have reported the importance of overall vegetation cover for ungulates (pudu [*Pudu puda*]; Silva-Rodríguez and Sieving 2012).

Support for the distance to plantation variable indicated higher occupancy in or close to plantation areas. This could be due to a greater understory cover in the 21–50-cm stratum found in plantation areas (25%) and the ecotone (30%) than in native forest (18.5%). The young age of the plantation trees in our study area (17–18 years old out of 40-year cycle) could have allowed for better conditions for understory development (Klinka et al. 1996) and favorable conditions for understory development where the plantation and native forest meet. The 51–100-cm height stratum was overall more sparsely vegetated than the 21–50-cm height stratum (6% and 24%, respectively) and did not constitute a significant part of the food supply (main species: Chilean firetree, bay-leafed barberry, and lenga). The highest cover strata (101–200 cm) was mainly composed of Chilean firetree, a highly palatable species, but had very low cover percentages (0.05% averaged across habitats). The negative association of occupancy with the higher cover strata (51–100 cm and 101–200 cm) may be related to light obstruction hindering vegetation growth in lower areas with highly palatable plants (21–50 cm). In addition, thick cover in high strata may obstruct visibility, making predator avoidance more difficult (Mysterud and Ostbye 1999). Finally, huemul have been reported to use areas with steep slopes to avoid predators (Povilitis 1998), in accordance with our findings of positive association with occupancy and slope.

Our findings highlight the importance of understory for huemul presence, supporting the evidence that understory (Ramírez and Simonetti 2011, Simonetti et al. 2013) and structural complexity (Castaño-Villa et al. 2014) in plantations play a critical role for the presence of fauna, and in particular native species, probably in terms of food and security cover. Even though fragmentation and habitat loss have been one of the most important factors in huemul population decline (Jiménez et al. 2008), the presence of huemul in altered environments, like forestry plantations, opens new opportunities for conservation if appropriately managed. We have seen that plantations do not necessarily fragment the environment for the huemul if certain characteristics of the environmental are intact. Efforts for improving the structure of plantations to create developed understories and habitat heterogeneity would help create suitable areas for huemul.

Future research should evaluate huemul occupancy in plantations of different ages and species. Older plantations probably present different huemul occupancies and detection rates, and possible changes in the importance of different environmental variables. Plantations immersed in different ecosystem matrices (e.g., steppe, pastures, rocky hillsides) may provide different levels of importance to local huemul populations in regards to resources and shelter. Furthermore, understanding the impact that clear-cutting may have on huemul populations is needed (Keenan and Kimmins 1993) to achieve long-term huemul presence in these areas.

MANAGEMENT IMPLICATIONS

To increase huemul presence in areas with forestry plantations, we suggest maintaining or developing an abundant and diverse lower (21–50 cm) understory. Tree thinning throughout the plantations' life cycle could stimulate the development of understory species (Thomas et al. 1999) and consequently increase the available habitat for huemul. Following these suggestions, it would be possible to create suitable habitat in forestry plantations, improving connectivity between populations (Brockerhoff et al. 2008) and minimizing the negative effects that unmanaged plantations may have on huemul populations.

Furthermore, allowing the development of the understory would benefit huemul and could enhance the habitat for other native species (e.g., hog-nosed skunks [*Conepatus spp.*] and culpeo foxes [*Pseudalopex culpaeus*]; Simonetti et al. 2013).

ACKNOWLEDGMENTS

We thank Forestal Mininco-Aysén S.A. for allowing us to work in its properties, and providing transportation for the research team. Special thanks to R. Eyzaguirre, P. Moreno, and P. Herranz for encouraging this research initiative. Also thanks to C. Angulo, C. Moreira, C. Bahamonde, and R. Jara for all their support in the field. E. Aedo and all the personnel of Campus Patagonia of Universidad Austral de Chile helped promote and support this study. D. Shackleton, R. Sarno, and 1 anonymous reviewer provided comments on an earlier draft to improve our work. Funding for the project was provided by Forestal Mininco-Aysén S.A. P. Corti also received funding from projects CONICYT 7912010016 and FONDECYT 3110187.

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Associate Editor: Steeve Côté.