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Low-density spruce plantations increase foraging by moose in a northeastern temperate forest

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ABSTRACT

Several North American jurisdictions are adopting new forest management practices that favor sustainable development and biodiversity conservation, but that are also expected to reduce timber yield. In many regions, forest managers have identified areas of intensive timber production where spruce plantations and thinning treatments are to be used extensively. Concomitantly, wildlife managers are concerned that intensive silvicultural treatments will have a negative impact on sport hunting by modifying the behavior and abundance of game species. We evaluated whether an experimental low-density spruce plantation (1350 stems/ha) could increase habitat suitability for moose *Alces americanus* compared to standard high-density plantations currently used throughout eastern Canada (~2000 stems/ha). We evaluated the effects of plantation type, pre-commercial thinning, and age class of plantations on proxies of habitat suitability and use by moose in a northeastern temperate forest of Bas-Saint-Laurent, Québec (Canada). We also considered various environmental characteristics measured locally and within 3.14-km^2 landscape contexts to explain spatial variations in use by moose among 540 sampling plots. Our results show that the proportion of stems browsed by moose increased with the number of available stems and decreased with vertical cover. The number of moose feces, an index of time spent by moose in sampling plots, was similar in both plantation types, but was lower in thinned and young (5 years old) stands as compared to unthinned and 15 years old stands. Variations in the proportion of browsed stems and the number of feces were not explained by broad-scale indices of food availability, density of edges between stands offering good cover and foraging opportunities, road density, elevation, or the area occupied by plantations and naturally regenerated stands around sampling plots. Moose used low-density plantations significantly more than standard plantations for browsing, and these stands supported higher stem densities and vertical cover than standard high-density plantations on average. Low-density plantations offered good foraging opportunities for moose by allowing a large variety of palatable deciduous species to grow between planted coniferous stems. However, we found high inter-site variability in environmental characteristics following plantation, even among equivalent treatments. This suggests that forest managers should aim for particular stand characteristics (i.e. high availability of stems and low vertical cover) *in situ* rather than prescribing specific post-harvest silvicultural treatments (e.g., plantation types) to favor moose. We recommend the use of unthinned low-density plantations in northern temperate regions where the management objective is to maintain high moose hunting success.

1. Introduction

During the 20th century, the goal of most North American forest services has been to maximize annual allowable timber yield. In many jurisdictions, including Québec, Canada, this practice has persisted throughout the beginning of the 21st century, leading to a relative homogenization of forest structure and composition, particularly in intensively managed areas (Coates and Burton,

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1997; Schulte et al., 2007). More recently, ecosystem-based management has been suggested as a way to improve resource extraction practices, including logging (Slocombe, 1993; Gauthier et al., 2008). This approach seeks to reach equilibrium between socioeconomic development and biodiversity conservation by emulating natural disturbances and broad-scale changes that prevailed during the precolonial era. As such, ecosystem-based management is expected to reduce allowable timber yield, which has led the industry to express concerns. In some regions, intensive timber production areas (hereafter ITPA) have been suggested as a way to compensate this potential economic loss. In ITPA, forest managers aim to use conifer plantations and repeated thinning operations to allow faster harvest rotations and higher timber yield (Lieffers et al., 2003). Although post-harvest silviculture has been shown to enhance wood supply (Pelletier and Pitt, 2008) and stem quality (Mäkinen and Isomäki, 2004), several studies have highlighted the negative impacts of intensive forest management on biodiversity (e.g., see reviews by Thompson et al., 2003 and Carnus et al., 2006). Notably, declines in habitat suitability have been reported for animals living in exotic tree plantations and monocultures, including forest birds (Hayes et al., 2003), small mammals (Homyack et al., 2005), and ungulates (Gill et al., 1996).

Depredation of plantations by wild herbivores is well documented, mainly because of its negative economic impacts (e.g., Heikkilä and Härkönen, 1996; McLaren et al., 2000). However, few studies have investigated the importance of conifer plantations in the habitat selection of wild ungulates. Gysel (1966) found that populations of white-tailed deer (*Odocoileus virginianus*) declined in areas planted with exotic red pines (*Pinus resinosa*) in Michigan. Staines and Welch (1984) found that red deer (*Cervus elaphus*) in Scotland preferred newly established Sitka spruce (*Picea sitchensis*) plantations over their traditional open-hill habitat. Peek et al. (1976) observed no particular selection of conifer plantations by moose (*Alces americanus*) year-round in northeastern Minnesota, although low-density plantations (<124 stems/ha) were selected during summer. According to these authors, reforestation became increasingly negative for moose populations as conifer stocking rates increased and available forage (i.e., low-ground regenerating trees and shrubs) decreased. More recently, Leclerc et al. (2012) demonstrated that moose densities in southeastern Québec increased with the proportion of spruce plantations in 60-km^2 aerial survey sampling plots. They also found fewer moose in areas where plantations were aggregated, suggesting that landscape context was an important driver determining the use of plantations by wild ungulates.

Moose is an important wildlife species across northern North America because of its ecological and economic roles. In eastern Québec, mainly in the Bas-Saint-Laurent (hereafter BSL) region, moose have reached unprecedented numbers. The region has a long and diversified history of forest management (>200 years; Boucher et al., 2009), which culminated with severe eastern spruce budworm (*Choristoneura fumiferana*) epidemics and concurrent salvage logging activities during the mid-1970s to mid-1990s (Boulanger and Arseneault, 2004). These large scale timber harvest operations have increased the representativeness of regenerating deciduous stands, which provide excellent forage and cover for moose (Potvin et al., 2005). Population growth has also been favored by the absence of gray wolf (*Canis lupus*) – the main predator of adult moose – since the late 1800s. Some particularly suitable areas now show densities of up to 33 moose/10 km^2, which are comparable to some of the highest densities in the country (Franzmann and Schwartz, 2007). Moose sport hunting has become a rapidly growing industry in BSL (benefits of ~26 M$ in 2007; CRE-BSL, 2010), with hunters achieving excellent success rates each year. In contrast, the timber economy (benefits of ~83 M$ in 2005; CRE-BSL, 2010) has slowed drastically during the last decade due to a generalized "forest crisis" originating from concerns about the sustainability of the province's forestry practices, declining demands from the U.S. market, and constraining laws and regulations (Barré and Rioux, 2012). From the perspective of wildlife managers, hunters, and outfitters, ITPA are seen as detrimental to the moose and its hunt. Consequently, there is a real need to assess the effectiveness of new management practices that could favor timber harvesting while maintaining relatively high moose densities and hunting success in ITPA.

Our objective was to evaluate if, and to what extent, an experimental low-density spruce plantation could increase habitat suitability for moose as compared to standard high-density plantations currently used throughout eastern Canada. High-density plantations are generally used as intensive silvicultural practices to maximize wood supply and profitability (Lieffers et al., 2003), but a pioneer study by Peek et al. (1976) suggested that low-density plantations could show characteristics favorable to moose. Plantations are often followed by thinning treatments to maximize the survival probability of planted trees against competing regeneration (Mäkinen and Isomäki, 2004). We therefore investigated the effect of pre-commercial thinning on habitat suitability and use by moose in both types of plantations (i.e., low- and high-density), as well as naturally regenerated stands. Finally, for each plantation type and thinning treatment, we sampled several replicates of varying age classes to document potential changes in use by moose through time. We performed analyses at fine and broad scales to consider most factors known to influence space use by moose, including forage and cover availability (Bjørneraas et al., 2012), interspersion between forage and cover (Dussault et al., 2006), topography (Leblond et al., 2010), and roads (Beyer et al., 2013).

2. Materials and methods

2.1. Study area

Our study area (2300 km^2) was located in the Bas-Saint-Laurent (BSL) region in Québec, Canada, southeast of Rimouski (Fig. 1). The area lies in the balsam fir (*Abies balsamea*) – yellow birch (*Betula alleghaniensis*) bioclimatic domain of the northern temperate forest, where yellow birch, white birch (*B. papyrifera*), balsam fir, white spruce (*Picea glauca*), white cedar (*Thuja occidentalis*), and sugar maple (*Acer saccharum*) are the main tree species. The understory is also composed of mountain maple (*A. spicatum*), hobblebush (*Viburnum lantanoides*), beaked hazel (*Corylus cornuta*), red elderberry (*Sambucus racemosa*), and Canadian yew (*Taxus canadensis*). Black (*P. mariana*) and white spruce plantations make up 13% of public forests in BSL (Leclerc et al., 2012), but they could represent more than 25% of the land following the establishment of ITPA in the region. Based on an aerial survey conducted in February 2014, moose density in BSL hunting zones (i.e., at the regional scale) was estimated at 11.4 ± 1.7 individuals/10 km^2, with local peaks reaching 33 moose/10 km^2 in particularly favorable areas (Ross et al., 2014). However, moose density was relatively high and homogeneous throughout our study area. Black bear (*Ursus americanus*) and coyote (*Canis latrans*) are potential predators of moose calves, but gray wolf is absent from the region.

2.2. Plantation types

The experimental low-density plantation at 1350 stems/ha (hereafter P1350) was originally designed to prevent the transition from mixed to conifer-dominated stands in the northern temperate zone (Laflèche et al., 2000). This approach, developed in 1995 by the BSL Model Forest (previously part of the Canadian Model Forest Network), advocates the use of a lower tree density to