Forest Ecology and Management 264 (2012) 115–124

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

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

Thinning of young Douglas-fir forests decreases density of northern flying squirrels in the Oregon Cascades

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ARTICLE INFO

Article history:
Received 14 June 2011
Received in revised form 26 September 2011
Accepted 27 September 2011
Available online 5 November 2011

Keywords:
Northern flying squirrel
Glaucomys sabrinus
Silvicultural thinning
Commercial thinning

ABSTRACT

Large-scale commercial thinning of young forests in the Pacific Northwest is currently promoted on public lands to accelerate the development of late-seral forest structure for the benefit of wildlife species such as northern spotted owls (*Strix occidentalis caurina*) and their prey, including the northern flying squirrel (*Glaucomys sabrinus*). Attempts to measure the impact of commercial thinning on northern flying squirrels have mostly addressed short-term effects (2–5 years post-thinning) and the few published studies of longer-term results have been contradictory. We measured densities of northern flying squirrels 11–13 years after thinning of young (55–65 years) Douglas-fir forest stands in the Cascade Range of Oregon, as part of the Young Stand Thinning & Diversity Study. The study includes four replicate blocks, each consisting of an unthinned control stand and one stand each of the following thinning treatments: Heavy Thin; Light Thin; and Light Thin with Gaps. Thinning decreased density of northern flying squirrels, and squirrel densities were significantly lower in heavily thinned stands than in more lightly thinned stands. Regression analysis revealed a strong positive relationship of flying squirrel density with density of large (>30 cm diameter) standing dead trees and a negative relationship with percent cover of low understory shrubs. Maintaining sufficient area and connectivity of dense, closed canopy forest is recommended as a strategy to assure that long-term goals of promoting late-seral structure do not conflict with short-term habitat requirements of this important species.

1. Introduction

In the Pacific Northwest of North America, forest managers confronted with the legacy of decades of clearcut harvest and subsequent plantation establishment are increasingly employing a strategy of multiple commercial thinnings and long rotations to accelerate the development of late-seral structure and function from young homogeneous forests (Hayes et al., 1997; Tappeiner et al., 1997; Carey et al., 1999b; Sullivan et al., 2001). Whereas there may be economic and other objectives in pursuing this strategy (Busing and Garman, 2002), one goal is to provide more complex habitat for wildlife species with a wide range of needs (Hagar et al., 1996; Hayes et al., 1997, 2003; Humes et al., 1999).

The northern flying squirrel (*Glaucomys sabrinus*) has been considered a keystone species (Carey, 2002; Smith, 2007) in Pacific Northwest forests because it serves several important ecological functions. In much of the region, this squirrel is the primary prey of the threatened northern spotted owl (*Strix occidentalis caurina*) (Carey et al., 1992; Forsman et al., 2001, 2004). In addition to this arboreal rodent's importance as prey for owls and other predators (Reynolds and Meslow, 1984; Wilson and Carey, 1996; Fryxell et al., 1999; Bull, 2000), its consumption of both hypogeous and epigeous fungi and dispersal of fungal spores aids in maintaining mycorrhizal communities (Maser et al., 1978; Li et al., 1986; Zabel and Waters, 1997; Gomez et al., 2005). Northern flying squirrels also are thought to be an important vector for dispersal of canopy lichens (Rosentreter et al., 1997; Zabel and Waters, 1997). Because of these relationships, this squirrel has been used as a forest-health indicator species in diverse regions of North America (McLaren et al., 1998; Betts and Forbes, 2005; Smith et al., 2005), and thus is of central concern in planning forest management and maintaining biological diversity in coniferous forests.

Considerable evidence exists that northern flying squirrels are relatively more abundant, and correlates of squirrel fitness are optimized, in forests with many large live trees (Smith et al., 2004; Gomez et al., 2005; Holloway and Malcolm, 2006; Lehmkuhl et al., 2006), many large dead trees (Carey, 1995; Smith et al., 2004; Holloway and Malcolm, 2006; Meyer et al., 2007b), well-developed understories (Carey et al., 1999a; Pyare and Longland, 2002), and many large logs on the ground (Carey et al., 1999a; Gomez et al., 2005; Smith et al., 2005). Collectively, these structural elements

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doi:10.1016/j.foreco.2011.09.043

are typical of late-seral (mature and old-growth) forests. Some or all of these elements are largely lacking in most of the young forests now covering extensive areas of the Pacific Northwest (Spies and Cline, 1988; Halpern and Spies, 1995; Franklin et al., 2002).

As stated above, a goal of some public land managers is to use commercial thinning to accelerate the development of late-seral features within young forests, to provide high-quality habitat for late-seral species, including the northern flying squirrel. In the last two decades, experiments and retrospective studies have been attempting to test the effectiveness of this strategy, with varying results. Most found negative short-term (2–5 years) impacts of thinning (Carey, 2001; Herbers and Klenner, 2007; Meyer et al., 2007a) or similar partial harvest techniques (Waters and Zabel, 1995; Bull et al., 2004; Holloway and Malcolm, 2006) on northern flying squirrel populations, though 2 studies found no short-term effect of thinning (Ransome and Sullivan, 2002; Gomez et al., 2005).

Because thinning is expected to eventually improve habitat conditions for northern flying squirrels through acceleration of large tree growth rates, increasing mid-story complexity, and enriching understory diversity, and because these developments are relatively slow and may change trajectory over decades, studies of wildlife responses over the long term gain value in proportion to time since thinning. Only three studies have been published which describe mid-to-long-term effects of thinning on northern flying squirrels, and results are contradictory. In a retrospective study of 55–65-year-old stands in western Washington, Carey (2000) reported lower abundance of flying squirrels in twice-thinned stands than in unthinned stands with legacies of large live trees, snags, and logs. Wilson (2010), in a re-sampling of Carey's sites 12 years after half of the stands were treated with variable-density thinning, found that flying squirrel densities were very low in both thinned and unthinned stands. Ransome et al. (2004) found that pre-commercial thinning of young densely-stocked lodgepole pine (*Pinus contorta*) forests had a neutral or positive effect on flying squirrel density 12–14 years after treatment.

A recent meta-analysis of effects of silvicultural practices on northern flying squirrels (Holloway and Smith, 2011) attempted to resolve the inconsistencies of the work done so far, and found that studies asserting a benefit or no effect of harvesting on squirrel populations (Cote and Ferron, 2001; Ransome and Sullivan, 2002; Gomez et al., 2005) lacked statistical power needed to support those assertions. The implication of Holloway and Smith's meta-analysis is that forest management practices that are currently widespread in the Pacific Northwest (thinning and clearcutting) have negative short-term and long-term impacts on northern flying squirrels.

As with most of the studies cited above, the major impetus for the Young Stand Thinning & Diversity Study (YSTDS) was to investigate the effects of commercial thinning on habitat for late-seral species and to assess the potential for accelerating the development of late-successional features such as those associated with high abundance of northern flying squirrels. Similar work has taken place in British Columbia (Ransome and Sullivan, 2002; Ransome et al., 2004), Washington State (Carey, 2000; Wilson, 2010), northeastern Oregon (Bull et al., 2004), and the northern Oregon Coast Range (Gomez et al., 2005), but the YSTDS is the only experiment of this kind in the Oregon Cascades. The design of the YSTDS facilitates testing of a set of three orthogonal hypotheses about differences among treatments, minimizing the Type I error rate relative to multiple comparisons (Lehmann, 1986). With respect to the northern flying squirrel in particular, the three null hypotheses are: (1) that flying squirrel density does not differ between thinned and unthinned treatments; (2) that flying squirrel density does not differ among different thinning intensities; and (3) that flying squirrel density does not differ between lightly thinned stands with and without small gaps.

Garman (2001) described responses of ground-dwelling small mammals and amphibians 2–5 years post-thinning for the YSTDS, but his protocol did not target tree squirrels and relatively few were captured, so data were insufficient to derive estimates of density. Nevertheless, Garman (2001) indicated that thinning had negative short-term impacts on flying squirrel densities, agreeing with most other studies that have more thoroughly investigated short-term responses of flying squirrels to thinning and similar silvicultural treatments. Here we describe patterns of density for northern flying squirrels 11–13 years after thinning in young Douglas-fir forests.

2. Methods

2.1. Study area description

The YSTDS comprises a randomized block design with 16 forest stands located on the Willamette National Forest on the west slope of the Cascade Range in Oregon (Fig. 1). The study is composed of four replicate blocks, each consisting of an unthinned control stand and 1 stand each of the following thinning treatments: (1) a Heavy Thin treatment leaving 125–137 trees per hectare (tph) and underplanted with native conifer seedlings; (2) a Light Thin treatment, approximating the timber industry standard, with 250–275 residual tph; and (3) a Light Thin with Gaps (hereafter simply "Gaps") treatment, again with 250–275 tph but with an additional 20% of the stand harvested to create 0.2-ha gaps planted with native conifer seedlings. Thinnings were conducted by removing trees of relatively small diameter.

All stands are located within the western hemlock (*Tsuga heterophylla*) zone of Franklin and Dyrness (1988) and were established after clearcutting and planting 55–65 years before thinning was initiated in 1995. Slopes range from 0% to 24%, and elevation ranges from 430 to 920 m. Stand areas average 31 ha, ranging from 15 to 53 ha.

Stands within two blocks (Christy and Sidewalk) are directly contiguous with each other or separated only by narrow riparian corridors or roads; distances among stands within the other two blocks (Cougar and Mill Creek) average 1.6 km and no two stands within a block are more than 4 km apart. Thus, landscape context for the stands within each block is similar over the scales at which northern flying squirrels can travel. Distances between blocks range from 2.5 km to 21 km.

Before thinning, Douglas-fir (*Pseudotsuga menziesii*) was the dominant overstory tree species with varying amounts of western hemlock (*T. heterophylla*), western redcedar (*Thuja plicata*), and hardwoods including bigleaf maple (*Acer macrophyllum*), and golden chinquapin (*Chrysolepis chrysophylla*). The understory consisted primarily of vine maple (*Acer circinatum*), cascara buckthorn (*Rhamnus purshiana*), bitter cherry (*Prunus emarginata*), Oregon-grape (*Mahonia nervosa*), salal (*Gaultheria shallon*), and swordfern (*Polystichum munitum*).

Pre-thinning sampling of the vegetative structure within each stand in 1993 established that stands within each block were similar with respect to tree basal area (overall mean 34.8 m^2/ha; average CV for 4 blocks = 8.7%) and tree density (overall mean density 718 trees per ha; average CV over 4 blocks = 10.1%; (Davis et al., 2007). Before treatment commenced, each stand was assigned randomly to one of the thinning treatments or as an unthinned control. Thinning began in late 1994, and was completed by February 1997. Most harvest activity occurred simultaneously on all blocks between February 1995 and September 1996 and with no particular pattern to order of treatments.