Crop Protection 30 (2011) 833–843

Contents lists available at ScienceDirect

Crop Protection

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

Balancing pest management and forest biodiversity: Vole populations and habitat in clearcut vs. variable retention harvested sites

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ARTICLE INFO

Article history:
Received 19 September 2010
Received in revised form
25 February 2011
Accepted 1 March 2011

Keywords:
Biodiversity
Clearcutting
Coniferous tree seedlings
Feeding damage
Green-tree retention
Microtus voles
Plantations
Red-backed voles
Variable retention harvests

ABSTRACT

Voles of the genus *Microtus* are long-standing pests in temperate and boreal forests of North America, Europe, and Asia where they feed on newly planted trees on cutover forest land. Clearcutting (CC) dominates forest harvesting and produces homogeneous habitats for voles. Variable retention (VR) harvests involve various partial cutting practices that produce heterogeneous habitat patterns compared with CC. This study tested the hypotheses (H) that compared to CC, VR harvesting will (H_1) limit population size of *Microtus* and feeding damage to tree seedlings; (H_2) provide some mature forest habitat for red-backed voles (*Myodes gapperi*); and (H_3) enhance abundance and species diversity of the terrestrial small mammal community. *Microtus*, red-backed voles, and other forest-floor small mammals were live-trapped for three years (2007–2009) on "young" and "older" CC and VR sites near Golden, British Columbia, Canada. Mean basal area (BA) and density of overstory coniferous trees were significantly ($P \leq 0.03$) higher in the young VR than CC sites. Abundance of herbaceous vegetation and grasses was similar in both harvesting systems at 3- and 5-years post-harvest. Although not statistically significant, the relatively higher numbers (2.3–2.9 times) of *Microtus* on CC than VR sites at 3–4 years post-harvest is suggestive that VR may reduce *Microtus* population size. However, the mean abundance of 35 *Microtus*/ha in VR sites at 3 years post-harvest was at the border-line of moderate to high risk of feeding damage. Based on equivocal levels of vole damage to plantation trees on CC and VR sites, the damage part of H_1 was refuted. With respect to H_2, VR harvesting did provide some forest habitat for red-backed voles, at least initially in the third year, and then again at 10–20 years, after VR cutting. Total abundance and species diversity of the terrestrial small mammal community were similar in CC and VR sites, and hence H_3 was rejected. The mean BA (14.7 m^2/ha) and density (73–127 trees/ha) of overstory (>10–20 m height) trees of our VR sites were insufficient to alter development of understory herbaceous vegetation and abundance of *Microtus*. Higher levels of VR should be investigated as a means of reducing this pest problem in young plantations.

1. Introduction

There is a long history of feeding damage to deciduous and coniferous tree plantations by voles of the genera *Microtus* and *Myodes* in North America, Europe, and Asia (Byers, 1984; Hansson, 1985; Shu, 1985; Bergeron and Jodoin, 1989; Gill, 1992). Voles feed on the bark, cambium, phloem, and roots of trees during winter months when alternative foods are unavailable (Huitu et al., 2003). Direct mortality may occur from girdling and clipping of tree stems, as well as reduced growth of trees that survive sub-lethal feeding injuries (Sullivan et al., 1990). Feeding damage typically occurs during winters of peak years in abundance. Such peak populations may occur on a multi-annual 3- to 5-year interval in northern latitudes (Krebs and Myers, 1974; Korpimäki and Krebs, 1996), and may be interspersed with annual fluctuations in abundance (Taitt and Krebs, 1985).

Feeding damage appears higher in seedlings with nursery fertilization regimes that enhance palatability and nutrition than in wildlings that arise from natural regeneration (Sullivan and Martin, 1991). This damage increases the cost to reforest these stands in time for "free growing status", results in loss of mean annual growth increment, and decreases net productive forested area. Feeding damage may impact conservation of natural forests because of limited regeneration of appropriate tree species in certain forest ecosystems. Damage appears to be associated with high populations of voles in early successional habitats that

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doi:10.1016/j.cropro.2011.03.001

develop after harvesting by clearcutting and wildfire (Hansson, 1989; Sullivan and Sullivan, 2001, 2010; Fisher and Wilkinson, 2005). Old fields (perennial grasslands, abandoned farmland) that are being afforested also provide prime habitats for voles and subsequent damage to planted trees (Radvanyi, 1980; Bergeron and Jodoin, 1989; Ostfeld and Canham, 1993). These habitats are usually composed of grasses, forbs, and shrubs that provide food and cover for *Microtus* voles (Batzli, 1985; Ostfeld, 1985).

The long-tailed vole (*Microtus longicaudus*), the meadow vole (*Microtus pennsylvanicus*), and the montane vole (*Microtus montanus*) are implicated as major consumers of tree seedlings in inland areas of the Pacific Northwest of North America (Sullivan and Sullivan, 2010). Populations of the southern red-backed vole (*Myodes gapperi*) occur primarily in mature stands of timber, and survive in recently cut areas for only 1–2 years after harvest (Gashwiler, 1970; Merritt, 1981; Klenner and Sullivan, 2003). Thus, this microtine usually does not feed on planted tree seedlings. The red-backed vole is considered an indicator species of late successional conditions in boreal and temperate forests of North America (Merritt, 1981; Nordyke and Buskirk, 1991). However, red-backed voles seem to persist in some partially harvested forests with conservation of at least some components of mature forest biodiversity such as large overstory coniferous trees, downed logs, and understory conifers.

There has been much interest in the relationship of habitat heterogeneity to population dynamics of small mammals (Hansson, 1977; Stenseth, 1980; Bondrup-Nielsen, 1987). Inherent in this relationship is the role of vegetative succession after disturbance by harvesting or wildfire. Amount of vegetative cover is an important component of habitat quality and selection, population density, and demography of *Microtus* species (Birney et al., 1976; Getz, 1985; Adler and Wilson, 1989). There seems to be a threshold level of cover and plant production that generates peak populations and potentially fluctuations of *Microtus* species (Birney et al., 1976; Laine and Henttonen, 1983). The herbaceous component, particularly grasses whether native or introduced, seem crucial to maintaining suitable habitat conditions for voles (Adler and Wilson, 1989; Sullivan and Sullivan, 2010). Habitats after forest harvesting or wildfire disturbance are typically dominated by herbs and grasses for up to 5–10 years, depending on the ecosystem.

Clearcutting has historically dominated harvesting of forests and results in relatively homogeneous early successional habitats. Variable retention harvests have generated much attention over the past 20 years in some temperate and boreal coniferous forests (Franklin et al., 1997; Burton et al., 2003). VR leaves large live trees, snags, and downed logs after harvest to provide some mature forest habitat, structural diversity, and continuity in the regenerating stand (McComb et al., 1993; Franklin et al., 2002). VR may involve various partial cutting practices such as individual tree selection, shelterwood, and seed-tree systems (Smith, 1986) that produce relatively heterogeneous habitat patterns compared with clearcutting. The degree of habitat heterogeneity generated by VR, and its consequent impact on *Microtus* voles and red-backed voles, likely depend on the number and distribution of residual trees and their influence on understory vegetation during the early successional years after cutting.

Emmingham et al. (1992) first suggested the use of alternative harvesting systems to manage feeding damage by mammals. Sullivan and Sullivan (2001) reported that mean abundance of *Microtus* was inversely, and that of red-backed voles positively, related to mean basal area (BA) and density of residual trees, up to three years after harvest. However, *Microtus* numbers at their peak, 3 years post-clearcutting, were relatively low (mean of 23 voles/ha), as was the incidence of feeding damage to seedlings (range of mortality 0.4–3.0%) (Sullivan and Sullivan, 2001). These equivocal results suggested strongly that we should compare the two harvesting methods in a region with a history of repeated plantation failures owing to feeding damage to trees by *Microtus*. Such an area exists in the Rocky Mountains near Golden, in the southern interior of British Columbia (BC), Canada (Sullivan and Sullivan, 2008, 2010).

This study was designed to test the hypotheses (H) that compared to clearcutting, variable retention harvesting will create habitat heterogeneity to (H_1) limit population size of *Microtus* and feeding damage to tree seedlings; (H_2) provide some mature forest habitat for red-backed voles; and (H_3) enhance abundance and species diversity of the terrestrial small mammal community.

2. Methods

2.1. Study areas

Study areas were located at Glenogle Creek and Roth Creek, 25 km east of Golden, BC (51°18′N; 116°45′W), within the Interior Douglas-fir (IDF_{dm}), Montane Spruce (MS_{dk}), and Interior Cedar-Hemlock (ICH_{mk}) biogeoclimatic (BEC) zones (Meidinger and Pojar, 1991). Topography ranged from hilly to very steep terrain at 1125–1540 m elevation.

The upper IDF and MS have a cool, continental climate with cold winters and moderately short, warm summers. The average temperature is below 0 °C for 2–5 months, and above 10 °C for 2–5 months, with mean annual precipitation ranging from 30 to 90 cm. Open to closed mature forests of Douglas-fir (*Pseudotsuga menziesii*) cover much of the IDF zone, with even-aged post-fire lodgepole pine (*Pinus contorta*) stands at higher elevations. The MS landscape has extensive young and maturing seral stages of lodgepole pine, which have regenerated after wildfire. Hybrid interior spruce (*Picea glauca* × *Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) are the dominant shade-tolerant climax trees. Douglas-fir is an important seral species in zonal ecosystems and is a climax species on warm south-facing slopes in the driest ecosystems. Trembling aspen (*Populus tremuloides*) is a common seral species and black cottonwood (*Populus trichocarpa*) occurs on some moist sites (Meidinger and Pojar, 1991). The ICH has an interior, continental climate with cool wet winters and warm dry summers. Mean annual temperature ranged from 2 to 8.7 °C. The temperature averages below 0 °C for 2–5 months, and above 10 °C for 3–5 months of the year. Mean annual precipitation was 50–120 cm, 25–50% of which falls as snow. Upland coniferous forests dominate the ICH landscape and comprise the highest diversity of tree species of any zone in BC. Western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) dominate mature climax forests, with lodgepole pine, white spruce, Engelmann spruce, their hybrids, and subalpine fir common in these stands (Meidinger and Pojar, 1991).

Prior to harvesting, all stands at the Golden study areas were composed of a mixture of lodgepole pine with variable amounts of Douglas-fir, spruce, and some subalpine fir. Average ages of lodgepole pine ranged from 80 to 120 years and for Douglas-fir ranged from 120 to 220 years. Average tree heights ranged from 10.5 to 19.5 m for lodgepole pine and from 16.7 to 27.5 m for Douglas-fir. There were no site preparation treatments on any of these harvested sites, prior to planting.

2.2. Experimental design and treatments

The study began with an "initial survey" of three clearcut (CC) and three variable retention (VR) sites in August 2006. This single sample was followed by a study with a randomized design with three replicates each of "young" (4–5 years post-harvest) CC and VR sites (Fig. 1a and b); and three replicates each of "older" (9–19