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Wildfire, clearcutting, and vole populations: Balancing forest crop protection and biodiversity

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ABSTRACT

Early successional forest habitats that develop after wildfire may provide ideal conditions for population build-ups and subsequent fluctuations by *Microtus* voles. Regeneration of burned-over forest land may be hindered by consumption of planted trees by voles. A high abundance of voles, occurring in the second growing season after a wildfire, may result in serious feeding damage to seedlings leading to major plantation failures. A wildfire occurred near Golden, British Columbia, Canada in the spring of 2011 and may have initiated the successional conditions to generate a vole population outbreak with consequent feeding damage to tree seedlings. We tested the hypotheses (H) that (H_1) abundance of herbaceous plants (grasses and forbs) will be greater, and (H_2) abundance of voles and incidence of feeding damage to tree seedlings will be higher, in burned than unburned (control) sites. *Microtus* voles and other forest-floor small mammals were live-trapped for four years (2011–2014) in replicated sites of a wildfire (burned plantation), control (unburned) plantation, and a new control clearcut. Abundance of total herbs and grasses, incidence of feeding damage, and mortality to tree seedlings by voles were measured in all sites. Mean abundance of total herbs and grasses were similar among treatments during the post-wildfire period. Mean annual peak numbers of *Microtus* in clearcut sites ranged from 18 to 30 per index-line. Annual peak numbers in the burned and control plantation sites ranged from 5 to 8 voles per index-line and were essentially stable at these numbers. Vole populations in the control and burned plantation sites were dominated by the meadow vole (*Microtus pennsylvanicus* Ord), and those in the clearcut sites by the long-tailed vole (*Microtus longicaudus* Merriam). Mean mortality of trees was significantly higher in the control clearcut sites at 30% compared with 13% in the burned plantation sites. These results did not support either H_1 or H_2. Wildfire, at least in this case, did not generate high populations of voles and significant damage to tree seedlings. Mean abundance of total small mammals was similar in burned and control plantation sites, but less than in clearcut sites. Populations of the deer mouse (*Peromyscus maniculatus* Wagner) increased after wildfire and those of the southern red-backed vole (*Myodes gapperi* Vigors) declined. Populations of the northwestern chipmunk (*Neotamias amoenus* J.A. Allen) and *Sorex* spp. did not show a clear preference for any of the treatments. Disturbance by clearcutting or wildfire seemed to reduce species richness and diversity, but all eight species of small mammals were present in each of the treatments.

1. Introduction

Forest lands in western North America and some other temperate and boreal ecological zones have increasing frequency and severity of wildfires because of dense forest conditions, heavy fuel loads, and drier conditions owing to climate change (Agee, 1993; Covington, 2000). Wildfire and some types of prescribed burning may convert unavailable mineral nutrients into forms more available to plants, thereby resulting in higher nutrient availability (Kimmins, 1987). This process may result in early successional vegetation that has high forage quality for herbivores. Depending on the severity of the fire disturbance, small mammals recolonize burned areas corresponding with species-specific habitat associations. Granivores/omnivores such as deer mice (*Peromyscus* spp.), harvest mice (*Reithrodontomys* spp.), and

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chipmunks (*Neotamias* spp.) dominate early successional sites which tend to be "open" habitats prior to substantial vegetative development (Fox, 1990; Fisher and Wilkinson, 2005). Herbivores such as *Microtus* spp. follow when grasses and herbs appear and provide sufficient food and cover (Batzli, 1985; Ostfeld, 1985). In particular, voles may thrive on this flush of vegetative growth and may generate population build-ups and subsequent fluctuations (Birney et al., 1976; Laine and Henttonen, 1983; Adler and Wilson, 1989). Grass seeding of burned and clearcut areas to stabilize soils and landforms (Beyers, 2004) may also rapidly produce vegetative food and cover conducive to *Microtus* spp. (Sullivan and Sullivan, 2010).

Forest lands subjected to wildfire often require some degree of artificial regeneration (planting of tree seedlings) to complement that occurring from natural sources. A potential problem is consumption of newly planted trees by voles (*Microtus* spp.), which may occur in the early successional vegetation and habitats arising after the fire. Feeding damage to deciduous and coniferous tree plantations by *Microtus* and *Myodes* species tends to occur on a site-specific basis, but is prevalent in North America, Europe, and Asia (Byers, 1984; Shu, 1985; Gill, 1992; Huitu et al., 2009). It is primarily during overwinter periods when microtines feed on bark, vascular tissues (phloem and cambium), and sometimes roots of plantation trees (Huitu et al., 2009). Direct mortality may result from girdling and clipping of tree stems, and reduced growth of trees that survive sub-lethal feeding injuries (Sullivan et al., 1990). Planted trees, with their nursery fertilization regime and enhanced palatability and nutrition, are nearly always preferred by voles over wildlings arising from natural regeneration (Sullivan and Martin, 1991). Lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.) and Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco. var *glauca* (Beissn.) Franco) are the most susceptible coniferous tree species to feeding damage by *Microtus* spp. in the interior of British Columbia (BC), although nursery-raised spruce (*Picea glauca* (Moench) Voss x *Picea engelmannii* Parry) and western larch (*Larix occidentalis* Nutt.) seedlings are also quite palatable (Sullivan et al., 1990). Feeding damage is most common with high vole populations in early successional habitats after clearcutting (Huitu et al., 2009; Sullivan and Sullivan, 2010), or in some cases, wildfire (Sullivan et al., 2007). Because voles preferentially feed on particular tree species (Bucyanayandi et al., 1990), this feeding damage may limit regeneration of appropriate tree species in certain forest ecosystems. Damage also increases the cost to reforest these stands in time for free growing status, decreases net productive forested area, and results in loss of mean annual increment.

The long-tailed vole (*Microtus longicaudus*) and the meadow vole (*Microtus pennsylvanicus*) are major consumers of tree seedlings in inland areas of the Pacific Northwest (PNW) of North America (Sullivan et al., 1990). The heather vole (*Phenacomys intermedius* Merriam) may also be present but occurs at very low abundance (1–2 animals/ha) (McAllister and Hoffman, 1988). Populations of the southern red-backed vole (*Myodes gapperi*) occur primarily in mature stands of timber (Merritt, 1981), but some animals may linger on recently cut areas for 1–2 years after harvest before disappearing for several decades (Zwolak, 2009). Populations of long-tailed voles seem to have an annual cycle of abundance that is tied to changes in early successional vegetation, at least in post-harvest forest sites (Van Horne, 1982; Sullivan et al., 1999; Sullivan and Sullivan, 2010). Populations of meadow voles tend to have cyclic fluctuations in abundance with a peak every 3–5 years, although these periods may be interspersed with annual fluctuations in abundance (Krebs and Myers, 1974; Getz et al., 2001).

Following wildfires in 1998 and 2003 in the southern interior of BC, populations of *M. longicaudus* and *M. pennsylvanicus* responded positively to post-fire habitat conditions reaching densities high enough for people to observe them, and spilling over into agricultural and residential areas of several communities during the second summer and fall, 2000 and 2005, respectively, after each fire (Sullivan et al., 2007). Similar responses were reported for *Microtus* populations that recovered in the second year in grassland and brush habitats (Cook, 1959), larch-fir forests after a light burn (Halvorson, 1982), and black spruce forests three years after a burn (Simon et al., 1998). Recovered populations often surpassed pre-burn numbers (Cook, 1959; Halvorson, 1982).

The proximity of agricultural land and riparian vegetation in nearby valleys may have provided source areas for grass and herb seed dispersal, as well as populations of voles, to colonize the burned-over forestland. This high abundance of voles, occurring in the second growing season after a wildfire, resulted in serious feeding damage to seedlings leading to major plantation failures (Sullivan et al., 2007). Voles declined dramatically overwinter to numbers <1/ha from peak populations (50–60/ha) in the previous autumn of each outbreak event. This population peak appeared to be independent of other fluctuations in vole numbers.

What, then, triggers a rapid build-up of vole numbers to levels capable of major tree loss in newly planted sites on burned-over forest land? Long-tailed voles, as well as other *Microtus*, seem to require a given threshold of cover to occupy a habitat and increase in abundance (Van Horne, 1982; Getz, 1985). For example, a threshold level of 50% cover was required in linear habitats composed of pasture grasses to generate suitable habitat for vole numbers to reach tree damage levels (Sullivan and Sullivan, 2010). Adler and Wilson (1989) also reported that abundance and survival of meadow voles increased linearly up to a critical level of grass cover of 30–40%.

Young forest plantations in the Rocky Mountains near Golden in south-central BC have a 20-year history of plantation failures owing to severe feeding damage from *Microtus* (Sullivan and Sullivan, 2010). A 20-ha wildfire occurred in the spring of 2011 and may have initiated the successional conditions to generate a vole population outbreak during or after the second growing season of recovery. Thus, over a 4-year period, we tested the hypotheses (H) that (H_1) abundance of herbaceous plants (grasses and forbs) will be greater, and (H_2) abundance of voles and incidence of feeding damage to tree seedlings will be higher, in burned than unburned (control) sites.

2. Methods

2.1. Study areas

Study areas were located at Roth Creek (51°18′N; 116°45′W) and East Palliser (51°14′39″ N; 116°41′27″ W), 25 and 30 km east of Golden, British Columbia (BC), Canada, respectively. Roth Creek study sites were within the Montane Spruce (MS_{dk}), and East Palliser sites in the Interior Cedar-Hemlock (ICH_{mk}) biogeoclimatic zones (Meidinger and Pojar, 1991). Topography ranged from hilly to very steep terrain at 1090–1280 m elevation.

The MS has 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. The MS landscape has extensive young and maturing seral stages of lodgepole pine, which have regenerated after wildfire. Hybrid interior spruce and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) 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* Michx.) is a common seral species and