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Short communication

Spruce beetles and timber harvest in Alaska: Implications for northern red-backed voles

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Abstract

Changes in structure and function of spruce forests occurred following a recent spruce beetle (*Dendroctonus rufipennis*) epidemic in the temperate forests of south-central Alaska. To assess the effects of this infestation and the subsequent land management practices used to reduce the risk of catastrophic fire, we measured northern red-backed vole (*Clethrionomys rutilus*) abundance over a 10-year period. We established eight live trapping grids across white spruce (*Picea glauca*) forests. Dead trees were harvested from four treatment grids; four grids remained as reference (not harvested). Northern red-backed vole populations synchronously declined across all sampling areas following the spruce beetle infestation, and began recovery by the end of the study. Population decline and subsequent recovery did not appear to be influenced by timber harvest.

Keywords: Alaska; *Clethrionomys rutilus*; *Dendroctonus rufipennis*; Kenai Peninsula; Northern red-backed vole; *Picea glauca*; Timber harvest; Spruce beetle

1. Introduction

Spruce beetle infestation has been the most significant disturbance agent affecting white spruce forests in Alaska in the last century (van Hees and Holsten, 1994). The recent and unusually severe epidemic of spruce beetles peaked in 1996 and killed an estimated 30 million spruce trees (USDA Forest Service, 1997). Changes in structure and function of spruce forests were profound. For example, following mortality of trees >30 cm diameter at breast height, stand structure was altered by opening of the forest canopy and increased growth rate of residual trees (Holsten et al., 1995). Beetle-infested spruce forests also have lower plant species richness and higher biomass production, snag density, and downed woody debris than non-infested forests (Holsten et al., 1995; Stone, 1995).

The distribution of northern red-backed voles is important because they serve as a dispersal agent for mychorizal fungi (Maser et al., 1978; Ure and Maser, 1982), are tied to conifer succession and regeneration (Terwilliger and Pastor, 1999), and are a primary prey species (Buskirk and MacDonald, 1984; Bull et al., 1989; Martin, 1994). Both spruce beetle infestations and timber harvest potentially affect red-backed vole abundances. The processes that are thought to govern these changes include changes in cover (Stone, 1995) and availability of foods, such as berries, lichens, forbs, arthropods, mosses, and spruce seeds (Whitney, 1976; West, 1979; Bangs, 1984; Suring et al., in press). The removal of trees by timber harvest has been reported to influence vole survival, reproduction, recruitment, and dispersal (Sullivan and Sullivan, 2001). Red-backed voles are adapted to survive periodic disturbances and may successfully use disturbed habitats (Campbell and Clark, 1980; West et al., 1980). However, the understanding of microtine response to disturbance is confounded by the reported cyclic nature of their populations, for which cause and duration have been debated (Pruitt, 1968; Krebs, 1978; West, 1979; Orrock et al., 2000).

We quantified northern red-backed vole population changes following infestation by spruce beetles and hypothesized that

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microtine abundance would change through time in both natural and managed forests. We expected that spruce beetle infestation would positively affect northern red-backed vole populations due to increased food production in open-canopy forests (Stone, 1995; Suring et al., in press) and increased accumulation of downed logs used for cover (Stone, 1995). Conversely, we expected that timber harvest would negatively affect northern red-backed vole populations due to their association with mature forests (Campbell and Clark, 1980; Ramirez and Hornocker, 1981; Halvorson, 1982; Martell, 1983; Walters, 1991).

2. Methods

2.1. Study area

Our investigation took place on the Chugach National Forest, Kenai Peninsula, south-central Alaska (60.5°N; 149.5°W) in a beetle-infested white spruce forest. White spruce forest (90% spruce) represented an introgression zone for white and Sitka spruce (*Picea sitchensis*) (Werner and Holsten, 1983). Mountain hemlock (*Tsuga mertensiana*), paper birch (*Betula papyrifera*) and quaking aspen (*Populus tremuloides*) accounted for the remaining 10% of overstory species and understory vegetation included alder (*Alnus* spp.), willow (*Salix* spp.), rusty menziesia (*Menziesia ferruginea*), and blueberry (*Vaccinium* spp.). We selected sampling areas based on similarity of elevation, aspect and forest age.

We selected eight grids within a 2.5 km^2 area, four as reference and four treated with mechanical timber harvest. Sampling grids were spaced >100 m apart, >100 m from a vegetation edge, and with >100 m of uncut forest buffer between reference and treatment areas. Study sites were infested by spruce beetles prior to 1991 and salvage harvest treatments were used to remove dead and dying trees during winter 1992 and 1993 (USDA Forest Service, 1990).

2.2. Field sampling

We trapped northern red-backed voles during August from 1991 to 2000. In each of the eight study sites we placed a 7 × 7 grid (49 trap stations with 10-m spacing) with two Sherman live traps at each station for a total of 98 traps per 3600-m^2 grid. We baited traps with commercial rodent food, opened them in the morning, and checked each subsequent morning for three consecutive 24-h periods. We sampled in accordance with the Alaska Department of Fish and Game ethics approval.

We trapped all eight grids in 1991. Timber harvests occurred in four of the white spruce grids between 1992 and 1993. We re-sampled all eight grids in 1994, 1996, 1997, and 2000. We collected vegetation data within a 12.8 m radius plot, at the center of each trap grid, in 1991 and 2000. We collected percentage of canopy cover by tree species, ferns, forbs, grass, lichens, shrubs, moss (DeVelice et al., 1999); counts of snags; number, mean length, diameter (large-end, small-end, mean), and decay class of downed logs (mean decay class, and counts of logs in each of five decay classes, one being little decay and five being highly decayed; Sollins, 1982).

2.3. Statistical analyses

We expressed an index of relative abundance of northern red-backed voles as catch per unit effort (CPUE; number of adults and juveniles captured per trap night) before and after spruce beetle infestation and subsequent timber harvest between four white spruce treatment grids and four white spruce reference grids (Slade and Blair, 2000). We assumed capture probabilities were homogeneous among all trap sites, although we did not validate that assumption. We did not adjust counts for detection or recapture probabilities nor did we examine sex ratios or age structure. We assumed the effective area sampled was constant among all trap sites. We compared relative abundance of northern red-backed voles pre-harvest to each year we sampled populations post-harvest to assess the influence of the infestation and timber harvest on changes in CPUE through time. We calculated pair-wise differences in mean CPUE between years for each sampling area and pair-wise differences between sampling areas for each year using Bonferroni alpha levels.

We used Poisson regression on each grid to predict the multiplicative difference in the pre- to post-1991 CPUE, using a before/after – control/impact (BACI) design to determine if timber harvest had an effect on northern red-back vole abundance (Green, 1979; Sokal and Rohlf, 1998). We estimated the abundance trend for each sampling area using linear regression on the time variable with CPUE as the response. We compared confidence intervals around each trend estimate to determine if abundance trends for one sampling area were significantly different from another. We considered trend estimates significantly different if the point estimate was not contained in the pre- or post-year's confidence interval.

To determine if aspects of vegetation change influenced changes in northern red-backed vole abundance, we used Student's *t*-tests to identify differences in habitat variables between treatment and control areas and among years. We also calculated Wald *t*-tests to determine if slopes of trend lines for each vegetation variable through time were significantly different from 0.

3. Results

Pre-treatment, in 1991, northern red-backed vole CPUE was greater in white spruce treatment sites than reference sites ($t = -0.209$, d.f. = 1, $p < 0.05$) (Fig. 1). Vole CPUE declined in both treatment and reference areas between 1991 and 1994, stabilized at low levels between 1994 and 1997, and began to recover between 1997 and 2000 (Fig. 1). We did not observe different recovery rates between treatments. Following treatment, we found no multiplicative differences in CPUE (BACI treatment effect from 1991 to 2000) between white spruce treatment and reference areas (1.97, 95% CI 0.89–4.35, $p = 0.1186$).

From 1991 to 2000 (one-sample *t*-test; $n = 4$; d.f. = 3), the number of snags decreased in both reference (−13.50;

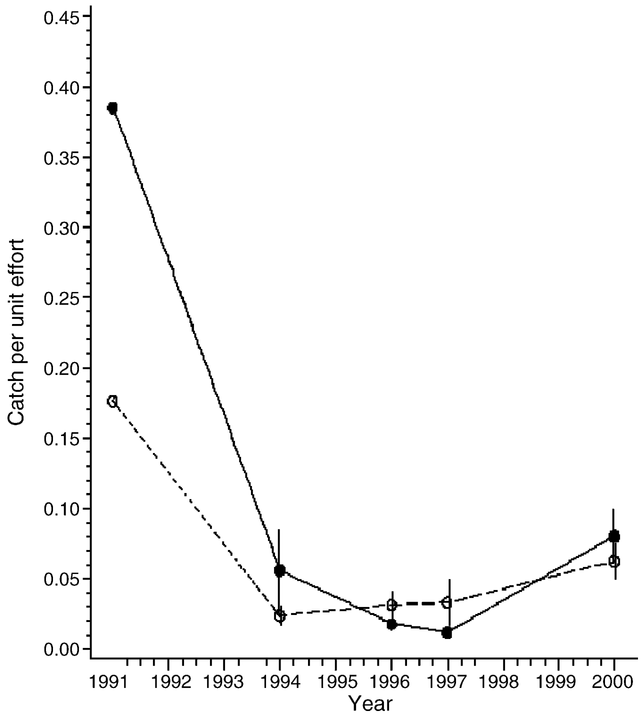

Fig. 1. Northern red-backed vole change in relative abundance (catch per unit effort) from 1991 to 2000, averaged over four reference and four treatment grids. Vertical lines represent 1 S.D. Solid circles represent the white spruce treatment grids and open circles represent the white spruce reference grids. Harvest treatments were completed in 1992 and 1993.

$t = -3.495$; $p = 0.0396$) and treatment (-17.25; $t = -7.314$; $p = 0.0053$) sites. The percentage of tall shrubs increased in reference sites (16.55; $t = 5.807$; $p = 0.0102$). We found no change in coarse wood debris in either reference (-4.00; $t = -1.1016$; $p = 0.3844$) or treatment (12.25; $t = 1.519$; $p = 0.2261$) sites.

In 1991, standing dead trees were at an approximate density of 18 trees/500 m^2, and logs were at an approximate density of 35 logs/500 m^2. We found no differences in vegetation characteristics between treatment and reference sites from 1991 to 2000, except that treatment sites (mean = -15.5) had a larger change in percentage of canopy cover of trees (two-sample t-test; $t = 2.46$; $n = 11$; d.f. = 9; $p = 0.0391$) than reference sites (mean = -3.775).

4. Discussion

Populations of northern red-backed voles were potentially influenced by three major disturbance mechanisms acting at different temporal and spatial scales: spruce beetle infestation; timber harvest; natural population cycles. The synergistic action of these disturbances may have confounded observed population responses to site conditions and treatment. In 1991 CPUE was higher in the sites scheduled for harvest. CPUE declined in both harvest and reference sites following spruce-beetle infestation, and recovery of CPUE occurred at similar rates in reference and harvest study sites.

Reported response of northern red-backed voles to spruce beetle infestation in Alaska is equivocal. High levels of beetle-induced spruce mortality in the Copper River Basin negatively affected northern red-backed vole abundance (McDonough, 2000), while spruce beetle infestations on the Kenai Peninsula positively affected northern red-backed vole abundance (Williams, 1999). Contradictory outcomes may be due to species composition of the forest prior to disturbance, intensity of disturbance, and subsequent vegetation succession on the site (Martell, 1983). They may also result from density-dependent habitat selection, which is especially likely in a cyclic species (Morris, 1987, 1996).

Small mammal population changes also have been linked to changes in vegetation resulting from timber harvest. Clough (1987) found that mature conifer forests in Maine supported a higher relative abundance of southern red-backed voles (*Clethrionomys gapperi*) than harvested sites, and attributed the difference in abundance to the alteration of the shrub and ground vegetation components rather than overstory removal. West et al. (1980) also reported that northern red-backed voles persisted in clearcut white spruce forests in central Alaska. Smith and Nichols (2004) found that southern red-backed vole populations in southeast Alaska may not be as sensitive to overstory removal as reported elsewhere. However, southern red-backed voles have been shown to persist in clearcuts up to 6 years after timber harvest then decline in subsequent years due to alteration of key habitat attributes (i.e., mesic conditions) as the clearcut aged (Sullivan et al., 1999).

In central Alaska, timing in peak density of northern red-backed voles has been variable and may be different by ecoregion (West, 1982). By employing single trapping episodes repeated each August, we may not have captured animals in a manner that precisely reflected the annual microtine cycle. Similarly, since we only measured northern red-backed vole CPUE in four reference and four treatment sites low power may have affected the results. Nonetheless, this study provides valuable insights since previous studies have not addressed the effects of both spruce-beetle infestation and timber harvest on northern red-backed voles. Timber harvest following spruce beetle infestation did not appear to exacerbate the effects of the infestation nor alter the recovery of voles following an apparent cyclic population decline. Since the two events were not additive or synergistic in their impact, forest managers may have additional options when considering tree removal following future beetle infestations.

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