Alternative conifer release treatments affect small mammals in northwestern Ontario

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Density changes of small mammals responding to different conifer release treatments (motor-manual [brush saw] cutting; mechanical [Silvana Selective] cutting; helicopter-applied herbicides [Release[®] (a.i. triclopyr), Vision[®] (a.i. glyphosate)]; controls [no treatment] were quantified. A total of 4,851 small mammals were captured and released during the three-year study. The most commonly captured (81% of total) species were: shrews (masked [*Sorex cinereus* Kerr], pygmy [*S. hoyi* Baird], arctic [*S. arcticus* Kerr]), southern red-backed voles (*Clethrionomys gapperi* Vigors), and deer mice (*Peromyscus maniculatus* Wagner). Northern short-tailed shrews (*Blarina brevicauda* Say), eastern (*Tamias striatus* L.) and least (*T. minimus* Bachman) chipmunks, meadow voles (*Microtus pennsylvanicus* Ord), ermine (*Mustela erminea* L.), and meadow jumping mice (*Zapus hudsonius* Zimm.) were common. Shrew (masked, pygmy, arctic, short-tailed) densities were statistically unaffected by these treatments. Red-backed vole densities were highest on control plots during the first post-treatment growing season, and highest on control and Vision[®] plots during the second post-treatment growing season. During the first two growing seasons after treatment, deer mouse densities were highest on Silvana Selective plots; eastern chipmunk densities were highest on control, Vision[®] and Silvana Selective plots; least chipmunk densities were highest on Vision[®] and Release[®] plots; and meadow vole densities were highest on Release[®] plots. Small mammal responses to the alternative conifer release treatments examined were species specific one and two-growing seasons post-treatment, but similar to responses common to the standard (Vision[®] herbicide) conifer release treatment.

Key words: conifer release, Fallingsnow Ecosystem Project, glyphosate, herbicides, Release[®], small mammals, spruce plantation, triclopyr, vegetation management alternatives, Vision[®], wildlife habitat

Cette étude s'est penchée sur les changements de densité survenus parmi les petits mammifères suite à la réalisation de différents traitements de dégagement des conifères: dégagement manuel mécanisé [scie débroussailluse]; dégagement mécanisé [Silvana Selective]; pulvérisations de phytocides au moyen d'un hélicoptère [Release[®] (é.a. triclopyr) et Vision[®] (é.a. glyphosate)]; et parcelles témoins [aucun traitement]. Un total de 4 851 petits mammifères furent capturés et relâchés au cours des trois années de l'étude. Les espèces les plus souvent capturées étaient: les musaraignes (cendrées [*Sorex cinereus* Kerr], pygmées [*S. hoyi* Baird], artiques [*S. arcticus* Kerr], des campagnols à dos roux (*Clethrionomys gapperi* Vigors), et des souris sylvestres (*Peromyscus maniculatus* Wagner). Les musaraignes à queue courte (*Blarina brevicauda* Say), des tamias rayés (*Tamias striatus* L.) et des tamias mineurs (*T. minimus* Bachman), ainsi que des campagnols des champs (*Microtus pennsylvanicus* Ord), des helettes à queue courte (*Mustela erminea* T.) et des souris sauteuses des champs (*Zapus hudsonius* Zimm.) étaient fréquentes. Les densités des musaraignes (cendrées, pygmées, artiques et à petite queue) ne furent statistiquement perturbées par ces traitements. Les densités de campagnol à dos roux étaient les plus élevées dans les parcelles témoins au cours de la première année de croissance après le traitement, et les plus élevées dans les parcelles témoins et les parcelles traitées au Vision[®] au cours de la deuxième année de croissance après traitement. Au cours des deux premières années de croissance après traitement, les densités de souris sylvestres furent les plus élevées dans les parcelles traitées au moyen du Silvana Selective; les densités de tamias rayés furent les plus élevées dans les parcelles témoins, et dans les parcelles traitées au moyen du Vision[®] et du Silvana Selective; les densités de tamias mineurs furent les plus élevées dans les parcelles traitées au Vision[®] et au Release[®]; et les densités de campagnols des champs furent les plus élevées dans les parcelles traitées au Release[®]. Les réactions des petits mammifères par rapport aux traitements alternatifs de dégagement des conifères étudiés étaient spécifiques aux espèces une et deux années de croissance après traitement, mais semblables aux réactions habituelles rencontrées lors de l'utilisation courante du traitement de dégagement des conifères (phytocide Vision[®]).

Mots clés: dégagement de conifères, projet écosystémique de Fallingsnow, phyphosphate, phytocides, Release[®], petits mammifères, plantation d'épinette, triclopyr, alternatives de contrôle de la végétation, Vision[®], habitat faunique

Introduction

Forest regeneration success in many North American ecosystems commonly depends on managing non-crop vegetation ("competition") (Walstad and Kuch 1987). In Canada aerial conifer release ("tending") with herbicides is the most commonly used forest vegetation management practice (Campbell 1990). Herbicides are preferred because they are the least expensive silvicultural treatment for increasing forest crop yield (Campbell 1990). Although foresters have relied on herbicides to control non-crop vegetation for the last three decades (Stewart *et al.* 1984), this practice has met

with increasing public resistance (Walstad and Dost 1984; Lautenschlager 1986; Campbell 1990; Freedman 1991; Wagner 1993). In 1989, 71% of Canadians thought "chemicals in the forest" were an unacceptable form of forest management (Environics Research Group 1989); in 1994, 80% of Ontario's public stated that aerial herbicide applications for forest management were unacceptable (Decision Research 1995).

In the early 1990s, concerns related to the increasing use of herbicides for forest management in Ontario contributed to the development of the Vegetation Management Alternatives Program (VMAP), part of the Ontario Ministry of Natural Resources Sustainable Forestry Initiative (Wagner 1992). The VMAP program seeks to develop forest management approaches (alternatives) that reduce dependence on aerially

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applied herbicides. After possible alternatives are identified, they are tested against standard (aerial) herbicide technologies for efficacy (non-crop reduction [short-term], crop tree growth [longer-term]) and to determine their environmental consequences.

This paper reports results of one aspect (small mammals) of a multi-disciplinary, integrated, large-scale, operational project (the Fallingsnow Ecosystem) (Lautenschlager *et al.* 1997), designed to document the environmental (abiotic and biotic) consequences of alternative conifer-release treatments in young spruce (*Picea* spp.) plantations. Because small mammals are ubiquitous, depend on plants for food and cover, periodically consume invertebrates, are important foods for avian and terrestrial predators (Sullivan 1990), and are sensitive to microhabitat changes (Miller and Getz 1977; Dueser and Shugart 1978; Yahner 1986), their responses to alternative conifer-release treatments interest forest ecologists and managers.

The objective of this study was to determine the effects of conifer-release, using standard herbicide technology (helicopter-applied Vision^{®2}, a.i. glyphosate) (Campbell 1990) and alternative treatments, on small mammal species composition and densities, as part of the larger Fallingsnow Ecosystem Project. Although 14 published studies have examined the effects of conifer-release with herbicides on small mammals, many lacked pre-treatment data and/or had minimal replication (Lautenschlager 1993). Also, except for Lautenschlager *et al.* (1995) and Runciman and Sullivan (1996), no studies have compared the effects of aerially applied herbicides with one or more of the proposed alternatives (motor-manual and mechanical cutting, different herbicides, and/or different application techniques). Comparative studies are critical to forest managers attempting to make informed decisions about the effects of conifer-release alternatives on costs (Bell *et al.* 1997a), crop growth, and ecosystem structure and function. (Documenting crop growth and ecosystem structure and function will require longer-term study, such as that being conducted by cooperators in the Fallingsnow Ecosystem Project [Lautenschlager *et al.* 1997]. Designing and recommending alternative forest management approaches, that balance concerns of the public and forest managers [environmental realities and treatment efficacy], will be possible only after this analysis is complete.)

Methods

Study Area and Treatments

The study area for the Fallingsnow Ecosystem Project (Lautenschlager *et al.* 1997), of which this small mammal research is one part, is 60 km southwest of Thunder Bay, Ontario, in Fraleigh Township. The area is part of the Great Lakes-St. Lawrence forest region (Rowe 1972). The randomized complete block design consists of four separate 28 to 52 ha blocks that were clearcut harvested and planted (with bareroot white spruce [*Picea glauca* {Moench} Voss] [three blocks] and black spruce [*P. mariana* (Mill.) B.S.P.] [one block]) four to seven years before the project began. Blocks, and plots within blocks, vary in elevation and topography; soils are predominantly imperfectly drained silt loam, but range from poorly to excessively drained (Simpson *et al.* 1997). Blocks range from 0.7 to 1.5 km apart, and each contains the following conifer-release alternatives: (1) motor-manual release with brush saws applied in mid-late October 1993; (2) mechanical release

with the Silvana Selective/Ford Versatile applied between late October and early November 1993; (3) Release^{®3} (triclopyr [a selective herbicide] @ 1.9 kg a.e. ha⁻¹) applied (16 August 1993) by helicopter (Bell 206); (4) Vision[®] (glyphosate [a broad-spectrum herbicide] @ 1.5 kg a.e. ha⁻¹) applied (16 August 1993) by helicopter (Bell 206); and (5) control (no treatment). Designated treatment plots ranged from 3.3 to 12.4 ha, and percentage of area treated ranged from 57% to 100%. Aerial herbicide applications treated less (~75%) of the designated treatment area than the brush saw and Silvana Selective treatments (~90%) (Bell *et al.* 1997a). See Bell *et al.* (1997a,b), in this volume, for additional details about site, treatments, and treatment effects on vegetation; see Thompson *et al.* (1997) for herbicide application, deposit, and vertical distribution details.

Small Mammal Trapping

Small mammals were live-trapped with 49 traps (Sherman — 7.5 × 9.0 × 23.5 cm) plot⁻¹ (245 traps block⁻¹; 980 total). Individual traps were placed 12 m apart in the center of plots on 7 × 7 trap grids. The closest traps on separate trap grids were a minimum of 100 m apart. Traps were baited with peanut butter and oatmeal, supplied with coarse brown cotton, and set so that minimal treadle pressure was required to close the trap. When the "draw"⁴ to outer traps was included, these grids sampled approximately 1 ha. Traps were examined morning and evening for five consecutive days during early August (pre-herbicide treatments) and September [post-herbicide, but pre-cutting (brush saw + Silvana) treatments] 1993, and mid-June, late-July, and late-August 1994 (first post-treatment growing season), and mid-June and late-July 1995 (second post-treatment growing season). Trapped animals were identified to species, sexed, aged, weighed, and reproductive condition and unique features noted. Animals were ear-tagged (National Band & Tag 1005-1, monel steel) and released at the point of capture.

Statistical Analysis and Nomenclature

The minimum number of animals known to be alive (density) (Krebs 1966) was calculated, based on captures, for small mammal species during each trapping period. These density data were analyzed as follows: (1) means and standard errors of non-transformed density data, and (2) general linear models, analysis of co-variance (pre-treatment [1993] average as the co-variate), with Duncan's multiple range test. Statistically significant ($P < 0.05$) results are discussed. Common and scientific names for small mammals are those used by Kurta (1995), and Fernald (1970) for plants.

Results

Fourteen small mammal species were captured. In 1993, 1,459 individuals were captured during the two trapping periods (August and September); in 1994, 2,141 were captured

⁴ "Draw" or "edge effect", an inherent problem associated with trapping grids, is related to an individual species' home range size (Bondrup-Nielsen 1983), and trapping season. The estimate of draw, for this study, was based on a comparison of the average capture rate for traps located on the outside edges of the trap grids with the rates for traps on the inside of the grids. Outside traps, depending on season, were up to twice as successful as inside traps, and inside traps sampled 6m in every direction (144 m²). It was assumed that outside traps sampled a 50% greater area than inside traps (216 m², or 6m on the inside but 12 m on the outside). Hence, a trap line (seven traps) sampled the interior (6 × 12m), plus the exterior (2 × 12m) for a total of 96 m, and each grid sampled approximately 1 ha (96 m × 96 m).

²Trademark of Monsanto.

³Trademark of DowElanco.

Fig. 1. Response ($X \pm SE$, $N = 4$) of red-backed voles (*Clethrionomys gapperi*) to alternative conifer release treatments. (Note: To facilitate comparison among years and treatments, only mid-summer (July, August) means are presented.)

Fig. 2. Response ($X \pm SE$, $N = 4$) of deer mice (*Peromyscus maniculatus*) to alternative conifer release treatments. (Note: To facilitate comparison among years and treatments, only mid-summer (July, August) means are presented.)

during three trapping periods (June, July, September); and in 1995, 1,251 were captured during two trapping periods (June and July). Percentage of total captures by species in 1993, 1994, and 1995 respectively were: *Sorex* spp. (masked [*Sorex cinereus* Kerr], pygmy [*S. hoyi* Baird]⁵, arctic [*S. arcticus* Kerr]) (39.7, 45.2, 19.0); southern red-backed voles (*Clethrionomys gapperi* Vigors) (24.8, 21.2, 28.1); deer mice (*Peromyscus maniculatus* Wagner) (18.6, 14.8, 28.3); northern short-tailed shrews (*Blarina brevicauda* Say) (8.3, 0.7, 0.2); eastern chipmunks (*Tamias striatus* L.) (4.0, 6.1, 12.9); least chipmunks (*T. minimus* Bachman) (1.6, 4.5, 6.6); meadow voles (*Microtus pennsylvanicus* Ord) (1.8, 3.1, 2.4); ermine (*Mustela erminea* L.) (0.5, 1.6, 1.5); meadow jumping mice (*Zapus hudsonius* Zimm.) (0.3, 0.4, 0.8). In addition two heather voles (*Phenacomys*

intermedius Merriam), one rock vole (*Microtus chrotorrhinus* Miller), and one water shrew (*S. palustris* Rich.) were caught during this study.

Densities of all shrew species (masked and pygmy [combined], arctic, and short-tailed) were statistically unaffected by these treatments. Treatments did affect (Duncan's, $P < 0.05$) mean densities of red-backed voles, deer mice, and least chipmunks (Table 1, Figs. 1–3). (Note that the apparent decrease in densities of most species between 1994 and 1995 is an artefact related to the seasonally lower densities associated with the 1995 sampling times. Small mammals were trapped in mid-June, late-July, and late-August 1994, but only during mid-June and late-July in 1995. The August/September trapping period consistently has the highest annual density [Table 2], and was not part of the 1995 sample.)

Red-backed vole densities were affected during both the first and second post-treatment growing seasons (Table 1). Densities

⁵Masked and pygmy shrews were not differentiated in the field and were identified as *Sorex* spp. when captured.

Fig. 3. Response ($\bar{X} \pm SE$, $N = 4$) of least chipmunks (*Tamias minimus*) to alternative conifer release treatments. (Note: To facilitate comparison among years and treatments, only mid-summer (July, August) means are presented.)

were highest on control, lower but statistically similar in brush saw and Silvana Selective, lower still on Vision®, and lowest on Release® plots during the first post-treatment growing season (Fig. 1). During the second post-treatment growing season red-backed vole densities were highest on the control and Vision®, lower but statistically similar on the Silvana Selective and brush saw plots, and lowest on Release® plots.

Deer mouse densities were statistically unaffected during the first post-treatment growing season but during the second post-treatment growing season densities were highest on Silvana and lowest on the Vision® plots (Table 1). Densities on Release®, control, and brush saw were statistically similar and confidence intervals overlapped both the highest (Silvana Selective), and lowest (Vision®) densities observed.

Eastern chipmunk densities were highly variable but statistically unaffected by these treatments during the first two growing seasons after treatment (Table 1). Least chipmunk densities were statistically unaffected during the first post-treatment growing season, but seemed to respond positively to both herbicide treatments (Table 1, Fig. 3). During the second post-treatment growing season, least chipmunk densities were highest on Vision® plots, lower but statistically similar on Release®, control, and Silvana Selective plots, and lowest on brush saw plots.

Meadow vole densities were highly variable, but statistically unaffected by these treatments (Table 1). Densities were, however, consistently highest on Release® plots during both the first and second post-treatment growing seasons (Table 2). Although ermine, meadow jumping mice, and heather voles were not uncommon, too few were caught during this study to draw conclusions about the effects of treatments on these species.

Discussion

No signs of direct treatment effects (abnormalities or death) were noted during this study. Existing research (Lautenschlager 1993) has concluded that density changes following herbicide treatments are related to habitat changes (changes in vegetation structure and composition) that indirectly affect small mammal populations.

The literature documenting effects of conifer-release treatments on shrew species is inconsistent. Borrecco *et al.* (1979) reported that one year after conifer release with a variety of herbicides, Trowbridge shrew (*Sorex trowbridgii* Baird) densities were higher in treated areas, and Sullivan and Sullivan (1982) reported that glyphosate had no negative effects on shrews during the growing season after treatment. Santillo *et al.* (1989), however, reported that insectivores (primarily *S. cinereus*) were less abundant on Roundup® (a.i. glyphosate) -treated plots for three growing seasons after treatment.

1,970 shrews were caught, representing four species (masked and pygmy, arctic, short-tailed), during this three year study. Eighty-two percent of the shrews captured were masked or pygmy. Although no attempt was made to identify these to species in the field, an examination (teeth under a dissecting microscope) of those that died in traps revealed that 80% of the dead *Sorex* spp. were masked (*S. cinereus*) and 20% were pygmy (*S. hoyi*). When caught and released in the field these very similar species were combined into *Sorex* spp.

Although the shrew species identified responded differently to the treatments, they were statistically unaffected (Table 1). Like red-backed voles, but to a lesser degree, *Sorex* spp. densities decreased following vegetation reductions (Table 2), either because of the reductions themselves, the associated microclimatic changes (increased near-ground temperatures and decreased relative humidity [Reynolds *et al.* 1997]), or because of changes in available food. Microclimate differences, however, are not as dramatic on this more productive spruce site as they are on more open, less productive pine sites. Indeed, shrews were so uncommon in one jack pine (*Pinus banksiana* Lamb.) plantation study area (Lautenschlager *et al.* 1995), that there were insufficient numbers for testing comparisons among treatments.

Studies of the effects of herbicides on red-backed voles (Clough 1987; D'Anieri *et al.* 1987; Freedman *et al.* 1988; Santillo *et al.* 1989; McMillan *et al.* 1990; Lautenschlager *et al.* 1995) consistently demonstrate reductions in density during the

Table 1. Means, and mean separation (Duncan's multiple range), *F*, and *P* values from ANCOVA (pre-treatment [1993] captures = covariate) for treatment and time effects on small mammal species captured during the first (4) and second (5) post-treatment growing seasons in the Fallingsnow study area

Species	Control	Brush saw	Silvana	Release®	Vision®	<i>F</i> Value	<i>P</i> > <i>F</i>
Masked and (4) ¹ pygmy shrews ² (5) ³	16.25a ⁴ 6.38a	17.17a 6.63a	14.83a 4.14a	15.08a 2.88a	10.58a 3.75a	1.47 1.06	0.2620 0.4232
Arctic (4) shrew (5)	1.83a 1.13a	1.75a 2.00a	1.92a 1.00a	2.92a 1.25a	2.33a 0.63a	1.34 1.72	0.3043 0.1937
Short-tailed (4) shrew (5)	0.00a 0.13a	3.25a 0a	0a 0a	0a 0.13a	0.25a 0.13a	0.76 0.83	0.5957 0.5518
Red-backed (4) vole (5)	14.92a 12.38a	11.08a,b 6.75a,b	10.58a,b 7.00a,b	2.92c 5.63b	5.58b,c 11.13a,b	8.18 1.89	0.0009 0.1601
Deer (4) mouse (5)	5.75a 8.63a,b	6.83a 7.25a,b	12.17a 12.88a	11.17a 9.13a,b	5.88a 4.50b	6.52 4.43	0.0025 0.0125
Eastern (4) chipmunk (5)	4.33a 5.75a	2.17a 2.38a	4.33a 4.25a	1.67a 3.00a	4.75a 4.13a	5.33 3.25	0.0060 0.0373
Least (4) chipmunk (5)	2.25a 1.88a,b	1.42a 0.63b	0.92a 1.50a,b	2.67a 2.75a,b	3.00a 3.63a	4.24 4.28	0.0148 0.0143
Meadow (4) vole (5)	1.33a 0.63a	1.58a 0.25a	0.50a 0a	2.25a 2.50a	0.67a 0.38a	3.59 2.79	0.0268 0.0595

¹ (4) and (5) = 1994 and 1995 respectively, 1993 captures used as the covariate.

² Includes *Sorex cinereus* and *S. hoyi* combined.

³ The apparent decrease in densities between 1994 and 1995 is an artefact related to the seasonally lower densities associated with the 1995 sampling times. Small mammals were trapped in mid-June, late-July, and late-August 1994, but only during mid-June and late-July in 1995. The August/September trapping period consistently has the highest yearly density, and was not part of the 1995 sample.

⁴ Means followed by the same letter in a row are not significantly ($P < 0.05$) different among treatments.

growing season following treatment. Here, red-backed vole densities were reduced on Vision® and Release® plots during the first post-treatment growing season. By the second post-treatment growing season, however, densities were similar on control and Vision®, lower but similar on Silvana and brush saw, and significantly lower than control on the Release® plots. In these spruce plantations red-backed vole density decreases seem to be associated with the removal of woody vegetation. Woody vegetation increased on control plots during this study, but was reduced dramatically on all treated plots during the first post-treatment growing season (Bell *et al.* 1997b). Of all the treatments, Release® plots had the greatest increase in forb, and grass/sedge vegetation following treatment (Bell *et al.* 1997b), and it may be that the decrease in red-backed vole density following that treatment was related to this abundance of near-ground vegetation.

Lautenschlager *et al.* (1995) reported that red-backed vole densities in a six-year-old jack pine plantation were reduced by an operational Vision® treatment during the first and second post-treatment growing seasons, but that by the third post-treatment growing season densities were within the range of controls. Here, red-backed voles seemed to recover from the operational Vision® treatment by the second post-treatment growing season, potentially because the more productive character of the soils in this spruce plantation produced vegetation biomass (food and cover) more quickly and in greater amounts than was produced on the coarser soils in the jack pine study. This may help explain differences among results previously reported, and supports Lautenschlager's (1993) argument that productive sites provide post-disturbance wildlife habitat sooner than less productive sites.

Deer mouse densities commonly increase following herbicide treatments (Borreco *et al.* 1979; McMillan *et al.* 1990; Milton and Towers 1990). In this study deer mouse densities were greatest on Silvana Selective, lower but similar on Release®, control, and brush saw plots, and significantly lower than Silvana Selective on the Vision® plots two growing seasons after treatment. The Silvana Selective and Vision® treatments both reduced non-crop woody vegetation, but by different degrees and in different ways. The Silvana Selective treated an average of 89.3%, while Vision® treated an average of 77.3% of the designated treatment area (Bell *et al.* 1997a). In addition, following the Silvana Selective and brush saw treatments woody stems were scattered across the ground, while they remained standing (defoliated) after the Vision® and Release® treatments. Although the Silvana Selective treatment reduced above-ground woody vegetation as much as any alternative tested, the percentage increase in near-ground vegetation (forb, grass/sedge) was less following the Silvana Selective than any of the other alternative treatments (Bell *et al.* 1997b). The Vision® treatment reduced non-crop woody vegetation, but that change led to increased near-ground vegetation (Bell *et al.* 1997b).

These differences in post-treatment vegetation communities, together with the deer mouse population response, suggest that deer mice may benefit from vegetation removal, but that benefit is greatest when near-ground vegetation production is also suppressed. This also may help explain differences among results previously reported but suggests that a knowledge of site productivity alone is insufficient to predict how individual small mammal species will respond to disturbance. Deer mouse densities increased following herbicide and

Table 2. Small mammal numbers ha⁻¹ (N=4) by trapping time and treatment, for the most common small mammal species captured pre-treatment (93), and post-treatment (94 and 95)

Time	Control		Brushaw		Silvana		Release®		Vision®	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
<i>Masked and Pygmy shrews combined</i>										
Aug. 1993	1.0	0.4	10.3	8.3	1.8	0.9	4.0	2.5	1.3	0.5
Sept. 1993	25.8	4.2	22.8	4.0	26.5	2.7	22.3	6.5	21.3	1.9
June 1994	1.3	0.8	1.3	0.5	1.8	0.9	1.3	0.9	0.8	0.8
July 1994	13.5	5.7	13.8	2.9	3.8	1.6	9.8	6.3	4.5	3.8
Aug. 1994	26.5	2.5	27.0	2.2	31.3	3.9	23.0	4.0	20.0	2.5
June 1995	0.5	0.5	0.3	0.3	1.0	0.6	1.5	1.2	0.3	0.3
July 1995	12.3	5.0	13.0	2.9	7.3	3.4	4.3	2.7	7.3	4.0
<i>Arctic shrew</i>										
Aug. 1993	0		0.5	0.3	0		0.3	0.3	0	
Sept. 1993	0.5	0.3	1.8	1.1	2.8	1.3	0.3	0.3	1.8	1.2
June 1994	0.3	0.3	0		0		0		0.3	0.3
July 1994	2.8	1.8	1.8	1.1	1.3	0.6	3.7	3.1	2.5	2.2
Aug. 1994	2.5	1.5	3.5	1.9	4.5	2.3	5.0	3.2	4.3	2.4
June 1995	0.3	0.3	0		0		0.3	0.3	0.3	0.3
July 1995	2.0	1.4	4.0	2.0	2.0	1.7	2.3	2.3	1.0	0.6
<i>Short-tail shrew</i>										
Aug. 1993	0		0.3	0.3	0.8	0.5	0.3	0.3	1.0	0.6
Sept. 1993	5.5	3.2	5.3	1.3	5.0	2.3	4.5	2.3	7.8	2.7
June 1994	0		0		0		0		0	
July 1994	0		0		0		0		0	
Aug. 1994	0		3.3	3.3	0		0		0.3	0.3
June 1995	0		0		0		0.3	0.3	0	
July 1995	0.3	0.3	0		0		0		0	
<i>Red-backed vole</i>										
Aug. 1993	2.5	1.8	3.5	1.2	2.0	1.4	0.8	0.5	3.8	1.4
Sept. 1993	19.0	5.2	15.0	3.6	24.3	6.3	10.3	1.9	11.3	3.5
June 1994	6.8	4.5	6.0	3.0	5.0	2.0	2.5	1.6	3.5	1.3
July 1994	17.8	7.3	11.5	3.7	11.8	4.3	2.0	1.2	5.3	2.1
Aug. 1994	20.5	6.1	16.0	4.7	15.3	5.9	4.3	2.7	8.0	5.1
June 1995	7.8	1.5	3.5	1.7	3.5	0.6	2.5	0.9	8.5	2.8
July 1995	17.5	2.1	10.0	3.5	11.0	2.0	8.8	2.2	14.0	3.5
<i>Deer mouse</i>										
Aug. 1993	3.0	3.0	3.5	3.2	5.3	3.5	3.0	2.7	3.8	1.4
Sept. 1993	12.3	2.4	17.0	5.1	7.5	3.1	14.8	4.8	11.3	3.5
June 1994	2.5	1.9	4.0	1.5	9.3	6.00	7.0	3.6	3.5	1.3
July 1994	5.8	3.8	7.0	4.5	13.3	6.7	12.5	7.2	5.3	2.1
Aug. 1994	9.0	4.5	9.5	4.9	14.0	6.0	14.0	7.6	8.0	5.1
June 1995	4.8	2.8	5.5	2.0	9.5	3.1	7.5	2.8	8.5	2.8
July 1995	13.0	2.5	9.5	1.8	17.5	4.3	10.3	5.0	14.0	3.5
<i>Eastern chipmunk</i>										
Aug. 1993	1.0	0.6	0.5	0.3	0		0		0.3	0.3
Sept. 1993	2.3	1.1	2.3	1.0	1.8	1.8	0		7.3	2.5
June 1994	2.5	1.0	1.0	0.6	3.0	1.7	0.8	0.5	3.5	1.3
July 1994	5.3	3.1	4.0	2.1	5.0	3.3	0.8	0.5	5.0	1.7
Aug. 1994	5.3	3.7	1.5	1.0	5.0	3.2	3.8	2.4	5.8	2.0
June 1995	3.0	1.8	1.5	1.0	1.8	1.1	1.3	0.8	1.8	1.1
July 1995	8.8	1.9	3.5	2.3	7.3	3.6	5.0	2.5	6.5	2.2
<i>Least chipmunk</i>										
Aug. 1993	0.5	0.3	0		0		0		0	
Sept. 1993	1.8	1.2	0.5	0.5	1.0	0.7	1.8	1.8	0.8	0.8
June 1994	1.5	1.0	1.3	0.9	0.5	0.5	2.0	1.2	0	
July 1994	2.5	2.2	1.5	0.6	0.5	0.3	4.7	0.6	5.0	1.8
Aug. 1994	2.8	1.6	1.5	1.0	1.8	1.2	1.3	2.3	4.0	1.5
June 1995	2.3	1.3	0.3	0.3	1.0	0.7	2.5	1.5	2.3	0.9
July 1995	1.5	1.0	1.0	0.7	2.0	0.9	3.0	1.5	5.0	2.1
<i>Meadow vole</i>										
Aug. 1993	0		1.0	1.0	0.8	0.8	1.3	1.3	1.5	1.2
Sept. 1993	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	1.0	1.0
June 1994	0		2.0	2.0	0.3	0.3	0.8	0.8	0	
July 1994	0.8	0.8	0.8	0.8	0.5	0.5	3.5	2.9	1.0	0.4
Aug. 1994	3.3	3.3	2.0	1.7	0.8	0.5	2.5	2.2	1.3	0.8
June 1995	0.5	0.5	0		0		0.5	0.5	0.3	0.3
July 1995	0.8	0.8	0.5	0.5	0		4.5	4.5	0.5	0.5

cutting treatments on coarse-textured, well-drained soils in a regenerating jack pine study (Lautenschlager *et al.* 1995), but not on finer-textured, moister, more productive soils where spruce are commonly planted (this study).

Eastern chipmunks seemed relatively unaffected by Vision® and Silvana Selective treatments during both the first and second post-treatment growing seasons; their densities were, however, reduced following the brush saw and Release® treatments during this time. Sullivan (1990) reported that Townsend chipmunk (*Eutamias townsendii*) densities declined during the first growing season following a Vision® application, and Lautenschlager *et al.* (1995) reported that both brush saw and operational Vision® treatments reduced eastern chipmunk densities for up to three growing seasons after treatment.

As with the other small mammals discussed above, the differences in eastern chipmunk responses may be due in part to differences in soils and productivity between the jack pine- and spruce-dominated study areas. An additional factor, however, may be the treatment plot size used in these studies. Treatment plot size in the jack pine area (Lautenschlager *et al.* 1995) averaged less than 1 ha, while plot size in this spruce study averaged over 5 ha. Home ranges of eastern chipmunks (usually less than 91 m across) (Burt and Grossenheider 1980) in the jack pine study likely included untreated vegetation, and resident eastern chipmunks simply adjusted their range to avoid the herbicide-treated areas. Eastern chipmunks captured on the larger plots in this study were less likely to have part of their home range untreated, and unless conditions were exceedingly unfavourable they continued to occupy their previous range. Therefore, density reductions were not as common following any treatment in this spruce study area as they were following brush saw cutting and the operational Vision® treatments in the jack pine study area.

Least chipmunk densities increased on herbicide-treated and decreased on cut plots, in relation to control, one and two growing seasons post-treatment. Lautenschlager *et al.* (1995) reported that least chipmunk densities also were reduced by brush saw cutting and increased following operational Vision® and annual removal with Vision® in the jack pine study area. At both the jack pine and this spruce study areas, least chipmunks seem to favor the more open vegetation character created by the herbicide treatments, but respond negatively to the seemingly equally open character following brush cutting. This response may be due to the physical obstruction caused by the cut-stem litter, the associated increased near-ground relative humidity (Reynolds *et al.* 1997) or decreased near-ground temperature (Reynolds *et al.* 1997), terrestrial predator avoidance associated with ground-level visibility, or interactions among these factors.

Milton and Towers (1990) reported increased meadow vole numbers in Vision®-treated areas, both naturally regenerated and plantations, three to five years post-treatment. In this study meadow vole densities increased, relative to untreated controls, following the Release® treatment during the first and second post-treatment growing seasons. During this time densities on control, Vision®, brush saw, and Silvana Selective plots decreased. Meadow voles are commonly found in grassy habitat, and their food consists mainly of grass and sedge (Burt 1957); therefore, it is not surprising that although there was a general decrease in vole numbers following all treatments, reductions were least on Release® plots where grass cover

increased dramatically (5.1 times pre-treatment) (Bell *et al.* 1996b).

Lautenschlager (1993) concluded that small mammal responses to herbicides are species specific. Some species are unaffected, while some select and others avoid herbicide-treated areas. Small mammal density changes are directly associated with each species' habitat requirements. Some species commonly invade recently disturbed areas where early successional vegetation predominates, while others, although found in these early successional communities, are more commonly found in older seral types.

As with herbicides, small mammal responses to alternative conifer release treatments are species specific, and only the Silvana Selective treatment seems to have eliminated a species (meadow vole) from treated sites. In general, densities simply change, sometimes significantly, in relation to specific alternatives. No alternative maintained consistently high densities of all of the common small mammals in the Fallingsnow small mammal community. During the first two growing seasons after treatment densities of *Sorex* spp. (*cinereus* and *hoyi* combined) were higher on brush saw plots; red-backed voles were highest on control plots; deer mice were highest on Silvana Selective plots; least chipmunks highest on Vision® plots; and meadow voles highest on Release® plots. Arctic shrew densities were highest on herbicide (Release®, Vision®) plots during the first post-treatment growing season, but highest on brush saw plots during the second post-treatment growing season. Densities of short-tailed shrews decreased dramatically but without a treatment-related pattern. Eastern chipmunk densities were highest on the Vision® plots during the first post-treatment growing season, but highest on control plots during the second post-treatment growing season.

Conclusions

This study demonstrates that for small mammals, species-specific short-term density changes that follow alternative conifer-release treatments are in many ways similar to the changes observed following standard conifer release treatments using herbicides. One or more of the species studied responded favourably to each of the conifer release treatments examined. Vegetation changes associated with each treatment type seem responsible for the density changes noted, but it is unclear whether changes in the vegetation itself, associated microclimates, potential food sources, densities of other small mammal species, predator avoidance, or interactions among these were responsible for the differential responses observed. Longer-term monitoring and integration among cooperators in the Fallingsnow ecosystem project, which is ongoing, should allow us to more clearly identify the factors responsible for these changes.

Acknowledgements

We thank Tom Sullivan, Brian McLaren, Rob Foster, Ian Thompson, two anonymous reviewers, and Wendeline Price for their critical reviews of an earlier draft of this manuscript; Tim Cooley, Andrew Smith, Olivier Pfister, and the dedicated small mammal trapping crews for their hard work and patience; John Winters, Nikki Wood, and Heather Barns for their assistance and logistical support; and Greg Hannah and Din Chen for data manipulation and statistical analysis. This work was supported by the VMAP (Vegetation Management Alternatives Program) under the Sustainable Forestry Initiative,

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