The Effects of Thinning on Forest-Floor Small Mammals in the Coast Range of Oregon

by

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Thinning of young Douglas-fir forests has the potential to enhance structural diversity and improve habitat for wildlife. I examined the effects of thinning and thinning intensity on abundance and demographic characteristics of forest-floor small mammals in the Coast Range of Oregon 5 and 6 years after thinning had occurred. Thinning resulted in greater densities of Townsend's chipmunks (*Tamias townsendii*), creeping voles (*Microtus oregoni*), and Pacific jumping mice (*Zapus trinotatus*), and densities of chipmunks and creeping voles were greater in heavily thinned stands than in moderately thinned stands. Movement of female chipmunks was less in heavily thinned stands and movement of female deer mice was less in thinned stands. Sex ratios of deer mice and creeping voles were skewed toward females in heavily thinned stands. Body mass of male deer mice was also greater in heavily thinned stands. Thinning had neutral effects on density of deer mice (*Peromyscus maniculatus*) and on populations of Trowbridge's shrews (*Sorex trowbridgii*), Baird's shrews (*Sorex bairdi*), Pacific shrews (*Sorex pacificus*), and shrew-moles (*Neurotrichus gibbsii*). Northern flying squirrels (*Glaucomys sabrinus*) were more abundant in unthinned stands than in thinned stands 5 years after thinning had occurred. Greater amounts of small-diameter down wood and

slash, and increases in percent cover of low shrubs after thinning may partially explain the increases in abundance of chipmunks, Pacific jumping mice, and creeping voles in thinned stands.

Thinning young Douglas-fir forests appears to enhance habitat quality for most species of forest-floor small mammals. In addition, heavy thinning may hasten development of mature forest conditions that may provide optimal habitat for these species. However, because some species appear to prefer closed canopy forests, it is recommended that some unthinned stands be retained as a component of the forested landscape.

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (continued)

The Effects of Thinning on Forest-Floor Small Mammals in the
Coast Range of Oregon

INTRODUCTION

Much of the Coast Range of Oregon consists of young forest stands (<50 years

old) of Douglas-fir (*Pseudotsuga menzeisii*) as a result of intensive forest management

practices and recent wildfires (Hayes et al. 1997). The conversion of old-growth forest

to young managed stands has raised concerns as to whether these stands can now support

the diversity and abundance of wildlife that existed before this conversion (Carey 1989,

Lemkuhl and Ruggerio 1991, Ruggerio et al. 1991). As a result, there has been an

increasing interest in maintaining or enhancing wildlife habitat in younger forests while

still maintaining an economically acceptable level of harvest.

Commercial thinning has long been a tool for an interim influx of capital while

accelerating growth of the remaining timber for future clearcut harvest. It is now

hypothesized that commercial thinning can also be used as a method to enhance structural

diversity in young forests and improve biological diversity (Carey and Curtis 1996,

Hayes et al. 1997, Carey 2000). Commercial thinning could also be used to accelerate

development of old-growth conditions that now make up a small percentage of historical

levels in the Coast Range of Oregon (Carey and Johnson 1995, Carey and Curtis 1996,

Hayes et al. 1997). Thinning is an approved silvicultural method for management of

federal lands in late-successional and matrix lands (Forest Ecosystem Management

Assessment Team 1993). Thinning is also a central component of the Oregon

Department of Forestry's management plan for state forest lands (Bordelon et al. 2000).

Tappeiner et al. (1997) found that naturally regenerating forests that developed after fire or windthrow events had greater growth rates and larger diameters than managed stands because of lower density of trees. Density of trees in former old-growth stands averaged 100-120 trees/ha compared to over 500 trees/ha that are now common in regenerating stands after timber harvest. Thinning young managed stands may provide conditions that are closer to historical levels of stocking in old-growth forests (Hayes et al. 1997, Tappeiner et al. 1997).

Young, unthinned stands between 20 and 100 years old generally have a closed canopy and are usually structurally simple with little understory development (Hayes et al. 1997). The influx of snags and down wood generated in the stem-exclusion stage of young forests is usually too small to act as important substrates to small mammal and terrestrial amphibian communities (Hayes et al. 1997, Johnson and O'Neil 2001:591). Thinning reduces stand density and opens the canopy. Additional light reaching the forest floor can promote development of herbaceous plants and shrubs, which can lead to a more structurally complex system (McComb et al. 1993, Tappeiner and Zasada 1993, Hayes et al. 1997, Bailey and Tappeiner 1998). Additionally, the remaining trees will grow more rapidly as a result of a reduction in competition for resources (Marshall et al. 1992). This will result in the eventual recruitment of larger snags and down logs that may improve habitat for small mammal and terrestrial amphibian communities (Hayes et al. 1997).

Old-growth forests may offer optimal habitat for a several species of small mammals (Lehmkuhl and Ruggiero 1991, Rosenberg et al. 1994, Carey and Johnson 1995). For this reason, studies of the influence of forest management on small mammals

have focused on comparisons of different successional stages of forests in an attempt to discover how conversion to younger forests has affected the abundance of small mammal communities (Hooven and Black 1976, Raphael 1988, Corn and Bury 1991, Rosenberg and Anthony 1993).

Limited information is available that addresses the influences of thinning on wildlife. Activity of bats is greater in thinned stands than in unthinned stands (Humes et al. 1999), and thinned stands can have greater species richness of birds and higher abundances of some species than in unthinned stands (Hagar et al. 1996, Hayes et al. in prep). Wilson and Carey (2000) compared small mammal abundance and community structure in thinned stands, unthinned stands with and without legacy trees, and old-growth forests. They found that small mammal abundance and biomass were greater in old-growth and thinned stands than unthinned stands with or without legacy trees, indicating that thinned stands may be providing better habitat than unthinned stands even where legacy trees have been retained.

Thinning young forests may ultimately improve overall suitability for many terrestrial small mammals. Gomez et al. (in prep) found that density, survival, and relative body mass of Townsend's chipmunks (*Tamias townsendii*) were not affected in the short term by thinning, but indicated that trends were suggestive of an increase in density related to positive response of understory shrubs to thinning. Suzuki (2000) examined the short-term effects of thinning on small mammal and amphibian populations. His experimental sites were thinned to moderate (RD35) and heavy (RD20) levels of intensity. Abundance of deer mice (*Peromyscus maniculatus*) and creeping voles (*Microtus oregoni*) increased within two years after thinning compared to

unthinned stands while abundance of seven other species of small mammals did not change significantly. However, western red-backed voles (*Clethrionomys californicus*) decreased in abundance within 2 years of thinning. Suzuki's study sites also included stands that had been thinned 7-20 years previously to adjacent unthinned stands. These stands were thinned to a slightly higher density than moderately thinned stands in his experimental study. At these sites, species abundance was similar or higher in thinned stands than in unthinned stands, indicating that decreases in abundance of small mammals caused by thinning may be reversed as understory vegetation becomes established.

In most experimental studies, effects are examined prior to and immediately after the management action has taken place (e.g., Hooven 1973, Chambers et al. 1999, Gomez et al. in prep, Gomez et al. submitted). In these cases, only the short-term effects of forest management are examined with little consideration given to long-term impacts. Although retrospective or observational studies are useful for establishing patterns, researchers are not able to determine cause-and-effect relationships that randomized experiments are capable of (Ramsey and Schafer 1997:5-7).

To fill the information gap between short-term research and long-term observational studies, I investigated the effects of commercial thinning and thinning intensity on abundance of terrestrial small mammals 5-6 years after stands were thinned. Because abundance may not be the best indicator of habitat quality (Van Horne 1983), I also investigated whether sex ratios, age-class ratios, body mass, distances moved, and density were affected by thinning. I hypothesized that small mammals that may benefit from opening of the canopy, such as deer mice (Gunther 1983, Wilson and Carey 2000),

Pacific jumping mice (Gunther et al. 1983), Townsend's chipmunks (Carey 2000, Gomez et al. in prep), and creeping voles (Hooven and Black 1976, Verts and Carraway 1998: 326-327) would respond positively to thinning due to increases in understory vegetation that would provide both food and shelter, along with increases in logging slash that may supply additional cover (Suzuki 2000, Gomez et al. in prep). If thinning improved habitat for these species, I predicted that density of deer mice, Pacific jumping mice, Townsend's chipmunks, and creeping voles, would increase and distances moved would decrease. I also predicted that sex ratios would be skewed toward higher numbers of females in thinned stands because less of the population would be composed of dispersing males (Hayes et al. 1995, Norrdahl and Korpimaki 1998, Carey and Johnson 1995).

STUDY AREA

My study area was located in the northern Coast Range of Oregon within the

Tsuga heterophylla forest zone (Franklin and Dyrness 1988). The area was burned by a

series of wildfires between 1933 and 1951 totaling 354,000 acres (Wells 1999). Most of

the area was salvage-logged and many of the snags that were not harvested were felled to

create firebreaks. The forest was replanted or seeded with Douglas-fir between 1949 and

1970 and is now comprised of an even-aged Douglas-fir forest between 35-50 years old.

Other tree species in the area include western hemlock (*Tsuga heterophylla*), western

redcedar (*Thuja plicata*), and noble fir (*Abies procera*). Red alder (*Alnus rubra*) is

common in moist areas. Common understory shrubs include salal (*Gaultheria shallon*),

red huckleberry (*Vacccinium parviflorum*), vine maple (*Acer circinatum*), and dwarf

Oregon grape (*Mahonia nervosa*). Common species of herbs include sword fern

(*Polystichum munitum*), and Oregon oxalis (*Oxalis oregana*).

Four forested blocks (replicates) were selected for study (Figure 1). Three of the

blocks are within the Tillamook State Forest, Tillamook County, and the fourth is on

property owned by the Stimson Lumber Company, Washington County. Each block was

comprised of three stands ranging from 26 to 40 ha ($\bar{x}$ = 34 ha). Blocks were selected to

minimize differences in initial tree density and stand age among treatments before stands

were thinned. Elevation ranges from 465 to 849 m ($\bar{x}$ = 612 m). Blocks were separated

by a minimum of 5.6 km. Some treatments within blocks were adjacent to each other.

However, trapping grids were separated by a minimum of 300 m.

Research has been conducted at the sites on cavity-nesting birds (Weikel and Hayes 1999), small mammals and amphibians (Suzuki 2000), flying squirrels (Gomez et al. submitted) and chipmunks (Gomez et al. in prep), deer and elk (Adam and Hayes, 1998), root rot (Thies and Westlind 1998), breeding birds (Hayes et al. in prep), and vegetation (Maas-Hebner and Emmingham 1998, Suzuki 2000).
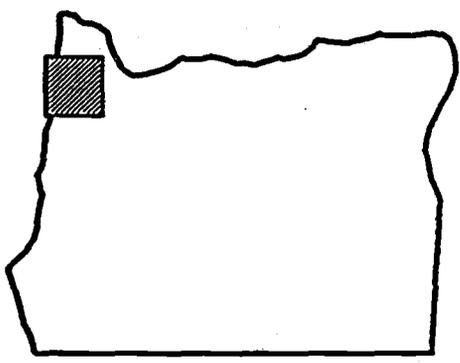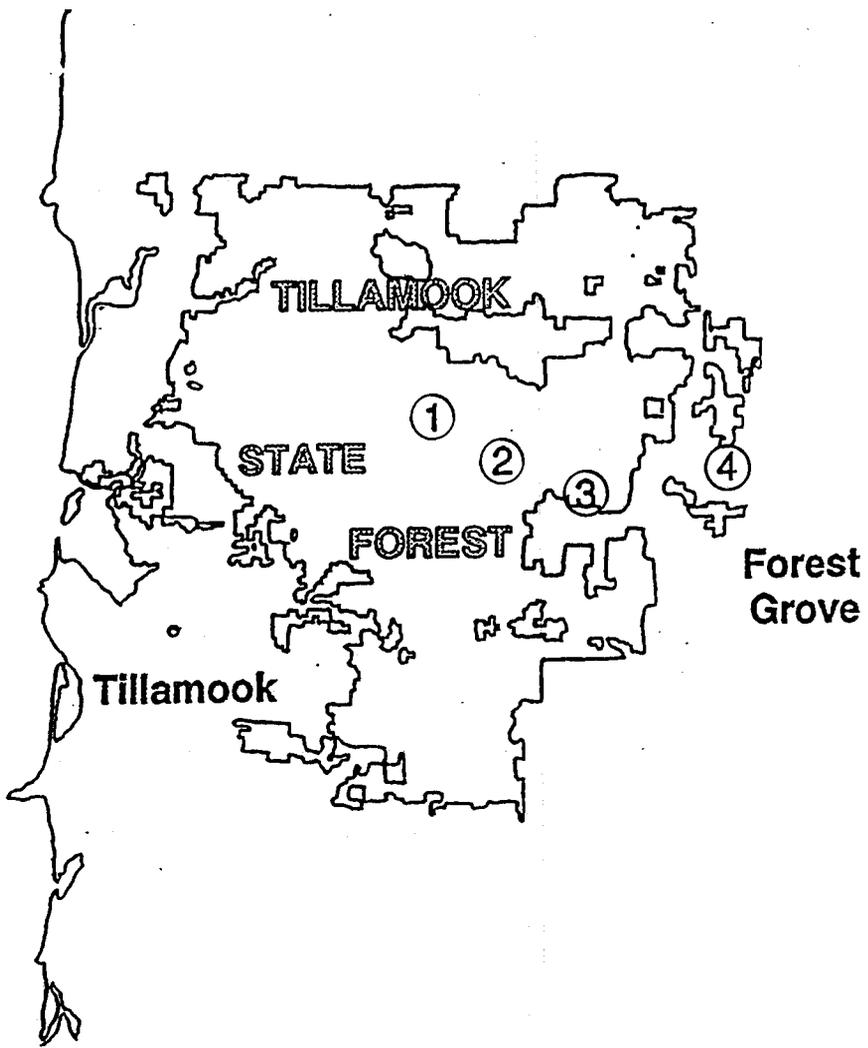
Study Sites

1. Deer Diamond
2. Ben Smith
3. C-Line
4. Stimson

Figure 1. Locations (1-4) of four replicate areas of unthinned, moderately thinned, and heavily thinned stands in the northern Coast Range of Oregon.

METHODS

Within each of the four replicates, three stands were randomly assigned to receive one of the following treatments: 1) no thinning (460-540 trees/ha), 2) moderate thinning to a relative density of 0.35 (248-286 trees/ha), and 3) heavy thinning to a relative density of 0.20 (186-201 trees/ha). The stands were thinned from below (Smith et al. 1997:99-102) between October 1994 and May 1995 by partial-suspension cable logging and tractor logging. A 10 x 15 grid (150 points) was established within each stand. Each grid point was 20 m apart and the entire grid covered approximately 5 ha.

Habitat sampling

I sampled habitat characteristics at 30 randomly selected grid points in each stand in 1999 and in 2000 for a total of 60 grid points in each stand. Each sampling point consisted of a five-meter radius circle centered within 2 m of the grid point. Percent cover of total shrubs, tall shrubs (>1.4 m), low shrubs (<1.4 m), salal, Oregon grape, huckleberry, and vine maple were visually estimated along with percent cover of mineral soil, moss, sword fern, bracken fern, Oregon oxallis, grass, and slash. Amount of down wood was determined by counting the number of pieces and total length of each piece within the five-meter radius. Down logs were classified by size (small: 10-29 cm; medium: 30-49 cm; large: > 50 cm) based on the largest diameter within the five-meter plot. All down wood was grouped into one of three categories of decay based on Maser et al. (1979): decay class 1 (hard), decay classes 2 and 3 (medium), and decay classes 4 and 5 (soft). I measured percent canopy cover using a spherical densiometer and litter

depth in centimeters 2 m from the point center in each of four cardinal directions. The four measurements of canopy cover and litter depth were averaged.

Sampling of small mammals

One foldable Sherman live-trap (7.7 x 7.7 x 25.6 cm) was placed within 2 m of each grid point. Traps were locked open 5-6 days prior to trapping and pre-baited with a mixture of peanut butter, molasses, sunflower seeds, and oats. During trapping sessions, each trap was placed inside a one-half gallon milk carton to protect animals from precipitation, and cotton or synthetic batting was placed inside each trap to reduce thermal stress to captured animals. Traps within a block were checked daily for 7 consecutive days. At the end of the trapping session, traps were pulled, cleaned, and moved to the next block where the procedure was repeated until all four blocks had been sampled. The procedure was repeated again 10 weeks later for a total of 25,200 trap-nights each year. Trapping was conducted in 1999 and 2000 for a total of 50,400 trap nights. Trapping was conducted from May 10 through June 29 (trap session 1 and 3), and from the July 19 through September 7 (trap session 2 and 4). I considered trap sessions 1 and 3 to be late spring, and trap sessions 2 and 4 to be early fall.

Each captured animal was identified to species and sex (with the exception of shrews), weighed using 50, 100, or 300 g Pesola scales (Pesola, Switzerland), and released. Two species of shrews were nearly identical in physical appearance. Therefore, shrews found dead in traps that were either Pacific (*Sorex pacificus*) or Baird's shrews (*S. bairdi*) and were unidentifiable because of tooth loss or poor condition were not included in this analysis. Shrews that were alive when traps were checked were not included in this analysis because it could not be determined if later captures of dead

shrews had not been captured alive previously. Shrews that were released alive represented 10% of captures for Trowbridge's shrew (*S. trowbridgii*) and 21% of captures for Pacific/Baird's shrew.

Six species of small mammals were marked with two uniquely numbered ear tags. Townsend's chipmunks (*Tamius townsendii*) and northern flying squirrels (*Glaucomys sabrinus*) received 0.178 g Monel ear tags (National Band & Tag Company, Newport, KY). Deer mice (*Peromyscus maniculatus*), creeping voles (*Microtus oregoni*), western red-backed voles (*Clethrionomys californicus*), and Pacific jumping mice (*Zapus trinotatus*) received 0.087 g fingerling tags (Neway Products, Salt Lake City, UT).

Animals exhibiting symptoms of hypothermia were placed in a cloth bag with a hand warmer and synthetic batting until the animal had recovered sufficiently to be released at the location where it was captured. Any animal that had not recovered at the end of the trapping session was held overnight and released the next day at the location where it was captured. Animals found dead in traps were uniquely labeled and frozen.

DATA ANALYSIS

I used program CAPTURE (White et al. 1982) to analyze mark-recapture data and estimate population size for Townsend's chipmunks, deer mice, creeping voles, Pacific jumping mice, northern flying squirrels, and western red-backed voles. I used the model selection option in CAPTURE to aid in choosing the most appropriate model to estimate population size for each species. Results of this procedure were consistent with Hammond's (1990) analysis of species-specific responses to mark-recapture studies. Capture probabilities for creeping voles, Pacific jumping mice, northern flying squirrels, and western red-backed voles were most affected by heterogeneity (Model M_h). Because sample sizes were small and capture probabilities were low, I used Chao's Moment estimator (Chao-Mh; Chao 1989) to estimate population size (N) for these four species. Capture probabilities for Townsend's chipmunks and deer mice were most affected by heterogeneity and behavior (Model M_{bh}). I used Pollock's removal estimator (Pollock-Mbh; Pollock and Otto 1983) to estimate population size for these two species.

Ages of animals (adult or juvenile) were determined by examining histograms of changes in body mass between sessions and/or examples from the literature. Minimum body mass for adults was ≥ 61 g for Townsend's chipmunks (Rosenberg and Anthony 1993), ≥ 16 g for deer mice (Van Horne 1981, Dewsbury 1992), ≥ 17 g for creeping voles, and ≥ 18 g for Pacific jumping mice.

Mean maximum distance moved (MMDM) was calculated for ear-tagged species in stands in which ≥ 2 animals of a species were captured >1 time (Rosenberg and Anthony 1993). I calculated MMDM in trap sessions 1 through 4 (1999, 2000) for

Townsend's chipmunks, and for trap sessions 3 and 4 (2000) for deer mice. I averaged MMDM over the four trap sessions for creeping voles and Pacific jumping mice because of missing values or inconsistent sample sizes in one or more treatments or trap sessions. I estimated the area effectively trapped (A) by adding one-half of MMDM to the perimeter of the grid for each species (Wilson and Anderson 1985). Density was estimated by dividing the estimated population size by the effective trapping area (D=N/A). MMDM of adult Townsend's chipmunks and of deer mice were evaluated separately by sex. I compared differences in MMDM between sexes for trap session 3 and 4 (2000) only because some stands did not meet the criteria for determination of MMDM for both sexes in 1999.

As distances between stands were not equal, animals that left a stand did not have an equal probability of entering another stand where they could be recaptured. Therefore, ear-tagged animals that were captured in one stand and subsequently recaptured in another stand were removed from all analyses. The number of animals that moved among stands was low. Less than 3 % of Townsend's chipmunks and 1% of deer mice were recaptured in more than one stand within a block.

In all statistical analyses, I examined response variables for normality and constant variance using histograms and residual plots (Sabin and Stafford 1990, PROC UNIVARIATE; SAS Institute 1990). I transformed variables that did not meet these assumptions by using logarithmic transformations [$ln(Y+1)$ or $ln(Y)$] for analysis of density; logit transformation [$ln(p/(1-p))$] for sex ratios and age-class ratios; and arcsine square-root transformations for habitat variables that were measured as percentages.

Because the number of replications (*n*=4) was small, I used $\alpha = 0.1$ to reduce the chances of committing type II errors.

I used a randomized complete-block design, using blocks as replicates to statistically compare differences in number of captures of untagged animals, density, MMDM, sex ratios, age-class ratios, and body mass between thinned and unthinned stands and between thinning intensities. I used repeated measures in PROC MIXED and PROC GENMOD (SAS Institute 1999) to assess the influence of thinning over time for Townsend's chipmunks, deer mice, creeping voles, Pacific jumping mice, Trowbridge's shrews, Pacific shrews, and Baird's shrews. I averaged estimated populations of northern flying squirrels and number of captures of shrew-moles (*Neurotrichus gibbsii*) over all four trap sessions in each stand. I eliminated one block from analysis for shrew-moles because there were no captures in any treatment. I then used orthogonal contrasts to analyze differences in abundance between thinned and unthinned stands for these two species. I was unable to assess the influence of thinning on western red-backed voles because of inconsistent sample sizes in one or more blocks or trap sessions.

I used binomial logistic regression (PROC GENMOD; SAS Institute 1999) for Townsend's chipmunks, deer mice, and creeping voles to test whether the odds of being a male or an adult differed over time and among treatments. I analyzed sex ratios and age-class ratios for Townsend's chipmunks for trap sessions 1 through 4 and for deer mice in trap session 3 and 4. I analyzed sex ratios and age-class ratios of creeping voles by first eliminating stands in trap sessions that did not have a minimum of 5 animals of one sex for sex ratios, and a minimum of 5 animals for age-class ratios. I used the WEIGHT statement in PROC GENMOD to give more weight to stands that had more trap sessions

(1-4) that met my criteria. I was not able to examine sex ratios or age-class ratios of Pacific jumping mice because of missing values or inconsistent sample sizes in one or more treatments or trap sessions.

I developed a set of 10 conceptual models to describe how response of small mammals might differ between thinned and unthinned stands, between thinning intensities, and whether these differences vary with time (Table 1). I used models with time as a consideration when examining MMDM by sex, sex ratios, age-class ratios, and body mass. I used models without time as a consideration to assess how number of captures and density differ five to six years after thinning has occurred. I evaluated the likelihood of each model using an information-theoretic method described by Burnham and Anderson (1998). I used Akaike's Information Criteria (AIC) generated by using the maximum-likelihood option (ML) in PROC MIXED and PROC GENMOD to assess which models best described the relationship of density and body mass (Townsend's chipmunks, deer mice, creeping voles, and Pacific jumping mice), number of captures from an enumeration of trap mortalities, (Trowbridge's shrews, Pacific shrews, and Baird's shrews), sex ratios and age-class ratios (Townsend's chipmunks, deer mice, and creeping voles), and MMDM by sex (Townsend's chipmunks and deer mice) among treatments. I adjusted AIC values for small sample sizes (AIC_c) in all analyses and also adjusted AIC_c for over-dispersion ($QAIC_c$) for binomially distributed data when assessing sex ratios and age-class ratios. I calculated Akaike weights (range 0-1) for each model to determine the relative strength of evidence in favor of a particular model. Relative weights were calculated as the ratio of the weight of the best model divided by the weight of a competing model. This allowed for evaluation of how strong the relative likelihood

of the model with the lowest AIC_c or $QAIC_c$ was against a competing model. However, any models that had ΔAIC_c or $\Delta QAIC_c < 2$ were considered to be competing models (Burnham and Anderson 1998:48). Therefore, any set of models with ΔAIC_c or $\Delta QAIC_c < 2$ that contained the null model (C=M=H) indicated no strong evidence of an effect of thinning. Once models with $\Delta < 2$ were computed, I used PROC MIXED and PROC GENMOD to generate point estimates and confidence intervals for each response based on these models.

Table 1. Conceptual models that were used in this analysis to test which model best fit the data. Models describe a particular response of a species to unthinned and thinned stands, thinning intensity, and whether this difference varies with time (SESSION).

Model	Explanation
control = moderate = heavy (C=M=H)	There is no difference in response of animals between thinned and unthinned stands or between thinning intensity.
control ≠ moderate = heavy (C ≠ (M=H))	There is a difference in response of animals between thinned and unthinned stands but not between thinning intensities.
control = heavy ≠ moderate ((C=H) ≠ M)	Unthinned and heavily thinned stands show no difference in response of animals, but the moderately thinned stands have a different response.
control = moderate ≠ heavy ((C=M) ≠ H)	Unthinned and moderately thinned stands show no difference in response of animals, but the heavily thinned stands have a different response.
control ≠ moderate ≠ heavy (C≠M≠H)	There is a difference in response of animals between thinned and unthinned stands and between thinning intensity.
SESSION (C=M=H)	There is no difference in response between thinned or unthinned stands or thinning intensity. However, there is a time-dependent response in all treatments.
SESSION (C ≠ (M=H))	There is a difference in response between thinned and unthinned stands. This response also varies with time.
SESSION ((C=M) ≠ H)	Unthinned and moderately thinned stands show no difference in response, but the heavily thinned stands have a different response. This response also varies with time.
SESSION ((C=H) ≠ M)	Unthinned and heavily thinned stands show no difference in response, but the moderately thinned stands have a different response. This response also varies with time.
SESSION (C≠M≠H)	There is a difference in response between thinned and unthinned stands and between thinning intensity. This response also varies with time.

RESULTS

Vegetative characteristics

Five and six years after thinning, canopy cover of overstory trees was significantly reduced in thinned stands ($t_6 = 5.85$, $p = 0.0011$) but did not significantly differ between thinning intensities ($t6 = 1.02$, $p = 0.3471$; Table 2). Basal area was also significantly reduced in thinned stands ($t_6 = 9.76$, $p < 0.0001$) and was less in heavily thinned stands than in moderately thinned stands ($t_6 = 3.26$, $p = 0.0173$).

There was no statistically significant difference in tall shrub cover between thinned and unthinned stands ($t_6 = 0.690$, $p = 0.5185$) or between thinning intensities ($t_6 = -0.150$, p $= 0.8853$). Low shrub cover was not significantly different between unthinned and thinned stands ($t_6 = -1.54$, $p = 0.1750$), but was greater in heavily thinned stands relative to moderately thinned stands ($t_6 = -3.13$, $p = .0204$). Percent cover of herbs was not different between thinned and unthinned stands ($t_6 = -1.070$, $p = 0.3277$) or between thinning intensities ($t_6 = 1.40$, $p = 0.2101$). Thinning increased percent cover of slash in thinned stands ($t_6 = -2.94$, $p = 0.0259$) relative to unthinned stands, but was not significantly different between thinning intensities ($t_6 = 1.05$, $p = 0.3342$). Litter depth was reduced in thinned stands relative to unthinned stands ($t_6 = 4.42$, $p = 0.0045$), but was not significantly different between thinning intensities ($t_6 = 0.07$, $p = 0.9427$). The effects of thinning on down wood varied among size classes (Table 3). Frequency and length of small diameter wood was greater in thinned stands compared to unthinned stands (frequency, $t_6 = -3.42$, $p = 0.0142$; length, $t_6 = -2.45$, $p = 0.0496$). However, there was no statistically significant difference in frequency or cumulative length of medium logs (frequency, $F_{2,6} = 0.59$, $p = .5968$; length, $F_{2,6} = 1.06$, $p = 0.4048$)

Table 2. Mean and 95% confidence intervals of 8 habitat variables, and *p*-values from orthogonal contrasts in ANOVA. C vs T tests whether there were differences in means between unthinned (C) and thinned (M, H) stands. M vs H tests whether there were differences in means between moderately (M) and heavily thinned (H) stands. Sample size was n=4 for unthinned, moderately thinned, and heavily thinned stands.

Variables	Treatment	x̄	95% CI	P
Canopy closure (%)	C	96	87, 100	C vs T 0.0011
	M	76	46, 96	M vs H 0.3471
	H	70	39, 93	
Basal area (m²/ha)	C	37.2	31.2, 43.2	C vs T <0.0001
	M	24.2	13.5, 34.9	M vs H 0.0173
	H	17.9	7.2, 28.6	
Tall shrub (%)	C	11.2	1.6, 27.7	C vs T 0.5186
	M	9.1	0.1, 36.2	M vs H 0.8853
	H	9.5	0.1, 37.0	
Low shrub (%)	C	20.6	5.4, 42.3	C vs T 0.1750
	M	19.8	1.3, 52.0	M vs H 0.0204
	H	31.7	10.2, 65.5	
Herb (%)	C	29.4	8.7, 56.1	C vs T 0.3277
	M	36.8	6.5, 74.8	M vs H 0.2101
	H	30.3	3.6, 68.9	
Sword fern (%)	C	14.6	4.2, 29.9	C vs T 0.2297
	M	13.6	0.2, 42.4	M vs H 0.1197
	H	7.1	0.4, 40.0	
Huckleberry spp. (%)	C	6.9	1.4, 16.2	C vs T 0.3157
	M	2.6	1.1, 17.1	M vs H 0.0502
	H	7.6	0.0, 26.8	
Litter depth (cm)	C	5.8	4.7, 6.9	C vs T 0.0045
	M	4.5	2.7, 6.4	M vs H 0.9427
	H	4.5	2.6, 6.4	
Slash (%)	C	6.2	3.1, 10.3	C vs T 0.0259
	M	12.0	3.9, 23.7	M vs H 0.3342
	H	9.8	2.7, 20.8	

Table 3. Mean frequency and length of down wood in 3 size classes, and *p*-values from orthogonal contrasts in ANOVA comparing differences in frequency and abundance of down wood between unthinned and thinned stands and among moderately and heavily thinned stands. Size of logs was measured at the midway point of a log that was within the 5-meter radius of a plot center. Length of logs was that portion of a log within the 5-meter radius.

Size class	Treatment	$\bar{x}$ 95% CI	*P*
Frequency (no./ha)			
Small	C	223.4 111.7, 446.8	C vs T .0142
(10-30 cm)	M	626.5 147.5, 2661.9	M vs H .4681
	H	493.5 116.2, 2097.1	
Medium	C	132.6 39.5, 225.7	C vs T .5851
(30-50 cm)	M	134.8 -54.7, 324.0	M vs H .4072
	H	169.8 -19.5, 359.0	
Large	C	212.2 115.3, 309.1	C vs T .6052
(>50 cm)	M	180.9 -16.3, 378.1	M vs H .5816
	H	204.8 7.6, 402.0	
Length (m/ha)			
Small	C	850.4 -156.6, 1857.5	C vs T .0496
(10-30 cm)	M	2073.3 -28.8, 4175.4	M vs H .2691
	H	1528.4 -576.7, 3630.5	
Medium.	C	390.5 120.8, 660.1	C vs T .6752
(30-50 cm)	M	357.6 -170.9, 886.0	M vs H .2155
	H	504.0 -24.5, 1032.4	
Large	C	818.6 515.58, 1121.6	C vs T .1163
(>50 cm)	M	591.5 -29.8, 1212.8	M vs H .7641
	H	632.4 11.1, 1253.7	

or of large down logs (frequency $F_{2,6}$ = 0.32, p = 0.7391; length, $F_{2,6}$ = 1.73, p = 0.2549) in thinned stands relative to unthinned stands or between thinning intensities.

Abundance of forest-floor small mammals

Over two years and four trapping sessions (50,400 trap nights), I captured 12,183 small mammals representing 18 species (Table 4). I ear-tagged 2,979 individuals of six species and subsequently recaptured them 6,719 times. Townsend's chipmunks comprised 21% of all individuals captured and 48% of recaptures of the six species that were ear-tagged. Other species of small mammals with > 30 captures included Trowbridge's shrew, deer mice, creeping voles, Pacific shrews, Baird's shrews, Pacific jumping mice, northern flying squirrels, western red-backed voles, and shrew-moles. Species with < 30 captures included short-tailed weasels (*Mustela erminea*), vagrant shrews (*S. vagrans*), marsh shrews (*S. bendirii*), Douglas squirrels (*Tamiasciurus douglasii*), coast moles (*Scapanus orarias*), long-tailed voles (*Microtus longicaudis*), brush rabbits (*Sylvilagus bachmanii*), and bushy-tailed woodrats (*Neotoma cinerea*).

Abundance and density of Townsend's chipmunks was different among treatments (Figure 2; Table 5). The model with the lowest AIC value was (C≠M≠H) and there were no competing models with Δ < 2. Estimated median density was 79% greater (90% CI = +27, +133) in moderately thinned stands, and 263% greater (90% CI = 132, 326) in heavily thinned stands compared to unthinned stands. Estimated median density was 2.67/ha (90% CI = 1.84, 3.89) in unthinned stands, 4.79/ha (90% CI = 2.62, 8.73) in moderately thinned stands, and 9.69/ha (90% CI = 5.31, 17.67) in heavily thinned stands. Abundance and density of creeping voles were also different among treatments (Figure 2; Table 5). The model with the lowest AIC value was (C≠M≠H) and there were

Table 4. Total captures of all species over two years and four trap sessions. Each silvicultural treatment was replicated four times. Numbers in parentheses are the number of recaptures of ear-tagged animals.

| Species | Silvicultural Treatment | | | | | | Total | |
	Unthinned (Control)		Moderate thin (RD35)		Heavy thin (RD20)			
Townsend'chipmunk	179	(564)	373	(1297)	566	(1909)	1118	(3770)
Trowbridge's shrew	402		304		241		947	
Deer mouse	178	(596)	321	(952)	284	(819)	783	(2367)
Creeping vole	91	(56)	261	(137)	359	(164)	711	(357)
Pacific shrew	189		162		214	—	565	
Baird's shrew	144		146		195		485	
Pacific jumping mouse	50	(65)	58	(63)	111	(218)	219	(346)
Northern flying squirrel	60	(84)	11	(6)	9	(29)	80	(119)
Western red-back vole	41	(19)	6	(3)	21	(11)	68	(33)
Shrew-mole	16		5		12		33	
Short-tailed weasel	6		7		14		27	
Vagrant shrew	3		4		16		23	
Pacific water shrew	8		4		1		13	
Douglas squirrel	0		2		4		6	
Coast mole	4		1		0		5	
Long-tail vole	0		1		3		4	
Brush rabbit	0		0		2		2	
Bushy-tailed woodrat	0		1		0		1	
Sorex species (unidentified)[1]	70		57		76		203	
Total	1441	(1384)	1724	(2458)	2128	(3048)	5293	(6890)

[1] 203 shrews with brown pelages were not identifiable because they were either released alive or were in too poor condition to positively identify to species.

Table 5. Models with $\Delta \leq 2$ when examining density with respect to treatment differences. Relative weight represents the strength of the best model compared to a competing model and is calculated as relative weight of the best model divided by the relative weight of a competing model. For example, if the relative weight of a competing model is 1.7, the best model could be considered to explain the data 1.7 times better than that competing model. Effect represents percent difference in median density based on the model. For example, if Effect is: M (+77) H (+259), median density was 77% higher in moderately thinned stands and 259% higher in heavily thinned stands than in unthinned stands.

Species	Δ AIC	AIC Weight	Relative Wt.	Model	Effect (% difference)	90% CI (low, high) (% difference)
Townsend's chipmunk	0	.98	1	(C≠M≠H)	M (+79) H (+263)	M (+27, +133) H (+132, +326)
Deer mouse	0	.32	1	(C=M) ≠H	H (+66)	H (+25, +129)
	.02	.32	1	C≠(M=H)	MH (+66)	MH (+16, +137)
	1.05	.19	1.7	(C=M=H)	No difference	
	1.59	.14	2.3	(C≠M≠H)	M (+40) H (+97)	M (-1, +98) H (+39, +178)
Creeping vole	0	.62	1	(C≠M≠H)	M (+177) H (+453)	M (+25, +516) H (+149, +1129)
Pacific jumping mouse	0	.60	1	(C≠M≠H)	M (+93) H (+198)	M (0, +270) H (+94, +357)
	1.79	.25	2.4	C≠(M=H)	MH (+153)	MH (+67, +281)
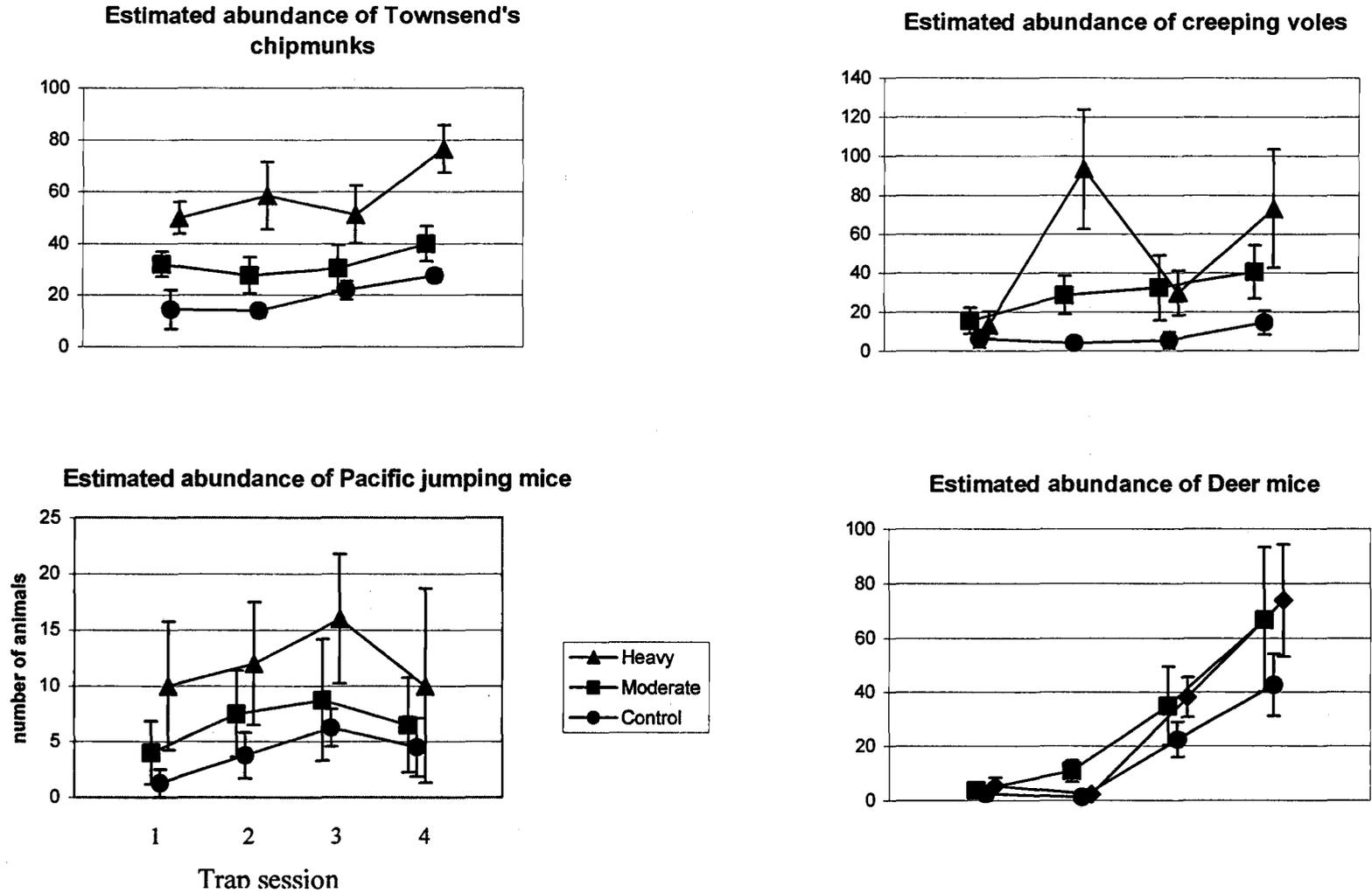
Figure 2. Changes over time of mean estimated abundance of 4 species in unthinned (n=4), moderately thinned (n=4), and heavily thinned (n=4) stands. Trap session 1 and 2 were in 1999. Trap session 3 and 4 were in 2000. Error bars represent plus and minus one SE of point estimates of abundance.

no competing models with $\Delta < 2$. Estimated median density was 177% greater (90% CI = +25, +516) in moderately thinned stands, and 453% greater (90% CI = 149, 1129) in heavily thinned stands compared to unthinned stands. Median estimated density was 1.75/ha (90% CI = 0.66, 4.63) in unthinned stands, 4.87/ha (90% CI = 0.83, 28.55) in moderately thinned stands, and 9.70/ha (90% CI = 1.65, 56.97) in heavily thinned stands.

Density of deer mice was higher in heavily thinned stands than in moderately thinned or unthinned stands (Table 5). The model with the lowest AIC value was ((C=M) ≠ H). Based on this model, estimated median density was 66% greater (90% CI = +25, +129) in heavily thinned stands compared to unthinned or moderately thinned stands. Estimated median density was 5.38/ha (90% CI = 2.63, 11.01) in moderately thinned and unthinned stands and 8.93/ha (90% CI = 3.06, 26.05) in heavily thinned stands. Another model with nearly equal weight of the best model indicated that density of deer mice was greater in thinned stands compared to unthinned stands (Table 5). The competing model was (C ≠ (M=H)). Estimated median density for this model was 66% greater (90% CI = +16, +137) in thinned stands compared to unthinned stands. Estimated median density was 3.09/ha (90% CI = 1.45, 6.62) in unthinned stands and 5.13/ha (90% CI = 1.69, 15.60) in thinned stands. Two other competing models with $\Delta < 2$ indicated that there was no difference in density among treatments (C=M=H), or that density was different among all treatments (C≠M≠H).

Pacific jumping mice showed distinct differences among treatments (Table 5). The model with the lowest AIC value was (C≠M≠H). Based on this model, estimated median density was 93% greater (90% CI = 0, +270) in moderately thinned stands 198% greater (90% CI = +94, +357) in heavily thinned stands. Median estimated density was

0.77/ha (90% CI = 0.49, 1.20) in unthinned stands, 1.48/ha (90% CI = 0.49, 4.44) in moderately thinned stands, and 2.28/ha (90% CI = 0.95, 5.49) in heavily thinned stands. A competing model indicated that estimated median density was greater in thinned stands compared to unthinned stands (C≠(M=H)).

There was no difference in mean number of captures of Baird's shrews among treatments (Figure 3; Table 6). The model with the lowest AIC value was (C=M=H) and there were no competing models with Δ < 2. Based on this model, mean number of captures averaged 6.9 animals (90% CI = 5.0, 8.9) in all treatments.

There was a slight decrease in moderately thinned stands and a slight increase in heavily thinned stands of number of captures of Pacific shrews compared to unthinned stands. The model with the lowest AIC value was (C≠M≠H). Based on this model, mean number of captures was 1.6 animals less (90% CI = -4.6, +1.7) in moderately thinned stands and 1.7 animals more (90% CI = -1.2, +4.7) in heavily thinned stands than in unthinned stands. Mean number of captures was 11.2 (90% CI = 4.4, 18.0) in unthinned stands, 9.6 (90% CI = 0, 19.5) in moderately thinned stands, and 12.9 (90% CI = 3.0, 22.9) in heavily thinned stands. A competing model with Δ < 2 indicated no difference in number of captures among treatments (C=M=H). Two other competing models indicated a slight decrease in number of captures in moderately thinned stands ((C=H) ≠M) compared to unthinned or heavily thinned stands, or a slight increase in heavily thinned stands ((C=M) ≠H) compared to unthinned or moderately thinned stands (Table 6).

Trowbridge's shrews had greater number of captures in unthinned stands compared to thinned stands. The model with the lowest AIC value was (C ≠ (M=H)).

Table 6. Models with $\Delta \leq 2$ when examining relative number of captures with respect to treatment differences. Effect size represents mean difference in number of captures based on the model. For example, if Effect is: M (-1.6) H (+1.7), mean number of captures was 1.6 less animals in moderately thinned stands and 1.7 more animals in heavily thinned stands than in unthinned stands.

| Species	Δ	Weight	Relative Wt.	Model	Effect (mean difference in # of captures)	90% CI (low, high (mean difference in # of captures)
Baird's shrew	0	.51	1	(C=M=H)	No difference	
Pacific shrew	0	.30	1	(C≠M≠H)	M (-1.6) H (+1.7)	M (-4.6, +1.3) H (-1.2, +4.7)
	.33	.26	1.2	(C=M=H)	No difference	
	.86	.20	1.5	(C=M) ≠H	H(+2.6)	H (-0.1, +5.2)
	.99	.18	1.7	(C=H) ≠M	M (-2.5)	M (-5.1, +0.1)
Trowbridge's shrew	0	.36	1	C≠(M=H)	MH (-8.1)	MH (-14.4, -1.7)
	.75	.25	1.4	(C=M=H)	No difference	
	1.16	.20	1.8	(C=M) ≠H	H (-6.9)	H (-13.8, -0.1)
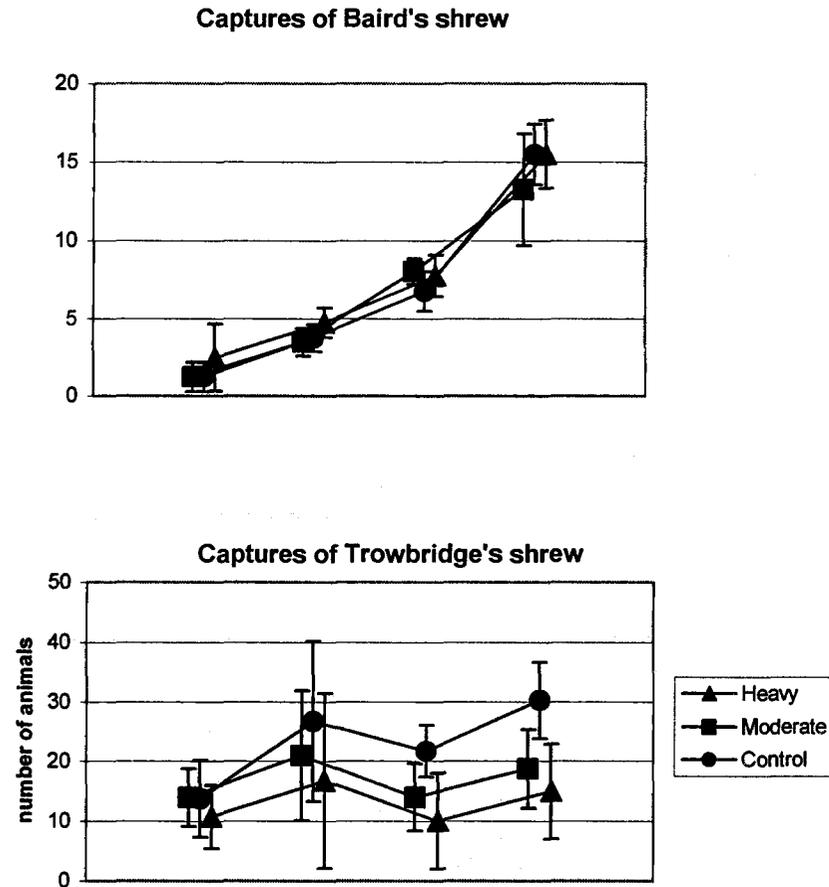
Figure 3. Changes over time of mean number of captures of 3 species in unthinned (n=4), moderately thinned (n=4), and heavily thinned (n=4) stands. Trap session 1 and 2 were in 1999. Trap session 3 and 4 were in 2000. Error bars represent plus and minus one SE of mean number of captures.

Based on this model, mean number of captures was 8.1 animals greater (90% CI = -14.4, -1.7) in unthinned stands compared to thinned stands. Mean number of captures in unthinned stands was 23.1 (90% CI = 8.6, 37.7) and 15.0 in thinned stands (90% CI = -5.9, 35.9). Competing models with $\Delta < 2$ indicated either no change in number of captures among treatments (C=M=H) or that the decrease in animals was confined to heavily thinned stands ((C=M) $\neq$ H).

Number of captures of northern flying squirrels was greater in unthinned stands compared to thinned stands (t_6=2.84, p=.0294). Captures of shrew-moles were not significantly different between thinned and unthinned stands (t_4=1.6, p=.1842). Western red-backed voles, Pacific water shrews, and coast moles were captured more frequently in unthinned stands than in thinned stands, whereas short-tailed weasels, vagrant shrews, long-tailed voles, and Douglas squirrels were captured more frequently in thinned stands than in unthinned stands (Table 4). However, captures of these species were too few for statistical analysis. Details of captures by treatment and block are shown in Appendix 1.

Mean Maximum Distance Moved (MMDM)

MMDM of adult female Townsend's chipmunks was less in heavily thinned stands than in unthinned or moderately thinned stands (Table 7). The model with the lowest AIC value was ((C=M) $\neq$ H) and there were no competing models with $\Delta < 2$. MMDM of adult females was 13.6 m less (90% CI = -18.7, -8.6) in heavily thinned stands than in unthinned or moderately thinned stands. MMDM of adult females in heavily thinned stands was 57.6 m (90% CI = 48.8, 66.5) and 71.2 m (90% CI = 66.1, 76.4) in moderately thinned and unthinned stands.

Table 7. Models with Δ ≤ 2 for Mean Maximum Distance Moved (MMDM) in meters. MMDM was analyzed for trap session 3 and 4. Effect size represents the mean difference in MMDM. For example, if Effect is: H (S3) (+28.6) H (S4) (-15.4), there was an increase in MMDM of 28.6 m in heavily thinned stands in trap session 3 and a decrease in MMDM of -15.4 m in heavily thinned stands in trap session 4 compared to trap sessions 3 and 4 in unthinned and moderately thinned stands.

Species	Sex	Δ	Wt	Rel. Wt.	Model	Effect (difference in MMDM)	90% CI (difference in MMDM)
Townsend's Chipmunk	F	0	.73	1	(C=M) ≠H	H (-13.6)	H (-18.7, -8.6)
Townsend's chipmunk	M	0	.35	1	SESSION	(S3) (+44.0)	(S3) (+30.3, +57.7)
		.50	.27	1.3	SESSION (C=M) ≠H	H (S3)(+28.6) H (S4)(-15.4)	H (S3)(-0.3, +57.5) H (S4)(-30.6, -0.2)
		.59	.26	1.3	SESSION C≠(M=H)	MH (S3)(+28.8) MH (S4)(-15.2)	MH (S3)(-0.2, +57.6) MH (S4)(-30.5, 0)
Deer mouse	F	0	.51	1	SESSION C≠(M=H)	MH (S3)(-2.6) MH (S4)(-16.2)	MH (S3)(-18.5, +13.3) MH (S4)(-26.2, -6.2)
		1.6	.23	2.2	SESSION (C≠M≠H)	M (S3)(+1.4) H (S3)(+6.6) M (S4)(-12.3) H (S4)(-20.2)	M (S3)(-15.7, +18.4) H (S3)(-23.7, +10.5) M (S4)(-23.4, -1.1) H (S4)(-31.4, -9.0)
Deer mouse	M	0	.37	1	SESSION C≠(M=H)	MH (S3)(+4.7) MH (S4)(-11.7)	MH (S3)(-14.7, +24.0) MH (S4)(-21.5, -2.0)
		.48	.29	1.3	SESSION	(S3) (+16.4)	(S3) (+6.8, +26.1)

MMDM of adult male Townsend's chipmunks differed among trap sessions (Table 7). The model with the lowest AIC value was (SESSION) and there were no competing models with $\Delta < 2$. Based on this model, MMDM of adult males was 44.0 m more (90% CI = 30.3, 57.7) in late spring than in early fall in all treatments. MMDM of adult males was 113.4 m (90% CI = 80.2, 146.5) in late spring and 69.4 m (90% CI = 49.9, 88.8) in early fall. A competing model with $\Delta < 2$ indicated that MMDM of adult males was greater in the heavily thinned stands in late spring and less in early fall than in moderately thinned or unthinned stands in the same time period (SESSION (C=M) $\neq$ H)) (Table 7). Another competing model with $\Delta < 2$ indicated that MMDM of adult males was greater in thinned stands in late spring and less in early fall than in unthinned stands in the same time period (SESSION C$\neq$(M=H)). Over all trap sessions and treatments, MMDM was 91.4 m (95%CI=81.9, 100.8) for males and 66.7 m (95%CI=57.2, 76.2) for females.

MMDM of adult female deer mice was less in thinned stands than in unthinned stands and also varied by trap session (Table 7). The model with the lowest AIC value was (SESSION C $\neq$ (M=H)). Based on this model, MMDM of adult females was 16.2 m less (90% CI = -26.2, -6.2) in thinned stands than in unthinned stands. MMDM of adult females was 72.3 m (90% CI = 55.1, 89.6) in unthinned stands and 56.1 m (90% CI = 28.9, 83.3) in thinned stands in late spring, and 58.7 m (90% CI = 47.4, 70.1) in unthinned stands and 42.5 m (90% CI = 21.2, 63.8) in thinned stands in early fall. A competing model with $\Delta < 2$ indicated MMDM of adult females was progressively greater in moderately thinned and heavily thinned stands in late spring, and progressively

less in moderately thinned and heavily thinned stands in early fall than in unthinned stands in the same time period (SESSION (C≠M≠H)) (Table 7).

MMDM of adult male deer mice was less in thinned stands than in unthinned stands and also varied by trap session (Table 7). The model with the lowest AIC value was (SESSION C ≠ (M=H)). Based on this model, MMDM of males was 11.7 m less (90% CI = -21.5, –2.0) in thinned stands than in unthinned stands. MMDM of adult males was 86.2 m (90% CI = 61.2, 111.3) in unthinned stands and 74.5 m (90% CI = 39.7, 109.3) in thinned stands in late spring, and 69.8 m (90% CI = 54.4, 85.2) in unthinned stands and 58.1 m (90% CI = 32.9, 83.2) in thinned stands in early fall. A competing model with Δ < 2 showed MMDM of males was not different among treatments but was greater in late spring than in early fall (SESSION) (Table 7). Over both trap sessions and all treatments, MMDM was 70.2 m (90% CI =63.1, 77.3) for males and 54.7 m (90% CI =51.7, 66.6) for females.

Sex ratios

Sex ratios of Townsend's chipmunks varied by trap session only (Table 8). The model with the lowest AIC value was (SESSION) and there were no competing models with Δ < 2. Based on this model, there were 1.94 (90% CI = 1.22, 3.00), 1.17 (90% CI = 0.72, 1.86), 1.70 (90% CI = 1.04, 2.70) and 1.38 (90% CI = 1.08, 1.78) times as many males as females in trap sessions 1, 2, 3, and 4, respectively. The sex ratio (male/female) for adult Townsend's chipmunks over time and treatments was 1.38:1 (90% CI = 1.08:1, 1.78:1).

Table 8. Models with $\Delta \leq 2$ for sex ratios. The odds of being an adult male is referenced to the trap sessions in parentheses with respect to each treatment specified by the model. For example, if Odds of being male is: (S1) 2.03 (M) 1.78, the odds of being an adult male is 2.03:1 for trap session 1 in the unthinned and heavily thinned stands, and 1.78:1 in the moderately thinned stands. Sex ratios of creeping voles were averaged over 4 trap sessions

Species	Δ	Wt	Rel. Wt.	Model	Odds of being male	90% CI
Townsend's chipmunk	0	.34	1	SESSION	(S1) 1.94 (S2) 1.17 (S3) 1.70 (S4) 1.38	(S1) (1.22, 3.00) (S2) (0.72, 1.86) (S3) (1.08, 2.70) (S4) (1.08, 1.78)
	1.04	.20	1.7	SESSION (C=H)≠M	(S1) 2.03 (M) 1.78 (S2) 1.22 (M) 1.08 (S3) 1.78 (M) 1.56 (S4) 1.44 (M) 1.27	(S1) (1.08, 3.17) (M) (0.82, 2.03) (S2) (0.72, 1.67) (M) (0.35, 1.68) (S3) (1.04, 2.85) (M) (0.79, 3.00) (S4) (1.08, 1.86) (M) (0.82, 2.03)
	1.38	.17	2.0	SESSION C≠(M=H)	(S1) 2.13 (MH) 1.85 (S2) 1.27 (MH) 1.13 (S3) 1.86 (MH) 1.63 (S4) 1.50 (MH) 1.38	(S1) (1.00, 4.26) (MH) (0.56, 6.14) (S2) (0.59, 2.70) (MH) (0.33, 4.00) (S3) (0.85, 4.00) (MH) (0.47, 5.67) (S4) (0.89, 2.57) (MH) (0.49, 3.76)
	1.55	.16	2.1	SESSION (C=M)≠H	(S1) 1.86 (H) 1.94 (S2) 1.13 (H) 1.17 (S3) 1.63 (H) 1.70 (S4) 1.33 (H) 1.38	(S1) (1.22, 2.85) (H) (1.00, 3.76) (S2) (0.72, 1.78) (H) (0.61, 2.33) (S3) (1.04, 2.57) (H) (0.85, 3.35) (S4) (1.08, 1.70) (H) (0.89, 2.23)

Table 8 (continued).

Species	Δ	Wt	Rel. Wt.	Model	Odds of being male	90% CI
Deer mouse	0	.64	1	SESSION (C=M) ≠H)	(S3) 1.78 (H) 1.17 (S4) 1.08 (H) 0.72	(S3) (0.96, 3.00) (H) (0.56, 2.33) (S4) (0.85, 1.38) (H) (0.49, 1.04)
	1.91	.25	2.6	SESSION (C≠M≠H)	(S3) (C) 1.86 (S3) (M) 1.70 (S3) (H) 1.33 (S4) (C) 1.13 (S4) (M) 1.04 (S4) (H) 0.69	(S3) (C) (1.27, 2.85) (S3) (M) (1.00, 3.00) (S3) (H) (0.69, 2.03) (S4) (C) (0.96, 1.33) (S4) (M) (0.75, 1.38) (S4) (H) (0.52, 0.96)
Creeping vole	0	.61	1	((C=M) ≠H)	(C, M) 1.37 (H) 0.64	(C, M) (0.98, 1.91) (H) (0.31, 1.31)

Sex ratios of deer mice varied by trap session but the ratio of males to females was less in heavily thinned stands compared to unthinned or moderately thinned stands (Table 8). The model with the lowest AIC value was (SESSION (C=M) ≠ H)) and there were no competing models with Δ < 2. Based on this model, there were 1.78 (90% CI = 0.96, 3.00) times as many males in moderately thinned and unthinned stands as females, and 1.17 (90% CI = 0.56, 2.33) times as many males as females in heavily thinned stands in late spring. There were 1.08 (90% CI = 0.85, 1.38) times as many males as females in moderately thinned and unthinned stands, and 0.72 (90% CI = 0.49, 1.04) times as many males as females in heavily thinned stands in early fall. The sex ratio (male/female) for adult deer mice over time and treatments was 0.92:1 (90% CI = 0.79:1, 1.08:1).

Sex ratios of adult creeping voles were skewed toward females in heavily thinned stands compared to unthinned or moderately thinned stands. The model with the lowest AIC value was ((C=M) ≠ H) and there were no competing models with Δ < 2. There were 1.37 (90% CI = 0.98, 1.91) times as many males as females in moderately thinned and unthinned stands and 0.64 (90% CI = 0.31, 1.31) times as many males as females in heavily thinned stands. The sex ratio (male/female) for creeping voles over time and treatments was 1.13:1 (90% CI = 0.82:1, 1.55:1).

Age-class ratios

Age-class ratios of Townsend's chipmunks varied by trap session (Table 9). The model with the lowest AIC value was (SESSION) and there were no competing models with Δ < 2. Based on this model, there were 11.50 (90% CI = 3.17, 49.00), 2.70 (90% CI = 0.49, 13.29), 11.50 (90% CI = 2.45, 49.0) and 5.67 (90% CI = 2.85, 11.50) times as

Table 9. Models with $\Delta \leq 2$ for age-class ratios. The odds of being an adult is referenced to the trap sessions in parentheses with respect to each treatment specified by the model. For example, if odds of being an adult is: (S1) 11.50 (H) 13.28, the odds of being an adult is 11.50:1 for trap session 1 in unthinned and moderately thinned stands, and 13.28:1 in heavily thinned stands. Age-class ratios for creeping voles were averaged over trap sessions

Species	Δ	Wt	Rel. Wt.	Model	Probability of being an adult	90% CI
Townsend's chipmunk	0	.35	1	SESSION	(S1) 11.50 (S2) 2.70 (S3) 11.50 (S4) 5.67	(S1) (3.17, 49.00) (S2) (0.49, 13.28) (S3) (2.45, 49.00) (S4) (2.85, 11.50)
	1.09	.20	1.8	SESSION (C=M) ≠H	(S1) 11.50 (H) 13.28 (S2) 2.45 (H) 3.00 (S3) 10.11 (H) 13.28 (S4) 5.25 (H) 6.69	(S1) (3.17, 32.33) (H) (3.00, 49.00) (S2) (0.49, 11.50) (H) (0.47, 19.00) (S3) (2.45, 49.00) (H) (2.33, 99.00) (S4) (2.85, 9.00) (H) (2.70, 15.67)
	1.13	.20	1.8	SESSION C≠(M=H)	(S1) 10.11 (MH) 13.28 (S2) 2.33 (MH) 2.85 (S3) 9.00 (MH) 11.50 (S4) 4.88 (MH) 6.14	(S1) (3.00, 32.33) (MH) (2.45, 49.00) (S2) (0.47, 11.50) (MH) (0.39, 19.00) (S3) (2.33, 32.33) (MH) (1.94, 99.00) (S4) (2.84, 9.00) (MH) (2.33, 15.67)
	1.67	.15	2.3	SESSION (C=H) ≠M	(S1) 11.50 (M) 11.50 (S2) 2.70 (M) 2.70 (S3) 11.50 (M) 10.11 (S4) 5.67 (M) 5.67	(S1) (3.17, 49.00) (M) (2.23, 49.00) (S2) (0.49, 15.67) (M) (0.35, 19.00) (S3) (2.45, 49.00) (M) (1.78, 49.00) (S4) (2.85, 11.50) (M) 2.13, 15.67)

Table 9 (continued).

Species	Δ	Wt	Rel. Wt.	Model	Odds of being an adult	90% CI
Deer mouse	0	.40	1	SESSION	(S3) 1.86 (S4) 0.72	(S3) (1.17, 3.00) (S4) (0.59, 0.82)
	1.39	.20	2.0	SESSION C≠(M=H)	(S3) 1.63 (MH) 1.94 (S4) 0.64 (MH) 0.75	(S3) (1.08, 2.85) (MH) (1.00, 3.76) (S4) (0.52, 0.75) (MH) (0.54, 1.04)
	1.53	.18	2.2	SESSION (C=M) ≠H	(S3) 1.78 (H) 2.03 (S4) 0.69 (H) 0.79	(S3) (1.08, 3.00) (H) (1.00, 4.26) (S4) (0.56, 0.82) (H) (0.54, 1.13)
Creeping vole	0	.47	1	((C=M) ≠H)	(C, M) 0.59 (H) 0.53	(C, M) (0.46, 0.77) (H) (0.32, 0.90)
	1.3	.25	1.9	((C=H) ≠M)	(C, H) 0.53 (M) 0.60	(C, H) (0.41, 0.68) (M) (0.36, 1.00)
	1.8	.19	2.5	(C≠M≠H)	(C) 0.52 (M) 0.60 (H) 0.53	(C) (0.29, 0.93) (M) (0.19, 1.88) (H) (0.17, 1.64)

many adults as juveniles in trap sessions 1, 2, 3, and 4, respectively. Over time and treatments, there were 5.67 (90% CI = 2.85, 11.5) times as many adults as juveniles.

Age-class ratios of deer mice also varied by trap session (Table 9). The model with the lowest AIC value was (SESSION) and there were no competing models with $\Delta <$ 2. Based on this model, there were 1.86 (90% CI = 1.17, 3.0) and 0.72 (90% CI = 0.59, 0.81) times as many adults as juveniles in trap sessions 3 and 4, respectively. Over time and treatments, there were 0.72 (90% CI = 0.64, 0.82) times as many adults as juveniles.

Age-class ratios of creeping voles were different in heavily thinned stands compared to unthinned or moderately thinned stands (Table 9). The model with the lowest AIC value was ((C=M) ≠ H). Based on this model, there were 0.59 (90% CI = 0.46, 0.77) times as many adults as juveniles in moderately thinned and unthinned stands and 0.53 (90% CI = 0.32, 0.90) times as many adults as juveniles in heavily thinned stands. A competing model with $\Delta < 2$ indicated that age-class ratios were different in moderately thinned stands compared to unthinned or heavily thinned stands ((C=H) ≠M). Over time and treatments, there was 0.56 (90% CI = 0.45, 0.70) times as many adults as juveniles.

Body mass

Body mass of adult female Townsend's chipmunks varied over time but did not vary between thinned and unthinned stands or with thinning intensity (Table 10&12)[1]. The model with the lowest AIC value was (SESSION) and there were no competing models with $\Delta < 2$. Mean body mass of adult females was greater in the first three trap

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[1] The average weights in Table 10 and 11 are statistical averages over time and treatments. The average weights in Table 12 are averages of all animals over all blocks, treatments, and trap sessions.

sessions than in trap session 4. Mean body mass of adult females in any treatment was 81.2 g (90% CI = 76.8, 85.5), 82.9 g (90% CI = 78.7, 87.2), 85.3 g (90% CI = 81.0, 89.5), and 76.5 g (90% CI = 72.3, 80.8) in trap sessions 1, 2, 3, and 4, respectively.

Body mass of adult male Townsend's chipmunks also varied over time but did not vary between thinned and unthinned stands or with thinning intensity (Table 10&12). The model with the lowest AIC value was (SESSION) and there were no competing models with $\Delta < 2$. Mean body mass of adult males was also greater in the first three trap sessions than in trap session 4. Mean body mass of adult males in any treatment over time was 71.0 g (90% CI = 69.3, 72.7), 72.0 g (90% CI = 70.3, 73.7), 71.7 g (90% CI = 69.9, 73.4), and 69.3 g (90% CI = 67.6, 71.0) in trap sessions 1, 2, 3, and 4, respectively. Adult females weighed 10.4 g (90% CI = 8.7, 12.1) more than adult males over time and all treatments. Mean weight of adult females was 81.4 g (95%CI=80.0, 82.8) and mean weight of adult males was 71.0 g (95%CI=69.6, 72.4).

Body mass of adult female deer mice did not vary over time and was not different between thinned and unthinned stands, or between thinning intensity (Table 10&12). The model with the lowest AIC value was (C=M=H). Based on this model, mean body mass of adult females was 20.1g (90% CI = 18.9, 21.3). A competing model with $\Delta < 2$ indicated that body mass varied between trap sessions (SESSION).

Body mass of adult male deer mice was greater in heavily thinned stands compared to moderately thinned or unthinned stands and did not vary over time (Table 10&12). The model with the lowest AIC value was ((C=M) ≠ H). Mean body mass of adult males was 17.8 g (90% CI = 17.3, 18.3) in moderately thinned and unthinned stands, and 19.0 g (90% CI = 18.1, 19.9) in heavily thinned stands. A competing model

with $\Delta < 2$ indicated that body mass also varied by trap session but was still greater in heavily thinned stands than in unthinned or moderately thinned stands (SESSION (C=M) $\neq$H)). Females weighed 1.6g (90% CI = 0.9, 2.4) more than males over time and all treatments. Mean weight of females was 20.1g (90% CI =19.5, 20.7) and mean weight of males was 18.5g (90 %CI = 17.9, 19.1).

Body mass of adult male and female creeping voles did not vary by treatments (Table 11&12). The model with the lowest AIC value was (C=M=H) for both sexes. Based on this model, mean body mass of adult males in any treatment was 19.5 g (90% CI = 18.7, 20.3). Mean body mass of adult females in any treatment was 19.2 g (90% CI = 18.6, 19.8). Two competing models with $\Delta < 2$ indicated that body mass of adult males was greater in heavily thinned stands compared to unthinned or moderately thinned stands ((C=M) $\neq$H), and body mass of females was greater in thinned stands compared to unthinned stands (C$\neq$(M=H)) (Table 11).

Body mass of adult female Pacific jumping mice was less in moderately thinned stands than in unthinned or heavily thinned stands (Table 11&12). The model with the lowest AIC value was ((C=H) $\neq$ M). Based on this model, body mass of adult females was 1.7 g less (90% CI = -3.4, 0.0) in moderately thinned stands compared to heavily thinned or unthinned stands. Two competing models with $\Delta < 2$ indicated that there was no change in body mass among treatments (C=M=H), or that body mass was greater in heavily thinned stands than in unthinned or moderately thinned stands ((C=M) $\neq$H) (Table 11).

Body mass of adult male Pacific jumping mice did not vary by thinning or thinning intensities. The model with the lowest AIC value was (C=M=H). Two

competing models with $\Delta < 2$ indicated that body mass was greater in heavily thinned stands than in unthinned or moderately thinned stands ((C=M) ≠H), or that body mass was greater in thinned stands than in unthinned stands ((C≠(M=H)). Mean body mass of adult male Pacific jumping mice in all treatments was 21.3 g (90% CI = 20.6, 22.0), and mean body mass of adult females in all treatments was 22.9 g (90% CI = 22.2, 23.6).

Table 10. Models with $\Delta \leq 2$ for body mass of Townsend's chipmunks and deer mice. Effect represents the mean difference in body mass. For example, if Effect is: S1(+3.8) S2(+6.4) S3(+8.7), there was an increase of 3.8 grams in body mass in trap session1, 6.4 grams in session 2, and 8.7 grams in trap session 3 compared to trap session 4. Bodymass of Townsend's chipmunks were analyzed over all trap sessions. Bodymass of deer mice were analyzed over trap sessions 3 and 4. Bodymass of creeping voles and Pacific jumping mice were averaged over all trap sessions.

Species	Sex	Δ	Wt	Rel. Wt.	Model	Effect (difference in body mass)	90% CI
Townsend's chipmunk	F	0	.59	1	SESSION	S1(+3.8) S2(+6.4) S3(+8.7)	S1(-0.7, +8.3) S2(+2.5, +10.3) S3(+4.6, +12.8)
Townsend's chipmunk	M	0	.63	1	SESSION	S1(+1.7) S2(+2.7) S3(+2.4)	S1(+0.7, +2.8) S2(+1.0, +4.4) S3(+0.2, +4.6)
Deer mouse	F	0	.33	1	(C=M=H)	No difference	
		.87	.21	1.6	SESSION	S3(-0.9)	S3(-2.1, +0.2)
Deer mouse	M	0	.45	1	(C=M) $\neq$H	H (+1.2)	H (+0.8, +1.6)
		.87	.29	1.6	SESSION (C=M)$\neq$H	H (S3)(+1.8) H (S4)(+1.2)	H (S3)(+0.8, +2.7) H (S4)(+0.8, +1.6)

Table 11. Models with $\Delta \leq 2$ for body mass of creeping voles and Pacific jumping mice. Effect represents the mean difference in body mass. For example, if Effect is: H (+0.6) there was an increase of 0.6 g of bodymass in heavily thinned stands compared to unthinned and moderately thinned stands. Body mass of creeping voles and of Pacific jumping mice were averaged over 4 trap sessions.

Species	Sex	Δ	Wt	Rel. Wt.	Model	Effect (difference in body mass)	90% CI
Creeping vole	F	0	.47	1	(C=M=H)	No difference	
		1.7	.19	2.4	C≠(M=H)	MH (+0.9)	MH (-1.0, +2.8)
Creeping vole	M	0	.49	1	(C=M=H)	No difference	
		1.7	.20	2.4	(C=M)≠H	H (+0.6)	H (-0.5, +1.7)
Pacific jumping mouse	F	0	.36	1	(C=H)≠M	M (-1.7)	M (-3.4, 0.0)
		.56	.27	1.3	(C=M=H)	No difference	
		1.2	.19	1.9	(C=M)≠H	H (+0.6)	H (-0.4, +2.9)
Pacific jumping mouse	M	0	.41	1	(C=M=H)	No difference	
		1.1	.24	1.7	(C=M)≠H	H (+0.7)	H (-0.3, +1.8)
		1.8	.16	2.5	C≠(M=H)	MH (+0.6)	MH (-0.7, +1.9)

Table 12. Comparison of weights of four species by treatment averaged over four blocks and four trap sessions. Weight is the average weight of n animals in each treatment. SE is the standard error of average weight

Species	Treatment	Sex	n	Weight	SE
Townsend's chipmunk	unthinned	M	86	71.1	0.7
		F	43	81.3	1.2
	moderate thin	M	166	70.8	0.8
		F	101	78.3	1.2
	heavy thin	M	243	69.5	0.7
		F	159	77.1	1.2
deer mouse	unthinned	M	50	18.3	0.5
		F	27	20.3	0.8
	moderate thin	M	88	18	0.4
		F	59	19.4	0.7
	heavy thin	M	74	19.1	0.6
		F	71	19.5	0.7
creeping vole	unthinned	M	15	18.4	0.4
		F	9	19.8	0.5
	moderate thin	M	51	19.7	0.5
		F	38	19.7	0.6
	heavy thin	M	45	20.3	0.6
		F	55	18.9	0.8
Pacific jumping mouse	unthinned	M	24	21.1	0.5
		F	15	23.3	0.6
	moderate thin	M	22	20.4	0.4
		F	23	22.2	0.6
	heavy thin	M	51	21.3	0.5
		F	36	23.7	0.7

DISCUSSION

Effects of thinning on forest-floor small mammals

The effects of thinning on small mammals were neutral or positive for most small mammals I analyzed five and six years after thinning had taken place. Density of Townsend's chipmunks, creeping voles, and Pacific jumping mice were greater in thinned stands compared to unthinned stands. Wilson and Carey (2000) also found Townsend's chipmunks and creeping voles to be more abundant in thinned stands than unthinned stands in Washington, even though unthinned stands had been managed for retention of large-diameter trees, snags, and down wood. One reason for these increases may be that response of low shrubs due to thinning may provide additional cover and forage (Hayes et al. 1995). In my study, cover of low shrubs increased in heavily thinned stands (Table 2). Increases in slash (Table 2) and small-diameter down wood (Table 3) from thinning operations may have also provided additional cover for these species.

Animals that are living in high-quality habitat may decrease movements due to greater food availability (Anderson 1986, Carey 1995) and more cover (Rosenberg and Anthony 1993, Hayes et al. 1995), have sex ratios skewed toward more females, and have greater body mass (Hayes et al. 1995). In my study, movements of female chipmunks decreased in heavily thinned stands compared to unthinned or moderately thinned stands, and movements of female deer mice decreased in thinned stands compared to unthinned stands. Movements of male deer mice also decreased in thinned stands compared to unthinned stands in early fall. Sex ratios in deer mice and creeping voles favored females in heavily thinned stands compared to unthinned or moderately thinned stands. Male

adult deer mice also had greater body mass in heavily thinned stands than in unthinned or moderately thinned stands. Therefore, thinned stands, and especially heavy thinning, may be providing better habitat than unthinned stands for these three species.

Although Gomez et al. (in prep) found that thinning had little influence on density of chipmunks on these study sites one to three years after thinning, they predicted that density of Townsend's chipmunks would increase in thinned stands due to structural changes caused by thinning that included increases in slash, shrubs, and herbaceous vegetation. Five and six years after thinning, density of Townsend's chipmunks had increased by 70% in moderately thinned stands and 263% in heavily thinned stands compared to unthinned stands. Because it appears that thinning is providing high-quality habitat for Townsend's chipmunks, I predict that density of chipmunks will continue to be higher in thinned stands than in unthinned stands, and greatest in heavily thinned stands for at least the next decade.

Creeping voles, deer mice, and Pacific jumping mice are most commonly found in open habitats with high percentages of herbs and shrubs (Doyle 1987, Morrison and Anthony 1989, Gomez and Anthony 1998). Increases in grasses and forbs in stands that have been thinned may favor species that are associates of open habitats or early seral stages such as deer mice and creeping voles (Maser et al. 1981, Verts and Carraway 1998:344). Increases in densities of creeping voles and Pacific jumping mice in thinned stands may be a result of this response. In addition, body mass of adult male deer mice, and proportions of adult female deer mice and creeping voles increased in heavily thinned stands compared to unthinned or moderately thinned stands. These demographic characteristics imply that heavy thinning may provide the best habitat in young Douglas-

fir forests for these species. Suzuki (2000) found similar results 1-2 years after thinning in the same stands as my study, but abundances in stands thinned 7-24 years previously were similar to unthinned stands. However, tree densities of thinned stands in Suzuki's retrospective study sites were higher than moderately thinned stands in this study and canopy closure may have already been in progress. Heavily thinned stands in my study sites will take much longer for canopy closure to occur and may have a different developmental path than a return to a dense overstory canopy. I predict that optimal habitat for deer mice and creeping voles will persist into the future for these species.

Of the seven species of small mammals that were analyzed utilizing information-theoretic methods, only Trowbridge's shrew was captured more frequently in unthinned stands. Trowbridge's shrews are found in many seral stages of Douglas-fir forest (Morrison and Anthony 1989, Corn and Bury 1991, Gomez and Anthony 1998). Butts and McComb (2000) found that Trowbridge's shrews were positively associated with fern cover and small diameter down wood. However, Craig (1995) and Lee (1995) found greater number of captures in sites with larger pieces and greater amounts of down wood respectively. Although Suzuki (2000) found no differences in abundance of Trowbridge's shrews between thinned and unthinned stands within 2 years of thinning in his experimental study, stands thinned 7-24 years previously had greater number of captures than adjacent unthinned stands. Suzuki speculated that Trowbridge's shrews are selecting habitat components based on availability and that preference may not be based strictly on small diameter down wood. Trowbridge's shrews also forage in the top layers of duff (Verts and Carraway 1998). Litter depth in my study was greater in unthinned stands compared to thinned stands (Table 2), and it is possible that thinning may have an

effect on litter depth in the short-term due to soil compaction. However, whether the average 1.3 cm difference in litter depth between thinned and unthinned stands is biologically significant is unclear and causal relationships warrant further study.

Estimated abundance of northern flying squirrels was greater in unthinned stands compared to thinned stands. This differs from the results of Gomez and Anthony (submitted) who found no difference in abundance among treatments at these study sites 1-3 years after thinning. It is possible that effects of thinning may have had a delayed effect on abundance of northern flying squirrels. This may be due in part to changes in abundance and biomass of hypogeous fungi, which has been positively correlated with abundance of flying squirrels (Carey et al. 1999, Gomez and Anthony submitted). However, my trapping design was not designed for captures of arboreal rodents, number of captures of flying squirrels was low, and I did not measure abundance or biomass of hypogeous fungi. Therefore these results should be treated with caution.

Results and subsequent discussion of responses to thinning relate to the model with the lowest AIC value. However, any model that has Δ AIC$_c$ or Δ QAIC$_c$ < 2 can be considered to be a competing model with the best model (Burnham and Anderson 1998:48). Therefore, if an analysis of a response has the null model (C=M=H) as one of the competing models with Δ < 2, it could be argued that strong evidence of a treatment effect does not exist. This scenario exists in density estimates for deer mice, in number of captures for Pacific and Trowbridge's shrews, and for body mass of Pacific jumping mice. On the other hand, models with Δ < 2 that indicate a treatment effect could be considered as competing models where the null model was considered the best model. This scenario exists in body mass comparisons for female deer mice and for both sexes of

creeping voles. In these cases, it may be prudent to also examine confidence intervals of point estimates where these scenarios exist. Models with 90% confidence intervals that capture no effect (0 for estimates of changes in density, number of captures, MMDM, and body mass; 0.5 for estimates of sex ratios and age-class ratios) may also be an indication that a model is weak in comparison to models with 90% confidence intervals that do not capture no effect.

In this study I examined the effects of thinning five and six years after thinning took place. In most experimental studies, effects are examined prior to and immediately after the management action has taken place (e.g., Hooven 1973, Chambers et al. 1999, Gomez et al. in prep, Gomez et al. submitted), and therefore, only the short-term effects of forest management are examined with little consideration given to long-term impacts. Suzuki (2000) examined effects of thinning in experimental and retrospective sites and found inconsistencies in responses of small mammals to thinning. He speculated that these differences were a result of responses varying over time. In my study, responses of most small mammals to thinning continue to be neutral or positive 5 and 6 years after thinning has taken place. Continued research of experimental studies such as this one may help to determine the long-term (10-25 years) consequences of thinning young Douglas-fir forests and help to validate results and/or hypotheses in observational studies.

Management implications

Thinning young second-growth Douglas-fir forests opens the canopy and allows for increases in understory vegetation (Bailey and Tappeiner 1998, Suzuki 2000). It may also be an effective method of accelerating development of desirable structural

characteristics in Douglas-fir forests while allowing for short-term benefits of commodity production and timber revenue (McComb et al. 1993, Hayes et al. 1997, Carey et al. 1999). This study indicates that thinning has neutral or positive effects on many forest-floor small mammals, and that thinning and thinning intensity may offer higher quality habitat than unthinned stands. All species with >10 captures were found in both thinned and unthinned stands 6 years after thinning had occurred. Therefore, both thinned and unthinned stands appear to be able to support populations of most small mammals over time, but thinning young Douglas-fir forests may enhance habitat conditions and increase carrying capacity for some species. Although number of captures was too small for analysis for nine species, several of these species had greater number of captures in unthinned stands. Northern flying squirrels were also more abundant in unthinned stands compared to thinned stands. Therefore, it is possible that unthinned stands may be currently providing better quality habitat than thinned stands for some species. For this reason, it is recommended that unthinned stands be retained as part of the forested landscape until thinned stands have time to reach canopy closure if the goals of forest management include managing ecosystems for biodiversity.

Use of both moderate and heavy thinning in second-growth Douglas-fir forests along with retention of unthinned areas may increase habitat diversity. Heavy thinning of second-growth Douglas-fir forests has been proposed as a tool to accelerate development of characteristics similar to old-growth forests (McComb et al. 1993, Hayes et al. 1997, Carey 1999). Heavily thinned stands will accelerate development of large-diameter trees and could provide for future input of large-diameter down wood, snags, and development of mature or old-growth forest characteristics that may provide optimal habitat conditions

for many species of small mammals. Moderately thinned stands have the potential to accelerate growth of trees for a second thinning to a lower density and provide additional opportunities to create additional large-diameter snags and down wood.

Scope and limitations

This study was conducted using experimental manipulations and a randomized block design. Three of the blocks are on the west slope of the northern Coast Range of Oregon while the fourth block is on the east slope of the northern Coast Range of Oregon. Inferences can be made to managed forests in the northern Coast Range of Oregon. However, it is probable that the effects of thinning and thinning intensity will have similar effects in other areas of western Oregon where young, second-growth Douglas-fir stands are present.

Relatively little is known about the ecology of shrews, and in some studies, shrews are grouped together (e.g., von Treba 1998, Bowman et al. 2000). Due to the difficulty of field identification of Pacific and Baird's shrews, I was unable to identity to species animals captured alive and subsequently released. Because one species may have been more capable of surviving in traps than another, it cannot be assumed that trap mortality was similar for these two species. I was also unable to positively identify 203 mortalities known to be either Baird's or Pacific shrews because of worn teeth or poor condition of specimens. Identification of these animals may have provided additional information about the influence of thinning on these two species. Therefore, the number of captures of Pacific and Baird's shrews may have been confounded by several factors in

my study, and results with respect to effects of thinning on Pacific and Baird's shrews should be treated with caution.

Lack of complete analysis of demographic characteristics of all small mammals in this area may limit understanding of effects of thinning on the overall community of forest-floor small mammals. Some small mammals were not caught in adequate numbers for analysis and may show different responses to thinning if the number of captures was larger. Inferences from this study are limited to 5-6 years after thinning had occurred. However, the response of understory shrubs and vegetation that are most likely responsible for the increase in abundance and density of most small mammals in this study are likely to persist for several decades until canopy closure is reached, and it is possible that heavily thinned stands may not close until naturally regenerating trees become established.

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Appendix 1. Number of captures of 10 species of small mammals with > 30 captures over four trap sessions. The top number is the mean number of captures over four trap sessions. The bottom numbers represent the minimum and maximum number of captures over four trap sessions. BS, CL, DD, and ST are replicate blocks. C = control stand (unthinned), M = moderately thinned stands (RD = 35), and H = heavily thinned stands (RD=20).

Block	BS			CL			DD			ST		
Treatment	C	M	H	C	M	H	C	M	H	C	M	H
Species												
Townsend's Chipmunk	9.50 7, 39	16.75 12, 21	37.8 27, 55	13.5 8, 21	21.25 19, 24	39.0 27, 65	17.75 11, 20	31.25 16, 49	60.5 51, 71	12.25 4, 20	41.25 38, 44	43.50 35, 53
Trowbridge's Shrew	32.00 16, 50	21.50 9, 33	8.25 6, 11	5.75 0, 20	1.50 1, 3	4.50 2, 10	14.25 10, 18	17.50 15, 20	4.25 1, 10	40.5 27, 68	27.25 11, 52	35.50 22, 57
Deer mouse	5.75 0, 13	9.75 2, 21	13.25 3, 26	12.25 1, 24	28.75 0, 69	26.25 0, 83	11.00 4, 24	12.25 5, 23	15.00 3, 32	19.25 1, 46	37.00 1, 79	25.50 0, 59
Creeping Vole	11.50 6, 17	18.50 15, 22	26.75 15, 41	4.75 0, 18	22.50 7, 39	26.50 0, 61	1.25 0, 2	2.00 0, 4	6.50 2, 14	5.25 2, 11	23.75 20, 26	30.75 17, 55
Pacific Shrew	12.25 9, 18	14.75 11, 17	16.25 11, 21	3.25 0, 8	4.50 1, 14	6.25 0, 12	7.25 5, 9	3.75 2, 6	11.75 2, 26	22.00 15, 28	15.25 9, 23	17.50 14, 21
Baird's Shrew	6.25 1, 14	9.5 1, 23	5.75 1, 12	6.75 0, 20	4.50 0, 9	6.50 0, 12	6.5 0, 17	4.75 0, 10	6.75 0, 17	7.25 4, 11	7.25 3, 14	11.50 6, 21
Pacific Jumping mouse	5.00 0, 8	2.0 0, 5	1.00 0, 2	0.75 0, 2	0.75 0, 2	19.25 11, 27	2.75 0, 5	5.75 2, 13	4.00 0, 9	4.25 0, 9	6.50 4, 11	7.25 2, 13
Northern Flying Squirrel	4.75 2, 10	2.25 0, 5	1.00 0, 2	1.00 0, 3	0.50 0, 1	2.00 0, 4	4.00 2, 6	0 0, 0	0 0, 0	2.75 0, 5	0 0, 0	0.75 0, 1
Western Red-backed Vole	0 0, 0	0 0, 0	0 0, 0	1.00 0, 2	0.75 0, 2	0 0, 0	0.50 0, 2	0 0, 0	0 0, 0	8.75 0, 23	0.75 0, 3	5.25 1, 10
Shrew-mole	2.00 0, 5	0.50 0, 1	0.25 0, 1	0.75 0, 3	0.50 0, 2	2.25 1, 3	0 0, 0	0 0, 0	0 0, 0	1.25 0, 3	0.25 0, 1	0.50 0, 2