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Fundy Model Forest Report: March 2007

Indicators of mixed-wood forest condition: The long-term effects of pre-commercial thinning on the abundance of small mammals

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Introduction

Forest managers use silvicultural practices such as, planting, herbicide application, pre-commercial thinning (PCT), and commercial thinning to promote forest growth and to ensure a continuous supply of timber. In New Brunswick, Canada, the area of forest that was pre-commercially thinned increased 2.3-fold between 1990 (15 012 hectares (ha) treated) and 2003 (34 833 ha treated) (Canadian Council of Forest Ministers 2005). Given that maintenance of biodiversity is a goal of many forest managers, knowledge of the impact of this treatment on wildlife, including small mammals is important.

Pre-commercial thinning reduces the density of trees in a young regenerating forest stands (APEC 2003) which reduces competition among the remaining trees for water, nutrients, and sunlight (BC Environment 1995). The reduced competition increases growth of the remaining trees which can shorten the rotation time of a stand (Smith *et al.* 1997; APEC 2003; Homyack *et al.* 2005). Pre-commercial thinning is usually done shortly after crown closure (approx. 15 yrs after stand initiation) when the trees are relatively small and unmarketable so the cut trees are left on site (Forestry Canada 1992; BC Environment 1995).

Previous studies investigating effects of thinning on small mammals have observed effects of commercial thinning (Carey 2000; Wilson and Carey 2000; Carey and Wilson 2001; Ransome and Sullivan 2002), which involves thinning of larger trees that are removed from the site to be used for commercial purposes (Forestry Canada 1992) or thinning of older (35-100 yrs), larger (30-51 cm dbh) trees (Suzuki and Hayes 2003) which is unlike conditions where pre-commercial thinning is used.

There is little information available on the influence of pre-commercial thinning on small mammal communities (Sullivan *et al.* 2002). Published effects of PCT on forest floor small mammals include: a study of the short term (1-5yrs) post treatment response, which had limited sample size (n=2) (Sullivan *et al.* 2002); a study of the long-term (1, 6 and 11 yrs post thinning) effects of PCT in sites previously treated with herbicide (Homyack *et al*. 2005) and two studies which involved pre-commercially thinned sites with repeated thinning, which also had limited sample size (n=3) (Sullivan *et al*. 2001; Sullivan *et al*. 2005).

The abundance of small mammals is associated with attributes of forest structure that can be altered by forest management. PCT can cause a number of structural changes that may affect small mammals, either positively or negatively. Thinning reduces stand density which creates gaps in the overstory canopy. This indirectly increases the amount of understory vegetation as more sunlight penetrates to the forest floor. Small mammals are associated with understory plant structure (Homyack *et al.* 2005; Pearce and Venier 2005) and are influenced by species composition of shrubs and forbs, stem densities, and the cover, volume, and diversity of ground vegetation (Santillo *et al.* 1989). PCT temporarily increases the amount of downed woody debris (DWD) on the forest floor as small and intermediate diameter (≤ 10 cm) trees are cut and left on site during thinning. Coarse woody debris (CWD) (> 10 cm) is known to be important to small mammals on the forest floor because it can provide protective cover, travel ways, nesting and burrowing sites, moist microclimates and food in the form of fungi, plants, and invertebrates (Carey and Johnson 1995; Loeb 1999; Pyle and Brown 1999; Fuller *et al*. 2004). The size of debris from thinning is smaller than CWD but, with the large number of pieces together, it has the potential to provide cover for small mammals. Larger logs provide more cover (Hayes and Cross 1987) and take longer to decompose than small logs (Sturtevant *et al*. 1997); hence provide more effective cover for a longer time than smaller logs.

It has been suggested that vertebrate species generally respond to forest structure rather than stand age (Hayes *et al.* 1997; Homyack *et al.* 2004) and that management activities can alter stand structure as well as the rate and direction of ecological succession (Hayes *et al.* 1997). Characteristics of forest stands such as tree size can vary with age; therefore, in addition to forest structure, the age of a forest stand at the time of PCT could have implications on observed ecological responses. The structure of a forest stand changes over time naturally, even in the absence of PCT, so it is important to observe and understand the long-term response of small mammals to PCT by examining sites that are: 1) within a wide range of years post treatment and 2) are representative of conditions observed in managed forests.

Different species of small mammal select different microhabitats as a way of reducing inter-specific competition (Mengak and Guynn 2003). Some species are able to use a wide variety of resources while other species have specific requirements (Geier and Best 1980) and thus, will likely respond differently to disturbances depending on their resource requirements. Body size is an important biological parameter that influences almost every aspect of an animal's life (McNab 1971; Swihart *et al.* 1988). Body size could affect the observed response of small mammals to PCT based on differences in metabolic rate and energy requirements which vary with body size. Metabolic rate determines the rate of food intake that is needed to balance the turnover of energy and nutrients (Schmidt-Nielsen 1984). The smallest mammals have higher metabolic rates compared to larger mammals which requires them to spend more time looking for resources and causes them to be more susceptible to temporary resource shortages (Randall *et al*. 1997).

Project Objectives

1) to determine if pre-commercial thinning affects the relative abundance of various forest floor small mammal species.

2) to identify relationships between vegetation and within-stand structure variables and the abundance of small mammals.

3) to identify any relationships that may exist between observed response to PCT and small mammal body size.

Research Questions and Hypothesis and Predictions

Research Question 1: Does pre-commercial thinning affect the relative abundance of small mammals?

The availability of suitable habitat is an important factor influencing the distribution and abundance of small mammals (Geier and Best 1980). Small mammals are positively associated with forest elements such as snags, downed and decaying dead wood, canopy gaps, microclimate conditions associated with closed overhead cover and diverse ground structure, and with characteristics of understory vegetation (Homyack *et al.* 2005; Pearce and Venier 2005). Pre-commercial thinning can modify stand structure and the rate and direction of ecological succession (Sullivan *et al.* 2001). PCT will temporarily reduce canopy cover and increase the amount of DWD and ground vegetation which will temporarily increase the amount of available cover and understory complexity (Muzika *et al*. 2004). Forest floor small mammals are positively associated with DWD and understory vegetation (Carey and Johnson 1995; Gagne *et al*. 1999; Carey 2000; Bellows *et al*. 2001; Muzika *et al*. 2004; Pearce and Venier 2005; Perry and Thill 2005) as they provide protective cover, food, and a moist microclimate (Hayes *et al* 1997; Carey and Harrington 2001; Homyack *et al*. 2005; Sullivan *et al*. 2005).Therefore, I expect PCT to affect the relative abundance of small mammals and that differences in the relative abundance of small mammals in pre-commercially thinned and un-thinned sites of the same age will reflect differences observed within these measured variables of stand structure. Although the benefits of increased ground vegetation and DWD following PCT will only be temporary they should persist until the canopy re-closes and/or the debris from thinning fully decays.

Hypothesis1: The abundance of forest floor small mammals is associated with forest structures that provide protective cover, which are influenced by pre-commercial thinning.

Prediction1: The abundance of small mammals will be highest in sites with the greatest amount of protective cover provided by downed woody debris, canopy cover, and ground vegetation.

Abundance of forest floor small mammals = Protective Cover = DWD + CC + GVeg

<u>Research Question 2 :</u> Does body size influence the response of small mammals to pre-commercial thinning?

Body size relations play a central role in animal ecology (Peters 1983). The mass specific metabolic rate of mammals increases with decreasing body mass, therefore, energy metabolism per unit body mass is higher in a smaller mammal than in a larger one (Schmidt-Nielsen 1984). Because the smallest mammals need to spend more time searching for resources I predict that they will be more heavily influenced by changes in the amount of protective cover and available resources than larger small mammals.

Hypothesis2: The body mass of small mammals influences the animals' response to changes to vegetation and stand structure caused by PCT.

Prediction 2: The magnitude of observed effects of PCT on small mammals will increase with decreasing body size.

Abundance of forest floor small mammals = Protective Cover * body size

Study location and site conditions

The study sites are located in south eastern New Brunswick in the Coles Island area and in and around the Acadia Research Forest near Noonan New Brunswick, Canada. Study sites are classified as Eco-Site 2 (typically black spruce dominant, mixed wood forest), and are characterized by moist soils dominated by spruce (*Picea sp*.). All sites were clearcut and left to regenerate naturally. The PCT treatment sites and corresponding control sites are similar with respect to age (time since clearcut) and forest type (Black Spruce dominant, Eco-site 2) but the control sites were not thinned. The treatment sites were pre-commercially thinned 10-15 years after clear cut.

Project Design

The long term response of small mammals to PCT is being examined by comparing the abundance of small mammals in PCT sites 5, 10 and 20 years after thinning to the abundance of small mammals in un-thinned sites of the same age. This chronosequence was chosen in an effort to represent pre-commercially thinned forest conditions at several stages of stand development. A number of replicate sites for each age group (5, 10 and 20 yrs after PCT) and treatment (PCT vs. un-thinned) were sampled. This project is one of three in a larger study examining the response of various taxa to PCT in this area.

Small mammal sampling and abundance estimation

Capture techniques including; pitfall traps (9-cm diameter) and Sherman live traps (dimensions 7.5 x 9.0 x 23.5 cm) were used to capture small mammals in each site. We established one 300m trap line with 16 Sherman traps and 16 pitfall traps paired at 20 m intervals along the transect. Transects are established >20m from open areas (eg. roads, clearing, wetlands) to avoid edge effects. Sherman live traps were baited with raw, husked sunflower seeds. Pitfall traps were not baited but contained a small amount of water in the bottom so that animals will not escape. Each site was trapped for 7 consecutive nights. Traps were checked daily and the number of animals that were captured/recaptured in each of the sites was recorded. The species, weight, and sex of captured animals was recorded and animals captured alive were marked with nail polish on their back (with the exception of squirrels and chipmunks which will not be marked) before they were released at the trap site.

The abundance of each species was calculated for all sites in order to determine the use of the thinned and un-thinned sites by small mammals. Trapping effort was standardized for the Sherman live traps by expressing the relative abundance of each species of small mammal captured as the number of captures per 100 trap nights (Table 1.), which accounts for variable trapping effort resulting from disturbed traps and capture of non-targeted species. One trap night (TN) counts as a capture of the desired species or one trap left open and baited for one entire night or 24-hour period. Half a TN is counted for; closed traps with no capture and captures of a non-targeted species (D'Eon and Watt 1994).

Snowshoe hare relative abundance was estimated once per trapping session in each site by counting the number of pellets in 7- 1m^2 circular plots located at 50 m intervals on the transects. The occurrence of squirrel calls was recorded in all sites during the 7 day sampling period as the traps were checked; the number of squirrel calls will be used to estimate the relative abundance of squirrels in each site.

Ground vegetation and within-stand structure sampling

The percent cover of ground vegetation (< 1m) by species, canopy cover (%) and the amount of small woody debris was sampled in 50 1-m^2 quadrats in each site. The amount of coarse woody debris (volume), number and size of stumps (< 2 m height) and snags (> 2 m), tree species, size (dbh), and height were measured in 6 larger circular fixed radius plots (5.64 m^2) in each site. A decay class was assigned to stumps and snagsn the using the decay classes described by Pyle and Brown 1998. CWD was sampled using the perpendicular distance sampling method. This information will be used to characterize the sites and to identify correlations between these variables the abundance of small mammals.

Progress to Date

During the 2006 summer field season we completed sampling of 35 sites (16 sites in the Coles Island area and 19 sites in the Acadia Research Forest) bringing the total number of sites sampled to 46. The number of replicate sites sampled for each treatment group ranged from 6 and 10 sites (Table 2).

Preliminary Results

NOTE: Please consider this report to be preliminary. Much of the results have not been analyzed as of yet and the following is an overview of the work done, and the trends in the data. A full report will be submitted in a few months containing the results with completed statistical analysis and conclusions.

A total of 1090 individuals from nine different species were captured in 2006, bringing the total number of captures from 2005 and 2006 to 1438 individuals from 10 species (Table 2). The most common species captured were shrews (*Sorex sp.*), and Red-backed Voles (*Clethrionomys gapperi*) (Table2).

Southern-bog Lemmings were only caught in 2006 and the only Short-tailed weasel was captured in 2005. It is interesting to note that only 2 Short-tailed shrews were captured over the span of the 2 year study, despite the expectation that they would be captured in high numbers in most stand types. This result may be related to area sampled but may also be due to the larger short-tailed shrews being able to escape from the pitfall traps. However, the short-tailed shrews should have been captured in the Sherman live traps. The number of squirrel calls recorded in the sites sampled in 2005 was notably higher than the number of calls recorded during the 2006 sampling season (Data is not provided in report).

Initial assessment of the data may suggest that PCT has no effect on the abundance of Red-backed Voles 5 years after thinning but may result in lower abundance 10 and 20 years after PCT compared to un-thinned sites of the same age (Fig.1). In contrast, when looking at the data from the Sherman live traps for *Sorex sp*., it appears that PCT may increase the abundance 5 years after thinning compared to the un-thinned control sites (Fig. 2). The abundance of *Sorex sp*. decreased with age in the PCT and control sites (Fig. 2). The data from the pitfall traps for *Sorex sp.* may indicate that abundance of *Sorex sp*. in PCT sites is similar to abundance in the un-thinned control sites 5 and 10 years after thinning but that abundance is lower in PCT sites than un-thinned sites 20 years after thinning (Fig. 3).

The abundance of Red-backed voles and *Sorex sp*. in PCT sites is lowest 20 years after thinning (Fig.1, Fig.2, and Fig. 3); this could be due to reduced near ground cover (eg. woody debris and ground vegetation) or increased overhead canopy cover in the older sites compared to the younger age class sites. The analysis of ground vegetation and other within stand structure data is being conducted.

The patterns of abundance for *Sorex sp*. in the Sherman live traps and pitfall traps are not the same (Fig.2 and Fig.3). The Sherman live traps are best suited for trapping small mammals that are heavy enough to set off the traps, and pitfall traps are better suited for trapping small mammals that are small enough that they can’t jump out of the trap. The bias of the two trap types is a plausible explanation for the different patterns observed. Using pitfall traps and Sherman live traps together may have increased the accuracy of our abundance estimations because the limitations of one trap type is accounted for by the bias of the other trap type.

All *Sorex sp.* are currently grouped together for the estimation of shrew abundance, but will be separated out by species before the analysis is completed. Given the apparent differences in the patterns of abundance of larger verses small shrews observed from the Sherman live trap and pitfall data, there may be some interesting patterns that emerge with analysis of each individual shrew species.

A number of the shrews that were captured have been identified as the maritime shrew (*Sorex maritimensis*) which is a species that is endemic to New Brunswick and Nova Scotia. The maritime shrew was previously thought to be a disjunct subspecies of the arctic shrew (*Sorex acrticus*). This finding is of great interest because the maritime shrew is considered to be a wetland habitat specialist and the characteristics of the sites in our study are not consistent with characteristics of wetland habitats. The maritime shrew is thought to be uncommon in New Brunswick and Nova Scotia, thus evaluation of habitat associations of the maritime shrew will be of interest to managers.

Future work and expected time frame

March- April 2007 - Coursework, data entry, shrew identification
April – June 2007 – Data analysis, thesis writing
July 2007- First draft copy of thesis
July-Sept. 2007- Thesis revisions

Shrew identification

The 1003 shrews captured in 2005 and 2006 need to be identified to species. There are several different species of shrews present within the study area. In order to properly identify shrews to species, several features of the skull and other morphological characteristics need to be examined. It can be very difficult to distinguish between the different species of shrews because many of them have similar external characteristics and there is some variance in these characteristics between seasons.

We have done some experimental work with DNA barcoding in an attempt to help with the identification process; however, the initial trial runs have been unsuccessful up to this point. Further work using different tissue sample types as the source of DNA will be conducted.

Data analysis

The information collected from the ground vegetation and stand structure plots will be used to characterize the sites and to identify correlations between these variables and the abundance and diversity of small mammals in the thinned and un-thinned sites. Predictive models of relative abundance of small mammals will be created using observed associations with structural characteristics measured in the field and the number of individuals captured for each species. Models will be created by determining which structural variables appear to be correlated to the abundance of each species or groups of species with similar body size and/or ecological requirements. Akaike's Information Criterion (AIC) will be used to select the best model. A 2-way ANOVA will be used to compare the mean abundance of each species in PCT vs. control sites in the three age categories.

Table 1. Mean number of captures/100 trap nights of the tree most common species in pre-commercially thinned and un-thinned sites.

	5 yr PCT	5yr Control	10 yr PCT	10 yr Control	20 yr PCT	20 yr Control
Red-backed Vole	4.13	4.43	5.77	9.10	1.41	6.69
Deer Mouse	1.14	0.33	2.78	1.97	2.12	3.36
Sorex sp.	5.70	3.56	1.88	3.01	0.94	1.91
Sorex sp. (Pitfall)	18.90	22.44	21.97	18.21	9.33	15.75
Red-backed Vole (Pitfall)	0.34	0.60	0.30	0.51	0.00	0.45

Table 2. Total number captures by species, number of trap nights, and number of sites sampled of for each treatment and age group in 2005-2006.

	5 yr PCT	5yr Control	10 yr PCT	10 yr Control	20 yr PCT	20 yr Control	**Total**
Number of trap nights	967.5	623	1075	732.5	848.5	630.5	4877
Number of sites	9	6	10	7	8	6	46
Red-backed Vole	40	28	62	66	12	42	250
Deer Mouse	11	2	30	14	18	21	96
Sorex sp.	55	22	20	22	8	12	139
Red Squirrel	2	0	3	4	3	6	18
Woodland Jumping Mouse	1	0	10	2	4	0	17
Eastern Chipmunk	0	11	0	13	1	3	28
Short-tailed Shrew	1	0	1	0	0	0	2
Flying Squirrel	0	0	1	0	0	0	1
Southern Bog Lemming	0	4	0	1	0	0	5
Short-tailed Weasel	0	0	0	1	0	0	1
Sorex sp. (Pitfall)	169	150	222	143	75	105	864
Red-backed Vole (Pitfall)	3	4	3	4	0	3	17
Total number of captures	279	217	349	265	121	189	1438

Figure 1. Mean number of captures/100 trap nights of Red-backed Voles captured in pre-commercially thinned and un-thinned control sites 5, 10 and 20 years after thinning using Sherman live traps. Error bars represent the 95% confidence intervals of the mean.

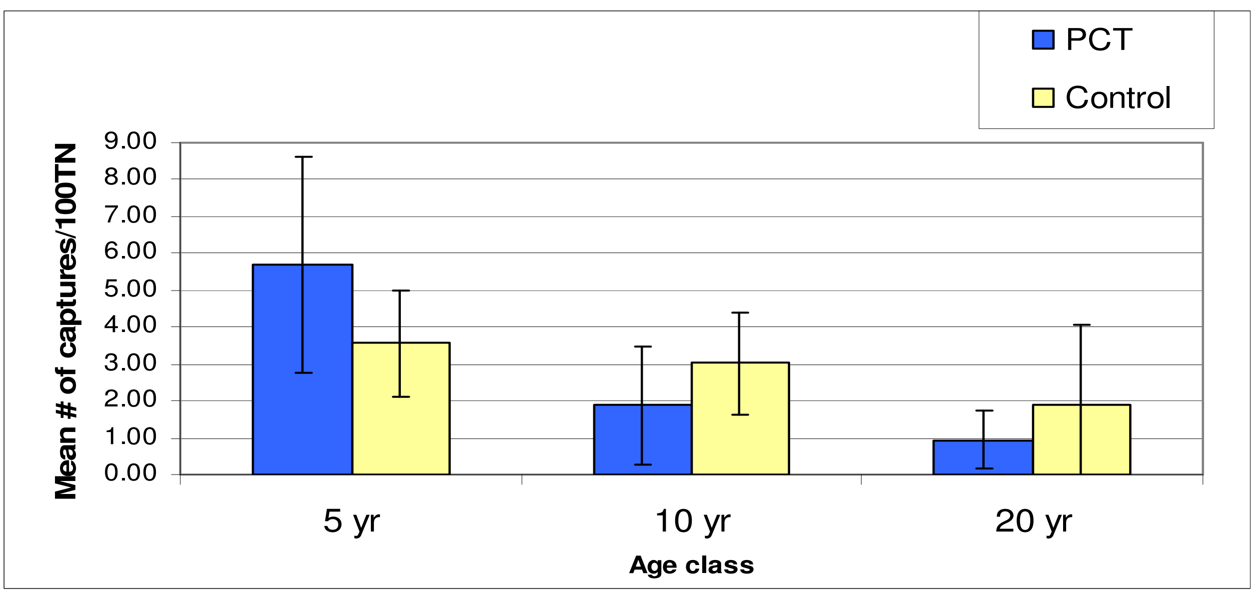

Figure 2. Mean number of *Sorex sp.* (captures/100 TN) in Sherman live traps in pre-commercially thinned and un-thinned control sites 5, 10 and 20 years after thinning. Error bars represent the 95 % confidence intervals of the means.

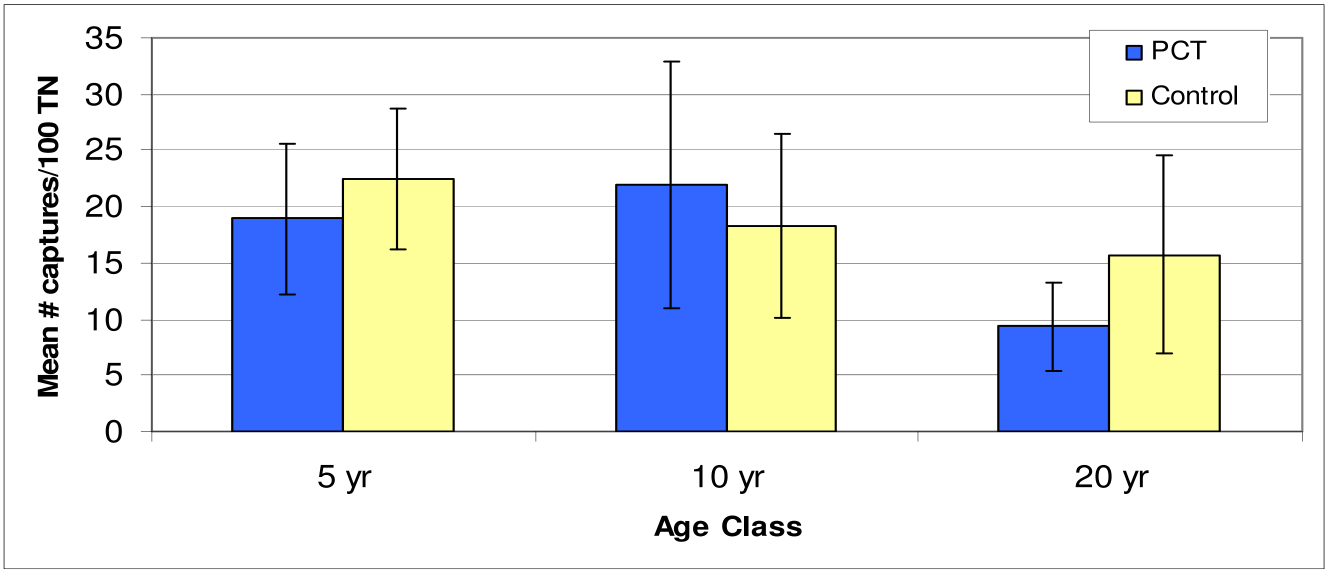

Figure 3. Mean number of *Sorex sp.* captures/100 TN in pre-commercially thinned and un-thinned control sites 5, 10 and 20 years after thinning using pitfall traps. Error bars represent the 95% confidence interval of the means.

References:

Atlantic Provinces Economic Council (APEC). 2003. The New Brunswick Forest Industry: The Potential Economic Impact of Proposals to Increase Wood Supply. Retrieved November 17, 2005 from the World Wide Web: http://www.gnb.ca/0078/APEC-e.pdf

BC Environment. 1995. Spacing guidebook: Forest practices code of British Columbia. Province of British Columbia. 50 pp.

Bellows, A. S., Pagels, J. F. and Mitchell, J. C. 2001. Macrohabitat and microhabitat affinities of small mammals in a fragmented landscape on the upper coastal plain of Virginia. *The American Midland Naturalist*. 146: 345-360.

Canadian Council of Forest Ministers. 2005. Compendium of Canadian Forestry Statistics, http://nfdp.ccfm.org. October 19, 2005

Carey, A. B. 2000. Effects of new forest management strategies on squirrel populations. *Ecological Applications*. 10: 248-257.

Carey, A. B. and Harrington, C. A. 2001. Small mammals in young forests: implications for management for sustainability. *Forest Ecology and Management*. 154: 289-309.

Carey, A.B. and Johnson, M.L. 1995. Small mammals in managed, naturally young, and old-growth forests. *Ecological Applications*. 52: 336-352.

Carey, A. B. and Wilson, S. M. 2001. Induced spatial heterogeneity in forest canopies: responses of small mammals. *Journal of Wildlife Management*. 65: 1014-1027.

D'Eon, R. G. and Watt, W. R. 1994. Small mammal habitat study: First year results. *Northeast Science and Technology*.

Forestry Canada. 1992. Silvicultural Terms in Canada. Ottawa. Science and Sustainable Development Directorate. 63 pp.

Fuller, A. K., Harrison, D. J. and Lachowski, H. J. 2004. Stand scale effects of partial harvesting and clearcutting on small mammal and forest structure. *Forest Ecology and Management*. 191: 373-386.

Gagne, N., Belanger, L. and Huot, J. 1999. Comparative response of small mammals, vegetation, and food sources to natural regeneration and conifer release treatments in boreal balsam fir stands of Quebec. *Canadian Journal of Forest Research*. 29: 1128-1140.

Geier, A. R. and Best, L. B. 1980. Habitat selection by small mammals of riparian communities: evaluating effects of habitat alterations. *Journal of Wildlife Management*. 44: 16-24.

Hayes, J. P. and Cross S. P. 1987. Characteristics of Logs used by Western Red-backed Voles, *Clethrionomys californicus*, and Deer Mice, *Peromyscus maniculatus*. *The Canadian Field-Naturalist*. 101: 543-546.

Hayes, J. P., Chan, S.S., Emmingham, W.H., Tappeiner, J. C., Kellog, L.D., and Bailey, J.D. 1997. Wildlife response to thinning in young forests in Pacific Northwest. *Journal of Forestry*. 28-33.

Homyack, J, A., Harrison, D. J., Krohn, W. B. 2004. Structural differences between precommercially thinned and unthinned conifer stands. *Forest Ecology and Management*. 194: 131-143.

Homyack, J. A., Harrison, D. J., and Krohn, W.B. 2005. Long-term effects of precommercial thinning on small mammals in northern Maine. *Forest Ecology and Management*. 205: 43-57.

Loeb, S. C. 1999. Responses of small mammals to coarse woody debris in a Southeastern Pine forest. *Journal of Mammalogy*. 80: 460-471.

Mengak, M. T., and Guynn, D. C. Jr. 2003. Small mammal microhabitat use on young loblolly pine regeneration areas. *Forest Ecology and Management*. 173: 309-317.

McNab, B. K. 1971. On the Ecological Significance of Bergmann's Rule. *Ecology*. 52: 845-854.

Muzika, R. M., Grushecky, S. T., Liebhold, A. M., and Smith, R. L. 2004. Using thinning as a management tool for gypsy moth: the influence on small mammal abundance. *Forest Ecology and Management*. 192: 349-359.

Pearce, J. and Venier, L. 2005. Small mammals as bioindicators of sustainable boreal forest management. *Forest Ecology and Management*. 208: 153-175.

Perry, R. W. and Thill, R. E. 2005. Small-mammal responses to pine regeneration treatment in the Ouachita Mountains of Arkansas and Oklahoma, USA. *Forest Ecology and Management*. 219: 81-94.

Peters, R. H. 1983. The Ecological implications of body size. New York. Cambridge University Press. 329 pp.

Pyle, C. and Brown, M.M. 1998. CWD decay classes for the Northeast. J. Torrey Bat. Soc. 125: 237-245.

Pyle, C. and Brown, M. M. 1999. Heterogeneity of wood decay classes within hardwood logs. *Forest Ecology and Management*. 114: 253- 259.

Randall, D, Burggren, W. and French, K. 1997. Using energy: Meeting environmental challenges. In: Animal physiology: Mechanisms and adaptations. 4th ed. New York. W. H. Freeman Company.

Ransome, D. B. and Sullivan, T. P. 2002. Short-term population dynamics of *Glaucomys sabrinus* and *Tamiasciurus douglasii* in commericially thinned and unthinned stands of coastal coniferous forest. *Canadian Journal of Forest Research*. 32: 2043-2050.

Santillo, D. J., Leslie, D. M. and Brown, P. W. 1989. Responses of small mammals and habitat to glyphosate application on clearcuts. *Journal of Wildlife Management*. 53:164-172.

Schmidt-Nielsen, K. 1984. Scaling: Why is size so important? New York. Cambridge University Press.

Smith, D. M., Larson, B. C., Kelty, M. J., and Ashton, P. M. S. 1997. Management of growth and stand yield by thinning. In: The practice of silviculture: Applied forest ecology. 9th ed. New York.

Sturtevant, B. R., Bissonette, J. A., Long, J. N. and Roberts, D. W. 1997. Coarse woody debris as a function of age, stand structure, and disturbance in boreal Newfoundland. *Ecological Applications*. 7: 702-712.

Sullivan, T. P., Sullivan, D. S. and Lindgren, P. M. F. 2001. Stand structure and small mammals in young lodgepole pine forest: 10-year results after thinning. *Ecological Applications*. 11: 1151-1173.

Sullivan, T. P., Sullivan, D. S., Lindgren, P. M. F., Boateng, J.O. 2002. Influence of conventional and chemical thinning on stand structure and diversity of plant and mammal communities in young lodgepole pine forest. *Forest Ecology and Management*. 170: 173-187.

Sullivan, T. P., Sullivan, D. S., Lindgren, P. M. F., Ransome, D. B. 2005. Long-term response of ecosystem components to stand thinning in young lodgepole pine forest II. Diversity and population dynamics of forest floor small mammals. *Forest Ecology and Management.* 205: 1-14.

Suzuki, N. and Hayes, J. P. 2003. Effects of thinning on small mammals in Oregon coastal forests. *Journal of Wildlife Management*. 67: 352-371.

Swihart, R. K., Slade, N. A., and Bergstrom, B. J. 1988. Relating Body Size to the Rate of Home Range use in Mammals. *Ecology*. 69: 393-399.

Wilson, S. M. and Carey, A. B. 2000. Legacy retention versus thinning: influences on small mammals. *Northwest Science*. 74: 131-145.