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# Influence of Alternative Timber Management Practices on Small Mammal Populations in Boreal Mixedwoods

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# INFLUENCE OF ALTERNATIVE TIMBER MANAGEMENT PRACTICES ON SMALL MAMMAL POPULATIONS IN BOREAL MIXEDWOODS.


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## ABSTRACT

This study examined the influence of various silvicultural systems and harvest methods on small mammal communities in the Black Sturgeon Forest of northwestern Ontario. In general, the timber management practices applied had little effect on overall species abundance, diversity or richness of small mammal communities. However, several of these systems and methods did affect the distribution of some species between treated and adjacent uncut forest areas. Full-tree and, to a lesser extent, tree-length harvest of clearcuts affected the use of cutover and uncut forests by several species whereas part-tree and cut-to-length harvesting in shelterwood or patch-cut systems had no effect on small mammals. To conserve the broadest range of small mammal species, foresters will need to implement a variety of silvicultural systems and harvest methods that provide an appropriate mixture of mature as well as regenerating areas within managed boreal mixedwood forests. The most successful conservation strategy will satisfy the requirements of both internal and disturbance-tolerant species and facilitate re-colonization of cutover areas following harvest. Applied with due diligence, alternative timber management practices can be used to maintain or enhance biodiversity of small mammal communities in boreal mixedwoods.

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# INTRODUCTION

Boreal mixedwoods are a major component of Ontario's forest resource base and are a major contributor to the industrial and social economies of northern Ontario. Sustainable development of this forest type is therefore critical to the health of the forest industry and to the existence of the many northern communities that it supports. Because of their complexity and wide distribution, boreal mixedwoods are also a primary source of many non-timber values such as wildlife habitat, aesthetics, recreation, landscape and biological diversity. Environmental pressures, particularly opposition to large-scale clearcutting and herbicide use, combined with increased consideration for non-timber values, have led to strong demands for alternative "integrated resource management" plans in support of "landscape" or "ecosystem management".

These broader management objectives are reflected in advisory and policy documents such as "Looking Ahead: A Wild Life Strategy for Ontario" (Ontario Wildlife Working Group 1991) and "Diversity: Forests, People, Communities - A Comprehensive Forest Policy Framework for Ontario" (Ontario Forest Policy Panel 1993). There is a general consensus that the Ontario Ministry of Natural Resources (OMNR) should move away from managing "featured species" to managing for conservation of biodiversity (i.e., for all species). In April, 1994, the Ontario Environmental Assessment Board released its decision on the "Class Environmental Assessment by the Ministry of Natural Resources for Timber Management on Crown Lands in Ontario" which directed the OMNR to develop and implement a program to monitor population trends of representative terrestrial vertebrates. The intent of this monitoring program is to evaluate the effects of natural and human disturbance on wildlife populations and to provide the basic information required for development of integrated resource management plans that maintain or enhance biodiversity.

Small mammals are important to the biodiversity of forest ecosystems because they disperse seeds and mycorrhizae, contribute to soil mixing and aeration processes, ingest insects, seeds and plants, and are a food source for many other wildlife species (Martell and Macaulay 1981, Kirkland 1985, Jenson and Nielson 1986, Bergeron and Jodoin 1994, Cazares and Trappe 1994, North and Trappe 1994, Carey and Johnson 1995). As such, the persistence of forest floor small mammals provides a measure of ecosystem function and may be an important indicator of forest sustainability (Carey and Harrington 2001, Sullivan and Sullivan 2001, Klenner and Sullivan 2003). Despite their obvious importance, the reaction of small mammals to timber harvest and wildlife conservation practices remain largely unknown and unstudied (Martell 1983, Gibbons 1988, Beier and Loe 1992, LeMay et al. 1992).

Forest management practices may alter both species composition and abundance of small mammal communities through modification of habitat quality (Kirkland 1990). Habitat quality, which is the ability of a habitat to contribute to the reproduction and survival of a species (Krohn 1992), is largely determined by direct and indirect factors that provide food and/or shelter for small mammals (Ecke et al. 2002). Of the processes that affect habitat quality, forest fragmentation may be the most serious (Harris and Scheck 1991, Noss 1991, Morrison et al. 1992, Kozakiewicz 1993) because it results in the break-up of large continuous mature forests into smaller isolated or semi-isolated remnants that are separated by habitat types that are either temporarily or constantly inhospitable to interior forest species (Hansson 1978, 1999; Bennett 1990; van Apeldoorn et al. 1992; Rajska-Jurgiel 1992; Kozakiewicz 1993; Rosenberg et al. 1994; Diffendorfer et al. 1995; Sullivan et al. 1999; Sullivan and Sullivan 2001). On the other hand, forest fragmentation may enhance habitat quality for species that typically occupy open habitats and are disturbance-tolerant (Hansson 1978, Kirkland 1990, Harris and Scheck 1991, Kozakiewicz 1993, Sullivan et al. 1999; Sullivan and Sullivan 2001). These latter species often increase in density and diversity at habitat boundaries, such as forest edges, due to simultaneous access to more than one environment (Leopold 1933). Thus, forest fragmentation may initially increase small mammal density and diversity of an area once covered by mature forest, but decreases species density and diversity of the region if internal forest-dwelling species are subsequently eliminated (Harris and Scheck 1991). The most successful conservation strategy will satisfy the requirements of both internal and disturbance-tolerant species. In areas of recent timber harvest it is often easier to satisfy the needs of disturbance-tolerant species than of internal forest-dwelling species, so foresters and wildlife managers must find ways to make timber harvesting less intrusive for the latter species when developing integrated resource management plans to maintain or enhance biodiversity.

Uncut strips of land, or "corridors", connecting habitat patches have been used by forest managers in an attempt to maintain the diversity and movement patterns of featured species, such as the commercially valuable moose, deer and bear, within clearcut areas (Corn et al. 1988, Gibbons 1988, Ontario Ministry of Natural Resources 1988, Szaro 1988, Harris and Atkins 1991, Ontario Wildlife Working Group 1991, Canadian Council of Forest Ministers 1992, Ruefenacht and Knight 1995). These featured species tend to be disturbance-tolerant, finding their food in cleared areas but requiring the shelter that corridors can provide (Ontario Ministry of Natural Resources 1988). During the era of featured species management it was often argued that addressing the needs of these larger featured species would ensure that the needs of most smaller, non-commercially important species were also met (Baker and Euler 1989, Voigt et al. 2000). Indeed, small mammals such as white-footed mice (*Peromyscus leucopus*) and eastern chipmunk (*Tamias striatus*) have been shown to preferentially move along corridors in fragmented habitat (Hobbs 1992). However, other small mammal species such as southern red-backed voles (*Clethrionomys gapperi*), are most successful in mature forest interiors (Merritt 1981, Nordyke and Buskirk 1988, Raphael 1988a, Mills 1995) and may decline in abundance following habitat fragmentation by clearcut timber harvesting (Hansson 1978, 1999; Rosenberg et al. 1994; Sullivan et al. 1999; Sullivan and Sullivan 2001). To maintain or enhance biodiversity, timber management practices must therefore retain sufficient habitat to accommodate the needs of both disturbance-tolerant and interior forest-dwelling species and facilitate re-colonization of cutover areas following harvest.

Other than corridors connecting habitat patches that were once continuous, there are several additional strategies forest managers can use to alter harvesting practices and alleviate the problems faced by interior forest species. One option is to decrease the differences found in habitat between clearcut and uncut forest, the "hard edge", so interior forest species can use more of the harvested land. Creation of "softer", or more permeable, edges can be accomplished by decreasing cut intensity on the sides of the harvested area, also known as "feathering", or on the entire cut stand (Stamps et al. 1987). Changing harvest intensity is not the only option available to forest managers. They can also alter the time, shape, size or position of clearcuts in accordance with the requirements of the internal forest species concerned. This may require harvesting at a specific time of year to avoid the breeding season, leaving features in cut areas that are of importance to particularly sensitive species by altering cut size, shape and position, and using equipment or harvesting methods during timber extraction that are less detrimental to the needs of individual species(Ontario Ministry of Natural Resources 1988).

A survey of published literature indicates that only two studies of small mammal responses to timber harvesting have been conducted in the boreal region of northern Ontario (Martell and Radvanyi 1977, Martell 1983). Consequently, the influence of disturbances such as existing forestry practices and new alternative timber harvesting approaches on habitat, wildlife populations and biological diversity in Ontario are uncertain. To provide additional information required by foresters and wildlife managers when developing integrated resource management plans to maintain or enhance biodiversity, four questions were investigated in this study: (1) are small mammal species abundance, diversity, richness and composition in edge habitats affected by the intensity of timber extraction; (2) are small mammal species abundance, diversity, richness and composition in edge habitats affected by the method used for timber extraction; (3) does the abruptness of the interface between harvested and un-harvested land influence how the small mammal edge community uses this habitat; and (4) are there differences in the movement patterns of deer mice (*Peromyscus maniculatus*) among the harvest treatments examined in this study and do they suggest adequate dispersal for detection of areas with good habitat quality?

# STUDY AREA

The study area comprised two stands situated on the Black Sturgeon Forest Management Agreement licence area (FMA) (49°10'N, 88°45'W), approximately 120km northeast of Thunder Bay, Ontario (Fig. 1). The closest long-term weather station is at Cameron Falls, approximately 50km east of the study site. This station reports an annual total precipitation of 826.3mm, 599.1mm of this falling as rain and the rest as snow, sleet and hail (Environment Canada 1992). Average monthly temperature extremes occur in January and July, and are -22.9°C and 24.9°C, respectively (Environment Canada 1992).

The Black Sturgeon site has an average elevation of 290m above mean sea level and is predominately a flat, till plain comprised of coarse to fine sands containing various amounts of cobbles and silt (Natural Resources Canada 1994). Erratics, which are large boulders set on the ground by glaciers, also occur in the area. Soils are generally slightly moist, well-drained and fertile (Scarratt 1996).

Before timber harvest treatments were applied in 1993, the area was covered with a second growth mixedwood forest overstorey dominated by *Populus tremuloides* Michx. (trembling aspen) and *Abies balsamea* (L.) Mill. (balsam fir). Other tree species present in the overstorey included *Picea mariana* (Mill.) B.S.P. (black spruce), *Picea glauca* (Moench) Voss (white spruce), *Betula papyrifera* Marsh. (white birch), *Pinus strobus* L. (eastern white pine) and *Pinus banksiana* Lamb. (jack pine). A previous harvest operation occurred between 1939 and 1942 that removed many of the larger pine from the area. As a result, both pine species were probably less extensive in 1993 than they were in the original forest (Scarratt 1996). Many large stumps left from the 1939-1942 harvest still covered the forest floor.

Severe *Choristoneura fumiferana* (Clem.) (spruce budworm) infestations occurred on the study area three times during the 1900s (Blair 1985, Bichon 1996, Scarratt 1996). The most recent outbreak occurred during the 10 years preceding this study and largely prevented flower or seed production of white spruce and balsam fir during that time (Scarratt 1996). As a result of these spruce budworm infestations, most of the overstorey coniferous trees were either dead or dying. As a consequence of the deteriorated overstorey, blow-down of single or large groups of trees was common throughout this forest before the 1993 harvest treatments. Subsequently, the forest floor was log-covered in many areas. Canopy openings also occurred as a result of these blow-downs and may have contributed to the vibrant shrub and herb growth evident in these stands.

In uncut areas, and before timber harvest, dominant shrub species included *Acer spicatum* Lam. (mountain maple), *Corylus cornuta* Marsh. (beaked hazel), *Cornus canadensis* L. (bunchberry), *Rubus* spp.(dwarf and wild red raspberry ) and various species of *Lonicera* spp. (honeysuckle). Regeneration of canopy level species, mainly balsam fir, was also evident in some areas. Ground cover consisted largely of leaf litter and moss, but some herb species such as *Linnaea borealis* L. (twinflower), *Pyrola* sp. (wintergreen), *Maianthemum canadense* Desf. (wild lily-of-the-valley), and *Clintonia borealis* (Ait.) Raf. (blue-beaded lily) were also present.

# METHODS

## Timber Harvest Treatments

Timber harvesting was conducted as part of the Black Sturgeon Boreal Mixedwood Research Project and occurred between September and December of 1993 (Scarratt 2001). Four harvesting methods were employed: full-tree, tree-length, part-tree and cut-to-length extraction. One or several of these methods were used to remove 0, 20, 70 or 100 percent of the merchantable timber volume from each of 21 treatment areas. The combination of harvest methods and intensities created 7 unique harvesting treatments, representing a gradient of woody material removal (Fig. 2).

Treatment areas were approximately square in shape and each one covered 10ha (Fig. 3). A 100m wide strip of uncut forest was left between each harvest area to allow for separation of treatment effects. Each of the 7 harvest treatments were randomly assigned to 3 of the 21 treatment areas (two in stand 1 and one in stand 2). Although the assignment of treatments in this project allowed for stand 1 and stand 2 to be treated statistically as separate blocks, this was not done in the following analysis due to their similarity in habitat structure and climate characteristics, as well as their close proximity: approximately 4km apart (Fig. 1). Although the part-tree shelterwood treatment was assigned to 3 treatment areas, it was replicated only twice due to the high cost of manual felling. Harvesting of all other treatment areas was completed as planned so that each was successfully replicated 3 times.

**Small Mammal Trapping**

Based on available distribution maps (Banfield 1974, Dobbyn 1994, Kurta 1995), 22 species of small mammals (average adult body weight <200g) occur in the area of the Black Sturgeon Boreal Mixedwoods Research site (Table 1). Because of the broad range of body sizes and differential response of species to traps (Getz 1961, Tanaka 1963, Brown 1967, Morris 1968, Wiener and Smith 1972, Boonstra and Rodd 1982, Williams and Braun 1983, Slade et al. 1993), different sizes and types of traps are required to sample the widest variety of potential species. Traps used at the Black Sturgeon site included non-collapsible Sherman (7.6 x 7.6 x 25.4 cm) and Longworth (6.5 x 8.5 x 14.0 cm) live-traps, Tomahawk live-traps (15.2 x 15.2 x 48.3 cm) and pitfall traps (Boonstra and Krebs 1978). These traps are suitable for all of the small mammal species expected at the site, and may occasionally capture medium-sized mammals such as snowshoe hares (*Lepus americanus*), muskrats (*Ondatra zibethicus*), marten (*Martes americana*), mink (*Mustela vison*) and striped skunks (*Mephitis mephitis*). Although pitfall trapping occurred on only a subset of the treatment areas, this information was valuable because pitfall traps capture small mammal species that weigh <20g more effectively than the live-traps used in this study. Therefore, use of pitfall trapping data in the current study counteracts biases that are present when only live-trapping data are used (Block et al. 1988, Szaro et al. 1988).

**Live-trapping**

Live-trapping grids consisted of 5 rows of 9 trap stations spaced 25 m apart (Fig. 4), giving an effective trapping area (Kirkland 1977) of about 2.8 ha. Because we wanted to determine the role of "corridors" (i.e., buffer zones) and harvest methods on small mammal populations, particularly immigration and emigration, the centre row of each trapping grid was aligned with the edge of each treatment block. Thus, 2 rows of each grid were in uncut forest and 2 rows were on each treatment block, providing a split plot experimental design. As well as trapping grids within each harvest treatment, 3 additional grids of the same shape and size were established in uncut forest stands in 1994, not less than 100m from harvest treatment edges. In total then, there were 23 live trapping grids used in this study (Fig. 3).

On each grid, a single Sherman or Longworth live-trap was placed within 1 m of each trap station. Whenever possible, traps were placed on the ground in freshly used runways or next to fallen logs or stumps. Small mammals perish rapidly in metal traps, so care was taken to ensure traps were covered with boards, especially on hot days. Each trap was supplied with cotton bedding and baited with a mixture of whole oats and sunflower seeds. These traps remained at the trapping station throughout the season and were locked open when not in use.

Tomahawk live-traps were located within 1 m of alternating trap stations on each of the 5 rows, giving an inter-trap distance of 50 m. Tomahawk traps were moved to their trapping location on the first pre-baiting day and moved away from the station after the last trap-checking day. While in place, traps were covered with vegetation and a mixture of whole oats and sunflower seeds were again used for bait.

Live-trapping grids were of 3 types: the treatment grids, the original control grids and the newer control grids (Fig. 3). The treatment grids and the original control grids were trapped with

Longworth traps for one session in the fall of 1993 (Table 2). To determine if natural annual fluctuations in the small mammal community existed, the original controls continued to be trapped with the same methods and on approximately the same dates in 1994 and 1995. The treatment areas and the newer controls were each trapped for 3 sessions between the beginning of June and the end of August in 1994 and 1995.

Each trapping session involved 3 days of pre-baiting followed by 3 or 4 nights of trapping: a fourth trapping night was conducted if the recapture rate on the third day was less than 60%. Two exceptions to this procedure occurred in 1993 when area 2 was trapped for a fifth night due to low recapture rates and area 24 was trapped for only 2 nights due to commencement of timber harvest. Live-traps were set in the early evening, checked each morning within 4 hours following sunrise, and locked open for the remainder of the day.

Upon capture, live-trapped animals were transferred to a high-sided container for further handling. Bog lemmings, mice, voles and chipmunks were tagged in both ears with serially numbered #1 Monel self-piercing tags (National Band and Tag Co., Newport, KY). Squirrels and medium-sized mammals were tagged in both ears with serially numbered #3 Monel self-piercing tags. Shrews and moles were not marked. The trap location, tag number, species, sex, sexual condition and weight of each animal were recorded before release at the site of capture.

**Pitfall trapping**

Pitfall traps were placed on areas harvested with full-tree extraction (stand 1, areas 1, 2, 3, 14; stand 2, areas 24, 26) and uncut "controls" (stand 1, areas 13, 4; stand 2, area 25) (Fig. 5). Pitfall traps were arranged in 2 parallel rows, separated from each other by 40 m, of 6 traps spaced 10m apart (Fig. 4). Pitfall trap lines started approximately 20m from the small mammal live-trapping grids and ran perpendicular to them. Pitfall traps were set into the ground with the top of the trap level with the surface. To prevent excessive amounts of rain and debris from entering, pitfall traps were covered with a board that was raised slightly above ground level with small rocks or branches. Pitfall traps were filled with sufficient ethylene glycol to ensure a humane death to any organisms captured and to preserve specimens for later identification and analysis.

In 1993, pitfall traps were set for 14days in the fall and examined once before timber harvest treatments were applied. In 1994 and 1995, all traps were examined 7 times throughout the summer, once approximately every 14 days between June and September. Any small mammals captured by these traps were recorded and preserved frozen. Identification of these specimens was later conducted following van Zyll de Jong (1983) and Kurta (1995).

***Peromyscus* Tracking**

Radio-collars (model MD-2C by Holohil Systems Limited, Woodlawn, Ontario, Canada), transmitting at individual frequencies between 164-168 MHz, were attached to adult *Peromyscus maniculatus* weighing 16g or more in the summers of 1994and 1995. In each year these collars were attached between early and mid-July and were tracked during the next 11-36 days. Radio-telemetry receivers (model SRX-400 by Lotek Engineering Inc. or model TR4 by Telonics Inc.) in combination with either a 3 or 4 element hand-held antenna, were used to locate the position of radio-collared mice during radio tracking. In 1995, radios were located in daylight hours only, but in 1994 some telemetry work was also accomplished at night.

Twelve radio-collared mice were tracked in 1994, while in 1995 13 were tracked (Table 3). Radio attachment was conducted from July 8$^{th}$ to July 16$^{th}$ in 1994, and from June 30$^{th}$ to July 16$^{th}$ in 1995. Mice on grids of clearcut areas 1 and 14, shelterwood cut area 5, and control area 42 were radio-collared in both years. In addition, mice on control grid 132 were radio-collared in 1994 while in 1995 mice were radio-collared on shelterwood grid 2. Although both male and female mice were radio-collared in post-harvest years, a much higher proportion of females were collared in 1995. This was in part a result of fewer captures of adult male mice during the radio attachment period of 1995. In 1994, 6 mice were tracked on harvested treatment areas, and on controls. In 1995, 8 mice were tracked on harvested treatment areas, while 5 were tracked on controls.

Mouse positions were flagged immediately after they were located with radio-telemetry equipment. The habitat features associated with that location (Table 4) and the position of the location with respect to harvest treatments were also noted. The distance and direction of these points from trapping stations was then measured. Finally, all day-refuge positions were assigned to one of two categories depending on their height. All day-refuges located 2m or more above the ground were included in the “elevated” category while day-refuges below 2m in height were categorized as “ground” positions.

In the fall, mouse radio-telemetry locations were more accurately determined with the global positioning system (GPS). A Trimble Pathfinder™ Basic+ receiver and external antenna were used for this purpose. Trimble Pathfinder™ software version 2.3 was then used for differential correction of the raw pseudo-range data. Other researchers have tested the accuracy of differentially corrected GPS data and found their positions were accurate to 3-7m (Deckert and Bolstad 1996, Rempel and Rodgers 1997). Because these researchers monitored GPS position accuracy in forests, and open canopy areas, it is probable that the differentially corrected positions, collected from clearcut and uncut forest during the current study, were also within this range of accuracy.

**Data Analysis**

**Effect of Timber Harvest Intensity**

Trapping data collected only from areas harvested with full-tree extraction and controls were used to ascertain the effects of timber harvest intensity on the small mammal community. Thus, 3 clearcut, 3 shelterwood cut, and 6 control grids were involved in this analysis (Figs. 3 and 5). Exclusion of areas that were harvested at these intensities but with other methods reduced difficulties of interpretation because harvest method was known to be consistent throughout the treatments compared and was not a secondary factor in the analysis.

The number of individuals of each small mammal species captured on each treatment area, by each trapping method in each year, was then determined. Next, pre-harvest data from all treatments were used to assess the ability of live-traps and pitfall traps to capture small mammal species. Use of only the pre-harvest data for this comparison was beneficial because it eliminated consideration of the differences in grid placement with respect to the harvest edge that occurred after timber harvest. Finally, the abundance of both the common and the rare species on each treatment during each year of this study were examined. Rare species were defined as those captured less than 5 times by a particular trapping method, within a particular year. After this, rare species were excluded from further data analysis for that trapping method in that year. This was done due to the difficulty in attributing any differences observed to biological, as opposed to random events, when so few animals were involved in the comparison.

After elimination of rare species, the total small mammal abundance, species richness and species diversity for each trapping method, on each treatment area in each year, were determined. Hill's diversity indices, N0, N1 and N2, were also calculated (Magurran 1988). These diversity indices were chosen for 3 reasons. First, they can easily be converted to other widely used diversity indices; N0 represents species richness, N1 is the exponent of the Shannon diversity index, and N2 is the reciprocal of Simpson's diversity index (Ludwig and Reynolds 1988, Magurran 1988, Krebs 1989). This property is important for comparison to other studies that have used other diversity indices. Secondly, Hill's diversity indices, N1 and N2, can have more power to discriminate between sites with similar communities than the Shannon or Simpson diversity index (Magurran 1988). Since the treatment grids in this study were all located within the same mixedwood forest, it was reasonable to expect species composition on the sites to be similar. As a result, the ability of diversity indices to discriminate between sites with similar communities was important. Finally, Hill's diversity indices are generally easier to interpret and understand than other diversity indices used in ecological studies (Ludwig and Reynolds 1988).

Species abundance, Hill's diversity indices N0, N1 and N2, and the total number of animals captured on each area were used for all comparisons among years and treatments of this study. First, a Friedman test was used to investigate the similarity between the two mixedwood stands monitored during this research. This comparison was conducted for pitfall and live-trapping data separately, and in each case small mammal community characteristics collected over the 3 years of this study on each original control area were combined. Then inter-year comparisons with Friedman tests for both pitfall and live-trapping data collected on the original control areas were completed. These tests were conducted to assess the natural population fluctuations of the small mammal community in the area of this study during the 3 years of research. Finally, Kruskal-Wallis tests were used to compare how small mammal communities were affected by the harvest intensity within each of the 3 years of this study. For live-trapping data, the inter-treatment comparison included data from the original control areas in 1993 and the newer control areas in 1994 and 1995.

**Effect of Timber Harvest Method**

The effect of different methods of timber harvest on small mammal edge communities associated with the clearcut and shelterwood silvicultural systems were analyzed separately. With clearcutting, the harvest methods included full-tree extraction (areas 1, 14 and 26) and tree-length extraction (areas 7, 9 and 21) (Fig. 6). Three harvest methods were involved in the shelterwood system comparison; full-tree extraction (areas 2, 3 and 24), part-tree extraction (areas 12 and 23) and cut-to-length extraction (areas 5, 11 and 22). Control areas were included in each comparison. In 1993, the original controls (areas 4, 13 and 25) were included in both comparisons, while in 1994 and 1995 the newer controls (areas 42, 132 and 252) were used. Separate analyses of data from the clearcut and shelterwood systems was required because the effect of timber harvest intensity was significant and needed to be controlled during comparison of timber harvesting methods.

Only live-trapping data, from the edges of treatment areas were used in analyses of timber harvest methods. Otherwise, methods of data analysis followed those employed for comparisons of harvest intensity. Kruskal-Wallis tests were first used to determine how similar the treatment areas used for comparisons within each of the clearcut and sheltervood silvicultural systems were before timber harvest. Comparisons of small mammal community characteristics relative to the alternative harvest methods used within the clearcut and shelterwood silvicultural systems were then made with Kruskal-Wallis tests.

**Effect of Timber Harvest Edge**

Live-trapping data collected from all harvest and control grids were analyzed to determine small mammal abundance and movement patterns at the edge of each treatment area. For each small mammal trapping grid the number of individuals of each species captured on the treated and buffer zone sides of the grid (Fig. 7) was determined separately for each year of the study. Also, Hill's diversity values N0, N1 and N2 and the total number of small mammals captured were calculated for each side of each small mammal grid during each of the 3 years of this study. A Mann-Whitney test was used to compare small mammal abundance, species richness and diversity, as well as the total number of small mammals captured on the two sides of each grid, of each treatment, during each year. During post-harvest years the original and newer controls were considered separate treatments for the purposes of these comparisons because trapping on these grids occurred at different times.

In cases where an individual small mammal was captured on both sides of a grid, it was included in calculations for both the treatment and buffer zone sides of that grid. Although this may inflate the apparent total number of small mammals captured on the entire treatment grid, it gives a more accurate portrayal of small mammal use of both sides of the harvest edge than would occur if these individuals were removed from the data. Also, since these individuals are included on both sides of the grid, their presence does not change the ranks of these two areas relative to each other, so comparison of the sides of each grid remains valid.

The number of individuals that crossed the harvest edge during this study was also determined for each species on each treatment area. The percent of animals that crossed the edge in relation to the total number of individuals of that species that were captured on each treatment was determined. Comparisons of the species that moved and the frequency of their movements were conducted by direct observation of these data.

***Peromyscus* Activity**

Following differential correction of the GPS locations where deer mice were found, a home range analysis program, (Tracker 1994: version 1. I, CamponotusAB and Radio Location Systems AB, Sweden) was used to assess the data. This work determined the duration of radio attachment for each mouse (duration), the number of times each mouse was located (locations), the number of unique positions where each mouse was found (day-refuges) and the distance mice travelled for every day-refuge they used (distance/day-refuge). Deermouse locations obtained outside daylight hours, between 2200 and 0500, were not used in the analyses because only a small number of night-time locations were obtained in 1994.

Several home range calculations were also performed. These were the 90% minimum convex polygon estimate, and the area within the 90%, 80% and 50% isopleths based on the harmonic mean home range estimate (Dixon and Chapman 1980, White and Garrott 1990). For female deer mice, a grid spacing of 4.9 was used for the latter method of home range estimation, while for males a grid spacing of 11.0 was employed. To attain these final grid spacings, the grid spacing recommended for each animal by the home range analysis program was first determined. Then the average recommended grid spacing for male and female mice was calculated. Finally, an iterative process was used to modify the average recommended grid spacing for each sex so that this number was within the limits allowed by the program for as many mice of that sex as possible.

The number of separate "active" areas associated with the 90%, 80% and 50% harmonic mean home range estimates of each animal was also determined. An active area was defined to be a section of a home range within a completely enclosed isopleth that was separate from other enclosed isopleth areas. Because the same grid spacing was used during harmonic mean home range estimation for deer mice of each sex, this count of active areas is another method of assessing and comparing the dispersion of radio-telemetry locations of females or males.

Because the duration of radio attachment varied among individual deer mice, variables that could be closely related to duration, such as the total distance travelled or the number of day-refuges could not be directly compared. For this reason, the ratios of distance/duration and the number of day-refuges/duration were used for comparing the activities of deer mice on different treatments. The ratio of distance/number of day-refuges was also calculated. As with the home range estimates, this variable described the degree of day-refuge dispersion. It had some advantages over the home range estimation methods because unlike them, values for this measure could be determined for every individual in the study.

After elimination of night radio-telemetry locations, and calculation of variables that described mouse activity, the scale at which deer mice were using their environment was investigated. All mice were included, with 2 females that had entered more than one treatment each being assigned to the treatment where they were originally radio-collared. The proximity of day-refuges and day-time radio-telemetry locations to uncut forest, timber harvest treatments and the border between these environments was determined for each mouse, on each treatment area. For the purposes of these analyses, borders were defined to stretch 5m on either side of the transition between cut and uncut forest. The percent of day-refuges and radio-telemetry locations within and outside of the treatments associated with the grids on which deer mice were radio-collared was determined. All of this was completed separately for female, male and both sexes of deer mice combined.

The relative importance of specific habitat features used as day-refuges by female, male and both sexes of deer mice combined were also summarized. The ratio of "elevated" day- refuges (those 2m above the ground) to "ground" day-refuges (those <2m above the ground) was determined for each sex on each treatment area. Results are presented separately for each sex on each treatment and for all mice on each treatment. Finally this ratio was determined for all deer mice regardless of their sex or treatment designation. As with the investigation into the scale of habitat use, all radio-collared mice were included, with the females that had entered more than one treatment assigned to the treatment where they were originally radio-collared. The percent of day-refuges in each habitat feature, regardless of the harvest treatment in which they occurred, was then calculated. The 5 habitat features most commonly used by each sex and for both sexes in combination were determined.

A Mann-Whitney test was used to compare the weights of female and male deer mice radio-collared in this study. For this comparison all deer mice were included regardless of the treatments with which they were associated. The activities of male and female deer mice on the shelterwood and control treatments were also compared using the Mann-Whitney test. For this comparison, 2 females radio-collared in 1995 had to be eliminated because each had entered 2 harvesting treatments and could not be assigned exclusively to one treatment. Also, variables associated with the harmonic mean home range estimates could not be used to compare between the sexes because this method is sensitive to changes in the grid spacing used for its calculation (White and Garrott 1990, Kie et al. 1996). Therefore, the variables that were used for this latter comparison were distance/duration, number of day-refuges/duration, distance/number of day-refuges and the 90% minimum convex polygon home range estimate.

Differences observed in the activity patterns of male and female deer mice indicated that data from the two sexes should be analyzed separately for all other comparisons. For each sex, data from the 2 years of collection and from the multiple grids associated with each treatment were combined after Mann-Whitney tests failed to find any statistically significant effect of grids or year in these data. The activity patterns of male and female deer mice in relation to harvest intensity were then compared. For female mice, the clearcut, shelterwood and control treatments were compared with Kruskal-Wallis tests. For male mice, the shelterwood and control treatments were compared with a Mann-Whitney test. For both of these comparisons deer mice were assigned to the treatment associated with the grid on which they were radio-collared and mice that entered more than one harvest treatment were eliminated from the comparison.

## RESULTS

### Effect of Timber Harvest Intensity

There was a large difference in the species captured by pitfall and live-trapping methods. Shrews (Family Soricidae) were captured more often by pitfall traps, while various species of rodents (Order Rodentia) were more prevalent in live-traps (Tables 5 and 6). In 1993, 4 Soricidae were captured by live-traps while 61 were captured by pitfall traps. Only live-traps captured deer mice (*Peromyscus maniculatus*), woodland jumping mice (*Napaeozapus insignis*), heather voles (*Phenacomys intermedius*) and yellow-nosed voles (*Microtus chrotorrhinus*) in that year. The only species captured by both trap types in 1993 was red-backed voles (*Clethrionomys gapperi*).

Red-backed voles, deer mice and yellow-nosed voles were the 3 species most commonly captured by live-traps during each of the 3 years of this study (Table 5). Northern flying squirrels (*Glaucomys sabrinus*), meadow voles (*Microtus pennsylvanicus*), southern bog lemmings (*Synaptomys cooperi*), least chipmunks (*Tamias minimus*) and short-tail weasels (*Mustela erminea*) or least weasels (*Mustela nivalis*) were captured in live-traps only after timber harvest. There were no species captured by live-traps only before harvest, so overall species richness was higher in post-harvest years based on live-trapping data.

In contrast to live-trapping, the 3 species most commonly captured in pitfall traps before timber harvest were masked shrews (*Sorex cinereus*), red-backed voles and smoky shrews (*Sorex fumeus*) (Table 6). Following harvest, pygmy shrews (*Sorex hoyi*) replaced smoky shrews as the third most common species captured. Pygmy shrews were the only Soricidae species detected exclusively during post-harvest years. Other species that appeared in pitfalls only after harvest were heather voles, yellow-nosed voles, southern bog lemmings and meadow voles. As with live-trapping, no species was captured in pitfall traps only before timber harvest, so overall species richness was also higher during post-harvest years based on pitfall trapping data.

Comparison of live-trapping data among the original control grids revealed that, in general, a larger number of small mammals were captured on grids 13 and 25 than on grid 4 during the 3 years of this research (Table 7). Also, red-backed vole abundance was lowest on grid 4, moderate on grid 13 and highest on grid 25 during every year (Tables 7 and 8). Inter-year comparison of the original controls revealed that abundance of deer mice and Hill's diversity numberN2 were higher in 1993 and 1995 than in 1994 (Table 9).

In contrast to live-trapping data, pitfall data revealed that control areas were similar to one another with respect to all small mammal community characteristics measured over the time of this study (Table 7). Inter-year comparison of control areas showed that over time, the total number of small mammals captured and the abundance of red-backed voles increased (Table 9). These comparisons also demonstrated that pygmy shrew abundance and Hill's diversity numbers N1 and N2 were higher in 1994 and 1995 than in 1993. Hill's species richness N0 was lowest in 1993, highest in 1994 and moderate in 1995.

Before timber harvest in 1993, one rare group of species, shrews (Soricidae), had 4 individuals captured in live-traps only on grids that were assigned to be clearcut (Table 5). Since all other rare species occurred only once or twice in live-traps during that year, their occurrence in areas later assigned to the same treatment type was likely due to random chance. Statistical testing indicated that the distribution of common species among the 3 harvest intensity treatments were even when pre-harvest live-trapping data were assessed (Table 10). Species richness and diversity indices based on live-trapping data also showed no statistically significant differences among the treatment areas when they were compared before harvest.

Comparison of red-backed vole abundance captured with pitfall traps on each treatment area before timber harvest in 1993 revealed differences that approached statistical significance (Table 10). For all other common species, statistical tests failed to show any differences among the treatments during the pre-harvest year. Also, Hill's species richness and diversity numbers based on pitfall trapping did not differ significantly with harvest treatment before timber extraction.

Evaluation of Hill's species richness N0 based on live-trapping data in 1994, revealed a significant difference among treatments, with lower values at the edge of the shelterwood cuts, than on controls and clearcut edges (Table 10). Also, southern bog lemmings were more prevalent on controls than on other treatments. All other commonly captured species showed no statistically significant differences among harvest treatments during the first post-harvest year. Likewise, pitfall-trapping data failed to show statistically significant differences among treatment areas in 1994 with respect to small mammal abundance, species abundance and Hill's species richness and diversity measures (Table 10).

In 1995, no significant differences were found for Hill's species richness (N0) or diversity (N1, N2) indices based on live-trapping data but pitfall data showed N0 and N1 were lower on controls than on cut areas and N2 approached statistical significance (Table 10). Pitfall trapping also showed that the abundance of heather voles was higher on shelterwood areas than on clearcut and control areas. The abundance of red-backed voles and northern flying squirrels determined by live-trapping showed differences among treatments that approached statistical significance ($P<0.100$); red-backed voles were less prevalent at clearcut edges than at shelterwood edges and in controls, while northern flying squirrels were captured predominantly on grids associated with clearcut edges.

**Effect of Timber Harvest Method**

Red-backed voles, deer mice and yellow-nosed voles were the 3 most commonly captured species on the treatment grids used for comparisons of harvest methods in both the clearcut and shelterwood systems (Tables 11 and 12). Less commonly captured species that appeared in both data sets during all years were heather voles and woodland jumping mice. Species that appeared in both data sets only after harvest were meadow voles, northern flying squirrels, least chipmunks and weasels. Of these, northern flying squirrels, least chipmunks and weasels appeared only on harvested grids and not on controls.

Before timber harvest, in 1993, shrews were more abundant on trapping grids later designated to the full-tree clearcut treatment than grids later designated to the tree-length clearcut and control treatments (Table 13). However, only 5 shrews were captured on the designated clearcut grids and live-trapping is not the most effective means of measuring shrew abundance. All other small mammal community measurements, including species richness and diversity measures, failed to show significant differences among the clearcut treatment areas during the pre-harvest year.

Similarly, there were no significant differences in the small mammal community on designated shelterwood treatment areas before timber harvest in 1993 (Table 14).

In 1995, northern flying squirrels were more prevalent on full-tree extraction clearcuts than on tree-length extraction clearcuts and controls (Table 13). However, none of the other measures, including species richness and diversity, showed differences among the clearcut treatments during the 2 post-harvest years.

During the first year after timber harvest on the shelterwood treatment grids, southern bog lemming abundance and Hill's diversity indices N1 and N2 had lower values than on the controls that approached statistical significance ($P<0.100$) (Table 14). In 1994, 2 southern bog lemmings were present on area 5, which was harvested with the cut-to-length method, but this species was absent from other shelterwood treatment areas regardless of the harvest method used (Table 12). Both Hill's diversity indices N1 and N2 were higher on full-tree extraction shelterwood grids than on grids associated with the other harvested shelterwood treatments in 1994 (Table 14). By 1995, there were no longer any differences among the shelterwood harvest treatments.

Although few statistical differences in species abundance and diversity were apparent following clearcut and shelterwood harvest treatments, there were changes in species composition of control and treatment areas among years (Tables 11 and 12). Shrews were absent from controls in 1993 and northern flying squirrels did not appear on controls in 1994 or 1995 (none were captured on any grid in 1993). Yellow-nosed voles were absent from shelterwood full-tree harvest grids before treatments were applied but reappeared on this treatment area in the first year post-harvest when they were then absent from part-tree shelterwood areas. Yellow-nosed voles were also absent from clearcut tree-length extraction grids in 1995. Woodland jumping mice were absent from tree-length clearcuts as well as cut-to-length and part-tree shelterwood grids. In 1995, northern flying squirrels were absent from control areas but were captured on at least one grid in all of the clearcut and shelterwood treatments.

Overall species richness of clearcut and shelterwood treatment areas was higher after timber harvest than it was in 1993 (Tables 11 and 12). Several species appeared on clearcut areas in 1994 that had not previously been captured; meadow voles, meadow jumping mice (*Zapus hudsonius*), least chipmunks, northern flying squirrels and weasels. Similarly, meadow voles, southern bog lemmings, least chipmunks, northern flying squirrels and weasels appeared on shelterwood areas in 1994. By 1995, meadow voles, meadow jumping mice and shrews no longer appeared on the clearcut treatment grids and meadow voles were no longer captured on shelterwood areas. As no new species were evident on clearcut or shelterwood treatment areas in 1995, overall species richness of both treatments was higher in 1995 than in 1993 and slightly higher in 1994 than in 1995.

**Effect of Timber Harvest Edge**

Before timber harvest in 1993, there were no statistical differences in small mammal species abundance, total numbers of small mammals captured or Hill's diversity numbers N0 andN1 between treated and buffer zone halves of treatment grids (Table 15). However, Hill's diversity number N2 was significantly higher on halves of the grids later designated full-tree extraction clearcuts than the buffer zone halves of these grids; this was primarily due to differences in the values of N2 between harvested and buffer zones on a single grid (14).

Significant differences in the abundance of red-backed voles and deer mice were observed on clearcut treatments in 1994, the first year after harvest; red-backed voles were more abundant on the uncut sides of both full-tree and tree-length clearcuts, while deer mice were more abundant on the harvested side of full-tree clearcuts (Table 16). In fact, 88% of deer mice captures on the full-tree extraction clearcuts occurred on the harvested side of the live-trapping grids, while 72% of red-backed vole captures on the same grids occurred on the buffer zone side. Largely due to the increases in red-backed vole abundance on the uncut sides of the grids, there was also a significant increase in the total numbers of small mammals captured on the buffer zone sides of both full-tree and tree-length extraction clearcuts.

In 1994, significant differences in Hill's diversity numbers N1 and N2 on both the uncut original and newer control grids were chiefly the result of juxtaposed species richness and total numbers of captures on a single grid in each case; i.e., a greater number of total captures but fewer species on one side ("buffer") of original control grid 4 than on the other side ("treated") or a greater number of total captures but fewer species on one side ("treated") of newer control grid 42 than on the other side("buffer") (Table 16).

During the second post-harvest year, red-backed voles and northern flying squirrels showed significant differences between the two sides of full-tree extraction clearcut grids while deer mice and the total numbers of small mammals captured differed between sides of full-tree shelterwood grids (Table 17). As in 1994, red-backed voles were more abundant on the buffer sides of full-tree extraction grids whereas deer mice were more abundant on harvested sides. Northern flying squirrels were also higher in abundance on the buffer zone sides of full-tree extraction clearcuts, but only because one individual was captured on the buffer zone side and no individuals were captured on the harvested side of each of these grids in 1995. Differences in total numbers of small mammals captured between sides of full-tree shelterwood grids were mainly due to the increased numbers of deer mice captured on the harvested sides of these grids (Tables 16 and 17).

Differences in species richness on the cut and uncut sides of grids on patch-cut treatments conducted with manual felling and cable skidding approached statistically significance (Table 17), but only because the number of species captured on the uncut side of the grids was one higher than on the buffer zone side in 1995.

As in 1994, both the newer and original control treatments showed differences in small mammal captures on the two sides of these completely forested trapping grids during the second post-harvest year (Table 17). The newer control areas had higher overall red-backed vole and total small mammal abundance values on the buffer zone side of the grids but statistical differences were due to the large decrease in red-backed voles on the "treated" side of a single grid (252). Hill's diversity number N1 was again significantly different between sides of the original control grids in 1995 due to the juxtaposition of species richness and total numbers of captures on a single grid; i.e., a greater number of total captures but fewer species on one side ("treated") of original control grid 25 than on the other side ("buffer").

Individuals of only 5 species crossed the centres between buffers and treated sides of trapping grids during this study; northern red-backed voles, deer mice, heather voles, yellow-nosed voles, and least chipmunks (Table 18). Of these, the most common species to move were red-backed voles and deer mice. Although red-backed voles crossed the grid centre on more treatments than deer mice, a larger percentage of deer mice moved across the centre of treatment grids than red-backed voles. For both species, the highest rate of movement occurred on the full-tree extraction shelterwood areas before timber harvest. During the first year after timber harvest, deer mice movement was higher on the newer and original controls than at the other treatment edges. By 1995, this pattern no longer existed because more deer mice moved across the centre of patch cut grids than control grids in that year. For red-backed voles no obvious differences among the treatments were noted when the number of individuals captured on each side of the grids was compared. Only 1 individual of each of the other 3 species crossed the grid centres during this entire study.

***Peromyscus* Activity**

The median distance moved by female deer mice in this study was 4.3 m/day, which was much less than the 23.2 m/day moved by males (Table 19). Large differences in the home range size of the two sexes were also observed with females having a median 90% minimum convex polygon home range of $8.2 \times 10^{-4}$ ha (8.2 $m^2$) and males with an average home range of $6.1 \times 10^{-3}$ ha (61.0 $m^2$). Most of the day refuges and radio-telemetry locations of individuals were within the treatment area associated with the grids on which they had been radio-collared (Table 20). Examined separately, the proportions of day refuges and radio-telemetry locations of individual females on treated areas generally decreased whereas those of males increased relative to the treatment area on which they had been radio-collared. In all cases, use of boundary habitat was less than use of uncut forest, shelterwood and clearcut areas; i.e., deer mice remained resident.

The most common habitat features used by the combined sexes of deer mice were decay class 3-5 root-balls, tree/snags and logs, slash-piles and areas of ground not associated with any above-ground features (Table 21). Four of these habitat features were particularly important to females; decay class 3-5 root-balls and logs, slash-piles and ground not associated with any obvious above-ground features. In addition, stumps of all decay classes were important to female deer mice. Three of the most common habitat features were also important to males; decay class 3-5 root-balls and tree/snags and areas of ground not covered by any obvious above-ground habitat features. Male deer mice also commonly used decay class 1-2 tree/snags and erratics. Of the five habitat features most commonly used by male deer mice, decay class 3-5 snags were the most heavily used. Ground-level day-refuges were generally used by deer mice more often than elevated refuges but males on the uncut control areas used elevated refuges three times more often than ground day-refuges.

Comparison of activity patterns between male and female deer mice on shelterwood and control treatments showed statistically significant differences between the sexes only on the shelterwood treatment (Table 22). On shelterwood areas, both the distance/duration and distance/number of day-refuges were higher for male than female deer mice.

Female deer mice associated with clearcut, shelterwood and control treatments travelled significantly different distances per day (Table 23). In particular, females associated with clearcuts travelled further for each day they were radio-collared than females associated with shelterwood and control treatments. Other variables that showed differences approaching statistical significance ($P<0.100$) were the number of day positions/duration and the distance between day positions; the values of these variables seemed to be higher for females associated with the clearcut treatment. Activity patterns of male deer mice were not statistically different between shelterwood and control treatments, although the 80% and 90% harmonic mean estimates of home range approached statistical significance with higher values on the shelterwood treatment than on the uncut controls (Table 23).

## DISCUSSION

Although several potentially negative effects of timber harvesting on small mammal communities were documented, the results of this study largely suggest that alternative timber management practices can be used to maintain or enhance biodiversity of small mammal communities in boreal mixedwoods. Indeed, species richness was maintained or increased on all treatment areas following timber harvest. An increase in overall species richness following timber harvest could be attributed to the effect of harvest intensity or methods of extraction on predation rates, interspecific (between species) and intraspecific (between individuals of the same species) competition, and on habitat quality. Timber harvest could affect predation rates by changing the number of predators hunting in an area, or by increasing or decreasing the availability of shelter for small mammals and hiding places for ambush predators. Interspecific competition may change with the addition and loss of species from an area and intraspecific competition can change the number of individuals of a species in an area. Habitat quality for small mammals can be altered by changes in the type and amount of food and shelter, as well as changes in the microclimate of an area due to alternative timber management practices.

Within any particular silvicultural system, different harvest methods can have notable effects on the habitat left for wildlife after timber extraction (Scarratt et al.1996). For instance, full-tree extraction removes much more unmerchantable woody debris, or slash, from a harvested area than cut-to-length extraction. Some other factors that change with different harvesting methods are the amount of soil compaction, soil erosion and residual tree damage to a stand (Deslauriers 1996, Pulkki 1996). Each of these factors could have effects on the small mammal community of a harvested site. Soil compaction and erosion can determine the health and vigour of vegetative re-growth after timber extraction (Hausenbuiller 1985). The severity and amount of residual tree damage can affect the health of the remaining trees in the new forest. This in turn can influence the number of seeds, insects and the regeneration success in the stand. Since seeds, insects and vegetative re-growth are important food sources for small mammals, their populations on harvested stands could also be influenced by residual tree damage. Finally, the amount and distribution of slash in an area can affect the habitat of small mammals by influencing the availability of shelter, herbaceous vegetation, insects, and moisture at the soil surface (Kirkland 1975, Wywialowski and Smith 1988, Deslauriers 1996). Since tree tops and limbs often carry seeds, leaving slash on the harvested area can also influence the availability of seeds which are used as a food source by many small mammals (Kirkland 1990, Deslauriers 1996). Of the harvest methods employed at the Black Sturgeon Boreal Mixedwoods Research Project, cut-to-length extraction leaves the least soil compaction, soil erosion, residual tree damage and the most slash on a harvested stand (Deslauriers 1996, Gingras 1996, Pulkki 1996).

In spite of the potential effects of timber harvesting on small mammal habitat, timber harvest intensity and methods of extraction had little impact on small mammal communities at the Black Sturgeon Boreal Mixedwoods Research site. In the first year following timber harvest, there was a drop in species richness on shelterwood cuts, and southern bog lemmings increased on control grids, but by the second post-harvest year there were no remaining effects of timber harvest intensity (i.e., shelterwood or clearcuts) on overall small mammal species abundance, diversity or richness in edge habitats of treated areas. Northern flying squirrels became more prevalent on full-tree extraction clearcuts in the second post-harvest year, otherwise overall small mammal species abundance, diversity and richness in edge habitats were not affected by the method used for timber extraction (i.e., full-tree, part-tree, tree-length or cut-to-length).

Several researchers have investigated the effects of clearcut timber harvesting on small mammal communities inside cut areas (Tevis 1956; Kirkland 1977; Martell and Radvanyi 1977; Martell

1983; Scrivner and Smith 1984; Swan et al. 1984; Monthey and Soutiere 1985; Clough 1987; Parker 1989; Walters 1991). Kirkland (1990) compared 22 of these studies, all conducted in North America, and found the response of small mammal communities to clearcut harvesting was similar in deciduous and coniferous forests during the first 6 years after disturbance. The majority of studies reviewed by Kirkland (1990) found higher species richness values on clearcuts than in uncut forest, whereas the present study showed no difference between clearcut and control areas. Similarly, Martell and Radvanyi (1977) observed no change in species richness between clearcut and uncut black spruce forest in Ontario. On the other hand, Martell (1983) observed lower species richness in clearcuts than in adjacent uncut black spruce forests. In Maine, Monthey and Soutiere (1985) found higher species richness in controls than in shelterwoods, similar to the present study, but lower species richness in clearcuts than in uncut softwood forest. Besides obvious differences in forest types and harvest methods, variation among studies in species richness response to timber harvesting undoubtedly reflects differences in species composition of the small mammal communities that were examined; i.e., some forest types may have been inhabited by small mammal species that are more sensitive, or respond differently, to the effects of timber harvesting than others. Such species-specific effects were evident from comparisons of small mammal abundance between harvested and uncut buffer zones adjacent to treatment areas in the present study.

Both timber harvest intensity and method of extraction had effects on the abundance of the two most commonly captured small mammal species, red-backed voles and deer mice, as well as some of the less common species, such as northern flying squirrels, at the interface between uncut forest and harvested areas at the Black Sturgeon Boreal Mixedwoods Research site. Full-tree harvest and, to a lesser extent, tree-length harvest of clearcuts resulted in increased use of uncut buffer zones by red-backed voles. Northern flying squirrels also increased in abundance in the uncut forest adjacent to full-tree clearcuts. In contrast, deer mice increased in abundance on the harvested sides of clearcuts the year after timber was removed by full-tree extraction and on the harvested sides of full-tree shelterwood areas 2 years after timber removal. There was little evidence that individuals of any species commonly traversed the interface between clearcut areas and adjacent forest.

Higher red-backed vole abundance on the uncut side of full-tree clearcuts agrees with observations of Mills (1995) and Sekgororoane and Dilworth (1995) who found this species to avoid disturbed habitat. However, Kirkland (1985) observed the opposite response, and Walters (1991) found red-backed vole activity similar on both sides of a forest/clearcut interface. Generally, red-backed voles were less abundant on clearcuts than shelterwood or control areas at the Black Sturgeon Boreal Mixedwoods Research site (Table 5). This agrees with the results of some researchers who studied mature coniferous forests of eastern (Martell and Radvanyi 1977, Martell 1983) and western (Corn et al. 1988, Nordyke and Buskirk 1988, Raphael 1988b) North America. In contrast, studies in coniferous forests of northern Maine (Monthey and Soutiere 1985), New Brunswick (Parker 1989) and Pennsylvania (Kirkland 1977) found more abundant red-backed vole populations on recent clearcuts than in uncut forests. In at least one study, the cause of this difference could be related to use of alternative timber harvesting methods; i.e., Monthey and

Soutiere (1985) noted large amounts of slash on cut areas at their research site suggesting full-tree harvesting may not have been used.

Generally higher abundance of red-backed voles in interior forests than recently clearcut areas (Raphael 1988a, Kurta 1995, Mills 1995) has led some researchers to suggest that the species might be useful as an indicator of old-growth conditions in western North American forests (Corn et al. 1988, Raphael 1988b, Wywialowski and Smith 1988). It is possible that the different forest types, composition and climate in western North America would preclude use of the same old-growth indicator species in eastern North America. However, the distribution of red-backed voles between harvested and uncut buffer zones adjacent to treatment areas in the present study suggests that the species might also be a useful old-growth indicator for boreal mixedwood forests in Ontario.

Similar to red-backed voles, northern flying squirrels generally prefer uncut forest habitat (Raphael 1988a, Kurta 1995, Waters and Zabel 1995). The appearance of northern flying squirrels in the second post harvest year, only on the forested side of full-tree extraction clearcuts in the present study, and predominantly on the forested side of harvested areas in general rather than uncut controls (Table 17), suggests that these squirrels actually use habitat edges more intensely than interior forest. Flying squirrels may use habitat edges as corridors for travel and adjacent cutover areas to forage for food and nesting material. *Bryoroa* spp. lichens, in particular, are commonly used by flying squirrels as food and nesting material (Mowrey and Zasada 1984, Hayward and Rosentreter 1994, Waters and Zabel 1995). These hair lichens, which grow on tree limbs, are often abundant in the slash piles of recent clearcuts, thereby providing an ample source of food and nesting material adjacent to harvested areas.

In contrast to red-backed voles and northern flying squirrels, deer mice were more abundant on the harvested than uncut sides of full-tree clearcuts at the Black Sturgeon Boreal Mixedwoods Research site during the first year following timber removal. These results support Walters (1991), who found higher deer mouse abundance on recently clearcut lands than in adjacent uncut forests, but not Sekgororoane and Dilworth (1995) who found very little difference between the harvested and un-harvested sides of a forest/clearcut interface. During the second post-harvest year, deer mice were more abundant on the cutover side of full-tree shelterwood treatments than uncut forest. Although no other studies have investigated the abundance of deer mice at the edge of shelterwood cuts, two studies in northeastern North America found higher abundance of deer mice in partially cut areas than in uncut forests (Swan et al. 1984, Monthey and Soutiere 1985), which coincides with the current study.

Deer mice have one of the most extensive geographic distributions of any North American mammal, reaching from the northern Yukon Territory of Canada southwards into central Mexico, and from the west, almost to the east coast of the continent (Hooper 1968, Burt and Grossenheider 1980, Kurta 1995). Throughout their range deer mice are known to occupy a diverse array of disturbance-driven and early successional habitats including agricultural fields, sand dunes, recent burns, regenerating clearcuts and shrubby areas, as well as mature forests (Ahlgren 1966, Burt and Grossenheider 1980, Sullivan 1980, Gilbert and Krebs 1981, Martell 1983, Probst and Rakstad

1987, Kurta 1995). Since harvesting of mature forests is one method of converting them to an earlier successional stage, timber harvest may positively influence deer mouse populations. Deer mice are primarily seed-eaters, although they also consume berries and insects. Indeed, high numbers of deer mice on seeded clearcuts attracted the interest of foresters during the early 1900s due to the presumed deleterious effect their presence had on forest regeneration (Sullivan 1979). Since that time, deer mice have been shown to provide many benefits to regenerating forests by assisting with control of insect pests, dispersal of mycorrhizal fungi and aeration of forest soils (Maser et al. 1978, Martell and Macaulay 1981, Kurta 1995). Thus, leaving slash material on harvested areas can increase the availability of seeds, as well as shelter, vegetative regrowth and insects that may attract and enhance deer mouse populations.

However, radio-tracking of deer mice in the present study showed that alternative harvesting practices can affect the activity patterns and habitat use of small mammals without causing significant differences in their longer-term overall abundance at habitat edges. For example, deer mice used a greater number of elevated day-refuges in trees than ground-level refuges in uncut control and shelterwood areas relative to clearcut treatments (Table 21). In addition, females tracked in clearcuts travelled further each day than those on shelterwood and control areas. Nonetheless, the majority of day refuges and radio-telemetry locations of individuals were within the treatment area associated with the grids on which they were radio-collared (Table 20). Since most deer mice remained resident in spite of these changes in habitat use and activity patterns, overall abundance did not vary among these treatment areas before or after timber was harvested (Table 10).

There were no differences in small mammal species abundance, diversity or richness between uncut and harvested sides of part-tree shelterwoods or cut-to-length shelterwoods in any of the 3 years of this study. Species richness was higher on the uncut side of part-tree patch cuts in the second year post-harvest, but only because a single individual of several species (Soricidae, *Mustela* sp., southern bog lemming and least chipmunk) was captured on the uncut side of a single grid (Table 17). Part-tree and cut-to-length harvesting methods would have left more slash on cut areas, thereby providing "softer" edges, than any of the other methods used in this project. Since these methods had no apparent effect, part-tree and cut-to-length harvesting, particularly in association with shelterwood or patch-cut silvicultural systems, may be best suited to the maintenance of biodiversity of small mammal communities in boreal mixedwoods.

Part-tree and cut-to-length extraction were not used with clearcut harvesting so it is not possible to determine if these methods would moderate differences in red-backed vole or deer mouse abundance between sides of forest/clearcut edges. However, tree-length extraction clearcuts, which like the part-tree and cut-to-length methods have more remaining slash than full-tree extraction, did not sustain any significant differences in red-backed vole numbers by the second post-harvest year (Tables 16 and 17). It is therefore possible that use of the part-tree and cut-to-length methods might also moderate the effects of timber extraction at forest/clearcut edges. More work on the effects of these two harvesting methods on small mammal communities in areas planned for clearcutting would be useful.

## CONCLUSION

The silvicultural systems and harvest methods examined at the Black Sturgeon Boreal Mixedwoods Research site had little effect on overall species abundance, diversity or richness of small mammal communities. However, several of these systems and methods did affect the distribution of some species between treated and adjacent uncut forest areas. In particular, full-tree and, to a lesser extent, tree-length harvest of clearcuts affected the use of cutover and uncut forests by red-backed voles and deer mice whereas part-tree and cut-to-length harvesting in shelterwood or patch-cut systems had no effect on these or other species of small mammals. Such species-specific responses of small mammals must be taken into consideration in the development of integrated resource management plans that maintain or enhance biodiversity, particularly in areas with species that are rare or at risk. To meet the habitat requirements and conserve the broadest range of small mammal species, foresters will need to implement a variety of silvicultural systems and harvest methods that provide an appropriate mixture of mature as well as regenerating areas within managed boreal mixedwood forests. The most successful conservation strategy will satisfy the requirements of both internal and disturbance-tolerant species and facilitate re-colonization of cutover areas following harvest. Applied with due diligence, alternative timber management practices can be used to maintain or enhance biodiversity of small mammal communities in boreal mixedwoods.

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Table 1. Small mammals that may be found at the Black Sturgeon Boreal Mixedwoods Research Site, based on known distributions in Ontario (Banfield 1974, Dobbyn 1994, Kurta 1995).

| Scientific Name | Common Names |
|---|---|
| INSECTIVORA (Insectivores) | |
| *Sorex cinerus* | Masked shrew, Dusky shrew, Common shrew |
| *Sorex palustris* | American water shrew |
| *Sorex fumeus* | Smoky shrew |
| *Sorex arcticus* | Arctic shrew, Black-backed shrew |
| *Sorex hoyi* | Pygmy shrew |
| *Blarina brevicauda* | Short-tailed shrew |
| *Condylura cristata* | Star-nosed mole |
| RODENTIA (Rodents) | |
| *Tamias striatus* | Eastern chipmunk |
| *Tamias minimus* | Least chipmunk |
| *Tamiasciurus hudsonicus* | Red squirrel |
| *Glaucomys sabrinus* | Northern flying squirrel |
| *Peromyscus maniculatus* | Deer mouse |
| *Clethrionomys gapperi* | Southern red-backed vole, Gapper's red-backed vole |
| *Synaptomys cooperi* | Southern bog lemming |
| *Phenacomys intermedius* | Heather vole, Heath vole |
| *Microtus pennsylvanicus* | Meadow vole |
| *Microtus chrotorrhinus* | Rock vole, Yellow-nosed vole |
| *Zapus hudsonius* | Meadow jumping mouse |
| *Napaeozapus insignis* | Woodland jumping mouse |
| CARNIVORA (Carnivores) | |
| *Mustela erminea* | Ermine |
| *Mustela frenata* | Long-tailed weasel |
| *Mustela nivalis* | Least weasel |

Table 2. Seasons and live-trap types used to monitor the small mammal community on the 3 treatment grid groups during the pre-harvest year (1993) and the 2 post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site.

| Year | Trapping Season | Trap Type Used | Treatment Grid Groups | | |
|---|---|---|---|---|---|
| | | | Original Control Grids | Harvested Treatment Grids | New Control Grids |
| 1993 | Fall | Longworth | X | X | |
| 1994 | Summer and Fall | Sherman | | X | X |
| 1994 | Fall | Longworth | X | | |
| 1995 | Summer and Fall | Sherman | | X | X |
| 1995 | Fall | Longworth | X | | |

Table 3. Numbers of radio-collars attached to female and male deer mice on each grid in each harvest treatment during the 2 post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site.

| Year | Sex | Treatments | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Controls | | Shelterwood Cuts | | Clearcuts | | Totals |
| | | Grid 42 | Grid 132 | Grid 2 | Grid 5 | Grid 1 | Grid 14 | |
| 1994 | Females | 1 | 2 | | 2 | 1 | 1 | 7 |
| | Males | | 3 | | 2 | | | 5 |
| | Total | 1 | 5 | | 4 | 1 | 1 | 12 |
| 1995 | Females | 4 | | 2 | 1 | 1 | 3 | 11 |
| | Males | 1 | | | 1 | | | 2 |
| | Total | 5 | | 2 | 2 | 1 | 3 | 13 |

Table 4. Definitions of the habitat features associated with the day-refuges of deer mice located by radio-telemetry during the 2 post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site.

| Habitat Features | Definitions |
|---|---|
| Ground | An area of land with a diameter of at least 1.5 m having no obvious above-ground features (such as logs, stumps, shrubs and rocks). These could have exposed soil, moss or a leaf litter covering. |
| Logs (decay class 1-2)[a] | These logs consisted of strong wood on the outside layers but could have wood rot well within the log. Logs were at least 1.5m long and =5cm in diameter and had to be resting directly on the ground at or above the position where the mouse was located with radio-telemetry. |
| Logs (decay class 3-5) | These logs consisted mainly of decayed wood material, even on the outside layers of the log. Logs were at least 1.5m long and =5 cm in diameter and had to be resting directly on the ground at or above the position where the mouse was located with radio-telemetry. |
| Trees/snags (decay class 1-2) | These trees/snags were alive and healthy, to declining in health, or almost dead. Trees and snags were any woody vegetation =5.0m in height and =5cm in diameter at breast height (DBH)[b]. |
| Snags (decay class 3-5) | These snags were dead and decayed woody material, =5.0m in height and =5cm in diameter at breast height (DBH). |
| Stumps (decay class 1-2) | These stumps consisted of strong wood on the outside layers but occasionally had wood rot at the centre of the stump. Stumps were =2.0m high and =5cm in diameter at the top of the stump, or at breast height if the stump was =1.3m high. |
| Stumps (decay class 3-5) | These stumps consisted of decayed wood throughout most of the stump. Stumps were =2.0m high and =5cm in diameter at the top of the stump, or at breast height if the stump was =1.3m high |
| Root-balls (decay class 1-2) | These root-balls were still strong and were not moss-covered. They were the roots of trees which had fallen over and were now above ground level. |
| Root-balls (decay class 3-5) | These root-balls were composed of decayed wood and were usually at least partially moss-covered. They were the roots of trees which had fallen over and were now above ground level. |
| Large rock | This was a rock located mostly underground that was too large to be moved without heavy equipment. |
| Erratic | This was a rock located mostly above ground that was too large to be moved without heavy equipment. |
| Slash-pile | This was a pile of harvesting debris (twigs, branches, treetops), each piece having a diameter of <5cm at its widest point. |
| Under shrub | This habitat designation was used when an animal was located in the ground less than 0.75m from a shrub. Shrubs were defined as woody vegetation >0.40m and =2.0m in height. |
| Camper trailer | A portable human built shelter for protection from inclement weather. |

[a]Decay class definitions are based on the description of gradual decay in logs adapted by Maser et al. (1979) and Thomas et al. (1979) from Fogel et al. (1973 as cited by Hunter 1990). In general

class 1-2 woody habitat features were comprised of intact to partially soft wood and held their living shape. Class 3-5 woody habitat features were comprised of decay levels characterized by large or small pieces of wood, or a powdery substance, and usually did not hold the shape they had when the tree was alive.

[b]DBH is approximately 1.3m above the ground.

Table 5. Numbers of small mammals live-trapped on grids associated with the control, shelterwood and clearcut treatments during the pre-harvest year (1993) and the two post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site.

| 1993 (pre-harvest) | SILVICULTURAL SYSTEM (later implemented) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Control | Control | Shelterwood | Shelterwood | Shelterwood | Clearcut | Clearcut | Clearcut | Species Totals |
| LIVETRAPPING GRID NUMBER | 4 | 13 | 25 | 2 | 3 | 24 | 1 | 14 | 26 | |
| *Clethrionomys gapperi* | 20 | 32 | 67 | 20 | 15 | 35 | 37 | 59 | 76 | 361 |
| *Peromyscus maniculatus* | 9 | 9 | 23 | 10 | 4 | 12 | 6 | 12 | 5 | 90 |
| *Microtus chrotorrhinus* | | | 2 | | | | | 3 | 9 | 14 |
| *Phenacomys intermedius* | | | | | | | | 1 | 1 | 2 |
| *Napaeozapus insignis* | 1 | | | | | | | | | 1 |
| Soricidae | | | | | | | 2 | 1 | 1 | 4 |
| EFFORT (# Trap Nights) | 180 | 180 | 180 | 225 | 135 | 90 | 135 | 180 | 180 | |
| | | | | | | | TOTAL CAPTURES (# individuals) | | | 468 |
| | | | | | | | TOTAL EFFORT (# trap nights) | | | 1485 |

| 1994 (post-harvest) | SILVICULTURAL SYSTEM | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Control | Control | Shelterwood | Shelterwood | Shelterwood | Clearcut | Clearcut | Clearcut | Species Totals |
| LIVETRAPPING GRID NUMBER | 42 | 132 | 252 | 2 | 3 | 24 | 1 | 14 | 26 | |
| *Clethrionomys gapperi* | 68 | 78 | 61 | 59 | 37 | 65 | 56 | 60 | 82 | 566 |
| *Peromyscus maniculatus* | 12 | 13 | 3 | 9 | 8 | 7 | 10 | 18 | 8 | 88 |
| *Microtus chrotorrhinus* | 8 | 11 | 17 | 5 | 2 | 3 | 1 | 12 | 5 | 64 |
| *Glaucomys sabrinus* | | | | 2 | | | 3 | 3 | | 8 |
| *Microtus pennsylvanicus* | | 2 | 2 | | 1 | | | 2 | 1 | 8 |
| *Napaeozapus insignis* | 1 | | 1 | | | 4 | 1 | 1 | | 8 |
| *Synaptomys cooperi* | 3 | 2 | 1 | | | | | 1 | 1 | 8 |
| *Phenacomys intermedius* | 2 | 1 | | | | | | 1 | | 4 |
| *Tamias minimus* | | | | | | | 1 | | | 1 |
| *Mustela sp.* | | | | | | | | 1 | | 1 |
| Soricidae | | 1 | | | | | | | | 1 |
| EFFORT (# Trap Nights) | 540 | 450 | 450 | 495 | 540 | 450 | 495 | 540 | 450 | |
| | | | | | | | TOTAL CAPTURES (# individuals) | | | 757 |
| | | | | | | | TOTAL EFFORT (# trap nights) | | | 4410 |

| 1995 (post-harvest) | SILVICULTURAL SYSTEM | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Control | Control | Shelterwood | Shelterwood | Shelterwood | Clearcut | Clearcut | Clearcut | Species Totals |
| LIVETRAPPING GRID NUMBER | 42 | 132 | 252 | 2 | 3 | 24 | 1 | 14 | 26 | |
| *Clethrionomys gapperi* | 44 | 49 | 44 | 51 | 45 | 44 | 26 | 38 | 40 | 381 |
| *Peromyscus maniculatus* | 17 | 28 | 5 | 12 | 10 | 11 | 20 | 21 | 3 | 127 |
| *Microtus chrotorrhinus* | 8 | | | | 2 | | | 5 | | 15 |
| *Glaucomys sabrinus* | | | | 2 | | | 5 | 2 | 2 | 11 |
| *Phenacomys intermedius* | 3 | 1 | | | 1 | | | 4 | | 9 |
| *Tamias minimus* | | | | 1 | | | 4 | | | 5 |
| *Napaeozapus insignis* | | 1 | 1 | | | 2 | | 1 | | 5 |
| *Synaptomys cooperi* | 3 | | | | 1 | | | 1 | | 5 |
| *Mustela sp.* | | | | | | 1 | | 1 | | 2 |
| Soricidae | | | | | 1 | | | | | 1 |
| EFFORT (# Trap Nights) | 450 | 540 | 450 | 405 | 405 | 495 | 450 | 405 | 495 | |
| | | | | | | | TOTAL CAPTURES (# individuals) | | | 561 |
| | | | | | | | TOTAL EFFORT (# trap nights) | | | 4095 |

Table 6. Numbers of small mammals pitfall trapped on the control, shelterwood and clearcut treatment areas during the pre-harvest year (1993) and the two post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site.

| 1993 (pre-harvest) | SILVICULTURAL SYSTEM (later implemented) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Control | Control | Shelterwood | Shelterwood | Shelterwood | Clearcut | Clearcut | Clearcut | Species Totals |
| TREATMENT AREA NUMBER | 4 | 13 | 25 | 2 | 3 | 24 | 1 | 14 | 26 | |
| *Sorex cinereus* | 15 | 4 | 3 | 4 | 5 | 3 | 12 | 2 | 3 | 51 |
| *Clethrionomys gapperi* | | | | 4 | 1 | 4 | | | 2 | 11 |
| *Sorex fumeus* | 3 | 1 | | | 2 | | | 1 | 1 | 8 |
| *Blarina brevicauda* | | 1 | | | | | | | | 1 |
| *Sorex arcticus* | | | | | | 1 | | | | 1 |
| EFFORT (# Trap Nights) | 168 | 168 | 168 | 168 | 168 | 168 | 168 | 168 | 168 | |
| | | | | | | | TOTAL CAPTURES (# individuals) | | | 72 |
| | | | | | | | TOTAL EFFORT (# trap nights) | | | 1512 |

| 1994 (post-harvest) | SILVICULTURAL SYSTEM | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Control | Control | Shelterwood | Shelterwood | Shelterwood | Clearcut | Clearcut | Clearcut | SPECIES TOTALS |
| TREATMENT AREA NUMBER | 4 | 13 | 25 | 2 | 3 | 24 | 1 | 14 | 26 | |
| *Sorex cinereus* | 11 | 7 | 25 | 12 | 9 | 10 | 7 | 17 | 9 | 107 |
| *Clethrionomys gapperi* | 4 | 8 | 15 | 10 | 9 | 12 | 12 | 13 | 7 | 90 |
| *Sorex hoyi* | 1 | 5 | 4 | 6 | 2 | 3 | 6 | 4 | | 31 |
| *Phenacomys intermedius* | | | 3 | 1 | | 8 | | 1 | | 13 |
| *Microtus chrotorrhinus* | 1 | | 3 | 2 | | 4 | | | 1 | 11 |
| *Synaptomys cooperi* | | | 1 | 1 | | 2 | 1 | | | 5 |
| *Sorex fumeus* | 1 | | 1 | | | 1 | | 1 | | 4 |
| *Microtus pennsylvanicus* | 1 | | | | | | | | | 1 |
| *Sorex arcticus* | | | | 1 | | | | | | 1 |
| EFFORT (# Trap Nights) | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | |
| | | | | | | | TOTAL CAPTURES (# individuals) | | | 173 |
| | | | | | | | TOTAL EFFORT (# trap nights) | | | 10800 |

| 1995 (post-harvest) | SILVICULTURAL SYSTEM | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Control | Control | Shelterwood | Shelterwood | Shelterwood | Clearcut | Clearcut | Clearcut | SPECIES TOTALS |
| TREATMENT AREA NUMBER | 4 | 13 | 25 | 2 | 3 | 24 | 1 | 14 | 26 | |
| *Sorex cinereus* | 10 | 21 | 25 | 24 | 18 | 15 | 20 | 24 | 18 | 175 |
| *Clethrionomys gapperi* | 10 | 8 | 21 | 13 | 14 | 8 | 2 | 8 | 7 | 91 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Sorex hoyi* | 2 | 1 | 2 | 6 | 3 | 6 | 2 | 12 | 2 | 36 |
| *Phenacomys intermedius* | | | | 2 | 4 | 5 | 2 | | 1 | 14 |
| *Peromyscus maniculatus* | | | | | 1 | 1 | 5 | 1 | | 8 |
| *Sorex arcticus* | | 1 | 1 | | 1 | 1 | | | | 4 |
| *Sorex fumeus* | 2 | | | 1 | 1 | | | | | 4 |
| *Synaptomys cooperi* | 3 | | | | | | 1 | | | 4 |
| *Microtus chrotorrhinus* | | | 1 | 1 | | | | 1 | | 3 |
| *Blarina brevicauda* | | | | | | 1 | | | | 1 |
| EFFORT (# Trap Nights) | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 | |
| | | | | | | | TOTAL CAPTURES (# individuals) | | | 340 |
| | | | | | | | TOTAL EFFORT (# trap nights) | | | 10800 |

Table 7. Minimum and maximum values of species abundance, richness and diversity of the small mammal community on original control areas determined by live- and pitfall trapping before (1993) and after (1994 and 1995) timber harvest at the Black Sturgeon Boreal Mixedwood Research site. Comparisons among treatments (all years combined) were made by Friedman tests.

| LONGWORTH TRAPPING DATA | Treatments Area 4 | Area 13 | Area 25 | P-value | PITFALL TRAPPING DATA | Treatments Area 4 | Area 13 | Area 25 | P-value |
|---|---|---|---|---|---|---|---|---|---|
| *Clethrionomys gapperi* | 18-40 (a) | 28-54 (b) | 55-67 (c) | 0.000* | *Sorex cinereus* | 10-15 | 4-21 | 3-25 | 0.790 |
| *Peromyscus maniculatus* | 0-9 | 6-26 | 5-23 | 0.180 | *Clethrionomys gapperi* | 0-10 | 0-8 | 0-21 | 0.250 |
| *Microtus chrotorrhinus* | 0-3 | 0-2 | 0-2 | 0.588 | *Sorex hoyi* | 0-2 | 0-5 | 0-4 | 0.907 |
| *Synaptomys cooperi* | 0-2 | 0-1 | 0-0 | 0.145 | *Microtus chrotorrhinus* | 0-1 | 0-0 | 0-3 | 0.145 |
| Capture (# individuals) | 25-45 (d) | 41-63 (e) | 60-92 (e) | 0.049 | *Sorex fumeus* | 1-3 | 0-1 | 0-1 | 0.134 |
| Species Richness (N0) | 2-4 | 2-4 | 2-3 | 0.934 | Capture (# individuals) | 18-24 | 5-30 | 3-49 | 0.790 |
| Species Diversity (N1) | 1.53-2.45 | 1.69-2.00 | 1.33-1.94 | 0.790 | Species Richness (N0) | 2-5 | 2-3 | 1-5 | 0.444 |
| Species Diversity (N2) | 1.26-1.83 | 1.34-2.00 | 1.18-1.69 | 0.444 | Species Diversity (N1) | 1.57-3.14 | 1.65-2.95 | 1.00-3.20 | 0.790 |
| | | | | | Species Diversity (N2) | 1.38-2.77 | 1.47-2.90 | 1.00-2.63 | 0.790 |

*Where P < 0.05 different letters indicate that treatment areas were significantly different

Table 8. Numbers of small mammals live-trapped on the original control grids during the two post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site.

| YEAR | 1994 | | | 1995 | | | Species |
|---|---|---|---|---|---|---|---|
| Original Control Grid Numbers | 4 | 13 | 25 | 4 | 13 | 25 | Totals |
| *Clethrionomys gapperi* | 40 | 54 | 55 | 18 | 28 | 59 | 254 |
| *Peromyscus maniculatus* | 0 | 6 | 5 | 2 | 26 | 15 | 54 |
| *Microtus chrotorrhinus* | 3 | 2 | 0 | 3 | 0 | 0 | 8 |
| *Synaptomys cooperi* | 2 | 1 | 0 | 2 | 0 | 0 | 5 |
| *Phenacomys intermedius* | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Soricidae | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| EFFORT (# Trap Nights) | 135 | 180 | 135 | 135 | 135 | 135 | |

Table 9. Minimum and maximum values of species abundance, richness and diversity of the small mammal community on original control areas determined by live- and pitfall trapping before (1993) and after (1994 and 1995) timber harvest at the Black Sturgeon Boreal Mixedwood Research site. Comparisons among years (all treatment areas combined) were made by Friedman tests.

| LONGWORTH | YEAR | | | | PITFALL | YEAR | | | |
|---|---|---|---|---|---|---|---|---|---|
| TRAPPING DATA | 1993 | 1994 | 1995 | P-value | TRAPPING DATA | 1993 | 1994 | 1995 | P-value |
| *Clethrionomys gapperi* | 20-67 | 40-55 | 18-59 | 0.444 | *Sorex cinereus* | 3-15 | 7-25 | 10-25 | 0.826 |
| *Peromyscus maniculatus* | 9-23 (a) | 0-6 (b) | 2-26 (a) | 0.049* | *Clethrionomys gapperi* | 0-0 (e) | 4-15 (f) | 8-21 (g) | 0.004* |
| *Microtus chrotorrhinus* | 0-2 | 0-3 | 0-3 | 0.790 | *Sorex hoyi* | 0-0 (h) | 1-5 (i) | 1-2 (i) | 0.049* |
| *Synaptomys cooperi* | 0-0 | 0-2 | 0-2 | 0.250 | *Microtus chrotorrhinus* | 0-0 | 0-3 | 0-1 | 0.145 |
| Capture (# individuals) | 29-92 | 45-63 | 25-74 | 0.790 | *Sorex fumeus* | 0-3 | 0-1 | 0-2 | 0.588 |
| Species Richness (N0) | 2-3 | 2-4 | 2-4 | 0.934 | Capture (# individuals) | 3-18 (j) | 18-48 (k) | 24-49 (l) | 0.004* |
| Species Diversity (N1) | 1.69-1.94 | 1.33-1.70 | 1.66-2.45 | 0.309 | Species Richness (N0) | 1-2 (m) | 3-5 (n) | 3-4 (o) | 0.004* |
| Species Diversity (N2) | 1.52-1.75 (c) | 1.18-1.34 (d) | 1.48-2.00 (c) | 0.049* | Species Diversity (N1) | 1.00-1.65 (p) | 2.95-3.20 (q) | 2.05-3.14 (q) | 0.049* |
| | | | | | Species Diversity (N2) | 1.00-1.47 (r) | 2.31-2.90 (s) | 1.78-2.77 (s) | 0.049* |

*Where $P < 0.05$ different letters indicate that years were significantly different

Table 10. Minimum and maximum values of species abundance, richness and diversity of the small mammal community at harvest treatment edges (live-trapping) and on harvest treatment areas (pitfall trapping) before (1993) and after (1994 and 1995) timber harvest at the Black Sturgeon Boreal Mixedwood Research site. Comparisons among treatment areas were made by Kruskal-Wallis tests.

| 1993 Livetrapping Data (pre-harvest) | SILVICULTURAL SYSTEM (later implemented) | | | |
|---|---|---|---|---|
| | Control | Shelterwood | Clearcut | P-value |
| *Clethrionomys gapperi* | 20-67 | 15-35 | 37-76 | 0.129 |
| *Peromyscus maniculatus* | 9-23 | 4-12 | 5-12 | 0.102 |
| *Microtus chrotorrhinus* | 0-2 | 0-0 | 0-9 | 0.199 |
| Capture (# individuals) | 29-92 | 19-47 | 43-90 | 0.329 |
| Species Richness (N0) | 2-3 | 2-2 | 2-3 | 0.264 |
| Species Diversity (N1) | 1.69-1.94 | 1.67-1.89 | 1.50-1.83 | 0.491 |
| Species Diversity (N2) | 1.52-1.75 | 1.50-1.80 | 1.32-1.51 | 0.113 |

| 1993 Pitfall Trapping Data (pre-harvest) | SILVICULTURAL SYSTEM (later implemented) | | | |
|---|---|---|---|---|
| | Control | Shelterwood | Clearcut | P-value |
| *Sorex cinereus* | 3-15 | 3-5 | 2-12 | 0.698 |
| *Clethrionomys gapperi* | 0-0 | 1-4 | 0-2 | 0.061 |
| *Sorex fumeus* | 0-3 | 0-2 | 0-1 | 0.768 |
| Capture (# individuals) | 3-18 | 7-8 | 3-12 | 0.737 |
| Species Richness (N0) | 1-2 | 2-3 | 1-3 | 0.513 |
| Species Diversity (N1) | 1.00-1.65 | 1.98-2.46 | 1.00-2.75 | 0.172 |
| Species Diversity (N2) | 1.00-1.47 | 1.96-2.13 | 1.00-2.57 | 0.172 |

| 1994 Livetrapping Data (post-harvest) | SILVICULTURAL SYSTEM | | | |
|---|---|---|---|---|
| | Control | Shelterwood | Clearcut | P-value |
| *Clethrionomys gapperi* | 61-78 | 37-65 | 56-82 | 0.329 |
| *Peromyscus maniculatus* | 3-13 | 7-9 | 8-18 | 0.472 |
| *Microtus chrotorrhinus* | 8-17 | 2-5 | 1-12 | 0.161 |
| *Glaucomys sabrinus* | 0-0 | 0-2 | 0-3 | 0.195 |
| *Microtus pennsylvanicus* | 0-2 | 0-1 | 0-2 | 0.427 |
| *Napaeozapus insignis* | 0-1 | 0-4 | 0-1 | 0.961 |
| *Synaptomys cooperi* | 1-3 (a) | 0-0 (b) | 0-1 (ab) | 0.048* |
| Capture (# individuals) | 85-106 | 48-79 | 71-97 | 0.174 |
| Species Richness (N0) | 5-6 (c) | 4-4 (d) | 5-7 (c) | 0.047* |
| Species Diversity (N1) | 2.37-2.39 | 1.92-2.06 | 1.81-3.16 | 0.252 |
| Species Diversity (N2) | 1.75-1.80 | 1.45-1.60 | 1.38-2.30 | 0.288 |

| 1994 Pitfall Trapping Data (post-harvest) | SILVICULTURAL SYSTEM | | | |
|---|---|---|---|---|
| | Control | Shelterwood | Clearcut | P-value |
| *Sorex cinereus* | 7-25 | 9-12 | 7-17 | 0.863 |
| *Clethrionomys gapperi* | 4-15 | 9-12 | 7-13 | 0.865 |
| *Sorex hoyi* | 1-5 | 2-6 | 0-6 | 0.989 |
| *Phenacomys intermedius* | 0-3 | 0-8 | 0-1 | 0.591 |
| *Microtus chrotorrhinus* | 0-3 | 0-4 | 0-1 | 0.441 |
| *Synaptomys cooperi* | 0-1 | 0-2 | 0-1 | 0.513 |
| Capture (# individuals) | 17-51 | 20-39 | 17-35 | 0.807 |
| Species Richness (N0) | 3-6 | 3-6 | 3-4 | 0.641 |
| Species Diversity (N1) | 2.60-3.74 | 2.58-5.05 | 2.38-3.23 | 0.491 |
| Species Diversity (N2) | 2.08-2.94 | 2.41-4.51 | 2.21-2.94 | 0.430 |

| 1995 Livetrapping Data (post-harvest) | SILVICULTURAL SYSTEM | | | |
|---|---|---|---|---|
| | Control | Shelterwood | Clearcut | P-value |
| *Clethrionomys gapperi* | 44-49 | 44-51 | 26-40 | 0.055 |
| *Peromyscus maniculatus* | 5-28 | 10-12 | 3-21 | 0.733 |
| *Microtus chrotorrhinus* | 0-8 | 0-2 | 0-5 | 0.939 |
| *Glaucomys sabrinus* | 0-0 | 0-2 | 2-5 | 0.056 |
| *Phenacomys intermedius* | 0-3 | 0-1 | 0-4 | 0.714 |
| *Tamias minimus* | 0-0 | 0-1 | 0-4 | 0.558 |
| *Napaeozapus insignis* | 0-1 | 0-2 | 0-1 | 0.801 |
| *Synaptomys cooperi* | 0-3 | 0-1 | 0-1 | 0.954 |
| Capture (# individuals) | 50-79 | 57-66 | 45-72 | 0.491 |
| Species Richness (N0) | 3-5 | 3-5 | 3-7 | 0.965 |

| 1995 Pitfall Trapping Data (post-harvest) | SILVICULTURAL SYSTEM | | | |
|---|---|---|---|---|
| | Control | Shelterwood | Clearcut | P-value |
| *Sorex cinereus* | 10-25 | 15-24 | 18-24 | 0.873 |
| *Clethrionomys gapperi* | 8-21 | 8-14 | 2-8 | 0.110 |
| *Sorex hoyi* | 1-2 | 3-6 | 2-12 | 0.122 |
| *Phenacomys intermedius* | 0-0 (e) | 2-5 (f) | 0-2 (e) | 0.042* |
| *Peromyscus maniculatus* | 0-0 | 0-1 | 0-5 | 0.211 |
| Capture (# individuals) | 22-48 | 35-45 | 28-45 | 0.661 |
| Species Richness (N0) | 3-3 (g) | 4-5 (h) | 4-5 (h) | 0.045* |
| Species Diversity (N1) | 2.05-2.55 (i) | 3.01-3.98 (j) | 2.56-3.03 (j) | 0.039* |
| Species Diversity (N2) | 1.78-2.37 | 2.58-3.49 | 2.07-2.58 | 0.077 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Species Diversity (N1) | 1.52-3.14 | 1.89-2.14 | 1.53-3.53 | 0.670 | | | | | |
| Species Diversity (N2) | 1.27-2.44 | 1.58-1.63 | 1.26-2.71 | 0.670 | | | | | |

*Where $P < 0.05$ different letters indicate that treatments were significantly different

Table 11. Numbers of small mammals live-trapped on controls, tree-length clearcuts and full-tree clearcuts during the pre-harvest year (1993) and the two post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site.

| 1993 (pre-harvest) | TREATMENTS (later implemented) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| CLEARCUTS | Control | Control | Control | Tree-length | Tree-length | Tree-length | Full-tree | Full-tree | Full-tree | Species |
| LIVETRAPPING GRID NUMBER | 4 | 13 | 25 | 7 | 9 | 21 | 1 | 14 | 26 | Totals |
| *Clethrionomys gapperi* | 20 | 32 | 67 | 36 | 62 | 65 | 37 | 59 | 76 | 454 |
| *Peromyscus maniculatus* | 9 | 9 | 23 | 3 | 9 | 16 | 6 | 12 | 5 | 92 |
| *Microtus chrotorrhinus* | | | 2 | 1 | 1 | 5 | | 3 | 9 | 21 |
| *Phenacomys intermedius* | | | | 1 | | 1 | | 1 | 1 | 4 |
| *Synaptomys cooperi* | | | | 1 | 1 | 2 | | | | 4 |
| *Napaeozapus insignis* | 1 | | | | | | | | | 1 |
| Soricidae | | | | | | 1 | 2 | 1 | 1 | 5 |
| EFFORT (# Trap Nights) | 180 | 180 | 180 | 180 | 180 | 225 | 135 | 180 | 180 | |
| | | | | | | | TOTAL CAPTURES (# individuals) | | | 581 |
| | | | | | | | TOTAL EFFORT (# trap nights) | | | 1620 |
| 1994 (post-harvest) | TREATMENTS APPLIED | | | | | | | | | |
| CLEARCUTS | Control | Control | Control | Tree-length | Tree-length | Tree-length | Full-tree | Full-tree | Full-tree | Species |
| LIVETRAPPING GRID NUMBER | 42 | 132 | 252 | 7 | 9 | 21 | 1 | 14 | 26 | Totals |
| *Clethrionomys gapperi* | 68 | 78 | 61 | 73 | 63 | 60 | 56 | 60 | 82 | 601 |
| *Peromyscus maniculatus* | 12 | 13 | 3 | 12 | 20 | 12 | 10 | 18 | 8 | 108 |
| *Microtus chrotorrhinus* | 8 | 11 | 17 | 6 | 9 | | 1 | 12 | 5 | 69 |
| *Glaucomys sabrinus* | | | | | | 5 | 3 | 3 | | 11 |
| *Microtus pennsylvanicus* | | 2 | 2 | 1 | 1 | 1 | | 2 | 1 | 10 |
| *Synaptomys cooperi* | 3 | 2 | 1 | 1 | | | | 1 | 1 | 9 |
| *Napaeozapus insignis* | 1 | | 1 | | | | 1 | 1 | | 4 |
| *Phenacomys intermedius* | 2 | 1 | | | | | | 1 | | 4 |
| *Tamias minimus* | | | | | | 2 | 1 | | | 3 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Zapus hudsonius* | | | | 1 | | | | | | 1 |
| *Mustela sp.* | | | | | | 1 | | 1 | | 2 |
| Soricidae | | 1 | | 1 | | | | | | 2 |
| EFFORT (# Trap Nights) | 540 | 450 | 450 | 540 | 540 | 495 | 495 | 540 | 450 | |
| | | | | | | | TOTAL CAPTURES (# individuals) | | | 824 |
| | | | | | | | TOTAL EFFORT (# trap nights) | | | 4500 |

| 1995 (post-harvest) CLEARCUTS | TREATMENTS APPLIED | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Control | Control | Tree-length | Tree-length | Tree-length | Full-tree | Full-tree | Full-tree | Species |
| LIVETRAPPING GRID NUMBER | 42 | 132 | 252 | 7 | 9 | 21 | 1 | 14 | 26 | Totals |
| *Clethrionomys gapperi* | 44 | 49 | 44 | 62 | 42 | 26 | 26 | 38 | 40 | 371 |
| *Peromyscus maniculatus* | 17 | 28 | 5 | 21 | 14 | 11 | 20 | 21 | 3 | 140 |
| *Microtus chrotorrhinus* | 8 | | | | | | | 5 | | 13 |
| *Glaucomys sabrinus* | | | | 1 | | 1 | 5 | 2 | 2 | 11 |
| *Phenacomys intermedius* | 3 | 1 | | 3 | | | | 4 | | 11 |
| *Tamias minimus* | | | | | | | 4 | | | 4 |
| *Synaptomys cooperi* | 3 | | | 2 | | | | 1 | | 6 |
| *Napaeozapus insignis* | | 1 | 1 | | | | | 1 | | 3 |
| *Mustela sp.* | | | | | | | | 1 | | 1 |
| EFFORT (# Trap Nights) | 450 | 540 | 450 | 405 | 405 | 405 | 450 | 405 | 495 | |
| | | | | | | | TOTAL CAPTURES (# individuals) | | | 560 |
| | | | | | | | TOTAL EFFORT (# trap nights) | | | 4005 |

Table 12. Numbers of small mammals live-trapped on controls, cut-to-length shelterwoods, part-tree shelterwoods and full-tree shelterwoods during the pre-harvest year (1993) and the two post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site.

| 1993 (pre-harvest) | TREATMENTS (later implemented) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHELTERWOODS | Control | Control | Control | Cut-to-length | Cut-to-length | Cut-to-length | Part-tree | Part-tree | Full-tree | Full-tree | Full-tree | Species |
| LIVETRAPPING GRID NUMBER | 4 | 13 | 25 | 5 | 11 | 22 | 12 | 23 | 2 | 3 | 24 | Totals |
| *Clethrionomys gapperi* | 20 | 32 | 67 | 54 | 27 | 56 | 30 | 45 | 20 | 15 | 35 | 401 |
| *Peromyscus maniculatus* | 9 | 9 | 23 | 7 | 6 | 13 | 8 | 13 | 10 | 4 | 12 | 114 |
| *Microtus chrotorrhinus* | | | 2 | | | 2 | 1 | 7 | | | | 12 |
| *Phenacomys intermedius* | | | | | | | 1 | | | | | 1 |
| *Napaeozapus insignis* | 1 | | | | | | | | | | | 1 |
| Soricidae | | | | | 1 | | | | | | | 1 |
| EFFORT (# Trap Nights) | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 225 | 135 | 90 | |
| | | | | | | | | TOTAL CAPTURES (# individuals) | | | | 530 |
| | | | | | | | | TOTAL EFFORT (# trap nights) | | | | 1890 |

| 1994 (post-harvest) | TREATMENTS APPLIED | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHELTERWOODS | Control | Control | Control | Cut-to-length | Cut-to-length | Cut-to-length | Part-tree | Part-tree | Full-tree | Full-tree | Full-tree | Species |
| LIVETRAPPING GRID NUMBER | 42 | 132 | 252 | 5 | 11 | 22 | 12 | 23 | 2 | 3 | 24 | Totals |
| *Clethrionomys gapperi* | 68 | 78 | 61 | 102 | 86 | 65 | 55 | 76 | 59 | 37 | 65 | 752 |
| *Peromyscus maniculatus* | 12 | 13 | 3 | 9 | 7 | | 12 | 8 | 9 | 8 | 7 | 88 |
| *Microtus chrotorrhinus* | 8 | 11 | 17 | 14 | | 8 | | | 5 | 2 | 3 | 68 |
| *Phenacomys intermedius* | 2 | 1 | | | | | | | | | | 3 |
| *Microtus pennsylvanicus* | | 2 | 2 | 1 | | | 2 | | | 1 | | 8 |
| *Synaptomys cooperi* | 3 | 2 | 1 | 2 | | | | | | | | 8 |
| *Napaeozapus insignis* | 1 | | 1 | | | | | | | | 4 | 6 |
| *Glaucomys sabrinus* | | | | | | | | | 2 | | | 2 |
| *Tamias minimus* | | | | 2 | | | | | | | | 2 |
| *Mustela sp.* | | | | | 1 | | | | | | | 1 |
| Soricidae | | 1 | | 2 | | | | | | | | 3 |

| EFFORT (# Trap Nights) | 540 | 450 | 450 | 540 | 540 | 540 | 450 | 495 | 495 | 540 | 450 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | TOTAL CAPTURES (# individuals) | | | | | 941 |
| | | | | | | | TOTAL EFFORT (# trap nights) | | | | | 5490 |

| 1995 (post-harvest) | TREATMENTS APPLIED | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SHELTERWOODS | Control | Control | Control | Cut-to-length | Cut-to-length | Cut-to-length | Part-tree | Part-tree | Full-tree | Full-tree | Full-tree | Species |
| LIVETRAPPING GRID NUMBER | 42 | 132 | 252 | 5 | 11 | 22 | 12 | 23 | 2 | 3 | 24 | Totals |
| *Clethrionomys gapperi* | 44 | 49 | 44 | 69 | 42 | 49 | 28 | 48 | 51 | 45 | 44 | 513 |
| *Peromyscus maniculatus* | 17 | 28 | 5 | 15 | 19 | 4 | 11 | 5 | 12 | 10 | 11 | 137 |
| *Microtus chrotorrhinus* | 8 | | | 5 | | 10 | | 7 | | 2 | | 32 |
| *Phenacomys intermedius* | 3 | 1 | | 4 | | 5 | | 2 | | 1 | | 16 |
| *Synaptomys cooperi* | 3 | | | | | | | | | 1 | | 4 |
| *Napaeozapus insignis* | | 1 | 1 | | | | | | | | 2 | 4 |
| *Glaucomys sabrinus* | | | | 1 | 1 | | 1 | | 2 | | | 5 |
| *Tamias minimus* | | | | 1 | 1 | 1 | | | 1 | | | 4 |
| *Mustela sp.* | | | | | 1 | 1 | 1 | | | | 1 | 4 |
| Soricidae | | | | | 1 | | | | | 1 | | 2 |
| EFFORT (# Trap Nights) | 450 | 540 | 450 | 450 | 450 | 495 | 405 | 450 | 405 | 405 | 495 | |
| | | | | | | | TOTAL CAPTURES (# individuals) | | | | | 721 |
| | | | | | | | TOTAL EFFORT (# trap nights) | | | | | 4995 |

Table 13. Minimum and maximum values of species abundance, richness and diversity of the small mammal community at harvest treatment edges of tree-length clearcuts, full-tree clearcuts and controls in the pre-harvest year (1993) and the two post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site. Comparisons among treatment areas were made by Kruskal-Wallis tests.

| 1993 (pre-harvest) | Treatments | | | |
|---|---|---|---|---|
| CLEARCUTS | Control | Tree-length | Full-tree | P-value |
| *Clethrionomys gapperi* | 20-67 | 36-65 | 37-76 | 0.561 |
| *Peromyscus maniculatus* | 9-23 | 3-16 | 5-12 | 0.550 |
| *Microtus chrotorrhinus* | 0-2 | 1-5 | 0-9 | 0.414 |
| Soricidae | 0-0 | 0-1 | 1-2 | 0.056 |
| Capture (# individuals) | 29-92 | 40-87 | 45-91 | 0.733 |
| Species Richness (N0) | 2-3 | 3-4 | 3-4 | 0.100 |
| Species Diversity (N1) | 1.69-1.94 | 1.46-2.11 | 1.76-1.95 | 0.733 |
| Species Diversity (N2) | 1.52-1.75 | 1.23-1.68 | 1.41-1.55 | 0.177 |

| 1994 (post-harvest) | Treatments | | | |
|---|---|---|---|---|
| CLEARCUTS | Control | Tree-length | Full-tree | P-value |
| *Clethrionomys gapperi* | 61-78 | 60-73 | 56-82 | 0.707 |
| *Peromyscus maniculatus* | 3-13 | 12-20 | 8-18 | 0.576 |
| *Microtus chrotorrhinus* | 8-17 | 0-9 | 1-12 | 0.288 |
| *Glaucomys sabrinus* | 0-0 | 0-5 | 0-3 | 0.345 |
| *Microtus pennsylvanicus* | 0-2 | 1-1 | 0-2 | 0.786 |
| *Synaptomys cooperi* | 1-3 | 0-1 | 0-1 | 0.103 |
| Capture (# individuals) | 84-106 | 78-93 | 70-97 | 0.874 |
| Species Richness (N0) | 4-5 | 4-5 | 4-6 | 0.564 |
| Species Diversity (N1) | 2.25-2.38 | 2.06-2.38 | 1.81-3.02 | 0.670 |
| Species Diversity (N2) | 1.71-1.76 | 1.57-1.94 | 1.38-2.26 | 0.670 |

| 1995 (post-harvest) | Treatments | | | |
|---|---|---|---|---|
| CLEARCUTS | Control | Tree-length | Full-tree | P-value |
| *Clethrionomys gapperi* | 44-49 | 26-62 | 26-40 | 0.170 |
| *Peromyscus maniculatus* | 5-28 | 11-21 | 3-21 | 0.967 |
| *Microtus chrotorrhinus* | 0-8 | 0-0 | 0-5 | 0.558 |
| *Glaucomys sabrinus* | 0-0 (a) | 0-1 (a) | 2-5 (b) | 0.032* |
| *Phenacomys intermedius* | 0-3 | 0-3 | 0-4 | 0.886 |
| *Synaptomys cooperi* | 0-3 | 0-2 | 0-1 | 0.939 |
| Capture (# individuals) | 49-78 | 38-89 | 45-71 | 0.670 |
| Species Richness (N0) | 2-5 | 2-5 | 3-6 | 0.717 |
| Species Diversity (N1) | 1.39-3.14 | 1.75-2.32 | 1.53-3.33 | 0.733 |
| Species Diversity (N2) | 1.22-2.44 | 1.60-1.84 | 1.26-2.61 | 0.670 |

*Where $P < 0.05$ different letters indicate that treatments were significantly different

Table 14. Minimum and maximum values of species abundance, richness and diversity of the small mammal community at harvest treatment edges of cut-to-length shelterwoods, part-tree shelterwoods, full-tree shelterwoods and controls in the pre-harvest year (1993) and the two post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site. Comparisons among treatment areas were made by Kruskal-Wallis tests.

| 1993 (pre-harvest) | Treatments | | | | |
|---|---|---|---|---|---|
| SHELTERWOOD CUTS | Control | Cut-to-length | Part-tree | Full-tree | P-value |
| *Clethrionomys gapperi* | 20-67 | 27-56 | 30-45 | 15-35 | 0.460 |
| *Peromyscus maniculatus* | 9-23 | 6-13 | 8-13 | 4-12 | 0.780 |
| *Microtus chrotorrhinus* | 0-2 | 0-2 | 1-7 | 0-0 | 0.212 |
| Capture (# individuals) | 29-92 | 33-71 | 39-65 | 19-47 | 0.536 |
| Species Richness (N0) | 2-3 | 2-3 | 3-3 | 2-2 | 0.190 |
| Species Diversity (N1) | 1.69-1.94 | 1.43-1.82 | 1.86-2.26 | 1.67-1.89 | 0.173 |
| Species Diversity (N2) | 1.52-1.75 | 1.25-1.52 | 1.58-1.88 | 1.50-1.80 | 0.207 |

| 1994 (post-harvest) | Treatments | | | | |
|---|---|---|---|---|---|
| SHELTERWOOD CUTS | Control | Cut-to-length | Part-tree | Full-tree | P-value |
| *Clethrionomys gapperi* | 61-78 | 65-102 | 55-76 | 37-65 | 0.195 |
| *Peromyscus maniculatus* | 3-13 | 0-9 | 8-12 | 7-9 | 0.528 |
| *Microtus chrotorrhinus* | 8-17 | 0-14 | 0-0 | 2-5 | 0.106 |
| *Microtus pennsylvanicus* | 0-2 | 0-1 | 0-2 | 0-1 | 0.541 |
| *Synaptomys cooperi* | 1-3 | 0-2 | 0-0 | 0-0 | 0.073 |
| *Napaeozapus insignis* | 0-1 | 0-0 | 0-0 | 0-4 | 0.340 |
| Capture (# individuals) | 85-106 | 73-128 | 69-84 | 48-79 | 0.148 |
| Species Richness (N0) | 5-6 | 2-5 | 2-3 | 3-4 | 0.108 |
| Species Diversity (N1) | 2.36-2.39 | 1.31-2.04 | 1.37-1.80 | 1.85-2.04 | 0.069 |
| Species Diversity (N2) | 1.75-1.80 | 1.16-1.53 | 1.21-1.50 | 1.45-1.60 | 0.086 |

| 1995 (post-harvest) | Treatments | | | | |
|---|---|---|---|---|---|
| SHELTERWOOD CUTS | Control | Cut-to-length | Part-tree | Full-tree | P-value |
| *Clethrionomys gapperi* | 44-49 | 42-69 | 28-48 | 44-51 | 0.725 |
| *Peromyscus maniculatus* | 5-28 | 4-19 | 5-11 | 10-12 | 0.693 |
| *Microtus chrotorrhinus* | 0-8 | 0-10 | 0-7 | 0-2 | 0.716 |
| *Phenacomys intermedius* | 0-3 | 0-5 | 0-2 | 0-1 | 0.517 |
| *Glaucomys sabrinus* | 0-0 | 0-1 | 0-1 | 0-2 | 0.518 |
| Capture (# individuals) | 49-78 | 62-94 | 40-62 | 55-65 | 0.330 |
| Species Richness (N0) | 2-4 | 3-5 | 3-4 | 2-4 | 0.557 |
| Species Diversity (N1) | 1.39-2.77 | 2.00-2.40 | 2.01-2.13 | 1.65-1.99 | 0.289 |
| Species Diversity (N2) | 1.22-2.26 | 1.76-1.82 | 1.16-1.77 | 1.47-1.58 | 0.296 |

'able 15. Numbers of small mammals live-trapped on the treated and uncut buffer zone sides of treatment areas before timber harvest in 1993 at the Black Sturgeon Boreal Mixedwood Research site.

| SILVICULTURAL SYSTEM | | Patch Cut | | | Shelterwood Cut | | Shelterwood Cut | | | Shelterwood Cut | | | Clearcut | | | Clearcut | | | Original Control | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HARVEST METHOD | | Part-tree | | | Part-tree | | Full-tree | | | Cut-to-length | | | Full-tree | | | Tree-length | | | Uncut | | |
| LIVETRAPPING GRIDS | | 8 | 10 | 27 | 12 | 23 | 2 | 3 | 24 | 5 | 11 | 22 | 1 | 14 | 26 | 7 | 9 | 21 | 4 | 13 | 25 |
| SPECIES | SIDE | | | | | | | | | | | | | | | | | | | | |
| *Clethrionomys gapperi* | treated | 18 | 2 | 31 | 15 | 25 | 9 | 1 | 17 | 20 | 18 | 30 | 17 | 23 | 33 | 21 | 30 | 29 | 13 | 18 | 34 |
| | buffer | 8 | 14 | 36 | 12 | 13 | 9 | 7 | 13 | 26 | 4 | 18 | 18 | 29 | 36 | 10 | 22 | 27 | 5 | 10 | 28 |
| *Peromyscus maniculatus* | treated | . | 1 | 3 | 5 | 9 | 6 | 6 | 4 | 3 | 2 | 6 | 2 | 7 | 1 | 2 | 3 | 6 | 6 | 6 | 6 |
| | buffer | 1 | 1 | 5 | 2 | 2 | 5 | 3 | 7 | 5 | 2 | 8 | 3 | 3 | 3 | 1 | 5 | 9 | 4 | . | 15 |
| *Microtus chrotorrhinus* | treated | . | . | 1 | 1 | 1 | . | . | . | . | . | . | 1 | 3 | 6 | 1 | . | 2 | . | . | 2 |
| | buffer | . | 1 | 2 | . | 4 | . | . | . | . | . | 1 | . | . | 2 | . | . | 2 | . | . | . |
| *Phenacomys intermedius* | treated | . | . | 2 | 1 | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . |
| | buffer | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | 1 | . | . | . |
| *Synaptomys cooperi* | treated | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | . | . | . |
| | buffer | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . |
| *Microtus pennsylvanicus* | treated | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | buffer | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| *Napaeozapus insignis* | treated | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . |
| | buffer | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Soricidae | treated | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . |
| | buffer | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | 1 | . | . | . |
| Captures (# individuals) | treated | 18 | 4 | 37 | 22 | 35 | 15 | 7 | 21 | 24 | 20 | 36 | 20 | 35 | 40 | 24 | 34 | 38 | 19 | 24 | 42 |
| | buffer | 9 | 16 | 43 | 14 | 19 | 14 | 10 | 20 | 31 | 6 | 27 | 21 | 32 | 42 | 12 | 27 | 41 | 9 | 10 | 43 |
| Species Richness (N0) | treated | 1 | 3 | 4 | 4 | 3 | 2 | 2 | 2 | 3 | 2 | 2 | 3 | 5 | 3 | 3 | 3 | 4 | 2 | 2 | 3 |
| | buffer | 2 | 3 | 3 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 4 | 3 | 2 | 6 | 2 | 1 | 2 |
| Species Diversity (N1) | treated | 1.00 | 2.83 | 1.84 | 2.41 | 2.00 | 1.96 | 1.51 | 1.63 | 1.72 | 1.38 | 1.57 | 1.68 | 2.75 | 1.71 | 1.58 | 1.53 | 2.11 | 1.87 | 1.75 | 1.81 |
| | buffer | 1.42 | 1.59 | 1.72 | 1.51 | 2.28 | 1.92 | 1.84 | 1.91 | 1.56 | 1.89 | 2.12 | 1.51 | 1.36 | 1.74 | 1.76 | 1.61 | 2.79 | 1.99 | 1.00 | 1.91 |
| Species Diversity (N2) | treated | 1.00 | 2.67 | 1.40 | 1.92 | 1.73 | 1.92 | 1.32 | 1.45 | 1.40 | 1.22 | 1.38 | **1.36** | **2.08** | **1.42** | 1.29 | 1.27 | 1.64 | 1.76 | 1.60 | 1.47 |
| | buffer | 1.25 | 1.29 | 1.40 | 1.32 | 1.91 | 1.85 | 1.72 | 1.83 | 1.37 | 1.80 | 1.87 | **1.32** | **1.20** | **1.35** | 1.41 | 1.43 | 2.06 | 1.98 | 1.00 | 1.83 |

Note: **bold** type and shading indicates a significant difference at $P < 0.05$ between treated and uncut buffer zones by Mann-Whitney test

Table 16. Numbers of small mammals live-trapped on the treated and uncut buffer zone sides of treatment areas during the first year after timber harvest (1994) at the Black Sturgeon Boreal Mixedwood Research site.

| SILVICULTURAL SYSTEM | | Newer Control | | | Patch Cut | | | Shelterwood Cut | | Shelterwood Cut | | | Shelterwood Cut | | | Clearcut | | | Clearcut | | | Original Controls | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HARVEST METHOD | | Uncut | | | Part-tree | | | Part-tree | | Full-tree | | | Cut-to-length | | | Full-tree | | | Tree-length | | | Uncut | | |
| TREATMENT AREA | | 42 | 132 | 252 | 8 | 10 | 27 | 12 | 23 | 2 | 3 | 24 | 5 | 11 | 22 | 1 | 14 | 26 | 7 | 9 | 21 | 4 | 13 | 25 |
| SPECIES | SIDE | | | | | | | | | | | | | | | | | | | | | | | |
| *Clethrionomys gapperi* | treated | 32 | 32 | 28 | 16 | 24 | 43 | 21 | 23 | 25 | 17 | 27 | 46 | 36 | 16 | **9** | **17** | **22** | **22** | **15** | **21** | 12 | 19 | 20 |
| | buffer | 33 | 34 | 28 | 26 | 24 | 48 | 30 | 46 | 25 | 18 | 37 | 48 | 36 | 42 | **42** | **34** | **51** | **36** | **33** | **33** | 18 | 27 | 28 |
| *Peromyscus maniculatus* | treated | 9 | 6 | 1 | . | 6 | 3 | 7 | 3 | 4 | 5 | 3 | 4 | 1 | . | **10** | **16** | **5** | 10 | 12 | 5 | . | 5 | 4 |
| | buffer | 2 | 4 | 2 | . | 2 | 5 | 4 | 4 | 2 | 2 | 5 | 5 | 4 | . | . | **1** | **3** | 2 | 10 | 5 | . | 2 | . |
| *Microtus chrotorrhimus* | treated | 4 | 7 | 9 | 4 | . | 3 | . | . | 1 | . | . | 7 | . | . | . | . | 1 | . | 3 | . | . | . | . |
| | buffer | 4 | 3 | 6 | 1 | . | 3 | . | . | 3 | . | . | 5 | . | 5 | . | 9 | 2 | 3 | 6 | . | . | . | . |
| *Phenacomys intermedius* | treated | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | buffer | 1 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . |
| *Synaptomys cooperi* | treated | . | 1 | 1 | . | 1 | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | 1 | 1 | . |
| | buffer | 1 | . | . | 1 | . | . | . | . | . | . | . | 2 | . | . | . | . | 1 | 1 | . | . | . | . | . |
| *Microtus pennsylvanicus* | treated | . | 1 | 2 | . | . | . | 1 | . | . | 1 | . | . | . | . | . | . | . | . | 1 | . | . | . | . |
| | buffer | . | 1 | . | . | 1 | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | 1 | . | . | . |
| *Napaeozapus insignis* | treated | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | buffer | . | . | . | . | . | . | . | . | . | . | 4 | . | . | . | . | . | . | . | . | . | . | . | . |
| *Tamias minimus* | treated | . | . | . | . | . | . | . | . | . | . | . | 2 | . | . | . | . | . | . | . | 2 | . | . | . |
| | buffer | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | 1 | . | . | . | . | . | . | . | . |
| *Glaucomys sabrinus* | treated | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | buffer | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 4 | . | . | . |
| *Zapus hudsonius* | treated | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| | buffer | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . |
| *Mustela sp.* | treated | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | 1 | . | . | . |
| | buffer | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | 1 | . | . | . |
| *Soricidae* | treated | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | 1 | . | . | . | . | . |
| | buffer | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Captures (# individuals) | treate | 45 | 47 | 41 | 20 | 32 | 49 | 29 | 26 | 30 | 23 | 30 | 60 | 37 | 16 | **19** | **35** | **28** | **33** | **31** | **29** | 13 | 25 | 24 |

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d buffer | 41 | 43 | 36 | 28 | 27 | 56 | 34 | 50 | 30 | 20 | 46 | 61 | 41 | 47 | **43** | **46** | **57** | **43** | **49** | **44** | 18 | 29 | 28 |
| Species Richness (N0) | treated | 3 | 5 | 5 | 2 | 4 | 3 | 3 | 2 | 3 | 3 | 2 | 5 | 2 | 1 | 2 | 4 | 3 | 3 | 4 | 4 | *2* | *3* | *2* |
| | buffer | 5 | 5 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | 3 | 5 | 3 | 2 | 2 | 5 | 4 | 5 | 3 | 5 | *1* | *2* | *1* |
| Species Diversity (N1) | treated | **2.18** | **2.64** | **2.51** | 1.65 | 2.11 | 1.58 | 2.00 | 1.43 | 1.71 | 2.00 | 1.38 | 2.26 | 1.13 | 1.00 | 2.00 | 2.49 | 1.85 | 2.09 | 2.87 | 2.31 | **1.31** | **1.93** | **1.57** |
| | buffer | **2.08** | **2.15** | **1.92** | 1.36 | 1.52 | 1.66 | 1.44 | 1.32 | 1.76 | 1.38 | 1.88 | 2.18 | 1.54 | 1.40 | 1.12 | 2.21 | 1.56 | 1.92 | 2.33 | 2.35 | **1.00** | **1.29** | **1.00** |
| Species Diversity (N2) | treated | **1.81** | **1.99** | **1.93** | 1.47 | 1.67 | 1.29 | 1.71 | 1.26 | 1.40 | 1.68 | 1.22 | 1.65 | 1.06 | 1.00 | 1.99 | 2.24 | 1.54 | 1.86 | 2.54 | 1.79 | **1.17** | **1.61** | **1.38** |
| | buffer | **1.51** | **1.56** | **1.57** | 1.16 | 1.25 | 1.34 | 1.26 | 1.17 | 1.41 | 1.22 | 1.50 | 1.58 | 1.28 | 1.23 | 1.05 | 1.71 | 1.24 | 1.41 | 1.96 | 1.71 | **1.00** | **1.15** | **1.00** |

Note: shading indicates a significant difference between treated and uncut buffer zones at P < 0.05 in **bold** type or P < 0.10 in italics by Mann-Whitney test

Table 17. Numbers of small mammals live-trapped on the treated and uncut buffer zone sides of treatment areas during the second year after timber harvest (1995) at the Black Sturgeon Boreal Mixedwood Research site.

| SILVICULTURAL SYSTEM | | Newer Control | | | Patch Cut | | | Shelterwood Cut | | Shelterwood Cut | | | Shelterwood Cut | | | Clearcut | | | Clearcut | | | Original Controls | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HARVEST METHOD | | Uncut | | | Part-tree | | | Part-tree | | Full-tree | | | Cut-to-length | | | Full-tree | | | Tree-length | | | Uncut | | |
| TREATMENT AREA | | 42 | 132 | 252 | 8 | 10 | 27 | 12 | 23 | 2 | 3 | 24 | 5 | 11 | 22 | 1 | 14 | 26 | 7 | 9 | 21 | 4 | 13 | 25 |
| SPECIES | SIDE | | | | | | | | | | | | | | | | | | | | | | | |
| *Clethrionomys gapperi* | treated | 21 | 21 | 6 | 27 | 14 | 20 | 16 | 28 | 25 | 24 | 20 | 36 | 18 | 22 | 9 | 9 | 12 | 23 | 19 | 11 | 13 | 10 | 23 |
| | buffer | 23 | 23 | 32 | 28 | 22 | 17 | 8 | 19 | 21 | 15 | 18 | 33 | 19 | 27 | 14 | 24 | 27 | 31 | 18 | 15 | 5 | 14 | 23 |
| *Peromyscus maniculatus* | treated | 8 | 10 | 1 | 6 | 3 | 5 | 5 | 3 | 9 | 7 | 8 | 9 | 9 | 4 | 14 | 10 | 3 | 14 | 9 | 2 | 1 | 13 | 7 |
| | buffer | 7 | 14 | 4 | 3 | 6 | 5 | 5 | 1 | 3 | 3 | 3 | 6 | 10 | . | 3 | 8 | . | 6 | 3 | 9 | 1 | 16 | 7 |
| *Microtus chrotorrhimus* | treated | 6 | . | . | 3 | . | 1 | . | . | . | . | . | 4 | . | 3 | . | . | . | . | . | . | . | . | . |
| | buffer | 3 | . | . | 2 | . | . | . | 5 | . | 2 | . | . | . | 6 | . | 5 | . | . | . | . | 2 | . | . |
| *Phenacomys intermedius* | treated | . | 1 | . | 1 | . | . | . | . | . | . | . | 1 | . | 1 | . | . | . | . | . | . | 1 | . | . |
| | buffer | 2 | 1 | . | 1 | . | . | . | 2 | . | 1 | . | 2 | . | 2 | . | 4 | . | 3 | . | . | . | . | . |
| *Synaptomys cooperi* | treated | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . |
| | buffer | 2 | . | . | 1 | . | . | . | . | . | 1 | . | . | . | . | . | 1 | . | 2 | . | . | 1 | . | . |
| *Napaeozapus insignis* | treated | . | 1 | . | . | . | . | . | . | . | . | 2 | . | . | . | . | . | . | . | . | . | . | . | . |
| | buffer | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . |
| *Tamias minimus* | treated | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | . | . | . | . | . | . | . | . |
| | buffer | . | . | . | . | . | 1 | . | . | 1 | . | . | 1 | 2 | . | 1 | . | . | . | . | . | . | . | . |
| *Glaucomys sabrinus* | treated | . | . | . | . | 1 | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . |
| | buffer | . | . | . | . | 1 | 1 | 1 | . | 1 | . | . | 1 | 1 | . | 1 | 1 | 1 | 1 | . | 1 | . | . | . |
| *Mustela sp.* | treated | . | . | . | . | . | . | 1 | . | . | . | 1 | . | . | 1 | . | . | . | . | . | . | . | . | . |
| | buffer | . | . | . | . | 1 | . | 1 | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . |
| *Soricidae* | treated | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . |
| | buffer | . | . | . | . | . | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 2 |
| Captures (# individuals) | treated | 36 | 33 | 7 | 37 | 18 | 27 | 22 | 31 | 34 | 31 | 31 | 50 | 27 | 32 | 25 | 19 | 15 | 37 | 28 | 14 | 16 | 23 | 30 |
| | buffer | 37 | 38 | 37 | 35 | 30 | 25 | 15 | 27 | 26 | 22 | 21 | 43 | 33 | 35 | 19 | 44 | 28 | 43 | 21 | 25 | 9 | 30 | 33 |
| Species Richness (N0) | treated | 4 | 4 | 2 | 4 | 3 | 4 | 3 | 2 | 2 | 2 | 4 | 4 | 2 | 6 | 4 | 2 | 2 | 2 | 2 | 3 | 4 | 2 | 2 |
| | buffer | 5 | 3 | 3 | 5 | 4 | 5 | 4 | 4 | 4 | 5 | 2 | 5 | 5 | 3 | 4 | 7 | 2 | 5 | 2 | 3 | 4 | 2 | 4 |
| Species Diversity (N1) | treated | 2.8 | 2.3 | 1.5 | 2.2 | 1.9 | 2.1 | 2.03 | 1.37 | 1.7 | 1.7 | 2.5 | 2.2 | 1.8 | 2.9 | 2.5 | 2.0 | 1.6 | 1.9 | 1.8 | 1.9 | 1.9 | 1.9 | 1.7 |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | 5 | 7 | 1 | 8 | 2 | 8 | | | 8 | 1 | 1 | 8 | 9 | 0 | 9 | 0 | 5 | 4 | 7 | 3 | **9** | **8** | **2** |
| | buffer | 3.09 | 2.15 | 1.59 | 2.13 | 2.17 | 2.64 | 2.89 | 2.40 | 1.96 | 2.81 | 1.51 | 2.22 | 2.89 | 1.95 | 2.29 | 3.91 | 1.17 | 2.53 | 1.51 | 2.23 | **3.16** | **2.00** | **2.35** |
| Species Diversity (N2) | treated | 2.39 | 2.01 | 1.32 | 1.77 | 1.57 | 1.71 | 1.72 | 1.21 | 1.64 | 1.54 | 2.05 | 1.79 | 1.80 | 2.00 | 2.24 | 1.99 | 1.47 | 1.89 | 1.77 | 1.56 | 1.49 | 1.97 | 1.56 |
| | buffer | 2.30 | 1.99 | 1.32 | 1.53 | 1.72 | 1.97 | 2.47 | 1.86 | 1.50 | 2.02 | 1.32 | 1.63 | 2.33 | 1.59 | 1.74 | 2.83 | 1.07 | 1.83 | 1.32 | 2.04 | 2.61 | 1.99 | 1.87 |

Note: shading indicates a significant difference between treated and uncut buffer zones at P < 0.05 in **bold** type or P < 0.10 in italics by Mann-Whitney test

Table 18. Total numbers of individuals of small mammal species live-trapped on the treated and uncut buffer zone sides of treatment areas, and the number and percentage that moved between treated and uncut buffer zones in the pre-harvest year (1993) and the two post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site.

| Year | | Newer Control Uncut | Patch Cut Part-tree | Shelterwood Cut Part-tree | Shelterwood Cut Full-tree | Shelterwood Cut Cut-to-length | Clearcut Full-tree | Clearcut Tree-length | Original Controls Uncut | Species Totals |
|---|---|---|---|---|---|---|---|---|---|---|
| 1993 | ***Peromyscus maniculatus*** | | | | | | | | | |
| | Number Moved (# individuals) | NA | 0 | 0 | 5 | 3 | 0 | 0 | 1 | 9 |
| | Captures (# individuals) | NA | 11 | 17 | 24 | 22 | 19 | 26 | 35 | 154 |
| | Percent Moved (%) | NA | 0.00 | 0.00 | 20.83 | 13.63 | 0.00 | 0.00 | 2.86 | 5.84 |
| | ***Clethrionomys gapperi*** | | | | | | | | | |
| | Number Moved (# individuals) | NA | 2 | 0 | 3 | 5 | 1 | 1 | 1 | 13 |
| | Captures (# individuals) | NA | 107 | 64 | 59 | 112 | 153 | 137 | 105 | 737 |
| | Percent Moved (%) | NA | 1.87 | 0.00 | 5.08 | 4.46 | 0.65 | 0.73 | 0.95 | 1.76 |
| 1994 | ***Peromyscus maniculatus*** | | | | | | | | | |
| | Number Moved (# individuals) | 2 | 1 | 1 | 1 | 0 | 2 | 2 | 1 | 10 |
| | Captures (# individuals) | 21 | 17 | 14 | 20 | 14 | 33 | 34 | 10 | 163 |
| | Percent Moved (%) | 9.52 | 5.88 | 7.14 | 5.00 | 0.00 | 6.06 | 5.88 | 10.00 | 6.13 |
| | ***Clethrionomys gapperi*** | | | | | | | | | |
| | Number Moved (# individuals) | 5 | 5 | 2 | 4 | 4 | 3 | 3 | 1 | 27 |
| | Captures (# individuals) | 184 | 165 | 95 | 142 | 201 | 174 | 156 | 113 | 1230 |
| | Percent Moved (%) | 2.72 | 3.03 | 2.11 | 2.82 | 1.99 | 1.72 | 1.92 | 0.88 | 2.20 |
| | ***Tamias minimus*** | | | | | | | | | |
| | Number Moved (# individuals) | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | Captures (# individuals) | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 4 |
| | Percent Moved (%) | NA | NA | NA | NA | 50.00 | NA | 0.00 | NA | 25.00 |
| 1995 | ***Peromyscus maniculatus*** | | | | | | | | | |
| | Number Moved (# individuals) | 2 | 3 | 0 | 2 | 1 | 0 | 0 | 4 | 12 |
| | Captures (# individuals) | 39 | 23 | 13 | 28 | 28 | 36 | 41 | 38 | 246 |
| | Percent Moved (%) | 5.13 | 13.04 | 0.00 | 7.14 | 3.57 | 0.00 | 0.00 | 10.53 | 4.88 |
| | ***Clethrionomys gapperi*** | | | | | | | | | |
| | Number Moved (# individuals) | 2 | 2 | 1 | 3 | 3 | 2 | 1 | 1 | 15 |
| | Captures (# individuals) | 121 | 106 | 61 | 114 | 134 | 90 | 108 | 87 | 821 |
| | Percent Moved (%) | 1.65 | 1.89 | 1.64 | 2.63 | 2.24 | 2.22 | 0.93 | 1.15 | 1.83 |
| | ***Microtus chrotorrhinus*** | | | | | | | | | |
| | Number Moved (# individuals) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | Captures (# individuals) | 8 | 6 | 4 | 0 | 12 | 4 | 0 | 2 | 36 |
| | Percent Moved (%) | 12.50 | 0.00 | 0.00 | NA | 0.00 | 0.00 | NA | 0.00 | 2.78 |
| | ***Phenacomys intermedius*** | | | | | | | | | |
| | Number Moved (# individuals) | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | Captures (# individuals) | 3 | 2 | 0 | 1 | 4 | 3 | 2 | 1 | 16 |
| | Percent Moved (%) | 0.00 | 0.00 | NA | 0.00 | 25.00 | 0.00 | 0.00 | 0.00 | 6.25 |

Table 19. Characteristics of deer mice (*Peromyscus maniculatus*) and their movement patterns as measured by radio-telemetry during the first and second post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site.

| Frequency | Year | Grid | Treatment | Sex | Weight | Duration | Distance / Duration | Locations | Day Refuges | Distance / Day Refuge | Day Refuges/ Duration | 90% Minimum Convex Polygon | Harmonic Mean Home Range And Active Area Estimates | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | 90% | 90% | 80% | 80% | 50% | 50% |
| (MHz) | | | | | (g) | (days) | (m/day) | | | (m/day refuge) | (day refuge/day) | ($m^2$) | ($m^2$) | (# areas) | ($m^2$) | (# areas) | ($m^2$) | (# areas) |
| 165.736 | 1994 | 132 | control | male | 18.0 | 30 | 1.9 | 19 | 3 | 19.0 | 0.10 | 8.19 | 250.73 | 2 | 250.73 | 2 | 11.68 | 1 |
| 165.813 | 1994 | 132 | control | male | 17.5 | 21 | 7.7 | 20 | 4 | 40.6 | 0.19 | 0.78 | 58.98 | 1 | 58.98 | 1 | 58.98 | 1 |
| 166.220 | 1994 | 132 | control | male | 17.0 | 19 | 26.7 | 10 | 4 | 126.7 | 0.21 | 740.98 | 1434.73 | 2 | 930.00 | 2 | 15.09 | 1 |
| 165.716 | 1995 | 42 and 132 | control | male | 20.5 | 25 | 23.2 | 13 | 5 | 116.2 | 0.20 | 2.01 | 171.82 | 1 | 171.82 | 1 | 66.99 | 1 |
| 165.754 | 1994 | 5 | shelterwood | male | 17.0 | 20 | 33.3 | 14 | 4 | 166.7 | 0.20 | 1242.15 | 3864.34 | 2 | 2571.03 | 2 | 18.35 | 1 |
| 166.145 | 1994 | 5 | shelterwood | male | 19.5 | 16 | 19.9 | 13 | 3 | 106.2 | 0.19 | 0.00 | 278.02 | 2 | 278.02 | 2 | 18.77 | 1 |
| 166.065 | 1995 | 5 | shelterwood | male | 17.5 | 17 | 46.1 | 14 | 5 | 156.8 | 0.29 | 11426.70 | 3760.79 | 4 | 2032.45 | 3 | 209.70 | 2 |
| 166.342 | 1994 | 42 | control | female | 21.5 | 36 | 2.6 | 25 | 3 | 31.2 | 0.08 | 163.27 | 187.76 | 2 | 187.76 | 2 | 0.50 | 1 |
| 165.946 | 1994 | 132 | control | female | 26.0 | 34 | 2.4 | 19 | 2 | 41.5 | 0.06 | 0.00 | 6.38 | 1 | 6.38 | 1 | 6.38 | 1 |
| 166.305 | 1994 | 132 | control | female | 19.0 | 27 | 2.5 | 15 | 3 | 22.2 | 0.11 | 59.00 | 245.80 | 2 | 245.80 | 2 | 12.51 | 1 |
| 165.635 | 1995 | 42 | control | female | 19.0 | 19 | 8.7 | 17 | 5 | 33.1 | 0.26 | 81.37 | 505.44 | 2 | 102.81 | 2 | 4.02 | 1 |
| 165.923 | 1995 | 42 | control | female | 16.5 | 18 | 0.0 | 16 | 1 | 0.0 | 0.06 | NA | NA | NA | NA | NA | NA | NA |
| 165.946 | 1995 | 42 | control | female | 20.0 | 30 | 2.3 | 25 | 3 | 23.0 | 0.10 | 0.00 | 9.45 | 1 | 9.45 | 1 | 9.45 | 1 |
| 165.654 | 1995 | 42 and 5 | control | female | 22.0 | 11 | 21.6 | 9 | 4 | 59.4 | 0.36 | 1554.36 | 1388.73 | 3 | 1047.88 | 2 | 1.40 | 1 |
| 165.675 | 1995 | 2 | shelterwood | female | 22.0 | 20 | 1.4 | 17 | 4 | 7.2 | 0.20 | 26.26 | 113.76 | 2 | 113.76 | 2 | 8.03 | 1 |
| 166.266 | 1995 | 2 | shelterwood | female | 22.0 | 20 | 0.1 | 17 | 2 | 1.2 | 0.10 | NA | NA | NA | NA | NA | NA | NA |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 165.607 | 1994 | 5 | shelterwood | female | 25.0 | 31 | 0.3 | 17 | 3 | 3.3 | 0.10 | 0.11 | NA | NA | NA | NA | NA | NA |
| 166.464 | 1994 | 5 | shelterwood | female | 18.0 | 17 | 4.8 | 11 | 2 | 40.7 | 0.12 | 0.00 | 35.70 | 2 | 35.70 | 2 | 2.61 | 1 |
| 165.984 | 1995 | 5 and 1 | shelterwood | female | 16.0 | 15 | 6.3 | 11 | 3 | 31.3 | 0.20 | 114.75 | 228.05 | 1 | 228.05 | 1 | 0.41 | 1 |
| 165.694 | 1994 | 14 | clearcut | female | 26.7 | 27 | 27.7 | 14 | 6 | 124.5 | 0.22 | 6275.03 | NA | NA | NA | NA | NA | NA |
| 166.184 | 1994 | 1 | clearcut | female | 18.5 | 29 | 8.2 | 18 | 3 | 79.4 | 0.10 | 0.00 | 3272.21 | 2 | 0.37 | 1 | 0.37 | 1 |
| 165.854 | 1995 | 14 | clearcut | female | 17.5 | 22 | 3.8 | 19 | 5 | 16.9 | 0.23 | 559.44 | 333.65 | 2 | 280.45 | 2 | 40.88 | 2 |
| 165.795 | 1995 | 14 | clearcut | female | 18.0 | 19 | 11.6 | 17 | 6 | 36.6 | 0.32 | 1126.58 | 172.62 | 3 | 125.51 | 3 | 89.03 | 2 |
| 165.896 | 1995 | 14 | clearcut | female | 20.0 | 18 | 12.3 | 16 | 4 | 55.4 | 0.22 | 34.50 | 183.07 | 1 | 183.07 | 1 | 34.43 | 1 |
| 166.184 | 1995 | 1 | clearcut | female | 21.5 | 25 | 4.8 | 15 | 3 | 40.3 | 0.12 | 62.98 | 45.79 | 2 | 44.58 | 2 | 10.11 | 1 |
| Median for males regardless of treatment | | | | | 17.5 | 20 | 23.2 | 14 | 4 | 116.2 | 0.20 | 8.19 | 278.02 | 2 | 278.02 | 2 | 18.77 | 1 |
| Median for females regardless of treatment | | | | | 20.0 | 21 | 4.3 | 17 | 3 | 32.2 | 0.12 | 60.99 | 185.41 | 2 | 119.63 | 2 | 7.20 | 1 |

Note: NA indicates the value could not be determined

Table 20. Percent of day refuge positions and locations situated within, outside and at the boundary of harvest treatment areas where deer mice (*Peromyscus maniculatus*; 18 females, 7 males) were radio-collared during the two post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site.

| | SEXES COMBINED (DAY REFUGES) | | | SEXES COMBINED (LOCATIONS) | | |
|---|---|---|---|---|---|---|
| Treatments where *P. maniculatus* Were Radio-Collared: | Control | Shelterwood | Clearcut | Control | Shelterwood | Clearcut |
| On treated area associated with the grid where mice were radio-collared (%) | 91.89 | 69.23 | 77.78 | 95.74 | 70.18 | 85.86 |
| Outside of areas like the treated part of the grid where mice were radio-collared (%) | 2.70 | 23.08 | 22.22 | 1.60 | 28.95 | 14.14 |
| In boundary areas (%) | 5.41 | 7.69 | 0.00 | 2.66 | 0.88 | 0.00 |
| Total number of day refuges or locations | 37 | 26 | 27 | 188 | 114 | 99 |
| Total number of mice radio-collared | 11 | 8 | 6 | 11 | 8 | 6 |
| | FEMALES (DAY REFUGES) | | | FEMALES (LOCATIONS) | | |
| Treatments where *P. maniculatus* Were Radio-Collared: | Control | Shelterwood | Clearcut | Control | Shelterwood | Clearcut |
| On treated area associated with the grid where mice were radio-collared (%) | 85.71 | 57.14 | 77.78 | 93.65 | 61.64 | 85.86 |
| Outside of areas like the treated part of the grid where mice were radio-collared (%) | 4.76 | 28.57 | 22.22 | 2.38 | 36.99 | 14.14 |
| In boundary areas (%) | 9.52 | 14.29 | 0.00 | 3.97 | 1.37 | 0.00 |
| Total number of day refuges or locations | 21 | 14 | 27 | 126 | 73 | 99 |
| Total number of mice radio-collared | 7 | 5 | 6 | 7 | 5 | 6 |
| | MALES (DAY REFUGES) | | | MALES (LOCATIONS) | | |
| Treatments where *P. maniculatus* Were Radio-Collared: | Control | Shelterwood | Clearcut | Control | Shelterwood | Clearcut |
| On treated area associated with the grid where mice were radio-collared (%) | 100.00 | 83.33 | NA | 100.00 | 85.37 | NA |
| Outside of areas like the treated part of the grid where mice were radio-collared (%) | 0.00 | 16.67 | NA | 0.00 | 14.63 | NA |
| In boundary areas (%) | 0.00 | 0.00 | NA | 0.00 | 0.00 | NA |
| Total number of day refuges or locations | 16 | 12 | NA | 62 | 41 | NA |
| Total number of mice radio-collared | 4 | 3 | NA | 4 | 3 | NA |

Note: NA indicates no male deer mice were radio-collared on Clearcut treatment areas

Table 21. Location and characteristics of day refuges used by radio-collared deer mice (*Peromyscus maniculatus*) on clearcut, shelterwood and uncut control treatment areas during the two post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site.

| SEXES COMBINED (based on 25 radio-collared deer mice) | | | | | | |
|---|---|---|---|---|---|---|
| HABITAT FEATURES | Class | Control | Shelterwood | Clearcut | Total | Percent |
| Root-balls (decay class 3-5) | ground | 8 | 5 | 1 | 14 | 15.56 |
| Snags (decay class 3-5) | elevated | 10 | 1 | 1 | 12 | 13.33 |
| Ground | ground | 2 | 2 | 7 | 11 | 12.22 |
| Logs (decay class 3-5) | ground | 3 | 5 | 3 | 11 | 12.22 |
| Slashpile (under or inside) | ground | 4 | 2 | 2 | 8 | 8.89 |
| Trees/Snags (decay class 1-2) | elevated | 6 | 0 | 0 | 6 | 6.67 |
| Stumps (decay class 1-2) | ground | 0 | 1 | 5 | 6 | 6.67 |
| Stumps (decay class 3-5) | ground | 1 | 3 | 2 | 6 | 6.67 |
| Erratics | elevated | 0 | 4 | 1 | 5 | 5.56 |
| Logs (decay class 1-2) | ground | 0 | 1 | 2 | 3 | 3.33 |
| Base of Tree/Snags (decay class 1-2) | ground | 2 | 0 | 1 | 3 | 3.33 |
| Shrubs (under) | ground | 1 | 0 | 1 | 2 | 2.22 |
| Base of Tree/Snags (decay class 3-5) | ground | 0 | 1 | 0 | 1 | 1.11 |
| Rock (under) | ground | 0 | 0 | 1 | 1 | 1.11 |
| Trailer | elevated | 0 | 1 | 0 | 1 | 1.11 |
| Root-balls (decay class 1-2) | ground | 0 | 0 | 0 | 0 | 0.00 |
| Total Day Refuge Sites | | 37 | 26 | 27 | 90 | 100.00 |
| Day Refuge Location Ratio (elevated:ground) | | 1:1 | 1:3 | 1:12 | 1:3 | |
| Percent of Day Refuges in Treatment | | 41.11 | 28.89 | 30.00 | 100.00 | |

| FEMALES (based on 18 radio-collared female deer mice) | | | | | | |
|---|---|---|---|---|---|---|
| HABITAT FEATURES | Class | Control | Shelterwood | Clearcut | Total | Percent |
| Root-balls (decay class 3-5) | ground | 5 | 3 | 1 | 9 | 14.52 |
| Snags (decay class 3-5) | elevated | 2 | 1 | 1 | 4 | 6.45 |
| Ground | ground | 1 | 0 | 7 | 8 | 12.90 |
| Logs (decay class 3-5) | ground | 3 | 5 | 3 | 11 | 17.74 |
| Slashpile (under or inside) | ground | 4 | 0 | 2 | 6 | 9.68 |
| Trees/Snags (decay class 1-2) | elevated | 2 | 0 | 0 | 2 | 3.23 |
| Stumps (decay class 1-2) | ground | 0 | 0 | 5 | 5 | 8.06 |
| Stumps (decay class 3-5) | ground | 1 | 2 | 2 | 5 | 8.06 |
| Erratics | elevated | 0 | 1 | 1 | 2 | 3.23 |
| Logs (decay class 1-2) | ground | 0 | 1 | 2 | 3 | 4.84 |
| Base of Tree/Snags (decay class 1-2) | ground | 2 | 0 | 1 | 3 | 4.84 |
| Shrubs (under) | ground | 1 | 0 | 1 | 2 | 3.23 |
| Base of Tree/Snags (decay class 3-5) | ground | 0 | 0 | 0 | 0 | 0.00 |
| Rock (under) | ground | 0 | 0 | 1 | 1 | 1.61 |
| Trailer | elevated | 0 | 1 | 0 | 1 | 1.61 |
| Root-balls (decay class 1-2) | ground | 0 | 0 | 0 | 0 | 0.00 |
| Total Day Refuge Sites | | 21 | 14 | 27 | 62 | 100.00 |
| Day Refuge Location Ratio (elevated:ground) | | 1:6 | 1:4 | 1:13 | 1:6 | |
| Percent of Day Refuges in Treatment | | 33.87 | 22.58 | 43.55 | 100.00 | |

| MALES (based on 7 radio-collared male deer mice) | | | | | | |
|---|---|---|---|---|---|---|
| HABITAT FEATURES | Class | Control | Shelterwood | Clearcut | Total | Percent |
| Root-balls (decay class 3-5) | ground | 3 | 2 | NA | 5 | 17.86 |
| Snags (decay class 3-5) | elevated | 8 | 0 | NA | 8 | 28.57 |
| Ground | ground | 1 | 2 | NA | 3 | 10.71 |
| Logs (decay class 3-5) | ground | 0 | 0 | NA | 0 | 0.00 |
| Slashpile (under or inside) | ground | 0 | 2 | NA | 2 | 7.14 |
| Trees/Snags (decay class 1-2) | elevated | 4 | 0 | NA | 4 | 14.29 |
| Stumps (decay class 1-2) | ground | 0 | 1 | NA | 1 | 3.57 |
| Stumps (decay class 3-5) | ground | 0 | 1 | NA | 1 | 3.57 |
| Erratics | elevated | 0 | 3 | NA | 3 | 10.71 |
| Logs (decay class 1-2) | ground | 0 | 0 | NA | 0 | 0.00 |
| Base of Tree/Snags (decay class 1-2) | ground | 0 | 0 | NA | 0 | 0.00 |
| Shrubs (under) | ground | 0 | 0 | NA | 0 | 0.00 |
| Base of Tree/Snags (decay class 3-5) | ground | 0 | 1 | NA | 1 | 3.57 |
| Rock (under) | ground | 0 | 0 | NA | 0 | 0.00 |
| Trailer | elevated | 0 | 0 | NA | 0 | 0.00 |
| Root-balls (decay class 1-2) | ground | 0 | 0 | NA | 0 | 0.00 |
| Total Day Refuge Sites | | 16 | 12 | NA | 28 | 100.00 |
| Day Refuge Location Ratio (elevated:ground) | | 3:1 | 1:3 | NA | 1:1 | |
| Percent of Day Refuges in Treatment | | 57.14 | 42.86 | NA | 100.00 | |

Note: bold type indicates habitat features considered important to deer mice and NA indicates no male deer mice were radio-collared on Clearcut treatment areas

Table 22. Minimum and maximum values of movement characteristics determined by radio-telemetry of radio-collared male and female deer mice (*Peromyscus maniculatus*) on shelterwood and uncut control treatment areas during the two post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site. Comparisons between males and females were made by Mann-Whitney tests.

| SILVICULTURAL SYSTEM | CONTROL | | | SHELTERWOOD | | |
|---|---|---|---|---|---|---|
| | Females | Males | P-value | Females | Males | P-value |
| Day refuges/Duration (day refuge/day) | 0.06-0.26 n = 6 | 0.10-0.21 n = 4 | 0.165 | 0.10-0.20 n = 4 | 0.19-0.29 n =3 | 0.108 |
| Distance/Duration (m/day) | 0.0-8.7 n = 6 | 1.9-26.7 n = 4 | 0.201 | 0.1-4.8 n = 4 | 19.9-46.1 n =3 | 0.034 |
| Distance/Day refuges (m/day refuge) | 0.0-41.5 n = 6 | 19.0-126.7 n = 4 | 0.201 | 1.2-40.7 n = 4 | 106.2-166.7 n =3 | 0.034 |
| 90% minimum convex polygon ($m^2$) | 0.00-163.27 n =5 | 0.78-740.98 n = 4 | 0.806 | 0.00-26.26 n =3 | 0.00-11426.70 n =3 | 0.376 |

Table 23. Minimum and maximum values of movement characteristics determined by radio-telemetry of radio-collared male and female deer mice (*Peromyscus maniculatus*) on clearcut, shelterwood and uncut control treatment areas during the two post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research site. Comparisons among treatment areas were made by Kruskal-Wallis tests for females and Mann-Whitney tests for males.

| MOUSE MOVEMENTS | FEMALES | | | | | MALES | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sample Size | Controls | Shelterwoods | Clearcuts | P-values | Sample Size | Controls | Shelterwoods | P-values |
| Day Refuges/Duration (day refuge/day) | 16 | 0.06-0.26 n = 6 | 0.10-0.20 n = 4 | 0.10-0.32 n = 6 | 0.064 | 7 | 0.10-0.21 n = 4 | 0.19-0.29 n = 3 | 0.593 |
| Distance/Duration (m/day) | 16 | 0.0-8.7 (a) n = 6 | 0.1-4.8 (a) n = 4 | 3.8-27.7 (b) n = 6 | 0.015* | 7 | 1.9-26.7 n = 4 | 19.9-46.1 n = 3 | 0.517 |
| Distance/ Day Refuges (m/day refuge) | 16 | 0.0-41.5 n = 6 | 1.2-40.7 n = 4 | 16.9-124.5 n = 6 | 0.076 | 7 | 19.0-126.7 n = 4 | 106.2-166.7 n = 3 | 0.157 |
| 90% Minimum Convex Polygon ($m^2$) | 14 | 0.00-163.27 n =5 | 0.00-26.26 n =3 | 0.00-6275.03 n = 6 | 0.198 | 7 | 0.78-740.98 n = 4 | 0.00-11426.70 n = 3 | 0.480 |
| 90% Harmonic Mean ($m^2$) | 12 | 6.38-505.44 n =5 | 35.70-113.76 n =2 | 45.79-3272.21 n =5 | 0.439 | 7 | 58.98-1434.73 n = 4 | 278.02-3864.34 n = 3 | 0.077 |
| 90% Harmonic Mean (# areas) | 12 | 1-2 n =5 | 2-2 n =2 | 1-3 n =5 | 0.502 | 7 | 1-2 n = 4 | 2-4 n = 3 | 0.115 |
| 80% Harmonic Mean ($m^2$) | 12 | 6.38-245.80 n =5 | 35.70-113.76 n =2 | 0.37-280.45 n =5 | 0.881 | 7 | 58.98-930.00 n = 4 | 278.02-2571.03 n = 3 | 0.077 |
| 80% Harmonic Mean (# areas) | 12 | 1-2 n =5 | 2-2 n =2 | 1-3 n =5 | 0.705 | 7 | 1-2 n = 4 | 2-3 n = 3 | 0.115 |
| 50% Harmonic Mean ($m^2$) | 12 | 0.50-12.51 n =5 | 2.61-8.03 n =2 | 0.37-89.03 n =5 | 0.291 | 7 | 15.09-66.99 n = 4 | 18.35-209.70 n = 3 | 0.480 |
| 50% Harmonic Mean (# areas) | 12 | 1-1 n =5 | 1-1 n =2 | 1-2 n =5 | 0.214 | 7 | 1-1 n = 4 | 1-2 n = 3 | 0.248 |

*Where $P < 0.05$ different letters indicate that treatment areas were significantly different

**FIGURE CAPTIONS**

Figure 1. Locations of the two harvest stands on the Black Sturgeon Forest Management Agreement licence area (49°10'N, 88°45'W), approximately 120km northeast of Thunder Bay, Ontario.

Figure 2. Gradient of timber harvest intensities associated with the harvest treatments applied in 1993 at the Black Sturgeon Boreal Mixedwood Research Site.

Figure 3. Locations of the 7 harvest treatments applied to the 21 10 ha treatment areas in 2 stands at the Black Sturgeon Boreal Mixedwood Research Site in 1993. The locations and numbers assigned to live-trapping grids used to monitor small mammals during the pre-harvest (1993) and 2 post-harvest years (1994 and 1995) are also shown.

Figure 4. Location of live-trapping grids and pitfall traps relative to uncut forest and treatment areas during the 3 years (1993-1995) of small mammal monitoring at the Black Sturgeon Boreal Mixedwood Research Site.

Figure 5. Treatment areas where pitfall trapping was conducted and the live-trapping grids used to monitor small mammals during the pre-harvest year (1993) and the 2 post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research Site.

Figure 6. Locations of small mammal live-trapping grids used to compare effects of clearcut and shelterwood harvest methods during the pre-harvest year and the 2 post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research Site.

Figure 7. Locations of live-traps used to compare small mammal use of uncut forest buffers and harvested areas during the pre-harvest year and the 2 post-harvest years (1994 and 1995) at the Black Sturgeon Boreal Mixedwood Research Site.

Figure 1

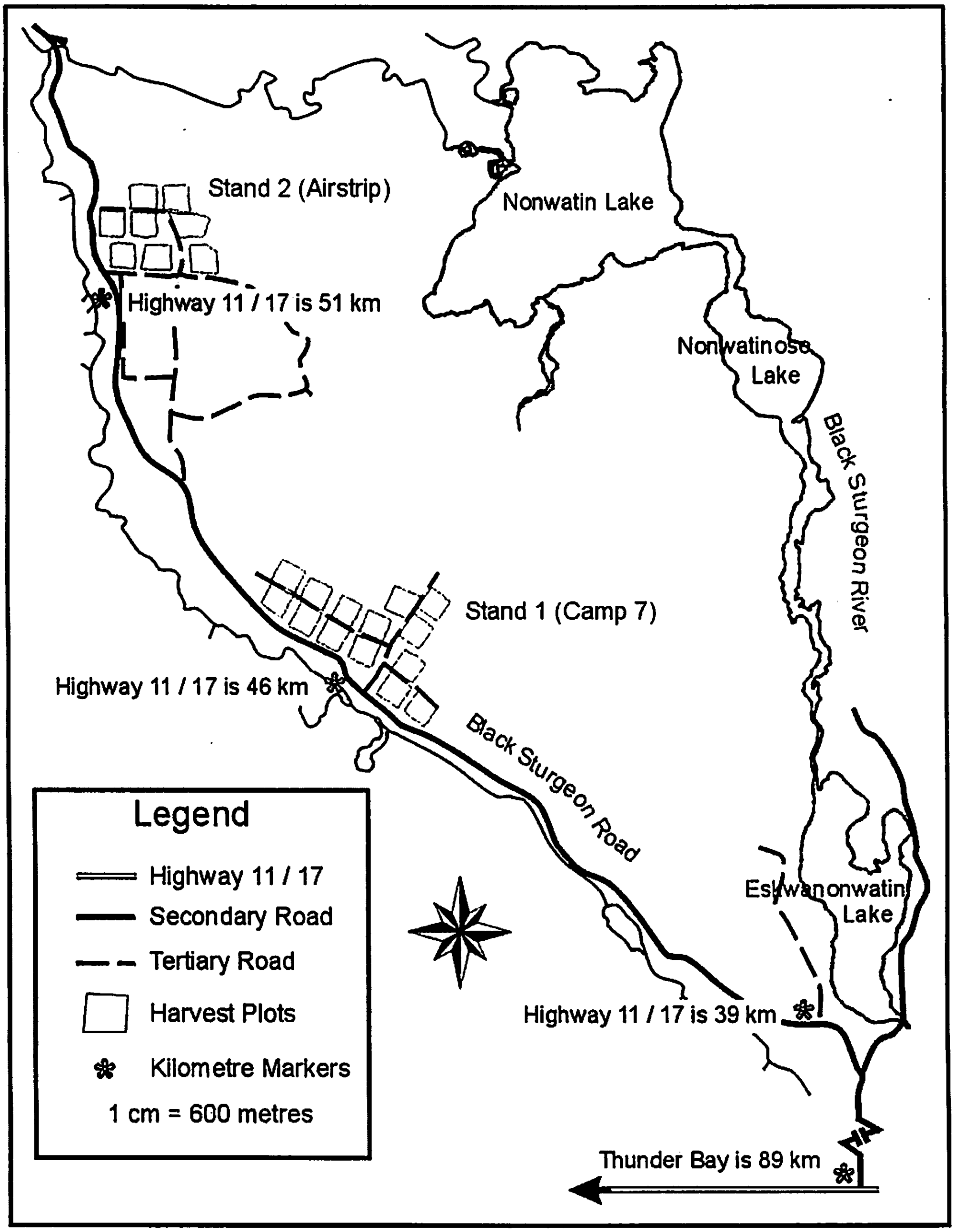

Stand 2 (Airstrip)
Nonwatin Lake
Highway 11 / 17 is 51 km
Nonwatinose Lake
Black Sturgeon River
Stand 1 (Camp 7)
Highway 11 / 17 is 46 km
Black Sturgeon Road
Legend
Highway 11 / 17
Secondary Road
Tertiary Road
Harvest Plots
Kilometre Markers
1 cm = 600 metres
Eskwanonwatin Lake
Highway 11 / 17 is 39 km
Thunder Bay is 89 km

Figure 2

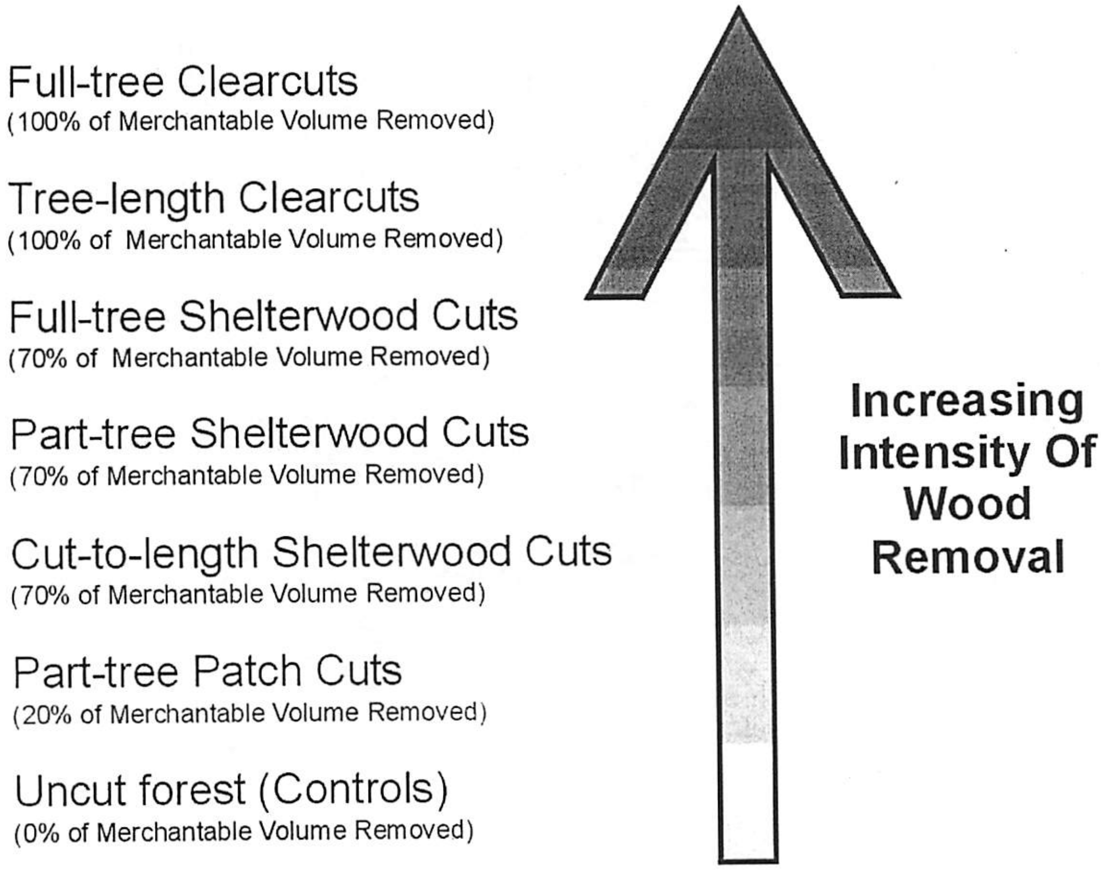

Full-tree Clearcuts
(100% of Merchantable Volume Removed)
Tree-length Clearcuts
(100% of Merchantable Volume Removed)
Full-tree Shelterwood Cuts
(70% of Merchantable Volume Removed)
Part-tree Shelterwood Cuts
(70% of Merchantable Volume Removed)
Cut-to-length Shelterwood Cuts
(70% of Merchantable Volume Removed)
Part-tree Patch Cuts
(20% of Merchantable Volume Removed)
Uncut forest (Controls)
(0% of Merchantable Volume Removed)
Increasing Intensity Of Wood Removal

Figure 3

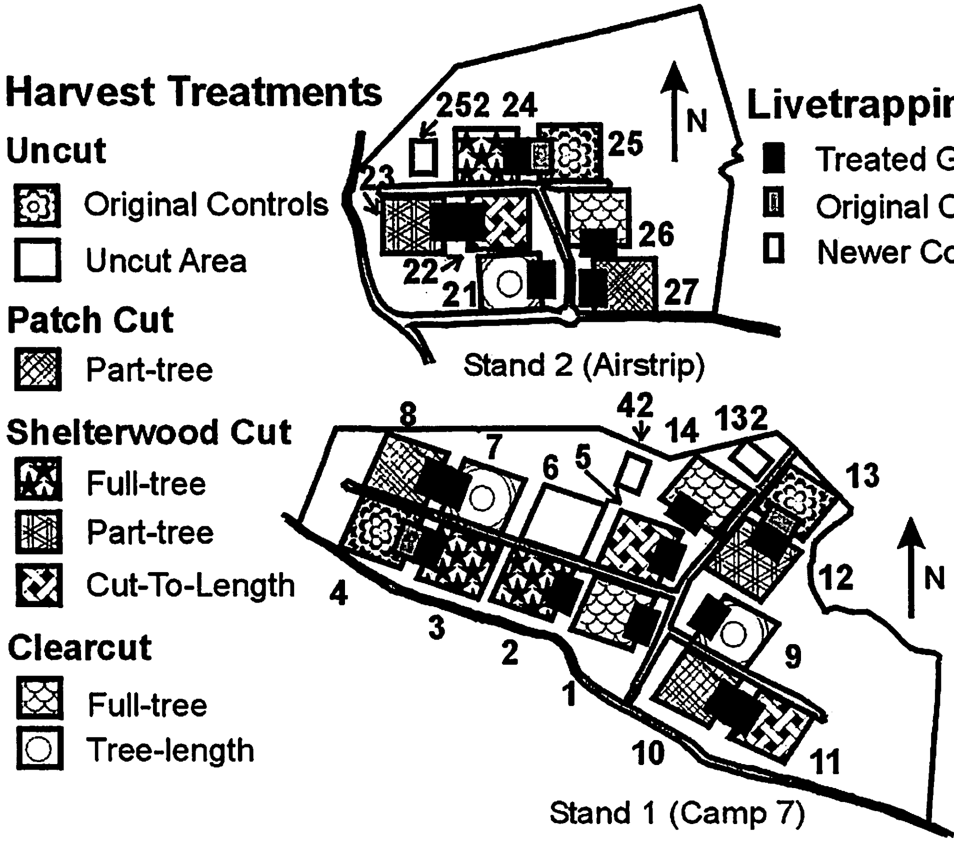
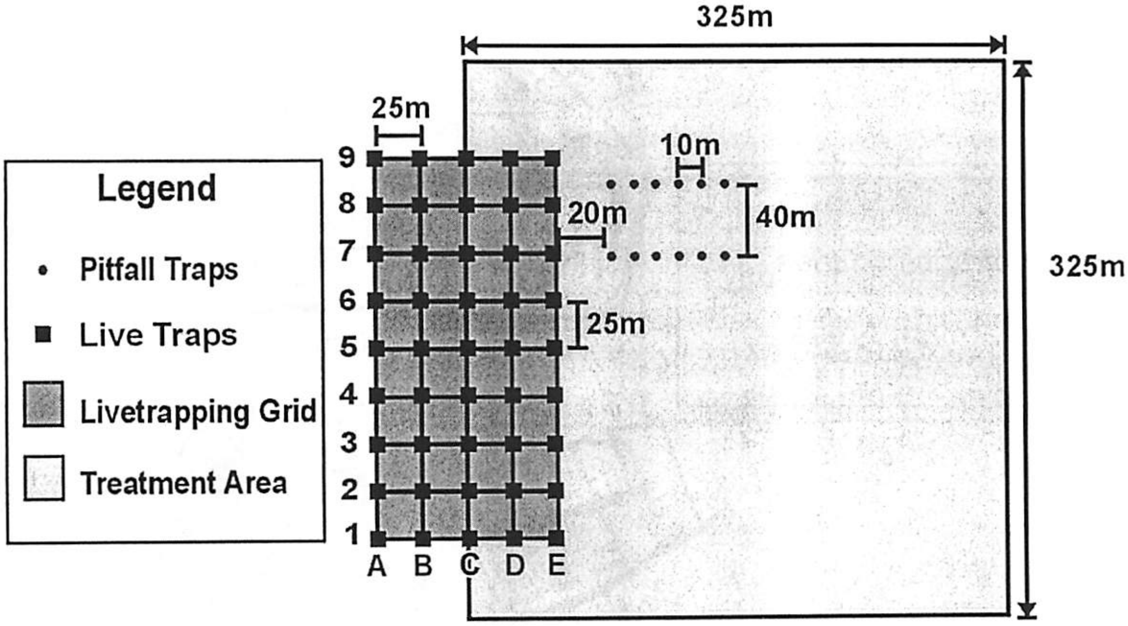

Harvest Treatments
Uncut
Original Controls
Uncut Area
Patch Cut
Part-tree
Shelterwood Cut
Full-tree
Part-tree
Cut-To-Length
Clearcut
Full-tree
Tree-length
Livetrapping Grids
Treated Grids
Original Controls
Newer Controls
N
252 24
23
25
26
22
21
27
Stand 2 (Airstrip)
8
7
6
5
42
14
132
13
4
3
2
1
12
N
9
10
11
Stand 1 (Camp 7)

Figure 4.



325m
325m
25m
10m
20m
40m
25m
Legend
Pitfall Traps
Live Traps
Livetrapping Grid
Treatment Area
9
8
7
6
5
4
3
2
1
A B C D E

Figure 5.

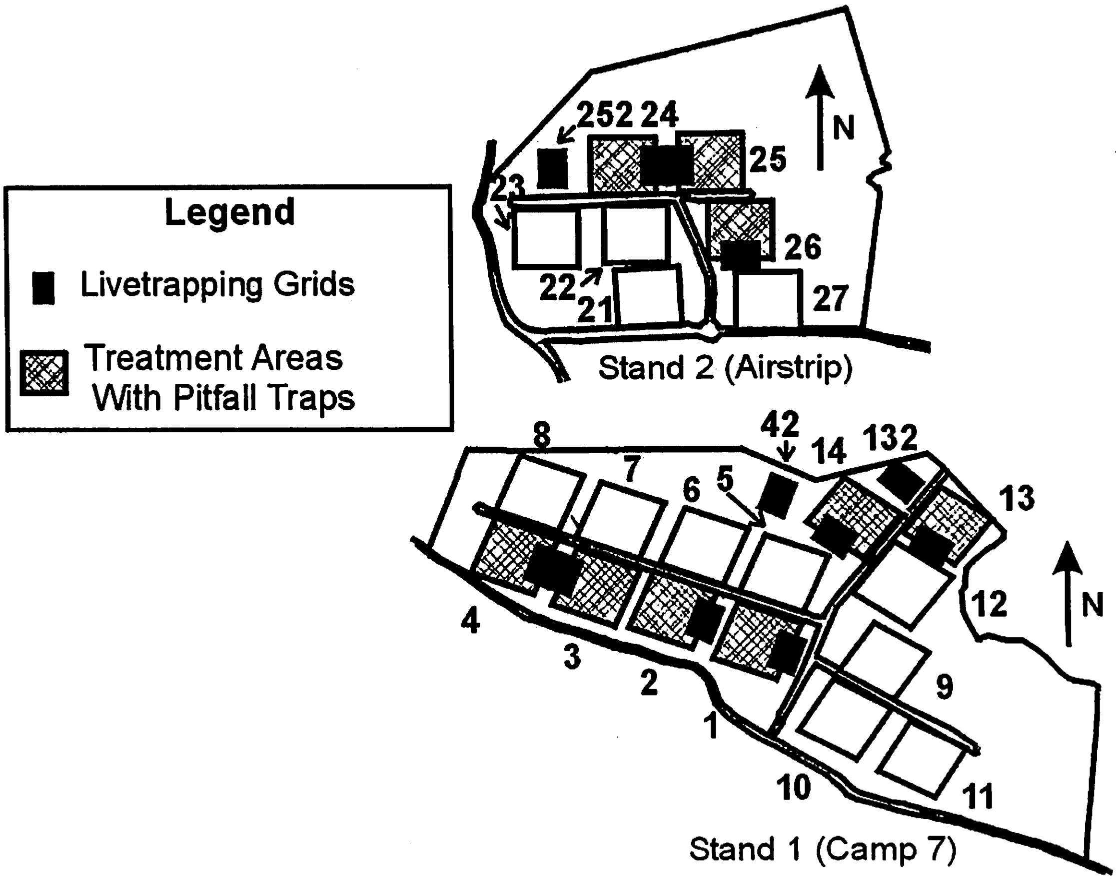

Legend
Livetrapping Grids
Treatment Areas
With Pitfall Traps
252
24
25
23
26
22
21
27
N
Stand 2 (Airstrip)
8
7
6
5
42
14
132
13
12
N
4
3
2
1
9
10
11
Stand 1 (Camp 7)

Figure 6.

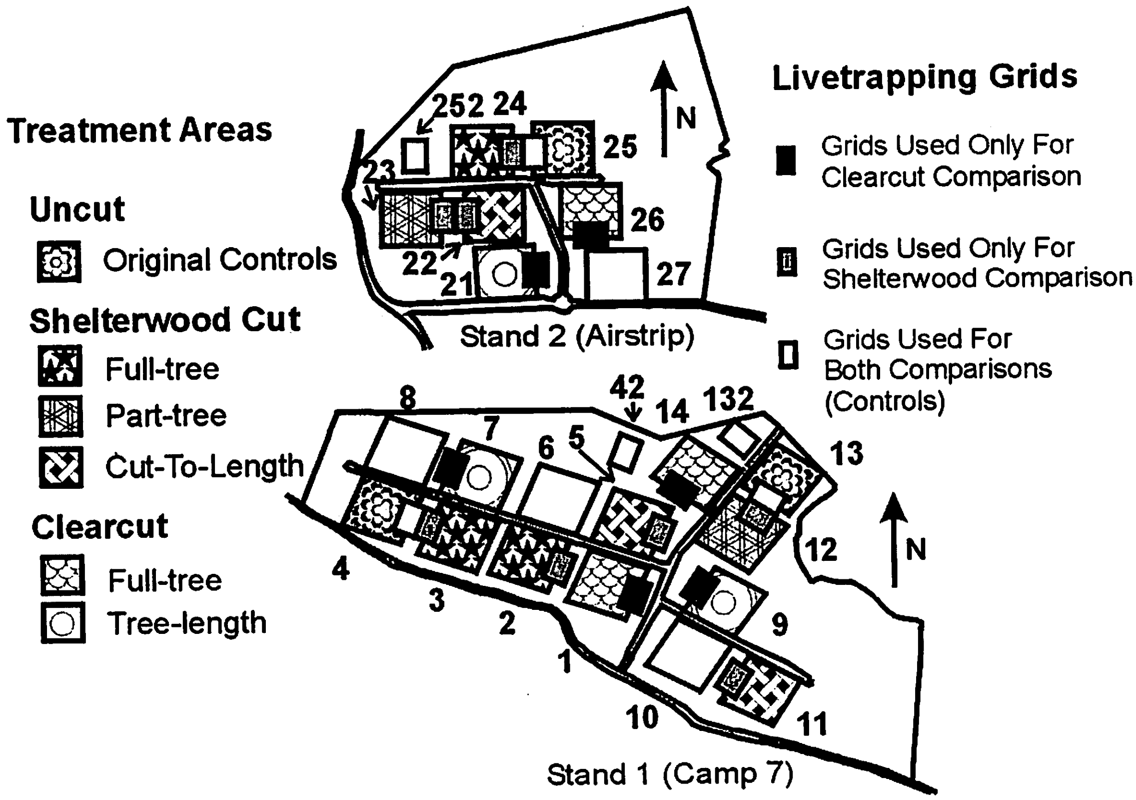
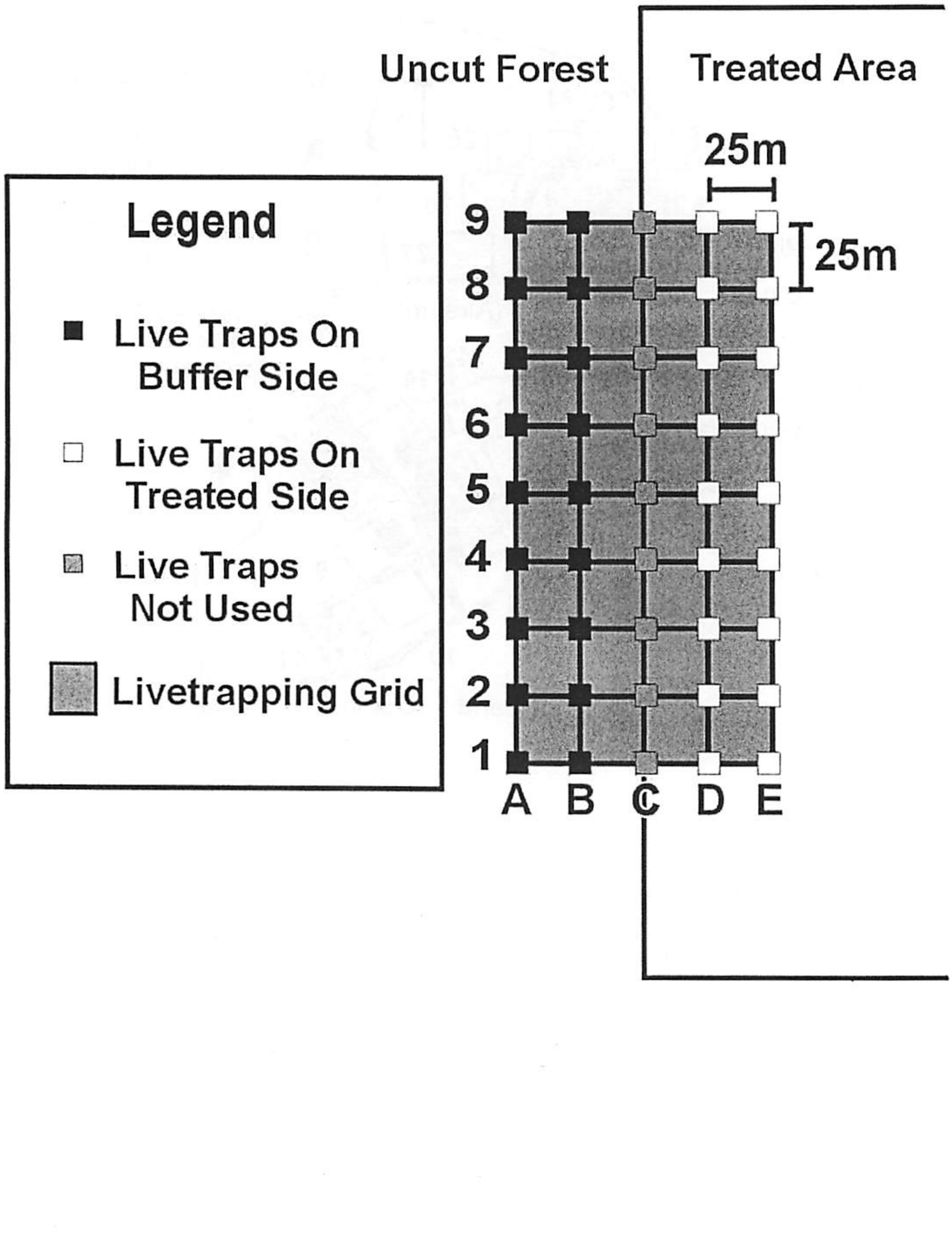

Treatment Areas
Uncut
Original Controls
Shelterwood Cut
Full-tree
Part-tree
Cut-To-Length
Clearcut
Full-tree
Tree-length
Livetrapping Grids
Grids Used Only For Clearcut Comparison
Grids Used Only For Shelterwood Comparison
Grids Used For Both Comparisons (Controls)
Stand 2 (Airstrip)
Stand 1 (Camp 7)
N
252 24
25
23
26
22
21
27
8
7
6
5
42
14
132
13
12
4
3
2
1
9
10
11
N

Figure 7.


Uncut Forest
Treated Area
25m
25m
Legend
Live Traps On Buffer Side
Live Traps On Treated Side
Live Traps Not Used
Livetrapping Grid
9
8
7
6
5
4
3
2
1
A B C D E