University of Alberta

USE OF RIPARIAN FOREST BUFFER STRIPS AROUND LAKES BY MAMMALS IN NORTH-CENTRAL ALBERTA

by

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of

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in

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled *Use of Riparian Forest Buffer Strips Around Lakes by Mammals in North-Central Alberta* submitted by *Jordan L. DeGroot* in partial fulfillment of the requirements for the degree of *Master of Science* in *Environmental Biology and Ecology.*

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Abstract

I investigated the effects of different widths of riparian forest buffer strips around lakes (20, 100, and 200 m) on habitat use and movement of mammals in the mixed-wood boreal forest of north-central Alberta. This research was conducted as part of the Terrestrial, Riparian, Organisms, Lakes, and Streams (T.R.O.L.S) Project between 1995-99. A total of 10,300 small mammals were live-trapped in 39,200 trap-nights. Small mammal abundance did not significantly differ between riparian and upland forest areas. Riparian forest buffer strip width did not significantly affect use by small mammals of forested areas adjacent to lakes. Snow-track count surveys, representing 14,691 tracks, indicated winter use by mammals (small mammals, red-squirrels, hares, weasel, mink, coyote, deer, and moose) of forest was similar at different distances from lakes. Different width buffer strips did not affect winter use by mammals of the riparian forest. This study indicates that different width riparian forest buffer strips do not significantly affect habitat use or travel of mammals in forested areas adjacent to lakes.

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CHAPTER I: GENERAL INTRODUCTION

Riparian forests have traditionally been perceived as important habitat for wildlife (Rosenberg *et al.* 1997). High structural diversity of vegetation and productivity of the land-water interface may provide life requisites such as food and cover for terrestrial vertebrates (Naiman and Decamps 1997). To protect habitats at the land-water interface, riparian forest buffer strips have been adopted as management prescriptions in forestry across North America.

Pressure to allocate forested land to linear strips of vegetation adjacent to open water has come mostly from concerns about aquatic habitat protection (e.g., Barton *et al.* 1985). Recently, the relative habitat use of riparian and upland forest by wildlife has received more attention in forest management. Some studies suggest riparian habitat supports greater numbers of small mammal and passerine bird species in elevated abundance (Stauffer and Best 1980, Doyle 1990). Other investigations of passerine birds (La Rue 1995, McGarigal and McComb 1992, Murray and Stauffer 1995) indicate few differences exist in species richness or abundance between riparian and upland forests.

If the riparian forest plays an important role as habitat or movement corridors, then protection of these areas may be justified. If the riparian forest is not unique habitat, riparian forest buffer strips may still play a role as habitat (Boutin 1997).

Simberloff *et al.* (1992) challenge the use of linear forest remnants in wildlife conservation, however, suggesting small areas of forest have limited value. Emerging from this controversy are two questions: (1) Do linear forest remnants, such as riparian forest buffer strips, effectively serve as wildlife habitat? And (2) How wide do riparian forest buffer strips need to be to maintain this function?

These questions have recently become important in northern Alberta, where a large area of forested land (270,000 km^2) has been allocated to forestry, and forest harvesting plans (for pulp and paper production) currently dictate 100 m wide riparian forest buffer strips be left adjacent to lakes (Alberta Environmental Protection 1998). To address these questions, the TROLS (Terrestrial, Riparian, Organisms, Lakes and Streams) experiment was implemented in north-central Alberta. TROLS examined the effects on various components of terrestrial and aquatic ecosystems caused by riparian forest buffer strips of different widths (20, 100, and 200 m).

In Chapter 2, I evaluate the relative importance of riparian and upland forest areas as productive wildlife habitat. If riparian forest is unique, I predicted that species richness and abundance would differ between riparian and upland areas. The applied objective of this research was to provide advice regarding whether forest harvesting operations should be excluded from riparian forest.

In Chapter 3, I examine the effects on small mammal abundance of different width riparian forest buffer strips (20, 100, 200 m wide). I compared small mammal abundance between riparian buffers and forest reference areas around 12 lakes. The objective of this work was to determine whether riparian forest buffer strips of different width affect small mammal abundance adjacent to lakes.

In Chapter 4, I investigate winter use of different width riparian forest buffer strips as habitat and movement corridors by small mammals, carnivores, and ungulates. I used snow-track count surveys to assess use of areas at different distances from lakes (0, 10, 50, 130 and 230 m), and to evaluate whether buffer strips affect this use. Behavioral investigations were also conducted by snow-tracking short-tailed weasels (*Mustela erminea*) and deer (*Odocoileous spp.).* The objective of this winter research was to evaluate use of different width buffer strips as habitat and movement corridors.

The Terrestrial, Riparian, Organisms, Lakes, and Streams (TROLS) research project was developed with the intention of providing reliable management recommendations to guide forestry operations adjacent to lakes in the mixed-wood boreal. The TROLS project was created by a group of university professors in conjunction with industry. Thinking about and planning of this research was an iterative process occurring through many workshops, conferences, and seminars held at the University of Alberta. Many variables were considered in evaluating the effects of different width buffer strips including mammals, birds, fish, amphibians, vegetation and hydrology. The objective of my thesis is to provide managers with scientific advice on the use by mammals of the riparian forest, and the effects of forest harvesting adjacent to lakes on this use.

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CHAPTER II: USE OF RIPARIAN AND UPLAND FOREST AREAS BY SMALL MAMMALS

INTRODUCTION

Riparian areas are often perceived as being highly productive habitats with high species diversity (Naiman *et al.* 1993). Greater productivity in riparian areas has been hypothesized to result in elevated food and cover for terrestrial vertebrates. Most of the studies of wildlife in riparian areas have been conducted in desert systems (Ellison and Van Riper 1998; Andersen 1994) and mountainous areas (Doyle 1993; McGarigal and McComb 1992, Gates and Giffin 1991). The relative value of riparian forest as wildlife habitat in the mixed wood boreal forest of north-central Alberta is unknown.

Small mammals play important roles in ecosystems as herbivores (Sullivan 1979), prey (Boutin *et al.* 1995), and dispersers of seeds and spores (Maser *et al.* 1978). Small mammal abundance is positively correlated to seed productivity at local and regional scales in desert systems (Brown 1973), and small mammal abundance may also be related to primary productivity in northern boreal forest (Krebs *et al.* 2001). I used small mammal abundance as a surrogate measure of productivity in riparian and upland forest areas (Bunnell *et al.* 1998).

The purpose of this study was to evaluate the value of riparian forest areas as productive wildlife habitat relative to upland areas. If the lakeside forest edge represents highly productive small mammal habitat, I predicted greater abundance, and higher reproductive rates of small mammals near lakes relative to upland areas. I compared abundance, numbers of breeding adults and numbers of juveniles at different distances from the lakeside forest edge (0, 50, 100, and 600-800m).

My objective in conducting this study was to provide advice to forest managers as to whether riparian forest represents unique small mammal habitat. If riparian forest areas do represent unique habitat, then different conservation initiatives may be required than in upland areas to ensure that small mammal populations are protected

METHODS

Study Area

This study was conducted in 1995 and 1996 in the boreal mixed-wood ecoregion of north central Alberta near 8 lakes which were grouped into two sites (each with 4 lakes) referred to as SCL (South of Calling Lake 55 07' 20" N 113 43' 30 W) and LLB (north of Lac La Biche at 55 8' 30" N 111 45' 45" W) (Figure 1).

The upland areas in the mixedwood boreal in Alberta are most often covered by forest dominated by aspen (*Populus tremuloides*), with lower densities of balsam poplar (*Populus balsamifera*) (Rowe 1972). Older stands are dominated by white spruce (*Picea glauca*), with lower densities of balsam fir (*Abies balsamea*) and paper birch (*Betula papyrifera*). Dominant understory shrubs include willow (*Salix spp.*), rose (*Rosa acicularis*) and beaked hazelnut (*Corylus cornuta*). We sampled in mature (i.e., 70-100 years old), aspen dominated stands as this forest stand type is the target of current harvesting operations.

Experimental Design

Live-trapping of small mammals occurred at each of the 4 lakes at both sites. Two trapping grids were established adjacent to each lake in aspen dominated forest stands (Figure 2). Each grid consisted of two, 300 m long trap-lines (A and U) oriented parallel to, and at different distances from, the lakeside forest edge. The A-line was located at the lakeside forest edge at the transition to non-forested riparian vegetation (between the high water mark and the lakeside forest edge). The U-line was situated in upland areas 600-800 m away from the lakeshore but in the same forest stand as the lines near the lake.

Trapping

Small mammals were live-trapped at all trap-lines at each grid (with some exceptions; see below) in the spring (May 1 –June 30) and autumn (late August to mid October) of 1995 and 1996. Henceforth, I refer to each of these four trapping sessions as “season-years”. Every season-year consisted of 3 consecutive nights of trapping. Thirty-one Longworth traps were placed at permanent trap stations separated by 10 m intervals along each 300 m long trap-line. Each Longworth trap was located within 3 m of a trap station and adjacent to the nearest source of cover, including fallen logs, shrubs, and grass. A handful of sunflower seeds and oats was placed at each trap station 4-5 days prior to each trapping session. On the first day of a trapping session, traps were baited with sunflower seeds and oats, and cotton stuffing was added as insulation. On each of the subsequent 3 days of a given trapping session, traps were generally checked and reset before 2:00 p.m. All trap-lines at both grids at each lake were checked at the same time. After completion of a three day trapping session, traps were moved to the next lake.

The following species were captured; red-backed voles (*Clethrionomys gapperi*), deer mice (*Peromyscus maniculatus*), meadow voles (*Microtus pennsylvanicus*), meadow jumping mice (Zapus *hudsonicus*), and shrews (*Sorex spp.*).

Upon capture of each previously unmarked mouse or vole in a trap, the species, reproductive condition (breeding or not), and weight of the animal was recorded. Due to difficulties in identifying shrews to species in the field, individuals of this genus (potentially 5 species) were identified as *Sorex* spp. Females were classified as breeding if they were lactating or if the vaginal opening was perforate. Males were classified as breeding by the presence of descended testes. Individuals weighing less than 15 grams in autumn and not breeding were designated as juveniles. The reproductive status of shrews and meadow jumping mice was not consistently recorded. Animals were marked by toe-clipping.

Analysis

To generate estimates of relative abundance for small mammals on each trap-line within each season-year the number of unique captures of each species was expressed as the number of captures per 100 trap-nights. To correct for the 3.8 % (375 of 9823) of traps in the study that remained empty because they were accidentally sprung (e.g., disturbed by black bears), a correction factor of one-half of a trap-night was subtracted for each disturbed trap in a session (Nelson and Clark 1973).

I conducted all analyses separately by species. In addition, because abundance of small mammals could be expected to vary considerably between seasons and years, I conducted all analyses for each species separately by trapping session in each season-year.

I was interested in examining three main response variables: abundance, number of breeding adults, and numbers of juveniles in relation to distance from the lakeside forest edge. To do this, I decided to compare abundance between lines situated at the riparian forest edge and in upland forest areas to ensure that the response variables were independent. Because I was not interested in differences between sites, lakes, or grids, I adopted a simple block ANOVA design, and I blocked by site-lake-grid (n=16 blocks) in all my analyses. Hence, for each combination of response variable, species, and trapping session, I tested for distance effects among trap-line distances (lakeside forest edge and 600-800 m) after blocking for site-lake-grid.

In most cases, all trap-lines were trapped at each grid and lake in each of four season-years. In these cases, total degrees of freedom (df) =31(16 blocks X 2 distances - 1); distance df = 1 (2 distances – 1); block df = 15 (16 [site-lake-grids] - 1); remainder (error) = 15).

ANOVA models included distance from lake (coded as A or U trap-lines) as a fixed factor, and study grid (1-16) as a random blocking variable and could be generally defined as:

$$A = \mu + \beta B + \chi C + \text{experimental error}$$

Where A = abundance of a species, μ = grand mean, B = distance, C = blocking term, and β, χ, respectively represent variation in B and C (As per ANOVA example in Table 1). Statistical tests were conducted using the SPSS statistical package and were considered significant at a level of $\alpha = 0.05$ (Zar 1984).

RESULTS

We captured 2231different animals in 9,823 trap-nights for a total trapping success of 22.7% over the entire study period. Red-backed voles (*C. gapperi*) and deer mice (*P. maniculatus*) were the most abundant small mammals in our study area, comprising 48.7 % (n=1086) and 33.8 % (n=754) of all captures, respectively. Meadow voles (*M. pennsylvanicus*) were the next most abundant species, comprising 10.8 % of all captures (n=240.9). Meadow jumping mice (*Zapus hudsonius*) and shrews (*Sorex spp.*) were captured in 2.7 % (n=60) and 3.9 % (n=87) of all capture events, respectively. Shrew species expected to be present in our study area include masked shrews (*S. cinereus*), pygmy shrews (*S. hoyi*), dusky shrews (*S. monticolis*), arctic shrews (*S. arcticus*), and water shrews (*S. palustris*). Most of these were likely masked shrews; it is the most frequently captured species accounting for up to 90% of captures in the study area (unpublished data). The remaining 1% of the captures was comprised of 12 short-tailed weasels (*Mustela erminea*), 14 least chipmunks (*Eutamius minimus*), 5 red squirrels (*Tamiascuirus hudsonicus*), and 3 northern flying squirrels (*Sabrinas glaucomys*).

Red-backed voles

Red-backed vole abundance, averaged across all trap-lines, increased between 7.5 fold (1995) and 6.9 fold (1996) between spring and autumn sessions, and between 1.2 fold (spring) -1.5 fold (autumn) between 1995 and 1996. Vole abundance was 1.1 fold greater at SCL than LLB.

Few differences in vole abundance were observed with distance from lake. Vole abundance did not significantly differ among lines at different distances from the lakeside forest edge in spring or autumn of either year (Table 2, Figure 3). Likewise, there were no significant differences in numbers of breeding (Figure 4) or juvenile (Figure 5) voles among lines at different distances from lakes.

Deer mice

In addition to temporal changes in abundance between seasons, large differences in deer mouse abundance were also observed among sites. Deer mouse abundance at LLB was 2.9 fold greater than at SCL, and increased 5.9 fold between spring and autumn sessions.

Few differences in mouse abundance were observed among lines at different distances from the lakeside forest edge in relation to this variation (Table 3). Abundance significantly differed among lines in autumn 1995 at SCL (Figure 6 a, $F_{3,21}$=3.099, p=0.049) and in spring 1996 at LLB (Figure 6 b, $F_{3,25}$=3.832, p=0.022) because abundance was lower on A-lines in those sessions. There were no significant differences in numbers of breeding mice among lines (Figure 7). Significant differences also did not exist in abundance of juvenile mice among lines (Figure 8).

Other Species

Abundance of other small mammal species also varied between spring and autumn seasons and between sites. Meadow voles and shrews were found in greater abundance in autumn sessions; whereas meadow jumping mouse abundance was elevated in spring. Meadow jumping mice captures were probably depressed in autumn because this species entered hibernation before the autumn trapping sessions. Abundance of meadow voles was elevated at LLB compared to SCL. Shrew abundance was greater at SCL than at LLB.

Meadow vole, jumping mice and shrew abundance was frequently observed to be greater on A-lines adjacent to wet, shrubby riparian zone areas. Meadow vole abundance significantly differed among lines in autumns 1995 and 1996 (Table 4, Figure 9), and abundance was greater on A-lines (Scheffe post-hoc test, $p<0.05$). Although we did not conduct statistical analyses for jumping mice or shrews because both species were rare, both species were often present on A-lines.

DISCUSSION

If riparian areas represent highly productive small mammal habitat I expected to observe elevated abundance closer to lakes. The abundance of red-backed voles and deer mice (comprising 85% of the small mammal community) was similar or lower at the lakeside forest edge. By contrast, abundance of meadow voles, meadow jumping mice, and shrews was greater in forest adjacent to wet, grass and shrub dominated riparian zone areas. Those habitat characteristics are also found in upland areas. Riparian forest areas do not support unique habitat for small mammal populations in the mixed-wood boreal forest.

If riparian forest areas are highly productive for all species, we expected abundance of all small mammal species would be elevated in those areas. Differences in abundance between riparian and upland areas were species dependent. We did not find any evidence to support the notion that riparian forest areas represent highly productive habitat for all species.

Red-backed voles

No significant differences in vole abundance were observed at different distances from lakes. Red-backed voles (*C. californicus*) existed in lower abundance adjacent to streams in mature Douglas-fir forest (Doyle 1990). Voles eat fungi on rotten or decayed logs, and Mills (1995) suggested that red-backed vole density (*C. californicus*) was lower adjacent to forest clear-cut edges due to lower densities of fungi in those areas. Riparian areas do not represent highly productive red-backed vole habitat in mixed-wood boreal forests.

Deer Mice

Deer mouse abundance was lower at the lakeside forest edge, and lower numbers of breeding adults and juvenile individuals were captured in those areas. Deer mice have been described as "opportunistic generalists" due to the wide variety of habitats and foods exploited by this species. If areas closer to lakes are highly productive, we expected that deer mice would cue into greater food availability in those areas (Doyle 1990, McComb *et al.* 1993). Instead, abundance of deer mice was often lower close to lakes. Riparian areas may function as population sinks for this species due to lower reproduction in those places (Andersen 1994).

Other Species

Meadow vole, jumping mice, and shrews were likely found on A-lines due to the presence of grass and shrub dominated habitat frequently found adjacent to lakes. Meadow voles use open grassy areas to build runways and may have been more abundant on A-lines due to presence of meadow habitat adjacent to lakes. Use of riparian zone areas by meadow jumping mice and shrews may have been elevated due to arthropod prey (Boonstra and Hoyle 1986) or moisture levels in those areas (Tester *et al.* 1993).

CONCLUSION

Riparian forest areas likely do not represent highly productive small mammal habitat relative to upland areas in the mixed-wood boreal forest. Abundance of forest dwelling species, such as red backed voles and deer mice, was similar at different distances from lakes. Abundance of meadow voles, meadow jumping mice, and shrews was greater adjacent to lakes in wet, grass and shrub dominated riparian zone areas. Although small mammal abundance was elevated in riparian zones, no significant differences were observed in small mammal abundance on interior forest transects further from lakes. Based on these results, we did not find any evidence to indicate that forestry activities should be excluded from the areas adjacent to lakes in boreal mixed-wood forest of north-central Alberta.

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Table 1: Example ANOVA Summary Table indicating degrees of freedom (DF), F-statistic (F), and p-value (p) outputs for ANOVA tests used to compare small mammal abundance on lines at different distances from the lakeside forest edge. Separate ANOVA analyses were conducted within each season-year. Total degrees of freedom (df) =31(16 blocks X 2 distances - 1); distance df = 1 (2 distances – 1); block df = 15 (16 [site-lake-grids] - 1); remainder (error) = 15)

Source of Variation	SS	DF	F	p
Total	308.89	31		
Distance	47.62	1	2.41	0.088
Site-lake- Grid	76.71	15	0.89	0.568
Error	184.56	15		

*Traps were not set adjacent to LLB 20 in autumn 1996 (A-lines flooded), or SCL 200 in spring 1995. Traps were not set on upland transects at SCL 20.

Table 2: ANOVA test results comparing mean red-backed vole abundance on lines adjacent to the lakeside forest edge (0 m) and in upland forest areas (600-800 m away from lakeside forest edge). Degrees of freedom described in Table 1.

	F	P
Abundance		
Spring 95	1.23	0.31
Autumn 95	0.16	0.70
Spring 96	5.31	0.04
Autumn 96	0.44	0.52
Breeders		
Spring 95	1.83	0.23
Autumn 95	0.59	0.46
Spring 96	3.35	0.09
Autumn 96	4.76	0.09
Juveniles		
Autumn 95	0.06	0.82
Autumn 96	1.49	0.25

Table 3: ANOVA test results comparing mean deer mouse abundance on lines adjacent to the lakeside forest edge (0 m) and in upland forest areas (600-800 m away from lakeside forest edge). Degrees of freedom as described in Table 1.

	F	P
Abundance		
Spring 95	0.01	0.93
Autumn 95	1.65	0.23
Spring 96	2.62	0.13
Autumn 96	4.12	0.07
Breeders		
Spring 95	0.20	0.67
Autumn 95	0.40	0.54
Spring 96	2.63	0.13
Autumn 96	5.03	0.05
Juveniles		
Autumn 95	0.13	0.72
Autumn 96	3.54	0.09

Table 4: ANOVA test results comparing mean meadow vole abundance on lines adjacent to the lakeside forest edge (0 m) and in upland forest areas (600-800 m away from lakeside forest edge). Degrees of freedom described in Table 1.

	F	P
Abundance		
Spring 95	0.06	0.82
Autumn 95	18.39	0.01
Spring 96	0.01	0.99
Autumn 96	6.75	0.02
Breeders		
Spring 95	0.342	0.58
Autumn 95	4.91	0.05
Spring 96	1.00	0.33
Autumn 96	3.55	0.09
Juveniles		
Autumn 95	5.02	0.04
Autumn 96	3.67	0.07

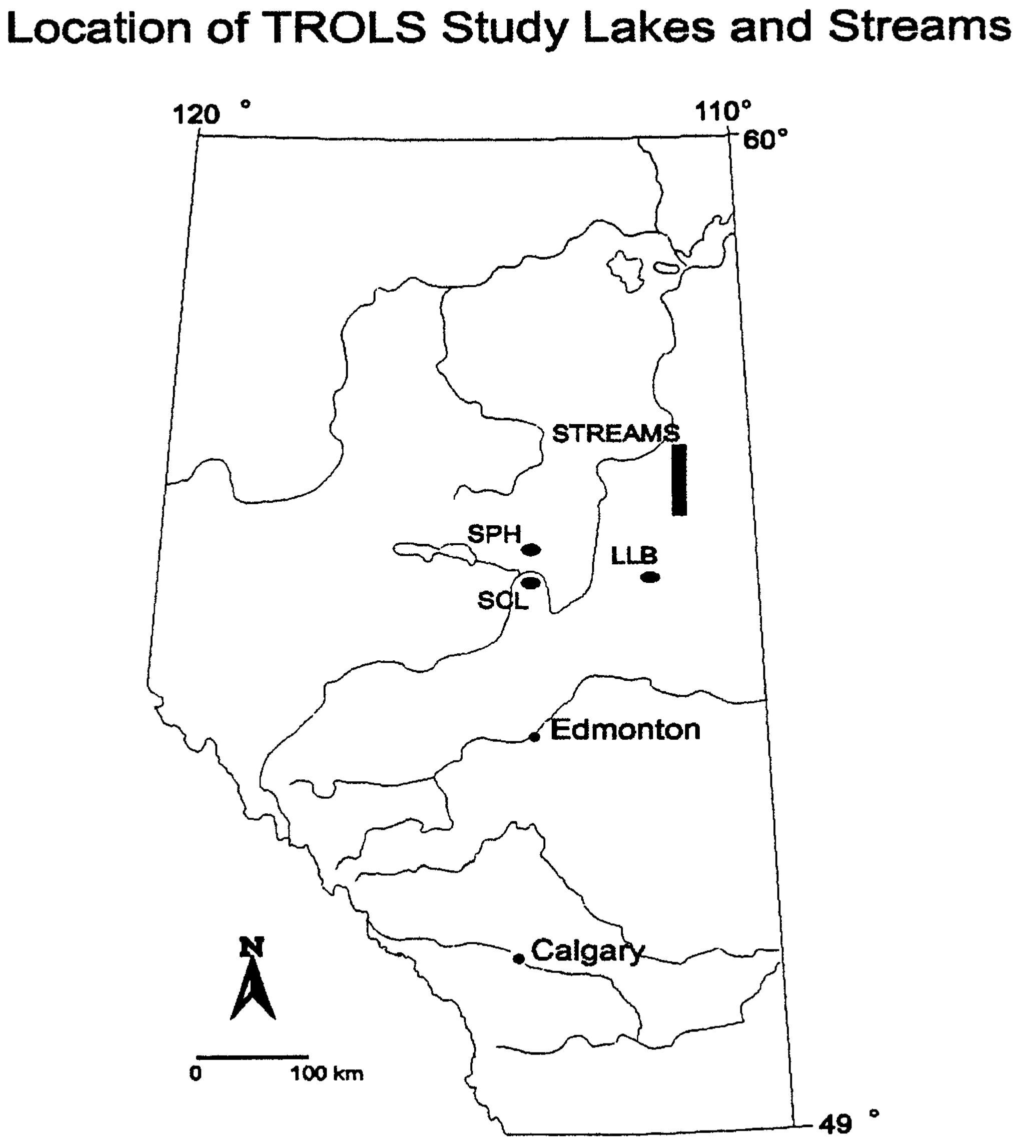

Figure 1: Map of Study Area showing the location of the three TROLS study sites in north-central Alberta. SPH=South Pelican Hills, LLB=Lac La Biche, SCL=South Calling Lake.

Figure 2: Pre-harvest sampling design of TROLS 1995-96. Lines represent trapping lines (A and U-lines at 0 and 600-800 m from a single study lake, respectively) on two grids.

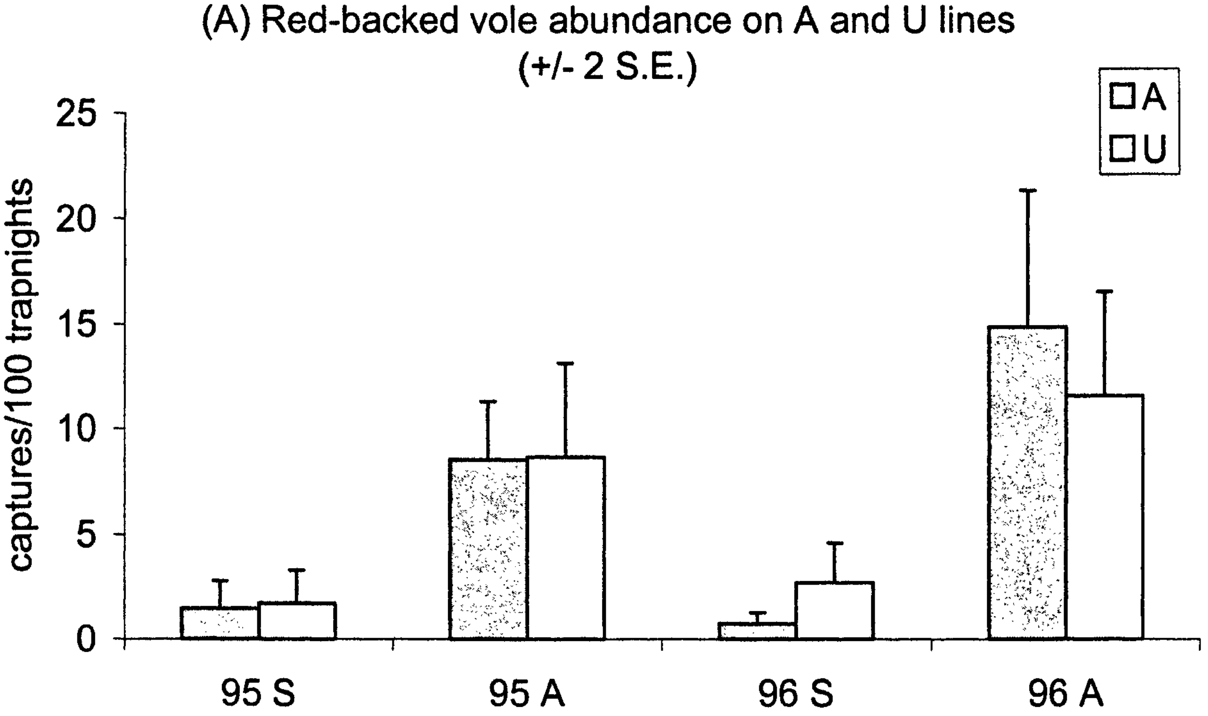

Figure 3: Mean red-backed vole abundance as captures/100 trap-nights on A and U-lines (O and 600-800 m distance from lakeside forest edge) in spring and autumn 1995-96 (+/- 2 S.E.; DF = 12-16 as described in Table 1).

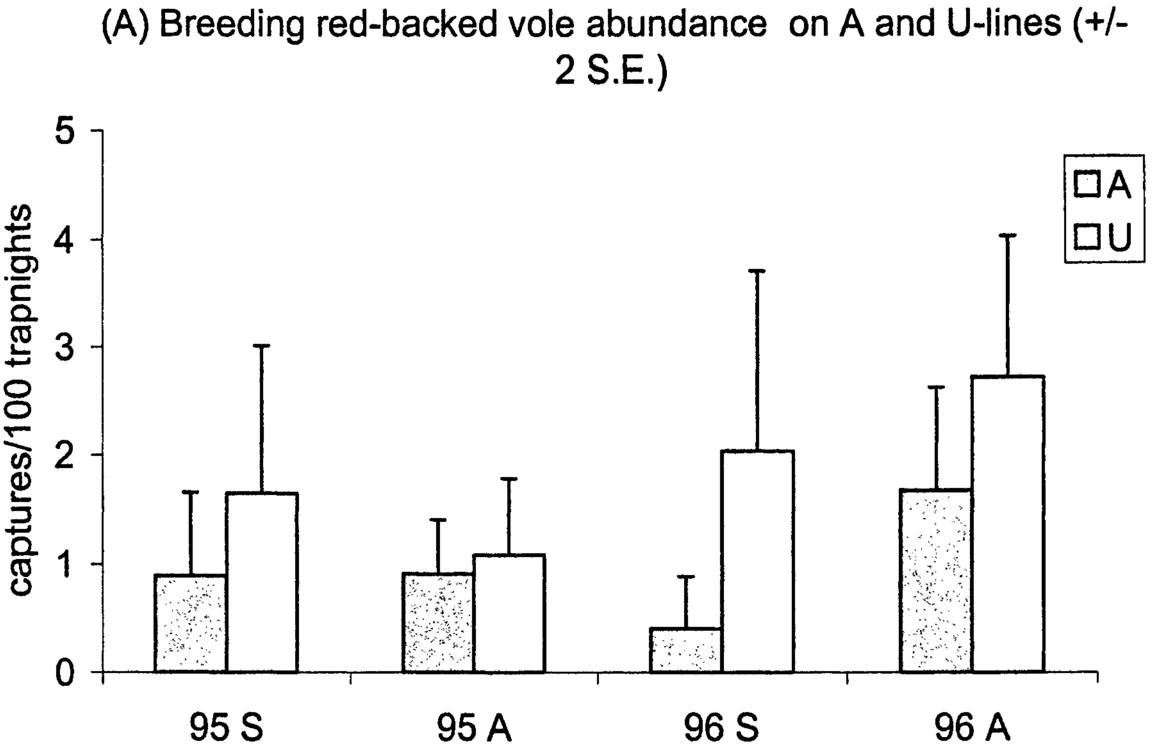

Figure 4: Mean breeding red-backed vole abundance as captures/100 trap-nights on A and U-lines in spring and autumn 1995-96 (+/- 2 S.E.; DF = 12-16 as described in Table 1).

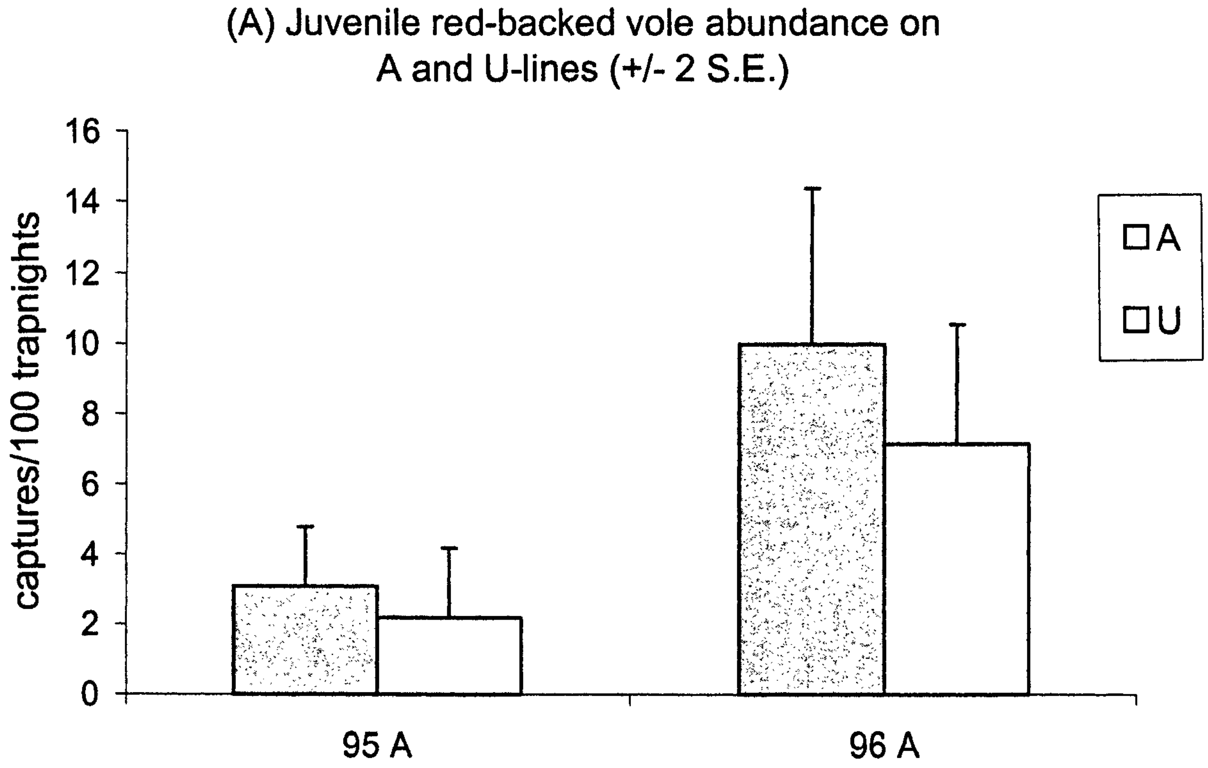

Figure 5: Mean juvenile red-backed vole abundance as captures/100 trap-nights on A and U-lines in autumn 1995-96 (+/- 2 S.E.; DF = 12-16 as described in Table 1)

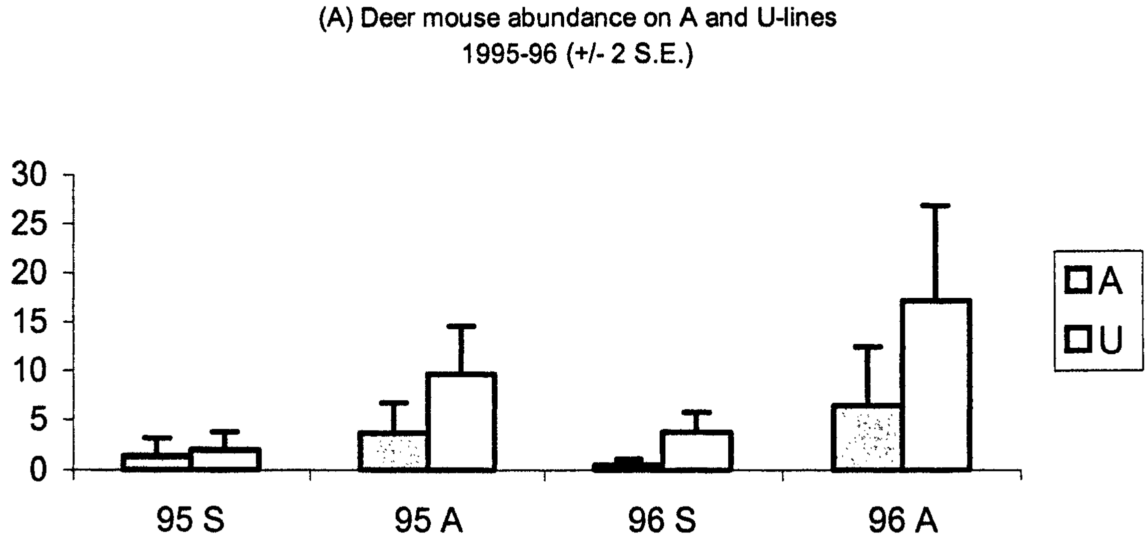

Figure 6: Mean deer mouse abundance as captures/100 trap-night on A and U-lines in spring and autumn 1995-96 (+/- 2 S.E.; DF = 12-16 as described in Table 1).

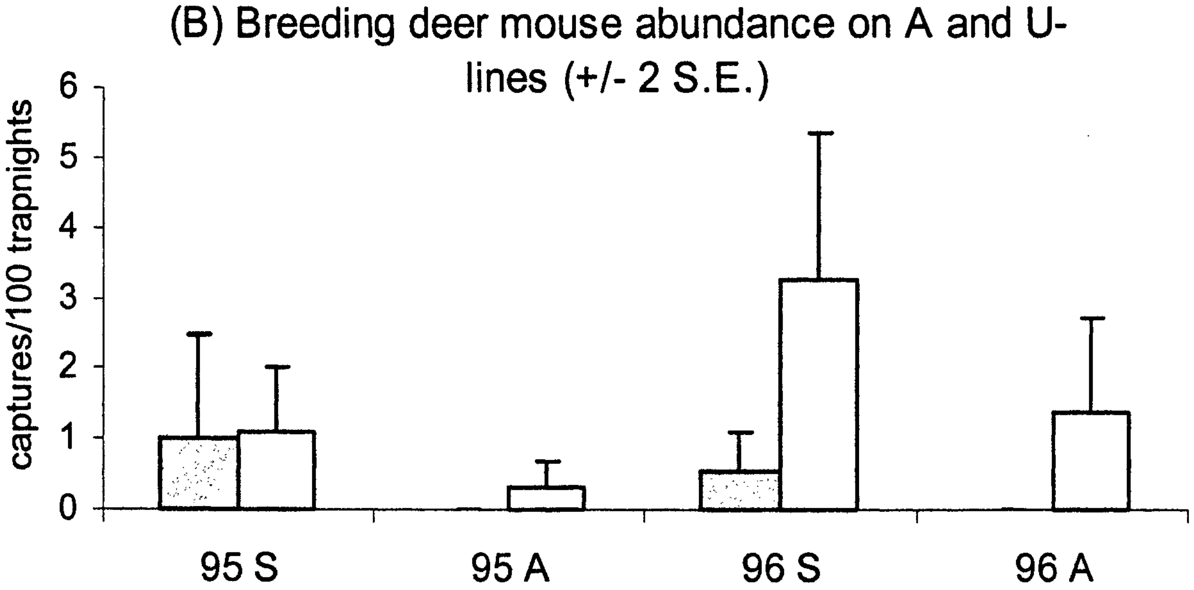

Figure 7: Mean breeding deer mouse abundance as captures/100 trap-nights on A nd U-lines in spring and autumn 1995-96 (+/- 2 S.E.; DF = 12-16 as described in Table 1).

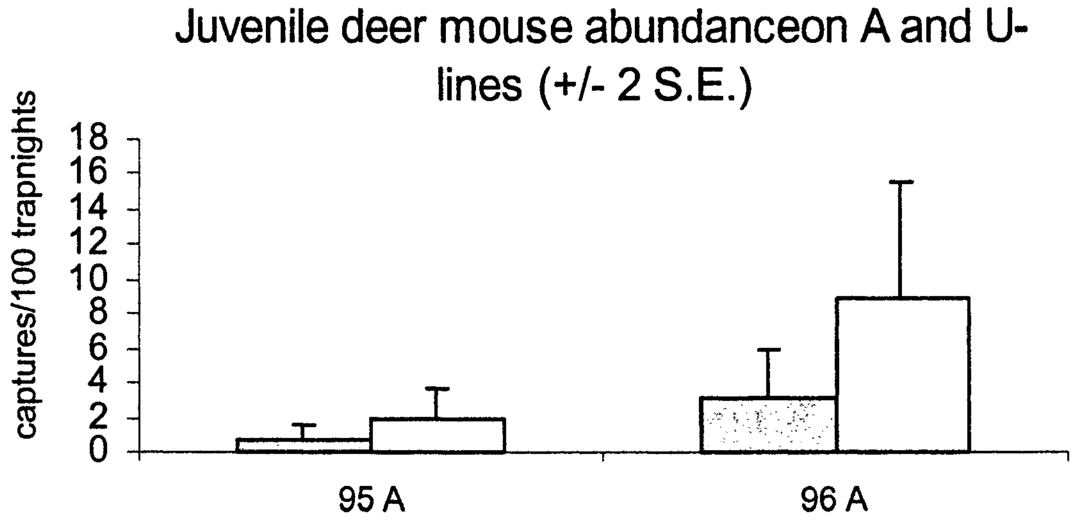

Figure 8: Mean juvenile deer mouse abundance as captures/100 trap-nights (+/- 2 S.E.) on A and U-lines in autumn 1995-96 (+/- 2 S.E.; DF = 12-16 as described in Table 1).

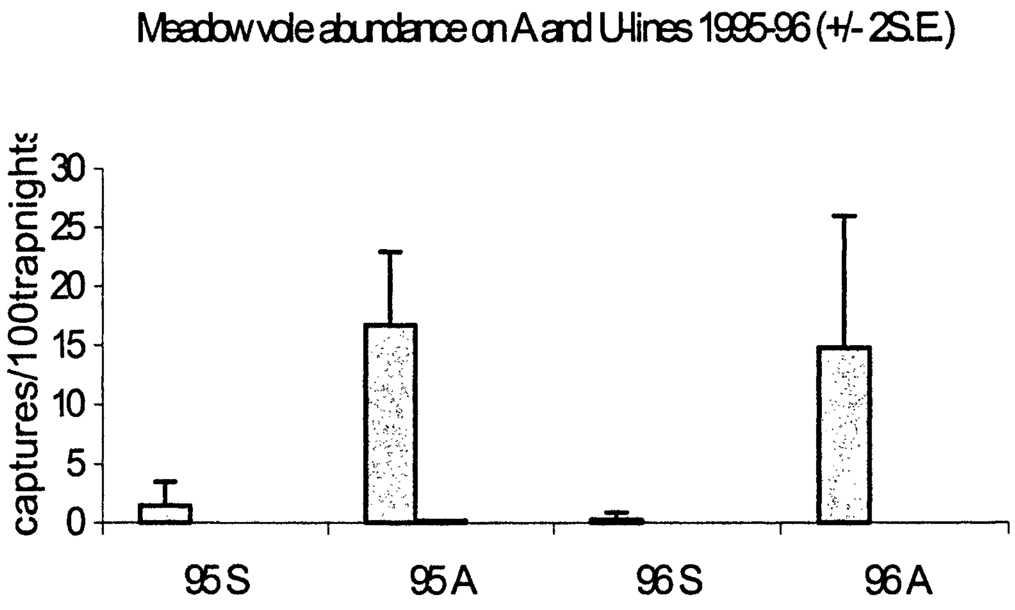

Figure 9: Mean meadow vole abundance as captures/100 trap-nights(+/- 2 S.E.) on A and U-lines in spring and autumn 1995-96 (+/- 2 S.E.; DF = 12-16 as described in Table 1).

CHAPTER III: USE OF RIPARIAN FOREST BUFFER STRIPS BY SMALL MAMMALS

INTRODUCTION

Riparian forests are often perceived as being important habitat for wildlife (Rosenberg *et al.* 1997). High structural diversity of vegetation and productivity of the land-water interface may provide life requisites such as food and cover for terrestrial vertebrates (Naiman 1997). To protect habitats at the land-water interface, riparian forest buffer strips have been adopted as management prescriptions in forestry across North America.

Pressure to allocate forested land to linear strips of vegetation adjacent to open water has come mostly from concerns about aquatic habitat protection (e.g., Barton *et al.* 1985). Recently, the relative use of riparian and upland forest by wildlife has received more attention in forest management. Some studies suggest riparian areas support greater numbers of small mammal and passerine bird species in elevated abundance (Stauffer and Best 1980, Doyle 1990). Other investigations of passerine birds (La Rue 1995, McGarigal and McComb 1992, Murray and Stauffer 1995) indicate few differences exist in species richness or abundance between riparian and upland forests.

Regardless of the role of these areas, riparian forest buffer strips may function as wildlife reserves after harvesting in the adjacent forest. If riparian forest plays an important role as habitat or movement corridors, protection of these areas may be justified. However, Simberloff *et al.* (1992) challenge the use of linear forest remnants in wildlife conservation, suggesting small areas of forest have limited value. Emerging from this controversy are two questions: (1) Do linear forest remnants, such as riparian forest buffer strips, effectively serve as wildlife habitat? (2) And how wide do riparian forest buffer strips need to be to maintain this function?

The importance of riparian buffer strips has recently become important in northern Alberta, where a large area of forested land (270,000 km^2) has been allocated to forestry. Forest harvesting regulations for pulp and paper production currently dictate 100 m wide riparian forest buffer strips (7% of the merchantable timber) be left adjacent to lakes. To address whether buffer strips are valuable habitat and how wide they should be, the TROLS (Terrestrial, Riparian, Organisms, Lakes and Streams) experiment was implemented in north-central Alberta. TROLS examined the effects on various components of terrestrial and aquatic ecosystems caused by riparian forest buffer strips of different widths (20, 100, and 200 m).

I studied small mammals in this experimental system. Small mammals play important roles in ecosystems as herbivores (Sullivan 1979), seed dispersers

(Maser *et al.* 1978, Johnson 1996), and prey (Henttonen *et al.* 1987, Hanski *et al.* 1991, Korpimaki and Nordhal 1991). Mills (1995) found density of red-backed voles (*Clethrionomys californicus*) was negatively related to the edge to area ratio of forest remnants, presumably due to lower suitability of edge habitat for this species. In contrast; the deer mouse is a habitat generalist known to exploit a variety of habitats, and their abundance typically increases in cut-blocks following forest harvesting (Kirkland 1990).

Because abundance alone can be a misleading indication of habitat quality (VanHorne 1983) I also evaluated the effects of buffer strips on numbers of breeding and juvenile individuals. Although many studies have compared small mammal species abundance in cut-blocks and forest control areas (for review Kirkland 1990), few large-scale studies have been conducted to evaluate the use buffer strips by small mammal species (e.g., Doyle 1990).

Given previous research, I hypothesized that red-backed vole abundance would decrease in riparian forest buffer strips; whereas deer mouse abundance would remain the same, or increase. I predicted red-backed vole abundance would be negatively affected by elevated edge to area ratios of narrow buffer strips, and that deer mouse abundance would increase due to favorable habitat conditions at forest-cutblock edges (due to increased food levels from fallen seeds and/or increased cover provided by fallen trees or slash). Furthermore, we expected the magnitude of the effects of forest harvesting adjacent to lakes would be negatively related to buffer strip width.

METHODS

Climate

The climate in the study area varied throughout the experiment. From 1995-97, winter temperatures ranged from –45 to 0 °C and snow covered the ground from mid-November to late March. In the winter of 1996-97 snow was unusually deep, whereas in the winter of 1997-98 snow did not permanently cover the ground until late December. Summer temperatures ranged from 10-30 °C, and the wettest month of the year was usually June. The summer of 1997 was the wettest due to an unusually large snow pack and above average amounts of precipitation.

Study Area

The TROLS study includes 4 lakes at each of 3 sites (Lac La Biche (LLB), South Calling Lake (SCL), and South Pelican Hills (SPH) [Figure 10a-b]). Four study grids were established around each lake and the grids consisted of 3 lines 300m long and running parallel to the lakeshore. The lines were placed at the lakeside forest edge, 50 and 100 m away from the lakeside forest edge lines. In winter

1996-1997 experimental buffers of 20, 100, 200 were cut on two of the four grids at each lake. The treatment applied to control lakes remained the same as in 1995 and 1996; no harvesting was conducted within 800 m of the lakeside forest edge. Each lake received a single buffer treatment and all treatments were applied at each site.

Experimental Design

The TROLS experiment is based on a blocked ANOVA design conducted within both pre- (1995-96) and post-harvest periods (1997-98) (Figure 10b). Single replicates of the 20, 100, 200, and 800m width treatment lakes were blocked within each of 3 sites. Paired comparisons of small mammal abundance indices (termed abundance, herein) were conducted between buffer strip and reference grids within spring or autumn trapping sessions at each lake.

Pre-Harvest- To monitor abundance prior to logging, live-trapping of small mammals occurred adjacent to 8 lakes in 1995-96 (SCL [4 lakes] and LLB [4 lakes]). Two grids were used at each lake. Each grid consisted of three trap-lines (A, C, and E) oriented parallel to, and at 0, 50, and 100 m from the lakeside forest edge. A-lines were thus located in relatively open areas, between the high water mark and the lakeside forest edge, as well as in closed canopy forest at the same grids.

Post-Harvest- In the winter of 1996-97, logging resulted in creation of either 20, 100, or 200 m wide buffer strips of trees, at least 450 m in length, in place of one grid at each of the corresponding 10 treatment lakes (SCL [4 lakes], LLB [4 lakes], SPH [20m and 100m treatment lakes]). We monitored abundance in 1997 on the same trap-lines we studied prior to harvest, located within either: (1) riparian forest buffer strips (buffer strip grids), or (2) forested reference areas (with cut-blocks located further than 800 m from the lake). In addition, abundance was also monitored adjacent to the 20 and 100 m treatment lakes at SPH. In 1998, an additional buffer strip and reference grid at each of the 20 and 100 m treatment lakes were also sampled.

A harvesting error occurred at the SCL 20 treatment grid in 1997. Therefore, we also monitored abundance in a different 20 m wide buffer strip (grid 3) and reference area (grid 4) at SCL20, until the spring of 1998 (when the grid 1 buffer strip was correctly harvested to a width of 20 m). In our evaluation of treatment effects we excluded grid 1 at SCL 20 in 1997 from statistical analysis.

Effects of Cut-blocks-To evaluate the influence of cut-blocks on small mammal abundance, we also trapped animals in cut-blocks and reference grid areas on lines located at similar distances from lakes. These lines were located 50m from the 20m treatment lakes in 1997-98, and 230 m from the 200m treatment lakes at SCL and LLB in 1997.

Trapping

Animals were live-trapped in the spring (May-June session) and autumn (late August-mid October session) from spring 1995 to spring 1998. All grids at 8 lakes were trapped over three consecutive nights in each session. On each line, trapping occurred over three consecutive nights. All traps were checked concurrently at each lake. After completion of a four day trapping session, traps were moved to the next lake.

Animals were captured in 31 Longworth traps at permanent trap stations, separated by 10 m intervals, along each trap-line (from 0-300 m). Each trap was located within 3 m of each trap station adjacent to the nearest source of cover, including fallen logs, shrubs, and grass. Recaptured animals were identified by clipped toes on the right hind foot.

A handful of sunflower seeds and oats was placed at each trap station 4-5 days prior to each trapping session. On the first day of a trapping session, traps were baited with sunflower seeds and oats, and cotton stuffing was added as insulation. On each of the subsequent 3 days, traps were generally checked before 2:00 p.m., and remained open for 24 hours between checks.

Upon capture of each previously unmarked mouse or vole, the species, reproductive condition (breeding or not), and weight of the animal were recorded with a Pesola spring balance. Females were classified as breeding if lactating or the vaginal opening was perforate. Breeding males were identified by the presence of descended testes. Pre-pubescent individuals (i.e., not breeding) weighing less than 15 grams in autumn were designated as juveniles. The reproductive status of shrews and meadow jumping mice was not consistently recorded and thus only abundance indexes are considered. Following handling, traps were reset.

Analysis

Abundance- To generate relative abundance estimates for each species on each trap-line, the number of unique captures per 100 trap-nights (C/TN) was calculated. To correct for the 5.2 % (2037) of traps remaining empty because they were accidentally sprung or disturbed by animals, a ½ trap-night was subtracted for each individual trap that was disturbed (Nelson and Clark 1974). Because few and/or small differences in species abundance existed among lines, abundance of red-backed voles and deer mice was calculated as captures/100 trap-nights for each grid including: A-lines at 20 m lakes; A, C-lines at 100m lakes; A, C, and E-lines at the 200 and 800 m treatment lakes. Because meadow voles were rare on interior forest lines, meadow vole abundance was calculated using A-lines only on each grid.

Statistical tests- ANOVA statistical tests were used to asses buffer strip treatment effects on small mammal abundance, numbers of breeders, and juveniles (sexes pooled). For each of the aforementioned dependent variables, the experimental unit is the paired difference between the buffer strip and reference grid, at each lake, within a season-year (or trapping session). Tests were conducted within spring or autumn seasons separately, because abundance differed between these two periods. Main effects included buffer strip "width" (20, 100, 200, or 800 m treatments), and "year" (1995-98). Effects due to harvesting different width buffer strips were evaluated with 2-way interactions (i.e., width X year). See ANOVA summary Table 5 as an example.

Effects of cut-blocks on small abundance were evaluated using ANOVA statistical tests, with the dependent variable being the difference in abundance between lines situated in cut-block and reference areas at 20 and 200 m lakes. Separate ANOVA analyses were conducted on spring and autumn data, with the main factor being year (i.e., within spring 1995-98, or autumn 1995-97; see Table 6 as an example). All ANOVA test results were considered significant at $\alpha = 0.05$.

RESULTS

We captured 10,300 animals in 39,271 trap-nights for a total trapping success of 26.2 % over the entire study period. Red-backed voles (*Clethrionomys gapperi*) and deer mice (*Peromyscus maniculatus*) were the most abundant small mammals in our study area, comprising 54.6 % (n=5620) and 25.6 % (n=2640) of all captures, respectively. Meadow voles (*M. pennsylvanicus*) were the next most abundant species, comprising 11.0 % of all captures (n=1128). Meadow jumping mice (*Zapus hudsonicus*) and shrews (*Sorex spp.*) were respectively captured in 4.1 % (n=425) and 4.0 % (n=407) of all successful capture events. The remaining 1 % of all captures was comprised of 27 least weasels (*Mustela rixosa*), 27 least chipmunks (*Eutamius minimus*), 26 red squirrels (*Tamiascuirus hudsonicus*), and 4 northern flying squirrels (*Sabrina glaucomys*). Because meadow jumping mice, shrews, least weasels, chipmunks, and squirrels were only periodically captured in traps, we focus on treatment effects on red-backed voles, deer mice, and meadow voles. We show abundance data of other species merely to demonstrate presence in different width buffer strips.

Red-backed Voles

Abundance- Red-backed vole abundance increased 3-fold between spring and autumn on reference grids, marked by similar over-winter declines, until autumn 1997 and spring 1998 when abundance was high (Figure 11). Over the course of the study, abundance varied 10.5-fold in spring (maximum spring abundance/minimum spring abundance) and 2.1-fold in autumn. Vole abundance did not significantly differ between buffer strip and reference grids among width treatments (20, 100, 200, and 800 m) and years in spring (Figure 12a-c; $F_{9,26}$=0.329, p=0.957) or autumn ($F_{6,15}$=0.375, p=0.883). Abundance of breeding voles was similar in buffer strips and reference grids among different buffer strip treatments and years in spring (Figure 13; $F_{9,25}$=0.307, p=0.965) and autumn throughout the study period($F_{6,14}$=0.759, p=0.788). Juvenile vole abundance was also similar in buffer strips and reference grids across different width treatments and years (Figure 14; $F_{6,15}$=0.370 p=0.560).

Effects of Cut-Blocks - The average difference in red-backed vole abundance between cut-blocks and reference areas in spring sessions did not significantly differ among years (Figure 17; $F_{3,11}$=1.94, p=0.181) or among years in autumn sessions 1995-97 ($F_{2,6}$=1.89, p=0.230). Average red-backed vole abundance was similar in cut-blocks and reference areas following harvest (Figure 15).

Deer Mice

Abundance- Deer mouse abundance on reference grids varied 4.3-fold in spring and 1.5-fold in autumn over the study period (Figure 16). Abundance was high in spring 1998 relative to spring abundance in previous years. Deer mouse abundance was greater at LLB than SCL and SPH (Figure 16a-c). At LLB, deer mice increased to greater abundance in 20 and 100 m wide buffer strips than reference grid areas in spring and autumn 1997 (Figure 16b). Increases in abundance in 20 and 100 m wide buffers at LLB were likely due to immigration (mature or non-breeding individuals), as numbers of breeding (Figure 17) and juvenile (Figure 18) individuals was similar in buffer strips and reference grid areas following harvest at LLB. Mouse abundance did not significantly differ between buffer strip and reference grids among width treatments and years in spring (Figure 16a-c, $F_{9,24}$=0.508, p=0.855) or autumn ($F_{6,13}$=1.198, p=0.367).

Effect of Cut-Blocks - The average difference in deer mouse abundance between cut-blocks and reference areas in spring sessions did not significantly differ among years (Figure 19; $F_{3,11}$=0.65, p=0.597) or among years in autumn sessions 1995-97 ($F_{2,6}$=1.16, p=0.374). However, deer mouse abundance significantly differed between cut-block and forest reference lines following harvest ($F_{1,40}$=23.19, p<0.001). Deer mouse abundance was significantly greater on cut-blocks than forest reference grids following harvest (Figure 19).

Other Species

Meadow voles- Meadow vole abundance did not significantly differ between buffer strip and reference grids among width treatments and years in spring (Figure 20a-c, $F_{8,23}$=0.824, p=0.590) or autumn ($F_{6,12}$=0.149, p=0.986). Meadow vole abundance was high in spring 1998 (Figure 20). Abundance varied 64.7-fold in spring and 1.4-fold in autumn over the course of the study.

Effect of Cut-Blocks - Furthermore, average difference in vole abundance between cut-blocks and reference areas did not significantly differ among years in spring sessions ($F_{3,11}$=2.81, p=0.086) or among years in autumn sessions 1995-97 ($F_{2,6}$=1.17, p=0.372). Meadow vole abundance did not differ between cut-blocks and reference areas (Figure 21).

Meadow jumping mice- Meadow jumping mice were present in 20, 100, and 200 m wide buffer strips following harvest (Figure 22a-c). Meadow jumping mice were captured more in spring than autumn. Abundance was greater in spring 1998 than previous years.

Shrews- Shrews were captured in buffer strips and reference areas at 20, 100, and 200 m treatments (Figure 23a-c). Shrew abundance was higher in autumn and at SCL. Shrews were not captured in 20 m wide buffer strips at LLB in autumn 1997.

DISCUSSION

Small mammals experienced marked annual fluctuations in abundance independent of our experimental manipulations of buffer strip width. Red-backed vole numbers were elevated in autumn 1997, whereas deer mouse abundance was more stable across years. Abundance of red-backed vole, deer mouse, meadow vole, and jumping mouse abundance was elevated in spring 1998 on reference grids. Deer mice, meadow vole and shrew abundance varied among sites. Riparian forest buffer strip width did not significantly affect small mammal abundance in mixed-wood boreal forest.

Red-backed Voles

Red-backed vole abundance was not influenced by our manipulations of riparian forest buffer strip width. If buffer strips represent poor vole habitat, we expected to observe lower numbers of breeding individuals, and greater numbers of juvenile individuals in buffer strips than in reference areas. Neither juvenile or breeding vole abundance significantly differed between buffer strip and reference grids.

Red-backed vole abundance did not significantly differ between cut-blocks and reference grids. Breeding female red-backed voles have home ranges of 10-30 m^2 (Bondrup-Nielsen and Karlsson 1985), and were likely residing entirely within buffer strips and/or adjacent cut-blocks. Similar survival and reproduction of red-backed voles was also observed between 1-2 year old cut-blocks and forest control areas in another study near Lac la Biche (Weaver 1995). This is contrary to other studies which suggest red-backed voles temporarily decrease in abundance in cut-blocks in aspen dominated forests (Probst and Rakstad 1987) and conifer forest (Martell and Radvanyi 1977; Gashwiler 1970; Martell 1983) following logging.

Deer Mice

Effects of buffer strip width on deer mouse abundance were minor. At LLB, the site where abundance was greatest, abundance was elevated on 20 and 100 m wide buffer strips with respect to reference grids in 1997. The co-occurrence of both breeders and juveniles in buffer strips suggests these areas were not functioning as sinks. Elevated abundance in the 20 m wide buffer strip may also have been due to “spill-over” of animals immigrating from the adjacent cut-block.

Deer mouse abundance was greater in cut-blocks than reference areas. Deer mice generally increase in numbers on cut-blocks following logging (Martell and Radvanyi 1977; Martell 1983; Sullivan and Krebs 1981). Sullivan (1983) suggested increases in deer mouse abundance in coastal rainforest cut-blocks occurred due to an irruption of deer mouse populations in adjacent forest, which resulted in an influx of juvenile males into adjacent cut-blocks. In this study, breeding and juvenile deer mice were both captured in cut-blocks, which suggests that cut-blocks represent source areas.

Other Species

Meadow vole abundance did not differ between buffer strips and reference grids. Meadow voles were rare in 20 m wide buffer strips making it difficult to evaluate effects of the width treatment. Meadow vole abundance did not increase in cut-blocks following harvest in black spruce dominated forest (Martell and Radvanyi 1977), however other work by Darveau *et al.* (2001) indicates meadow voles do use cut-blocks in balsam fir forest.

Meadow jumping mice were present in buffer strips and reference areas, and abundance was high in spring 1998. Meadow jumping mice have been reported as rare in other studies, and are often associated with grassy, moist areas (Boonstra and Hoyle 1986). Meadow jumping mice enter hibernation in autumn (Banfield 1981), and were thus captured mostly during spring.

Shrews were also present in buffer strips and reference areas. Most (65-85%) of the shrews captured in this study were masked shrews (DeGroot and Boutin, unpublished data). Although the masked shrew is a habitat generalist, this species is often associated with moist areas (Pagels *et al.* 1994).

CONCLUSION

Overall, buffer strip width had minor effects on small mammal abundance in the mixed-wood boreal forest. Red-backed vole and deer mouse abundance was similarly elevated in 20, 100, and 200 m buffer strips and reference areas following harvest. Meadow voles, meadow jumping mice, and shrews were all present in riparian forest buffer strips of different width. This study indicates that riparian forest buffer strip width does not affect small mammal abundance adjacent to lakes in mixed-wood boreal forest.

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Table 5: Example ANOVA Summary Table indicating degrees of freedom (DF), F-statistic (F), and p-value (p) outputs for ANOVA tests used to evaluate effects of harvesting different width buffer strips on small mammal abundance. Dependent variable is the paired difference in species abundance between buffer strip and reference grid, at each lake, within a trapping session. Separate ANOVA analyses were conducted for Spring and Autumn sessions. Effects due to harvesting different width strips were evaluated by "width X year" interaction.

Source of Variation	SS (Type III)	DF	F	p
Total	2262.31	42		
Width	27.46	3	0.122	0.946
Year	180.99	3	0.805	0.502
Width X Year	222.01	9	0.329	0.957
Error	1947.47	26		

* Live-trapping was not conducted adjacent to the 200 m treatment lake at SCL in spring 1995. Furthermore, live-trapping on the (A)-lines at LLB20 was not conducted in autumn 1995 due to problems associated with flooding. Additional grids were trapped adjacent to SPH 20 and SPH 100 in Spring 1997, Autumn 1997, and Spring 1998. In Spring 1998, traps were also set on 2 additional grids (one situated in a buffer strip, and one in reference forest area) adjacent to 20 and 100 m wide treatment lakes at SCL, LLB and SPH.

Table 6: Example ANOVA Summary Table indicating degrees of freedom (DF), F-statistic (F), and p-value (p) outputs for ANOVA tests used to evaluate effects of harvesting cut-blocks on small mammal abundance. ANOVA conducted on red-backed vole abundance in spring trapping sessions only. Dependent variable is the paired difference in species abundance between cut-block and reference grid, at each lake, within a season-year. Separate ANOVA analyses were conducted for Spring and Autumn. Effects due to harvesting cut-blocks were evaluated by comparing mean difference in abundance among "years" 6.

Source of Variation	SS (Type III)	DF	F	p
Total	1277.33	15		
Year	280.09	3	1.94	0.181
Error	528.85	11		

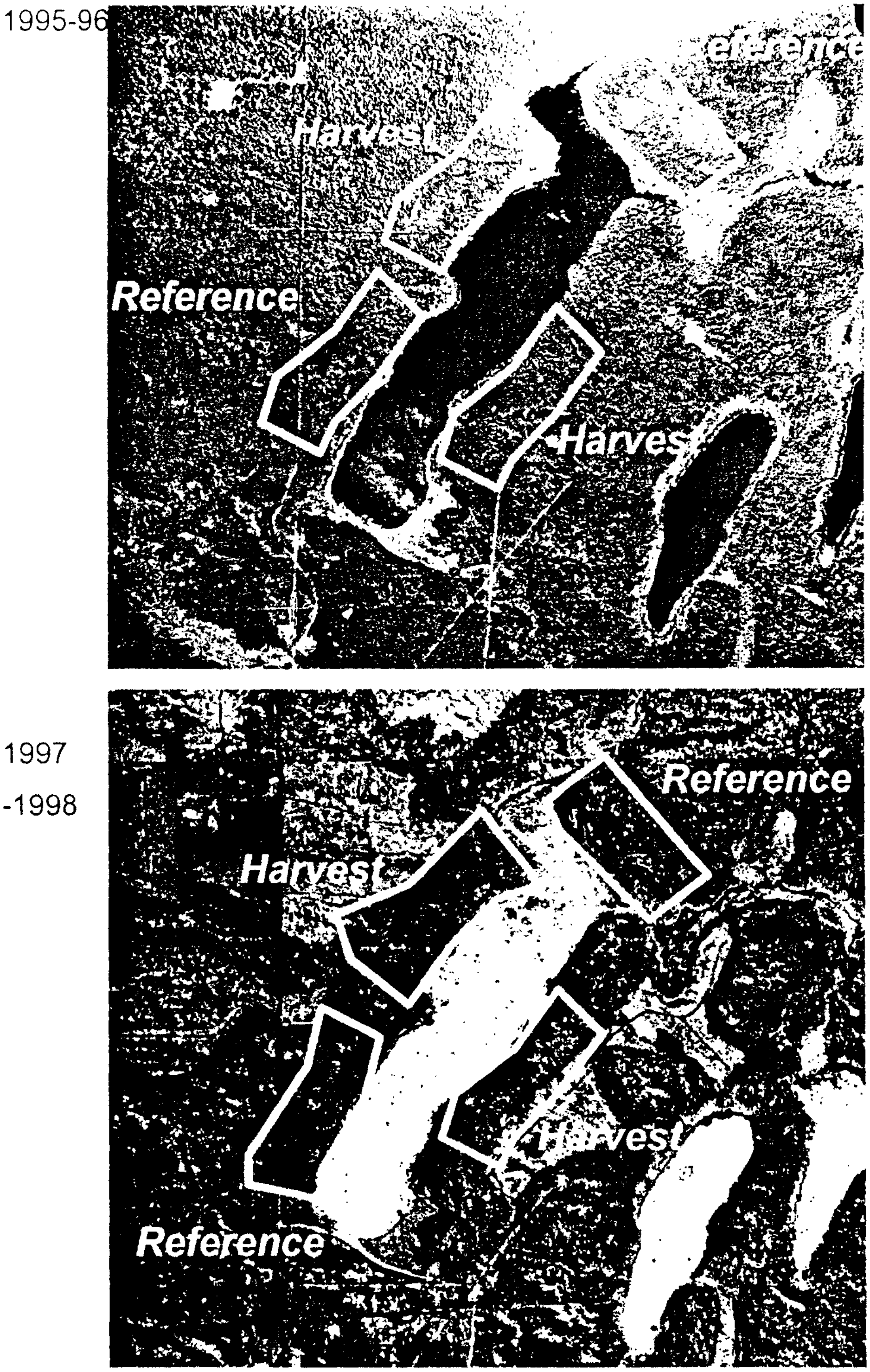

Figure 10: Pre- and Post-Harvest Experimental Design of TROLS.

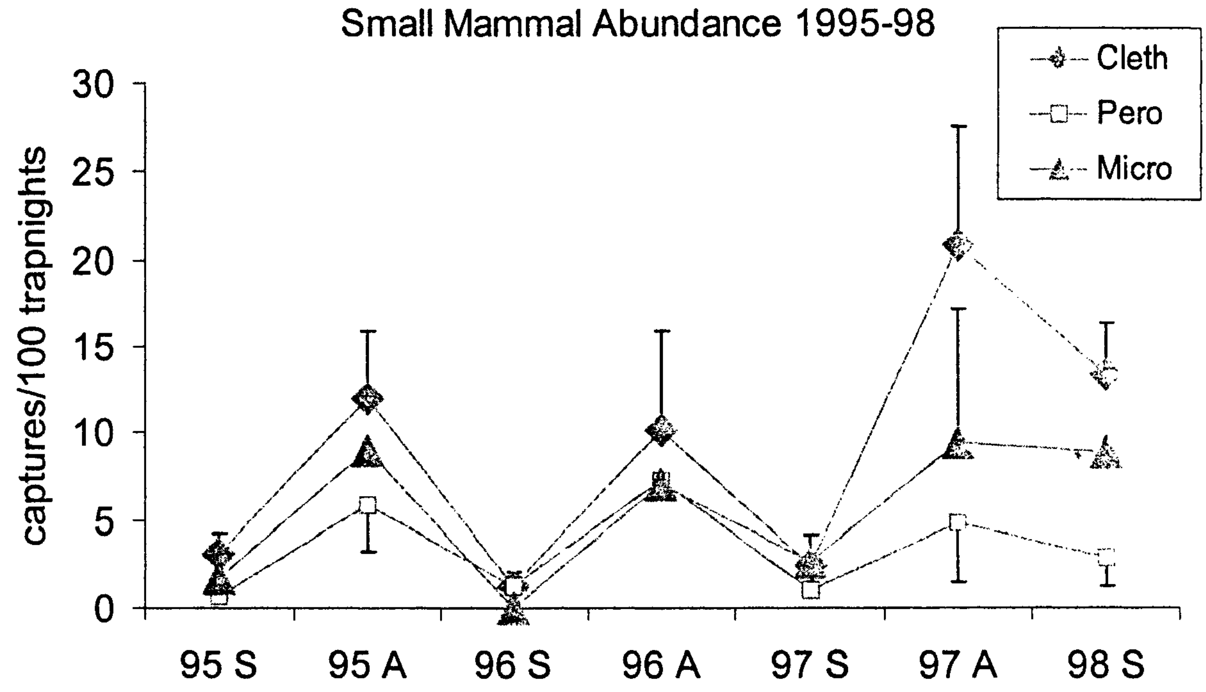

Figure 11: Mean abundance of red-backed voles (Cleth), deer mice (Pero), and meadow voles (Micro) in spring and autumn 1995-98 on reference grids (n=7-8, +/- 2 S.E.)

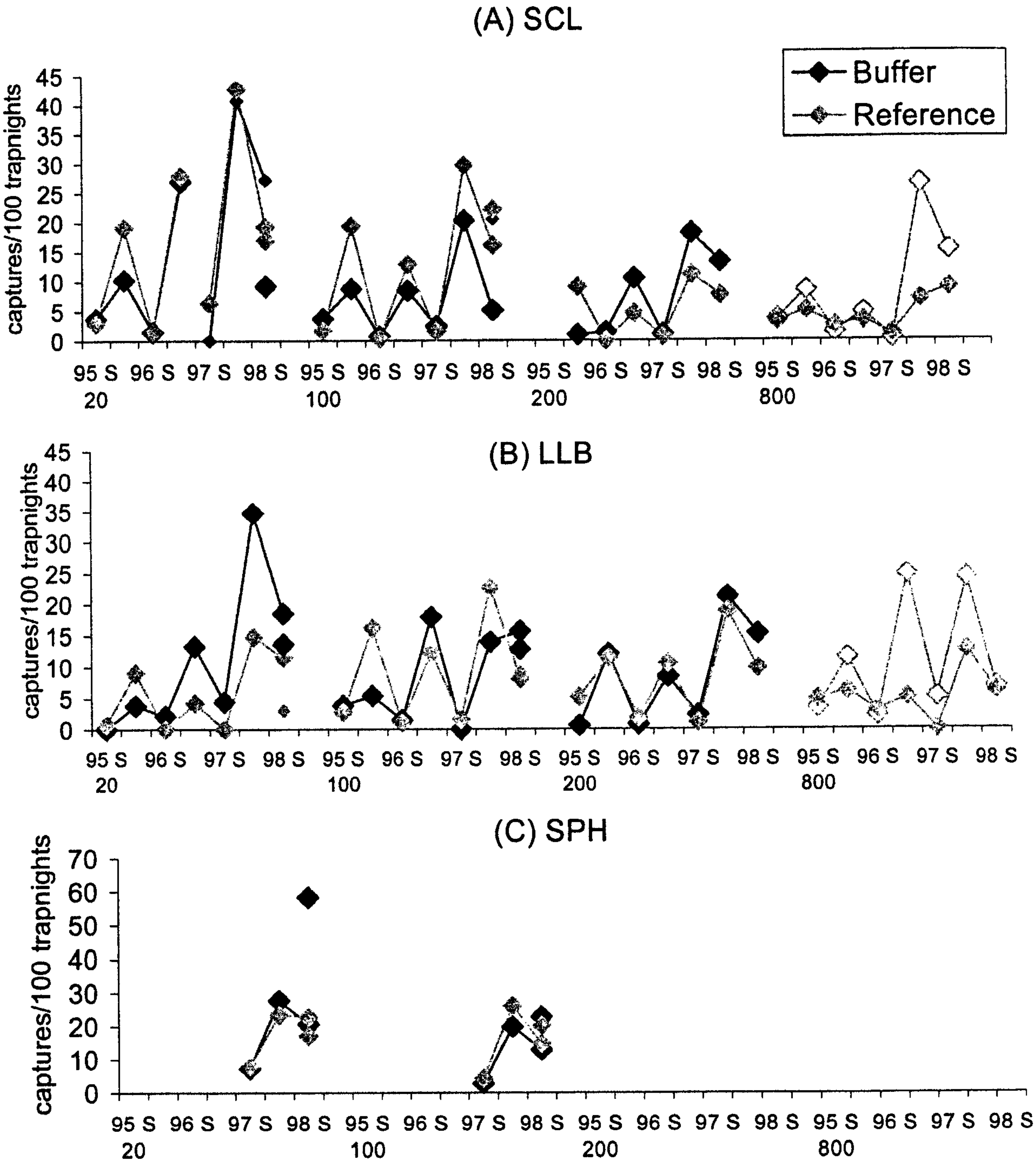

Figure 12: Red-backed vole abundance in buffer strips and reference grids at 20, 100, 200 and 800 m treatment lakes, in spring and autumn, 1995-98 at (A) SCL, (B) LLB, and (C) SPH.

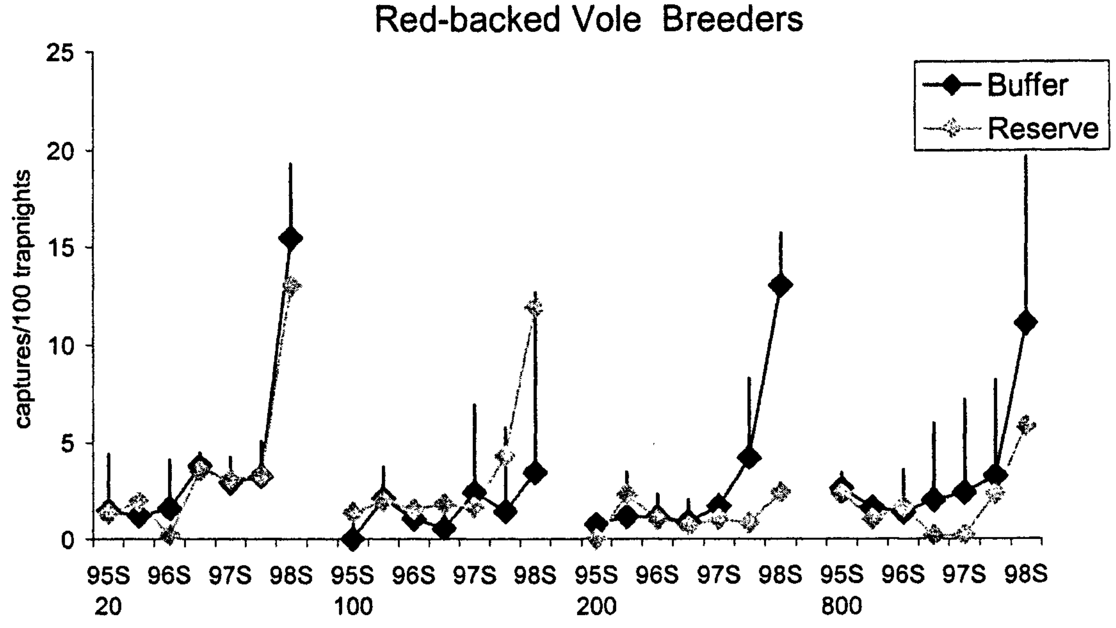

Figure 13: Average abundance of red-backed vole breeders on buffer strip and reference grids at 20, 100, 200, and 800 m treatment lakes in spring and autumn 1995-98. Error bars only reported on buffer strip statistics for clarity (n=2-3, +2 S.E.).

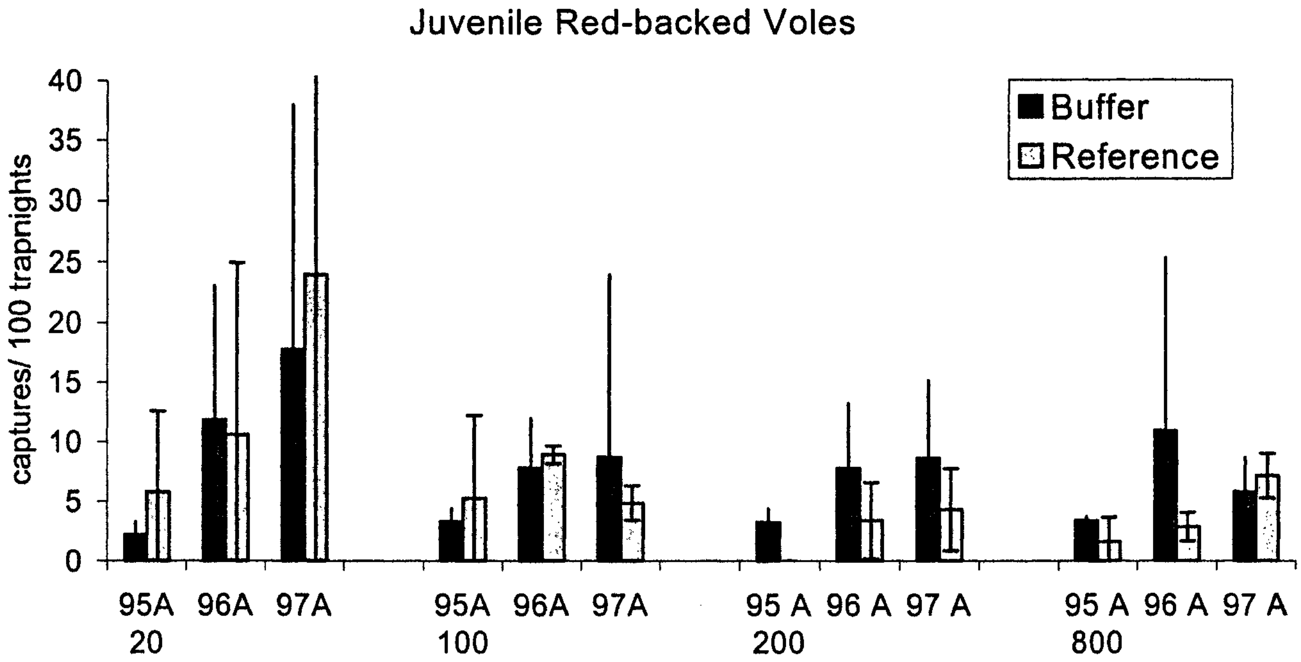

Figure 14: Average abundance of red-backed vole juveniles on buffer strip and reference grids at 20, 100, 200, and 800 m treatment lakes in spring and autumn 1995-98 (n=2-3, +/-2 S.E.).

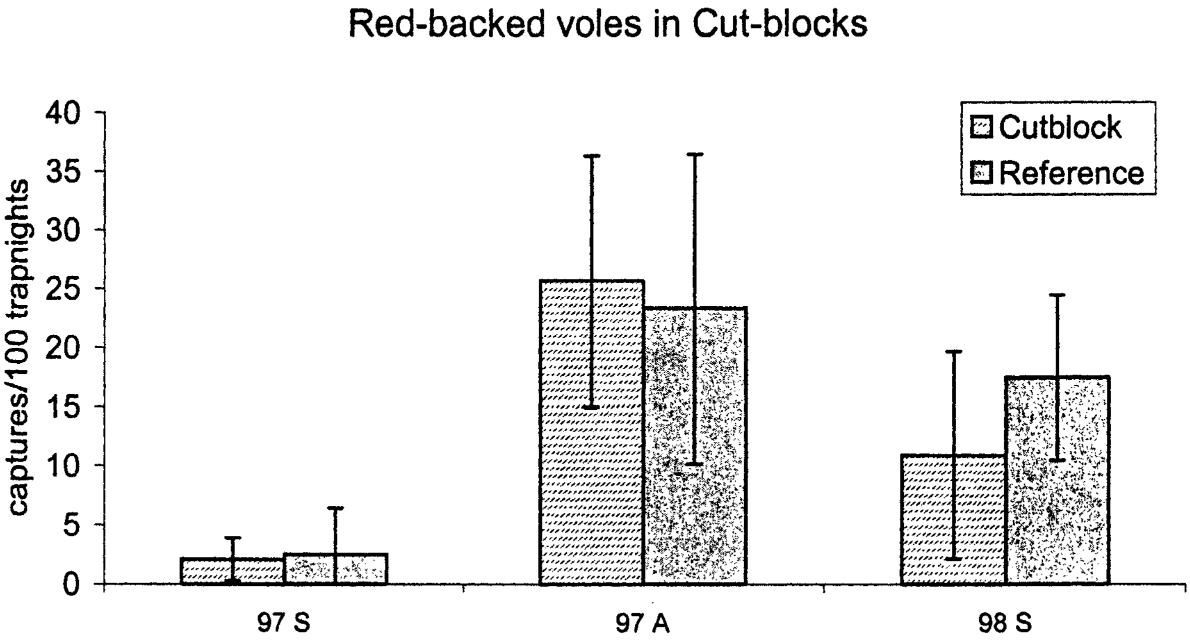

Figure 15: Average red-backed vole abundance on cut-blocks and reference lines 1997-98 (n=5-6,+/- 2 S.E.)

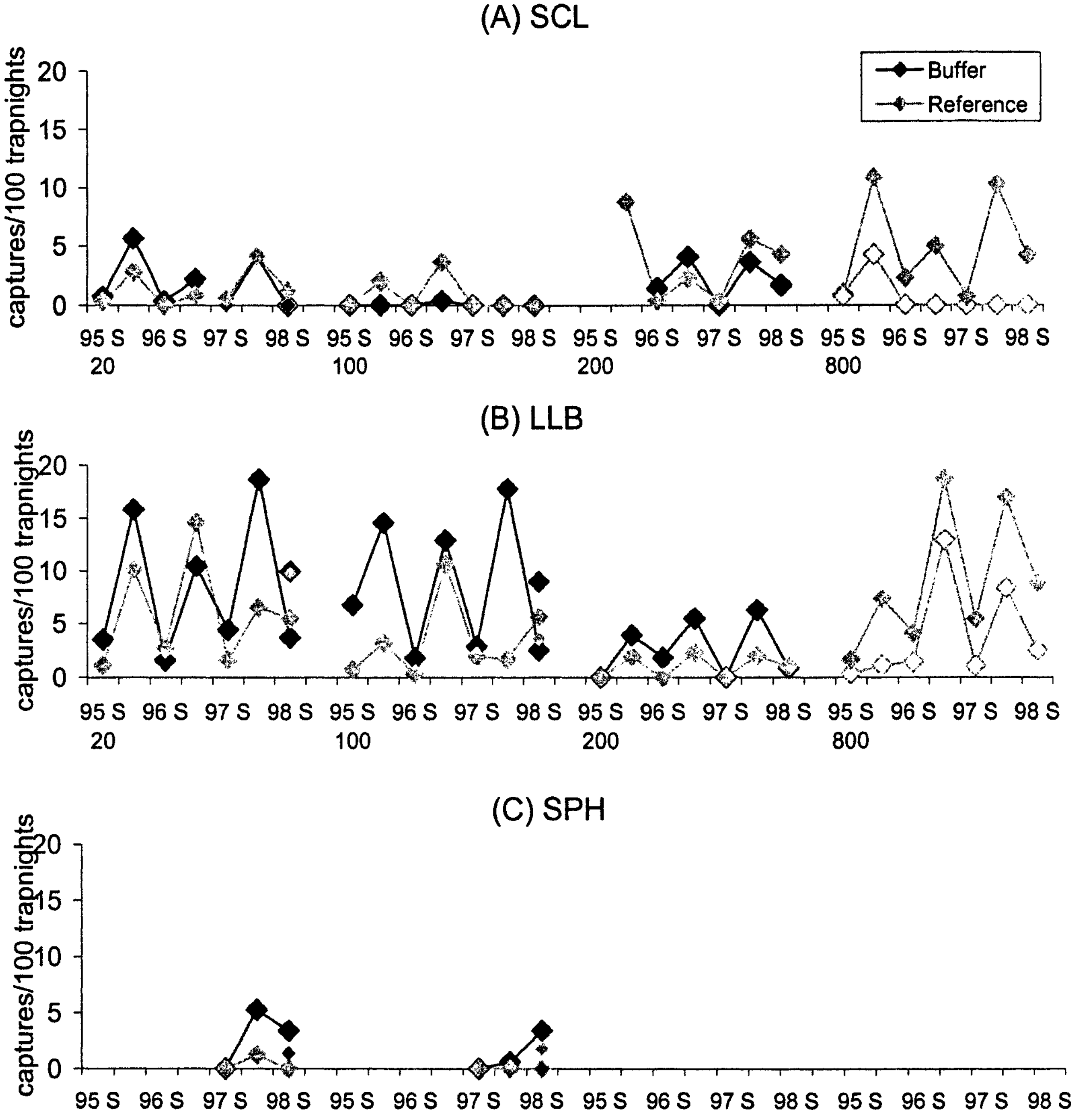

Figure 16: Deer mouse abundance in buffer strips and reference grids at 20, 100, 200 and 800 m treatment lakes, in spring and autumn, 1995-98 at (A) SCL, (B) LLB, and (C) SPH.

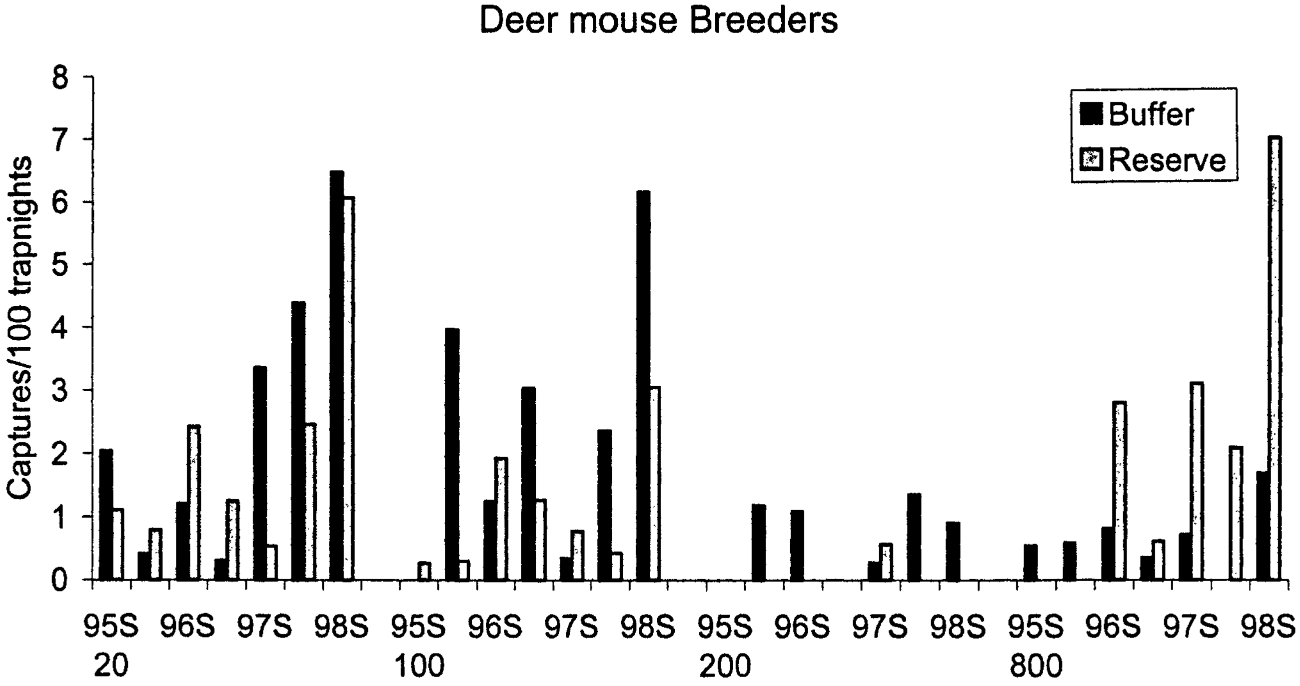

Figure 17: Abundance of breeding deer mice on buffer strips and reference grids at 20, 100, 200, and 800 m treatments at LLB in spring and autumn 1995-98.

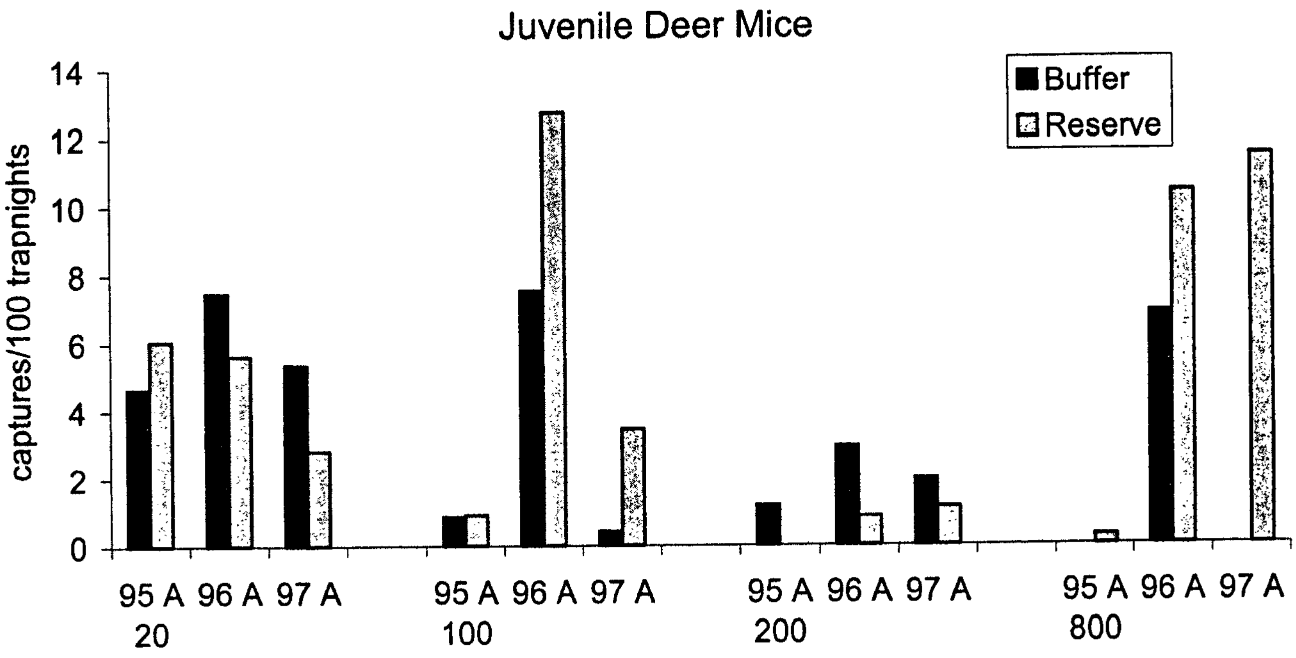

Figure 18: Abundance of juvenile deer mice on buffer strips and reference grids at 20, 100, 200, and 800 m treatments at LLB in spring and autumn 1995-98.

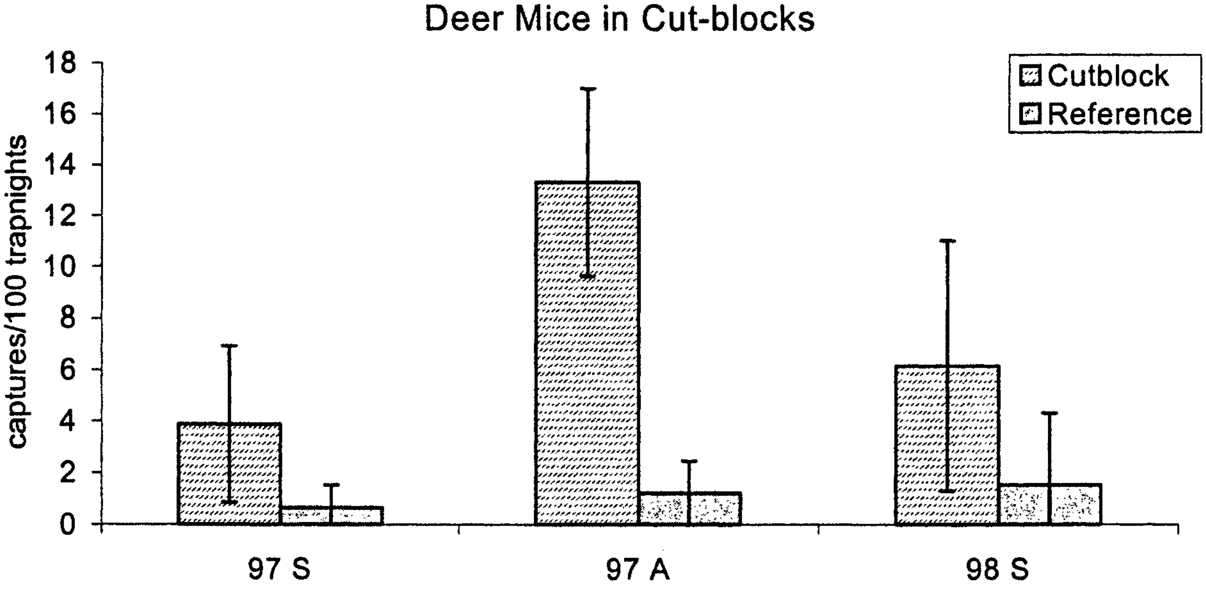

Figure 19: Average deer mouse abundance on cut-block and reference lines 1997-98 (n=5-6,+/- 2 S.E.).

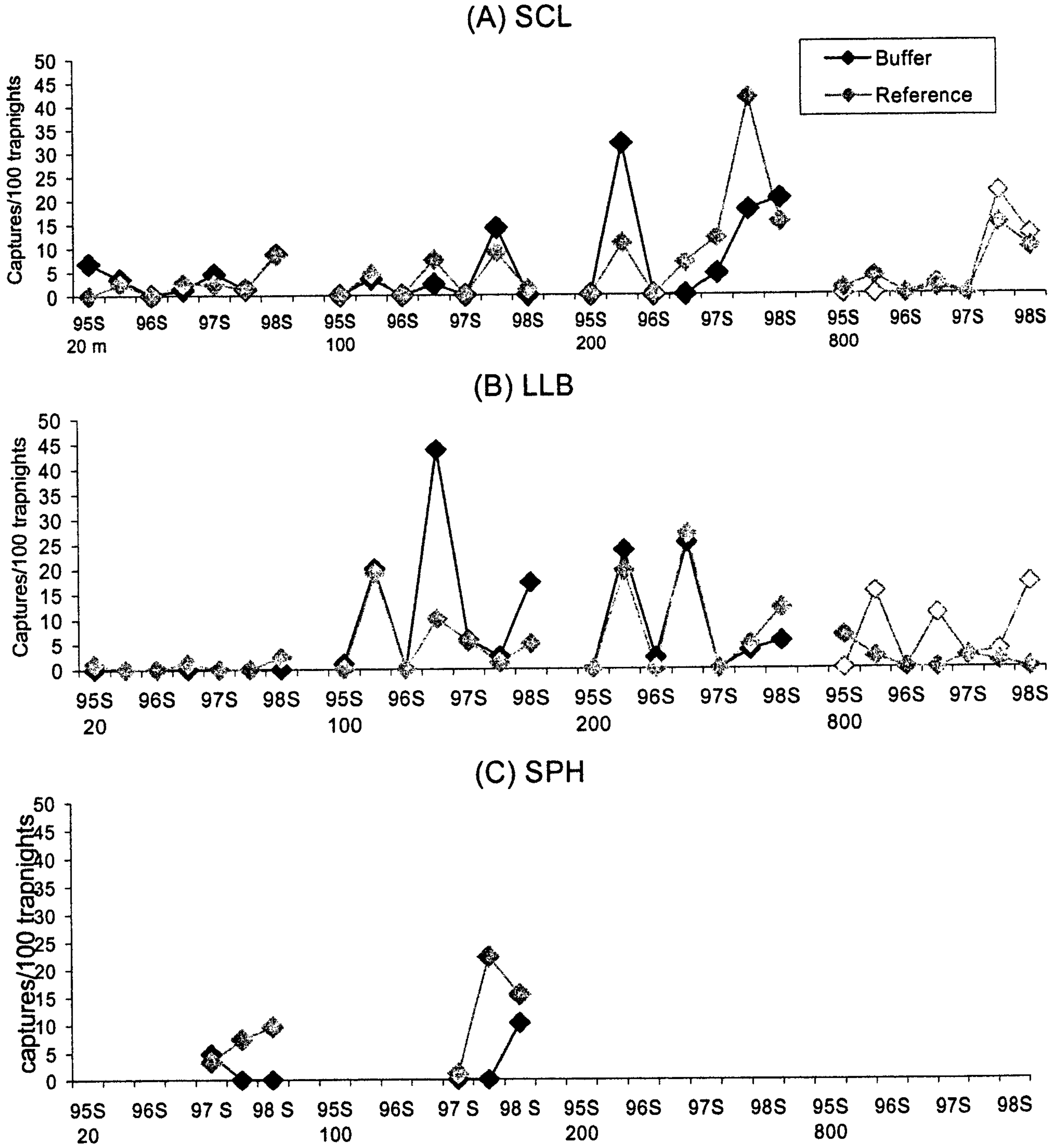

Figure 20: Meadow vole abundance in buffer strips and reference grids at 20, 100, 200 and 800 m treatment lakes, in spring and autumn, 1995-98 at (A) SCL, (B) LLB, and (C) SPH.

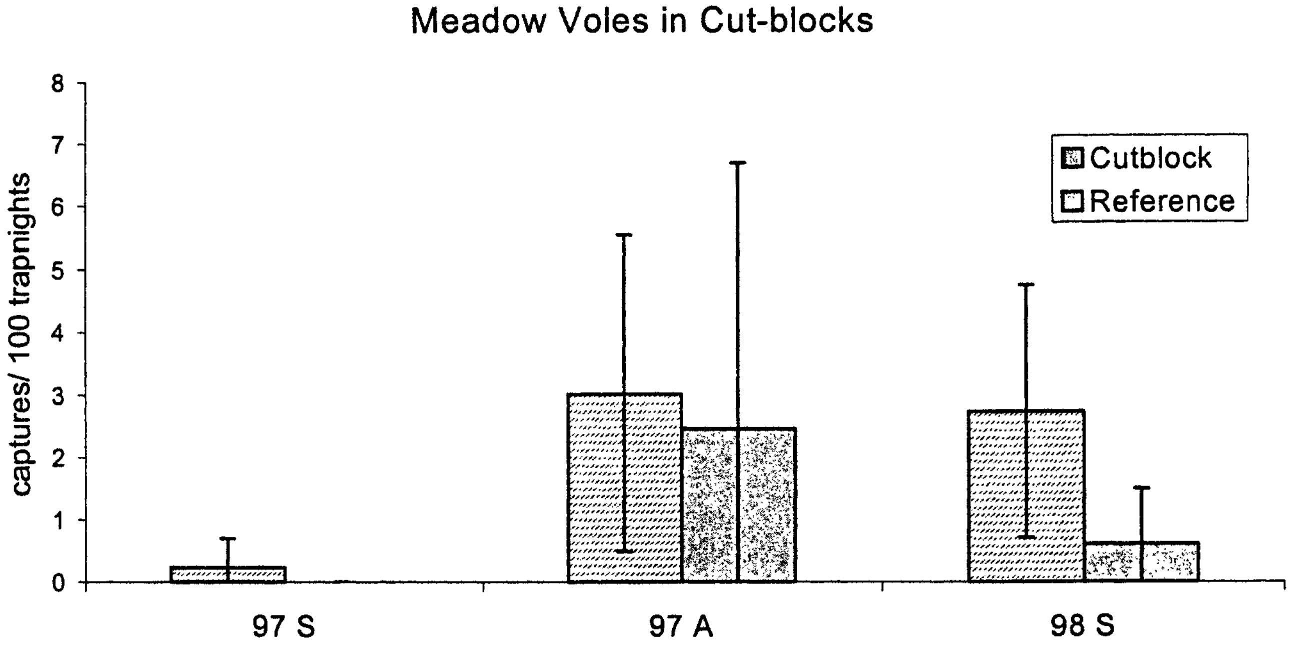

Figure 21: Average meadow vole abundance on cut-block and reference lines 1997-98 (n=5-6,+/- 2 S.E.)

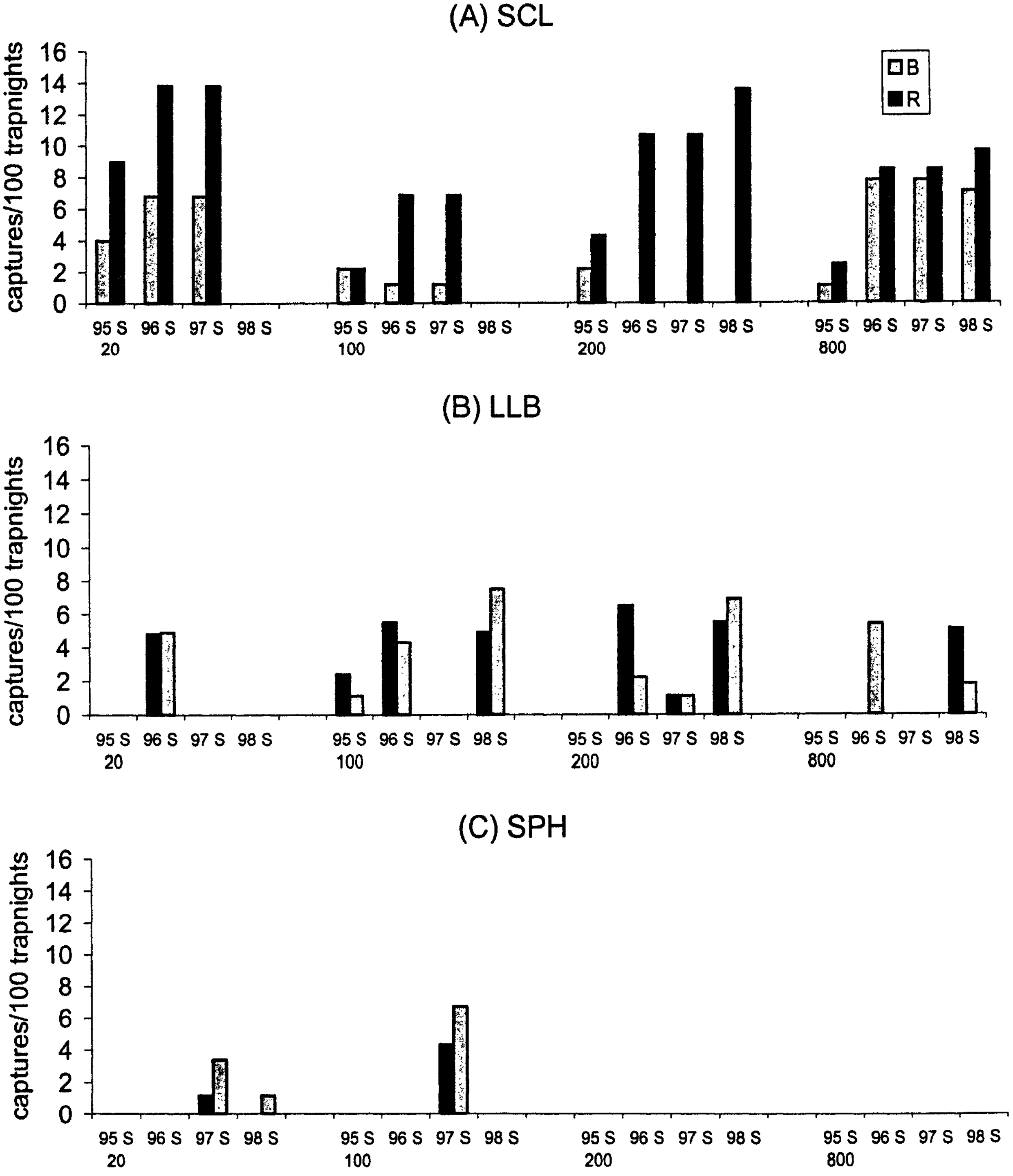

Figure 22: Meadow jumping mouse abundance on buffer strip and reference grids at 20, 100, 200, and 800 m wide treatment lakes at (A) SCL, (B) LLB, and (C) SPH.

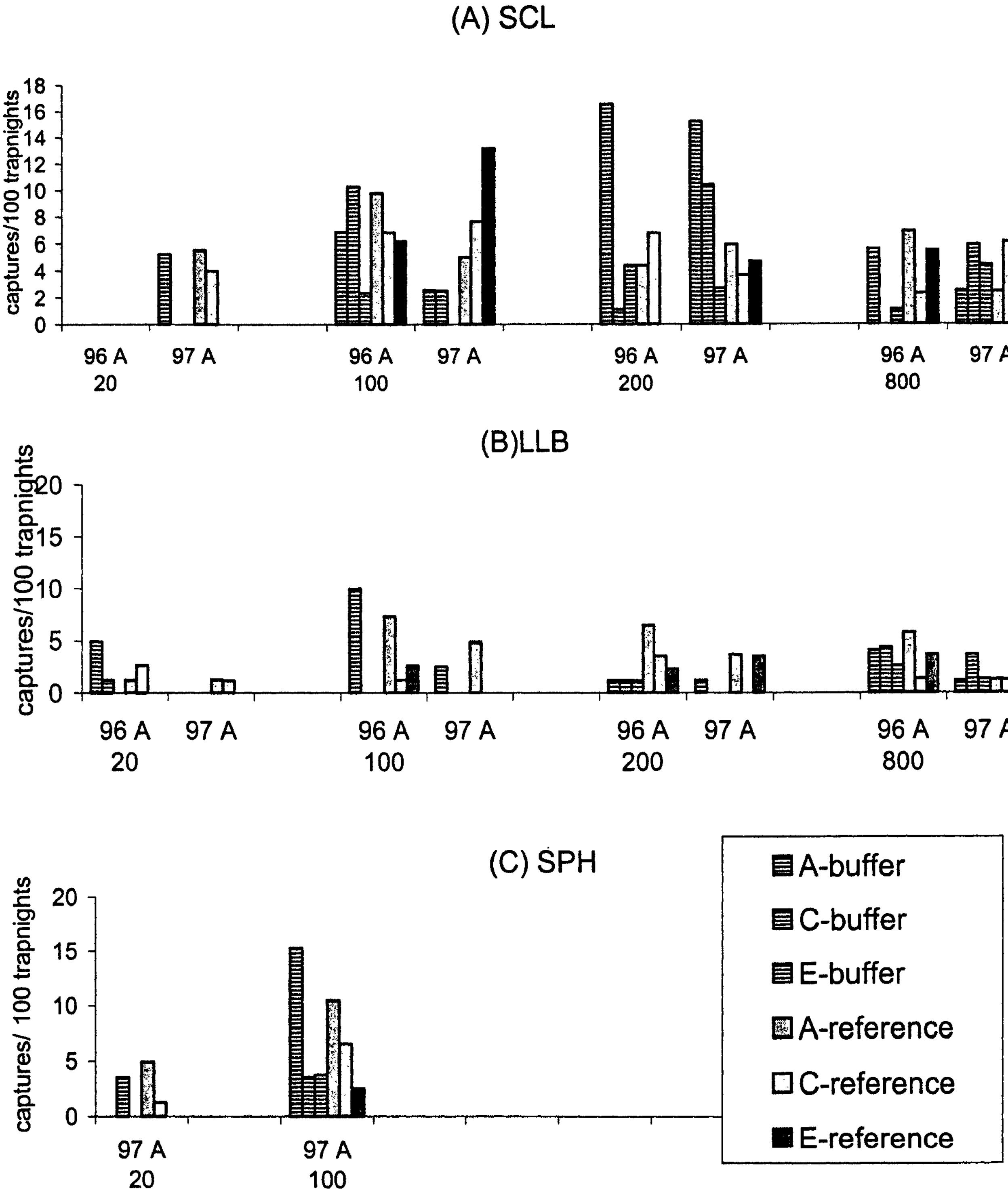

Figure 23: Shrew captures on buffer strip and reference grids at 20, 100, 200 and 800 m treatment lakes in autumn 1996 and 1997 on A,C,E-lines at (A) SCL, (B) LLB, and (C) SPH.

CHAPTER IV: WINTER USE OF RIPARIAN FOREST BUFFER STRIPS AROUND LAKES BY MAMMALS IN NORTH-CENTRAL ALBERTA

INTRODUCTION

Riparian areas may function as important habitat and movement corridors for wildlife (Naiman 1997). As productive habitat, riparian areas provide elevated food and cover for many types of terrestrial organisms, and may facilitate movement of animals across landscapes. To protect riparian areas, riparian forest buffer strips are now commonly utilized as management prescriptions in forestry across North America.

Although buffer strips were originally developed to protect aquatic systems, leave strips are increasingly left as wildlife reserves adjacent to open water (Naiman 1997). Riparian forest buffer strips may also promote movement of terrestrial organisms across inhospitable terrain, restoring the connectivity of fragmented landscapes (Fahrig and Merriam 1985). Of the relatively few investigations that have examined movement of terrestrial vertebrates in buffer strips (Simberloff *et al.* 1992), none have been conducted in winter.

This study examines winter use by mammals of riparian forest areas in the mixed-wood boreal forest of north-central Alberta. My first objective was to determine whether or not riparian forest areas serve as important winter habitat for mammals, thereby warranting protection with buffer strips. I used track counts to assess use of areas at different distances from lakes (0, 10, 50, 130 and 230 m) by a wide range of mammal species.

Riparian forest habitat may be influenced by logging in several ways. Creation of cut-blocks adjacent to lakes will result in habitat loss, reduced habitat connectivity, and impacts associated with interfaces between cut-block and forest areas. So called "edge effects" may result in reduced quality of lakeside habitat for some species, while other species may benefit from creation of cutblock-forest edges near lakes. My second objective was to assess winter use by mammals of 20, 100, and 200 m wide riparian forest buffer strips. I predicted mammals would aggregate in wider buffer strips if cut-blocks act as inhospitable sites.

My third objective was to determine if riparian buffer strips serve as movement corridors. If buffer strips promote movement of animals across inhospitable terrain, we expected that mammals would avoid cut-blocks, and be "funneled" through buffer strips as they travel across the landscape.

I used snow-tracking techniques to study movement of mammals in winter. Past studies have inferred movement in corridors from numbers of captured animals (Machtans *et al.*1997, Merriam *et al.*1992). Snow-track counts provide a reliable index of abundance for many species of mammals (see Boutin *et al.* 1995), and may also be used as a movement index. If buffer strips promote movement through inhospitable terrain, I predicted that the number of tracks would be elevated in buffer strips with respect to similarly-sized reference areas, and no tracks would be present in cut-blocks.

To more directly assess use of areas as movement corridors, I followed snow-tracks of individual animals over set distances to determine what animals are doing adjacent to lakes. I recorded browsing along tracks of a common herbivore, the white tailed deer (*Odocoileous virginianus*). In addition, I measured tortuosity of movement of a small carnivore, the short-tailed weasel (*Mustela erminea*), along snow-tracks in areas adjacent to lakes. If buffer strips are strictly used as movement corridors, we expected animals would not be foraging in those areas.

Movement of ungulates in winter allows deer to access food (i.e., woody browse), refuge from predators, and thermal cover. Carnivores also need to travel to find prey and dens. Little is known, however, about the role of different width riparian forest buffer strips in promoting movement across forest landscapes in winter.

My objective was to provide advice on winter habitat use and movement of mammals, and the effects on this use of forestry activities adjacent to lakes.

METHODS

Study Area

This study was conducted in winter 1996-97, 1997-98, and 1998-99 in the mixed-wood boreal forest of north central Alberta near 12 lakes which were grouped into three sites, including SCL (South of Calling Lake at 55 07' 20" N 113 43' 30 W), LLB (north of Lac La Biche at 55 8' 30" N 111 45' 45" W), and SPH (south of Pelican Hills at 55 23' 45" N 113 38' 00") areas (Figure 1). Tracking commenced in January and ended in mid-March of each year.

The winter weather conditions in the study area varied throughout the experiment. In winter 1997 mean monthly temperatures ranged from -32 to 0 °C and deep snow covered the ground from mid-November to late March. The El Nino winter of 1997-98 was significantly milder, with snow only covering the ground between late December to late March.

Experimental Design

The TROLS experiment is based on a blocked ANOVA design. Single replicates of the 20, 100, 200, and 800 m width treatment lakes were blocked within each of 3 sites. There were only forest reference grids adjacent to the 800 m control lakes. Four study grids were situated around each lake. In the winter of 1996-97, logging resulted in creation of either 20, 100, or 200 m wide buffer strips of trees, each at least 400 m in length, at 2 grids adjacent to each of the corresponding treatment lakes.

A harvesting error occurred at one of the SCL 20 buffer strip grids in 1996-97. Because the buffer strip was not harvested to a width of 20 m until spring 1998 we did not include data from this lake in the 1997 analysis.

Use of Areas at Different Distances from the Lakeside Forest Edge-
To assess use by mammal species of areas at different distances from lakes, tracks were surveyed on 400 m transects on reference grids in winters 1996-97 and 1997-98. Transects were oriented parallel to, and at 0, 10, 50, 130 and 230 m (A, B, C, E, or H, respectively) away from the lakeside forest edge. The riparian zone transect (0 m) was generally located along the lakeside forest edge comprising the outside perimeter of tall shrubs (>2 m) and large trees (> 10 cm in diameter).

Use of Different Width Buffer Strips- To evaluate the effects of different width buffer strips, paired comparisons of species track counts were made between buffer strips and reference areas. We counted tracks along 400 m long transects in buffer strips situated at 0 and 10 m distances from lakeside forest edge.

Use of Cut-blocks- To determine whether cut-blocks are avoided by different species, I also surveyed tracks in cut-blocks and reference grid areas at similar distances from lakes. These transects were located 50, 130, and 230 m from the 20, 100, and 200 m treatment lakes, respectively.

Assessment of Foraging Activity in Buffer Strips– I searched for tracks by walking the perimeter of different zones adjacent to each lake. Zones were situated between the high water mark and A-line (A-zone); and between the A- and B-line transects (B-zone). Animals were back-tracked. Tracking occurred in zones on each of 4 grids at 20, 100, and 200 m treatment lakes in 1999. Grids in buffer strips and reference areas were divided into zones including: A-zone (between edge of ice and A-transect); B-zone (0-20 m away from A-transect into forest); and C-zone (between 20-50 m from the A-transect in forest). No sampling occurred in A-zones on grids where there was no riparian zone (i.e., the tree-line abutted the edge of the lake ice.)

Tracking Techniques

Track Count Surveys- Sampling took place between January 1st and March 18th in 1997 and 1998. Trackers would visit all 12 lakes within 4-6 days of fresh snowfall to complete a round. At each lake, we took note of the number of days since fresh snowfall to standardize for differences in track counts due to elapsed time since snowfall (i.e., the numbers of tracks for each species on a line were divided by the number of days since fresh snowfall). After all treatment lakes at a site were surveyed, trackers moved to the next randomly selected site. Overall, we were able to complete 5 rounds each year.

Trackers wore snowshoes, recording the species of tracks crossing each transect. Tracks intercepting a transect two or more times were counted only once if the track remained within 5 m either side (perpendicular distance) of the snowshoe packed trail. Species were identified by footprint and gait according to Halfpenny (1988). Coyote and fox tracks were pooled because tracks of these species could not be distinguished. White-tailed and mule deer tracks were also pooled. Tracks that could not be reliably identified comprised less than 1% of all tracks encountered, and were excluded from the analysis.

In this study, a track is defined as a series of footprints following a single path. In instances where a track was made by two animals, or the same animal followed a path twice, the track was multiplied by a factor of two. The track was multiplied by a factor of three if it was followed three or more times by one or more animals (e.g., snowshoe hare trails). We also noted areas where tracks were highly aggregated due to intensive use, such as deer yards and red squirrel middens.

Assessment of Foraging Activity in Buffer Strips- To determine whether animals use buffer strips as travel corridors, tracking surveys on individual animals were conducted between January 1st and March 1st in 1999. Trackers followed deer and weasel tracks in zones on buffer strip and reference grids at each lake. After 4 lakes at a site were surveyed, trackers moved to the next site. A round, or complete survey in each zone adjacent to the 9 treatment lakes, was usually finished within 3 days. We completed 6 rounds in 1999.

We followed deer tracks to determine whether animals were feeding or moving adjacent to lakes. Trackers searched for deer tracks in each zone by walking transects adjacent to the A-, B- and C-zones. Each deer track was followed for a distance of 200 tracker steps. Trackers recorded the number of freshly browsed stems (i.e., the color of the browsed twig end was not gray or black) within 1 m of either side of the deer track.

If weasels use areas adjacent to lakes to travel, we expected animals would not be foraging there. For weasels, foraging was measured as the tortuosity of an animals' track. Tortuosity, or the linearity of an animals path, is an indication of searching behavior. We followed weasel tracks for a distance of 100 tracker steps. For this measure, we recorded numbers of "turns", or changes in direction greater than 45° away from the direction of travel indicated by the animals previous 2 bounds. Although weasels search for prey on the surface of the snow, they occasionally dive into the subnivean in pursuit of small mammals and other prey. Marks in the snow indicating this sort of activity were referred to as "plunges".

For each tracker, we recorded the number of steps required to walk a set distance (50 m) to calculate the average number of steps per distance (1.36 steps/ m). There were negligible differences between trackers in average step length.

Analysis

For each species we calculated the number of tracks per 100 km for each distance from the lake edge as the tracks averaged over two grids and 5 rounds on each lake. In other words, 10 measures were averaged to give one value for each distance from the lake and each buffer or reference treatment. Similarly, foraging indexes of deer or weasel in either A, B, or C-zones were also averaged across buffer strip or reference grids at each lake, and then averaged across rounds. All statistical tests were conducted using the SPSS statistical package, and considered significant at a level of p= 0.05.

Use of Areas at Different Distances from the Lakeside Forest Edge-
ANOVA statistical tests were used to compare species track counts on transects at different distances from lakes on reference grids. Site (SCL, LLB, or SPH) and lake (1-12) were included as random blocking variables (i.e., random factors) in ANOVA models. Years were analyzed separately and because of the cutting error in 1997, the 20 m buffer lake at LLB was not included in the analyses for that year.

Use of Different Width Buffer Strips- One-way ANOVA statistical tests were used to compare, for each species, paired differences in use between buffer strips and reference grid areas among buffer strip width treatments. This analysis was performed using track-counts on 0 or 10 m transects only. The main effect was buffer strip "width" (20, 100, 200, or 800 m treatments). Site (SCL, LLB, or SPH) was included as a random blocking variable (i.e., random factor) in ANOVA models. Years were analyzed separately and because of the cutting error in 1997, one of the 20 m wide buffer strips at SCL was not included in the analyses for that year. See Table 7 for an example output of the one-way ANOVA used.

Use of Buffer Strips as Travel Corridors- One-way ANOVA statistical tests were also used to compare paired differences in foraging indexes between buffer strip and reference grids among width treatments (20, 100, and 200 m). For weasels we compared paired differences in numbers of turns or plunges per step, for A- or B-zones and among width treatments. For deer, a similar analysis was used to compare numbers of browsed stems per step within each zone and among width treatments.

To test the assumption that tortuosity is a reliable indicator of foraging behavior I used correlation analyses to test whether numbers of "turns" per step within zones are related to small mammal track or tunnel counts on adjacent snow-track count transects from the previous year (1997-98).

RESULTS

Overall 14,691 tracks were counted in 1997 and 1998. The taxonomic breakdown of tracks was small mammal (*Clethrionomys gapperi*, *Peromyscus maniculatus*, *Microtus pennsylvanicus*) 2341 tracks (18.9%), red squirrel (*Tamiasciurus hudsonicus*) 2118 tracks (14.4%), snowshoe hare (*Lepus*

($F_{4,35}$=3.31, p=0.021). Although snowshoe hare track counts were elevated on 10 m transects, differences among transects were not significant in 1997 ($F_{4,35}$=2.24, p=0.089). However, differences among lines were significant in 1998 ($F_{4,35}$=3.31, p=0.021).

Carnivores- Weasel track counts were elevated on riparian zone transects, and differences were significant in 1998 (Figure 25b, $F_{4,35}$=5.63, p=0.001) and marginally significant in 1997 (Figure 25a, $F_{4,29}$=2.50, p=0.064). Weasel track counts were positively related to small mammal track counts (Pearson Correlation [R] = 0.693, n = 62, p = 0.00). This relation was also valid on 0 m transects (Pearson correlation [R] = 0.726, n= 12, p= 0.01) but not on 10 m (Pearson correlation =0.142, n= 12, p= 0.66) or 50 m transects (Pearson correlation = 0.125, n= 12, p= 0.70).

Mink track counts were also greater on riparian zone transects than at distances further away from lakes. Those differences were significant in 1997 ($F_{4,29}$=2.96, p=0.036).

Coyote track counts did not differ significantly among transects at different distances from lakes in 1997 ($F_{4,29}$=1.05, p=0.40) or 1998 ($F_{4,35}$=1.29, p=0.292). There was no significant correlation between coyote track counts and red squirrel (Pearson correlation = 0.120, n = 12, p= 0.069) or hare (Pearson correlation = 0.110, n= 12, p= 0.63) track counts.

Ungulates- Deer track counts were lower in riparian zone areas than at distances further from lakes (Figure 26). Differences in deer track counts among distance from lake transects were significant in both 1997 ($F_{4,29}$=2.80, p=0.044) and 1998 ($F_{4,35}$=8.14, p=0.000). Moose track counts did not significantly differ at different distances from lakes ($F_{4,35}$=1.56, p=0.180).

Use of Different Width Buffer Strips

Small mammal prey- There were no significant differences in species track counts among buffer strip width treatment lakes areas for small mammals, red squirrels, or snowshoe hares in 1997 or 1998 (Tables 8-9; Figure 27).

Carnivores- Use by weasel, mink, and coyote did not differ between buffer strips and reference grids in 1997 or 1998 (Tables 8-9; Figure 28).

Ungulates- There were significant differences in deer track counts between buffer strips and reference grid 10 m transects among width treatments in 1997 but not 1998 (Table 14; Figure 29). Elevated use by deer of 20 m wide buffer strips was likely due to abundant forage available from wind-thrown trees in 20 m wide strips. Moose track counts did not significantly differ between buffer strip and reference grid areas among width treatments (Tables 8-9).

Use of Cut-blocks- Significant differences in use of cut-blocks and reference areas were not observed for most mammal species (Figure 30a-b). In 1998 there were significant differences in both small mammal ($t_{(2),8}$=2.43,p<0.05) and weasel track counts ($t_{(2),8}$=2.56,$p<0.05$). Differences were due to greater use of cut-blocks by both species.

Use of Buffer Strips as Travel Corridors

Behavioral investigations did not support the notion that weasel or deer use riparian forest buffer strips as movement corridors. Both species were foraging in riparian forest buffer strips. This indicates that buffer strips are not strictly used as movement corridors by weasel and deer.

Weasels- There tended to be more plunges and turns per step traveled in A-zone areas relative to areas farther from lakes (Figure 31 a-b). There were significant differences in numbers of plunges per step traveled ($F_{3,23}$=3.05, p=0.049) and no significant differences in numbers of turns per distance traveled ($F_{2,23}$=2.79, p=0.086) among zones (A-, B-, and C-zones). To account for this variation, analyses used to test for differences between buffer strips and reference areas in foraging activity were conducted for A- or B-zones separately.

If weasels use buffer strips as movement corridors, we expected that weasels would not be foraging as much in those areas. Average plunges per step between buffer strip and reference grid areas did not significantly differ among buffer strip width treatments in the A-zone (Figure 32, $F_{2,4}$=12.881, p=0.072) or B- zone ($F_{2,4}$=5.17, p=0.078). There were no significant differences in average turns per step traveled between buffer strip and reference grids and among width treatments in the B-zone (Figure 28; $F_{2,4}$=9.14, p=0.167).

Weasel foraging indexes were correlated to small mammal track counts. There was a positive correlation between plunges per step traveled in all zones in 1998 and small mammal track counts on all adjacent transects in 1997 (Pearson Correlation [R] = 0.490, N = 55, $p < 0.001$). There was also a positive correlation between turns per step traveled in 1998 and small mammal track counts in 1997 (Pearson Correlation [R]= 0.384, N = 55, $p < 0.001$). Turns or plunges per distance traveled in riparian zones were also positively related to small mammal track counts on 0 m transects (Pearson correlation [R]= 0.567, n = 9, p=0.022), and 10 m transects (Pearson correlation [R]= 0.767, n=9, p = 0.001, respectively). This suggests that indexes such as turns or plunges are reliable measures of weasel foraging behavior.

Deer- There were no significant differences in numbers of browsed stems per distance traveled by deer among A-, B- and C-zones ($F_{2,6}$=0.830, p=0.490). There were no significant differences in numbers of browsed stems per distance traveled between buffer strips and reference grids and among width treatments (Figure 33; $F_{2,4}$=2.146, p=0.235). This indicates deer do not use riparian forest buffer strips as movement corridors.

DISCUSSION

My investigations of winter use of riparian forest areas suggest these areas do not represent important habitat relative to areas farther from lakes for most mammal species. Harvesting forest buffer strips of different widths has negligible effects on winter use of riparian forest areas by mammals. I found no evidence to indicate that riparian forest buffer strips serve as movement corridors for mammals in mixed-wood boreal forest.

Use of Areas at Different Distances from the Lakeside Forest Edge

Small Mammal Prey- Use of riparian forest areas by small mammal prey species was greater closer to lakes. Small mammal track counts were elevated on riparian zone transects, likely due to the greater combined abundance of small mammal species (i.e., red-backed voles, deer mice, meadow voles, and shrews) in those areas. Red squirrel track counts were greater on 10 m line transects in 1997 and 1998, and greater use of this area may be due to elevated spruce tree density near the lakeside forest edge. Snowshoe hare track counts were also greater close to the lakeside forest edge in both years. Hik (1995) suggested snowshoe hares use dense cover offered by shrubs and spruce cover to avoid predators. Greater use by small mammal prey of areas close to lakes is likely due to the combination of habitats, provided by open meadows, shrubs, deciduous and conifer trees. This type of vegetation is also found in upland areas.

Carnivores- Riparian zone areas provide attractive habitat for some carnivores, however, this use is highly localized and likely does not extend into forested areas adjacent to lakes. The diet of the short-tailed weasel includes red-backed voles, deer mice, meadow voles, and shrews (Lisgo 1999). However, meadow voles are preferred prey of weasels (Henttonen 1987) and weasels likely used riparian zone areas due to elevated abundance of meadow voles. Mink also eat small mammals, as well as other prey, and distribution of this species is strongly linked with aquatic systems (Banfield 1981). Coyotes also prey on small mammals, red-squirrels and hares, however, there were no significant differences in use by this species of areas at different distances from lakes.

Ungulates- Although both deer and moose are often associated with riparian areas (e.g., La Rue *et al.* 1994), neither species used forest areas closer to lakes to a greater extent than areas further away from lakes. Deer may avoid riparian zone areas in winter due to deeper snow, lack of palatability of shrub forage, or lack of cover. La Rue *et al.* (1994) found elevated use by deer of riparian forests as compared to uplands in boreal forest, however, no gradient in use was observed within the first 150 m of the riparian forest edge. The scale of our investigation may have been too small to detect trends in habitat use by ungulates.

Use of Different Width Buffer Strips

Manipulations of riparian forest buffer strip width did not affect mammalian use of areas adjacent to lakes.

Small mammal prey- There were no significant differences in use between buffer strip and reference areas among width treatments by small mammals, red squirrels, or snowshoe hares. This is contrary to the suggestion of Darveau *et al.* (1999) that snowshoe hares were are rare in riparian forest buffer strips after logging in boreal forest. Some studies indicate that clear-cuts are used less by mammals in boreal forest (Kirkland 1990, Thompson *et al.* 1989), however, the response of small mammal prey to development of forest cut-blocks was not negative in my study.

Carnivores- No significant differences in use by carnivores were observed between buffer strips and reference areas among width treatments. Weasel track counts were significantly elevated in both 20 m wide buffer strips and cut-block areas in 1998, possibly due to elevated abundance of small mammal prey (including mice and voles) in those areas. Lisgo (1999) also suggested female weasels use cut-block areas, likely due to good cover provided by slash and abundant small mammal prey.

Ungulates- Harvesting different width riparian forest buffer strips had minor effects on use by deer and moose of areas adjacent to lakes. Deer used 20 m wide buffer strips to a greater extent than adjacent reference areas in 1997, but not 1998. This short-term response was likely due to elevated browse from wind-thrown trees, twigs and branches left in 20 m wide buffer strips and adjacent cut-blocks.

Moose use of areas adjacent to lakes was not affected by harvesting different width buffer strips. However, moose used 60 m wide timber reserves adjacent to lakes more than adjacent forest control areas in boreal forest (Brusnyk and Gilbert 1983).

Use of Buffer Strips as Travel Corridors

This study indicates that riparian forest buffer strips do not function as winter travel corridors for mammals in mixed-wood boreal forest. If mammals "funnel" through riparian forest buffer strips while traveling across the landscape, I predicted that mammals would avoid cut-blocks, and that use of buffer strips would be elevated with respect to reference areas. Although deer used 20 m wide buffer strips more than reference areas in 1997, cut-block areas were not avoided during the same period. Greater use by weasels of 20 m wide buffer strips with respect to adjacent reference areas was mirrored in cut-blocks.

More detailed behavioral investigations also indicated that buffer strips are not used as travel corridors by weasel or deer. Weasels and deer also use different width riparian forest buffer strips as feeding areas.

CONCLUSION

Track-count surveys of small mammal prey, carnivores, and ungulates indicate that winter use forest areas does not significantly differ with distance from lakes in mixed-wood boreal. I did not detect any significant differences in winter use among 20, 100, 200 m wide buffers and forest reference areas. Riparian forest buffer strips likely do not function as movement corridors for mammals in the mixed-wood boreal forest. I found no evidence to suggest forestry activities should be excluded from the riparian forest, or that different width riparian forest buffer strips affect winter habitat use or movement of mammals.

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Table 7: Example ANOVA Summary Table indicating degrees of freedom (DF), F-statistic (F), and p-value (p) outputs for ANOVA tests used to evaluate effects of harvesting different width buffer strips on winter snow-track counts in winter 1996-7. Statistical significance of average differences in species track counts between buffer strips and reference grid areas and among width treatments on A-lines (0 m transects adjacent to lakeside forest edge) in 1997. F-statistics and P values are for a one-way ANOVA with 4 buffer widths (20,50,200, and 800 m-control) and 3 replicates per treatment. Dependent variable is the paired difference in track counts between buffer strips and reference grids, at each lake. 7.

Source of Variation	SS (Type III)	DF	F	p
Total	2262.31	11		
Width	1308151	3	2.69	0.13
Site	180.99	2	0.89	0.45
Error	971542	6		

*One 20 m wide buffer strip at SCL was not included in the analyses due to the cutting error at SCL 20 in 1996-97.

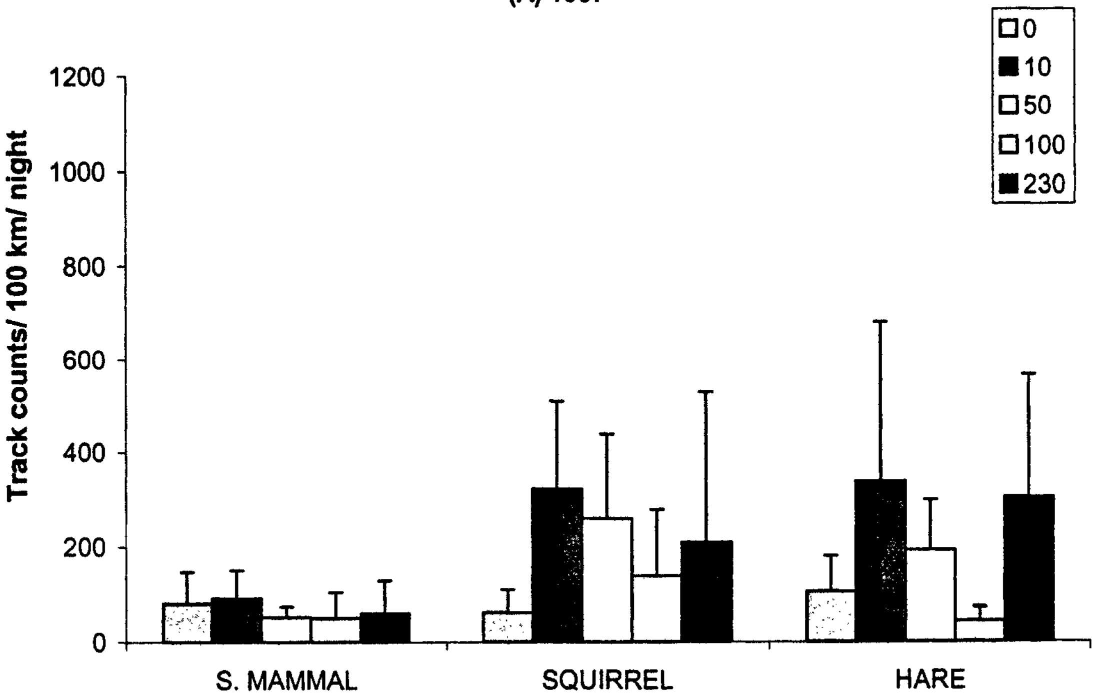
Table 8: Statistical significance of average differences in species track counts between buffer strips and reference grid areas and among width treatments on 0 m transects in 1997 and 1998. F-statistics and P values are for a one-way ANOVA with 4 buffer widths (20,100,200, and 800 m control) and 3 replicates per treatment. 8

0 m Transect	F Statistic	p-value
1997		
Small Mammal Prey		
Small mammals	0.19	0.90
Red squirrels	0.99	0.46
Snowshoe hares	0.98	0.46
Carnivores		
Weasel	0.61	0.92
Mink	0.62	0.63
Coyote	1.50	0.30
Ungulates		
Deer	0.35	0.79
Moose	0.87	0.51
1998		
Small Mammal Prey		
Small mammals	2.69	0.14
Red squirrels	1.44	0.32
Snowshoe hares	3.52	0.09
Carnivores		
Weasel	0.35	0.79
Mink	0.86	0.51
Coyote	1.12	0.45
Ungulates		
Deer	3.15	0.11
Moose	2.05	0.21

Table 9: Statistical significance of average differences in species track counts between buffer strips and reference grid areas and among width treatments on 10 m transects in 1997 and 1998. . F-statistics and P values are for a one-way ANOVA with 4 buffer widths (20, 100, 200 and 800 m control) and 3 replicates per treatment. 9

10 m Transect	F Statistic	p-value
1997		
Small Mammal Prey		
Small mammals	0.07	0.97
Red squirrels	0.66	0.60
Snowshoe hares	1.33	0.35
Carnivores		
Weasel	0.61	0.63
Mink	0.95	0.47
Coyote	2.03	0.21
Ungulates		
Deer	10.91	0.01
Moose	1.03	0.44
1998		
Small Mammal Prey		
Small mammals	0.68	0.59
Red squirrels	0.08	0.97
Snowshoe hares	0.03	0.99
Carnivores		
Weasel	1.37	0.34
Mink	0.80	0.54
Coyote	1.12	0.41
Ungulates		
Deer	1.12	0.41
Moose	2.0	0.21

(A) 1997



(B) 1998

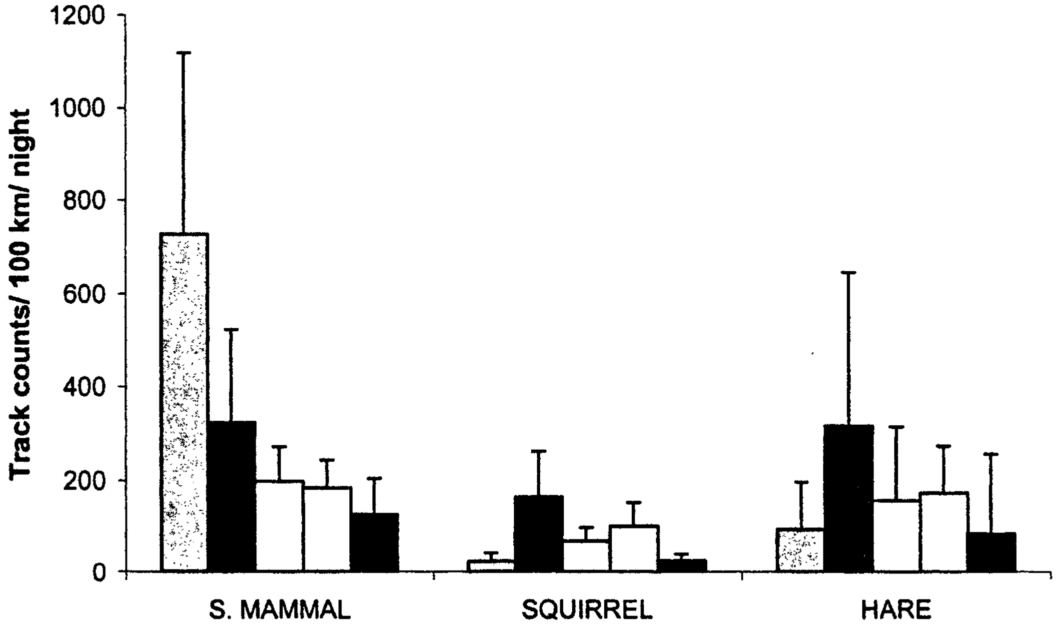


Figure 24: Mean small mammal prey track counts at different distances from lakes (0, 10, 50, 130, and 230 m) on reference grids in (A) 1997 and (B) 1998 (+/- 2S.E.; n=12).

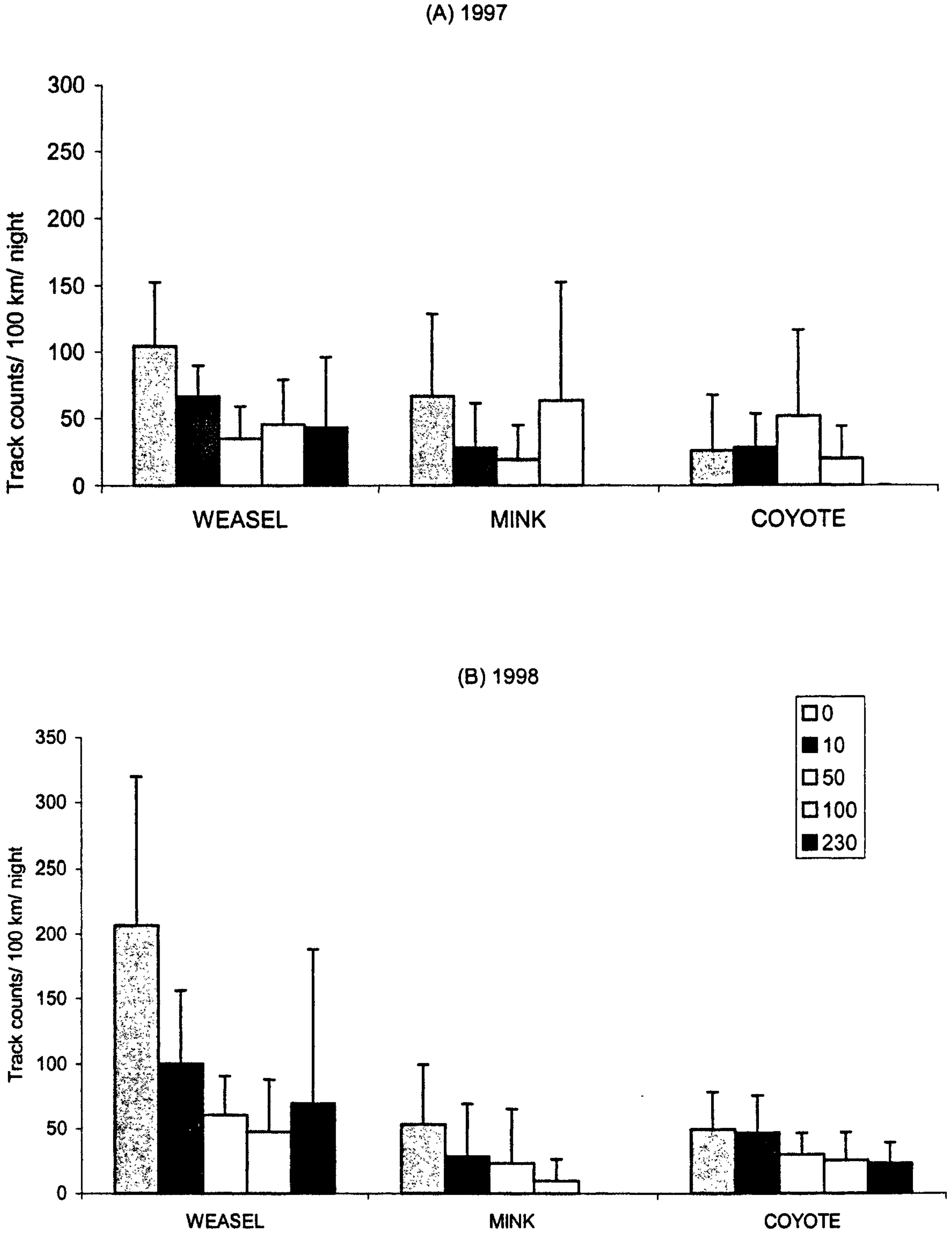


Figure 25: Mean carnivore track counts at different distances from lakes (0, 10, 50, 130, and 230 m) on reference grids in (A) 1997 and (B) 1998 (+/- 2S.E.; n=12).

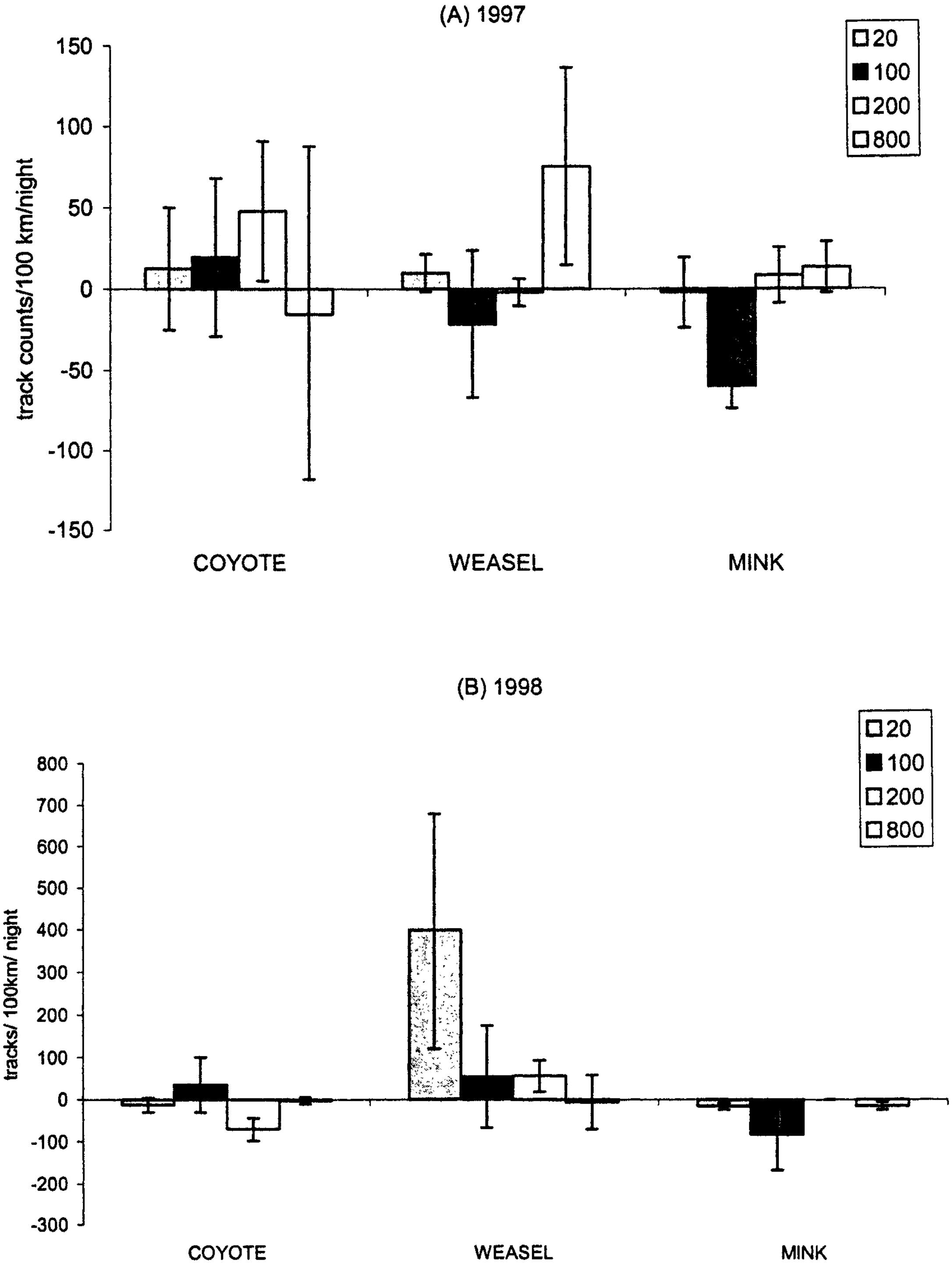


Figure 28: Average differences in carnivore track counts between buffer strips and reference grid areas (tracks on buffer strip -reference) on 10 m lines at 20, 100, 200, and 800 m width treatments in (A) 1997 and (B) 1998 (+/- 2 S.E.; n=3).

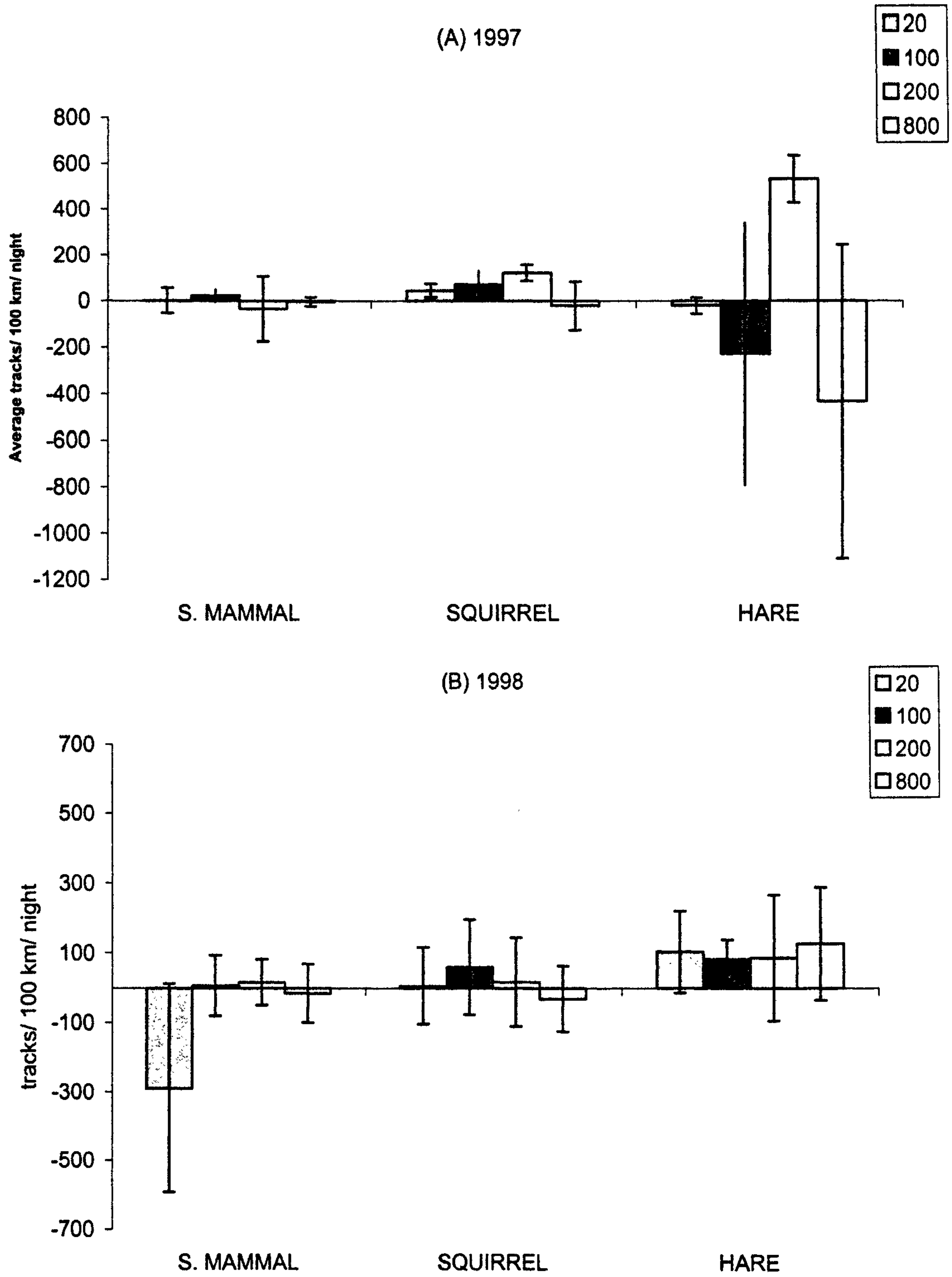


Figure 27: Average differences in small mammal prey track counts between buffer strips and reference grid areas (track counts on buffer strip –tracks on reference lines) on 10 m lines at 20, 100, 200, and 800 m width treatments in (A) 1997 and (B) 1998 (+/- 2 S.E.; n=3).

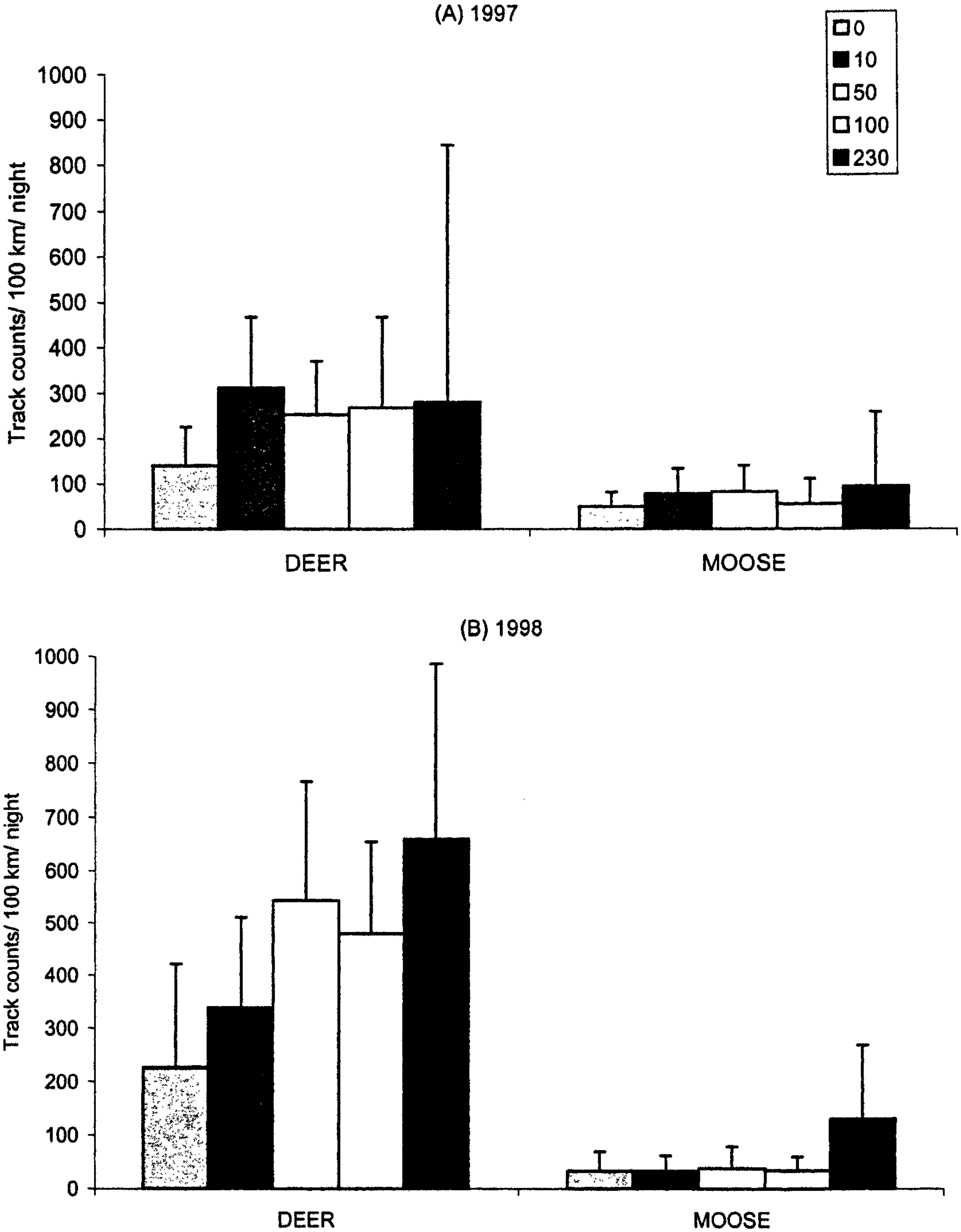


Figure 26: Mean ungulate track counts at different distances from lakes (0, 10, 50, 130, and 230 m) on reference grids in (A) 1997 and (B) 1998 (+/- 2S.E.; n=12).

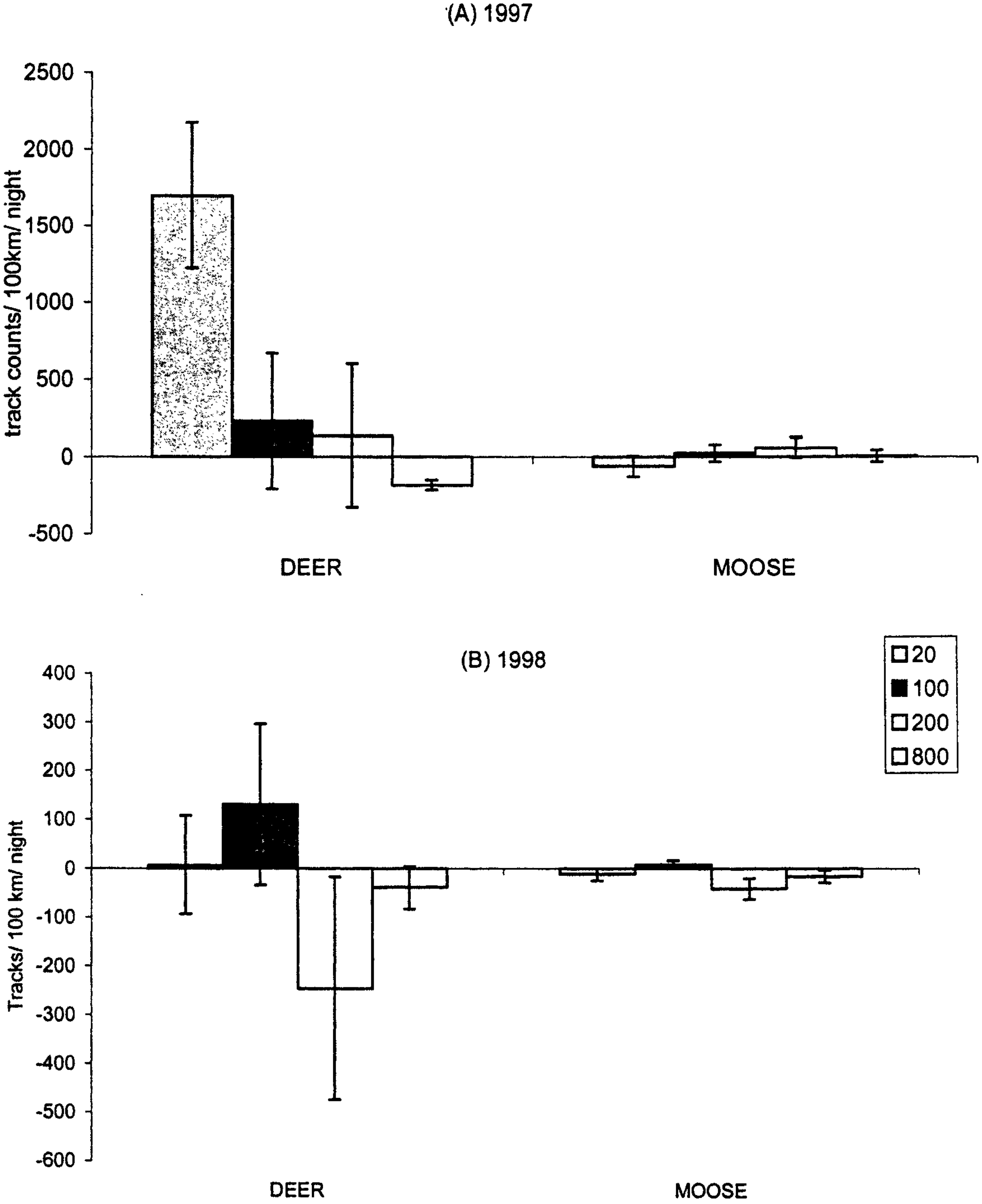
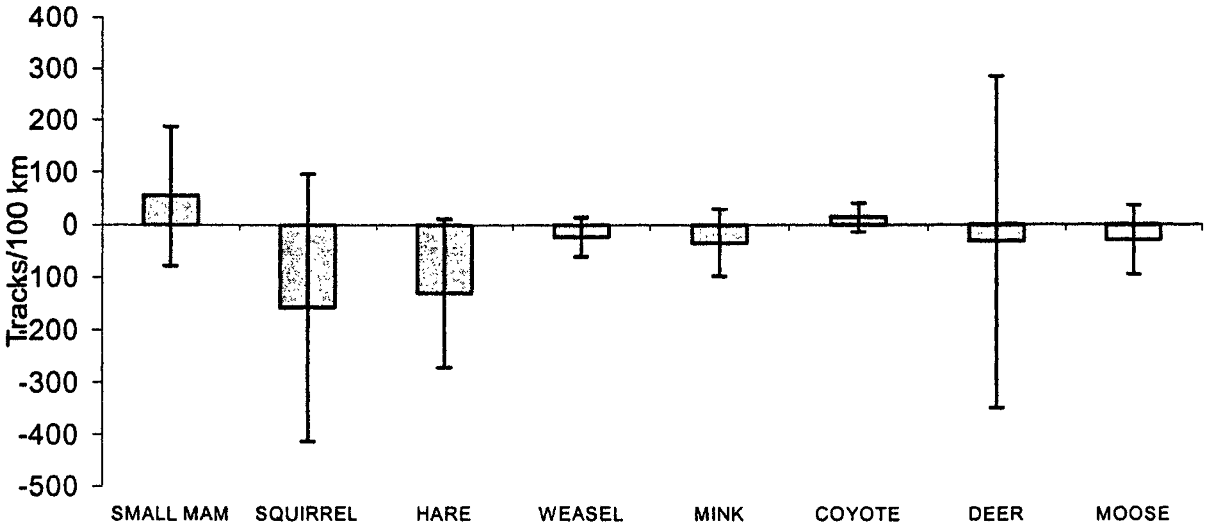


Figure 29: Average differences in ungulate track counts between buffer strips and reference grid areas (tracks on buffer strip – tracks on reference lines) on 10 m lines at 20, 100, 200, and 800 m width treatments in (A) 1997 and (B) 1998 (+/- 2 S.E.; n=3).

(a)1997



(b) 1998

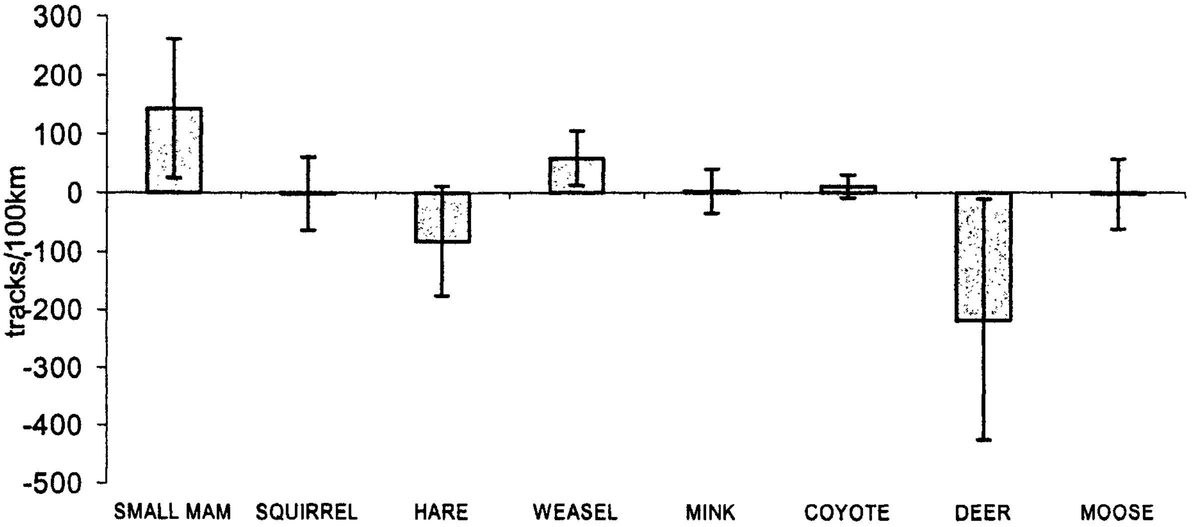
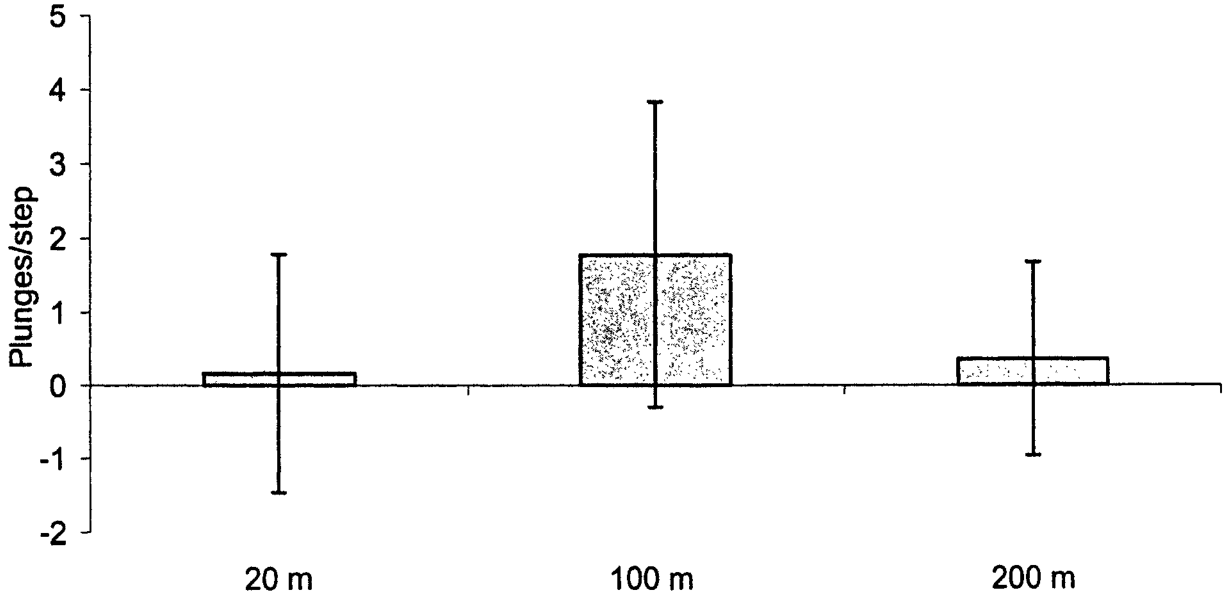


Figure 30: Mean difference in track counts between cut-block and reference areas in (A) 1997 and (B) 1998 (+/- 2 S.E.; n=9).

(A) Mean difference in plunges between buffer strips and reference grid areas at 20, 100m, and 200 m wide lakes (+/- 2 S.E.)



(B) Mean difference in turns/step between buffer strips and reference grid areas at 20, 100m, and 200 m wide lakes (+/- 2 S.E.)

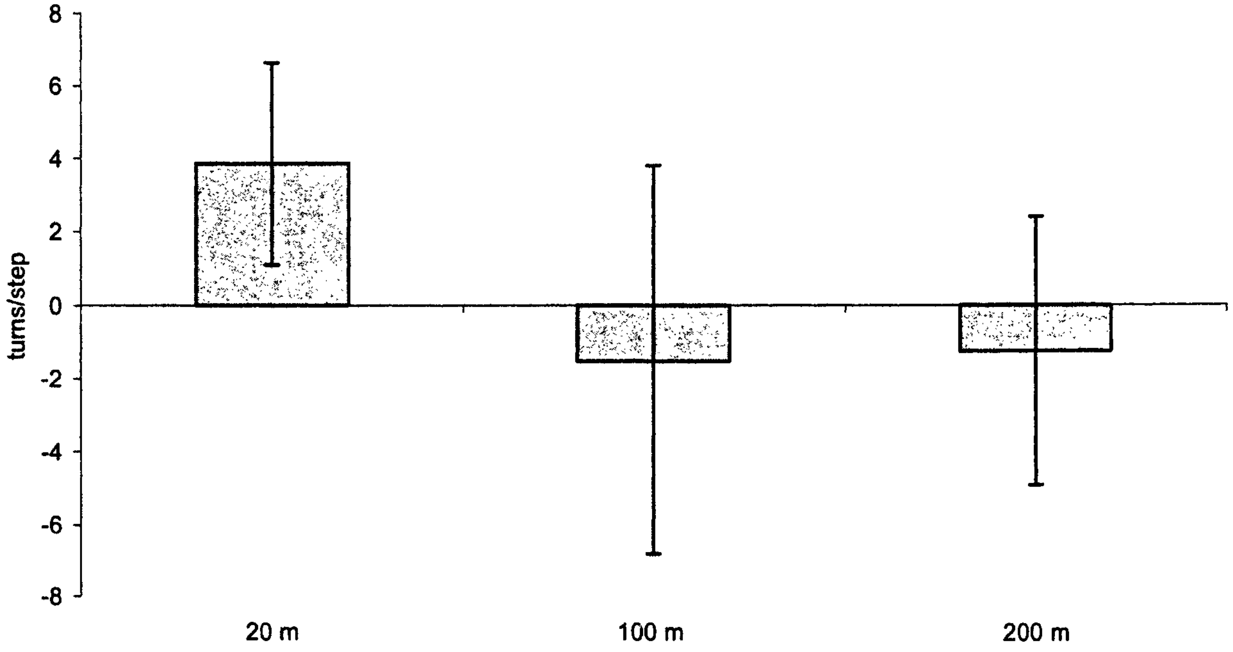
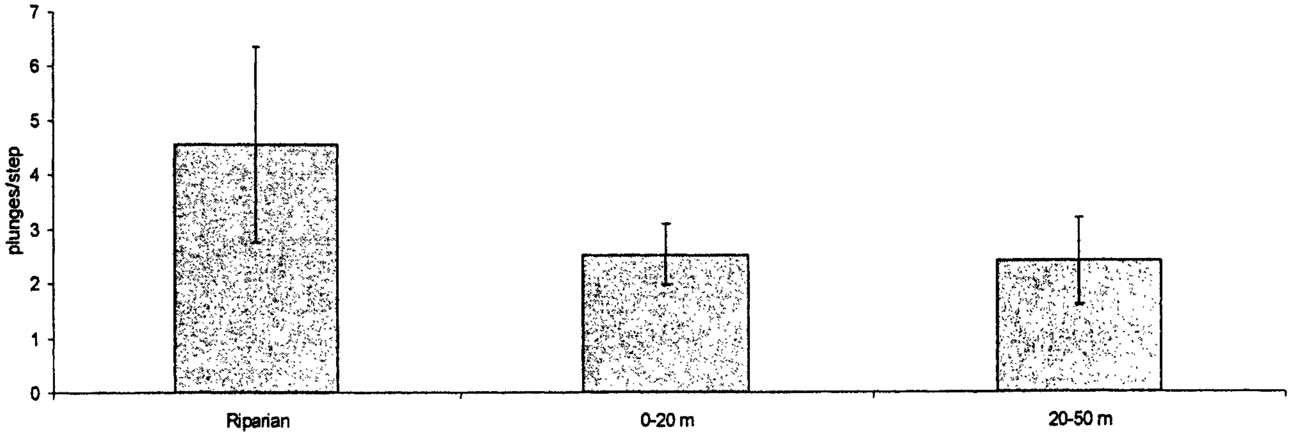


Figure 32: Average difference in plunges / step and turns/step between buffer strips and reference grid areas at 20, 100m, and 200 m wide lakes (+/- 2 S.E.=3).


(A) Average plunges/step

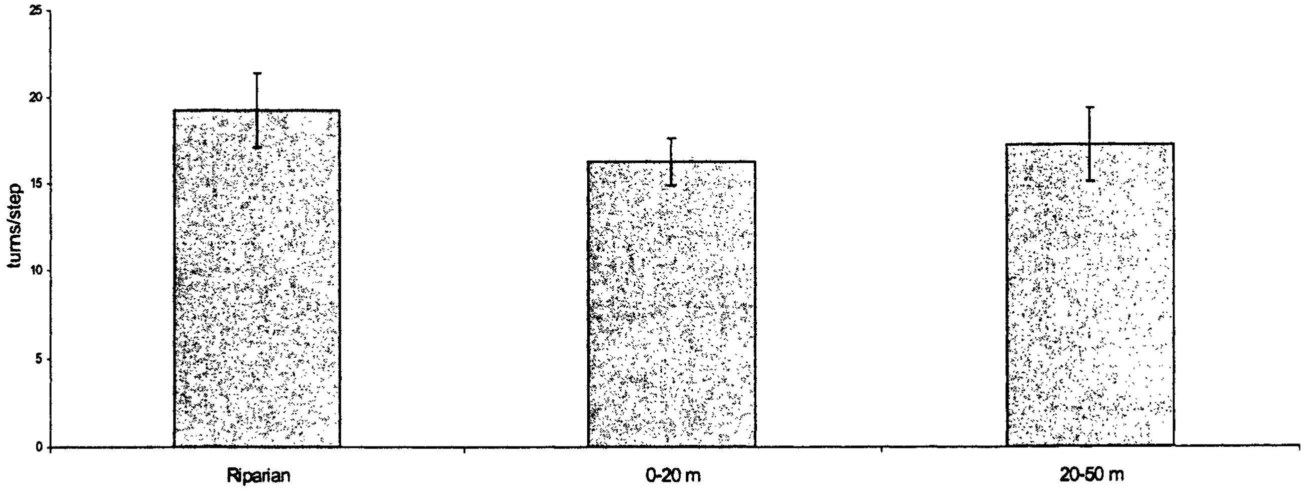

(B) Average turns/step

Figure 31: Average foraging indexes of weasel (A) plunges/step and (B) turns/step in zones at different distances from lakes (+/- 2 S.E.; n=9).

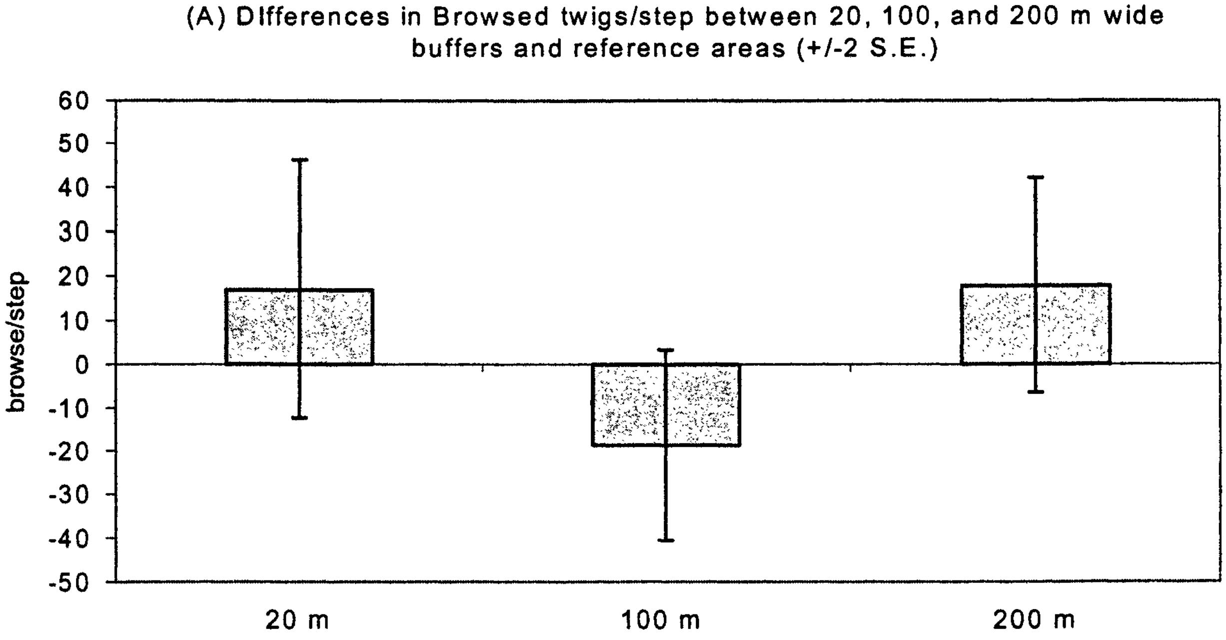


Figure 33: Average differences in browsed twigs/step between 20, 100, and 200 m wide buffers and reference areas (+/-2 S.E.; n=3).

CHAPTER V: MANAGEMENT IMPLICATIONS

Fish and wildlife management involves complex decision making processes. Those processes can be divided into Science and Management. The role of Science is to provide advice to Management. Management, in turn, evaluates scientific information, in conjunction with stakeholder interests, to make decisions. Those decisions are used to regulate industry during resource extraction activities. Past management decisions have been criticized due to suppression of scientific uncertainty, and those decisions have had disastrous economic and social consequences in Canada (Hutchings *et al.* 1997).

The Terrestrial, Riparian, Organisms, Lakes, and Streams (TROLS) research project was developed with the intention of providing reliable management recommendations to guide forestry operations adjacent to lakes in the mixed-wood boreal. The TROLS project was created by a group of university researchers in conjunction with industry partners. Thinking about this research was an iterative process occurring through many workshops, conferences, and seminars held at the University of Alberta. Many variables were considered in evaluating the effects of different width buffer strips including mammals, birds, fish, amphibians, vegetation and hydrology. This scientific advice needs to be considered in light of the operational limitations associated with forest harvesting in the mixed-wood boreal. It is not the role of scientific researchers to generate management recommendations in isolation. Management decisions will ultimately be generated following consultation with the full gambit of stakeholders including industry, First Nations, environmental groups, and public (including different levels of government).

The goal of my thesis was to provide managers with scientific advice on the use by mammals of the riparian forest, and the effects on use by mammals of forest harvesting adjacent to lakes. I evaluated use by mammals of 20, 100, 200 m wide buffer strips with respect to forest reference areas. Ecological processes governing the distribution and abundance of organisms are poorly understood (Underwood 1990), and ecosystem experiments will be required to further our understanding of those mechanisms (Carpenter *et al.* 1995). Some of the inferences I have made regarding ecological processes may legitimately be questioned. For this reason, I have emphasized the results I obtained while conducting my research. Those results will form a useful basis for discussion regarding management of riparian forest areas. I trust my advice will not be filtered or swayed in the management decision making process:

1. SMALL MAMMAL ABUNDANCE DOES NOT DIFFER BETWEEN RIPARIAN FOREST AND UPLAND FOREST AREAS.

   Abundance of forest dwelling species, such as red backed voles and deer mice, was similar, or sometimes lower, near lakes as compared to farther away. Abundance of meadow voles, meadow jumping mice, and shrews was greater adjacent to lakeside forest edge in wet, grass and shrub dominated riparian zone areas. Although small mammal abundance was elevated in riparian zones, no significant differences in small mammal abundance were observed among interior forest transects (50, 100, and 800 m) further from lakes. Based on these results, I did not find any evidence to indicate that forest harvesting activities should be excluded from the riparian forest.

2. RIPARIAN FOREST BUFFER STRIP WIDTH DOES NOT AFFECT SMALL MAMMAL ABUNDANCE IN FOREST ADJACENT TO LAKES.

   Buffer strip width had minor effects on small mammal abundance in the mixed-wood boreal forest. Red-backed vole and deer mouse abundance was similarly elevated in 20, 100, and 200 m buffer strips with respect to forest reference areas following harvest. Meadow voles, meadow jumping mice, and shrews were all present in riparian forest buffer strips of different width. This study indicates that riparian forest buffer strip width (20, 100, or 200 m) does not affect small mammal abundance adjacent to lakes in mixed-wood boreal forest.

3. RIPARIAN FOREST BUFFER STRIP WIDTH DOES NOT AFFECT WINTER HABITAT USE OR MOVEMENT OF MAMMALS ADJACENT TO LAKES.
   Track-count surveys of small mammal prey, carnivores, and ungulates indicate that winter use of forest areas does not significantly differ with distance from lakes in mixed-wood boreal. We did not detect significant differences in winter use among 20, 100, 200 m wide buffer strips and forest reference areas. Different width riparian forest buffer strips likely do not affect winter habitat use by mammals. Riparian forest buffer strips likely do not function as travel corridors for mammals, any more than upland areas, in the mixed-wood boreal forest.

The above management implications pertain to mammals in the mixed-wood boreal forest of north-central Alberta. Management decisions regarding buffer strip widths adjacent to lakes should also incorporate other taxonomic groups such as fish, amphibians, and songbirds (Hannon *et al.* 2002, in press). Future research should address cumulative effects on fish and wildlife populations of other industrial development operations adjacent to lakes in addition to forestry (e.g., oil and gas exploration).

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