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**Small Mammal Response to Habitat Change Following Fire
in the Taiga of Southeastern Manitoba**

By

Monica Reid-Wong

**A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree of**

MASTER OF SCIENCE

**Department of Zoology
University of Manitoba
Winnipeg, MB**

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A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University

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of

Master of Science

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Abstract

Small Mammal Response to Habitat Change Following Fire in the Taiga of Southeastern Manitoba

by

Monica Reid-Wong

The influence of fire on small mammal populations was investigated in the taiga of southeastern Manitoba. Small mammals were sampled by annual removal trapping in six different habitats over twenty-five years at Taiga Biological Station (TBS). Changes in temporal patterns of short-term abundance and long-term population synchronicity were investigated for fluctuating numbers of small mammals. The southern red-backed vole (*Clethrionomys gapperi*), the deer mouse (*Peromyscus maniculatus*), and the masked shrew (*Sorex cinereus*), were the three most common small mammals captured.

Examination of population fluctuations revealed that while fire-induced changes in food availability, cover and moisture were likely responsible for differences in small mammal abundance, populations of individual species were alternatively affected by unknown, large-scale, synchronizing influences. This discovery became evident through the common occurrence of similar peak abundance years for *C. gapperi*, regardless of habitat-type or distance between sampling sites. Additionally, the examination of annual combined small mammal biomass revealed a distinct pattern, with a repetitive maxima occurring every 3- to 4- yrs at TBS across all six sites.

The response of small mammal communities to habitat succession was assessed through changes in species richness, diversity and trophic structure over time. Species richness and diversity among the small mammal communities increased during the initial five years following fire, but declined during subsequent years across most sites. The granivore-omnivore, *P. maniculatus*, and to a lesser extent the grazer-omnivore, *C. gapperi*, were very responsive to the recently burned habitat through their rapid increases in numbers on several of the sites. The insectivore, *S. cinereus*, responded to conditions on severely burned sites through a reduction in its numbers across many of the plots, for several years following the fire.

Finally, the influence of biotic and abiotic factors on small mammal distribution and abundance was examined. Individual microhabitat variables surrounding each trapping station were identified and quantified through percent cover estimates to determine if they had an effect on small mammal capture rates. While several microhabitat features appeared to be associated with a particular small mammal species, overall macrohabitat (i.e., the entire area encompassed by the trapping grid) characteristics were better determinants of species presence and abundance.

Acknowledgements

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My initiation into field research began with the deposition of Brian my son, Sasha my dog, and me, along with all of our food and equipment at the mouth of the Blind River in late April, by Bill Conley and his ATV. Bill's parting comment after assessing the dubious nature of the river ice (and after providing Brian with a long pole to test the ice before he took another step) was, "good luck lady".

To the many visitors I have had during my time at the station, thank-you for your good company and cheerful help with the myriad of camp chores. To my family, thank-you for your patience and support. Financial assistance for this project was provided by the Taiga Biological Station Research Trust, the Orville Erickson Memorial Scholarship Fund (Canadian Wildlife Federation), and the Richard C. Goulden Memorial Scholarship (Manitoba Chapter of the Wildlife Society).

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General Introduction

The boreal forest or taiga forms a broad circumpolar belt between 47° to 70° north latitude encompassing an area of 14.7 million km², approximately 11% of the earth's land surface and about 35% of Canada's land area (Kimmins and Wein 1986; Bonan and Shugart 1989; Bourgeau-Chavez et al. 2000). The North American segment of this circumboreal forest is the most extensive forest ecosystem of our continent and probably the least understood, especially in terms of the effects from perturbations on the structural and compositional complexity of the forest (Schmiegelow et al. 1997). A mixture of coniferous and deciduous tree species, the boreal forest covers an east-west region from Newfoundland, across central and northern Canada, westward to the Rocky Mountains and northwestward to Alaska (Rowe 1972; Scotter 1972). Much of this biome is populated by inherently flammable plant material (Auclair 1983) providing fire an evolutionary opportunity in boreal ecosystem development (Mutch 1970; Rowe 1983).

Fire influences floristic and faunistic diversity through ecological disturbance of the landscape (Rowe and Scotter 1973). Disturbance regimes created by fire operate at different spatial and temporal scales and provide heterogeneity to the environment through the production of stand patches of different age and size, vegetation structure and floristic composition (Heinselman 1970; Morneau and Payette 1989; Payette et al. 1989). Plant and animal species' distribution are often modified by such disturbance regimes (Payette 1992) and many changes may occur in the community ecology of small mammals during

post-fire vegetative succession (Fox 1983). Difficulty arises in any attempt to pinpoint cause and effect relationships between the action of fire and the response of small mammals to habitat change, in part, because of the multitude of variables in the environment that have now been altered (Bendell 1974).

Boreal forest small mammals have evolved in an environment characterized by periodic ecosystem disturbances. Species will respond positively or negatively to habitat change, depending upon whether changes in the physical and biological environment are towards or away from the creature's optima, in terms of its survival requirements (Kirkland 1990).

This thesis investigates the effects of fire on patterns of small mammal abundance, distribution and community composition through time, following the May 1980 forest fire at Taiga Biological Station, Wallace Lake, MB.

Thesis Background and Objectives

Small mammals comprise a significant proportion of the faunal biomass in forest communities (Hamilton and Cook 1940) and are an integral base of the forest consumer food chain (Golley 1960). The small mammal community is an important component of the forest ecosystem in its consumption of primary production and for its contribution to secondary production as producers of animal protein for higher trophic levels (Pruitt 1966; Maser et al. 1978; Rose and Birney 1985).

An advantage of research on small mammals is that their populations can be readily sampled with standard trapping techniques and they provide many different opportunities for measuring species responses to habitat change (Tevis 1956; Ahlgren 1966; Naylor and Bendell 1982; Martell 1984; Clough 1987). Small mammals such as the southern red-backed vole (*Clethrionomys gapperi*) have been used as indicator species for old-growth (stable-aged) forests (Nordyke and Buskirk 1991) and in the assessment of habitat required by animal species classified as *sensitive*. Some of these sensitive species include the northern flying squirrel, *Glaucomys sabrinus* (Payne et al. 1989), the hoary bat, *Lasiurus cinereus* (Franklin et al. 1981) and amphibian species such as the giant salamanders, *Dicamptodon spp.* (Blaustein et al. 1995). Therefore, small mammals allow us to enhance our understanding of forest ecosystems through their association with a particular habitat type and/or condition.

The six study plots for small mammal research were originally established in 1977 at Taiga Biological Station (TBS) to track species and populations over time. They have been used also for studies on the effects of subnivean CO₂ on small mammals by Penny (1978). The morphometric data on the small mammals presented in this thesis were collected over this period of twenty-five years by a dedicated group of volunteers with varying degrees of trap-setting experience. The vegetation data presented are from plant surveys conducted during three separate time periods (1976, 1982 and 2000) of TBS history. Major emphasis was placed on plant data collected during the most recent vegetation survey of the small mammal study plots. However, the primary focus of this thesis will be on the small mammal communities inhabiting the six study plots at TBS.

The main goals of the thesis are:

- (i.) to investigate the long-term response of small mammal populations after fire through the changing patterns of species distribution and abundance over twenty-five years;
- (ii.) to examine the influence of habitat succession following fire on small mammal community structure across sequentially shorter intervals of time;
- (iii.) to identify factors within the microsite or immediate trapping area that may affect small mammal activities and capture rates.

The information obtained in this thesis is largely the result of a retrospective survey of small mammal trapping records collected over twenty-five years. The analyses of the data are intended to be exploratory. Cause and effect

relationships (as derived through controlled experimentation) cannot be shown between habitat variables and population response. However, it may be possible to describe factors that are important in predicting structure and diversity of small mammal communities (Carey and Johnson 1995) and relating those measurements of habitat properties to the distribution and abundance of the communities at TBS.

SECTION I.

Patterns in the Distribution and Abundance of Small Mammals

Section I. Abstract

Populations of small mammals were sampled annually by removal trapping in six different habitats over a twenty-five year period (1977-2001) near Wallace Lake, Manitoba. A total of 2,384 small mammals and 179 sciurids representing 14 species were captured in 43,800 trap-nights. The three most common species captured, in descending order of abundance, were *Clethrionomys gapperi* (southern red-backed vole), *Sorex cinereus* (masked shrew) and *Peromyscus maniculatus* (deer mouse). Changes in small mammal populations following fire were observed over time and the temporal patterns of short-term fluctuation and long-term synchronicity were examined.

Deer mice increased in number within the first few years following the burn to population levels above pre-fire levels; subsequent trapping sessions were unable to duplicate these early post-fire capture levels for *P. maniculatus*. Red-backed voles also increased in abundance within three months after the fire on most sites, but they soon experienced a rapid decline in numbers until their short-term recovery during the mid- to late- 1980's.

Similarities in the fluctuating abundance of red-backed voles were noted across several of the sampling plots at TBS, providing some evidence to suggest that extrinsic agents are affecting *C. gapperi* populations through the synchronous occurrence of peak abundance years. Additionally, evidence of synchrony in small mammal biomass production was noted, with peak accumulations every 3- to 4- yrs among the fauna at TBS.

Section I. Patterns in the Distribution and Abundance of Small Mammals

Introduction

Population variations or cycles occur when the temporal abundances of small mammals change. Temporal abundance is influenced by spatial patterns of distribution. Small mammals are often distributed in clumps or patches of aggregations - the result of response by the animals to habitat differences, stochastic events, reproductive patterns and social behaviour (Smith 1996). The field records at Taiga Biological Station suggest that populations of small mammals fluctuate considerably over time and space with little evidence of periodicity (regularity) in most species. Studies of microtine rodent (voles and lemmings) cycles showing regular and/or extreme density fluctuations have been well documented in the past (Elton 1942; Kalela 1962; Koshkina 1965; Fuller 1969). In central and northern Fennoscandia (Hansson and Henttonen 1985; Marcstrom et al. 1990) and in the coastal tundra of Barrow, Alaska (Batzli et al. 1980), vole populations are considered to be cyclic with a 3- to 4-year periodicity.

A number of theories have been advanced regarding rodent cycles because "of their enigmatic appeal to ecologists since such phenomena seem to violate balance and equilibrium" (Sandell et al. 1991, p 281), and because of the controversy surrounding the origin of forces behind cycling hypotheses in small mammals (Krebs 1996). Distinctions occur between the factors affecting population increase in small mammals: theories that stress extrinsic agents

(weather, food supply, predators, parasites) and theories that stress intrinsic agents (hormonal, genotypical, behavioural) (Krebs et al. 1973; Begon et al. 1990).

The primary aim of this section is to investigate the response of small mammal populations after fire, through the examination of species distribution and abundance in six different habitats over twenty-five years. Specifically, this section will (1) compare long-term small mammal population fluctuations among study plots to check for any apparent patterns of co-occurrence of periodicity between species; (2) attempt to identify large-scale patterns of synchronicity among individual species.

Literature Review

Temporal and spatial processes:

Temporal and spatial processes that impact population demography and determine species abundance, assemblage and distribution are still poorly understood (Brown and Heske 1990; Steen et al. 1996; Peles et al. 1999). Most organisms live in spatially heterogeneous environments (Diffendorfer et al. 1999) that are distributed neither uniformly nor randomly, but instead, often form aggregates called patches (Legendre and Fortin 1989; Bowers and Matter 1997). Consequently, the temporal abundance of small mammals can exert a strong influence on the community in which they live, and in turn, on the breeding success and survival of many of the terrestrial and avian predators dependent upon this food base (Hamilton and Cook 1940).

Small mammal distribution across the landscape is affected by their selection of habitat. The distribution patterns of northern small mammals depend in large part on differential habitat use (Adler and Wilson 1987; Wywiałowski 1987; Barry et al. 1990). These small-bodied, short-lived species, with high reproductive rates and high habitat specificity, when found in small patches of disturbed forest, often show strong, short-term density responses to fragmented landscapes (Martell and Radványi 1977; Monthey and Soutiere 1985; Sullivan et al. 1999).

Understanding the methods by which animals select habitat may be useful in predicting changes in community structure that follow alterations of

ecosystems (Dunning et al. 1992). If small mammals recognize different habitats as patches, then the size of the patch greatly influences the animal's activity and strategies of habitat use (Morris 1984). The macrohabitat (i.e., a large patch type relative to the movements of the individual) constitutes a unit or area in which the individual performs all of its biological functions during a typical activity cycle. The microhabitat (i.e., a small patch size relative to the movements of the individual) consists of physical and chemical variables that influence the allocation of time and energy invested by the animal (Morris 1989).

Small mammal populations may need to be examined over a broad range of scales (i.e., one to several hundred kilometres) in order to determine if a phenomenon such as spatial synchrony occurs within their population dynamics (Steen et al. 1996). Little consensus exists however, on the spatial scales wherein habitat use should be monitored (Morris 1989). Characterizing an ecological system at different temporal scales (i.e., short-term intervals of several years or long-term periods of several decades), and at different spatial scales (i.e., microhabitat-size vs. macrohabitat-size study areas), can affect the interpretations of ecological patterns and processes (Menge and Olson 1990; Brady and Slade 2001). Consequently, any study of habitat preference must identify the spatial and temporal scale at which the habitat influences patterns of distribution and abundance (Morris 1989; Diffendorfer et al. 1999; Orrock et al. 2000).

Caution must be exercised in any attempts to extrapolate results from studies conducted at one scale to predict the outcome at another scale (Bowers

and Matter 1997). By ignoring scale, the risk of drawing incorrect conclusions regarding species relative abundance and habitat importance, increases (Wiens et al. 1989).

Population cycles:

The response of a single species and/or community to fluctuations in abiotic conditions, availability of resources, and abundance of other species, may provide information on factors affecting local distribution and abundance of each species. Insight into these relationships must come from long-term studies (Brown and Heske 1990; Marcstrom et al. 1990; Meserve et al. 1999; Getz et al. 2001).

For many years, arvicoline rodents (*Clethrionomys* and *Microtus*) have been known to fluctuate in numbers (Koshkina 1966; Fuller 1969) and exhibit population variations or "cycles" across many amplitudes and frequencies. Batzli et al. (1980) noted that in studies of lemming populations conducted at Barrow, Alaska, a large fluctuation has been traditionally called a "cycle" if the amplitude is three or more orders of magnitude compared with previous and subsequent trapping records. Krebs and Myer (1974) described the structure of the population cycle as a series of phases, including: increase, peak, decline, and low numbers. In their summary of the changes that accompany population cycles in voles and lemmings, Krebs and Myers (1974) suggested that an intrinsic, self-regulatory system could exist within the small mammals, preserved by natural selection, if it provided a genetic advantage to such populations.

The use of “cycle” does not imply regularity (Birney et al. 1976). Many rodent populations fluctuate erratically and seldom show regular amplitudes and frequencies. However, the term *cycle* does refer to a repeatable process in time (Krebs 1996). Non-cyclic populations of small mammals have been identified in North America (Taitt and Krebs 1985; Wolfe 1996) and in southern Fennoscandian forests (Hansson and Henttonen 1985; Hanski et al. 1993), which do not exhibit dynamic oscillations in density, fluctuating only seasonally in abundance.

Krebs (1996) expressed the view that the mathematical definition of cyclic fluctuations appearing in Fennoscandian research in the early 1980's created confusion, because it was now possible to have “cyclic” and “non-cyclic” population definitions based on unrelated platforms. Instead, Krebs (1996) maintained a biological definition, which sought to define population cycles through behavioural and genetic parameters involving phase-related changes in age at sexual maturity, reproductive rates and survival.

Many competing hypotheses on the underlying mechanisms of small mammal population cycles have been described (Chitty 1960; Krebs and Myers 1974; Hansson and Henttonen 1985; Batzli and Lesieutre 1991; Hanski et al. 1993). Boonstra et al. (2001) noted two major peaks in *Clethrionomys rutilus* populations in the Kluane Lake ecosystem, which coincided with the late decline or low phase of the snowshoe hare cycle. Four possible explanations were proposed for this relationship, based on factors such as: competition, predation, stochastic processes and nutrient release. Boonstra et al. (2001) surmised that

the key variable limiting *Clethrionomys* in the boreal forest of North America was their overwintering survivability, which is a function of the availability of overwintering food (i.e., berries from dwarf shrubs) and features of the snow cover, not predation.

Many of the hypotheses presented as significant factors in cycling can readily fit into the four main categories proposed by Boonstra et al. (2001) to describe the inverse relationship between vole abundance and snowshoe hare decline. *Competition*, particularly interference competition has been extensively studied in the past to determine if competitive interactions were responsible for small mammal distribution, resource use and relative abundance (Getz 1969; Morris and Grant 1972; Crowell and Pimm 1976; Price 1978; Abramsky et al. 1979).

Galindo and Krebs (1985) criticized several of these earlier experimental studies because of their numerous drawbacks in terms of a lack of replication and application to the natural environment of the creatures involved. Populations of *Peromyscus maniculatus*, *Clethrionomys rutilus* and *Microtus pennsylvanicus* were investigated in southwestern Yukon, and no evidence of competitive interactions were found to influence these species use of habitat and relative abundance. Wolff and Dueser (1986) found also a lack of competitive behaviour between *Clethrionomys gapperi* and *Peromyscus maniculatus* (sympatric species at TBS) in deciduous forests of Virginia, even though these species have extensive habitat overlap. Nonaggressiveness was due to differences in resource use and habitat selection. Morris (1996) searched for potential competitive

interactions among two habitat specialists (*Peromyscus maniculatus* and *Clethrionomys gapperi*), and one generalist (*Tamias amoenus*), during a study of habitat specialization in southwestern Alberta. *Peromyscus* was found to specialize on the xeric habitat, *Clethrionomys* on the alternative mesic habitat, while *Tamias amoenus* was an opportunist, with no preference for either habitat, and existed by exploiting the underused margins of the two specialists. Habitat specialization allowed for coexistence among these species.

The *predation* hypothesis for rodent cycles asserts that direct mortality caused by predators and indirect pressures created by their continued presence are sufficient to cause cyclic fluctuations (Krebs 1996). Virtually all predators in the boreal forest eat *Clethrionomys*, but Boonstra et al. (2001) could find little evidence to support weasel (*Mustela erminea*) abundance as a limiting factor in vole population density in the Kluane region. In southern Fennoscandia and central Europe, stable populations of microtines appear to be controlled by generalist predators that are able to alternate between prey species (Hansson and Henttonen 1985; Hansson 1987). In central and northern Fennoscandia the number and density of prey species decrease as latitude increases and many specialist predators exist that share one main prey species. The lack of diversity for alternative prey is suspected of being unable to buffer the variations in vole abundance, therefore, the cycling of voles ensues.

Mustelid-rodent dynamics in northern Fennoscandia and western Finland generate a 3- to 5- yr small mammal cycle produced by delayed density-dependence of specialist predators, such as the least weasel *Mustela nivalis*, on

its prey species, *Microtus agrestis* (Hanski et al. 1993). Lindstrom (1994) also examined the role of predation on field vole fluctuations and indicated that foxes in Sweden may limit *Microtus agrestis* populations.

Sandell et al. (1991) and Krebs (1996) have both rejected this north-south dichotomy reported from numerous Fennoscandia microtine cycle studies. Sandell et al. (1991, p 281) argued that the distinction between "cyclic" and "non-cyclic" small mammal populations was artificial. He suggested the whole spectrum of population behaviours (i.e., stable to chaotic) be examined, because "the underlying mechanisms behind the population dynamics of small mammals may be the same for all populations". Krebs (1996) indicated that Fennoscandian studies were based on mathematical definitions for cycles, which used s -values (standard deviation of the logarithms of population size) to calculate the size of population cycles. In addition, Krebs (1996) suggested that southern areas of Fennoscandia have been subject to intense habitat fragmentation from agriculture that may dampen or eliminate cyclic fluctuations that may have otherwise existed in the south.

Stochastic events often involve climatic variables that create seasonal variations from year to year in the abiotic and biotic parameters of the habitat. Some of these events include: thickness and duration of snow cover, impact of weather on plant growth and berry crop production, and variations in temperature and precipitation levels. Lindstrom (1994) in southern Sweden found that the field vole (*Microtus agrestis*) did exhibit a pattern that resembled a 3- to 4- yr cycle, but was interrupted during winters of little snow cover. Increased snow cover is

assumed to make the hunting of generalist predators more difficult, while decreased snow cover has a dampening effect on vole populations by making them more accessible to predators (Hansson and Henttonen 1985).

West (1982) noted that the duration of snow cover in central Alaska during spring melt could adversely affect *Clethrionomys rutilus* populations, particularly if the snow disappeared too quickly, exposing the overwintering berry supply to foraging birds and insects. The critical period of food shortage (or time of lowest fruit abundance) in early summer, coincided with the time of first litter reproduction, low survivorship and lowest annual density.

Vickery and Bider (1978) examined the effects of weather on *Sorex cinereus* activity. Rainfall was the most important factor influencing *Sorex*, with total summer activity and population size being enhanced by warm, wet springs. Vickery and Bider (1981) also discovered that rainfall had a major effect on the activity of the three rodents: *Clethrionomys*, *Peromyscus* and *Napaeozapus* in the forests of Quebec. The rodents were most active on rainy and on warm nights. Vickery and Rivest (1992) suggested that differential food availability (i.e., insect activity) associated with weather change was the more likely mechanism responsible for habitat choice among small mammals.

The role of food and nutrients as important factors underlying microtine demographic patterns has been extensively studied. Fluctuations in weather and variations in temperature determine both the assimilation of reserves (nutrients) and the timing of flowering in northern ecosystems. Plants in the tundra and taiga require a threshold of accumulated degree-days for flowering and fruiting (Kalela

1962). The quality and quantity of food such as *Eriophorum angustifolium* and *Solidago virgaurea*, subjected to the vagaries of northern climate, are the basic factors that are responsible for the cyclic nature of rodents in Lapland (Tast and Kalela 1971). Laine and Henttonen (1983) studied microtine populations in northern Fennoscandia to test if favourable climatic conditions (which are partially responsible for creating pulses in seed and vegetative production) triggered microtine cycles. Due to the short growing season in northern latitudes, plants require several years to accumulate sufficient reserves for growth and reproduction. The general flowering peak coincided with the increase phase of rodents; however, predators (mainly small mustelids) contributed to the depth of microtine decline.

Pucek et al. (1993) studied the population dynamics of forest rodents, *Clethrionomys glareolus* and *Apodemus flavicollis*, collected over 33 years in mature hornbeam and oak deciduous forests of eastern Poland. Small mammals reached their highest numbers in autumn of the year following the mast peaks. The heaviest seed crops of oak and beech (at intervals of 6- to 9- yrs) influenced by warm June-July temperatures were followed by subsequent, synchronous, outbreaks of forest rodents, from northeastern Russia to Western Europe. The dichotomy between "cyclic" and "non-cyclic" rodent population dynamics discussed by Sandell et al. (1991), may be a reflection of the recurrent exchanges of energy that flow between producers (trees), to primary consumers (rodents), rather than being restricted in its cause to exclusively small mammal dynamics.

Batzli and Lesieutre (1991) indicated that the availability of high quality food determined the relative abundance and pattern of habitat use by microtine rodents (*Microtus oeconomus* and *M. miurus*), in northern Alaska. High quality food spurred population growth, even when factors such as predators and disease continued operating on the population. Boonstra et al. (2001) proposed that the 10- yr snowshoe hare cycle resulted in a secondary cycle in northern red-backed voles. Food required by *Clethrionomys rutilus* (particularly sources obtained from herb and dwarf shrubs) is fertilized by large quantities of rabbit pellets. Approximately two years is needed before the berry crops respond to the influx of nutrients from pellets, with *C. rutilus* populations lagging behind population peaks of hares by 2-3 years. While smaller vole peaks are noted independent of the hare cycle, they are generally associated with stochastic weather events that affected the size of vole food (dwarf shrub berries and fungi) production.

Many hypotheses have been proposed to explain cyclic phenomena in arvicoline rodents (Getz et al. 2001), with most theories developed to reveal the mechanism of the population crash (Bondrup-Nielsen and Ims 1988). Yet, in order to understand small mammal dynamics (i.e., the cyclicity/stability dichotomy), populations must be studied over the long-term and under a variety of conditions and densities (Bondrup-Nielsen and Ims 1988).

Materials and methods

Study Area:

The study area consists of six permanent one acre or 0.4ha study plots in the vicinity of Taiga Biological Station, 51°03'40"N latitude and 95°20'40"W longitude, situated north of Wallace Lake in southeastern Manitoba (Fig. 1). The study area lies within the Northern Coniferous Section of the Boreal Forest Region Rowe (1972) or the Low Boreal Land Region (Woo et al. 1977). About 60,000 hectares of land surrounding Wallace Lake were burnt during the spring of 1980 (Fig. 2), exposing much of the local bedrock. The geology is dominated by granitic, volcanic, and metamorphic rocks of Precambrian age that have been subjected to intense glaciation. The aftermath of glaciation produced a relief of irregular, rocky, parallel ridges seldom exceeding 30m in height, and separated by poorly-drained bogs, fens and narrow lakes, that follow irregular drainage patterns towards Lake Winnipeg (Woo et al. 1977). Soils of the Wallace Lake area may consist of luvisolic, brunisolic, and organic types which developed under the humid, cooler conditions in eastern Manitoba (Mills 1984).

The study site is climatically within the low boreal land region (Woo et al. 1977) with temperature extremes of -42.5°C in winter to $+36.5^{\circ}\text{C}$ in summer (TBS weather records). Annual mean precipitation for the area is 574.0 mm with 145.2 mm as snowfall and 428.8 mm as rainfall (Environment Canada 1990). Snow may occur during October, lasting until April or May. A continuous ice cover develops in late October-early November on most lakes and waterways,

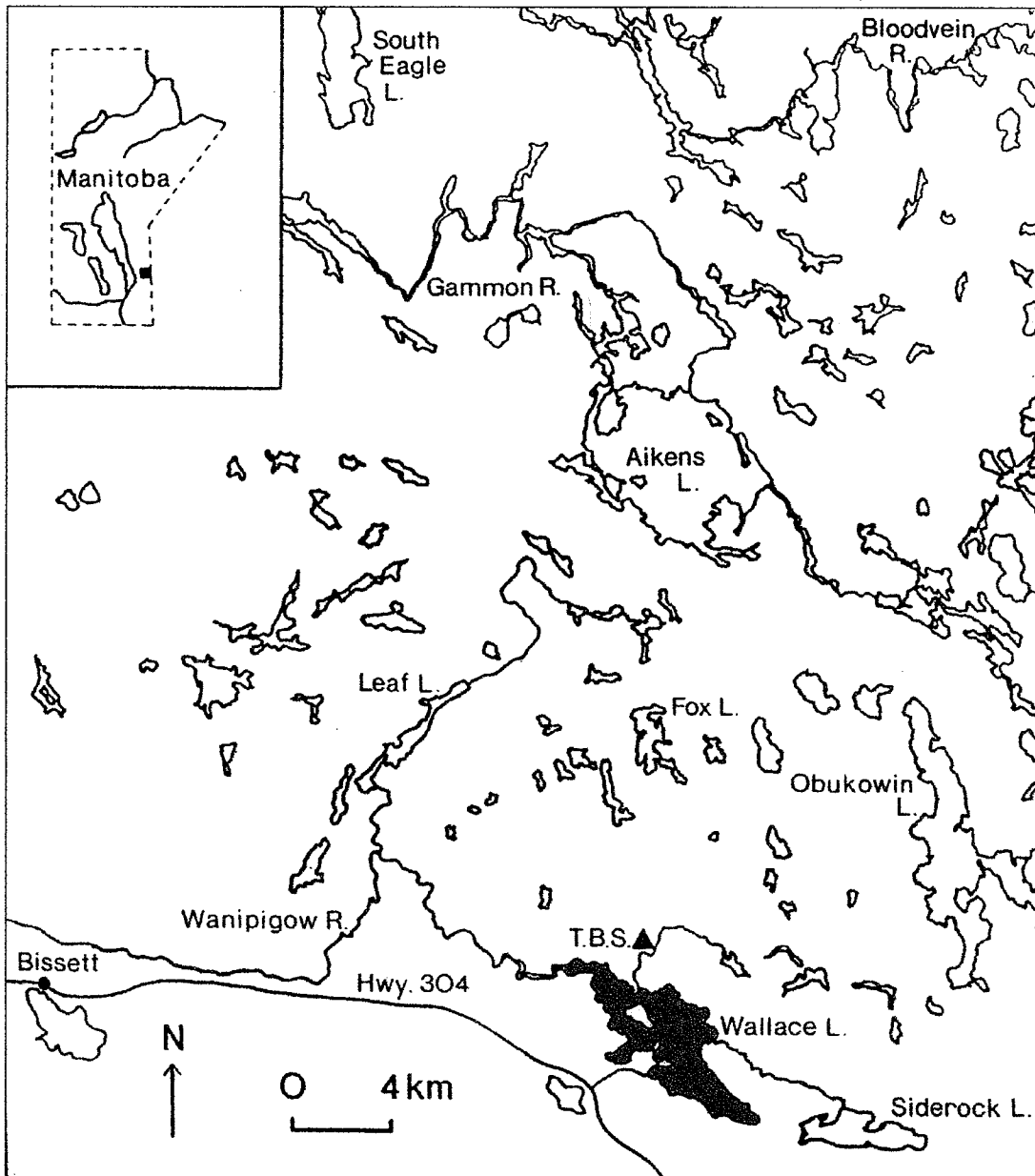


FIG. 1. The Wallace Lake study area including the location of Taiga Biological Station (T.B.S.) along the Blind River (after Schaefer and Pruitt 1991).

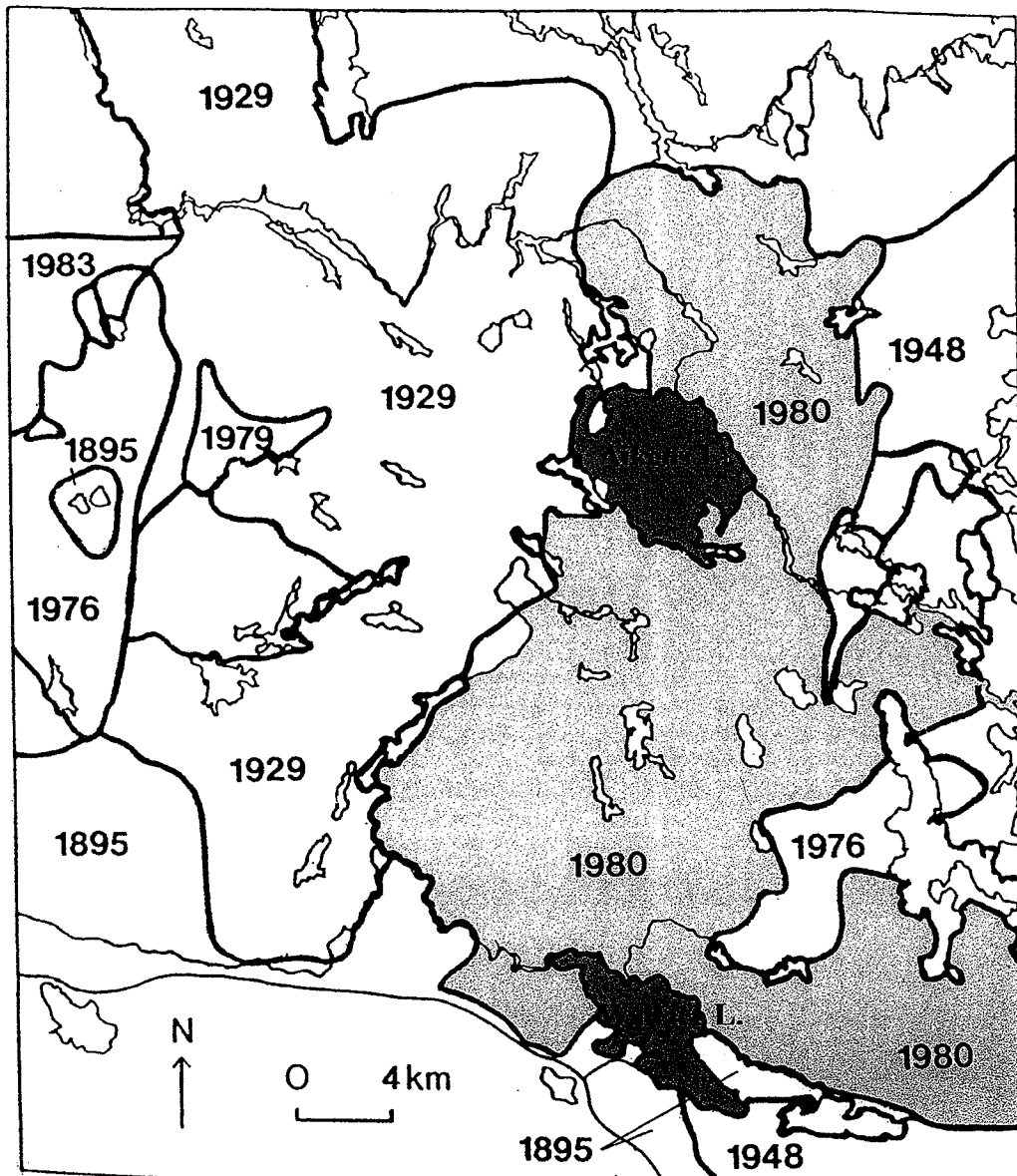


FIG. 2. Distribution and year of fire occurrence surrounding the Wallace-Aikens Lakes study area (after Schaefer and Pruitt 1991).

except in areas of fast flowing water. Breakup begins in late April or early May (TBS Blue Book records).

The study area's six small mammal plots are all located within one kilometre of the Blind River, a tributary of Wallace Lake (Fig. 3). Habitat names were chosen as being representative of the most dominant tree species on each study plot. The habitats examined included:

- | | |
|-------------------------|--------|
| (1) Alder-Tamarack Bog | (ATB) |
| (2) Aspen Upland | (ASP) |
| (3) Blackspruce Bog | (BSB) |
| (4) Alder-Ridge Ecotone | (ECO) |
| (5) Jackpine Ridge | (JPR) |
| (6) Jackpine Sandplain | (JPSP) |

Trapping:

The 0.4ha study plots were established with a square 10x10 grid with peripheral axes labelled 1 to 10 and A to J (see Fig. 4). The small mammals were captured according to methods used by Pruitt and Lucier (1958) and Pruitt (1968). One hundred labelled wooden trap markers (i.e., A1, A2, A3, etc.) per plot were placed approximately 6.5m apart at each trapping station. Two types of snap traps (Museum Specials and Schuylers) were set in an alternating arrangement on each plot for a combined total of 100 traps per plot. Each trap was attached to its identified wooden marker with a cord approximately 80cm in length; this allowed placement of the trap within the same 2m² each year and reduced trap loss.

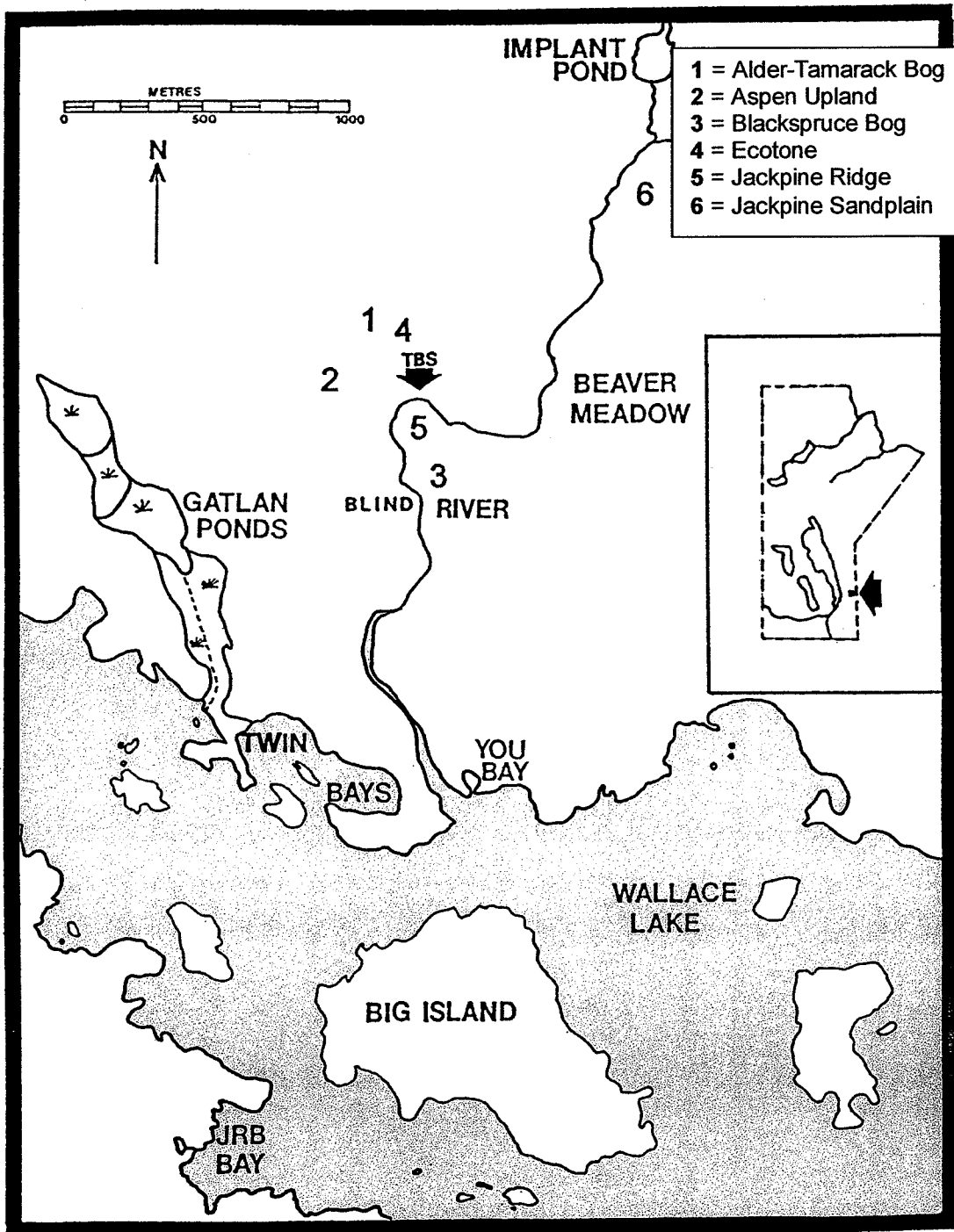


FIG. 3. Locations of the six small mammal study plots along the Blind River, a tributary of Wallace Lake (after Wheatley 1989).

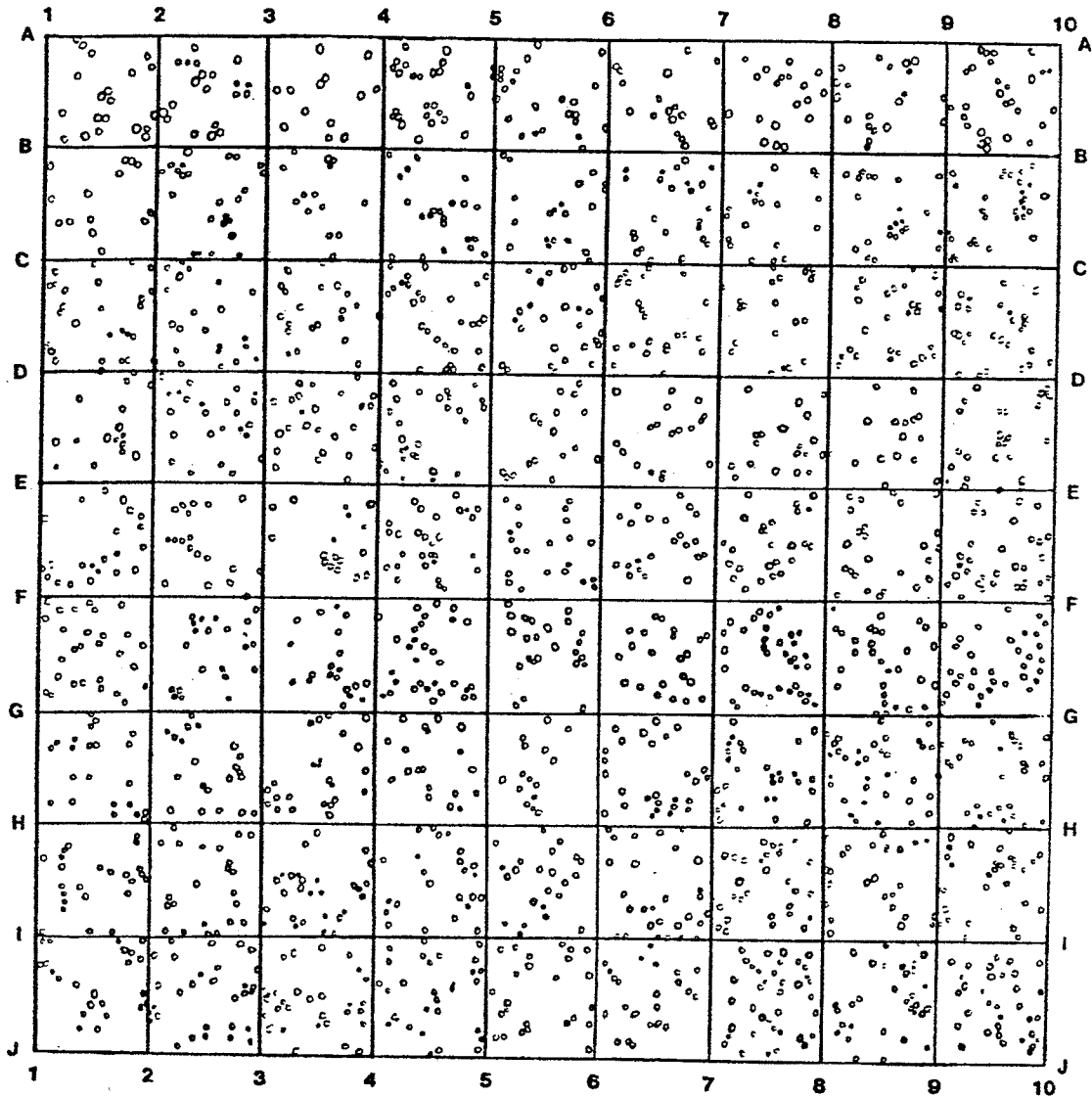


FIG. 4. A small mammal trapping grid on the Blackspruce Bog plot. Dots represent the locations of the upper canopy trees found standing two years after the 1980 fire at Wallace Lake, Manitoba (from Martin 1983).

In 2000, new Museum Specials were substituted for 25 of the older Museum Specials on each plot. The trap manufacturer company (Woodstream Corp., Lititz, Pa.), no longer produces the original Museum Special with its wooden and metal treadle. The new version has a large bright yellow plastic treadle (which is very attractive to song birds) with adjustable sensitivity. Eventually, the older Museum Specials will need replacement at TBS; therefore, a slow integration of the new trap model was indicated. The new Museum Specials were placed on all plots in 2000, and will be present thereafter for all consecutive trapping seasons. Traps were baited once, with a mixture of peanut butter, rolled oats, chopped raisins and bacon fat, and remained set for three consecutive nights. Traps were set on the afternoon of Day 1 and checked each morning on Day 2, 3 and 4. Specimens were collected on Day 2, 3 and 4 and placed in individual brown paper bags with plot location, grid marker (trapping station) number, trap type, date of capture, and brief characteristics of the surrounding habitat; the traps were then reset.

At TBS, an outdoor work area was set up for specimen preparation; here individuals could be identified and have their standard morphological measurements taken, including: total length, tail length, length of hind foot, length of ear from notch, body weight and reproductive condition. Testis size was measured in males and female reproductive tracts were examined, with the number of embryos and/or placental scars recorded. Ectoparasites were recorded, collected and preserved. Information from all small mammal specimens was transferred into a permanent record book at TBS. Skeletons from

the specimens were catalogued at the Manitoba Museum, with ectoparasites being saved for further entomological analyses.

The plots were trapped each year during the following periods: August (1982–1988; 1990–2001), September (1979) and September to October (1977, 1978, 1980, 1981 and 1989). In 1984, only the Blackspruce Bog and Jackpine Sandplain plots were trapped. The lack of trapping data in the remaining four plots during August 1984 accounts for the hiatus in many of the graphical presentations. The data provided in tables and figures may differ from actual total captures recorded in some cases; this is an effect of insufficient information (particularly during the earlier years) when gender and trap type were sometimes omitted from the records. Only whole specimens (i.e., those not badly anted or anatomically incomplete) were used in analyses of body weights and lengths.

Data analysis:

Small mammal summary data (from Tables A.1a-f) were used in the figures of annual distribution and abundance of the three most common small mammal species from each of the six study plots. Data were presented as i) smooth continuous curves (Figs. 5a-5f), in order to view the amplitude of change in fluctuating numbers of individuals and for the observation of any periodicity among the species; and ii) as bar graphs (Figures A.1a-f), which expressed small mammal abundance as a discontinuous distribution.

Population peaks were identified using the distribution curves shown in Figs. 5a-5f. Population peaks were defined as a year with a higher population

than that of the previous year and of the following year; if the population is similar in two successive years, then the second year is taken to be the “peak year” (Kalela 1962). Cole (1954) defined a peak as any sequence of three numbers such that $a < b > c$. Getz et al. (2001) selected a minimum density that constituted a population peak (i.e., 25 voles/ha in tall grass).

Large fluctuations were extremely rare in TBS capture records; therefore, population peaks were chosen by selecting the most prominent densities (animals per 0.4ha) recorded by each common species (see Tables A.1a-f). Comparisons were made individually of the three main species when peak years were combined from all six sites; this was done in order to observe possible patterns of large-scale synchrony within a single species as shown in Figs. 6a-6d. Additionally, synchrony among the peak abundance years of red-backed voles was examined and compared across different sampling sites within the province (Table 4).

Yearly accumulations of small mammal biomass (Tables A.2a-f) from individual study plots at TBS were examined, since biomass accretion may be reflective of a habitat's productivity. Species biomass was combined annually (without the inclusion of squirrels and chipmunks) to determine peak years of production across the plots (Fig. 7). If synchrony was discovered, then perhaps large-scale external factor(s) (i.e., climatic, meteorological, predatorial and/or broad vegetative changes) may have more influence on the populations of small mammals at TBS, rather than small-scale external agents (i.e., the variety and volume of habitat variables) found within the immediate capture area.

Results

Small mammal trapping summaries:

During the past twenty-five years at TBS, 2,563 mammals in 43,800 trap-nights have been captured, of which 2,384 are considered “small mammals”; those animals <100g in adult body mass or not belonging to family Sciuridae (the squirrels and chipmunks). The small mammals represent 12 species in 11 genera (five Muridae; four Soricidae; one Talpidae; one Zapodidae). The larger more mobile Sciuridae members of the taiga fauna are mostly >100g in adult body mass (with the exception of the chipmunks, which have an approximate mean body weight of 40-50g). Individual Sciuridae occasionally appear in TBS traps (though they are not intentional captures), but because of their size and mobility, and lower site affiliation, have been excluded from much of the habitat analyses. Taxonomy and nomenclature in this thesis follow Wilson and Reeder (1993) and Wilson and Ruff (1999) with the caveat that rodent taxonomy is constantly being refined and rearranged.

The distribution of individual species along with the number of sampling-years a species was captured on a particular plot at TBS is described in Table 1. The Aspen Upland and Ecotone study plots have the highest total captures, with 625 and 567 individuals, respectively. They have also exhibited the greatest mammalian diversity, with 13 different species reported from capture records in each plot. The three most abundant and ecologically widespread species of small mammals at all sites were *Clethrionomys gapperi*, *Sorex cinereus* and

TABLE 1. Taiga Biological Station (TBS) mammal diversity 1977 through 2001.
 (Number in brackets refers to the number of sampling-years a species was found on the plot).
 Sampling-years = 24 yrs for ASP, ATB, ECO, JPR and 25 yrs for the BSB and JPSP.

Aspen Upland (ASP)

13 species
 625 individuals
Blarina brevicauda (3)
Clethrionomys gapperi (23)
Microsorex hoyi (1)
Microtus pennsylvanicus (10)
Peromyscus maniculatus (21)
Phenacomys intermedius (3)
Sorex arcticus (1)
Sorex cinereus (21)
Synaptomys sp. (2)
Zapus hudsonius (5)
Glaucomys sabrinus (7)
Tamias minimus (10)
Tamiasciurus hudsonicus (3)

Ecotone (ECO)

13 species
 567 individuals
Blarina brevicauda (6)
Clethrionomys gapperi (24)
Condylura cristata (1)
Microsorex hoyi (3)
Microtus pennsylvanicus (12)
Peromyscus maniculatus (12)
Sorex arcticus (2)
Sorex cinereus (24)
Synaptomys sp. (3)
Zapus hudsonius (2)
Glaucomys sabrinus (3)
Tamias minimus (13)
Tamiasciurus hudsonicus (6)

Alder-Tamarack Bog (ATB)

10 species
 439 individuals
Blarina brevicauda (4)
Clethrionomys gapperi (20)
Microsorex hoyi (2)
Microtus pennsylvanicus (14)
Peromyscus maniculatus (3)
Sorex arcticus (4)
Sorex cinereus (24)
Synaptomys sp. (3)
Glaucomys sabrinus (1)
Tamiasciurus hudsonicus (3)

**Jackpine Ridge
(JPR)**

7 species
 358 individuals
Blarina brevicauda (1)
Clethrionomys gapperi (23)
Peromyscus maniculatus (14)
Sorex cinereus (11)
Glaucomys sabrinus (2)
Tamias minimus (11)
Tamiasciurus hudsonicus (10)

Blackspruce Bog (BSB)

10 species
 226 individuals
Clethrionomys gapperi (20)
Microsorex hoyi (1)
Microtus pennsylvanicus (4)
Peromyscus maniculatus (6)
Sorex arcticus (2)
Sorex cinereus (19)
Synaptomys sp. (1)

Jackpine Sandplain (JPSP)

10 species
 348 individuals
Clethrionomys gapperi (22)
Microtus pennsylvanicus (1)
Peromyscus maniculatus (22)
Phenacomys intermedius (1)
Sorex cinereus (9)
Synaptomys sp. (1)
Zapus hudsonius (5)

Peromyscus maniculatus. *P. maniculatus* was the third most abundant species in five out of six habitats – with the exception of the Alder-Tamarack Bog, where *Microtus pennsylvanicus* (meadow vole), usurped its third place position. The remaining small mammal species shown in Table 1 have accounted for less than six percent of the total species contribution across most study plots. The Ecotone differed in that its total contribution of small mammal species, other than the three most common ones, was slightly over nine percent.

Therefore, the primary focus of data analysis is on the three main species, with the exception of the *Microtus* substitution for *Peromyscus* in the Alder-Tamarack Bog. The study plots hereafter will be referred to by their abbreviated forms (see Table 1).

The apportionment of individual small mammal species is shown in Tables 2a-2f. Contributions by each individual species have been presented in two ways: firstly, in smaller sequential units of time (i.e., of several years) and secondly, as over-all species contribution (i.e., over twenty-five years). Several notable features included the changes in percentage contribution by *Clethrionomys* and *Sorex* throughout the years. Contributions by *Clethrionomys* have declined on the ATB, while *Sorex* contributions have increased; concurrent events were noted on the ASP plot (Table 2b). *Sorex* never fully recovered its pre-fire levels on the JPR and JPSP (see Tables 2e and 2f). The primary, overall contributor to the small mammal fauna on the ASP, BSB, ECO and JPR habitats has been *Clethrionomys* over the past twenty-five years. *Sorex* is the dominant species on the ATB, while *Peromyscus* fulfills this role in the JPSP.

TABLE 3. A comparison of annual biomass totals (in grams per 0.4ha) of all small mammal species combined (without sciurids) across six sites at Taiga Biological Station. Peak biomass years were chosen by selecting the most notable change in biomass between three consecutive years (i.e., $a < b > c$). Plot names have been abbreviated.

Years	ATB	ASP	BSB	ECO	JPR	JPSP
1977	278.6	56.2	29.9	148.9	126.2	22.8
1978	228.6	245.9	15.8	216.1	105.5	40.2
1979	216.6	289.3	36.2	260.5	211.7	65.7
	352.1	469.9	261.7	612.7	354.3	264.1
1981	192.4	208.1	34.7	207.6	140.4	153.8
1982	98.1	229.2	37.4	328.2	307.2	75.9
	103.8	353.6	125.1	224.6	809.0	90.3
	0.0	0.0	438.1	0.0	0.0	437.2
1985	168.8	437.1	32.2	348.2	195.8	249.0
	465.0	730.3	138.8	713.1	439.2	266.3
	317.7	707.9	338.9	561.3	538.0	284.5
1988	230.5	586.9	186.4	500.5	347.9	133.7
1989	250.0	602.4	165.3	397.3	264.4	388.8
	317.3	513.2	171.1	267.6	188.8	183.8
	225.3	548.5	171.8	537.5	164.4	181.2
1992	41.8	427.3	15.4	37.4	0.0	94.2
	279.8	589.6	187.5	286.3	46.1	293.4
	145.7	325.3	71.5	147.4	113.6	302.4
1995	131.9	275.7	69.9	159.5	36.5	189.6
	183.0	140.7	72.0	168.2	47.6	320.0
	43.5	156.4	79.1	63.7	57.3	148.3
1998	121.0	130.7	30.0	77.0	97.4	83.5
1999	88.3	163.3	88.3	77.6	166.4	144.5
	15.0	277.7	42.4	67.1	206.9	197.7
	45.1	220.1	58.8	220.9	80.0	312.8

TABLE 4. A comparison of *Clethrionomys gapperi* peak abundance years based on small mammal capture records from five different areas in Manitoba and one in Minnesota (about 7 km south of the MB border). All animals were captured using kill-traps except the Long Point study which used live-traps. Long Point was not trapped in 1982. While the sampling time and method varied between sites, a general consistency in the occurrence of peak abundance years for *Clethrionomys gapperi* over a relatively large area (100's of kilometres) of Manitoba can be seen.

Sampling area	Taiga Biological Station (TBS)	*Fort Whyte Nature Centre	Long Point Peninsula MB	Hadashville MB (Spruce Siding)	N. Minnesota (Roseau Bog)	Pinawa MB (**WNRE)
Location	256 km north-east of Winnipeg	In Winnipeg	408 km north of Winnipeg	88 km southeast of Winnipeg	140 km south-east of Winnipeg	95 km northeast of Winnipeg
General habitat	Mixed boreal forest	Mixed deciduous forest	Mixed boreal forest	Tamarack/ black spruce forest	Tamarack/ black spruce forest	Mixed boreal forest
Peak years of abundance		1971 1975 1978 1980 1982 1986 1987 1989 1991 1993 1999	1971 1975 1980 1987 1989	1986 1991 1993 1999	1988 1991 1993 1997 1999	1970 1974 1977 1980

*Peak years recorded by all sites (except Fort Whyte) represent data collected from different habitat types (i.e. blackspruce, jackpine, open field, bog and/or mixed deciduous forest) at each location in MB. Fort Whyte represents animals captured from mixed deciduous forest habitat only, while other locations had several different vegetation types per location.
(**WNRE) = Whiteshell Nuclear Research Establishment.

Species' response shortly after the fire:

The small mammal study plots at TBS were affected to varying degrees by the fire. A full description of habitat disturbance experienced by each plot is provided in Appendix A.1. In general, plots that were subjected to severe damage were predominantly dry, coniferous habitats - the JPR, JPSP and BSB plots. *Clethrionomys* reported increased trap captures on the ATB, BSB, ECO, JPR and JPSP three months after the fire, compared to pre-fire trapping results. *Sorex* responded with increased captures in 1980 from the previous year, in the ATB exclusively. *Sorex* showed decreased capture rates following the fire, on the ASP, BSB, JPR and JPSP plots. Only the ECO reported no change in *Sorex* capture rates from pre-fire sessions. *Peromyscus* was absent from trapping records on the ASP, BSB, ECO, JPR and JPSP prior to 1980 at TBS; only one individual was captured in 1979 on the ATB. Three months after the fire, the ASP, ECO, JPR and JPSP plots all reported elevated *Peromyscus* captures. However, *Peromyscus* was not reported in 1980 and for several years afterwards, on the ATB plot, and did not appear in BSB capture records until 1981.

Cyclic fluctuations and patterns in small mammal populations:

Population peaks were identified (Getz et al. 2001) based on the most conspicuous fluctuations found within each habitat over twenty-five sampling-years. Four key observations were derived from these long-term data sets:

- i.) Synchronicity (i.e., the occurrence in time of similar peaks and troughs) in the fluctuating abundance of different small mammal species was not evident at TBS.
- ii.) *C. gapperi*, the red-backed vole, did not display a 3- to 4- yr population cycle at TBS as indicated by some arvicoline (vole and lemming) studies.
- iii.) *C. gapperi* did exhibit synchronous peaks in its abundance across several of the TBS plots, as well as across the province, regardless of habitat type (i.e., black spruce, jack pine, mixed coniferous/deciduous forests).
- iv.) Combined small mammal biomass (without sciurids) at TBS showed evidence of periodicity (i.e., regularity) in the occurrence of trough phases across all habitats.

Observation i, derived from Figs. 5a-5f, indicated that synchronicity in fluctuating populations was not evident among the various species across different habitats, except for the period immediately after the burn. During this time, *Clethrionomys* and *Peromyscus* both exhibited positive responses through increased abundance. More commonly however, when *Clethrionomys* experienced a peak phase, *Sorex* or *Peromyscus* lagged behind by several years or expressed a similar peak period, with much smaller amplitude. For example, the years 1986 and 1987 were peak years for *Clethrionomys*, but troughs or low periods for *Peromyscus* across several of the sites at TBS.

Observation ii, from Fig. 6a, showed that small mammal communities at TBS do display populations that fluctuate annually, but patterns showing periodicity are not evident. A 3- to 4- year arvicoline cycle was not observed (from visual analysis of population fluctuations) for most *Clethrionomys*

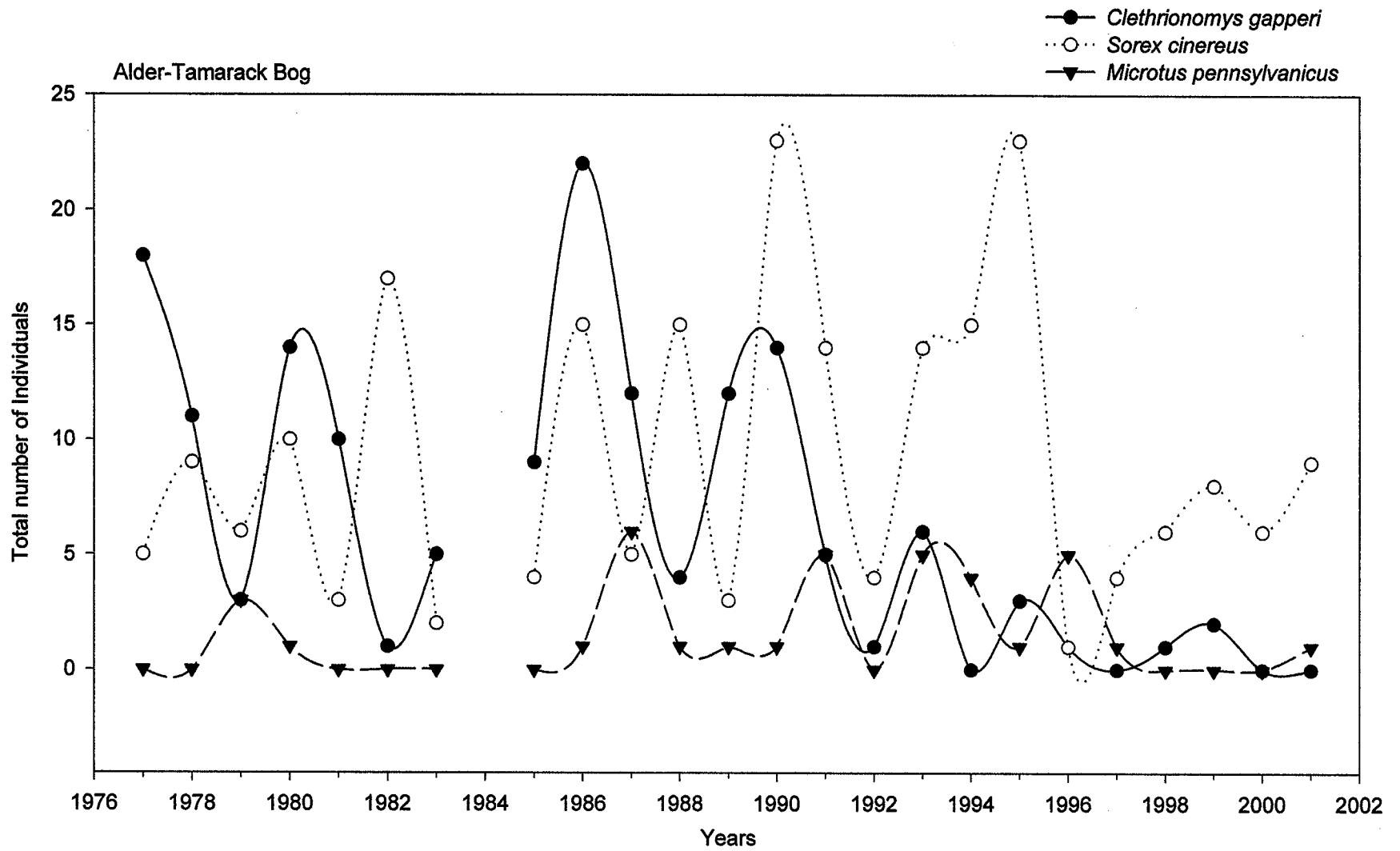


FIG. 5a. Frequency distribution of the three main small mammal species found in the Alder-Tamarack Bog during twenty-four annual trapping seasons at Taiga Biological Station. The plot was not trapped in 1984. Note that the zero value on the Y-axis has been elevated for clarity of presentation.

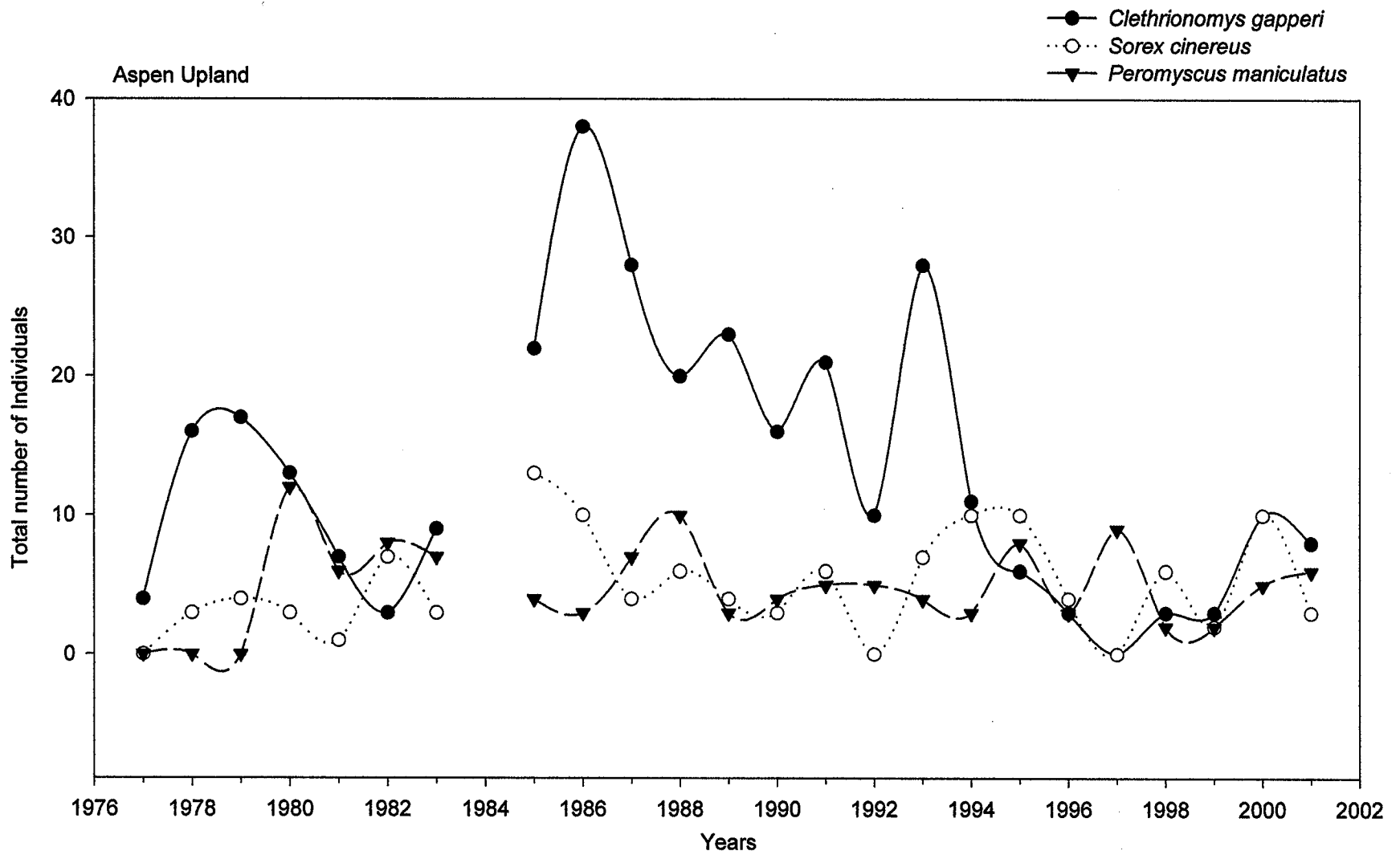


FIG. 5b. Frequency distribution of the three main small mammal species found in the Aspen Upland during twenty-four annual trapping seasons at Taiga Biological Station. The plot was not trapped in 1984.

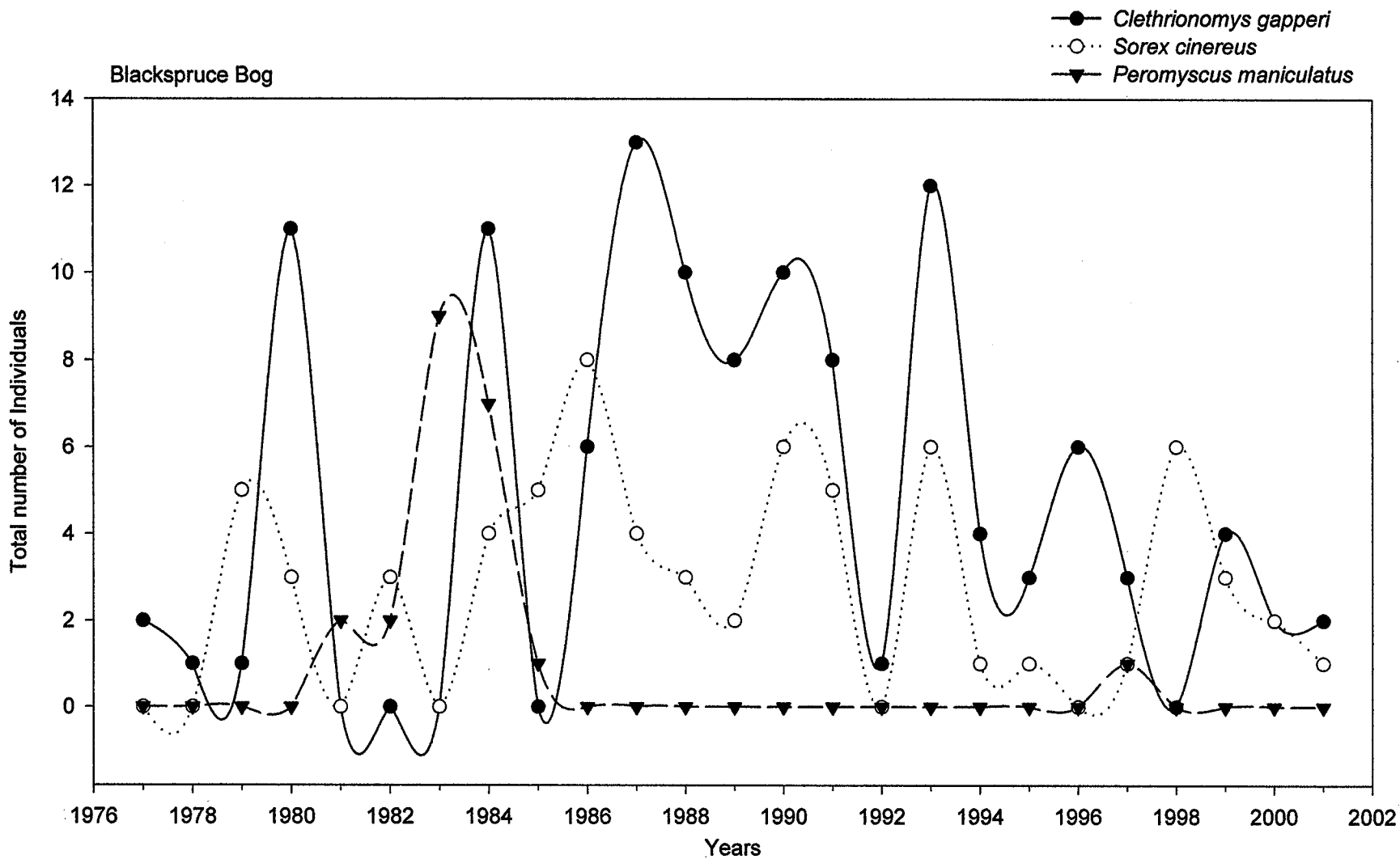


FIG. 5c. Frequency distribution of the three main small mammal species found in the Blackspruce Bog during twenty-five annual trapping seasons at Taiga Biological Station.

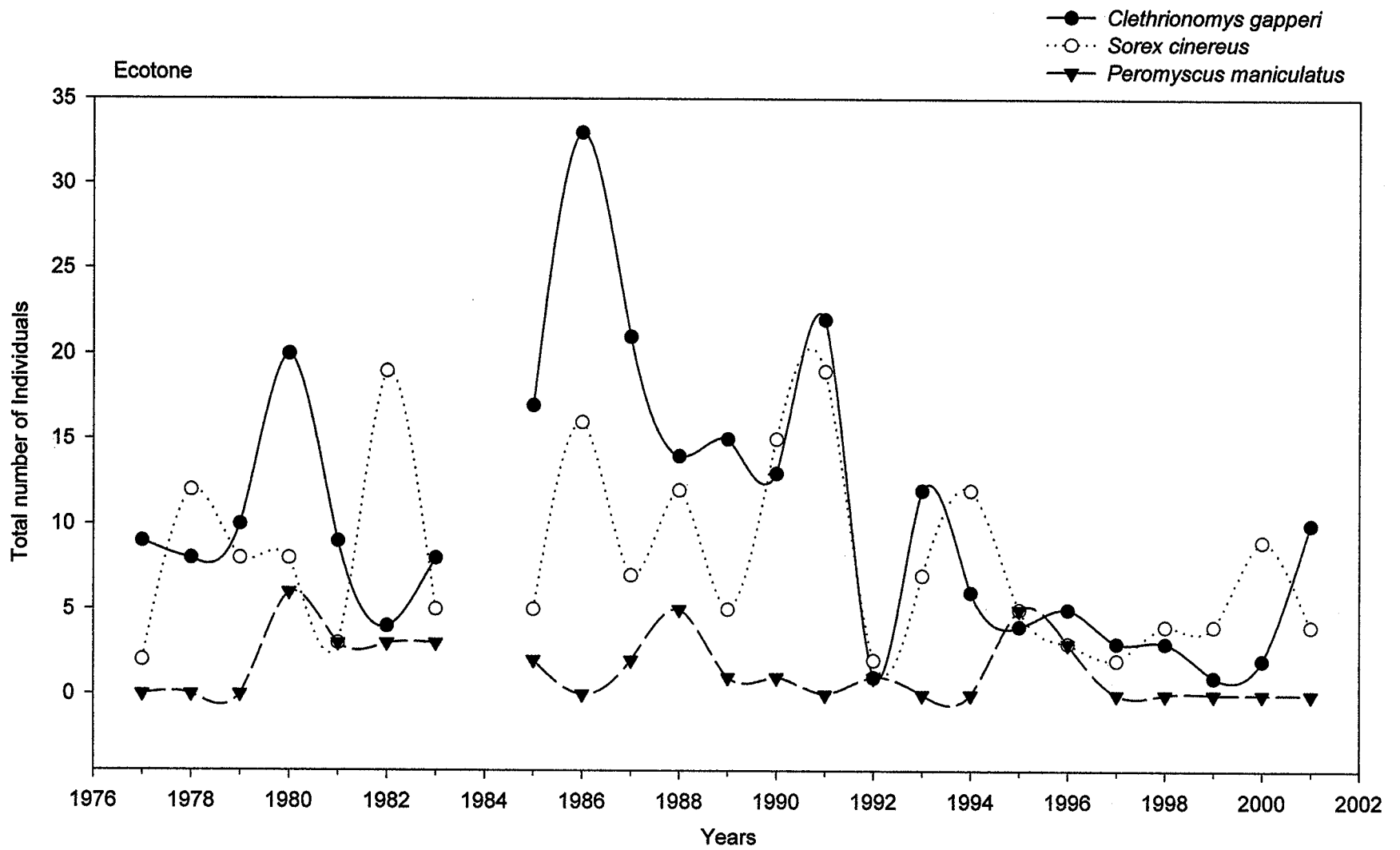


FIG. 5d. Frequency distribution of the three main small mammal species found in the Ecotone during twenty-four annual trapping seasons at Taiga Biological Station. The plot was not trapped in 1984.

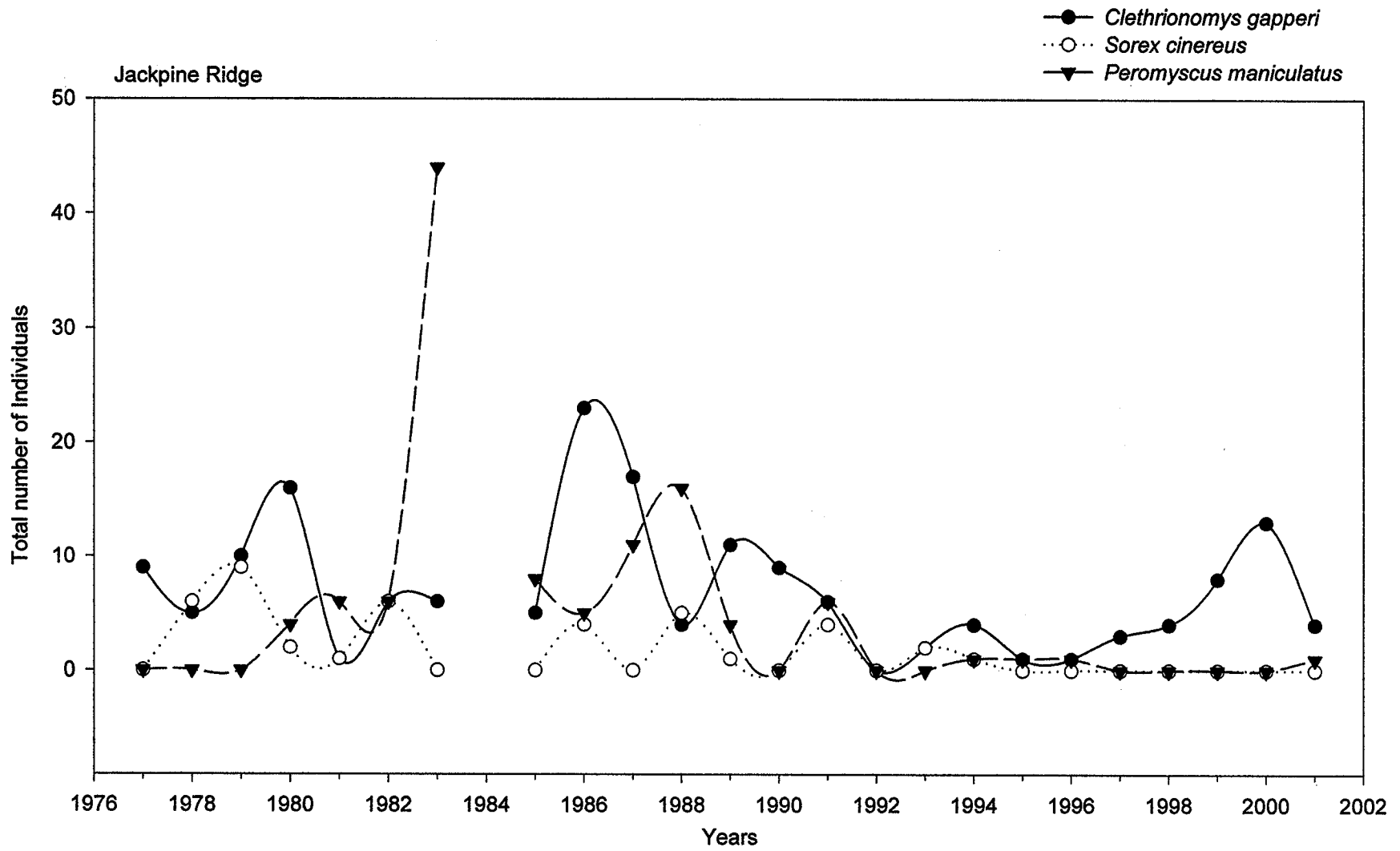


FIG. 5e. Frequency distribution of the three main small mammal species found in the Jackpine Ridge during twenty-four annual trapping seasons at Taiga Biological Station. The plot was not trapped in 1984.

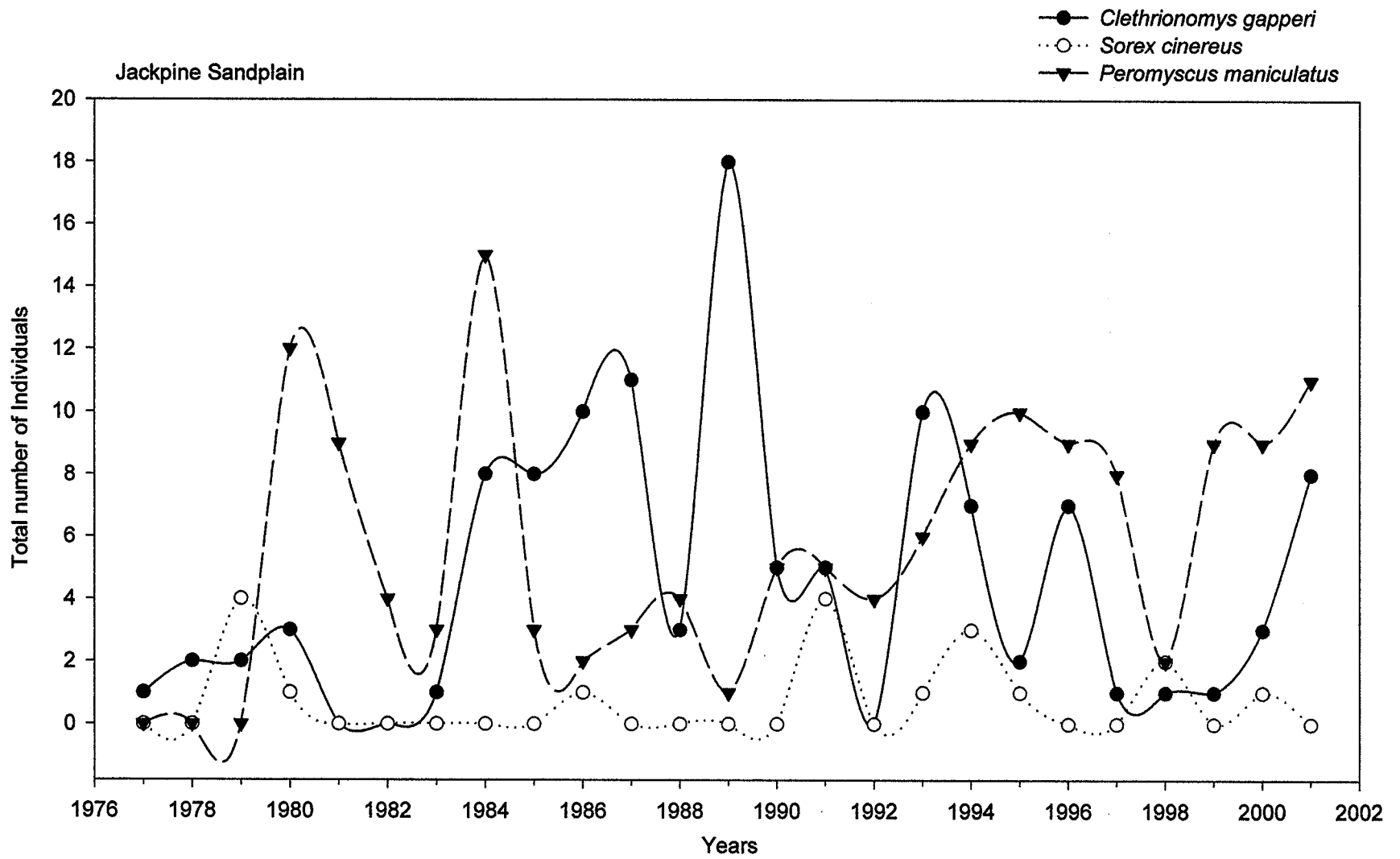


FIG. 5f. Frequency distribution of the three main small mammal species found in the Jackpine Sandplain during twenty-five annual trapping seasons at Taiga Biological Station.

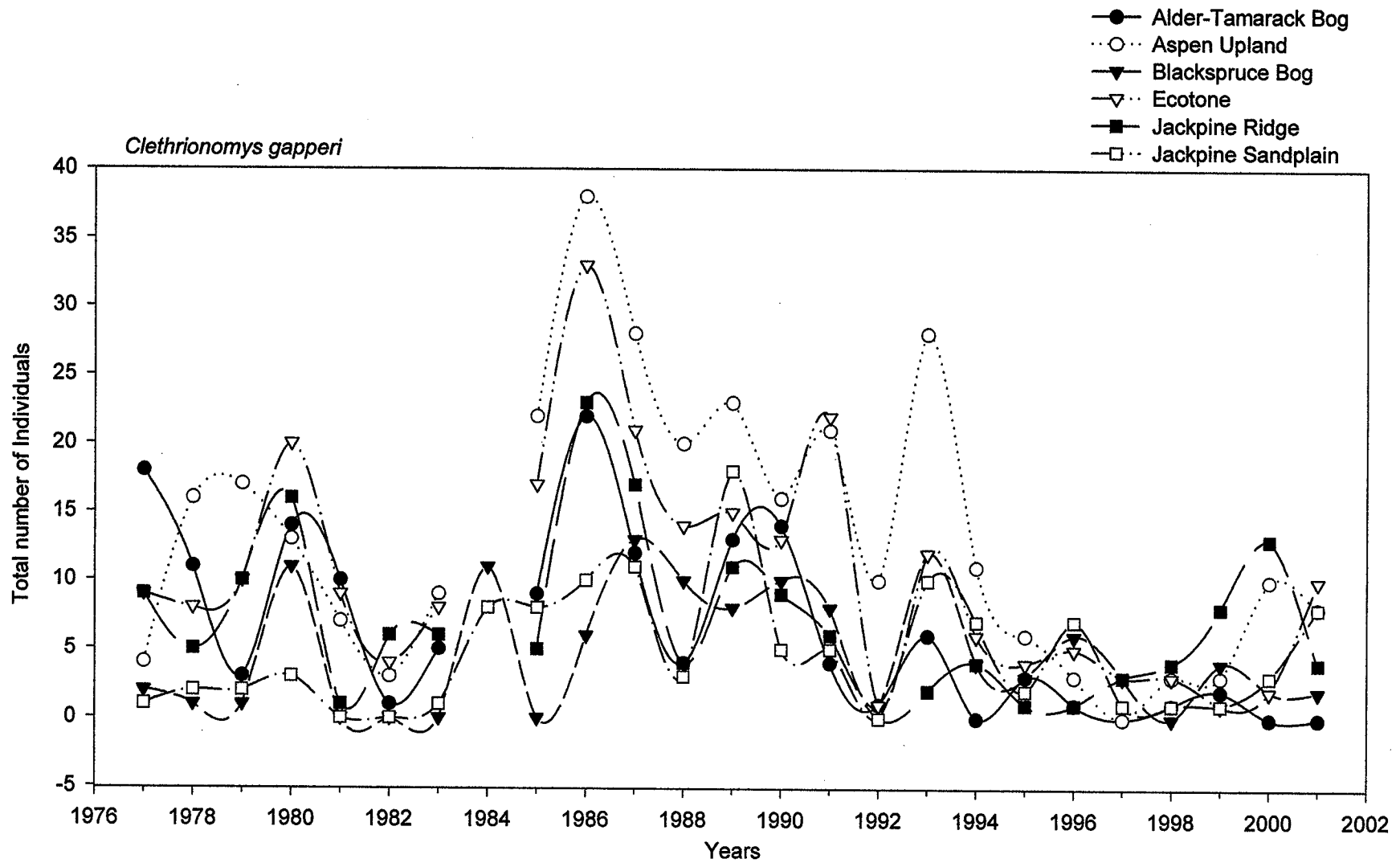


FIG. 6a. Comparison of *Clethrionomys gapperi* distribution across six habitats at Taiga Biological Station. The plots experienced various intensities of fire damage during the spring of 1980, ranging from undisturbed to extremely damaged. Four of the above plots were not trapped during 1984.

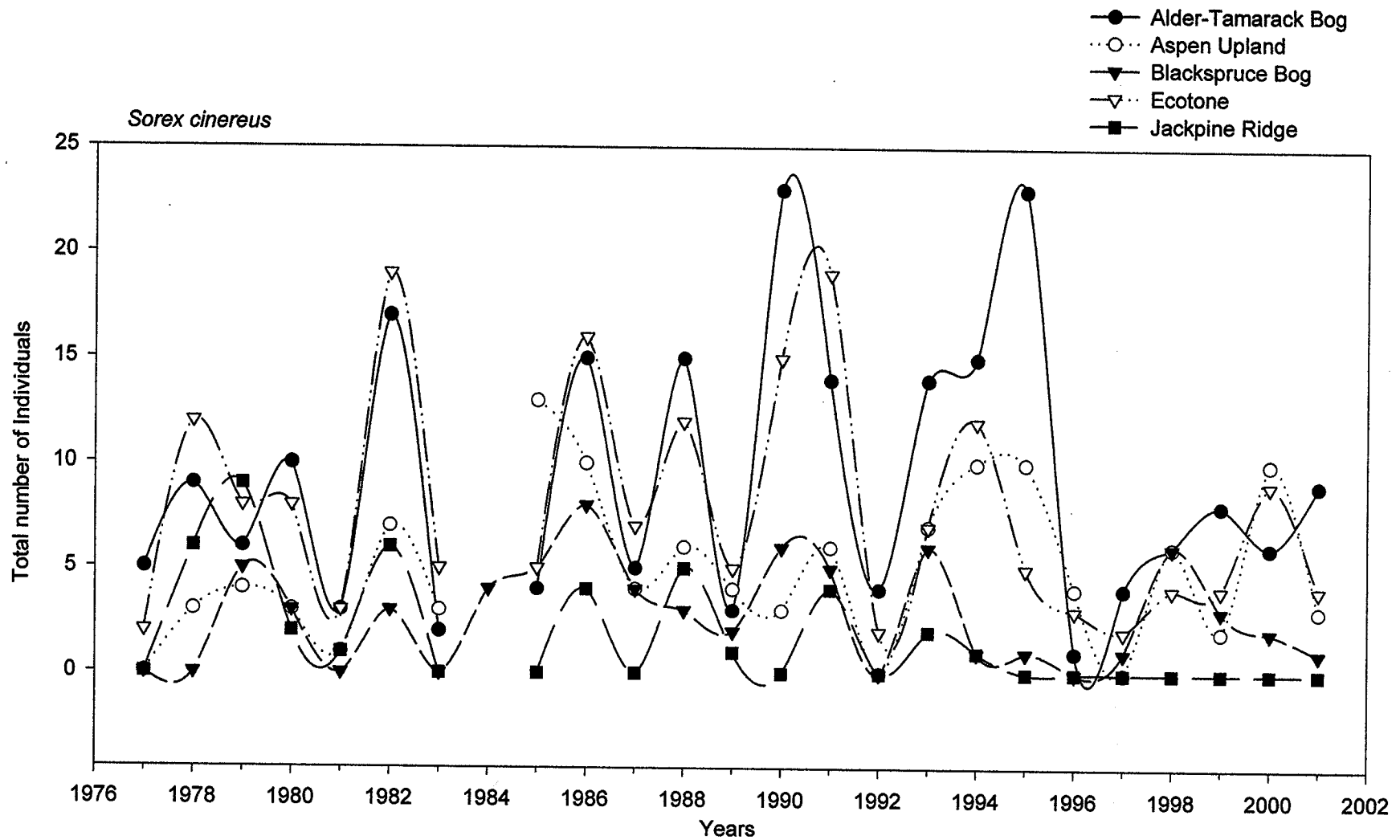


FIG. 6b. Comparison of *Sorex cinereus* distribution across five habitats (the Jackpine Sandplain was omitted because of low numbers) at Taiga Biological Station. The plots experienced various intensities of fire damage during the spring of 1980, ranging from undisturbed to extremely damaged. Four of the above plots were not trapped during 1984.

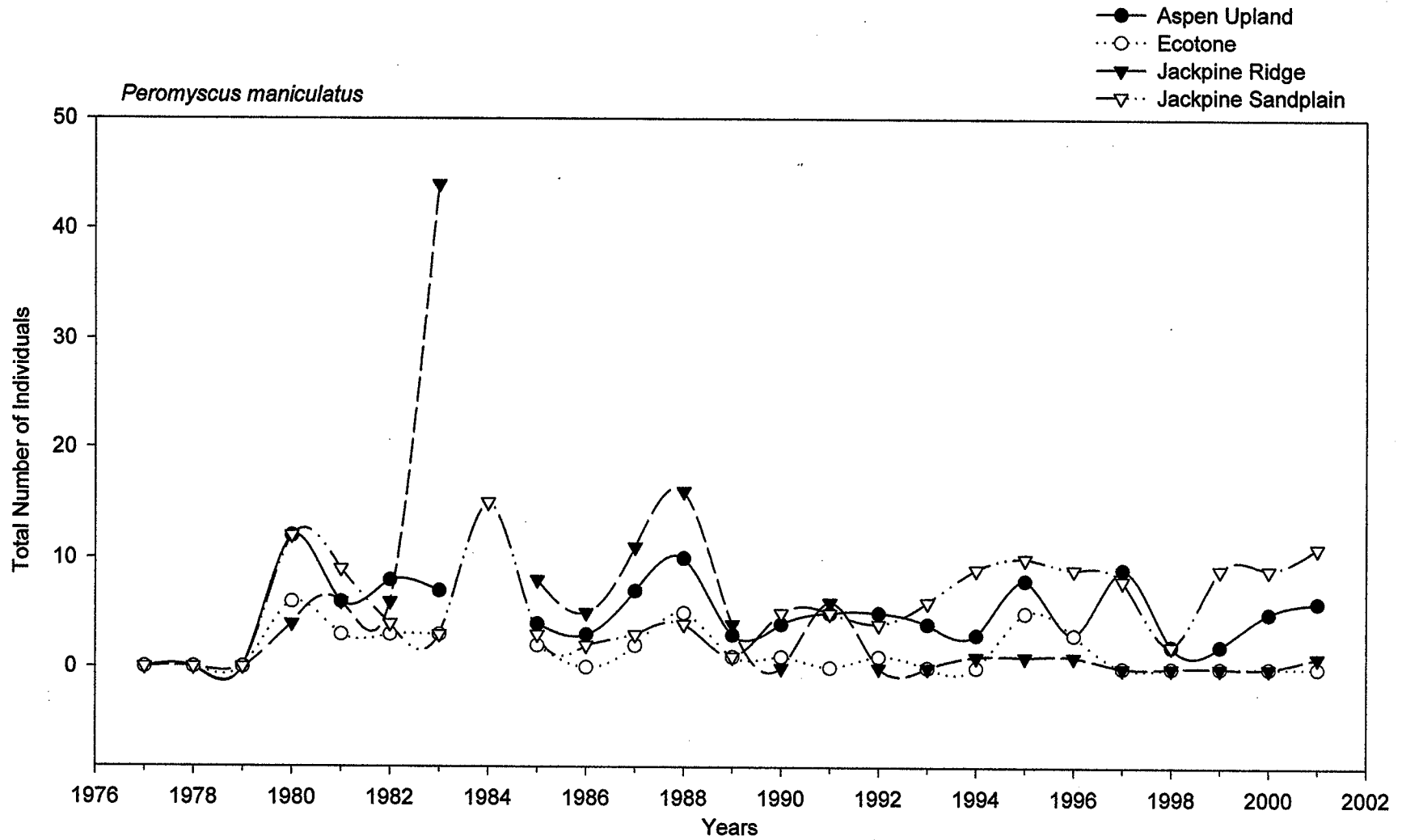


FIG. 6c. Comparison of *Peromyscus maniculatus* distribution across four habitats at Taiga Biological Station. The plots experienced various intensities of fire damage to their vegetation during the spring of 1980, ranging from undisturbed to extremely damaged. Three of the above plots were not trapped during 1984.

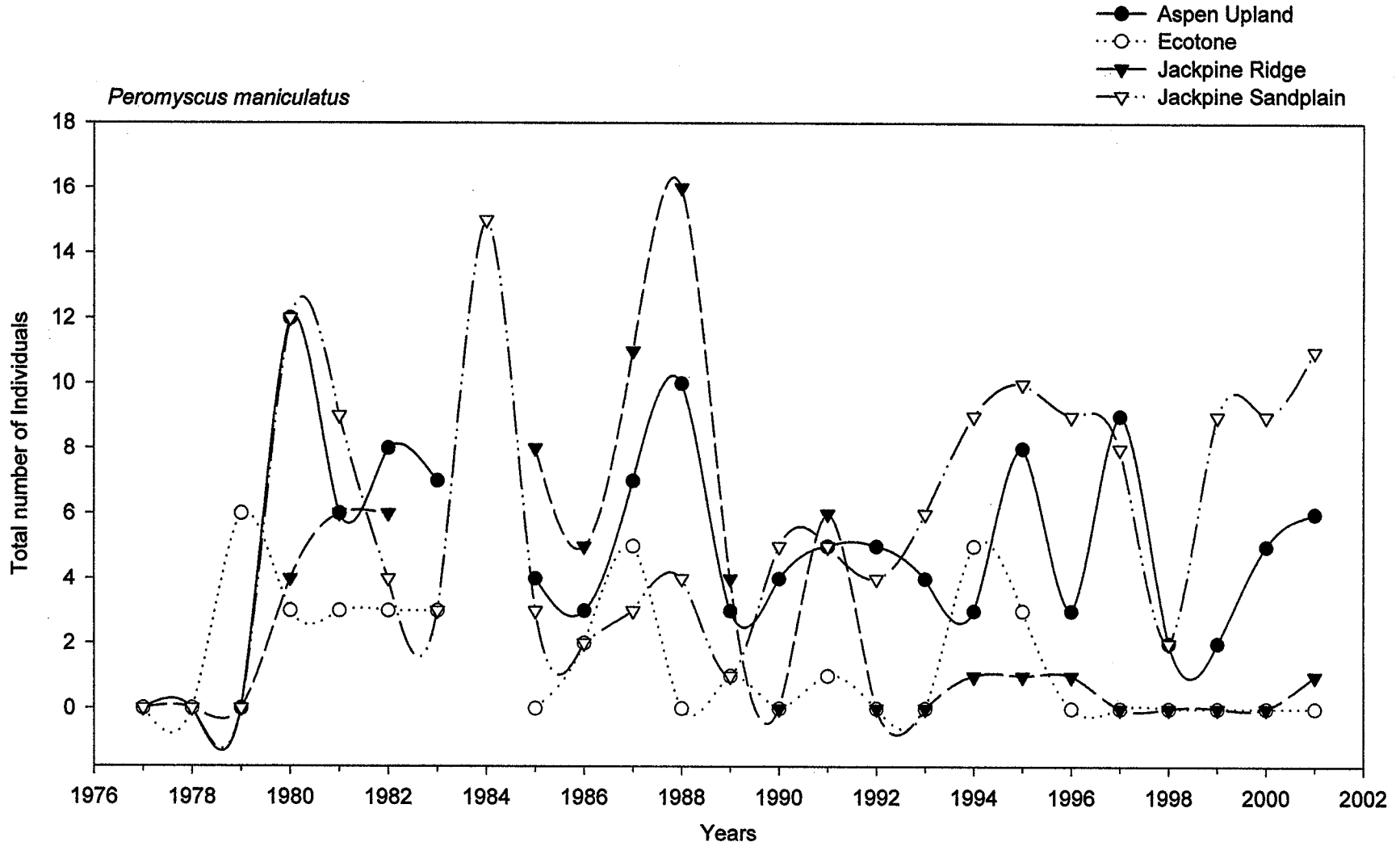


FIG. 6d. Comparison of *Peromyscus maniculatus* distribution across four habitats at Taiga Biological Station. The capture data from the JPR during 1984 was omitted because it had a dampening effect on the oscillations of the animals found within the other plots.

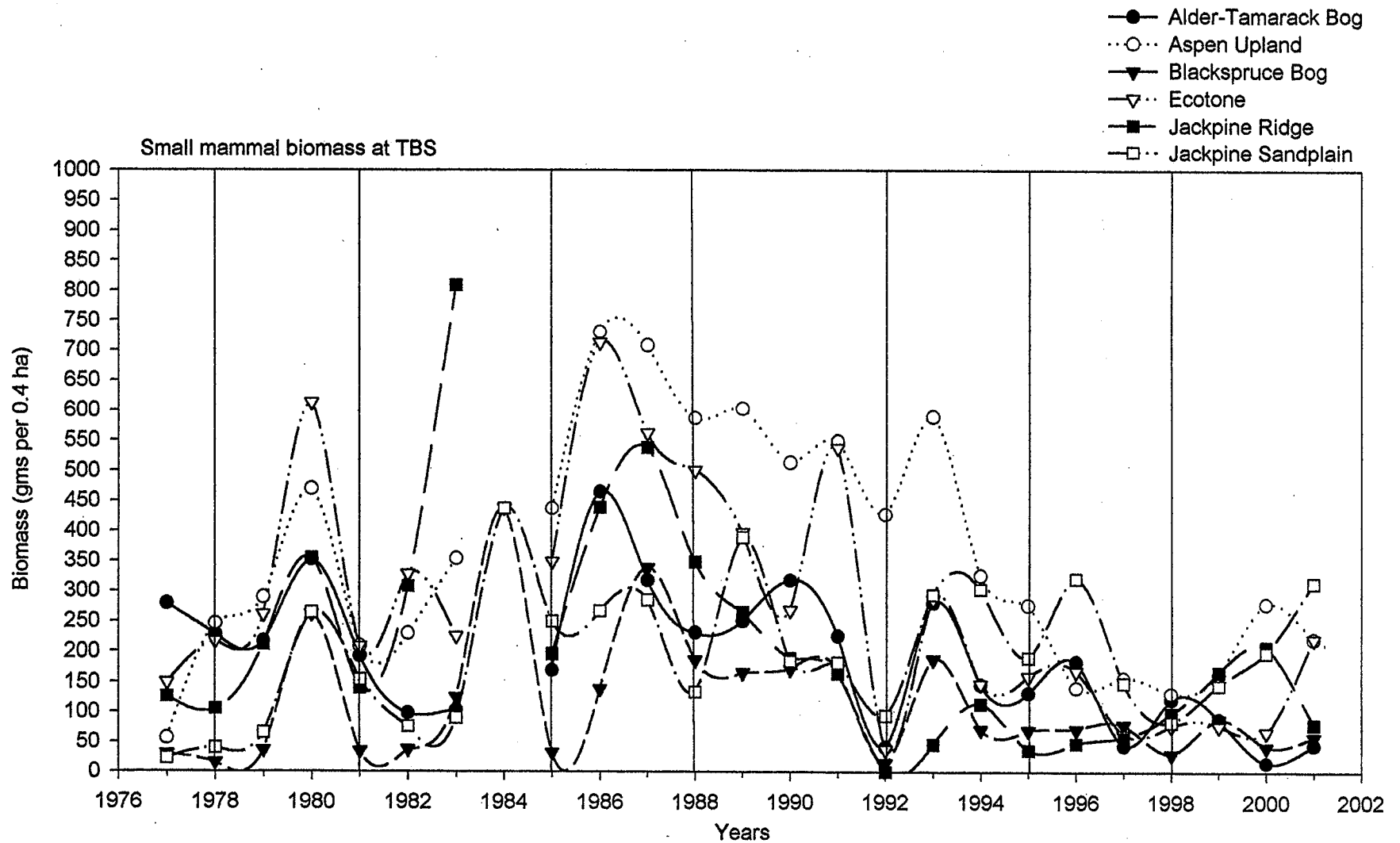


FIG. 7. Annual accumulations of small mammal biomass (without sciurids) compared across six sites at Taiga Biological Station over time. The vertical lines represent common low periods or troughs in biomass that occur approximately every 3- to 4- yrs across all habitats.

populations across the different sites. One exception occurred with *Clethrionomys*' distribution on the Blackspruce Bog; here some evidence of a 3- to 4- yr cyclicity in *Clethrionomys*' abundance pattern may be seen (Fig. 6c).

Observation iii from Figs. 5a-5f revealed that *Clethrionomys* (when compared with *Sorex* and *Peromyscus* species), expressed the greatest similarity in the timing of its peak years across habitats at TBS. During 1980 (three months after the fire), four plots responded with an increase in *Clethrionomys* numbers. On two occasions (1986 and 1989), peak years occurred for *Clethrionomys* in four out of six sites. In 1993, five of the study plots responded with elevated captures. Low phases among populations of *Clethrionomys* have also occurred with noticeable similarity; in Fig. 6a, troughs appeared during 1982, 1988 and 1992.

The latter part of **observation iii** (i.e., the synchronous occurrence in peaks of *C. gapperi* across the province) discovered synchrony in the fluctuating abundance of red-backed vole populations across the province (Table 4). On separate occasions, and across different habitats, populations of *Clethrionomys* reached peak abundance years in 1980, 1986, 1987, 1989 and 1993 at TBS. Koonz (1988) reported red-backed vole densities to be greatest in 1971, 1975, 1980 and 1987 from live-trapping surveys conducted at Long Point Peninsula, south of Grand Rapids, Manitoba. Fort Whyte's small mammal study plot in Winnipeg (established in 1969) displayed peak years of *Clethrionomys* abundance during 1971, 1975, 1978, 1982, 1987, 1989 and 1999. A fifteen-year snap-trapping study (1967-72) at the Whiteshell Nuclear Research Establishment

in Pinawa, Manitoba, described peak years for *Clethrionomys* abundance during 1970, 1974, 1977 and 1980. Two other sampling surveys begun in 1986 indicated peak years of red-backed vole abundance during: 1986, 1991, 1993 and 1999 for Spruce Siding (near Hadashville), Manitoba, and 1988, 1991, 1993, 1997 and 1999 for the Roseau Bog site in Minnesota.

Finally, **observation iv** involved a summary of annual biomass totals of the small mammals (in grams per 0.4ha), described in Table 3. Peak biomass (standing crop) years were chosen by selecting the most notable change in biomass between three consecutive years, based on Cole's (1954) definition of a peak year, where $a < b > c$. In Table 3, the shaded-values indicate peak biomass years. In 1980, all six sites experienced a high, followed by several groups of years where peak biomass production occurred across the different sites. For example, if we look at Table 3, selecting the second year of occurrence (when years are grouped together) as a peak year, then on average, every 3- to 4- yrs at TBS, maxima in small mammal biomass are reached on separate plots at relatively the same time. These years include 1980; 1983-1984; 1986-87; 1990-91; 1993-94; 1996-97; and 2000-01. Congruently, minima in small mammal biomass were observed during 1978, 1981, 1985, 1988, 1992, 1995 and 1998 (Fig. 7).

Discussion

Small mammal trapping summaries:

Of the total 2,384 small mammals captured over the years at TBS, almost half of the specimens were arvicoline rodents (*Clethrionomys*, *Microtus*, *Synaptomys* and *Phenacomys*). The second and third most abundant species in the TBS capture summaries included *Sorex cinereus*, an insectivore, and *Peromyscus maniculatus*, a granivore-omnivore. The arvicolines, however, are notably the most ecologically and numerically dominant species at TBS, fulfilling this role in very diverse habitats. Microtine (or arvicoline) rodents are typically the numerically dominant species in grassland habitat (Rose and Birney 1985), in mixed conifer and hardwood forest habitat (Clough 1987), and in boreal forest habitat (Martell 1984). It is not uncommon within the boreal community to have one or two numerically dominant small mammal species accompanied by a greater number of sparsely populated species (Galindo and Krebs 1985; Vickery et al. 1989; Morris 1996). The TBS small mammal fauna composition (in terms of possessing a few dominant species accompanied by a greater number of numerically subordinate species) is similar with rodent assemblages found in other areas of Canada's boreal forest.

The local distribution and abundance patterns of small mammals points to habitat selection, rather than interspecific competition as a force in species assembly (Morris 1983). M'Closkey and Fieldwick (1975) indicated that the local distribution of *Peromyscus* and *Microtus*, ecologically sympatric species in

southern Ontario (as well as at TBS), was related to the availability of preferred microhabitats. Therefore it is probable that species distribution and abundance patterns, having influenced the outcome of trapping results for the past twenty-five years at TBS, are the result of distinct habitat preferences by each species.

Species response shortly after the fire:

P. maniculatus

The selection of habitat likely became pronounced and most significant to the fitness of the animals shortly after the fire. *Peromyscus* exhibited strong habitat preference after the burn by selecting disturbed habitat over others. For example, this preference for burned areas was demonstrated by its rapid increase in numbers on four out of six plots; the ASP, ECO, JPR and JPSP all reported elevated *Peromyscus* captures three months post-fire. On the Jackpine Ridge, which suffered extensive fire-damage, *Peromyscus* made up almost 59% of the small mammal fauna from 1980 to 1985. *Peromyscus* is an adaptable species at TBS that appears well equipped to vary its reproductive and dispersal strategies in response to local conditions.

This opportunistic species was able to colonize and increase rapidly in density in response to temporarily favourable conditions, such as an increase in either the quality or quantity of its food supply (i.e., seeds and/or insects) initiated by the actions of fire. But the downward trend in *Peromyscus* numbers in subsequent years suggests that habitat conditions deteriorated for this species

over time (perhaps through the successional changes experienced by the fire-damaged plots).

Studies concerned with the initial effects on small mammals from burning and clear-cutting have indicated that granivorous (seed-eating) rodents compared with graminivorous (grass and herb-eating) species respond favourably to habitat change after disturbances (Tevis 1956; Gashwiler 1959; Ahlgren 1966; Krefting and Ahlgren 1974; Sullivan 1980; Martell 1984). Bock and Bock (1983) found *Peromyscus* was more abundant on the prescribed burn areas in Ponderosa pine communities of South Dakota during the first post-fire summer - an effect that disappeared or even reversed itself by the second year. This effect (albeit some-what delayed) was noted on the JPSP and JPR where *Peromyscus* numbers remained relatively elevated up until 1984 and 1988, respectively, then rapidly diminished during subsequent years.

C. gapperi

Clethrionomys also exhibited increased density following the fire on many of the plots. The ATB, BSB, ECO, JPR and JPSP all experienced increased red-backed vole captures three months after the 1980 fire, perhaps in response to the sudden novelty and/or availability of food resources and structural features newly present. Observations on *Clethrionomys* have reported both increased and decreased responsiveness in abundance following habitat disturbance. Martell and Radvanyi (1977) noted that red-backed voles, while common in uncut stands of upland black spruce, increased on clear-cuts until they predominated in the

small mammal community up to the early part of the second summer after harvest, when they rapidly declined. Kirkland (1977) also reported an initial increase of *Clethrionomys* in response to clear-cutting in coniferous and deciduous forests of West Virginia. Other studies have found that *Clethrionomys* avoids or remains rare in disturbed areas for up to ten years after clear-cutting and slash-burning (Gashwiler 1970; Krefting and Ahlgren 1974).

Clethrionomys reported increased captures in five of the six plots following the 1980 fire, indicating that some variable(s) in the burned habitats became more attractive to this species. It seems possible that *Clethrionomys*, while found in greatest abundance in mesic habitats with good overhead cover (i.e., conditions found in the ASP and ECO plots), was able to adapt temporarily to disturbances at the local scale within the different habitats, and utilize the sudden availability of these resources. However, captures declined during the next trapping session (one-year post-fire) on many of the plots, particularly on the BSB where no captures were reported for three consecutive years following the burn. The JPR also reported diminished red-backed vole captures. These declines were most likely due to the loss of overhead canopy in both plots, and to the lack of suitable microhabitat features needed by *Clethrionomys*, for its long-term residency (Miller and Getz 1972; Gillis and Nams 1998).

Clethrionomys' increased trapping response following fire at TBS was concomitant with findings at Long Point Peninsula and Pinawa Research Station (two separate small mammal surveys being conducted during the same period in Manitoba). Both surveys reported elevated red-backed vole captures during their

1980 trapping sessions. It is therefore entirely possible that fire had less influence on *Clethrionomys*' abundance than initially anticipated at TBS. Perhaps elevated numbers of this species would have occurred in 1980 at TBS, regardless of any disturbances created by fire. Rather than fire inducing *Clethrionomys* populations to increase, there may have simply been more available voles per area (as a result of a population peak at the time) to effectively fill newly-made vacant niches on the plots.

S. cinereus

Sorex responded negatively towards its fire-altered habitats. Fewer captures were reported across most plots, with four out of the six plots (i.e., the ASP, BSB, JPR and JPSP) reporting decreased *Sorex* captures. The increase of *Sorex* into the undamaged ATB may have been caused by a temporary emigration response by populations in nearby stressed habitats. However, Monthey and Soutiere (1985) reported *Sorex spp.* to be collectively more common in harvested stands than either uncut softwoods or hardwoods and suggested an increased invertebrate food availability as cause. Kirkland (1977) and Martell and Radvanyi (1977) both reported increased captures of *Sorex cinereus* in clear-cut forests compared to uncut forests. On the ECO, *Sorex* has been captured in pitfall traps located on a xeric rock ridge surface covered in lichens, 7-8 cm in depth (personal observation). At TBS, *Sorex* appears to prefer (as demonstrated by its abundance) moist habitat with abundant overhead cover;

conditions that occur in both the lower portion of the ECO plot and throughout the ATB plot.

Cyclic fluctuations and patterns in small mammal populations:

Observation i, that synchronicity was seldom found in the fluctuating abundances of different small mammal species (except for the period immediately after the burn), suggests that small mammals differ markedly in many of their niche requirements at TBS. Species with roughly similar food habits (e.g., *Clethrionomys* and *Peromyscus*) are more likely to respond in the same manner to sudden changes in food supply (e.g., during the brief period after the burn) than species with dissimilar food habits such as *Sorex* (Swihart and Slade 1990).

In general, amplitudinal displays of numbers captured were irregular among species and plots. The length of period between peak years varied depending on species and on habitat, and ranged between two to seven years for *Clethrionomys*, *Sorex*, and *Peromyscus*, across different sites. Small mammal distributions displayed on the linear graphs (Figs. 5a-5f) did not provide any indication of an association between degree of habitat destruction by fire and oscillatory response of small mammal numbers over the long-term. For example, the BSB, JPR and JPSP were severely burnt in the 1980 fire, while the ATB not at all. Yet, all four plots showed widely fluctuating numbers, regardless of habitat type. *Clethrionomys* began to return in higher numbers to many of the sites beginning about five years after the burn, while *Peromyscus* experienced a

decline during this time. Therefore, it would be unlikely to find a lengthy synchronous population response between these two species following disturbance because of their incongruent densities.

Fryxell et al. (1998) noted evidence of synchronized population dynamics among small mammal species in Algonquin Provincial Park, Ontario. Trophic linkages due to shared predators, common food supplies and pathogens, or common reactions to environmental variability were suggested as possible extrinsic agents affecting synchrony among the small mammals. These same agents are likely to exert pressure on TBS animals, but perhaps because of their low densities, the small mammals at TBS have not responded in a similar synchronized manner. Getz et al. (2001) also found no evidence of synchrony in population fluctuations between two related species, the prairie vole *Microtus ochrogaster* and the meadow vole *M. pennsylvanicus*, after monitoring these two populations on a monthly basis for 25 years in east-central Illinois.

Why TBS small mammals appear nonsynchronous might likely result from the habitat change which followed fire. It seems that extrinsic influences created from burned habitat have differentially affected species at TBS, eliciting varying responses from the animals in terms of trap capture success. Because these temperate-zone species differ markedly in diet, behaviour and morphology (Morris 1983), many of the small mammals at TBS would have different biotic and abiotic requirements. Therefore the animals would colonize and exploit differentially the various habitats, depending on the availability of local resources and the degree of habitat disturbance, within each study plot. Animals respond to

habitat change after disturbance according to their habitat preferences (Sullivan 1980), and in turn, population densities reflect the dynamics of their resources (Mazurkiewicz and Rajska-Jurgiel 1998). Conversely, small mammal studies have revealed that habitat quality is not necessarily associated with annual or multiannual population cycles (Getz et al. 2001) and that high density alone should not infer quality habitat (Van Horne 1983).

Observation ii, that small mammal communities display populations which fluctuate annually, but lack patterns showing periodicity, suggests that the animals are either noncyclic or at densities too low to detect any signs of cyclical behaviour. TBS small mammal captures per 100 TN are lower than values recorded by other Manitoba surveys (Schwartz 1985; Koonz 1987). Bondrup-Nielsen (1987, p 277) concluded from vole demographic studies near Lesser Slave Lake, Alberta that "*Clethrionomys gapperi* is not a cyclic species" ... and that ... "populations of *Clethrionomys gapperi* do not have 3- to 4- year cycles" ... as indicated by several other researchers of *Clethrionomys spp.* (Fuller 1969; Hansson and Henttonen 1985). Merritt (1981) observed that populations of *C. gapperi* in North America do not appear to show a 3- to 4- year oscillation. Fryxell et al. (1998) noted little evidence of long-term periodicity in seven out of eight species (including *C. gapperi*) in their 43-yr small mammal study in Algonquin Provincial Park, Ontario.

Although TBS small mammals exhibit irregular peaks in abundance, most years recorded as "peak years" were not exceptionally higher in numbers of

individuals compared with other sampling years. Red-backed voles are captured in a variety of different habitats and often at very low densities in some of these habitats (e.g., the BSB and ATB). According to Bondrup-Nielsen and Ims (1988), filling up of population space is necessary before a population can peak and the difficulty lies in determining the carrying capacity for breeding voles in different habitats. At TBS, habitat carrying capacity would need to be determined for each plot, before assuming that vacancies exist for breeding individuals. If population space exists, then we might conclude that TBS *Clethrionomys* represent stable, noncyclic populations. Therefore, searching for evidence of cyclicity becomes irrelevant.

Observation iii revealed the occurrence of synchronous peaks in *Clethrionomys*' abundance across several of the TBS plots, as well as across sampling sites within the province, regardless of habitat type. *Clethrionomys* expressed the greatest degree of large-scale synchrony across the different macrohabitats (i.e., individual study plots) at TBS, as well as at other locations. The sampling surveys displayed in Table 4 indicate that peak years in arvicoline populations do not occur as random events. The number of peak years held in common suggests that the arvicoline populations are influenced by large-scale phenomena on a recurring basis.

While the distance of separation among the TBS small mammal plots is only a matter of a kilometre and a fraction, it does provide evidence or support for suggesting that factors other than local microhabitat conditions are responsible

for this numerical synchrony. Less remarkable synchrony (but still noteworthy) occurred among individuals of *Sorex* and *Peromyscus* species, across three or more of their sites during different time periods and under completely different habitat conditions.

Many species exhibit regional synchrony in population dynamics. Steen et al. (1996) examined *Clethrionomys glareolus* population fluctuations based on a 5-yr trapping series spaced along a 256 km transect in southeastern Norway. The authors found that at smaller spatial scales of 30-40 km, local populations exhibited significant synchrony in growth patterns and suggested that population synchrony was related to intrinsic population scaling properties such as dispersal capacity. It has also been suggested that predators might influence the scale of population synchrony because of the predator's capacity for rapid, long-distance movements and ability to track local prey populations (De Roos et al. 1991). Krebs and Myers (1974) suggested fluctuations that occur in synchrony over large geographical areas may result from large areas having similar cover (usually a result of similar weather patterns), and dispersal of individuals would then lead to an equilibrium in density among surrounding populations.

Other factors involving weather have been implicated in the occurrence of large-scale synchrony of small mammal populations. These include the occurrence of El Niño years in the desert region of southwestern USA which is characterized by unusually heavy winter precipitation. Increased moisture levels lead to greater food productivity which consequently stimulates increases in many rodent populations. This climatic effect creates a five-year repeatable

pattern of population peaks in biomass that track El Niño years (Brown and Heske 1990).

The temporal synchrony of populations in different habitat conditions at TBS is challenging to explain. Myrberget (1973) indicated that the connection between ecosystem productivity and influences on these ecosystems from extrinsic factors such as weather (Kalela 1962) or "cosmic" factors involving meteorological events (Pruitt 1968), may synchronize cycles of small rodents. Intrinsic agents, however, should not be ignored.

Birney et al. (1976) offered the reminder that it is the relationship between the internal (genetic, physiological and behavioural) and the external (cover, predators and interactions among individuals) environment of the animal, which is important to the biology of microtine fluctuations; this could be said of non-microtine species as well.

Observation iv found evidence of periodicity (or regularity) in the accumulations of small mammal biomass at TBS. This parameter, of animal weight per unit area, was defined by Allee et al. in Pruitt (1968) and is also referred to as the standing crop biomass. Annual standing crop biomass is the result of the predominantly herbivorous small mammal species conversion of vegetation into animal protein for use by higher trophic levels. Standing crop biomass therefore provides some indication of ecosystem productivity.

A general synchrony in the occurrence of small mammal biomass peak years was discovered among study plots at TBS. Approximately every 3- to 4-

yrs, the small mammal fauna at TBS exhibits elevated biomass accumulations across the different plots. This synchrony suggests that perhaps large-scale extrinsic agents are affecting the fauna, but a direct cause and effect relationship cannot be shown. It only expresses the possibility of such forces being at work on the small mammals at TBS.

Pruitt (1968) found synchrony among the accumulated biomass of small mammals taken in sample plots located over a large geographic area (1200 by 560 km), across widely-scattered regions of Alaska. Pruitt (1972) also reported synchronous biomass fluctuations between small mammal populations on Newfoundland plots and southern Labrador which are separated by the Strait of Belle Isle; 15 km at its narrowest point. Productivity of the boreal ecosystem was expressed in a recurrent manner; with maxima biomass production noted every 3 or 5 years.

Although *Clethrionomys* might be the main support behind biomass synchrony at TBS, evidence of any periodicity (or regularity) in the cyclical behaviour of the small mammal fauna did not become fully apparent until they were examined as a unit (i.e., having annual biomass of all small mammals combined). Individual species (i.e., using only single species abundance data as shown in Figs. 6a-6f) tended to obscure synchronous, cyclical trends in the capture records.

Small mammal biomass may therefore represent the cyclic nature of ecosystem productivity present within the TBS area, and beyond. Perhaps this cyclical behaviour is induced by extrinsic factors such as pulses in vegetative

productivity, changes in predator/prey relationships, climatic/meteorological variations and/or a combination of the above. All these factors however, may be capable of inducing synchronous patterns of change in the small mammals, overriding any particular habitat variability within the plots.

Summary

The population dynamics of the small mammals revealed a variety of fluctuating patterns among the different species at TBS. Individual small mammal species across the six study sites responded to temporal change in the same environments in very different ways. Because coexisting species differ in taxonomic relatedness, body size, food habits and life history, it is not unexpected to find different patterns of fluctuations in the same environment and period of time.

The synchronicity in population fluctuations of single species such as *Clethrionomys* at TBS is indicative of large-scale processes at work. The same periodicity occurred in *Clethrionomys* populations regardless of habitat type and/or quality. Therefore, two spatial scales (if not more) appear to be operating on the small mammal fauna at TBS. Local areas (with desirable habitat variables) appear to concentrate a particular species for the short term following disturbance, while regional trends (not as readily identifiable and unaffected by habitat change), lead to synchronicity of individual species over the long term. Evidence of this large-scale synchrony in *Clethrionomys* populations is partially supported from studies (Koonz 1988) at Long Point, on the west side of Lake Winnipeg, approximately 300 km from Taiga Biological Station, as well as by the other provincial surveys.

An important discovery made through the examination of the small mammal fauna at TBS was that populations must be examined at several

different scales and ecological units. For example, capture records of a single species from one particular habitat cannot fully uncover patterns in ecosystem productivity. However, small mammals examined as a unit over several habitats reflect the cyclical nature of the boreal foodchain base. Periodicity (regularity) in the fluctuating numbers of small mammals at TBS was not evident; periodicity became evident when the biomass of the combined populations was examined. Synchronicity in arvicoline population peaks was not fully appreciated until capture records were examined across several plots at TBS, as well as across the province.

Therefore, our interpretation of small mammal events can change, depending on the scale and unit (i.e., either as individual species or an ecologically relevant combination of species) of measurement employed in the analysis of populations and habitats. In general, small mammal abundance has been on a decline at TBS for the past six or seven years. For most plots, the heyday of recorded small mammal captures occurred during the five to ten year period following the 1980 fire. Some startling exceptions occurred. *Peromyscus* varied from being virtually absent from most sites in pre-fire times to demonstrating substantial increases in number shortly after the fire.

During the mid- to late 1980's, all six study sites contributed to small mammal population increases at TBS; the causative factors of which remain largely unknown. Perhaps predator (mustelid) cycles were experiencing a low phase, or stochastic (climatic) variables in the abiotic environment became significant, and/or the vegetation composition and structure had sufficiently

changed to cause an upswing in prey cycles. During this particular period, it is assumed that many of the fire-killed standing dead trees were recruited by the forest floor, which may have allowed some species to utilize advantageously this new resource through the attributes (shelter, protection, runways) it provided.

The patterns of small mammal response are not a direct response to fire, but rather a reaction to their fire-altered habitats. Responses to habitat change in the small mammal fauna may either appear rapidly or slowly depending upon the adaptability of each species to its altered environment. Consequently, the dynamics of the small mammal response to habitat change is best understood over the long term, in the fluctuating population numbers, by the accretion or loss of individuals, and through changes in species diversity and trophic structure.

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SECTION II.

Small Mammal Community Response to Habitat Change

Section II. Abstract

The effects of secondary succession following forest fire on the structure of plant communities and the population attributes of small mammal communities were investigated in six different habitats surrounding Taiga Biological Station (TBS) in southeastern Manitoba. Changes in small mammal community structure were assessed using several methods.

Peak periods of relative abundance and biomass for *Peromyscus maniculatus*, the deer mouse, occurred during 1980-85 (within five years of the 1980 fire). *Clethrionomys gapperi*, the red-backed vole, experienced peak periods of relative abundance and biomass during 1986-90, the 5- to 10- yr post-fire period. The rank abundance curve of the small mammal fauna assumed a logarithmic shape which is indicative of habitats that have a small number of abundant species, with a larger number of species of intermediate, and of few individuals. Changes in trophic contribution revealed that *P. maniculatus*, the granivore-omnivore, rapidly exploited the recently burned habitat. *C. gapperi*, the grazer-omnivore, experienced brief initial increases shortly after the fire, but overall required a more lengthy recovery period. Species richness and diversity of the small mammal community increased for a short period of time (several years) across most sites following the 1980 burn.

The rates of vegetation recovery within the small mammal habitats at TBS were found to be site specific and dependent on the degree of fire damage.

Section II. Small Mammal Community Response to Habitat Change

Introduction

Fire creates abrupt changes in the boreal forest landscape resulting in cover composed of burned logs and stumps, charred bedrock and exposed surfaces, and islands and clumps of unburned vegetation. Forest removal can have a pronounced effect, at least temporarily on small mammal populations. However, the fluctuating severity and intensity of each burn ensures that not all small mammal populations are eliminated by fire. The long-term relationships and interactions among the various components of the boreal environment, including floral and faunal compositions, abiotic and edaphic factors, have created an ecosystem which is not irreconcilably disrupted by fire. Removal of one species of small mammal during a particular recovery stage does not damage the boreal ecosystem complex (Hooven 1969).

Through the process of secondary succession, conditions alter small mammal habitat by affecting the availability of resources within the environment. Small mammals respond to resource limitations in different habitats with variations in their own community compositions over time. As boreal ecosystems progress through successional time, changes in the vegetation community after habitat destruction may cause corresponding changes in the small mammal community during different stages of recovery.

Small mammal community structure can be assessed using several methods of evaluation. At TBS these included following the changes in species richness, diversity and trophic composition through time. Section II. will therefore examine: (1) the changes in small mammal numbers (including relative abundance and biomass) over grouped intervals of time of between five to six years in length, in order to observe small-scale temporal trends in the response of the populations to environmental perturbation; (2) the influence of habitat succession on small mammal community structure by describing changes in species diversity and trophic composition across the six sites.

Literature Review

Survivability of small mammals following destruction of habitat:

Beck and Vogl (1972) expressed caution in the acceptance of alleged mortality and increased vulnerability risks of small mammals to starvation, exposure, and predation through reductions in food resources and vegetation cover following fire. The outcome or "fate" of the individual small mammal during and after fire depends on many factors: during the fire, the creature's attachment to site, its mobility, and ability to find refuge with a survivable microclimate of suitable temperature and humidity (Bendell 1974). After the fire, survivorship depends on the ecomorphological traits of the animal that enable an increase in the abundance of those species that can exploit the new open habitat (Henriques et al. 2000), as well as the availability of fundamental niches sufficient to encompass the altered conditions (Kirkland 1990).

Some responses of small mammals to habitat change:

Forest fires, either natural or anthropogenic and clear-cut logging are the major large-scale disturbances of the boreal forest (Simon et al. 1998). Many of the effects of these ecosystem disturbances on small mammal productivity, diversity, and mortality are still little known (Beck and Vogl 1972; Monthey and Soutiere 1985; Masters et al. 1998). Differential responses of small mammals to these perturbations are the result of numerous factors that fall into two main categories: (1) factors that revolve around the disturbance and (2) factors that

focus on the small mammals themselves. The former group includes the amount of destruction involved in forest removal and subsequent changes that follow in soil exposure, litter structure and moisture content; the geographic locality and pre-disturbance forest characteristics; and the proximity to other habitats which can serve as immigration sources. Variables surrounding small mammal populations include density, reproduction and behaviour, as well as the time of year and method of collection that may account for the wide variations in results reported on the impact of these various disturbances on small mammal communities (Clough 1987; Parker 1989).

Fire cannot be generalized simply as "fire". The behaviour of wildfire is dictated by strong gradients in moisture-dependent variables and by topographic features of slope and aspect (Clark 1990), and by the distribution of biotic and physical parameters that affect the moisture content of fuel loads within the stands (Wein and MacLean 1983). However, removal of the vegetation and ground cover either through fire or clear-cutting (especially in conjunction with scarification) leads to large oscillations in soil moisture and air temperature.

Fox (1983) reviewed the literature on changes in the community ecology of small mammals during post-fire succession of the boreal forest and noted a broad trend of increased numbers and biomass for the herbaceous stage, followed by lower values recorded in the shrub and sapling stages than in the mature forests. Examination of individual cases of post-fire response in small mammal populations is often contrary. Some studies have indicated a decrease in the abundance of certain species immediately after fire (Cook 1959; Spires

and Bendell 1983; Kirkland et al. 1996; Henriques et al. 2000) while others have shown the opposite trend towards increased abundance of a species following fire (Tevis 1956; Tester 1965; Sims and Buckner 1973; Krefting and Ahlgren 1974; Bock and Bock 1983; Masters et al. 1998).

One of the most challenging tasks facing ecologists is to interpret the pattern of distribution and abundance of species in an ecosystem (M'Closkey 1975). The patterns of post-fire response of a species to habitat modifications by fire are site specific. Therefore, wide generalities about small mammal response to altered habitats either through fire and/or logging are not practical because of the variation that occurs in the disturbance regime itself, the anomalies within the habitat and the ecological character of the species involved.

Influences of habitat succession on small mammal communities:

The successional or recovery process following disturbance occurs both in the vegetation and in the small mammals that make up the ecological community within a particular habitat. Post-fire changes in small mammal communities are therefore generally associated with changes in vegetation structure and composition (Ahlgren 1966; Beck and Vogl 1972). Small mammals reflect these changes in habitat structure through changes in their distribution pattern and population density.

A trend of post-fire recovery in small mammal communities exists in the literature for the north-central coniferous forests of North America. Early successional stages of the forest are dominated by seed-eaters (granivores)

such as *Peromyscus* and *Tamias spp.* (Krefting and Ahlgren 1974; Spires and Bendell 1983; Martell and Macaulay 1981). *Peromyscus maniculatus* is a universal North American invader of logged or burned areas (Fox 1983), foraging for seeds exposed by fire in the forest floor (Tester 1965) and from seeds propagated by early successional plants (Ahlgren 1966).

The effects of successional stage on *Clethrionomys gapperi* populations were investigated by Nordyke and Buskirk (1991) in coniferous forests of southeastern Wyoming. The red-backed voles found in the late-successional or (old-growth) spruce-fir forests were more abundant and in the best body condition, followed by voles in early-successional lodgepole pine, with lowest abundance recorded from the mid-successional stage of mature spruce-fir habitat. The highest body weights occurred in adult males in the old-growth stands with the lowest weights found among males in early-successional lodgepole stands. The researchers suggested that early successional sites may serve as dispersal sinks for subordinate *Clethrionomys* during peak populations.

Carey and Johnson (1995) sampled small mammal communities in the coniferous forests of Oregon and southern Washington. They found that while the small mammal community composition was similar in both the younger naturally-regenerated forests and clear-cut regenerated managed forests (to those communities in old-growth), the old-growth habitats supported one and a half times more individuals and biomass than managed forests. Pearson (1994) examined populations of *Clethrionomys gapperi* and *Peromyscus maniculatus* in four successional stages of cedar-hemlock forests in Glacier National Park and

found that abundance of *Clethrionomys gapperi* and *Peromyscus maniculatus* increased with increasing stand age.

A generalized pattern of replacement in small mammal communities exists with *Clethrionomys* dominating mature coniferous forests in northern ecosystems and through habitat alteration, either from logging and/or fire, is replaced by opportunistic invaders such as *Peromyscus*. However, from the various studies presented, it is evident that secondary successional patterns in small mammal populations can be highly individualistic and site specific. Regional differences in geography, climate, and vegetation lead to site-specific variations in the structure of small mammal populations recovering in disturbed areas (Fox 1983).

Materials and methods

Trapping:

The method of small mammal trapping was described in section I. Although the trapping design was identical on all plots, the total trapping effort varied slightly among the plots. Each plot at TBS contributed 300 trap-nights per year (i.e., 100 traps were set for three consecutive nights on each plot). In total 43,800 trap-nights (TN) were set over twenty-five years, with 7500 TN each being contributed by the BSB and JPSP plots, respectively. The ATB, ASP, ECO and JPR plots contributed 7200 TN apiece in twenty-four years of trapping surveys.

Data analysis:

The analyses of trap results were done by habitat and by species. Response of the small mammal communities to fire within the six habitats was evaluated by employing different measures of small mammal abundance and community structure. These measures included:

- 1) relative abundance and relative biomass
- 2) species-abundance modelling
- 3) trophic composition and contribution
- 4) species diversity and similarity
- 5) species richness and evenness

Statistical analysis methods were chosen in order to express and measure the changes that have occurred in small mammal community structure through successional time.

1.) *Relative abundance and biomass* - Populations were measured using two types of units: catch per unit effort (i.e., numbers captured per 100 trap-nights of effort) and biomass (i.e., body mass in grams per 100 trap-nights). Relative abundance and biomass values were then grouped into smaller units of time (several years) to represent periods of "mini" successional change: (*pre-fire*); (*early post-fire*); (*middle post-fire*) and (*late post-fire*). Grouped units of time (five to six years in length), were chosen to reflect a sufficient time period in which noticeable vegetative changes might have occurred within the habitats, as well as among the mammalian communities living within these habitats. By grouping the data, overall trends were made apparent that would have otherwise been obscured in a long-term data set.

The above units are not intended to reflect actual lengths of time (i.e., years) of post-fire successional periods. The five different time periods employed in this thesis (i.e., pre-fire, post-fire, etc.) were chosen simply to reflect smaller units of time that might indicate more accurately the time frame in which small mammals were most affected by changes in their habitat following fire, rather than using fewer periods of unequal lengths, to characterize habitat changes that occur after fire (i.e., 0-1 year is newly burned; 1-5 years is moss-herb; and 3-30 years is tall shrub-sapling) (see Dyrness et al. 1986).

The *pre-fire period* (1977-79) at TBS is the shortest, simply from the lack of time collecting data before the 1980 fire struck. The next successional phase is an *early post-fire period* (1980-85), followed by an extended middle phase which covers two units of time: an *early-middle post-fire period* (1986-90), and a *late-middle post-fire period* (1991-95). The latest successional phase is referred to as the *late post-fire period* (1996-01).

The purpose of using relative values over absolute is that it allows for comparisons to be made between units that reflect unequal sampling effort, as indicated in the above. Relative values of abundance and biomass for the different units of time were based on the actual number of years within each unit. For example, a total of 64 *Clethrionomys* were captured between (1986-90) on the Alder-Tamarack Bog. The total number of trap-nights during that period was 1500 TN. Relative abundance is expressed as the number of individuals captured in 100 TN which would be 4.27 in this example (see Table B.1a).

2.) *Species-abundance modelling* - The overall pattern of species abundance provides a useful method of characterizing the community and allows ecological statements to be made about the response of communities to environmental change (Kempton 1979). Abundance data from the small mammal summaries (Tables A.1a-f) were presented in rank order/abundance plots (Krebs 1989) with the log abundance (number of individuals) of each species plotted against the rank (species sequence). The purpose of using population models is

to describe the species-abundance relationship in a community through its attributes - which consist of species richness and equitability or evenness.

Diversity is usually examined through four main distribution models with each model having a characteristic shape on a rank/abundance plot (Krebs 1989). Starting with the geometric series (which represents a condition in which only one or a few species are dominant), through the log series and log normal, to the broken stick (which represents the greatest degree of evenness or equality in species abundances); it is possible to follow the various patterns of species distribution (Magurran 1988). Species distribution patterns might be a more sensitive indicator of recent habitat disturbance than species richness (Kempton 1979).

Ecological studies search for repeatable and recognizable patterns in the behaviour of natural systems. Therefore, fitting a statistical distribution to empirical data leads to both economy of description (by allowing a large mass of data to be summarized by naming the distribution that fits it) and to the discovery of consistencies or uniformities in the forms of species-abundance distribution (Pielou 1975).

3.) *Trophic composition and contribution* - The effects of successional change on small mammal community structure can be measured by changes in trophic composition over time. Small mammal communities were analyzed through the various trophic levels found in each habitat. Species were first divided into two major groups - the shrews or insectivores (i.e., *Sorex* and

Blarina) and the rodents, which were then subdivided into grazer-omnivores (i.e., *Clethrionomys*, *Microtus*, *Phenacomys* and *Synaptomys*) and granivore-omnivores (i.e., *Peromyscus* and *Zapus*) categories. The sciurids (squirrels and chipmunks) were treated separately from the other small mammals and recognized as granivore-omnivores (i.e., *Tamias minimus*, *Tamiasciurus hudsonicus* and *Glaucomys sabrinus*). All species were utilized in order to represent each trophic level completely.

4.) *Species diversity and community similarity indices* - If communities do not fit into one particular distribution model and the purpose is to compare them, then diversity indices provide an alternative approach to measuring species diversity (Magurran 1988). Diversity measures can be divided into three main categories: (1) *species richness* or simply the number of species in a defined sampling unit; (2) *species-abundance models* (as described earlier); and (3) *nonparametric measures of heterogeneity* based on the proportional abundances of species that take both evenness and species richness into account, but make no assumptions about the shape of the underlying species-abundance model (Magurran 1988).

The purpose of measuring species diversity is to relate this measure to other properties in the community such as productivity or stability, or to environmental conditions to which the community has been exposed (Pielou 1975; Legendre and Legendre 1983). The species diversity results of TBS small

mammal and vegetation data were obtained using the "*Species diversity and richness*" computer program designed by Henderson & Seaby (1997).

The most widely used measures of species diversity are based on information theory (Peet 1974; Magurran 1988; Krebs 1989). The main objective of information theory is the measurement of order (or disorder) contained within the system (Krebs 1989). The uncertainty associated with predicting species identity can be measured by the Shannon-Wiener function H' or now commonly referred to as the Shannon Index. The larger the value of H' , the greater the uncertainty; function H' increases with the number of species in the community. The Shannon Index is theoretically valid only when the sample whose diversity is to be measured comes from a supposedly infinite population (or at least one not perturbed by sampling) (Pielou 1975).

The Shannon Index is often referred to in this thesis because although it is recognized that species number influences this index; it gives more weight to the rare species (Krebs 1989). In studies of habitat change (as experienced by most of the TBS small mammal habitats following the fire) it is important to focus on the rare species (Sekgororoane and Dilworth 1995).

where H' = Information content of a sample

$$\text{and } H' = - \sum p_i \log_n p_i$$

and p_i ($i = 1, \dots, s$) is the proportion of the total sample belonging to the i th species

Many studies have used the Shannon function H' as a measure of species diversity and it is still widely used today (Sekgororoane and Dilworth 1995; Hansen and Hounihan 1996; Kirkland et al. 1996; Silva et al. 2000; Brady and Slade 2001). However, the information theory approach has been criticized for its biases in the past (Hurlbert 1971; May 1975; Kempton and Taylor 1976; Routledge 1980) and is said to be strongly influenced by species number (Southwood and Henderson 2001). The most effective source of error in this diversity measure occurs if there is failure to include all species from the community in the sample (Peet 1974). No index, according to Magurran (1988) has received approval of even the majority of researchers in the field.

In general, indices that are weighted towards species richness (e.g., Shannon measures) are more useful for detecting differences between sites (one of the main reasons for employing the Shannon index was to separate TBS habitats using a descriptive statistic) than indices that emphasize the dominance/evenness (e.g., Simpson index) component of diversity (Magurran 1988). Species richness indices, though better at discriminating between samples, are more affected by sample size than dominance/evenness measures.

Consequently, it is useful to determine before hand whether an index will be most sensitive to changes in the rare or the common species (Peet 1974). A diversity index to be effective should be able to distinguish between communities in not too widely different environments, and not over-emphasize the commonest or rarest species (Kempton and Taylor 1976).

The species similarity index or *Jaccard coefficient* used in this thesis provides a simple measure of the extent to which two habitats have species in common based on the presence-absence relationship between the number of species in each habitat and the total number of species (Krebs 1989).

$$\text{Jaccard index of community similarity} = \frac{C}{S_1 + S_2 + C}$$

where C = number of species common to both habitats

S₁ = number of species in habitat 1

S₂ = number of species in habitat 2

5.) *Species richness (S) and evenness (J')* – Community structure can also be measured through species richness and evenness. Species richness (S) is simply the number of species captured at each habitat. Equitability or evenness indices are based on the evenness with which importance is distributed among the species (Peet 1974). The evenness (J') of the apportionment of individuals among species in a habitat was measured according to Pielou (1975). It is a ratio of the measured diversity (obtained from the Shannon index) to the maximum value that it can attain.

$$\text{where } J' = \frac{H}{\text{Log}_n S}$$

J' is also known as equitability (J') and states that diversity is at a maximum when all species within a community are equally abundant (Southwood and Henderson 2001).

An evenness measure based on the Shannon Index (as used in this thesis) will give more weight to the equitability of the rarer species than an index based on the Simpson measure (Peet 1974). This is important, as only a few species at TBS contribute most, towards the small mammal communities.

Results

1.) *Relative abundance and biomass summaries of the small mammals:*

Relative abundance results of the small mammals for separate periods and habitats are shown in Tables B.1a-f and presented over time in Figs. 1a-1f. During the period 1986-90, *Clethrionomys* attained its highest relative abundance on all six plots regardless of habitat type. *Sorex* was the most variable species in terms of its time periods of greatest relative abundance, with the ATB, ASP and JPSP plots reaching *Sorex* highs in 1991-95; the BSB and ECO in 1986-90; and the JPR in 1977-79. *Peromyscus*' highest relative abundance period on the ASP, BSB, ECO, JPR and JPSP occurred during 1980-85, and on the ATB in 1977-79.

A summary of the overall (total) relative abundance of small mammals (both with and without sciurids) is compared across six habitats over grouped intervals of time (Figs. 2a-2b). All six plots attained their highest relative abundance during the period 1986-90, the 5- to 10- yr period following the 1980 fire (when sciurids were included). However, without the sciurids, only four out of six plots reached their highest relative abundance during 1986-90.

A summary of the total biomass of all small mammals collected during annual sampling surveys across six sites is presented in Tables B.2a-b. Beginning with the largest accumulation (g) by habitat and ending with the smallest over time are the ASP, ECO, JPR, JPSP, ATB and BSB (Table B.2a). These values do not necessarily correspond with the total number of individuals

captured from each plot, due to small accretions in biomass from *Sorex spp.*, which fell on average between 2.5 – 4.5g per individual.

Relative biomass values were also based on the number of captures per 100 TN and grouped into similar periods, as were the relative abundance data. Individual plots are presented in Tables B.3a-b to B.8a-b, with relative biomass separated into grouped intervals of time. Five out of six plots exhibited their highest levels of relative biomass (both with and without sciurids) during the period 1986-90; these included the ATB, ASP, BSB, ECO and JPSP plots.

Initially, the sciurids (squirrels and chipmunks) were purposefully separated from biomass and abundance tables because single sciurids might weigh from 100 to 200g more than an individual murid or soricid. They were therefore thought to have a significant impact on the interpretation of results, especially on plots with abundant sciurid captures (Fig. 3). While it was discovered that the sum totals of biomass, and numbers of individuals, were influenced by the addition of sciurids (Tables B.2a-b), the occurrence of peak periods in relative abundance and biomass remained basically the same, regardless if the sciurids were included or not.

In summary, the relative abundance of *Clethrionomys* reached its peak level across all six habitats during the same 1986-90 time period. *Peromyscus* reached its peak relative abundance on all six plots during 1980-85. Overall relative abundance and biomass of the small mammals in all six habitats (with all species included) attained their highest levels during 1986-90.

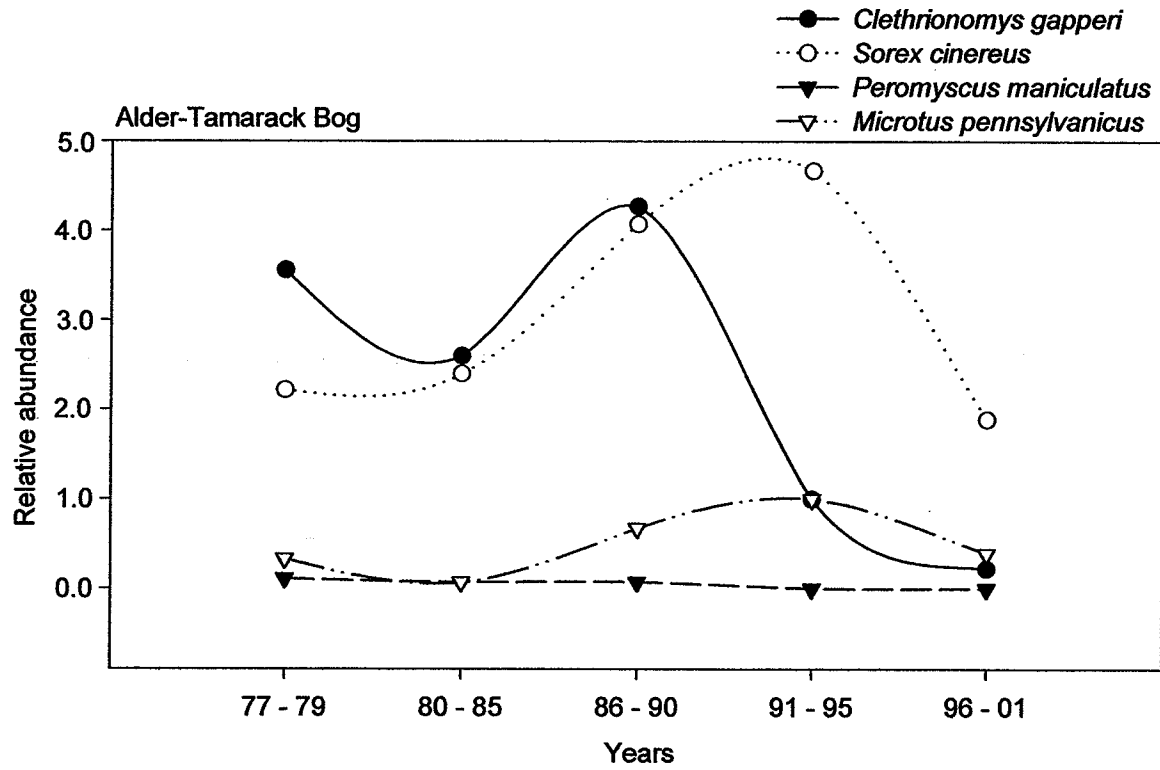


FIG. 1a. Relative abundance (numbers captured/100 trap nights) of small mammals in the Alder-Tamarack Bog.

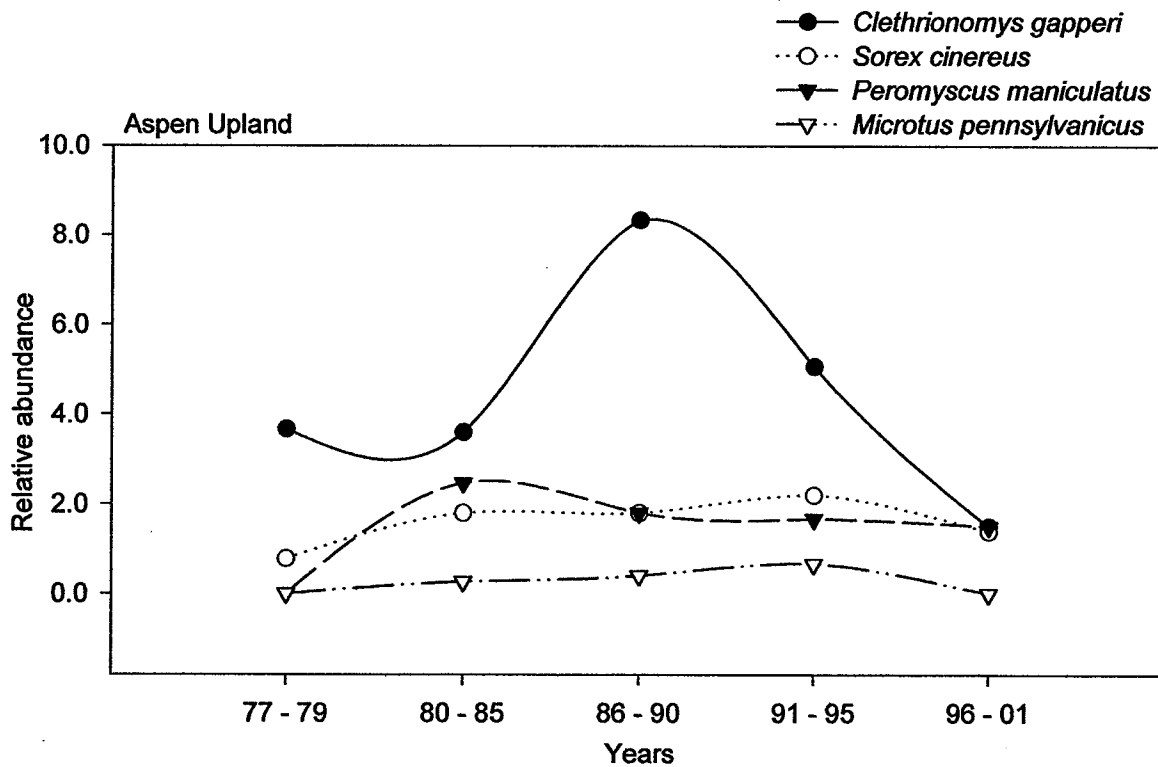


FIG. 1b. Relative abundance (numbers captured/100 trap nights) of small mammals in the Aspen Upland.

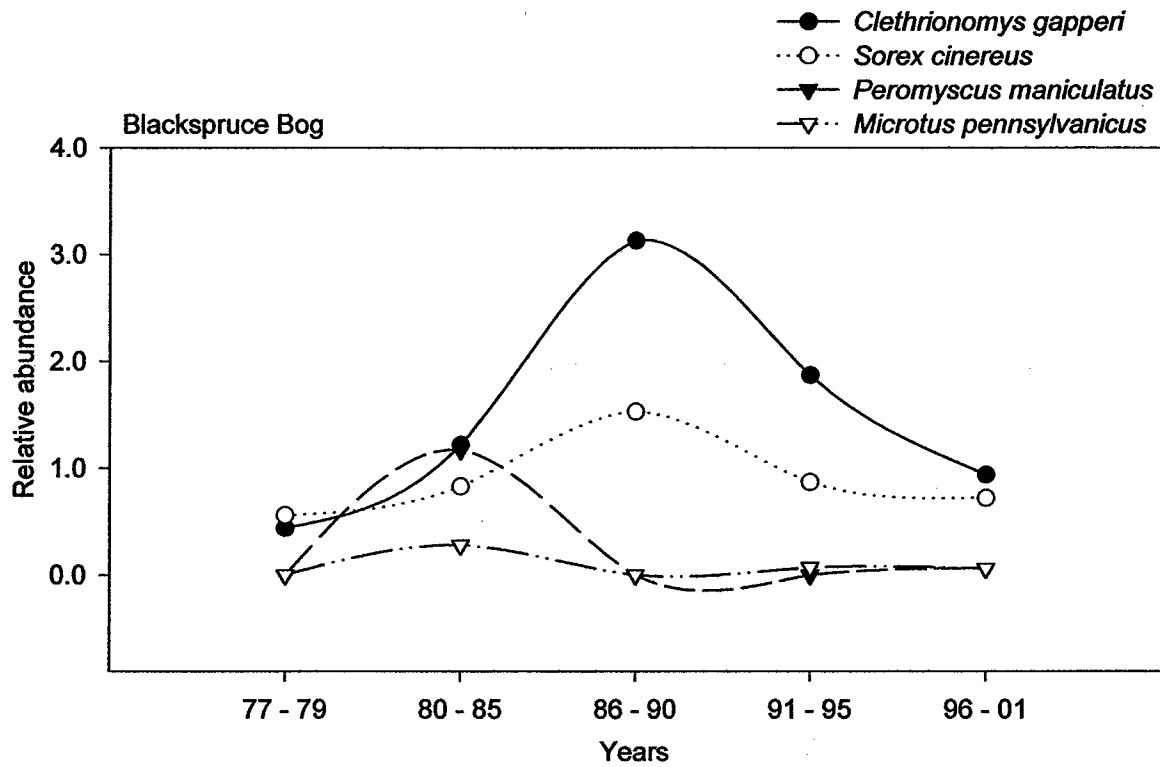


FIG. 1c. Relative abundance (numbers captured/100 trap nights) of small mammals in the Blackspruce Bog.

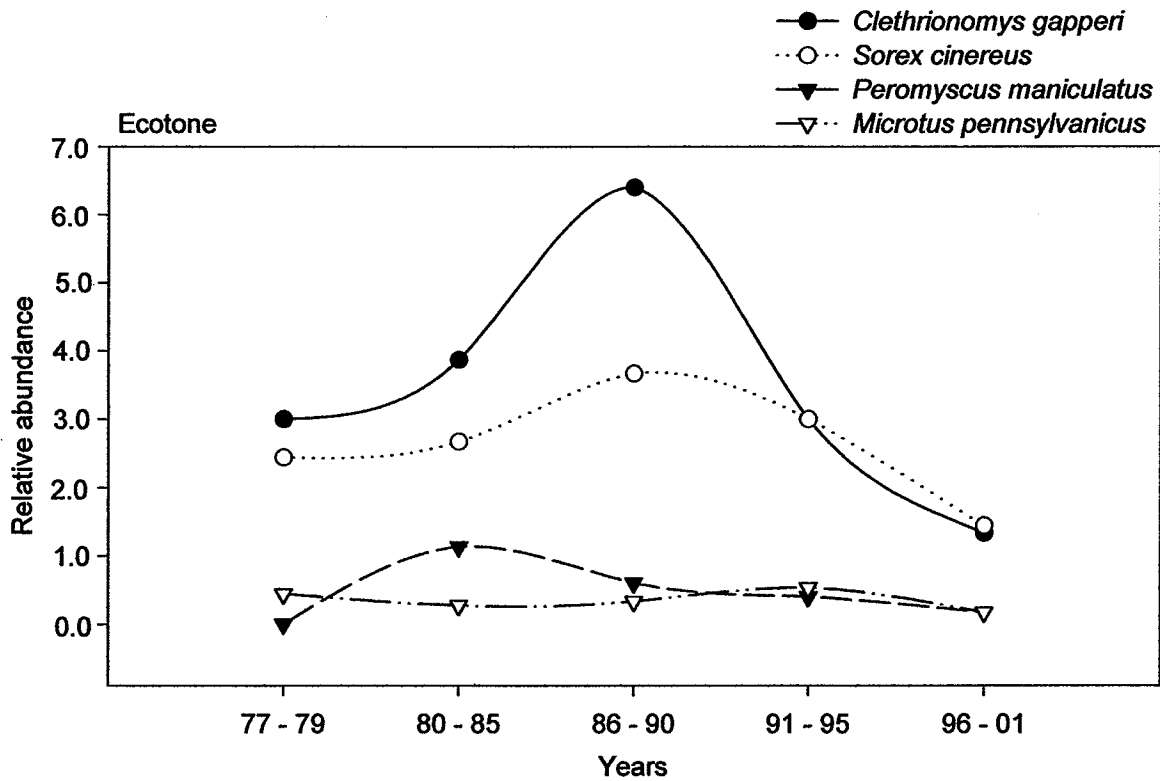


FIG. 1d. Relative abundance (numbers captured/100 trap nights) of small mammals in the Ecotone.

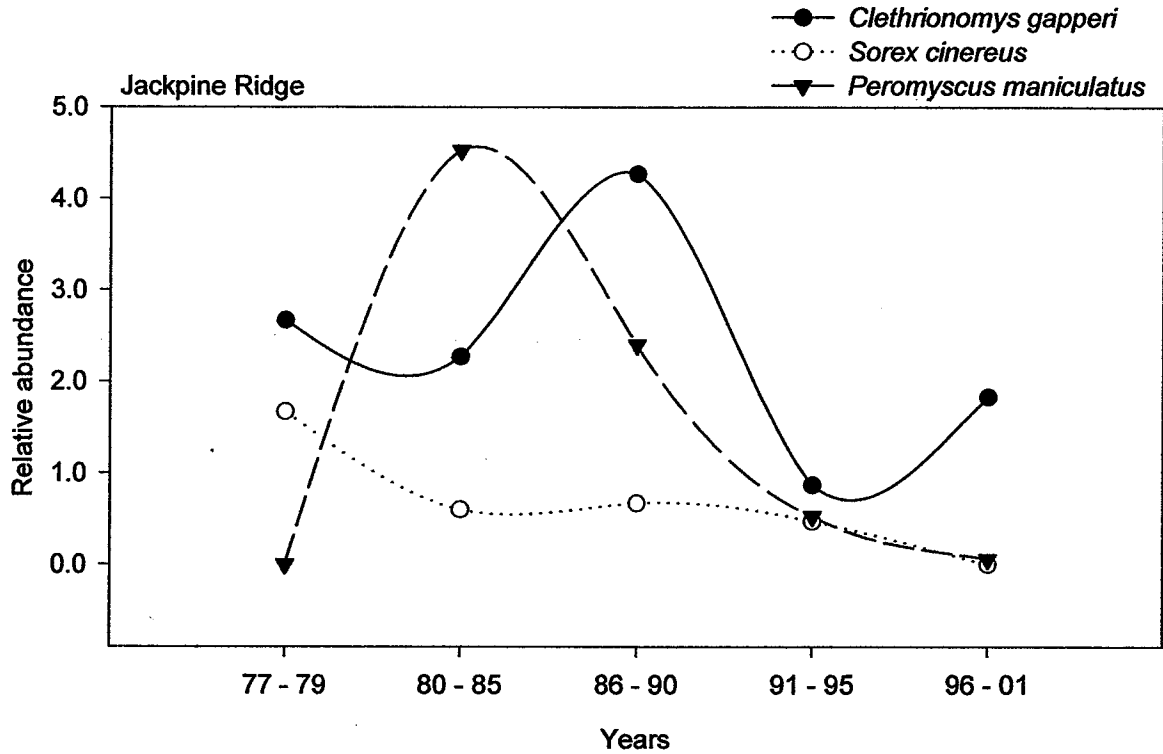


FIG. 1e. Relative abundance (numbers captured/100 trap nights) of small mammals in the Jackpine Ridge.

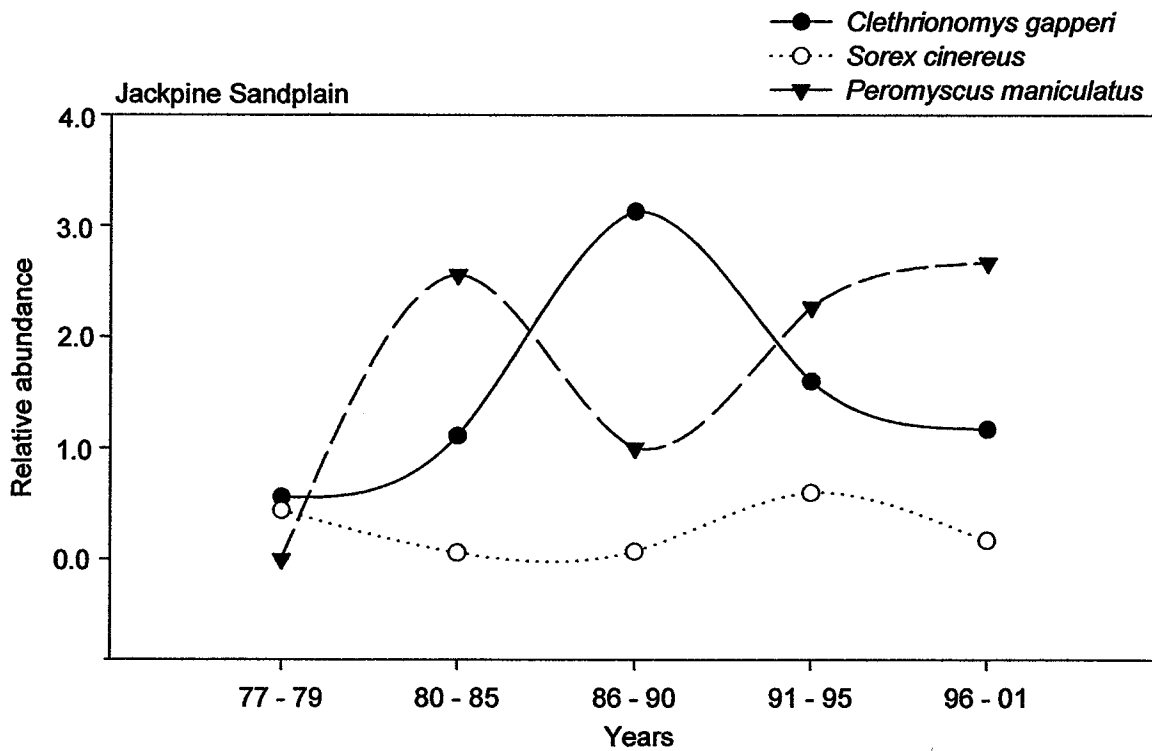


FIG. 1f. Relative abundance (numbers captured/100 trap nights) of small mammals in the Jackpine Sandplain.

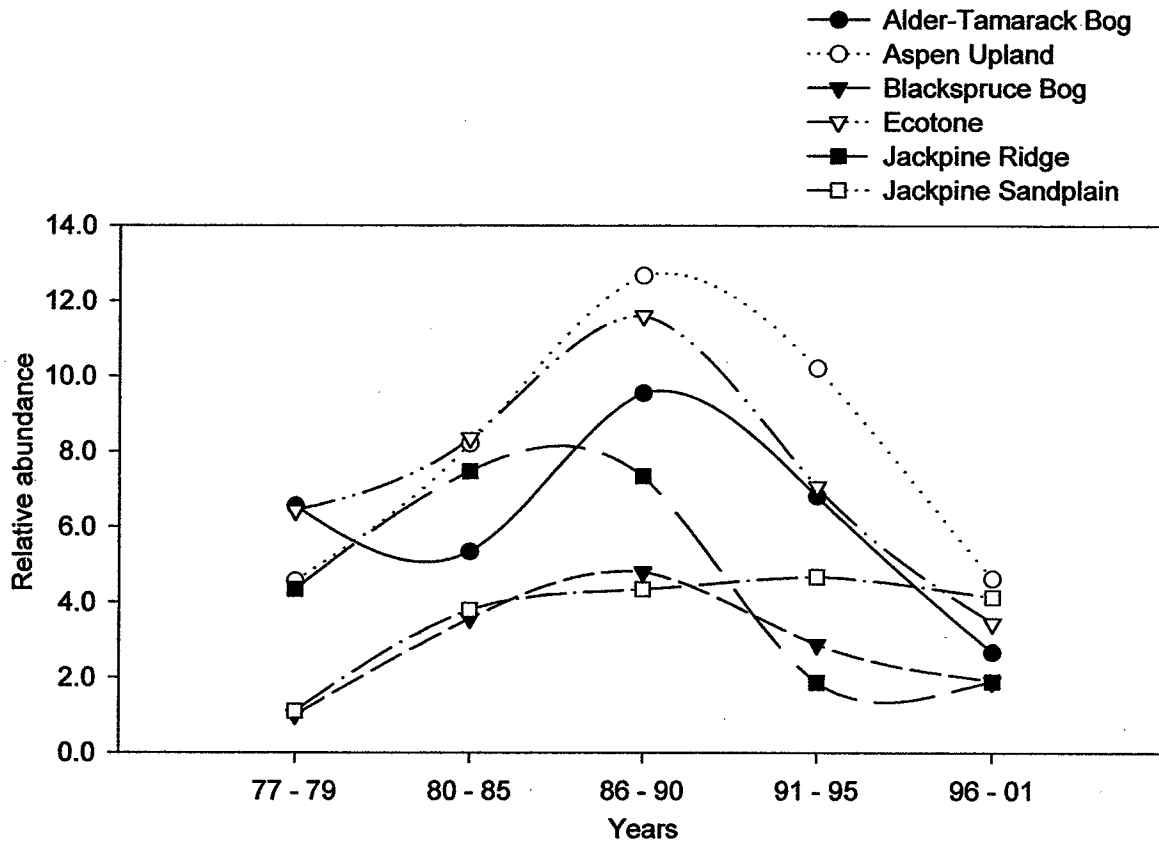


FIG. 2a. Total relative abundances (numbers captured/100 trap nights) of all small mammals (without sciurids) across six habitats at Taiga Biological Station.

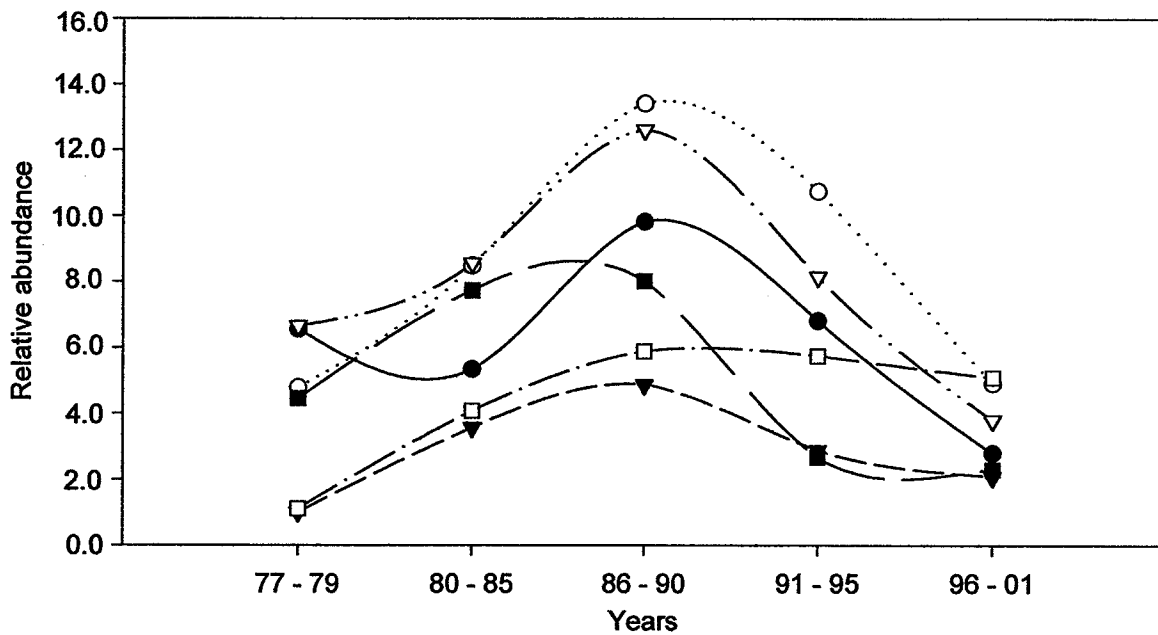


FIG. 2b. Total relative abundances (numbers captured/100 trap nights) of all small mammals (including sciurids) across six habitats at Taiga Biological Station.

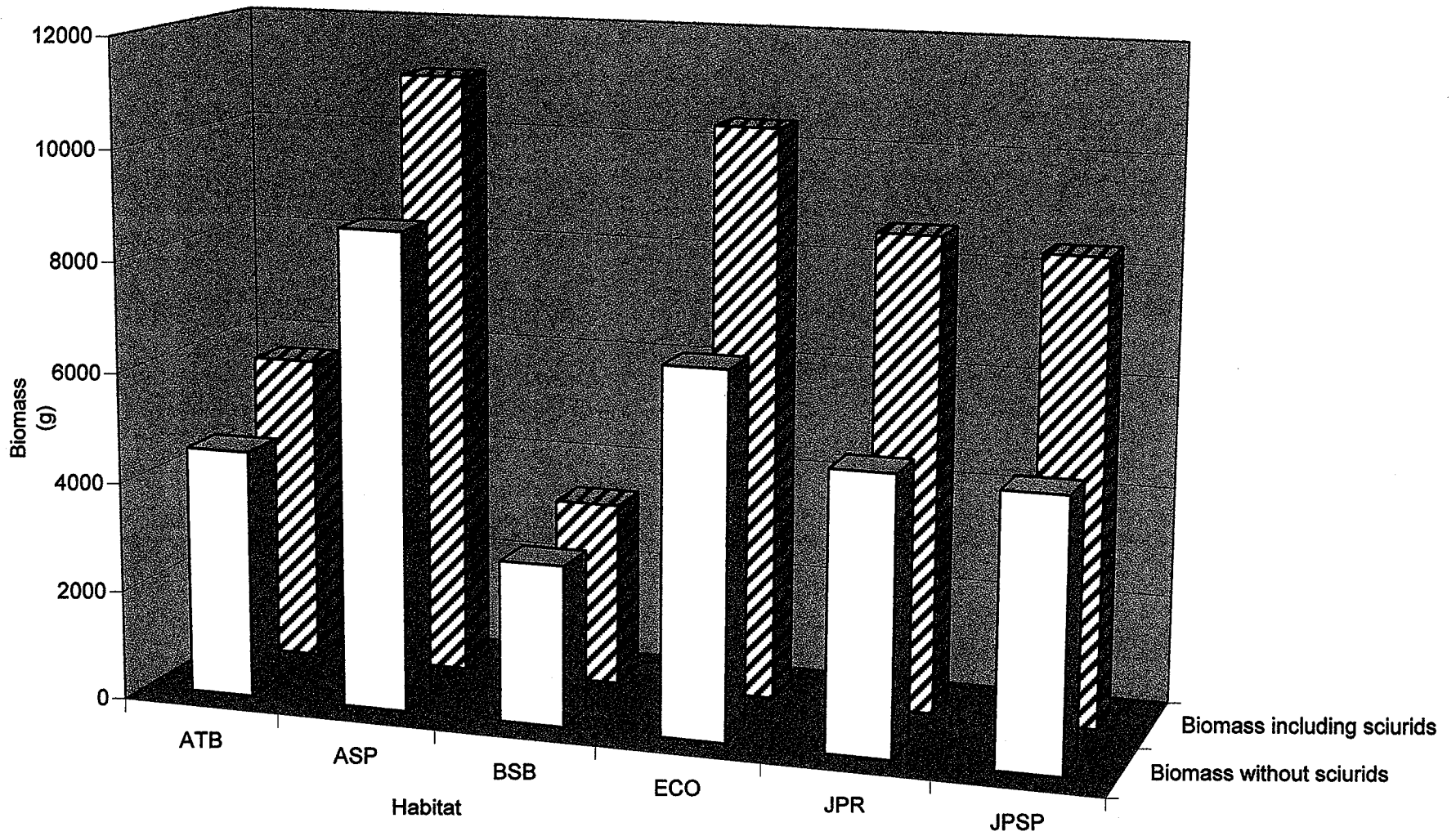


FIG. 3. A comparison of accumulated biomass (with and without sciurids) across six sites at Taiga Biological Station.

Whittaker Plot of Mammal Abundance Across Sites

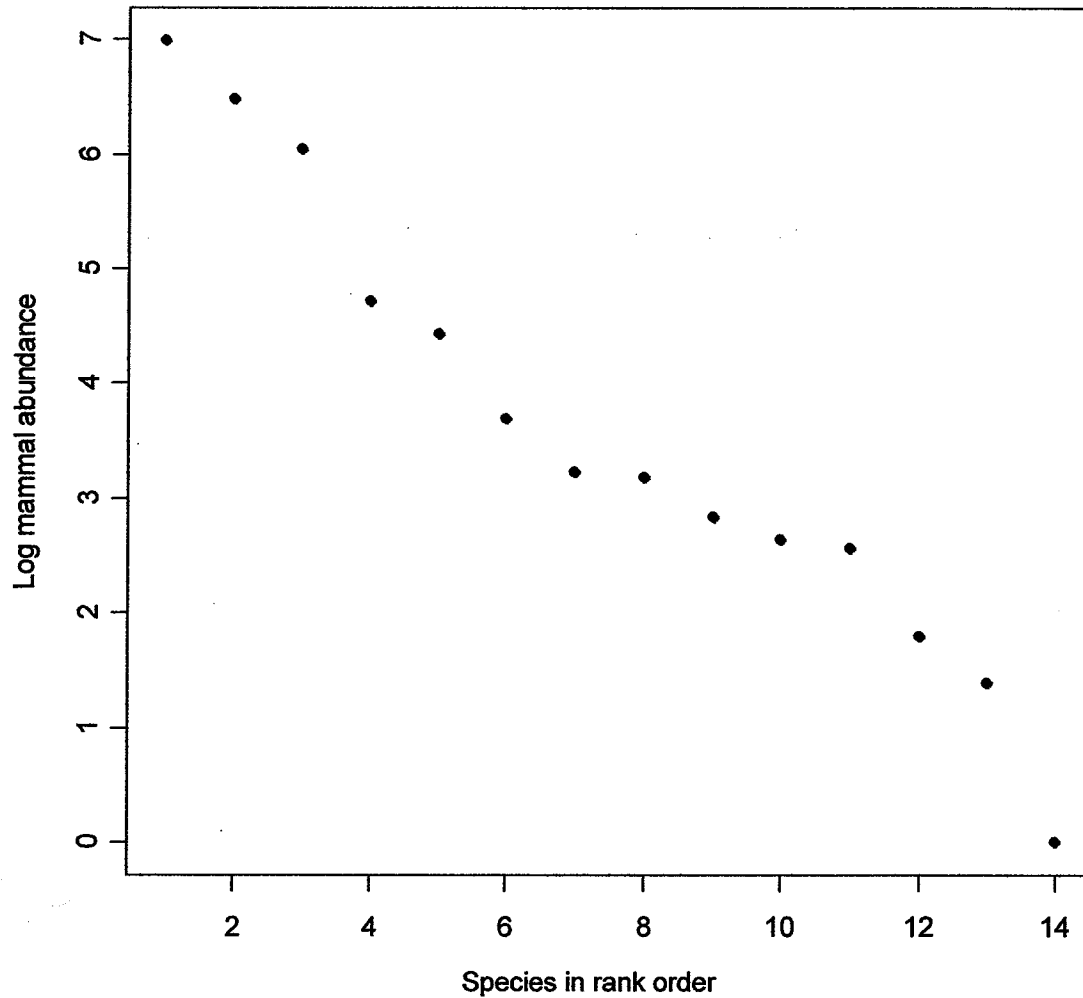


FIG. 4. A Whittaker plot of the small mammal species abundance data from Taiga Biological Station representing all species and habitats combined. The theoretical Whittaker plot for a logarithmic series produces a nearly straight line while the lognormal distribution predicts a reverse S-shaped curve (Krebs 1989). The above small mammal abundance curve appears to fall in between these two types of species distributions.

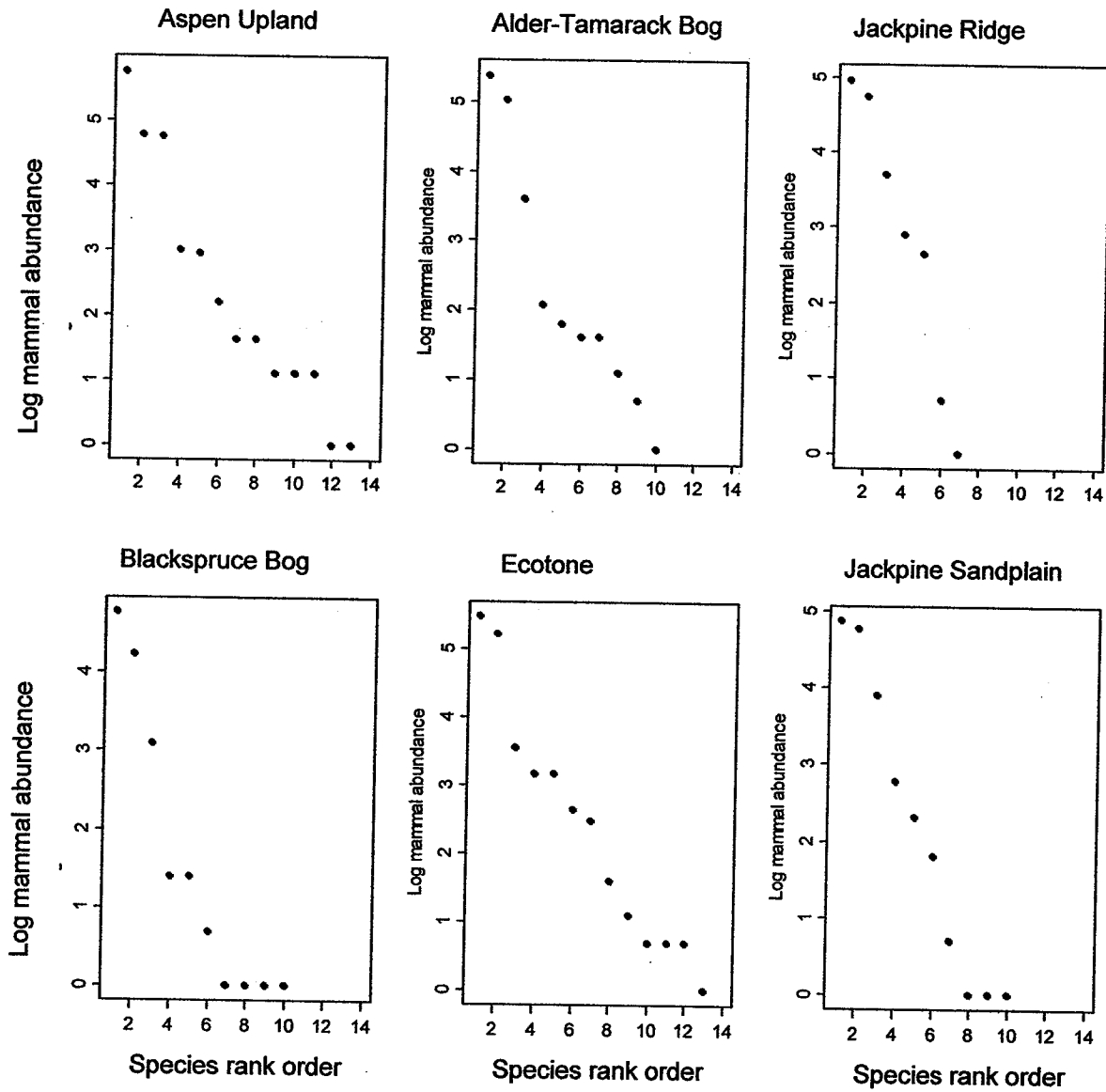


FIG. 5. Whittaker plots of small mammal species abundance data from Taiga Biological Station representing six habitats. A characteristic feature of these communities is that they contain a few species that are common and a greater number of species that are less common or rare.

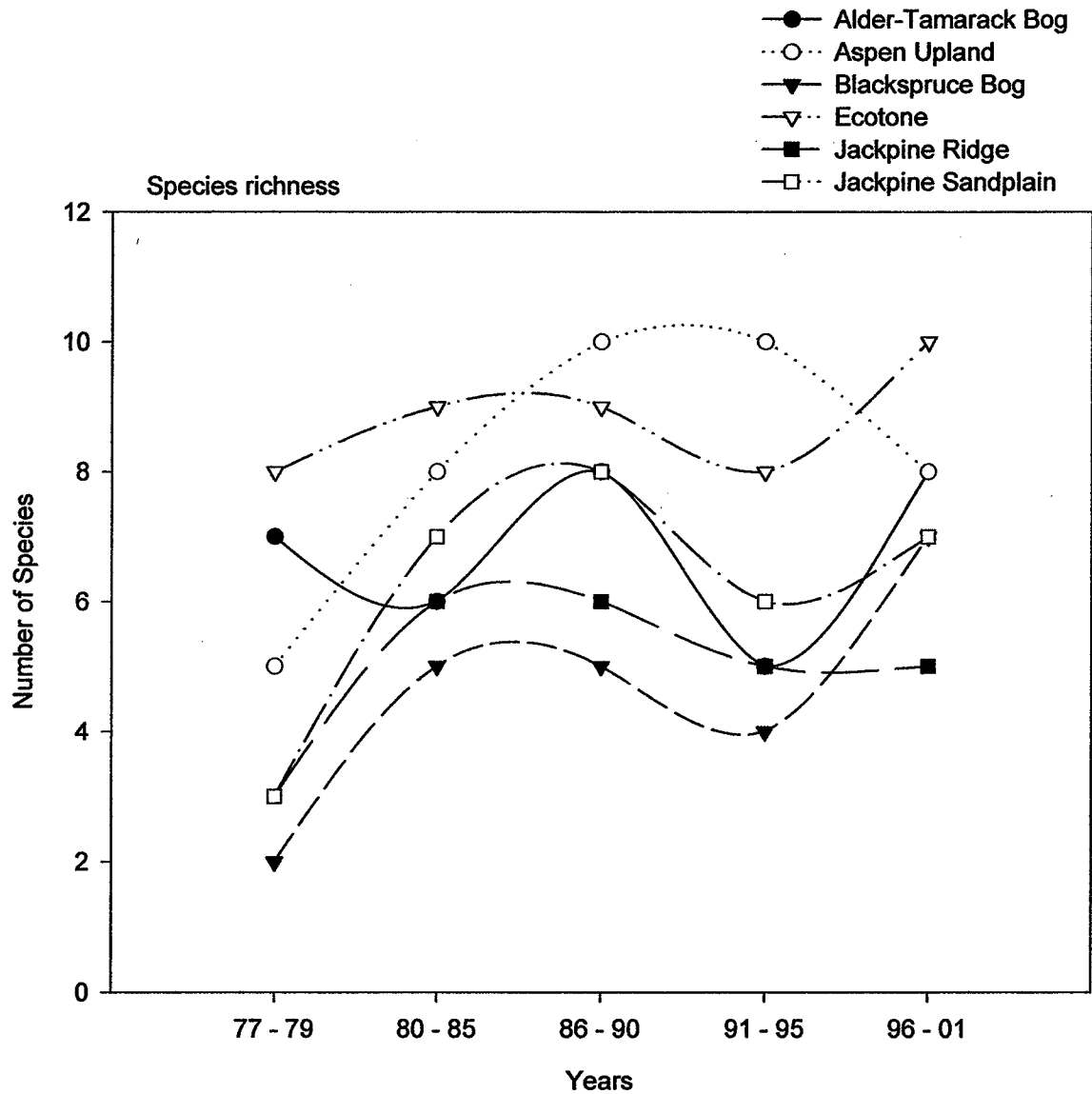


FIG. 6. Species richness (the number of species in a defined sampling unit) for small mammals (including sciurids) in six habitats at Taiga Biological Station. The numbers are cumulative for grouped time intervals.

2.) *Species-abundance models:*

The rank abundance curve produced from small mammal (log) abundance data plotted against species in rank order approximated a relatively straight line. This shape is a reflection of a logarithmic distribution (Fig. 4) which identifies the community as having a small number of abundant species, with a larger number of species represented by intermediate, and by few individuals (Krebs 1989). This relationship is true for most plots, with *Clethrionomys*, *Sorex* and *Peromyscus* being the major contributors towards the small mammal fauna at TBS. Whittaker plots of species abundance data are shown in Fig. 5 for each habitat. Each plot approximates a logarithmic distribution pattern to varying degrees. The ECO and ASP plots have captured the most number of uncommon species at TBS (see Table 1 in Section I).

3.) *Trophic composition and contribution:*

The composition of small mammal communities by habitat and by trophic structure through time is represented in Tables 1a-1f. Since sampling began in 1977, the Alder-Tamarack Bog has shown a steady rise in the contribution of its insectivores towards overall trophic structure, from approximately 37% in 1977-79, to 75% during the 1996-01 period. Concomitantly, there has been a decrease in trophic input by the grazer-omnivores (i.e., *Clethrionomys*, *Microtus*, *Phenacomys* and *Synaptomys*), from 61.0% in 1977-79, down to 22% during this latest 1996-01 period. Individuals belonging to the granivore-omnivore category have had little input towards trophic structure on this particular plot.

The Aspen Upland also expressed a similar trend among its shrews, with the insectivore trophic level on the rise since 1991 and a corresponding decrease in the grazer-omnivore trophic level since 1986. The granivore-omnivore category including *Peromyscus* and *Zapus* fell during 1986-95, but is now back to 1980-85 contribution levels of approximately 30% towards overall trophic structure on the ASP.

The Blackspruce Bog has shown wide fluctuations in its insectivore trophic level throughout the years, varying from 25% to 55%. The grazer-omnivore community experienced an increased level of input during the years 1986-95 on the BSB, making a large contribution (66%) towards overall community trophic structure during this decade.

The Ecotone has shown minor fluctuations in its insectivore trophic level throughout the years, with slight variations in overall contribution towards community trophic structure. The grazer-omnivore community of *Clethrionomys*, *Microtus*, *Phenacomys* and *Synaptomys* has experienced an overall decline on the ECO since trapping began in 1977. The peak granivore-omnivore trophic contribution occurred during 1980-85, with only minor input by this trophic category over the years.

The Jackpine Ridge insectivore trophic level has yet to recover its robust 1977-79 period. During 1991-95, the input from this particular trophic level doubled from the previous decade, but in the past six years there has been no contribution by the shrews towards overall community trophic structure. The grazer-omnivore community on the JPR has provided the greatest input by a

trophic category during 1996-01. Both granivore-omnivore categories, *Peromyscus* and *Zapus*, and the sciurids, have experienced a general decline in the past six years (1996-01) on the JPR.

The Jackpine Sandplain has also never recovered the insectivore trophic levels held during 1977-79. The grazer-omnivore category (*Clethrionomys*, *Microtus*, *Phenacomys* and *Synaptomys*) and granivore-omnivore category (*Tamias spp.* and *Glaucomys*) rose substantially during the 1986-95 period, while the small mammal granivore-omnivore category (*Peromyscus* and *Zapus*) fell during the same time period on the JPSP.

4.) *Species diversity and similarity:*

Community structure was additionally assessed through species diversity and similarity indices calculated for each of the various small mammal communities. A summary of mammal community characteristics in each habitat is shown in Tables B.2a-b. The Shannon Index is presented in two ways depending on whether sciurids have been included or excluded. Without sciurids, Table B.2a describes the sequential order from greatest to least diversity (combined over 25 sampling-years) as follows: ECO, ASP, BSB, ATB, JPSP and JPR. If sciurids are included (Table B.2b), then the order has changed: ECO, ASP, JPSP, JPR, BSB and ATB. Overall (i.e., diversity measured over 25 sampling-years), the most diverse habitat has been the ECO.

The JPSP produced the greatest number of sciurid captures over time (61 individuals), as shown in Table B.2b. The BSB and ATB plots have captured the

fewest sciurids (5 and 6 individuals, respectively). This increased abundance and species richness affects diversity measurements calculated over the long-term. The inclusion of sciurids can provide an additional three species per plot, therefore species diversity data have been presented without sciurids and with sciurids, and separated into shorter time periods, to reveal any influence habitat succession may have had on small mammal diversity (see Tables B.3-8).

The community characteristics of individual habitats are described in Tables B.9 and B.10. It was noted that in all plots the highest diversity values were the same for each period of years, per plot, whether sciurids had been included or excluded. In the ATB and JPSP (Table B.9) without sciurids, the species diversity dropped during the five-year period following 1980. All other plots responded with an increase in diversity. Observing the same data, but with sciurids (Table B.10), all plots reported an increase in species diversity, except the ATB. The ATB was the only plot not to be directly affected by fire damage.

A Jaccard community similarity index (Tables 2 and 3) of the TBS small mammal fauna and habitat vegetation were used to compare community structure between sites. The BSB and JPR had the most dissimilar small mammal communities, having a Jaccard coefficient of only 0.4167 or 42% similarity - which is the ratio of common species to all species found in these two sites. The ECO and ASP were the most similar in terms of number of species and individuals within each habitat, with a Jaccard coefficient of 0.8571 or 86% similarity. These two plots reported 12 species in common while the JPR and BSB had only five species in common (Table 2).

5.) *Species richness and evenness:*

Species richness (as measured by the number of species in a defined sampling unit) increased in five out of six plots (Fig. 6) during the period 1980-85, except for the ATB, and remained elevated on all plots during the subsequent 1986-90 period. These results held whether sciurids were included or not (Tables B.9 and B.10). A general overall decline in species richness (Fig. 6) was experienced by most habitats during (1991-95), 10- to 15- yrs post-fire. But since the 1996-01 period, both the ATB and BSB plots have experienced notable increases in species richness through the inclusion of sciurid species (Table B.10). Less apparent increases in species richness were noted (Table B.9) when sciurids were omitted.

Evenness values overall appear to be little influenced by the inclusion of sciurids (Tables B.9 and B.10). The highest values occurred during similar time periods whether sciurids had been included or not. The only exception was in the ECO, where the highest levels of evenness took place during 1991-95 with sciurids, and during 1996-01 without sciurids. The greatest evenness or equitability of distribution of the individuals among the different species is quite variable among the habitats. For example, the BSB and JPSP reached their peak equitability during 1977-79; the ATB during 1986-90; the ECO and JPR during 1991-1995; and the ASP peak equitability in 1995-01.

TABLE 1. Composition of small mammal communities by trophic category through time in six habitats at Taiga Biological Station. Percentages of numbers and of biomass at each trophic level within the study plots are indicated (with number of animals in parentheses). All species of shrews are insectivorous. The rodents are separated as grazers-omnivores (*Clethrionomys*, *Microtus*, *Phenacomys* and *Synaptomys*) and as granivore-omnivores (*Peromyscus* and *Zapus*). Sciurids are in the granivore-omnivore category.

(a) Alder-Tamarack Bog					
Trophic Level	(77 - 79)	(80 - 85)	(86 - 90)	(91 - 95)	(96 - 01)
Insectivore					
Number	37.3 (22)	46.3 (37)	46.3 (68)	69.6 (71)	74.6 (37)
Biomass	14.2	15.4	12.9	28.7	20.6
Grazer-Omnivore					
Number	61.0 (36)	52.6 (42)	50.3 (74)	30.4 (31)	21.5 (11)
Biomass	83.8	84.6	52.7	71.3	39.4
Granivore-Omnivore					
Number	1.7 (1)	1.3 (1)	0.7 (1)	0.0	0.0
Biomass	2.1	1.2	0.8	0.0	0.0
Sciurids					
Number	0.0	0.0	2.7 (4)	0.0	4.0 (2)
Biomass	0.0	0.0	33.7	0.0	38.0
(b) Aspen Upland					
Trophic Level	(77 - 79)	(80 - 85)	(86 - 90)	(91 - 95)	(96 - 01)
Insectivore					
Number	17.0 (8)	22.1 (28)	14.4 (29)	20.5 (33)	31.8 (28)
Biomass	5.7	4.8	2.7	3.9	8.8
Grazer-Omnivore					
Number	78.7 (37)	45.6 (58)	66.7 (134)	55.2 (89)	30.7 (27)
Biomass	72.9	49.0	72.0	55.5	28.9
Granivore-Omnivore					
Number	0.0	29.1 (37)	13.4 (27)	19.2 (31)	31.8 (27)
Biomass	0.0	24.9	11.3	17.6	26.0
Sciurids					
Number	4.2 (2)	2.4 (3)	5.5 (1)	4.3 (3)	4.5 (3)
Biomass	21.3	21.3	14.0	23.0	36.2

TABLE 1. Composition of small mammal communities by trophic category continued.

(c) Blackspruce Bog					
Trophic Level	(77 - 79)	(80 - 85)	(86 - 90)	(91 - 95)	(96 - 01)
Insectivore					
Number	55.6 (5)	24.6 (16)	32.9 (24)	31.8 (14)	37.8 (14)
Biomass	21.5	6.4	7.9	7.6	9.1
Grazer-Omnivore					
Number	44.4 (4)	41.5 (27)	65.8 (48)	65.9 (29)	48.6 (19)
Biomass	78.5	60.8	88.0	64.7	48.4
Granivore-Omnivore					
Number	0.0	32.3 (21)	0.0	0.0	5.4 (2)
Biomass	0.0	32.7	0.0	0.0	10.7
Sciurids					
Number	0.0	1.5 (1)	1.4 (1)	2.3 (1)	8.1 (3)
Biomass	0.0	NA	4.1	27.7	31.7

(d) Ecotone					
Trophic Level	(77 - 79)	(80 - 85)	(86 - 90)	(91 - 95)	(96 - 01)
Insectivore					
Number	43.3 (26)	35.2 (45)	33.4 (63)	37.7 (46)	41.1 (28)
Biomass	15.6	12.0	11.7	4.8	11.0
Grazer-Omnivore					
Number	53.4 (32)	49.2 (63)	53.4 (102)	44.3 (54)	41.2 (31)
Biomass	53.9	63.3	61.0	28.8	39.8
Granivore-Omnivore					
Number	0.0	13.3 (17)	5.3 (10)	4.9 (6)	8.8 (6)
Biomass	0.0	14.2	4.9	2.4	5.7
Sciurids					
Number	3.4 (2)	2.4 (2)	7.9 (15)	13.1 (16)	8.9 (6)
Biomass	30.6	4.6	22.4	64.0	43.5

TABLE 1. Composition of small mammal communities by trophic category continued.

(e) Jackpine Ridge

Trophic Level	(77 - 79)	(80 - 85)	(86 - 90)	(91 - 95)	(96 - 01)
Insectivore					
Number	37.5 (15)	8.7 (10)	8.3 (10)	17.5 (7)	0.0
Biomass	7.5	2.3	1.6	1.1	0.0
Grazer-Omnivore					
Number	60.0 (24)	29.3 (34)	53.3 (64)	32.5 (13)	80.5 (33)
Biomass	61.3	31.4	53.2	12.6	42.2
Granivore-Omnivore					
Number	0.0	58.6 (44)	30.0 (36)	20.0 (8)	2.4 (1)
Biomass	0.0	45.5	21.8	5.1	2.1
Sciurids					
Number	2.5 (1)	3.4 (4)	8.3 (10)	30 (12)	17.0 (7)
Biomass	31.3	20.9	23.4	81.3	55.6

(f) Jackpine Sandplain

Trophic Level	(77 - 79)	(80 - 85)	(86 - 90)	(91 - 95)	(96 - 01)
Insectivore					
Number	40.0 (4)	1.4 (1)	1.1 (1)	10.5 (9)	3.3 (3)
Biomass	12.4	0.2	0.1	1.7	0.6
Grazer-Omnivore					
Number	60.0 (6)	27.4 (20)	54.5 (48)	27.9 (24)	24.2 (22)
Biomass	87.6	24.9	38.7	28.0	24.2
Granivore-Omnivore					
Number	0.0	64.4 (47)	18.1 (16)	43.0 (37)	53.8 (49)
Biomass	0.0	39.3	8.1	31.8	37.1
Sciurids					
Number	0.0	6.8 (5)	26.1 (23)	18.6 (16)	18.7 (17)
Biomass	0.0	35.7	53.1	38.5	38.1

TABLE 2a. Jaccard community similarity index for six small mammal habitats at Taiga Biological Station. The Jaccard index is based on the presence-absence relationship between the number of species common to a pair of communities and the total number of species in each of the two communities, adjusted for the common species. The similarity coefficients equal 1 in cases of complete similarity and 0 if the sites are dissimilar and have no species in common (Magurran 1988).

Habitat	Aspen Upland	Alder-Tamarack Bog	Jackpine Ridge	Blackspruce Bog	Ecotone	Jackpine Sandplain
Aspen Upland	1.0000	0.7692	0.5385	0.7692	0.8571	0.7692
Alder-Tamarack Bog		1.0000	0.5455	0.6667	0.7692	0.5385
Jackpine Ridge			1.0000	0.4167	0.5385	0.5455
Blackspruce Bog				1.0000	0.7692	0.6667
Ecotone					1.0000	0.6429
Jackpine Sandplain						1.0000

TABLE 2b. Number of small mammal species involved in the Jaccard similarity index. The numbers following the diagonal represent total numbers of species found at each location. Off-diagonal values represent the number of common species between habitats.

Habitat	Aspen Upland	Alder-Tamarack Bog	Jackpine Ridge	Blackspruce Bog	Ecotone	Jackpine Sandplain
Aspen Upland	13	10	7	10	12	10
Alder-Tamarack Bog		10	6	8	10	7
Jackpine Ridge			7	5	7	6
Blackspruce Bog				10	10	8
Ecotone					13	9
Jackpine Sandplain						10

TABLE 3a. Jaccard community similarity index for six vegetation habitats at Taiga Biological Station. The Jaccard index is based on the presence-absence relationship between the number of species common to a pair of communities and the total number of species in each of the two communities, adjusted for the common species. The similarity coefficients equal 1 in cases of complete similarity and 0 if the sites are dissimilar and have no species in common (Magurran 1988).

Habitat	Alder-Tamarack Bog	Aspen Upland	Blackspruce Bog	Ecotone	Jackpine Ridge	Jackpine Sandplain
Alder-Tamarack Bog		0.2438	0.2439	0.3444	0.2474	0.1981
Aspen Upland			0.1357	0.5758	0.2714	0.3431
Blackspruce Bog				0.1479	0.2656	0.2429
Ecotone					0.2381	0.2617
Jackpine Ridge						0.4930
Jackpine Sandplain						

TABLE 3b. Number of plant species involved in the Jaccard similarity index. The numbers following the diagonal represent total numbers of species found at each location. Off-diagonal values represent the number of common species between habitats.

Habitat	Alder-Tamarack Bog	Aspen Upland	Blackspruce Bog	Ecotone	Jackpine Ridge	Jackpine Sandplain
Alder-Tamarack Bog	71	39	20	52	24	21
Aspen Upland		128	19	95	38	47
Blackspruce Bog			31	21	17	17
Ecotone				132	35	39
Jackpine Ridge					50	35
Jackpine Sandplain						56

Discussion

1.) Relative abundance and biomass:

a) *Trends in relative abundance and biomass* - Although *Peromyscus* increased on five of the plots during the early post-fire stage (1980-85), it did not maintain its elevated numbers much past this period. Clearly, *Peromyscus* responded favourably and successfully during a short time to the opportunities made newly available through the burned environments. Plots that experienced minor to moderate fire damage (i.e., ASP and ECO) showed increased *Peromyscus* numbers as did the more severely burned habitats (i.e., JPR, BSB and JPSP). As habitats recovered, conditions on the plots deteriorated for this species, except on the JPSP, where the relative abundance of *Peromyscus* has not substantially changed over time. *Clethrionomys* populations across many of the habitats at TBS showed increased relative abundance during the 5- to 10- yr period after the fire. Where differences appeared among the species was in the timing of their response in reaction to habitat change.

It is apparent that individual small mammal species have different response times towards habitat change and may respond either rapidly (e.g., *Peromyscus*), or with somewhat of a delay (e.g., *Clethrionomys*), to the altered conditions in their environment. What is particularly notable, however, is that even minimal habitat change was sufficient to stimulate *Peromyscus* populations into exploiting the newly available space of a diverse range of habitat types.

b) *Dietary items of small mammals affecting local abundances* - In

Appendix A.1, a description of the vegetative changes that have occurred within the small mammal habitats over the past twenty-five years has been provided. Overall, the small mammal fauna responded favourably to the early successional stages of vegetation change at TBS; *Peromyscus* thrived during this period. Tevis (1956) suggested that curiosity may be an important factor for increased deer mice on recently burned habitat, but that the chief reason was due to the vacuum created by the removal of the resident population. In this scenario, release from competition over space would allow individuals the freedom to increase. At TBS, the availability of food resources rather than competition for space would seem more likely as an extrinsic population factor that affects *Peromyscus* population dynamics, as well as other sympatric species.

Fire may have caused a release of nutrients into the habitats which subsequently enhanced the fertility, and therefore the productivity of newly sprouting vegetation on the affected plots. Fire has been noted to release pulses of nutrients that are reflected in increased mineral contents of new vegetation (Ahlgren 1960; Bendell 1974).

Three months after the May 1980 fire, many of the fire-killed trees on the BSB were found lying across the bog surface knocked over by strong winds. The bog substrate at this time consisted of brown, steam-killed sphagnum, interspersed with patches of charcoal-covered ground, depressions (water bowls) of collected rainfall, and clumps of *Ledum* and other ericeaceous shrubs that had managed to regenerate following the intense burn (K. Johnson, pers. comm.).

Recently fallen trees that had not been completely consumed by the flames may have provided an abundant food source in the form of seed cones (which had previously been off limits to many of the small mammals), across several of the fire-damaged sites.

On the JPR, Martin (1983) reported the presence of many temporary post-fire colonizing plant species as well as species that re-established themselves following fire. Scattered jack pine seedlings were noted to be growing in the crevices of the burned rock surfaces on the ridge, while some of the mature, wind-thrown, fire-killed, *Pinus banksiana* trees were observed lying on the ground at this time (K. Johnson, pers. comm.).

On the JPSP, over half of the upper canopy layer consisting of mature *Pinus banksiana* was destroyed by the fire. The ground cover of lichens was mostly burned down to the sand substrate, with the organic/mineral ash layer washed away by rainfall (K. Johnson, pers. comm.). Martin (1983) two years post-fire reported the presence of a thin herbaceous layer along with the presence of *Pinus banksiana* seeds and seedlings. Many of these plant species that made an appearance for several years following the fire might have contributed dietary and nesting items for the small mammals at TBS.

Northern red-backed voles (*Clethrionomys rutilus*) have been known to consume a wide variety of items that include seeds of *Arctostaphylos spp.*, *Vaccinium spp.*, *Geocaulon lividum*, and spruce; leaves of several shrubs such as *Shepherdia and Vaccinium*; horsetails and leaves of herbs *Equisetum pratense*, *Geocaulon*, and *Cornus*; lichens *Alectoria*, *Usnea*, *Cladonia spp.*,

Parmelia spp., *Peltigera* spp.; fungi *Laccinum*, *Russula*, *Clavaria*, *Hygrocybe*, and *Hydnellum* and some mosses (Boonstra et al. 2001). Most of these plant species occur at TBS, distributed in varying proportions both spatially and temporally across the plots. Martin (1983) noted many arboreal lichens on branches on the ground that had fallen from mature surrounding jack pine trees. However, these did not appear to be of sufficient enticement for *Clethrionomys* to reappear substantially until 1984 on the JPSP.

Vickery (1979) studied food preferences of populations of *Clethrionomys* in the mixed deciduous forests of Quebec and found that fruit, while comprising only 20% to 30% of its annual diet, is the preferred food type when it is locally available. *Clethrionomys* preferred the fleshy fruit of *Fragaria virginiana* and *Prunus virginiana* more often than other available fruits. He noted that few tree seeds were taken during the tests of food preference and suggested that the timing of their availability is important for the inclusion of tree seeds into *Clethrionomys*' diet.

While *Peromyscus* is very successful at exploiting recent burns, Martell and Macaulay (1981) observed that deer mice do not actively search for seeds of black spruce (*Picea mariana*), or jack pine (*Pinus banksiana*). In contrast to these findings, Ahlgren (1966) reported that deer mice consumed quantities of *Pinus banksiana* seeds on recent burns. Martell and Macaulay (1981) observed that the diet of *Peromyscus* is quite diverse and plastic, enabling these creatures to utilize a number of food resources available on disturbed and successional sites. Food habits of *Peromyscus* were determined by food availability, showing a distinct

seasonal pattern (i.e., seeds were most important in early May and in the fall; arthropods were most important from May to July, while berries became important from July to early September).

Peromyscus most likely encountered and incorporated a fair number of *Pinus banksiana* seeds within its diet on the JPR and JPSP shortly after the fire simply because of the sheer abundance and adventitious occurrence (i.e., late May) of these potential food items.

Martell (1981) noted that *Clethrionomys* also exhibited seasonal patterns in its food consumption. In northern Ontario, *Cladina spp.* and *Cladonia spp.* dominated its diet in early May, with fresh herbaceous matter eaten primarily in mid-May to mid-July. Berries were taken in late July while fungi (mushrooms) were one of the main food items in late summer and early fall. Conifer seeds made a minimal contribution to *Clethrionomys* diet. On clear-cuts and in uncut coniferous stands, lichens and fungi made up most (80-89%) of their diet. He found that when *Clethrionomys* persisted on unscarified clear-cuttings, this was related to the presence of the mostly dead moss layer and low shrub layer which provided cover, helped maintain humidity, and supplied food. Therefore, according to Martell (1981), habitats that have unfavourable conditions for supporting fungi and lichen growth, such as on recent clear-cuts or burns, witness a rapid decline in *Clethrionomys* numbers.

Relative abundances of *Clethrionomys* (with the exception of the notable short-lived increase in numbers immediately after the fire) did not respond as rapidly or as favourably to burning, as did *Peromyscus*. There was a 5- to 10- yr

delay in response to habitat change by *Clethrionomys*. However, red-backed vole fluctuations at TBS may not be so strongly influenced by the products of habitat change (as was seen with *Peromyscus*), but suggest instead, unknown large-scale forces are affecting this species' population response.

The association of *Clethrionomys* with moist habitats (Gunderson 1959; Miller and Getz 1973; 1977) and cover (Lovejoy 1975; Morris 1983) indicate that for the most part, during the initial five-year period after the fire, *Clethrionomys* avoided the severely burned xeric habitats. Either this avoidance was due to the loss or depletion in suitable food items (i.e., lichens and fungi) and/or to the lack of sufficient herbaceous layers that could provide adequate cover and moisture levels. Rapid increases in numbers of *Clethrionomys* were observed in August 1980 on the ATB, BSB, ECO and JPR (compared with previous years). The attraction of this species to either the products from fire-stimulated plant growth (i.e., berries, seeds, herbaceous matter) or to changes in habitat structural features (i.e., fallen trees and exposed root stumps) may be one of the explanations for this response. However, this does not sufficiently explain the similar increase in *Clethrionomys* on the ATB. Perhaps the plants at TBS have cyclical periods (independent of the effects from fire) that the small mammals respond to as well.

While the overall relative abundances of all small mammals at TBS increased during the 1986-90 period, either a simultaneous occurrence of improved habitat conditions across the plots occurred or some external large-scale environmental factor stimulated the TBS fauna to respond with increased

abundance, over the same five year period. In general, not until five years after the fire would sufficient time have passed to enable habitat conditions to become more suitable or less restrictive towards *Clethrionomys*, as well as the other less common small mammal species.

c) Recovery of vegetation and its effect on small mammal abundance -

The first stage of revegetation, the *seedling-herb stage*, usually lasts from one to four years (Viereck 1983), or two to eight years (Fox 1983), depending on the site and fire conditions. Seedlings usually become established during this stage in coniferous ecosystems. The herbaceous plant cover may increase rapidly during this seedling-herb stage from 0% to as much as 40 or 50% (Viereck 1983). Early arrivers on freshly burned dry sites (Rowe 1983) tend to belong to a group of wind-disseminated propagules that consist of *Ceratodon purpureus*, *Polytrichum spp.*, *Betula papyrifera*, *Salix bebbiana*, *Epilobium angustifolium* and *Populus tremuloides* on the Precambrian Shield (familiar species that have been reported on the JPR and many other plots at TBS after the burn).

The small mammals at TBS utilized many if not most of the above plant species as they became locally available during the different stages of succession. The plots at TBS today are entering a long mid-successional phase dominated by sapling growth in many areas which may account for the decline in small mammal captures during the past six or seven years. As the saplings increase in height, changes in light intensity will take place which will undoubtedly have some effect on the lower herbaceous level, particularly in

regard to its density and composition. Viereck (1983) noted that the tree canopy begins to dominate from twenty-five to thirty years following fire, with changes in the lower layers occurring more slowly. At TBS, tree canopies across many of the sites will require decades of continued growth to acquire properties similar to pre-fire conditions (i.e., in terms of their height and shade).

Bendell (1974) in his review of post-fire communities found little change occurred in the density of small mammals in response to fire. He observed that small mammal communities displayed considerable stability of their population numbers, and therefore, suggested many birds and mammals control their own populations independently (through intrinsic means) of the changing environment. This may perhaps explain synchronous changes among *Clethrionomys* at TBS, but individual species definitely responded numerically to the different periods of "mini-succession".

The most prolific period occurred during the *seedling-herb* stage for *Peromyscus*, with the abundance of short-lived propagules, the increased robustness of sedge and graminoid seed-head growth, and the availability of surplus coniferous seeds – all of which stimulated an increase response in *Peromyscus* population dynamics. For *Clethrionomys*, its most prolific period occurred during the *late seedling-herb/early shrub* stages, which required the initial early successional period to advance sufficiently for the herbaceous layer to have time for greater re-establishment. This species indicated its requirement for a longer adjustment time to the altered habitat conditions through its reduction in numbers following the 1980 trapping session. This behaviour may be

attributable to *Clethrionomys*' lack of flexibility in its niche requirements, compared to *Peromyscus*' plasticity of adaptation following change.

2.) Species abundance models:

Communities often contain several similar species with similar requirements which differ widely in relative abundance. Therefore, investigating models that might account for species abundance relationships helps to describe the diversity of a community, and provides the basic pattern of niche utilization in the community (Pielou 1975; Southwood and Henderson 2001).

The log series model represents the basic environmental structure of the habitats at TBS and presents the range of populations it can support. A common feature among boreal forest rodent communities is the relatively large number of sparsely distributed species (Martell and Radvanyi 1977; Martell 1983a; Morris 1996; Kirkland et al. 1998). The small mammal communities surrounding TBS appear to be composed of a few numerically dominant species that include *Clethrionomys*, *Peromyscus* and *Sorex* (with the exception of *Microtus* in the ATB), and that have accounted for most of the captures during the past twenty-five sampling-years. However, the numerically subordinate species (i.e., those consisting of few individuals) outnumber the dominant species in diversity and may have contributed upwards of seven to eight additional species of low frequency, per plot.

Vickery et al. (1989) studied habitat use and population density of small mammals in Pinawa, Manitoba and found that *Peromyscus* and *Clethrionomys*

species had remained numerically dominant over the 14-yr study, with *Microtus*, *Zapus* and *Sorex* recorded much less frequently. All other small mammal species were listed as being "permanently rare" within this community. Martell (1983a) examined small mammal communities living in upland black spruce and mixed wood stands in north-central Ontario and found that the three most dominant species were *Clethrionomys gapperi*, *Peromyscus maniculatus*, and *Sorex cinereus*. Analysis of a 43-yr live-trapping study from Algonquin Provincial Park revealed *Peromyscus maniculatus* to be consistently more abundant than any other species, followed by *Tamias striatus* and *Clethrionomys gapperi* (Fryxell et al. 1998).

Therefore the composition and abundance patterns of the small mammal species at TBS (i.e., the relatively few numerically dominant species with a greater proportion of less common or rare species), appears to be similar to faunal conditions found in other parts of the Canadian boreal forest.

3.) Trophic composition and contribution

On the ATB plot, *Clethrionomys* maintained its position of numerical dominance for ten years following the 1980 fire, but soon afterwards became numerically subordinate to *Sorex*. The ATB did not experience compositional or structural changes within its vegetation following the fire as had the other plots; therefore the switch in species dominance was not a reflection of vegetational succession, but rather of other population-controlling mechanisms at work. The ASP plot also reported increased trophic contributions by the insectivores (since

the early 90's), with a corresponding decrease (since the late 70's) of its grazer-omnivores. Some factor(s) were clearly affecting both populations simultaneously in two different habitats. But what was most perplexing was the ECO plot which, adjacent for almost half of its length to the ATB, did not exhibit similar increases in its insectivore contribution as those reported in both the ATB and ASP plots. The ECO insectivore category has remained fairly stable throughout the plot's 24-yr history, with a slow decline in the grazer-omnivore input throughout the years.

The ASP and ECO have always been the preferred habitats for the grazer-omnivore, *Clethrionomys*. It would seem, then, that the habitat variables (because of their variety and availability) within these two plots should be less responsible for the decline in the grazer-omnivore category. Instead, a large-scale population mechanism appears to be affecting this trophic category in three of the habitats (with smaller decreases in the BSB and JPSP since 1986). The JPR has substantially increased its grazer-omnivore input since 1996, and it appears that the insectivores have responded to this increase by their complete disappearance from traps over the past six years, on the JPR.

The JPR today is a mostly xeric habitat supporting rare pockets of moisture that may be attractive to *Sorex* species. This particular habitat, however, is becoming increasingly suitable to *Clethrionomys*, perhaps because of its moderate recolonization of lichen and fungi species which are slowly returning to the fire-damaged rock surfaces.

Because the ATB and ASP are separated through distance, elevation and plant species composition, the factors responsible for the increased *Sorex* contribution on both plots are more challenging to identify. Perhaps dietary items of *Sorex spp.*, which can include insects and cocoons of the larch sawfly (Buckner 1964), or other invertebrates such as sowbugs, snails and spiders (Hamilton 1941), experienced simultaneous increases in abundance on the ASP and ATB. The ECO habitat is quite similar to the ASP plot in many ways. No apparent habitat variable provided a plausible explanation as to the reason for the ECO not experiencing a similar increase in *Sorex* as well. The most likely explanation was that there was simply no ecological room (i.e., fundamental niche space) for this trophic category to expand into (i.e., the grazer-omnivore category has only declined slightly over the years).

4.) Species diversity and similarity:

During the early habitat recovery stages of 1980-85, small mammal communities at TBS responded with an increase in diversity in five out of six plots following the 1980 fire. Kirkland (1977), Clough (1987) and Parker (1989) reported increases in species diversity following clear-cutting. Martell (1983b) reported that following logging in northcentral Ontario, species diversity and evenness of the small mammals increased or remained stable in the first 1-3 years following tree removal, decreased on older 3-16 year cuts, and then increased over time until values were similar to uncut stands. Martell (1983b) recognized site-specific differences in plant and animal species following habitat

disturbance as the main determinant of patterns of change in diversity and evenness of the small mammals. Differences in post-recovery habitat conditions across the sites were also found to influence strongly TBS species diversity and evenness.

While diversity and species richness increased among most of the small mammal communities following the fire, the effects were temporary. During the subsequent time period of 1986-90, species diversity either stabilized or dropped and it was not until 10- to 15- yrs post-fire, did species diversity reach its pinnacle on most of the plots. Clearly, the small mammals needed a recovery period after habitat disturbance of sufficient length before they could significantly re-establish themselves within the different habitats. The main anomaly (to this sequence) occurred on the JPR where diversity has dropped during these past six years to pre-fire levels. While *Clethrionomys* has increased in abundance on the JPR, species diversity has correspondingly declined within this particular plot.

Peak time periods of diversity were identical whether sciurids were included or omitted, as were periods of peak species richness. Where the inclusion of sciurids was thought to influence or affect the outcome of results most was on the plots that reported higher captures (i.e., >40) of squirrels and chipmunks, compared to plots that recorded fewer (i.e., <10) captures. For example, the ECO and JPSP (Tables B.9 and B.10) were plots that should have been most affected by the inclusion of sciurids in reporting peak years of relative abundance and biomass, because these two plots when compared to others, have captured the most sciurids. However, it was observed that the numerical

differences between peak years of relative abundance and biomass with or without sciurids were negligible.

Clough (1987) studied the effects of forest management practices on small mammals in northern Maine and noted that while relative abundance and relative biomass were greater in mature conifer habitats, species diversity, richness, and evenness, were lower in mature conifer habitat compared with either the early successional stage habitats of conifer forests, or mature mixed hardwood/conifer habitats. Most diversity values from the pre-fire period at TBS were lower than any subsequent period. This would corroborate with Clough (1987) in that mature habitats had less species diversity. However, the pre-fire period at TBS represents the shortest sampling period and it is difficult to make strong comparisons and generalizations regarding this particular period of vegetation succession.

Clough (1987) attributed moderate to high relative abundances and species richness and diversity of small mammals to sites possessing well-developed ground and shrub layers of vegetation and litter. Sites depauperate in these factors adversely affected the small mammal populations more than the removal of the tree canopy. Removal of the tree canopy cover by fire appeared to have little impact on TBS diversity during the first few years of recovery, as this was found to be the time of greatest small mammal diversity at TBS.

Brady and Slade (2001) examined a long-term small mammal data set with the ecologically and numerically dominant species, *Microtus ochrogaster*. Monthly live-trapping sessions over a ten-year period were carried out in old-field

habitat in Kansas. Changes in vole abundance had little or no influence on the relative abundance of other community members, as well as no noticeable influence on diversity of the non-vole community. Brady and Slade (2001) found their results especially noteworthy because they were contrary to other studies which have reported significant impact by arvicolines on the abundance and diversity of other rodent species (Redfield et al. 1977; Swihart and Slade 1990). The results of Brady and Slade (2001) are relevant in that a single species, *Clethrionomys*, also predominates across most TBS habitats.

To what extent small mammal community structure and species diversity are impacted by *Clethrionomys*' presence at TBS, is currently unknown. *Clethrionomys* is ecologically and numerically the most dominant species at TBS, yet, plots where it occurs in greatest abundance also produce the most diverse number of species. Because the small mammal fauna is highly adaptable to the different environments of the boreal forest, and is able to survive under diverse conditions, it appears unlikely that their niche requirements would overlap to any major extent. It is when dominant species exclude or affect the abundance of other species that community structure and diversity are affected (Heske et al. 1994).

Jaccard coefficients were calculated for each habitat using data collected over the complete twenty-five sampling years. Over that time, the ASP and ECO plots have reported the highest similarity values between habitats in terms of their plant and animal species. The ASP and ECO plots have also produced the largest biomass of small mammals recorded over all years. These two plots

possess a wide mixture of deciduous, coniferous and herbaceous species, irregular topography and moisture levels. Both plots would be considered to be very heterogeneous in their array of habitat variables available to their small mammal communities.

The most dissimilar plots in terms of plant and animal species compositions are the BSB and the JPR. With only five small mammal species captured in common over twenty-four sampling years, little movement between these habitats is indicated. The BSB and JPR are spatially very close (approximately 500 m apart), yet the habitats are very much physically and compositionally divergent. The physical barriers imposed by the elevation, the xeric environment, and the lack of herbaceous variability on the JPR, may prove too restrictive for many species, except for the most opportunistic and flexible.

5.) Species richness and evenness:

Species richness (or the number of species captured in each habitat over a defined unit of size and time) increased on five of the six plots, except on the ATB during the initial 5- yr post-fire period. While the initial after-effects of fire did produce an increase in species number (above pre-fire levels), it is evident that a characteristic feature across these six sites has been their irregular or nonstable levels of species richness over the years. Small mammal species were neither permanently removed nor permanently demoted to a subordinate numerical status by the other species through this habitat disturbance. Although *Clethrionomys* showed a reduction from trap-capture records for several years

following the burn, the return of this species to its position of numerical dominance on the badly damaged plots is eventual, as the habitats recover.

Fox (1983) noted in his studies of the different successional stages of the boreal forest that species richness remained very similar throughout time, with the same set of species being present in most successional stages. What did change, he observed, were the relative abundances and the identity of the dominant species over time.

At TBS there is a strong association between habitat heterogeneity and species richness (in terms of the number of different small mammals a habitat can support). A study by Naylor and Bendell (1983) on the influence of habitat diversity on the abundance and diversity of small mammals in north-central Ontario, found that mixed forests were both floristically and physiognomically more complex than pure pine stands, and contained a greater diversity of small mammals. Both the density and diversity of small mammals were lowest in the most homogeneous boreal forests they examined.

Similar findings were discovered with the TBS small mammal data. The ASP and ECO plots are both mixed-forest types being the most floristically and physiognomically complex study plots and possessing the greatest diversity and abundance of small mammals. In contrast, the BSB, JPR and JPSP are relatively homogenous monocultures made up of fewer species of similar plants, having both lower animal diversity and density. Increases in both species richness and diversity were found to lower evenness values.

Overall, the evenness values were found to be highly variable across the sites. These results were not unexpected in that the small mammal fauna at TBS reflects a logarithmic series distribution pattern that does not support species of similar density within a community. High evenness values were mostly uncommon. When they did occur, this was mostly a reflection of fewer species captured during a particular time period and greater numbers of one particular species within a plot. Brady and Slade (2001) reported that changes in evenness might be a result of changes in the most numerically dominant species (i.e., when a species is very abundant it lowers the evenness measure of the community). While the number of species can affect evenness values, it is the degree of apportionment of the individuals among the different species that determines the equitability of a small mammal community.

Although the fire-altered habitats at TBS stimulated several predictable responses from their small mammal communities, the variation in the intensity of the burn, the anomalies within the habitat, and the ecological character of the species involved made it evident that small mammal response to habitat change is highly site specific. Under these conditions of spatial and temporal variability in the quality of the habitats, natural selection favours exploration and dispersal behaviours in small mammals (Stenseth and Lidicker 1992) living in heterogeneous environments. Therefore, the investigation of the role of partitioning microhabitat variables in determining rodent habitat associations (among the different study plots) was thought to provide insight into small mammal community ecology.

Summary

Taiga ecosystems have a natural tendency toward periodic perturbation at intervals of 50- to 200- yrs that recycle the ecosystem and maintain periodic waves of peak diversity (Loucks 1970). Peak diversity and species richness occurred within five of the six plots during the initial five years following the 1980 fire. A general decline in both species richness and diversity of the small mammal fauna was experienced by most plots 10- to 15-yrs post-fire.

In summary, at TBS certain small mammals are associated with particular periods of ecological succession more than others. *Peromyscus* exploited advantageously the habitats disturbed by fire during the initial phase of successional recovery (in the very early part of the 1980's). *Clethrionomys* required five to six years after the fire (mid- to late- 1980's) before its numbers substantially increased (abundances which have not been duplicated since). Fire provided opportunities for changes in species diversity and trophic contribution within the small mammal communities. However, changes or shifts in species dominance were temporary in nature and strongly influenced by the processes of habitat succession at TBS.

The faunal composition of small mammals at TBS did not change significantly in terms of the elimination of a species from a plot (especially in severely burned habitats) since sampling began in the late 1970's. I observed shifts in small mammal species dominance with a slow return to what are assumed to be (due to the lack of long-term pre-fire information), a return to pre-

fire faunal conditions. Because the small mammals at TBS are inhabitants of a fire-dependent landscape (being relatively new neighbours within the past 9,000 years), having evolved together in an unpredictable landscape, it is unlikely to expect long-term equilibrium or stability in the relationships among these small mammal communities.

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SECTION III.

Factors Influencing the Local Distribution of Small Mammals

Section III. Abstract

The influence of biotic and abiotic features in small mammal habitat was examined in the boreal forest of southeastern Manitoba to determine if certain factors affected species distribution and abundance. Individual microhabitat variables, including vegetation and structural characteristics of the microsite (a 4m² area surrounding each trap) were found to be less reliable indicators of species presence than overall macrohabitat (e.g., blackspruce bog, mixed coniferous/deciduous forest, jackpine sandplain) characteristics of the small mammal environment.

The method of small mammal sampling can introduce bias into the collection and interpretation of data. Museum Special traps captured most of the small mammal fauna near Taiga Biological Station while Schuyler traps proved more variable in terms of their weight capture response. Highly productive small mammal plots (i.e., the number of individuals captured and degree of habitat heterogeneity), had more multiple species captures at trap stations than plots reporting fewer small mammal captures, with less vegetative heterogeneity.

Male animals of the different species were captured more frequently than females. Although fewer *Clethrionomys gapperi* (red-backed voles) were captured on fire-recovering *Pinus banksiana* plots, a higher proportion of these individuals were reproductive females. Actual red-backed vole captures were larger on mixed coniferous/deciduous plots, but consisted of fewer reproductive females.

Introduction

The primary aim of this third and final section is to examine the biological, physical and experimental factors within the microsite (a 4m² area surrounding each trap marker) that may affect small mammal activity and/or susceptibility to capture, and thus ultimately influence the characterization of the small mammal community living within a particular habitat. The purpose of evaluating these three factors at the smaller spatial scale of the microsite is to look for repeatable patterns of occurrence in the vegetation, in the physical structures (i.e., logs, snags, root stumps and rocks), and in the selection and location of trapping equipment, to determine the relative importance of these features in species distribution and capture. If capture frequency is indicative of habitat preference (Gunderson 1959), then sites with higher capture rates should include variables that correlate with greater species abundance. The study of repeated patterns in species distribution is an important component of ecology that allows for the development of predictive syntheses on the utilization of space by animal species (Morris 1979).

The topics to be examined in Section III will include: (1) biotic factors – those including plant and animal information recorded from each capture site such as species identity, percent plant cover and morphological characteristics of the small mammals; (2) structural factors – those involving physical habitat features such as the number and circumference of the fallen trees, percent cover of coarse woody debris, rocks, sand and water; (3) experimental factors – those

that may affect the collection of results at each trapping station (i.e., selection and placement of traps by the researcher, trap sensitivity and selectivity) within the sampling grid.

By evaluating the relative importance of habitat variables and structures in a small mammal's environment, it may be possible to demonstrate that there are differences among the microhabitat of species; however it cannot be assumed that these are the causal agents of separation (Morris 1979).

Literature Review

Microhabitat features influencing small mammal activity:

Microhabitat use is a reflection of many factors: predation risks, energetic costs associated with food acquisition, meeting microclimatic requirements (i.e., finding sites of suitable temperature and humidity) and social pressures based on the status of the individual (Yahner 1986). Dueser and Shugart (1978) described microhabitat differences among the small mammal species in upland forests of eastern Tennessee to determine if structural differences occurred among the microhabitats of sympatric forest small mammals. Three of the four small mammal species exploited microhabitats that differed significantly in structure.

Peromyscus leucopus occurred at sites with low density of trees and high density of shrub-understory vegetation; *Tamias striatus* occurred at sites with high density of trees and low density of shrub vegetation; while *Ochrotomys nuttalli* was found primarily at sites with evergreen canopy and dense woody and herbaceous foliage.

Vickery (1979) studied the activity patterns of three rodent species in mixed deciduous-coniferous forests of Quebec. Rodents may be active in the same habitat but partition their habitat by several methods: being active at different times of night, having some specific food differences, and possessing seasonal variability in their population sizes. Wywiałowski (1987) indicated both habitat structure and risk of predation as important factors in influencing rodent community composition in different habitats. *Clethrionomys* is a habitat specialist

whose abundance seems closely correlated with habitat structure. In areas where *Clethrionomys* and *Peromyscus* both occur, predation may be a major factor in microhabitat partitioning and prey coexistence between the species, since *Clethrionomys* favoured areas of greater densities of both vertical and horizontal ceiling cover, and is noted to be the preferred mammalian prey of *Mustela spp.* (Wywiałowski 1987).

Price (1978) measured microhabitat use through capture frequency records based on the assumption that capture frequency and foraging effort are strongly correlated in desert rodents. She cautioned however, that trapping results are not a precise measure of foraging activity because the animals may have been captured in transit while travelling through a poorer patch, in order to reach a more appropriate one. Wywiałowski and Smith (1988) suggested that dispersers and subordinate animals are more likely found in suboptimal habitats. The female-dominated social organization of *Clethrionomys* (Kalela 1957; Mihok 1979) may provide insight into microsite selection; those locations which have captured mature, adult females in greatest abundance, should be the optimal sites for this species (Bondrup-Nielson 1986).

Habitats change temporally; therefore, depending on the time of year and successional stage of the community, the strength of association between the density of small mammals and a particular habitat variable may improve or weaken in importance (Lambert and Adler 2000).

The influence of coarse woody debris near capture sites:

Dead and down woody material including branches, logs and fallen trees are considered essential habitat components that may influence the distribution and abundance of small mammals (Maser and Trappe 1984; Hayes and Cross 1987; Planz and Kirkland 1992; Loeb 1998; Butts and McComb 2000). Coarse woody debris (CWD) provides cover, nesting sites, travel routes and food (in the form of invertebrates and fungi) that invade the decaying logs and snags (Maser and Trappe 1984).

Barry and Franco (1980) investigated the major physical features of *Peromyscus leucopus* habitat that is used by the mouse in short-range orientation and navigation, with variable results. In one of two woodlots studied, highly significant correlations between capture rate success and the number of logs at a trap station were found, as well as between capture rate success and total diameter of the logs at a trapping station. Mice were captured more frequently than expected by chance at stations with logs (in one particular woodlot only). Within the second woodlot, there was no association between mice and logs. The mice actually avoided stations where logs were abundant in the second woodlot.

Planz and Kirkland (1992), using fluorescent tracking powder, noted that *Peromyscus leucopus* preferred to travel along downed logs and branches, rather than directly on the ground covered in leaf litter. The reduction in auditory cues available to predators was suggested as a possible explanation for log use. Barnum et al. (1992) also employed the use of fluorescent tracking powder in the

forests of Minnesota and Maryland and found that *Peromyscus leucopus* tended to travel along larger-diameter logs, because it was postulated that this method of activity required less energy and time spent on balancing by the animal, and provided the quietest pathway of travel.

Amaranthus et al. (1994) examined the relationship between hypogeous fungi (truffles), coarse woody debris, and small mammal (*Clethrionomys californicus*) dependence on truffles for food. The highest truffle production was associated with CWD of mature Douglas-fir forests compared to CWD found in tree plantations. Within the plantations, both the substrate and logs were more susceptible to high temperatures that inhibited sporocarp production. Tallmon and Mills (1994) investigated patterns of space use by *Clethrionomys californicus* in southwestern Oregon and noted that voles used logs more significantly than expected by chance, and that the voles were found more often with logs in advanced stages of decay. The California red-backed vole's association around decaying logs in the dry summer season was thought to be related to the availability of caches of hypogeous sporocarps of mycorrhizal fungi.

Factors affecting trappability of small mammals:

In the study of population demography, samples taken from small mammal populations should be relatively unbiased (Martell 1979). Biases can be introduced by the choice of sampling method, the location and size of the study area (which are often chosen for the convenience and capability of the investigator), and by numerous variables that may involve weather, temperature,

season, resources and equipment - all of which can impose limitations on field studies.

The effects of weather on *Sorex cinereus* activity was examined by Vickery and Bider (1978). *Sorex cinereus* was observed to be significantly more active on nights when rain fell between dusk and dawn than on nights when no rain fell, or only daytime rain occurred. Rainfall was the most important factor affecting *Sorex* activity, and therefore the researchers cautioned, *Sorex* should not be assumed to be equally trappable on every night. Vickery and Bider (1981) also examined the influence of weather on the summer activity of several other small mammal species in the mixed coniferous-deciduous forests of Quebec. All three rodent species: *Clethrionomys*, *Peromyscus* and *Napaeozapus* were mostly nocturnal (over 95% of their activities occurred during nightfall) and mostly active when rain fell and when temperatures were high. This increase in small mammal activity on rainy nights was not due so much to changes in food availability, but rather to the reduction in acoustic cues available to predators of these small mammals.

Weather was found to influence deer mice activity patterns and to a lesser extent, red-backed vole activity rates as well. Vickery and Rivest (1992) reported that deer mice shift their use of habitat according to weather. On clear nights, *Peromyscus maniculatus* distributed its activities evenly over three different habitats; on cloudy, dry nights there was much more activity in mixed forest habitat than elsewhere; while on rainy nights, coniferous habitat received the most activity per station. *Clethrionomys* was found to be less affected by cloud

cover or rainfall in its habitat use and was consistently more active in coniferous habitat, regardless of weather. However, rainfall leads to increased *total* activity in red-backed voles. Kirkland et al. (1998) also examined the impact precipitation had on trapping results and found an increase in abundance and diversity of the small mammal community reported on nights when it rained. Pruitt (1959) noted that the degree of moonlight and position of the moon (with respect to the horizon) were important factors regulating nocturnal activity of small mammals. The number of activity periods increased with increased darkness.

Although potential biases are acknowledged in the various methods used for small mammal sampling, trapping still provides a practical method of determining presence and abundance of many animals. Long-term data sets might help to elicit any differential responses in capture rates of the small mammals due to weather and/or lunar influences (Williams and Braun 1983). Additionally, the type of trapping equipment has been identified as a factor having potential impact on small mammal captures.

Many researchers have shown that certain trap-types can be more effective than others in capturing particular species of small mammals. Pruitt and Lucier (1958) noted that while *Clethrionomys rutilus*, *Microtus miurus* and *M. oeconomus* appeared equally susceptible to trap capture by either Museum Special or Schuyler traps, *M. oeconomus* was captured exclusively by Schuyler traps during a summer trapping program in Alaska. Pitfalls were found to be more efficient than snap (kill) traps at capturing shrews (Briese and Smith 1974; Williams and Braun 1983; Mengak and Guynn 1987). However, Williams and

Braun (1983) noted that while pitfall traps captured greater numbers and diversity of small mammals, they were poorer for capturing deer mice and other species that had well-developed scansorial or bipedal locomotion.

Smith et al. (1971) reported that spring tension on the kill bar and sensitivity of the trigger mechanism differed among kill traps and suggested using two trap-types per station. West (1985) also reported a difference in the performance between two models of kill traps: old Museum Specials with a smaller wood and metal treadle and new Museum Specials with a larger plastic treadle. Both spring strength and treadle release pressure differed between the models, with old traps possessing a stronger spring and slightly higher release pressure, while new traps were found to release more consistently than the wood and metal treadles. The old model traps captured significantly greater numbers of larger mammals such as *Tamias townsendii* and reported fewer sprung traps in the field. New model traps captured over three times as many *Sorex trowbridgii* because of the treadle sensitivity towards lower weight animals.

It should be recognized that traps do not necessarily capture a random sample of small mammals (Innes and Bendell 1988); therefore a combination of trapping methods should yield the most complete data on small mammal community compositions (Briese and Smith 1974).

Influence of interspecific encounters:

Boonstra et al. (1982) studied the response of *Microtus pennsylvanicus* to Longworth live traps that had either: previously captured a *Blarina* (a potential

predator of *Microtus*); had been empty prior to their capture; or had captured other species. *Microtus* had a 15% higher probability of entering a trap that had not previously captured a *Blarina* than one that had. *Microtus* most readily entered traps that had previously captured a *Microtus*, and showed a significant avoidance of traps that had captured no animals. But interestingly, *Microtus* did not avoid *Blarina*-visited traps more than it avoided *Mus*, *Peromyscus* or *Zapus*-visited traps. Fulk (1972) also reported that *Microtus* tended to avoid places frequented by *Blarina*.

Dueser and Shugart (1978) found that most captures of their small mammals were at trap sites at which no other species was encountered and no more than two species were observed at any trap site. However, *Peromyscus leucopus* and *Tamias striatus* showed significant association (meaning these two species were trapped more frequently at the same stations than expected). Hallett et al. (1983) noted that while frequency of capture of a species at a trap station might be due to habitat conditions, it might also be attributable to the presence or absence of other species in the vicinity of the traps.

Experimental error (sources of potential bias):

Traps on the boundary of a trapping grid may have more captures than those inside the grid, particularly grids within homogeneous environments (Hallett et al. 1983). This "perimeter bias" produced by animals that move into the vacant areas of the grid (due to removal of the residents) was reduced by excluding these captures from analyses (Sekgororoane and Dilworth 1995). Perimeter bias

can also be reduced by restricting the length of the trapping period to three trap-nights, before major immigration (W. Pruitt, pers. comm.)

Other researchers provide two traps per station to reduce the possibility of competition and to reduce trap saturation by one particular species, which can lead to biased population estimates of other resident species (Batzli and Jung 1981; Brady and Slade 2001). Jorgensen and Demarais (1999) observed that physical disturbance associated with maintenance of the trap lines may have a greater impact on open, sandy areas compared to areas covered by detritus. The rodents may be attracted to different disturbances in the substrata, caused by researchers, when the traps are set.

Materials and methods

Vegetation data:

a) *Vegetation surveys* - A comparison of the vegetation survey results across six habitats at TBS is described in Tables C.1a-f. Three different plant surveys have been conducted during the years 1976, 1982 and 2000-01 within each of the study plots, in association with small mammal research. Comparisons of the most abundant plant species were made in order to determine the overall vegetative changes that have occurred during the past twenty-five years. The purpose of comparing the vegetation data during separate periods of time was to determine the magnitude of change that may have occurred within the various habitats following the fire. If plant species composition did not significantly change (i.e., plants that were dominant before the fire were also dominant several years after fire as well as twenty years following the fire), then plant information collected most recently could be extrapolated into the past, allowing for associations between small mammal capture sites and plant species to be made.

b) *Vegetation sampling methods* - Plant communities in the six study plots were examined using the quadrat sampling method with a 4m² quadrat placed systematically around each small mammal trap marker. Vegetation data (percent coverage by each species) were estimated from 100 quadrats per plot and recorded on field data sheets (Table C.2). A quadrat size of 4m² was chosen in

order to include structural components of the microsite that may have influenced small mammal activity patterns. All small mammal trapping stations were sampled firstly because of the differences in the range of captures recorded at each site, and secondly, to identify microsite variables (i.e., plant species and/or structural features) that might have been associated with a particular small mammal species and its rate of capture.

A collection of pressed plant specimens from many of the identified species was made and will be available as a reference collection for future work. Several floras and books were used in the identification of the herbaceous plants, shrubs, and trees (Scoggan 1957; Looman and Best 1979; Soper and Heimburger 1982; Johnson et al. 1995). Fungi were identified using keys by Bossenmaier (1997) and Baron (1999). Lichens and mosses were identified using keys by Thomson (1984) and Ireland and Bellolio-Trucco (1987).

Information on coarse woody debris (CWD), which included fallen trees, logs, snags and branches, was also collected from each site. From the literature it was recognized that certain sized logs and their decay state might be associated with the occurrences of individual species of small mammals. By identifying these habitat relationships it may be possible to predict individual species response to the amount and type of CWD available in their habitats. Therefore, the circumference and structural class (after Bull et al. 1997) of each log was recorded, as well as the percent cover these variables occupied within each trapping station quadrat. Log information (from Tables C.3a-d) was then used in Figs. 1a-1b to reveal any associations that might have existed between

the mean number of logs per quadrat and number of captures of *Clethrionomys* and *Sorex* individuals.

The median value obtained from all measured CWD in each habitat was used in the classification of logs. The median was chosen because it represents the 50th percentile (or the centre) of the distribution of CWD; with skewed distributions the median is a better measure of centre than the mean (Moore 1995). For example, the median value of CWD on the ASP plot was 28.3 cm and on the ECO plot, 34.5 cm. All CWD above the individual median value for each plot was classified as a "log". This criterion was selected because the plots produced trees of different girths depending on habitat conditions. Therefore to avoid bias by restricting the classification of logs to one size, the individual medians of CWD from separate habitats were used to categorize their fallen trees as logs.

In the literature, log classifications vary depending upon tree species, climate, precipitation, length of growing season and soil condition. Coarse woody debris considered as "logs" can vary in size and type/source (i.e., logs may include any CWD >10cm in diameter, including branches, snags and stumps) and sizes are chosen at the researcher's discretion. Some examples of CWD log size classifications were: logs >5cm and <5cm in diameter (Barnum et al. 1992); logs >10cm in diameter (Tallmon and Mills 1994; Butts and McComb 2000); logs ≥ 10 cm in diameter (McCay 2000).

The mean number of logs per quadrat for each capture category was determined by counting the total number of logs found in 0, 1, 2, 3, 4, 5 or ≥ 6

capture sites on the ASP and ECO plots (Figs. 2 and 3), respectively. Capture categories were combined at the high end because the sample size (i.e., the number of quadrats) from single capture categories was too low. The total number of quadrats that reported a particular capture rate then subsequently divided the sums of these logs. For example, in the Aspen Upland there were 17 logs found within the 18 quadrats surrounding stations that reported only one *Clethrionomys* capture. The mean number of logs per quadrat would then be 0.94 logs for ASP sites that reported one *Clethrionomys* capture (Fig. 1a).

c) *Comparison of habitat variables with rates of capture* - The vegetation data were examined using two separate scales of resolution: a low resolution of grouped habitat variables with combined capture rates, followed by a high resolution of individual habitat variables with separate rates of capture. In Tables 1a-1f, mean percent cover values of *combined* habitat variables (i.e., those of similar species and strata grouped together) were described across three different capture categories (i.e., poor, moderate and good), regardless of small mammal identity. Grouped cover values over extended capture categories provided a "low resolution approach" in the search for possible broad trends (i.e., areas of notable increase or decrease) in vegetation and/or structural features that corresponded with a particular range of capture (i.e., 0-2, 3-5, ≥ 6). The purpose of combining numerous plant species into smaller ecologically descriptive units was to identify environmental characteristics (i.e., dry, moist, shady, open, sheltered and/or exposed) that most of the small mammal species

selected or associated with, and to identify broad patterns of habitat use in each of the plots.

Additionally, mean percent cover values of *individual* habitat variables for separate rates of capture and species were compared (Tables C.5a-l). The purpose being to discover if sites with higher capture rates noticeably differed in a specific habitat variable(s) from sites with fewer captures, for each species; a "high resolution approach". Ideally, sites with increased rates of small mammal captures possessed preferred habitat variables that would allow for associations to be made identifying important microhabitat features necessary to the well-being of the individual.

Mammal data:

a) *Comparison of small mammal responses to trapping* - Several features of small mammal morphology were examined including gender, weight and species identity, to determine if these variables had an effect on susceptibility to capture and/or were biased towards a particular trap-type. In Tables C.6a-f, a summary of the distribution of common small mammal captures over twenty-five years was provided for the different trap-types. The distribution of mean body mass (g) of the males and females captured in two different trap-types over time is described in Tables C.7a-f.

Comparisons were made and tested between: (i) median body mass (g) of the different small mammal species and trap response, to determine if body weight was a significant factor in capture response between trap-types; (ii)

median body mass (g) of the small mammals and gender, to discover if weight of the males and females differed significantly at capture; (iii) gender of the small mammals and trap-type, to observe if the sex of the animal affected its susceptibility to capture by a particular trap type. Additionally, the reproductive status of female *Clethrionomys* from each habitat was compared over twenty-five years to observe the total proportions of reproductive versus nonreproductive females (Table C.8).

Tests of the above comparisons were performed using the Wilcoxon Rank Sum test at the 5% significance level, using (JMP IN Software). This nonparametric test provided a method to analyze and test data that do not depend on distributional assumptions (i.e., normality assumptions). The Wilcoxon rank sum test tests the equality of the medians of two independent groups by ranking the responses and analyzing the ranks instead of the original data. The null hypothesis is that the two independent random samples are drawn from populations having the same parent distribution and medians. The sample size for each sample does not have to be the same. The p -value of the Wilcoxon test is based on a chi-square distribution approximation to the true sampling distribution of the Wilcoxon rank sum statistic.

b) Measurements of interspecific association - Measurements of association were made using occurrence (based on presence/absence data) of capture-combinations of the three most common small mammals found on each plot. Smith (1996) recognized that some species may occur together more

frequently than by chance alone due to symbiotic relationships, foodchain dependency or similarities in adaptation and response to environmental conditions. The purpose of measuring association is to provide a method of recognizing species interactions. Positive associations may indicate a natural grouping of species and/or species that require similar conditions while negative associations may indicate antagonistic interactions such as interspecific competition (Southwood 1966; Smith 1996). Association coefficients are based on presence-absence data because this type of information allows one to measure the extent to which two species requirements are similar, whereas abundance data can be strongly influenced by both association and competition (Hurlbert 1969).

The frequency of capture-combinations found at each trapping station (100 recordings per plot) is presented in Tables C.9a-f. Capture-combinations were derived from long-term trapping records collected at each trap station. For example, in Table C.9a, only 17 trap stations in total captured the three main species in isolation during the twenty-four sampling years on the ATB. At 46 trap stations, combinations of *Clethrionomys* and *Sorex* have occurred, while only five trap stations have reported capturing *Clethrionomys* exclusively.

The presence-absence data from Tables C.9a-f were arranged from each habitat in the form of a 2 x 2 contingency table (Southwood 1966; Smith 1996).

		<i>Species A</i>		
		+	-	
<i>Species B</i>	+	<i>a</i>	<i>b</i>	<i>a + b</i>
	-	<i>c</i>	<i>d</i>	<i>c + d</i>
	+	<i>a + c</i>	<i>b + d</i>	<i>a + b + c + d = n</i>

where:

- a* = samples containing both species A and B
- b* = samples containing only species B
- c* = samples containing only species A
- d* = samples containing neither species

Three types of contingency tables were presented. The first type, shown in Tables C.10a, C.12a, C.14a, C.16a, C.18a, C.20a, contained trapping observations recorded from the six study plots over twenty-five years (see Tables C.9a-f) presented in the form of a 2 x 2 x 2 contingency table, representing eight possible capture-combinations.

The second type of contingency table (Tables C.10b-d, C.12b-d, C.14b-d, C.16b-d, C.18b-d and C.20b-d) involved the presence and/or absence of only two species. Here, the third species was marginalized (i.e., meaning its captures had been summed over in order to obtain the results for two species, exclusively). For example, in Table C.10b, *Sorex* and *Clethrionomys* were examined and found present in 63 (i.e., 17+46) out of 100 trapping stations on the ATB and absence from only 2 (i.e., 1+1) stations during twenty-five years of

sampling, (when *Microtus* captures were ignored). In Table C.10c of the ATB, if *Clethrionomys* was marginalized, *Microtus* and *Sorex* were found to occur in 23 (i.e., 17+6) trapping stations and absent from 6 (i.e., 5+1) stations.

The third type of contingency table is called a conditional table because it specifically depends on the presence or absence of a third species. In Tables C.11a-f, C.13a-f, C.15a-f, C.17a-f, C.19a-f and C.21a-f, one particular species is selected and represented as either being present or absent. Occurrences of two sympatric species are then presented under the conditions of presence or absence of the chosen species. For example, in Tables C.11a-b of the ATB, under the conditions of *Clethrionomys* presence and absence, *Microtus* is more likely to be absent from *Sorex* trapping stations if *Clethrionomys* is present, rather than when *Clethrionomys* is absent (i.e., 46 stations vs. 22) from these stations.

Using data within the contingency tables, a coefficient of association C was calculated (see formulae in Southwood 1966; Smith 1996). The value of C has the same range as the correlation coefficient (r), where +1 = complete positive association, - 1 = complete negative association, and 0 = no association. To determine whether the coefficient of association is significant, a chi-square test (χ^2) is applied to identify whether the discrepancies between the observed values of the contingency table and the expected values based on chance association are sufficiently large.

where chi-square equals:

$$\chi^2 = \sum \frac{(\text{observed} - \text{expected})^2}{\text{expected}}$$

and where the expected values for each cell can be determined by:

$$a = (a+b) (a+c)/n$$

$$b = (a+b) (b+d)/n$$

$$c = (c+d) (a+c)/n$$

$$d = (c+d) (b+d)/n.$$

The *p-value* or significance level of the chi-square statistic was then calculated (using the R program from the Statistical Advisory Service), to determine which interspecific associations are significant at $P < 0.05$ among the small mammal species.

Results

Vegetation data:

A comparison of plant surveys - The results from the three separate vegetation surveys (1976, 1982, 2000-01) revealed that the major plant categories (i.e., ground cover, ferns and allies, low shrubs, tall shrubs, trees, herbaceous cover and grasses/sedges) had not significantly changed in species composition over the years (Tables C.1a-f). Most changes have occurred in the ground cover and tree stratum of severely burned plots such as the BSB, JPR, and JPSP - all of which reported thick lichen and/or moss pre-fire ground cover in association with mature canopy coverage. A description of pre-fire habitat conditions and post-fire colonizing plant species is provided for each plot in Appendix A.1. Low shrubs, tall shrubs, herbaceous cover and grasses/sedges appeared to have the most resilience to fire damage and changed the least in composition during the different survey periods.

Low resolution habitat variables - A comparison of the three capture categories (i.e., poor, moderate and good) including all small mammal species (except sciurids) is shown in Tables 1a-1f. Individual plant species (described in Table C.2) were grouped into 19 habitat categories based on physiognomy and vegetation height to determine low resolution or macrohabitat features that might influence the rates of capture of the small mammals. Overall, very few habitat

variables or structural features were notably different (in comparison to the grouped mean values) across all six sites (Tables 1a-1f).

Some of the main key features from each habitat, beginning with the ATB study plot were that good capture sites (those with ≥ 6 small mammal captures over time) had slightly more deciduous shrubs ($>1\text{m}$ tall) and less conifer tree coverage than poorer sites (those with ≤ 2 captures over time). On the ASP plot, poor capture sites had less dead wood (logs) and less deciduous shrubs ($<1\text{m}$ tall) than the grouped mean values from that habitat. Additionally on the ASP, poorer sites had more gramineae cover than the grouped mean. The BSB was very homogeneous in that the mean percent cover values of the different habitat variables were relatively evenly distributed across all capture categories. The ECO plot reported poorer capture sites with having slightly less hydric moss cover and less deciduous shrub layers. Poorer sites on the ECO also had more coniferous tree cover compared with the grouped mean. The JPR was also quite homogeneous in its mean percent cover values, with one exception: there were more lichens present in good capture sites. Finally, the JPSP had more deciduous shrubs ($<1\text{m}$ tall) at good capture sites with slightly less litter/organic debris, compared to grouped mean values.

In summary, the plots which reported the highest number (n) of active trap stations (i.e., ≥ 6 captures) also produced the greatest numbers of small mammal captures over twenty-five years (as seen in the ASP and ECO). Plots that produced fewer small mammal captures had a larger number (n) of less active

TABLE 1. Mean percent cover values of 19 habitat variables recorded from vegetation quadrats across six sites at Taiga Biological Station. Mean cover values are grouped into three capture categories of small mammals (poor, moderate and good) including the grouped mean cover values for all captures combined. Standard deviations of the grouped means are comprised from 100 values per habitat variable (n = number of quadrats within a particular capture category).

		Bare rock	Bare soil/sand	Standing water	Litter/organic debris	Dead wood, logs	Lichens	Fungi	Mesic habitat mosses	Hydric habitat mosses	Ferns and Allies	Low Evergreens & Ericaceae	Deciduous Shrubs (<1m)	Deciduous Shrubs (>1m)	Coniferous Trees	Deciduous Trees	Snag basal area	Herbaceous Layer	Gramineae	Cyperaceae	
(a) ATB																					
	n																				
Poor (0 - 2)	25	0.0	0.0	16.6	40.2	4.4	5.2	0.5	1.7	80.6	9.0	57.2	0.8	45.3	25.2	0.0	1.6	10.2	2.1	18.5	
Moderate (3 - 5)	48	0.0	0.0	17.9	42.0	3.6	5.8	0.6	2.1	79.6	8.3	55.8	1.7	42.8	21.0	0.0	1.2	8.2	1.7	16.5	
Good (≥ 6)	27	0.0	0.0	17.6	42.3	3.3	5.4	0.5	1.0	78.3	6.1	58.0	0.7	53.9	16.7	1.4	0.7	6.0	1.5	17.4	
Grouped mean	100	0.0	0.0	17.5	41.7	3.7	5.6	0.6	1.7	79.5	7.9	56.7	1.2	46.4	20.9	0.4	1.2	8.1	1.7	17.2	
Std. Dev.		0.0	0.0	16.1	21.2	6.3	2.8	1.1	2.9	14.0	6.4	17.5	2.7	18.1	22.9	3.8	3.5	7.7	2.2	11.9	
(b) ASP																					
	n																				
Poor (0 - 2)	17	14.9	0.0	0.4	80.2	9.2	33.0	0.2	24.9	0.8	1.1	23.9	13.2	11.2	35.1	22.3	0.0	59.5	20.2	2.6	
Moderate (3 - 5)	26	9.7	0.0	1.9	84.3	16.4	21.8	0.3	16.1	1.6	2.9	20.0	24.7	26.9	31.3	23.8	0.0	51.3	14.1	0.8	
Good (≥ 6)	57	12.9	0.2	0.7	83.6	15.6	29.7	0.4	18.5	1.8	3.0	21.2	23.3	14.2	37.7	21.3	0.0	41.1	11.0	2.3	
Grouped mean	100	12.5	0.1	1.0	83.0	14.5	28.6	0.3	19.0	1.6	2.6	21.3	22.1	17.0	35.6	21.9	0.0	46.7	13.6	2.0	
Std. Dev.		19.0	0.6	4.2	12.5	11.0	35.7	0.8	13.9	4.7	4.6	19.8	14.6	18.8	29.7	25.4	0.0	27.7	10.4	5.8	
(c) BSB																					
	n																				
Poor (0 - 2)	65	0.0	0.0	0.0	27.7	29.5	5.5	1.2	5.2	77.5	0.0	90.2	3.7	0.0	63.4	0.1	0.6	8.4	1.0	0.0	
Moderate (3 - 5)	29	0.0	0.0	0.0	30.8	34.9	6.0	1.1	4.6	79.2	0.0	90.8	5.3	0.0	69.7	0.5	1.1	6.5	0.5	0.0	
Good (≥ 6)	6	0.0	0.7	0.0	35.5	30.0	4.3	1.0	6.5	81.0	0.0	93.5	4.2	0.0	57.5	0.0	0.0	5.0	0.5	0.0	
Grouped mean	100	0.0	0.1	0.0	29.0	31.1	5.6	1.2	5.2	78.3	0.0	90.2	4.2	0.0	64.7	0.2	0.8	7.7	0.8	0.0	
Std. Dev.		0.0	0.4	0.0	15.1	13.8	4.6	1.2	5.7	16.0	0.0	17.5	4.3	0.0	21.9	1.1	2.0	7.0	2.4	0.0	

TABLE 1. Mean percent cover values of 19 habitat variables from vegetation quadrats continued.

		Bare rock	Bare soil/sand	Standing water	Litter/organic debris	Dead wood, logs	Lichens	Fungi	Mesic habitat mosses	Hydric habitat mosses	Ferns and Allies	Low Evergreens & Ericaceae	Deciduous Shrubs (<1m)	Deciduous Shrubs (>1m)	Coniferous Trees	Deciduous Trees	Snag basal area	Herbaceous Layer	Gramineae	Cyperaceae	
(d) ECO																					
	n																				
Poor (0 - 2)	18	0.3	0.3	2.3	78.6	24.7	15.8	1.0	19.2	20.4	7.1	29.9	17.2	23.7	54.8	15.4	0.0	22.5	4.4	7.7	
Moderate (3 - 5)	36	0.8	0.1	4.3	73.4	20.5	11.4	0.8	15.0	26.3	8.4	31.3	18.3	26.7	54.1	16.6	0.0	25.6	4.3	10.1	
Good (≥ 6)	46	0.6	0.1	6.8	76.1	19.2	9.9	0.8	17.0	27.7	8.8	30.1	22.6	30.7	46.3	19.0	0.0	28.7	3.7	8.4	
Grouped mean	100	0.6	0.1	6.0	76.5	20.2	11.0	0.8	17.4	26.4	8.5	30.1	21.6	29.4	47.8	18.3	0.0	27.6	3.9	8.3	
Std. Dev.		1.5	0.5	14.3	20.3	15.7	10.9	1.3	20.0	37.0	13.6	21.8	17.4	31.4	35.3	20.2	0.4	17.5	4.4	13.9	
(e) JPR																					
	n																				
Poor (0 - 2)	38	29.9	0.1	0.0	84.1	8.3	48.8	2.6	51.1	0.0	0.0	1.4	0.3	4.9	75.1	4.8	0.0	0.2	0.2	0.0	
Moderate (3 - 5)	52	30.9	1.5	0.0	79.5	8.2	45.5	2.2	38.7	0.0	0.3	2.3	1.4	3.4	75.3	4.3	0.0	0.3	0.3	0.1	
Good (≥ 6)	10	35.7	0.0	0.0	80.7	7.3	62.6	2.9	40.5	0.0	0.0	1.5	1.4	2.6	73.0	3.4	0.4	0.3	0.3	0.0	
Grouped mean	100	31.0	0.8	0.0	81.4	8.1	48.5	2.4	43.6	0.0	0.2	1.9	1.0	3.9	75.0	4.4	0.0	0.4	0.2	0.04	
Std. Dev.		25.3	6.9	0.0	11.0	5.7	28.8	2.6	21.4	0.1	0.9	4.9	3.3	5.5	32.7	6.6	0.4	1.2	1.0	0.4	
(f) JPSP																					
	n																				
Poor (0 - 2)	63	1.4	0.6	0.0	87.0	23.3	33.4	1.2	18.4	0.0	0.9	45.2	3.3	0.7	33.3	0.0	0.5	8.4	3.4	0.1	
Moderate (3 - 5)	22	0.0	0.8	0.0	86.7	20.8	36.5	2.1	24.2	0.0	1.1	43.2	3.1	0.5	48.3	0.6	0.6	10.9	3.8	0.0	
Good (≥ 6)	15	0.1	0.1	0.0	80.4	25.9	27.2	1.9	19.4	0.0	1.6	41.7	10.6	3.5	48.0	0.7	0.7	6.4	0.9	0.0	
Grouped mean	100	0.9	0.6	0.0	86.0	23.2	33.2	1.5	19.9	0.0	1.0	44.2	4.4	1.1	38.8	0.2	0.5	8.7	3.1	0.1	
Std. Dev.		4.1	1.7	0.0	14.1	10.7	24.2	1.9	12.3	0.0	2.9	21.2	7.4	5.2	25.9	1.5	2.3	7.2	3.6	0.4	

trapping stations (i.e., 0-2 captures per marker) as found in the BSB, JPR and JPSP.

High resolution habitat variables - Individual microhabitat features (i.e., those within the 4m² quadrat surrounding each trap marker) with which small mammals were associated, were identified through the different levels of capture. The strength of these associations was based on capture rates reported at each trapping station (Tables C.5a-l).

Beginning with the ATB, *Clethrionomys* and *Sorex* capture rates ranged from 0 to ≥ 4 individuals reported at each trapping station. On the ATB plot, sites with increased *Clethrionomys* captures had slightly more litter/organic debris, *Ledum groenlandicum* shrub layer and *Larix laricina* overhead canopy. Sites with increased *Sorex* captures had only two variables showing notable trends – a decreasing amount of *Ledum groenlandicum* and an increasing *Picea mariana* cover compared to poorer capture sites.

On the ASP plot, *Clethrionomys* and *Sorex* capture rates ranged from 0 to ≥ 6 and 0 to ≥ 3 individuals, respectively. The ASP sites of increased *Clethrionomys* captures were noted to have slightly more litter/organic debris, dead wood (logs) and the grass *Calamagrostis canadensis* - with a decreasing amount of the grass *Danthonia spicata*. Greater *Sorex* capture sites had less bare rock and crustose lichens, but increasing amounts of *Sphagnum*, *Alnus rugosa* and moist *Carex* spp.

The BSB capture rates ranged from 0 to ≥ 3 individuals reported at each trapping station. The BSB reported sites with greater *Clethrionomys* captures as possessing slightly more dead wood (logs) and *Ledum groenlandicum*. *Sorex* capture sites showed no particular trends among its habitat variables. The ECO capture rates ranged from 0 to ≥ 5 individuals for both *Clethrionomys* and *Sorex* species. Sites of greater *Clethrionomys* capture had less standing water and moist *Carex spp.* compared to its poorer sites. Better capture sites also had more dead wood (logs) and *Populus tremuloides* cover. *Sorex* capture sites on the ECO showed the reverse trend of many of the *Clethrionomys* habitat-capture associations. Better *Sorex* sites had more standing water, *Sphagnum*, *Ledum groenlandicum* and *Betula glandulosa*, with decreasing amounts of *Pinus banksiana* cover.

The JPR supported relatively few individual plant species, especially among the herbaceous and shrub layers. *Clethrionomys* capture sites did not express any particular trends in habitat variables with capture rate. *Peromyscus* replaced *Sorex* on the JPR as the second species associated with the various habitat variables. Only one particular feature stood above the rest; sites of better *Peromyscus* captures had more exposed rock.

On the JPSP, *Clethrionomys* and *Peromyscus* capture rates ranged from 0 to ≥ 4 individuals reported at each trapping station. Sites of greater *Clethrionomys* captures had slightly more *Ledum groenlandicum*, *Cornus canadensis* and overhead *Pinus banksiana* coverage. *Peromyscus* capture sites

had very few variables that were notably different among the range of captures. Better sites had slightly more fruticose soil lichens and *Arctostaphylos uva-ursi*.

Associations of small mammals with coarse woody debris - The association between the amount of coarse woody debris (mean number of logs per quadrat) and the rate of *Clethrionomys* and *Sorex* captures is presented in Figs. 1a-1b. Two of the six study plots (the ASP and ECO) were examined because they possessed the most even distribution of quadrats among the different rates of capture and contained logs under various stages of decay (personal observation), that represented many different size-classes. The data were tested using Spearman rank correlation coefficients (using JMP IN) because of the small sample sizes and the lack of assumptions about the form of the frequency distribution. The underlying null hypothesis is that there is no correlation between the variables (i.e., the mean number of logs vs. capture rate). Individual *Clethrionomys* of the ASP and the ECO did not display any significant correlations between logs and capture rate ($r_s = 0.5714$ and $r_s = 0.3929$), respectively. For *Sorex*, there were stronger correlations between the number of logs per quadrat and the rates of capture. The Spearman rank correlation coefficients were ($r_s = 0.6325$ and $r_s = -1.000$) for the ASP and ECO, respectively.

The ASP and ECO plots contained a mixture of *Pinus banksiana* and *Populus tremuloides* logs mostly consisting of structural classes one and two, respectively, as shown in Figs. C.1a-b. The mean log circumference (cm) was

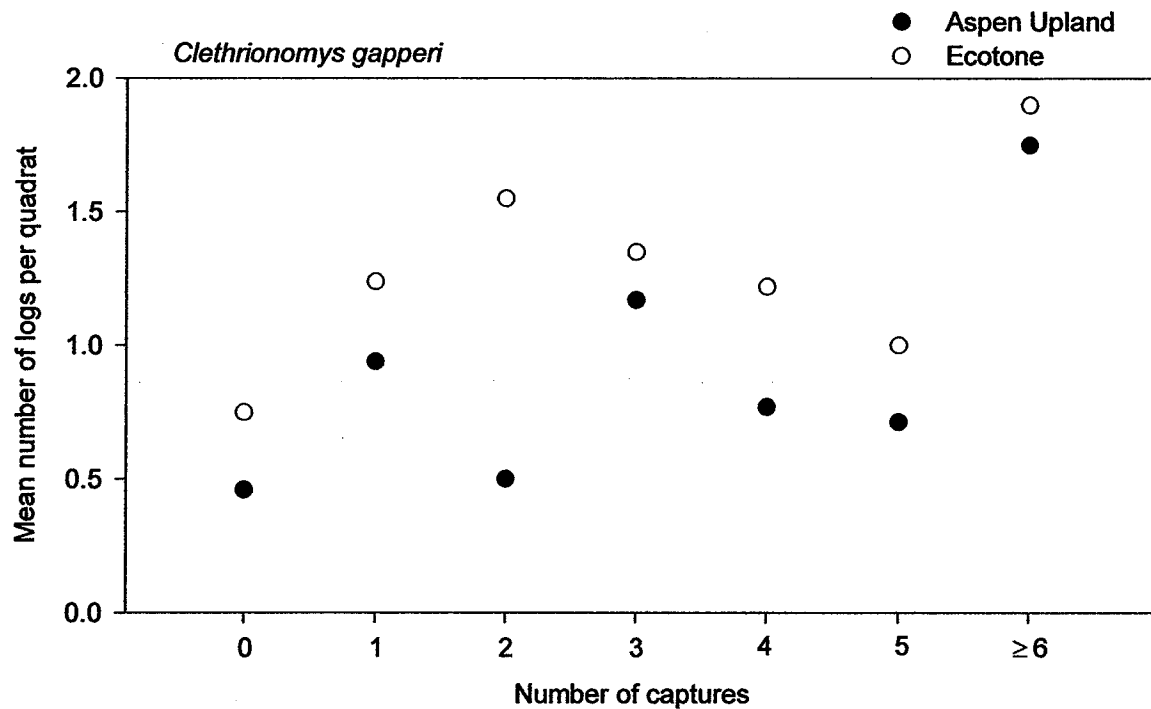


FIG. 1a. The association between the amount of coarse woody debris and number of *Clethrionomys gapperi* found within each capture site category. Number of logs and quadrats in each capture category are shown in Tables C.3a-d.

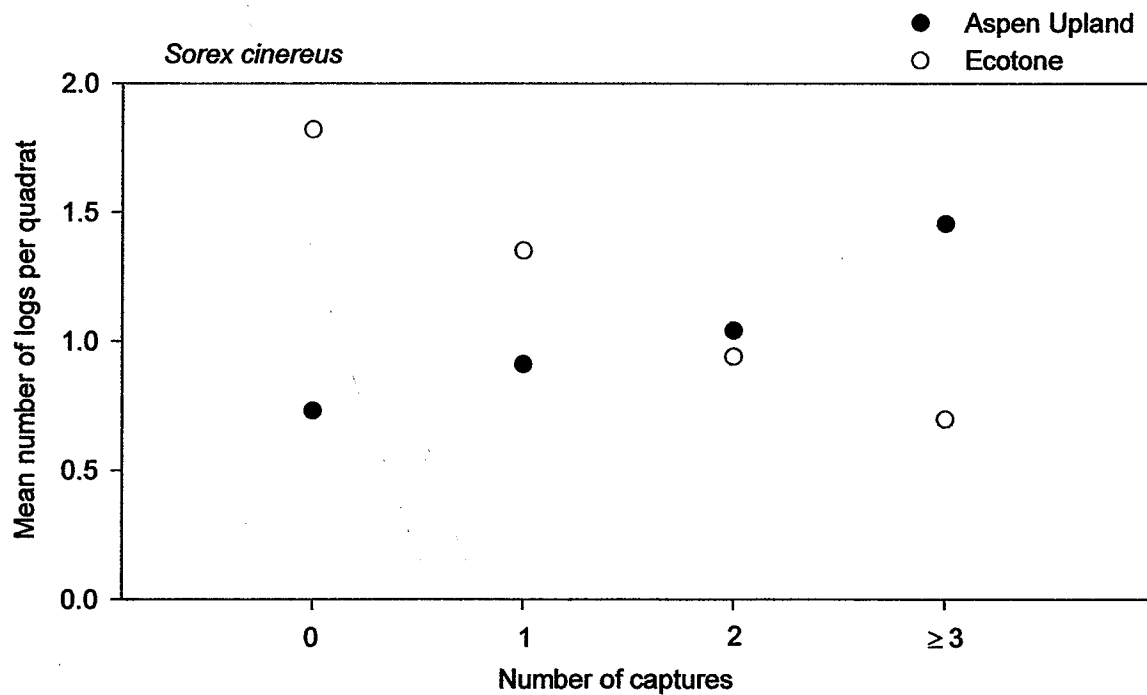
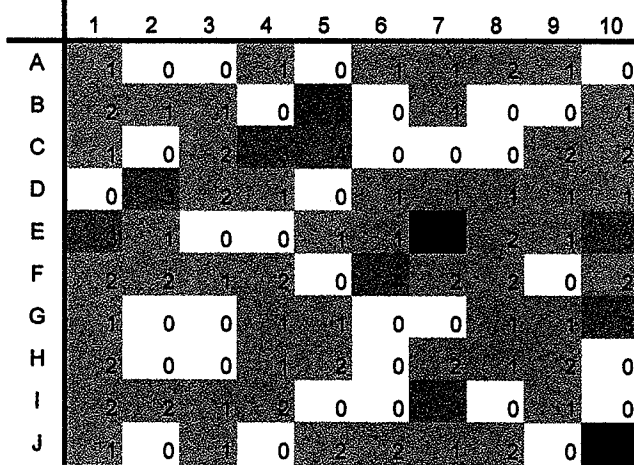
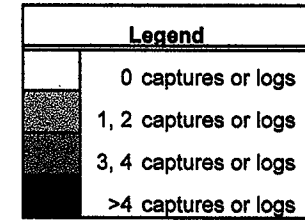
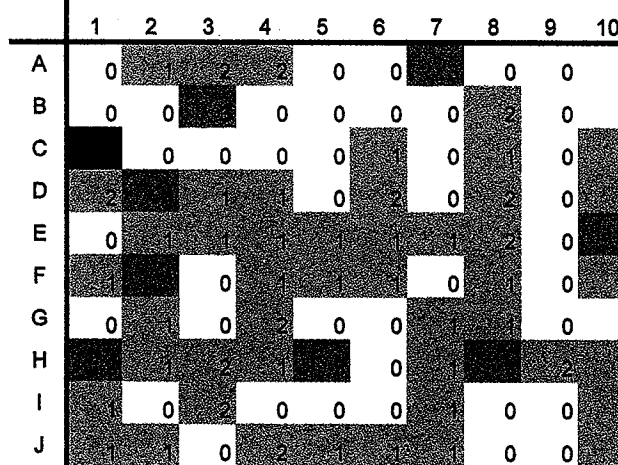


FIG. 1b. The association between the amount of coarse woody debris and number of *Sorex cinereus* found within each capture site category. Associations between capture rates and number of logs on the Ecotone represents an artifact of habitat conditions rather than avoidance by *Sorex* of the logs.

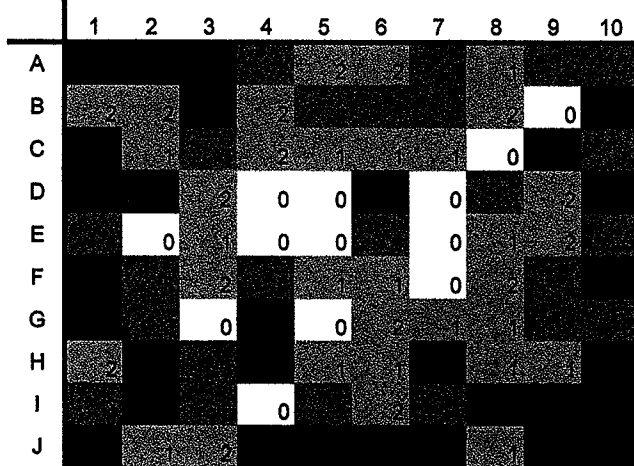
Aspen Upland *Sorex cinereus* captures/trap marker



Aspen Upland number of logs/4m² quadrat



Aspen Upland *Clethrionomys gapperi* captures/trap marker



Aspen Upland number of logs/4m² quadrat

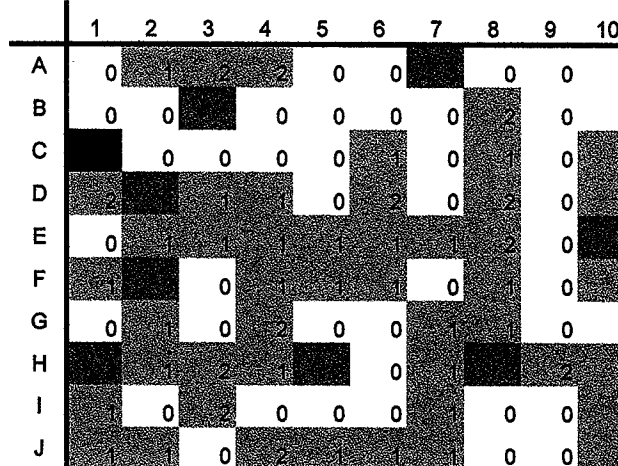
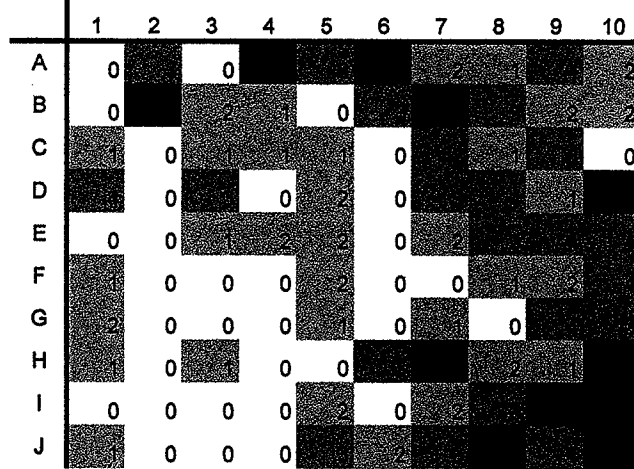
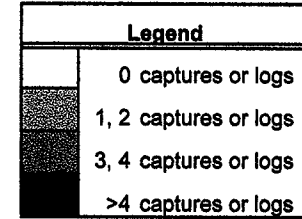
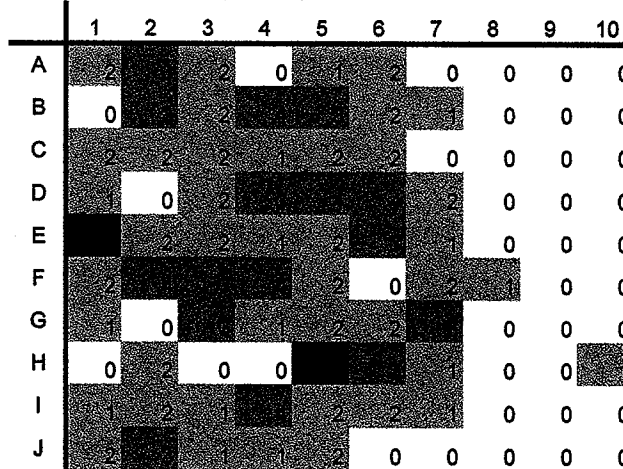


FIG. 2. Total number of animals captured over 25 years and the number of logs (>28.5cm in circumference) per station located on the Aspen Upland plot.

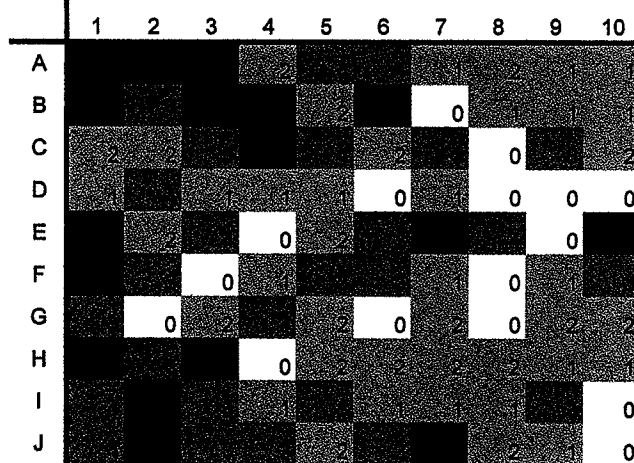
Ecotone *Sorex cinereus* captures/trap marker



Ecotone number of logs/4m² quadrat



Ecotone *Clethrionomys gapperi* captures/trap marker



Ecotone number of logs/4m² quadrat

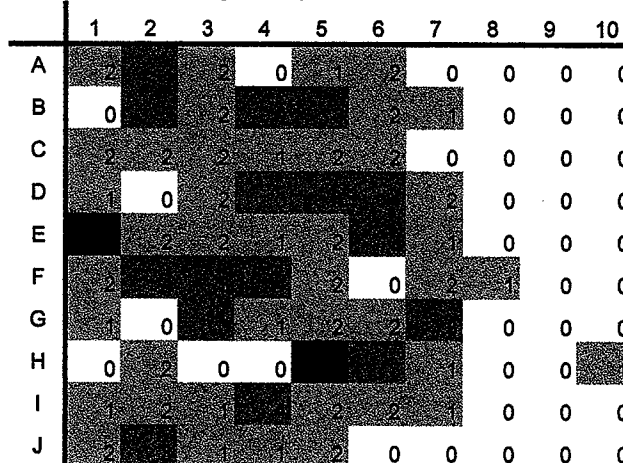


FIG. 3. Total number of animals captured over 25 years and the number of logs (>34.5cm in circumference) per station on the Ecotone plot.

also measured from each capture site with no notable differences observed among either the mean circumference values using the median logs only (Tables C.3a-d), or mean circumference values using all coarse woody debris combined (Tables C.4a-d), with different rates of capture.

Mammal data:

Characteristics of the trapped small mammals – In Tables C.6a-f, a summary of the most common small mammal captures is described by trap-type and gender across six habitats over twenty-five sampling years at TBS. Beginning with the ATB, *Clethrionomys* reported more animals captured by Museum Special (MS) traps than by Schuylers (SCH) traps (i.e., 62% vs. 19%) of the total sampled population; with 19% of its captures from unrecorded trap-types. Of the total *Clethrionomys* captured on the ATB, 37% were females, 53% were males, and 10% were of indeterminate or unknown sex. *Sorex* on the ATB has been captured more often by MS traps than by SCH traps (53% vs. 43%), respectively. More male *Sorex* (40%), than female *Sorex* (30%), have been captured, including a large percentage of unknown sexes (30%) over the years.

The ASP recorded more *Clethrionomys* captures by MS traps (72%), than SCH traps (24%), with 8% from unknown trap-types. An almost equal ratio of males to females has been presented in the traps: male animals contributed 46% to trapped populations, females 44%, and unknown sexes 10%. *Sorex* on the ASP has also been captured more often by MS traps than by SCH traps (56% vs. 42%), respectively. The proportion of sexes in the trapped population over time consisted of females 37%, males 27%, and unknown sexes 36%. *Peromyscus*'

response towards the different traps was also examined on the ASP. Again, more deer mice were captured by MS traps (59%), than SCH traps (34%), with 2% from New Museum Special (NMS) traps, and 5% from unknown trap-types. The trapped population consisted of females (40%), males (53%), and unknown sexes (7%), over twenty-four sampling years.

The BSB captured more of its *Clethrionomys* with MS traps (71%), and fewer with SCH traps (27%), including 2% from unrecorded trap-types. More male red-backed voles (58%), than female (38%), have been recorded; with 4% contributed by unknown sexes. *Sorex* has reported more captures by MS traps (58%), than by SCH traps (42%), on the BSB. The trapped population consisted of females (48%); males (26%); and a large proportion of unknown sexes (26%), over twenty-five sampling years.

The ECO plot reported more *Clethrionomys* captures from MS traps (67%), and fewer from SCH traps (25%), including 8% from unrecorded trap-types. *Sorex* on the ECO has also been captured more often by MS traps than by SCH traps (51% vs. 46%), respectively. The proportion of sexes in the trapped population over time consisted of females (23%), males (44%), and many individuals of unknown sex (33%). *Peromyscus*' response towards the different traps was examined on the ECO. MS traps (71%) captured more deer mice than SCH traps (20%). The trapped population consisted of females (43%); males (49%); and unknown sexes (8%), over twenty-four sampling years.

The JPR captured most of its *Clethrionomys* with MS traps (66%), while SCH traps contributed (31%), including 2% from NMS traps and 1% from

unrecorded trap-types. More female red-backed voles (49%), than male (44%), have been recorded; with 7% of unknown sex. *Sorex* reported more captures by MS traps (58%), than by SCH traps (37%), on the JPR. The trapped population consisted of females (29%), males (27%), and by a much larger proportion of unknown sexes (44%), over twenty-four sampling years. MS traps (67%) captured *Peromyscus* more often than SCH traps (27%); with 6% captured by unrecorded traps. More female deer mice (55%), than male mice (44%), were reported in the traps; with 1% of unknown sex.

Clethrionomys on the JPSP has also been captured more often by MS traps than by SCH traps (74% vs. 22%), respectively. The NMS traps have captured 3% of the trapped population, with only 1% reported from unrecorded trap-types. The proportion of sexes in the trapped population over time consisted of females (52%), males (45%), and unknown sexes (3%). SCH traps (50%) have captured more *Sorex* on the JPSP, than by MS (39%); with 2% unknown trap types recorded. The population consisted of 22% females, 28% males, and 50% from unknown sexes, over twenty-five sampling years. *Peromyscus* has had more captures by MS traps (67%), than by SCH traps (24%); with 3% from NMS traps and 6% from unknown trap-types. More male deer mice (49%), than female mice (45%), were reported in the traps; with 6% of unknown sex.

Summary of species and gender responses to trapping - The majority (meaning over 50%) of the trapped small mammal populations of the three most

common species were captured using Museum Special traps. Only the JPSP plot had 50% of its *Sorex* captures made by Schuyler traps.

In general, males of the three main species were more frequently captured than females across all six sites. Input by male animals ranged from approximately 5% to 20% above female contributions towards the total captured populations. For *Clethrionomys*, greater numbers of males were found on the ATB, ASP, BSB and ECO plots, while more females were captured on the JPR and JPSP. For *Sorex*, the plots were evenly divided in terms of male/female trap dominance. Three of the plots, ATB, ECO and JPSP had more male *Sorex*, while the ASP, BSB and JPR had greater numbers of females. *Peromyscus* was represented in three of the plots by greater numbers of males on the ASP, ECO, and JPSP and more females in the BSB and JPR.

Mature animals were individuals that possessed certain characteristics in their morphology that separated them from immature members of their species. For example, mature males in most cases had well-developed testes compared with immature males which had either non-measurable or minimal-sized testes. Mature females often had placental scars or embryos present within their uterine horns and were noticeably heavier than the remaining trapped female population. Animals of unknown sex were largely indicative of immature or nonreproductive creatures whose reproductive organs were difficult to identify.

Trapping that occurred three months after the fire captured on average, immature individuals. Trapping that occurred during peak capture years also

tended to capture more immature animals compared with non-peak years. For example, on the ATB, *Clethrionomys* captures in 1980 consisted of all immature animals, mostly males. In 1986, a peak in *Clethrionomys* appeared on the ATB, while the population gender ratio was evenly divided, most of the captured animals were immature. *Sorex* populations in 1980 after the fire all consisted of unknown sexes. Population peak years of *Sorex* in 1990 and 1995 on the ATB were composed mainly of immature individuals or ones of unknown sex.

The ASP also reported *Clethrionomys* populations composed of immature animals after the 1980 fire. Again in 1986, 1987 and 1993, *Clethrionomys* captures were practically all immature individuals during these three peak years. *Peromyscus* on the ASP during 1980 consisted mostly of immature males.

Clethrionomys populations on the BSB in 1980 were evenly divided between the sexes, but again were all immature animals. The ECO during 1980 produced captures of mostly immature *Clethrionomys* and *Peromyscus* populations. Again during the peak year of 1986 on the ECO, *Clethrionomys* populations were mostly composed of immature males.

On the JPR, following both the 1980 fire and the 1986 peak, most of the *Clethrionomys* populations were made up of immature males. In 1980, 1983 and 1988, *Peromyscus* species on the JPR consisted of relatively equal numbers of immature males and females. On the JPSP, *Clethrionomys* during its 1989 peak were mostly immature males. *Peromyscus* populations during 1980 and 1989 were again immature animals of fairly even gender distribution.

Additionally, the reproductive condition of female *Clethrionomys* was compared across all six habitats (Table C.8). Differences among the sites were tested and found significant ($\chi^2 = 13.94$, $df = 5$, $p = 0.0160$, $n = 481$). The null hypothesis is that the proportion of reproductive female red-backed voles within each *Clethrionomys* population is similar across all habitats.

Mean body mass and gender response to trap-type - In Tables C.7a-f, the mean body mass (g) of the different male and female small mammal species captured in two trap-types is presented. Overall, on the ATB, *Clethrionomys* females were heavier than their male counterparts by several grams regardless of trap-type. Females tended to be heavier in MS traps than those captured by SCH traps. However, MS and SCH *Clethrionomys* trapped males were almost equal in mean body weight (16.65g and 16.88g), respectively. *Sorex* males and females were generally equal in weight with no notable selectivity by the traps for a lighter or heavier animal.

The ASP *Clethrionomys* females captured in both trap-types were heavier than the males. *Clethrionomys* males captured in SCH traps were slightly heavier than those captured in MS traps. Females captured in both trap-types showed basically no difference in mean body weights. *Sorex* on the ASP exhibited almost equal mean body weights between the sexes, with little difference between weight selectivity of the trap-types. For *Peromyscus*, females were slightly heavier with MS and SCH traps capturing relatively equal mean body weights.

There were no noticeable differences between mean body weights of male and female *Clethrionomys* on the BSB. However, SCH traps tended to capture heavier animals of both sexes. Again *Sorex* on the BSB exhibited almost equal mean body weights between the sexes with little difference shown in trap-weight selectivity.

Clethrionomys captured on the ECO showed that females were heavier than males in both trap-types. Overall, SCH traps tended to capture females that were heavier than those captured in MS traps. Males were relatively equal in mean body weights from both trap-types. No noticeable differences were observed between the *Sorex* sexes, in either their mean body weights or trap selectivity.

On the JPR, *Clethrionomys* females were several grams heavier than the males captured in both trap-types. SCH and MS traps reported animals of similar weights with no apparent selectivity in weight class. The *Sorex* sexes had relatively equal mean body weights and trap-type response. *Peromyscus* males and females showed very similar mean body weights and trapping responses towards both trap-types.

On the JPSP, *Clethrionomys* females were several grams heavier than males captured in both trap-types. Each trap-type responded similarly to the mean body weights of the males and females. No noticeable differences were observed between the *Sorex* sexes in either their mean body weights or trapping selectivity. *Peromyscus* males and females showed again very similar mean body weights and trapping responses towards both trap-types.

The results in Tables C.22a-f express whether significant differences might have arisen between the median body masses of the small mammal species captured by the two different trap-types. The null hypothesis was that there was no difference in median body weight captured by the two trap-types. Each null hypothesis was tested using the Wilcoxon statistic. All p -values indicated non-significant differences (i.e., $P > 0.10$). Therefore the null hypothesis failed to be rejected in all cases.

The results in Tables 2a-2f examine whether significant differences might have arisen between median body mass and gender of the small mammals. The null hypothesis for the Wilcoxon statistic was that there was no difference in median body weights between captured males and females. The Wilcoxon test indicated several significant differences in male and female weights at ($P < 0.05$). *Microtus pennsylvanicus* females were significantly heavier than males in both the ECO and ASP. Significant differences in median body weights between the genders of *Clethrionomys* were found on the ASP, ECO, JPR and JPSP plots, with females reporting a median body weight roughly 3-4 grams heavier than males. *Peromyscus* on the BSB and JPSP indicated significant differences between male and female median body weights as well.

Finally, the results from Tables C.23a-f investigated whether significant differences exist between gender and trap-type response. The null hypothesis for the Chi-square statistic was that there was no association between trap type and gender. Only on the ASP plot did *Clethrionomys* exhibit a significant difference between male and female susceptibility to trap-type capture. More males were

TABLE 2. Median body mass (g) of male and female small mammals captured across six sites at Taiga Biological Station using Wilcoxon rank sum tests. The Wilcoxon test uses a chi-square distribution approximation. Shaded p-values are statistically significant at ($P < 0.05$), providing evidence against the null hypothesis (i.e., no difference between male and female body mass).

(a) Alder-Tamarack Bog						
<i>Microtus pennsylvanicus</i>	χ^2	d.f.	p-value	Gender	Female	Male
	7.0205	1	0.0081	Median weight (g)	26.88	20.11
				Number	16	19
				Std. Dev.	7.40	7.69
(b) Aspen Upland						
<i>Clethrionomys gapperi</i>	χ^2	d.f.	p-value	Gender	Female	Male
	29.9839	1	< 0.0001	Median weight (g)	21.37	16.54
				Number	135	141
				Std. Dev.	7.39	4.65
(c) Blackspruce Bog						
<i>Peromyscus maniculatus</i>	χ^2	d.f.	p-value	Gender	Female	Male
	7.9928	1	0.0047	Median weight (g)	15.73	12.29
				Number	13	8
				Std. Dev.	3.00	0.84
(d) Ecotone						
<i>Clethrionomys gapperi</i>	χ^2	d.f.	p-value	Gender	Female	Male
	7.3872	1	0.0066	Median weight (g)	19.44	17.02
				Number	99	132
				Std. Dev.	5.92	4.54
<i>Microtus pennsylvanicus</i>	χ^2	d.f.	p-value	Gender	Female	Male
	3.8629	1	0.0494	Median weight (g)	21.56	15.72
				Number	10	10
				Std. Dev.	6.941	5.412
(e) Jackpine Ridge						
<i>Clethrionomys gapperi</i>	χ^2	d.f.	p-value	Gender	Female	Male
	14.9266	1	0.0001	Median weight (g)	21.76	18.09
				Number	78	72
				Std. Dev.	7.27	4.83
(f) Jackpine Sandplain						
<i>Clethrionomys gapperi</i>	χ^2	d.f.	p-value	Gender	Female	Male
	17.1806	1	0.0001	Median weight (g)	24.24	19.01
				Number	61	52
				Std. Dev.	6.95	5.21
<i>Peromyscus maniculatus</i>	χ^2	d.f.	p-value	Gender	Female	Male
	4.6261	1	0.0315	Median weight (g)	15.95	14.70
				Number	63	69
				Std. Dev.	3.58	2.43

captured by MS traps than expected, and fewer by SCH traps ($\chi^2 = 5.117$, $df = 1$, $p = 0.0237$, $n = 282$). The reverse order occurred in females; fewer females were captured by MS traps and more by SCH traps than expected. All remaining plots and species expressed no significant differences between gender and trap-type response.

Interspecific associations among small mammal species - The frequency of capture-combinations is described in Tables C.9a-f for the three most common species found at each trapping station across six sites at TBS. Overall, four out of six plots (ATB, ASP, ECO and JPR) were represented by having the majority of their stations consisting of two or three combinations of small mammal species, rather than by an individual species alone, over twenty-five sampling years. The three most common combinations of species co-occurrence at trap markers were: *Clethrionomys* and *Sorex*; *Clethrionomys* and *Peromyscus*; and *Clethrionomys* alone. Only on the BSB and JPSP plots did trapping stations with single species, and no species, make appreciable contributions towards capture-type frequency. On the BSB, the category "*Clethrionomys* alone", and on the JPSP, the category "*Peromyscus* alone", provided the largest inputs of capture frequencies. Both of these plots also reported the highest number of "no captures recorded" categories.

Tables C.10a-d, C.12a-d, C.14a-d, C.16a-d, C.18a-d, C.20a-d, present the small mammal capture-combinations based on presence-absence data (from Table C.9a-f) in a contingency table format. The purpose of tabulating the data

was to calculate coefficients of association, C , for the various capture-combinations. The six conditional tables produced from each plot (Tables C.11a-f, C.13a-f, C.15a-f, C.17a-f, C.19a-f and C.21a-f) represent interspecific associations based on data collected from 600 trapping stations, over twenty-five sampling years.

A generalized summary of the six conditional tables, beginning with the ATB, found in Tables C.11a-f, is simply this - when *Microtus* is absent from a particular trapping station, then *Clethrionomys* and *Sorex* occur more frequently at these *Microtus*-free locations. The ASP (see Tables C.13a-f), represented small mammal associations found among *Clethrionomys*, *Sorex* and *Peromyscus*. In summary, all three species were more likely to occur together than separately at the various trapping stations within the ASP. On the BSB (Tables C.15a-f), *Clethrionomys* occurs more frequently at trapping stations that are *Sorex* and *Peromyscus*-free. The ECO small mammal association summary (Tables C.17a-f) found that when *Peromyscus* was absent, *Clethrionomys* and *Sorex* occurred more frequently together at trapping stations within this plot. Associations on the JPR (Tables C.19a-f) indicated that when *Sorex* was absent, *Clethrionomys* and *Peromyscus* occurred more often at the same trapping station. Finally, (Tables C.21a-f) for the JPSP, showed that at *Clethrionomys* and *Sorex*-free sites, *Peromyscus* occurred more frequently at these particular trapping stations.

Interspecific association measurements from the small mammal capture records showed that significant correlations were uncommon among most of the

small mammals at the 5% significance level. Some exceptions, as shown in Table 3, included the following: on the ASP, a strong negative association existed between *Peromyscus* and *Clethrionomys* when *Sorex* was present. On the ECO, *Sorex* and *Peromyscus* were negatively associated in general, without any particular conditions being applied. On the ECO, *Sorex* and *Peromyscus* were negatively associated both in the presence and absence of *Clethrionomys*. The remaining associations of small mammals within the different plots did not produce any associations with statistical significance. Capture locations of the small mammal interactions over time are shown in Figs. C.2a-e.

TABLE 3. Measurements of interspecific association based on presence-absence data from long-term small mammal capture records across six sites at Taiga Biological Station. The coefficients of association have the same range as the correlation coefficient (r), i.e., +1 = complete positive association, -1 = complete negative association, and 0 = no association. The chi-square statistics use an estimated p-value obtained by a Monte Carlo method which is more accurate when the expected counts are small in one or more cells. Only significant correlations were shown at ($P < 0.05$).

Aspen Upland			
	Coefficient of association	χ^2	p-value of chi-square statistic
<i>P. maniculatus</i> vs. <i>C. gapperi</i> with <i>Sorex cinereus</i> present	-0.7167	3.6764	0.0175

Ecotone			
	Coefficient of association	χ^2	p-value of chi-square statistic
<i>S. cinereus</i> with <i>P. maniculatus</i>	-0.4172	11.8740	0.0010
<i>S. cinereus</i> vs. <i>P. maniculatus</i> with <i>Clethrionomys gapperi</i> present	-0.3140	5.7993	0.0070
<i>S. cinereus</i> vs. <i>P. maniculatus</i> with <i>Clethrionomys gapperi</i> absent	-1.0000	9.5897	0.0066

Discussion

Vegetation data:

A comparison of plant surveys – In general, plant species belonging primarily to the herbaceous and shrub layers present before the fire regenerated and resumed their status after the fire. Lichen/moss ground cover and coniferous tree species suffered extensively on the severely burned areas of the plots, particularly on plots such as the BSB and JPR where rock ridges and tree canopies will require decades of recovery time to some what resemble pre-fire conditions. Most tree species present during pre-fire times have come back, but not necessarily with the same proportional distributions as in the past (see Martin 1983).

Vegetation recovery following burning was examined in northwestern Ontario forests (Methven et al. 1975). Burned tree stands regenerated to the same species that were dominant during pre-fire times although their relative abundances can vary because of seed-invaders such as aspen and birch. Also noted after the burn, was the rapid recovery of minor vegetation during the subsequent post-fire year period. Ohmann and Grigal (1981) examined vegetation recovery after disturbance by comparing forest communities during the first growing season following both spring and summer fires in northeastern Minnesota. Differences in vegetation response following the two fires were due to the seasons in which the fires occurred. The spring fire removed only the top few centimetres of humus while the forest floor was still moist from snowmelt,

whereas the summer fire removed the organic layer down to the mineral soil, which produced a more favourable seedbed for *Pinus banksiana*. The spring fire was intense in terms of canopy destruction; however, the cool, moist, forest floor moderated the impact of the fire to that of low-intensity status. Plants were able to reproduce vegetatively after the spring fire, whereas vegetation developed mainly from seed after the summer fire. Therefore, fire intensity played a large role in the rate of recovery on the burns and affected the plant species composition that returned.

The May long-weekend fire at TBS responded more typically in the manner of an intense summer fire in that the organic debris and humic layers were completely consumed and/or heat-killed on several of the plots, particularly on the JPR, JPSP and BSB. At TBS following the burn, an influx of post-fire disturbance species including herbs and mosses such as *Epilobium angustifolium*, *Corydalis sempervirens*, *Polygonum cilinode*, *Polytrichum* spp. and *Ceratodon purpureus* occurred on the JPR and several surrounding plots (described in detail in Appendix A.1).

Seed-reproduced species that colonize severe burns may maintain temporary dominance for up to five years after the burning, but begin to decline as vegetatively reproduced species i.e., *Vaccinium* spp., *Ledum groenlandicum*, *Diervilla lonicera*, *Arctostaphylos uva-ursi* and others, recover (Ahlgren 1960). These temporary seed-invaders observed during the early post-fire years have given way to the herbaceous and low shrub species seen on the plots today.

Plant species located within the ASP, ECO and ATB would have been the least affected by fire, as these moister sites with their many concave surfaces would be less conducive to burning. Areas within these plots were subjected to different intensities of burning that involved (i) high-intensity *Pinus banksiana* canopy fires on the ECO ridge top; (ii) individual *Pinus banksiana* on the ASP that became resinous torches under intense heat and; (iii) low-intensity ground fires on the surface layers of both the ECO and ASP, which resulted in only partially killed, above ground, graminoid and shrub parts.

Therefore, while the upper-most vegetation stratum was destroyed in many of the plots, the majority of the boreal plant species appeared to return following the fire. These conditions then allowed for possible associations to be investigated between the small mammals and the vegetation within the different habitats, especially on plots less affected by fire damage.

Low resolution variables associated with small mammals – The investigation of possible associations of grouped habitat variables (i.e., individual plant species combined into fewer descriptive categories) with rates of small mammal capture revealed only a minor number of macrohabitat structural features that could be associated with the small mammals, collectively. A common theme among many of the plots was that good capture sites (all small mammals included) had increased deciduous shrub cover, fewer graminoid species and extremely variable tree canopy coverage. For example, the presence of deciduous trees in good capture sites was important on the ECO

when all small mammal species were combined, whereas increasing amounts of coniferous tree canopy coverage were important to the small mammals on the JPSP.

Therefore, features closer in proximity to the small mammals themselves that perhaps offered food and shelter (but not complete visual obstruction) were apparently more influential to overall animal distribution, particularly on the ASP, ECO and JPSP plots, than overhead cover provided by the upper canopy well above the trap markers.

At TBS, the numbers of *Clethrionomys* captured on the ASP and JPR plots during the past six years have been comparable (27 vs. 33 individuals, respectively) and are shown in Tables A.1a-f, yet, both habitats are strikingly different in biotic diversity, vegetative cover and moisture levels. They do however share several physical attributes in common, including an uneven landscape, interspersed with areas of exposed, elevated rock ridges that are fringed by dense *Pinus banksiana* saplings. The necessary macrohabitat variables needed by this animal appear to be large amounts of coarse woody debris, lichens and coniferous tree species. Sufficient soil moisture available to food plants of *Clethrionomys*, in order to allow adequate water in the voles' diet (as indicated in Getz 1968), does not seem to be a necessity or a priority to species living on the JPR.

Miller and Getz (1973) studied factors influencing the local distribution of red-backed voles and found that the amount of debris cover available (in the form of fallen trees and logs, brush piles and rocky areas) affected densities of

Clethrionomys, with a positive correlation found between debris cover and abundance of red-backed voles. Wywiałowski and Smith (1988) reported that *Clethrionomys* preferentially used habitats with abundant cover; density of cover and the structure of the vegetation were more important in determining probable vole capture sites rather than floristic composition.

The ATB supports the largest *Sorex* biomass (Table A.2a) and is characterized by abundant hydric mosses, moist *Carex spp.*, and dense ericaceous shrubs, with moderate amounts of long-term standing water. While the BSB has many similar mosses and shrubs, it is almost xeric in terms of its moisture availability due to its elevated surface layers of *Sphagnum spp.* well above the water table, and to its lack of lush, moist sedge species. Wrigley et al. (1979) observed that the highest population of *Sorex cinereus* in Manitoba occurred in a white cedar (*Thuja*) forest, with a ground cover of sedge; cedar forests without sedge undergrowth were found to be depauperate in shrews. The most productive *Sorex* habitat in this study were hydric communities of grass-sedge marsh and willow-alder fen.

Pruitt (1953) found *Sorex cinereus* restricted to coniferous bogs in the northern part of the Lower Peninsula of Michigan and that the physical factors of temperature and moisture (Pruitt 1959) were important variables in affecting the distribution of local shrew populations. Getz (1961) found no correlation between type and physiognomy of the vegetation and the captures of *Sorex cinereus*, but acknowledged the importance of cover in maintaining high humidity conditions. *Sorex* was most abundant in areas where standing water was present and

because of its small size and body weight, was able to efficiently utilize a wide number of smaller invertebrates, and was more agile in its movements than heavier animals in this type of environment.

The ATB plot at TBS typically possesses high humidity levels due to the densely packed layers of shrubs and long-term presence of standing water. *Sorex* reflects its restricted distribution at TBS by its lack of occurrence in traps on the JPR and JPSP plots - two very xeric plots with few areas of favourable moisture conditions.

The ASP and JPSP today support many (in comparison to the other habitats) *Peromyscus*, yet, these two plots are strikingly different from one another in terms of their vegetative diversity, plant cover and moisture levels. Parts of the ASP are quite xeric along the exposed rock ridges and therefore very similar to JPSP areas in their exposed openness. Pockets of recovering *Pinus banksiana* occur on both plots along with relatively large amounts of space between the mature trees. Dueser and Shugart (1978) found that *Peromyscus* occurred mostly with deciduous canopy, low density of trees and high density of shrub-understory. The presence of nearby scattered mature jack pine trees, relatively open unhindered habitat beneath the canopy, and xeric conditions, appear to be important variables in *Peromyscus* habitat at TBS.

Low resolution (macrohabitat) variables may provide some general indication of habitat preference by the small mammals at TBS. But because of the highly varied environment within each plot in terms of vegetative diversity, amount and type of canopy coverage, range of substrate moisture levels, and

variation in the numerical dominance of the small mammal species present, defining specific macrohabitat variables (that are inclusive of all small mammal species across all sites), is both nonviable and impractical. Individual microhabitat features associated with a specific small mammal species were therefore suspected of being better indicators of habitat selection by the TBS small mammals.

High resolution variables and small mammal associations – Small mammals were separated by species and by rates of capture at each of the trapping stations across the various habitats, to observe possible small-scale (microhabitat) associations between plants and animals. Overall, it was discovered that only minor associations could be made between a particular species of plant and animal (based on mean percent cover values of the habitat variables). There were notably few definitive trends among the two variables in terms of an association between a particular plant species and a small mammal's capture rate (i.e., there were no sharp increases or decreases reported in mean cover values of the different habitat variables which correspondingly correlated with ascending or descending capture rates of the small mammals). Small changes in mean percent cover (i.e., about 10 –15% on average) indicated habitat variables that differed slightly among the various levels of capture.

While large-scale macrohabitat variables indicated that canopy coverage was important to *Clethrionomys* and *Sorex* on the ATB, microhabitat variables that indicated the type of canopy cover (i.e., tree species) directly over the

trapping station provided insight (sometimes conflicting) into the effect particular vegetation types had on small mammal distribution. Although canopy cover was dense across the upper half of the ECO plot, much of this consisted of *Pinus banksiana* which was associated with decreasing numbers of *Sorex* captures. Improved *Clethrionomys* capture sites on the ECO were associated with increased *Populus tremuloides* cover rather than either *Larix laricina* or *Pinus banksiana*. In contrast to these findings, sites of better *Clethrionomys* capture on the JPR reported abundant *Pinus banksiana* overhead canopy. On closer examination, *Clethrionomys* were most likely responding to factors beyond the particular species of tree coverage, but rather to the protection that it offered, along with a combination of other factors associated with habitat change. These factors perhaps included the increased presence of fire-recovering lichens, the seasonal abundance of fungi during the month of August, and/or the increased growth of jack pine saplings - all of which likely played important roles in *Clethrionomys*' increased capture numbers on the ridge.

Therefore, it was discovered that individual microhabitat variables were of little help in identifying features important to small mammal habitat selection unless the macrohabitat and its associated large-scale habitat variables were first identified. For example, while the species of tree that makes up the canopy first appears significant in determining the species of small mammal found beneath it, the overall conditions of the environment on the plot (i.e., xeric, mesic or hydric), along with the diversity and combination of food and shelter variables available to the animal, are perhaps better indicators of habitat preference than individual

variables. Individual variables are of little informational value unless the macrohabitat (i.e., the entire area that encompasses each trapping grid) as a whole is considered, particularly when plant species such as *Picea mariana*, *Ledum groenlandicum* and *Vaccinium spp.*, which are ubiquitous across TBS habitats, are involved.

Miller and Getz (1973) studied factors influencing red-backed vole distribution in New England and could find no general correlation between the local distribution of *Clethrionomys* and cover provided by a given plant species or plant category. *Clethrionomys* was distributed independently of tree or shrub cover. Morris (1984) also studied microhabitat separation of two small mammals, the White-footed mouse (*Peromyscus leucopus*), and Meadow voles (*Microtus pennsylvanicus*), and could find no single structural variable that could consistently describe species separation and account for microhabitat differences. Microhabitat measurements were found less effective predictors of rodent density than was the macrohabitat.

Homogenized macrohabitats (meaning plots with less vegetative diversity) including the ATB, BSB, JPR and JPSP and heterogenized environments (habitats with more vegetative diversity) such as the ASP and ECO, may influence small mammals in a number of ways. The diversity of small mammals might be related to both the diversity of food items and to the structural attributes of the habitat (Naylor and Bendell 1983). Therefore, the overall characterization of a plot (i.e., homogeneous or heterogeneous), in properties such as vegetative diversity and physiognomy, are stronger determinants of small mammal

presence than microhabitat features at TBS. Both the ASP and ECO habitats support a greater diversity and abundance of small mammal species.

In summary, to identify plant-animal associations at TBS, it was valuable to have small mammals and capture rates separated, to allow for the emergence of several minor patterns among habitat variables and individual species of animal. However, few trends could be elucidated through the association of individual variables with rates of small mammal capture; this was perhaps both a reflection of the sampling technique involved in small mammal capture and the elementary method of vegetation analysis which failed to detect associations between the two variables. At TBS, it was discovered that biotic associations are strictly site specific, and depend on species and macrohabitat properties.

Small mammal associations with coarse woody debris – Within their habitats, the presence of logs benefit small mammals. Fallen trees at TBS provide habitat for food items (such as invertebrates and fungi) eaten by the insectivorous and partially fungivorous mammals, *Sorex* and *Clethrionomys*. As well, the softly decayed logs (as opposed to the hard fire-damaged trees) can provide refuges of relatively high humidity for *Sorex* activities within the more mesic and xeric portions of the different plots.

In general, some associations were found between the small mammals, their various rates of capture, and the number of fallen trees found within the quadrats surrounding each trap marker. Gunderson (1959) attempted to determine factors in a Minnesota forest that affected the distribution of red-

backed voles and found that stations with high frequency vole use reported the most rotting stumps, root systems and logs. *Clethrionomys* at TBS did not produce any significant correlations among the above variables until extreme conditions or boundaries were met. For example, the plotted rates of capture ranging from 0 to ≥ 6 individuals per station (Fig. 1a), showed no particular trend or change in the amounts of CWD found within their quadrats until either poor sites (with 0 captures), or very good sites (those with ≥ 6 individuals), were examined.

A trend did appear among the outermost values of the capture range described in Fig. 1a. Sites which never captured *Clethrionomys* consistently recorded the fewest number of logs within their quadrats, while sites with the highest capture rates reported the greatest number of logs within their quadrats. In contrast, *Sorex* showed strong correlations between the number of logs per quadrat and the number of captures on both the ASP and ECO plots. The overall mesic conditions on the ASP and ECO plots have supported relatively constant numbers of *Sorex* throughout the years, with the ECO being the richer of the two *Sorex* habitats. However, the results obtained from *Sorex* log data (Fig. 1b) in the ECO plot were contrary to those found on the ASP plot.

On the ASP, good capture sites for *Sorex* were positively associated with the number of logs (i.e., good capture sites were found to have more logs than poorer sites). On the ECO, *Sorex* appeared to be strongly negatively correlated with the number of logs surrounding each trap marker; the sites of best capture had the lowest number of logs per quadrat.

Sorex results obtained from the ECO are suspect in that they are most likely an artifact of the variable macrohabitat conditions found on the plot, rather than direct avoidance by this small mammal of log presence. The ECO plot represents a transition zone between a xeric *Pinus banksiana* habitat with rock lichens, and a hydric *Alnus rugosa* and *Larix laricina* habitat with moist sedges and sphagnum. Most of the recorded fallen trees occurred within the burned xeric portion of the study plot, habitat with unfavourable moisture conditions. Fire-killed trees, especially the coniferous species at TBS, are often hard, solid cylinders of dried wood, supporting little moisture and fungi growth even after a lapse of several decades. The bog portion of the ECO also contained fewer fallen trees.

In general, the ATB and lower ECO had the least amount of CWD compared to all other plots, but correspondingly held the highest humidity levels. Here, CWD would be less necessary under these moist conditions, whereas on the ASP plot, the soft decaying logs represented microsites of greater humidity and food resources surrounded by less favourable conditions for *Sorex*.

Butts and McComb (2000) found that the probability of encountering a Trowbridge's shrew (*Sorex trowbridgii*) in the Douglas-fir forests of western Oregon increased with cover of CWD on the forest floor. This particular animal is abundant around fallen trees, especially those of decay classes III and IV that are well-settled on the forest floor (Maser and Trappe 1984).

Large-scale disturbances (e.g., tornados or strong winds) can produce areas with significant amounts of CWD. Loeb (1998) found that while these disturbed areas in the managed pine forests of South Carolina may have had an

initial negative effect on small mammals, areas with large amounts of CWD appeared to recover more rapidly. Interestingly, the BSB plot at TBS contains the largest volume of wood (personal observation), and yet reports the fewest number of small mammal captures. The large accumulation of “jack-straw” logs on the BSB represent fire-killed, wind-blown trees that appear to have little influence or attractiveness to the TBS small mammal species. The fallen trees on the BSB are typically hardened cylinders of silvery-gray wood, elevated well above the ground, and therefore are far removed from many of the small mammal niches, except perhaps of those of the more scansorial species.

Mean log circumference of the fallen trees did not appear to be a factor in microhabitat selection for *Clethrionomys* and *Sorex* at TBS (Tables C.3a-d and C.4a-d). Circumference values for *Clethrionomys* logs varied by approximately 10cm, ranging in size from 45 to 55cm across all capture rate categories on the ASP, and 55 to 65cm on the ECO, regardless of capture rates. Circumference values for *Sorex* logs also did not notably differ, ranging from 50 to 60cm across all capture rate categories on the ASP and from 55 to 60cm on the ECO, regardless of capture rates.

Hayes and Cross (1987) in the southern Oregon Cascades studied capture rate successes of *Clethrionomys* and *Peromyscus* at locations containing different sized logs. Their study revealed no significant correlations with the number of *Peromyscus* and between any measured log variable (i.e., log length, log diameter, state of decay). However, captures of *Clethrionomys* were positively correlated with mean log diameter and the size of the log overhang,

suggesting that voles use large diameter logs more frequently than small diameter logs with poor overhangs. At TBS, logs of large circumferences (i.e., > 50cm) were relatively uncommon on most plots, and in general, large diameter trees appear to be relatively rare in the Manitoba mid-continental boreal forest dominated by black spruce trees.

Mammal data:

Trap influence on small mammals - Museum Special traps have captured the bulk (over 75%) of the trapped small mammals living within the different communities at TBS. Lighter weight animals, especially *Sorex spp.*, have not been equally represented by both trap-types; more Museum Special traps have captured *Sorex spp.* than Schuyler traps. Correspondingly, MS traps have also failed to capture many of the *Sorex* living in the various study plots. For example, many of the wooden trigger platforms have been covered with *Sorex* pellets, the bait removed, and the trap unsprung, as witnessed on numerous occasions during trapping seasons (personal observation).

The assumptions of a particular trap-type possessing more sensitivity than the other have not been supported by the data. Museum Special traps have adequately represented the majority of the small mammal species living at TBS. Extremely light weight and/or juvenile animals appear to be consistently under-represented in TBS traps, as well as the semi-fossorial species *Blarina*, and fossorial species *Condylura*, because they are less likely to encounter traps during their foraging activities. Juvenile animals are also unlikely to appear in

traps until after the adults have been removed from the sampling area or until they are at least one month old (Mihok 1979). The three night trapping period may not be of sufficient length to recruit juveniles.

Different types of kill traps (Museum Specials, Victor mouse traps and Holdfast traps) were used to sample small mammal populations in northern Ontario boreal forest. Martell (1979) found that *Clethrionomys* and *Zapus* caught in Museum Specials were significantly heavier than those caught in Victor traps. Relative to Museum Specials, Victors captured proportionally fewer of all species, whereas Holdfasts captured more soricids, equal numbers of cricetids (arvicolines), and fewer zopodids and sciurids. At TBS, Schuyler traps often captured heavier individuals, but concurrently, they were also capable of being extremely trigger sensitive towards shrew activity. When the Schuyler traps worked properly, they were extremely efficient in small mammal capture; however, when they were not functioning correctly, many small mammals escaped being captured by this particular trap (as indicated by the missing bait).

Soricid species will consistently be under-represented or excluded in many of the traps at TBS (particularly on the ATB plot) unless pitfalls are employed. If an index of most or ideally all small mammal species living in each habitat is desired, then pitfalls, along with drift fences would be required. Kirkland et al. (1998) compared the results of sampling with four combinations of trap-type and drift fencing. These included pitfalls with and without drift fences and Museum Specials with and without drift fences. Pitfalls with drift fences yielded significantly higher numbers of shrews and rodents and that even *Peromyscus*

leucopus, a scansorial species, was taken in greater numbers in this particular trapping array compared to the other trapping combinations. Soricids were greatly under-represented during sampling periods without precipitation, or in sites that employed snap-traps.

At TBS, weather can have a large impact on trapping success. Traps that are set in the open and lack overhead cover from either shrubs or fallen trees can be easily sprung by hard rainfall. Alternatively, if too much precipitation occurs, the bait becomes unattractive to the small mammals (i.e., it becomes dilute and runny and grayish in colour).

Mean body mass and gender response to trapping - At TBS, reproductively active female *Clethrionomys*, *Peromyscus* and *Microtus* are usually several grams heavier than their male counterparts, particularly during the August trapping season. However, these differences in body mass were not significant enough to produce biases in capture-response by the two main trap-types. Both trap-types captured individuals of relatively equal mean body weights. While female rodents tended to be slightly heavier than males (in contrast to the insectivores which reported negligible differences between their mean gender weights), there were no significant differences observed (except for *Clethrionomys* in the ASP plot) between male and female susceptibility to trap-type captures. More males were captured by MS traps than SCH traps on the ASP, yet the gender ratio was virtually 1:1.

The greater general response by males (in terms of numbers captured in traps) on the ATB, BSB, and ECO for *Clethrionomys*, had no association or similarity to the numbers of males captured from other species in traps of these identical plots. Males of *Clethrionomys* tend to have larger home ranges and travel greater distances than the nesting females (Bondrup-Nielsen 1987). Gillis and Nams (1998) indicated *Clethrionomys*' home range diameter to be around 60 to 70 metres. Therefore, it is not unexpected to encounter slightly more male animals within the TBS traps because of the trapping grid size which easily encompasses the home range of an individual. Bowman et al. (2000) found no differences in distance moved *within* species based on gender or age group for deer mice, red-backed voles and woodland jumping mice. However, *among* species, deer mice moved farther than either of the other species.

A female *Clethrionomys* can produce several litters throughout her reproductive season (Banfield 1974). If mature female *Clethrionomys* are indicative of optimal habitat locations (Bondrup-Nielsen 1987), then at TBS, plots with more female captures, or ones with more equitability in their ratios of males to females, should represent preferred *Clethrionomys* habitat. Interestingly, the JPR and JPSP reported more female than male *Clethrionomys* captures over the years, with the ASP showing an almost equal ratio of genders. The JPR and JPSP represent disturbed, xeric, habitat that is in the long-term process of recovery from fire.

The greater general response by younger (juvenile) individuals of *Clethrionomys* and *Peromyscus* species (i.e., those up to 17g in body weight)

during peak years or periods following habitat disturbance, may be a reflection of the proportions of breeders in both species. Mazurkiewicz and Rajska-Jurgiel (1998) found that in low density years the populations of voles and mice consisted mainly of mature individuals, whereas in high density years, immature individuals prevailed (as found at TBS). Density and maturation rate of the populations are influenced by resource conditions; resource deficiency can account for increased mobility (Anderson 1989). Areas that offer a good supply of vacant space (such as the ECO or ASP) may be attractive to young dispersing small mammals.

Interspecific associations of the small mammals – A few trends became apparent among the various study plots and the frequency of capture-combinations within them. The plots that reflected the most homogeneous environments in terms of vegetative diversity, relief, and substrate moisture levels were correspondingly the plots that supported the least number of multiple captures of small mammals at their trapping stations. The BSB and JPSP have recorded the highest number of both single species captured, and no species captured, compared with the remaining four plots. These two plots have also produced the fewest number of multiple capture sites. Highly productive plots in terms of their large numbers of individuals trapped possessed the greatest numbers of multiple capture sites, and were the most heterogeneous in their vegetative diversity, relief, and substrate moisture levels. Examples of these conditions are found on the ASP and ECO plots.

For the most part, at TBS, the presence of one particular species did not significantly appear to influence the behaviour or occurrence of another species trapped at the same location. Only on the ASP did a strongly negative association exist between *Sorex* and *Peromyscus*. Again, this result may be an artifact of trapping within an ecotone environment. There is a definite tier system of small mammal occurrence/avoidance on the ECO plot that is related to microhabitat selection by the small mammals. At the top of the ECO ridge, *Peromyscus* is more likely to be captured within this xeric, fire-disturbed habitat covered in scattered fallen logs; *Clethrionomys* is more likely to be trapped along the wide mesic belt of the plot which is filled with a thick herbaceous layer; and *Sorex* shows a definite preference for the hydric conditions at the bottom of the plot, located mainly within a humid *Alnus rugosa* and *Larix laricina*-sedge bog. Rather than *Sorex/Peromyscus* representing avoidance of one another within the ECO plot, these two species are unlikely to encounter one another in their activities - due to their preferences for opposite habitat conditions. Therefore, a negative association between species may not be applicable to actual animal behaviour on the ECO study plot, but rather to habitat conditions.

It was not surprising to discover the lack of negative associations among the small mammals at TBS. Vickery (1981) suggested that the dynamics of forest rodent communities have all the prerequisites for coexistence; rodent species coexistence is possible through seasonal variability in population size, food availability, food quality and feeding rates, predator saturation and learning effects. Morris (1983) indicated most small mammal encounters will be between

members of the same species because these creatures are habitat selectors with divergent microhabitat preferences. Mihok (1979) noted that two or more *Peromyscus* were likely to occur more frequently in multiple capture traps than were *Clethrionomys* individuals.

Sites that have fewer multiple captures of animal species rather than being indicators of areas of reduced competition among the different species may actually represent sites of reduced competition among individuals of the same species. For example, the ATB has reported the highest numbers of single *Sorex* captures but has correspondingly produced the largest number of *Sorex* in traps over time. *Peromyscus* single capture sites have been most abundant on the JPSP which has also produced the greatest number of *Peromyscus* in traps, throughout the years. However, *Clethrionomys* does not fit into the above pattern in that the greatest number of single-capture sites for this creature is on the BSB, while the ASP plot has produced the largest numbers of *Clethrionomys* trapped over the years. Perhaps because of this creature's flexibility in its niche requirements, the optimal habitat conditions for *Clethrionomys* are more difficult to define and identify at TBS.

M'Closkey and Fieldwick (1975) suggested that the occurrence of joint captures of *Peromyscus* and *Microtus* have two alternative explanations. Either the localities representing joint captures are optimal, or that exclusive microhabitats are optimal (exclusive *Peromyscus* or exclusive *Microtus*), and that joint captures simply represent niche overlap.

Experimental factors affecting small mammal captures – The location of traps within the sampling grid may have an impact on trap success or failure depending on the small mammal species captured. In Figures C.3a-e, layouts of the 10x10 sampling grids across six different habitats of the most common species are presented. For *Clethrionomys*, an edge or boundary effect is apparent on the ASP and ECO plots and along the northwest side of the JPSP plot. At these peripheral locations, more *Clethrionomys* have been captured than at trap stations within the sampling grid interior. The numbers of increased captures can range from a few, to six or seven *Clethrionomys* above central trap markers locations. Quadrats with no captures are also less common around the periphery.

Sorex and *Peromyscus* presented fewer edge-effects compared to *Clethrionomys*. *Sorex* showed a moderate edge effect along the J line from one to ten, adjacent to Aikens Lake Road. However, this area is reflective of the greatest vegetative diversity found on the ATB plot. The ECO also exhibited an edge-effect with *Sorex* (across the row of number 10 trap markers), which is again adjacent to Aikens Lake Road and separated by metres from the ATB J line. *Peromyscus* exhibited moderate edge-effect on the ASP plot along the J line (from one to ten), as did the row of number one markers on the JPR plot. The plots with quadrats located in areas with notable edge effects did not appear to have any particular impact or influence on the recognition of microhabitat variables found in higher capture sites, compared with moderate or poorer capture sites at TBS.

Other experimental factors that might have an effect on the interpretation of results involving associations between small mammals and microhabitat variables concerns the night of capture. Both from personal observation and from the literature, adults tend to be captured during the first night of trapping rather than juvenile members of the small mammal community. Mihok (1981) found that mature female *Clethrionomys* were dominant, occupying preferred habitats, and that these territorial adult females were most likely to be removed during the first night of trapping. Wywiałowski and Smith (1988) noted in their research that by using only the first night's small mammal capture data (where the trapped voles consisted mostly of adults), 80% of the sites were correctly classified. In other words, there was an 80% success rate at predicting suitable *Clethrionomys* capture sites. However, the reliability of this method declined when the second night's data (which consisted mostly of juveniles) were added.

At TBS, I could find no discernible difference between trapping stations that captured mature *Clethrionomys* females (i.e., animals ≥ 25 g in body weight, showing placental scars and/or embryos) with those of immature females (i.e., ≤ 24 g in body weight and not possessing placental scars and/or embryos).

Of particular interest regarding the overall female demography at TBS (with all sampling years combined), was that while traps on the ASP and ECO plots captured the greatest numbers of female *Clethrionomys*, the JPR and JPSP plots captured the highest numbers of *reproductive* female *Clethrionomys*. By examining past trapping records and selecting reproductive females on the basis of possessing placental scars and/or embryos (regardless of weight), the JPR

and JPSP have supported reproductive female populations of 54% and 57%, respectively. In contrast, the ASP and ECO plots have reported fewer reproductive females, with only 48% and 33% of their female populations being contributed by reproductive females. The period with the highest number of reproductive females occurred during 1986-90 for four of the plots (i.e., ASP, ECO, JPR and JPSP).

Bondrup-Nielsen (1986) indicated that home range size for mature female *Clethrionomys* is not a function of density but of habitat type. Van Horne (1983) found that two different habitats were distinguishable for adult and juvenile *Peromyscus* – with high-density adult habitat being of high quality, and high-density juvenile habitat being of low quality. The higher numbers of mature female *Clethrionomys* on the JPR and JPSP may indicate that these are the preferred habitats for territorial females even though they appear resource “poor”. Species living on more limited food resources should hold larger home ranges, and species depending on scarcer food resources should be more prone to disperse (Mazurkiewicz and Rajska-Jurgiel 1998). The ASP and ECO plots perhaps serve as areas receptive (i.e., sinks) to dispersing juvenile *Clethrionomys*.

Summary

Boreal forests are mainly dependent on periodic fire for their continued existence (Van Wagner 1978). In response, the forest undergoes a series of vegetation readjustments to site instability (Dix and Swan 1971). The small mammal study plots at TBS experienced varying degrees of fire-induced damage as a result of a combination of factors, some of which included: habitat relief, substrate moisture level, forest stand composition, and fuel availability in the form of materials such as conifer needles, hardwood leaves, grasses, and finely divided shrubs. All of the above factors affected the behaviour of fire and the intensity of burn at Wallace Lake, in May of 1980.

The plant surveys during different time periods revealed that abundant species in the pre-fire forest will predominate after fire. The large-scale or macrohabitat variables that characterize each plot can be used to identify broad patterns of habitat preference by the different small mammal species at TBS. However, small-scale or microhabitat variables surrounding each trap marker proved to be less effective in identifying preferential patches of habitat within many of the plots. Few trends could be elucidated through the associations of individual habitat variables with rates of small mammal capture. The overall heterogeneity of a plot in terms of its food availability and structural components were more reliable indicators of species presence than its individual vegetation attributes.

The small mammal communities were adequately sampled by Museum

Special traps (particularly when sciurid captures are undesired) and with experience, the New Museum Special traps should prove to be effective at a wider range of small mammal captures. The different trap-types captured animals of relatively equal median body weights; however, arvicoline and sigmodontine females tended to be heavier than their male counterparts at the time of capture. Overall, more male animals were captured than females - this may be a reflection of differences in home range size and in social behaviour between the sexes.

A higher number of reproductive arvicoline females were found on the JPR and JPSP plots throughout the years while actual population sizes were larger on both the ECO and ASP plots. Perhaps the latter plots serve as areas of dispersal for many juvenile members because of the availability of resources in these rich, heterogeneous environments. Within these types of environments, more multiple species captures occurred at trap markers than individual species captures. As well, little support existed for negative interspecific associations among the species, since the presence of one species on the ASP and ECO plots (the two most productive plots in terms of capture numbers) appeared to have little effect on habitat use and relative abundance of another species inhabiting the same plots.

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Recommendations

Getz et al. (2001) remarked on the need for long-term small mammal data sets noting that the average length of many of these studies was slightly over three and a half years. The rare number of small mammal studies of long-term duration was noted to suffer from a lack of infrequent trapping. In earlier work, Getz et al. (1987) recommended live-trapping on a monthly basis to avoid missing the actual peak density of the populations, particularly since small mammals may not peak at the same time each year, nor in the same location. Annual trapping does not allow the researcher to examine in detail, data on the demographic traits of the small mammal populations, especially the role of changes in survival, reproduction, sex ratio and other traits that may generate annual or multiannual cycles (Getz et al. 2001).

At TBS, a preliminary live-trapping study (away from the current small mammal study plots to avoid their disturbance) could be performed in the fall to determine the feasibility and practicality of conducting this method of research. Because of the distance, effort and time required to perform a monthly analysis across six plots, either a bimonthly trapping session or a reduction in the number of habitats sampled would be more expedient. Live-trapping would allow the development of a data base on the demographic characteristics of the populations throughout the year (or at least 6 to 8 months of the year) and corresponding increase identification of conditions that create peak years in small mammal communities. Live-trapping could assist in the identification of

contemporary habitat variables that might influence the presence/absence of a particular species. The purpose of identifying these associations would be to enhance our understanding of habitat selection and preference of these small mammals, and to develop long-term goals important in the maintenance of specific habitats required by the various species for their survival and longevity. Because small mammals are the base of boreal food chains, the more we know about the requirements of these creatures, then the more comfortable we can become on making decisions regarding the management of habitat for other wildlife species that are strongly dependent on this food base.

For example, Raine (1981) noted that fires and clear-cut logging reduced the populations of arvicoline rodents (*Clethrionomys* and *Microtus*) - the favoured prey of the mustelid (*Martes americana*) and increased the populations of *Peromyscus* which marten seemed to avoid eating. Raine (1981) found that both fisher and marten were easily trapped and have low reproductive potentials. Therefore, it would be advantageous to select habitat (*a priori*) that would be supportive in the successful reintroduction of these mustelid species.

The current method of removal sampling at TBS should be continued because it exists as a rarity in that it represents one of the few ongoing long-term small mammal studies, in the taiga of Manitoba. This method of sampling is relatively efficient and expedient in its requirements of the trapper, in time and effort. While the biases of removal sampling methods have been previously described, yearly monitoring of the small mammals living within the different

habitat-types through snap trapping can provide an effective means of recording changes in the communities through time.

By keeping long term records of the natural history (over 25 years worth at TBS), we can witness changes that have taken affect in small mammal populations and their surrounding habitats. If these areas are to be disturbed in the future, records exist then that will inform us how things once were, and therefore, hopefully serve and provide an informative database from which sound scientific advice can be sought.

APPENDICES

TABLE A.1a Summary of the number of small mammals captured by species during twenty-four sampling years on the Alder-Tamarack Bog at Taiga Biological Station. The plot was not trapped in 1984.

Years	<i>Clethrionomys gapperi</i>	<i>Sorex cinereus</i>	<i>Peromyscus maniculatus</i>	<i>Microtus pennsylvanicus</i>	<i>Blarina brevicauda</i>	<i>Sorex arcticus</i>	<i>Synaptomys sp.</i>	<i>Microsorex hoyi</i>	<i>Glaucomys sabrinus</i>	<i>Tamiasciurus hudsonicus</i>
1977	18	5	0	0	0	0	0	0	0	0
1978	11	9	0	0	0	0	0	0	0	0
1979	3	6	1	3	1	1	1	0	0	0
1980	14	10	0	1	0	0	2	0	0	0
1981	10	3	0	0	0	0	0	0	0	0
1982	1	17	1	0	1	0	0	0	0	0
1983	5	2	0	0	0	0	0	0	0	0
1984										
1985	9	4	0	0	0	0	0	0	0	0
1986	22	15	0	1	0	0	0	0	0	0
1987	12	5	0	6	0	0	0	1	0	0
1988	4	15	1	1	2	3	0	0	0	0
1989	12	3	0	1	0	0	0	0	0	1
1990	14	23	0	1	0	1	0	0	0	3
1991	5	14	0	5	0	1	1	0	0	0
1992	1	4	0	0	0	0	0	0	0	0
1993	6	14	0	5	0	0	0	0	0	0
1994	0	15	0	4	0	0	0	0	0	0
1995	3	23	0	1	0	0	0	0	0	0
1996	1	1	0	5	0	0	0	0	0	0
1997	0	4	0	1	0	0	0	0	0	0
1998	1	6	0	0	0	2	0	1	0	1
1999	2	8	0	0	1	0	0	0	1	0
2000	0	6	0	0	0	0	0	0	0	0
2001	0	9	0	1	0	0	0	0	0	0
Totals	154	221	3	36	5	8	4	2	1	5
									In total	439

TABLE A.1b Summary of the number of small mammals captured by species during twenty-four sampling years on the Aspen Upland at Taiga Biological Station. The plot was not trapped in 1984.

Years	<i>Clethrionomys gapperi</i>	<i>Sorex cinereus</i>	<i>Peromyscus maniculatus</i>	<i>Microtus pennsylvanicus</i>	<i>Blarina brevicauda</i>	<i>Microsorex hoyi</i>	<i>Sorex arcticus</i>	<i>Synaptomys sp.</i>	<i>Phenacomys intermedius</i>	<i>Zapus hudsonius</i>	<i>Glaucomys sabrinus</i>	<i>Tamias minimus</i>	<i>Tamiasciurus hudsonicus</i>
1977	4	0	0	0	0	0	0	0	0	0	0	0	0
1978	16	3	0	0	0	0	1	0	0	0	1	1	0
1979	17	4	0	0	0	0	0	0	0	0	0	0	0
1980	13	3	12	2	0	0	0	0	0	0	0	0	0
1981	7	1	6	0	0	0	0	0	0	0	0	0	0
1982	3	7	8	0	1	0	0	0	0	0	2	0	0
1983	9	3	7	2	0	0	0	0	0	0	0	0	1
1984													
1985	22	13	4	0	0	0	0	0	0	0	0	1	0
1986	38	10	3	0	0	0	0	1	0	0	1	2	0
1987	28	4	7	2	0	0	0	0	0	0	0	3	0
1988	20	6	10	1	0	1	0	0	0	0	0	4	0
1989	23	4	3	1	1	0	0	0	1	0	0	1	0
1990	16	3	4	2	0	0	0	1	0	0	0	0	0
1991	21	6	5	4	0	0	0	0	1	2	0	0	0
1992	10	0	5	4	0	0	0	0	1	0	1	0	0
1993	28	7	4	1	0	0	0	0	0	1	0	0	1
1994	11	10	3	0	0	0	0	0	0	2	0	1	0
1995	6	10	8	1	0	0	0	1	0	1	1	4	0
1996	3	4	3	0	0	0	0	0	0	0	0	0	0
1997	0	0	9	0	0	0	0	0	0	1	0	0	0
1998	3	6	2	0	0	0	0	0	0	0	0	1	1
1999	3	2	2	0	3	0	0	0	0	0	1	0	0
2000	10	10	5	0	0	0	0	0	0	0	0	0	0
2001	8	3	6	0	0	0	0	0	0	0	1	2	0
Totals	319	119	116	20	5	1	1	3	3	7	8	20	3
												In total	625

TABLE A.1c Summary of the number of small mammals captured by species during twenty-five sampling years on the Blackspruce Bog at Taiga Biological Station.

Years	<i>Clethrionomys gapperi</i>	<i>Sorex cinereus</i>	<i>Peromyscus maniculatus</i>	<i>Microtus pennsylvanicus</i>	<i>Synaptomys sp.</i>	<i>Microsorex hoyi</i>	<i>Sorex arcticus</i>	<i>Zapus hudsonius</i>	<i>Tamias minimus</i>	<i>Tamiasciurus hudsonicus</i>
1977	2	0	0	0	0	0	0	0	0	0
1978	1	0	0	0	0	0	0	0	0	0
1979	1	5	0	0	0	0	0	0	0	0
1980	11	3	0	2	0	0	0	0	0	1
1981	0	0	2	0	0	0	0	0	0	0
1982	0	3	2	0	0	0	0	0	0	0
1983	0	0	9	0	0	0	0	0	0	0
1984	11	4	7	3	0	0	0	0	0	0
1985	0	5	1	0	0	0	0	0	0	0
1986	6	8	0	0	0	0	0	0	0	0
1987	13	4	0	0	0	1	0	0	1	0
1988	10	3	0	0	0	0	0	0	0	0
1989	8	2	0	0	1	0	0	0	0	0
1990	10	6	0	0	0	0	0	0	0	0
1991	8	5	0	0	0	0	1	0	0	0
1992	1	0	0	0	0	0	0	0	0	0
1993	12	6	0	0	0	0	0	0	0	0
1994	4	1	0	0	0	0	0	0	0	0
1995	3	1	0	1	0	0	0	0	0	0
1996	6	0	0	0	0	0	0	0	0	0
1997	3	1	1	0	0	0	0	1	0	1
1998	0	6	0	0	0	0	1	0	0	1
1999	4	3	0	0	0	0	0	0	0	1
2000	2	2	0	0	0	0	0	0	0	0
2001	2	1	0	1	0	0	0	0	0	0
Totals	118	69	22	7	1	1	2	1	1	4
									In total	226

TABLE A.1d Summary of the number of small mammals captured by species during twenty-four sampling years on the Ecotone at Taiga Biological Station. The plot was not trapped in 1984.

Years	<i>Clethrionomys gapperi</i>	<i>Sorex cinereus</i>	<i>Peromyscus maniculatus</i>	<i>Microtus pennsylvanicus</i>	<i>Blarina brevicauda</i>	<i>Synaptomys sp.</i>	<i>Sorex arcticus</i>	<i>Microsorex hoyi</i>	<i>Zapus hudsonius</i>	<i>Condylura cristata</i>	<i>Glaucomys sabrinus</i>	<i>Tamias minimus</i>	<i>Tamiasciurus hudsonicus</i>
1977	9	2	0	1	0	0	0	0	0	0	0	0	0
1978	8	12	0	0	0	0	2	0	0	0	0	1	1
1979	10	8	0	3	2	1	0	0	0	0	0	0	0
1980	20	8	6	3	1	0	1	0	0	0	0	0	0
1981	9	3	3	0	0	0	0	0	0	0	0	0	0
1982	4	19	3	0	3	0	0	0	0	1	1	0	0
1983	8	5	3	1	0	0	0	0	0	0	0	2	0
1984													
1985	17	5	2	0	0	0	0	0	0	0	0	0	0
1986	33	16	0	0	0	0	0	0	0	0	0	2	0
1987	21	7	2	3	0	0	0	1	0	0	0	1	0
1988	14	12	5	1	4	0	0	1	1	0	0	3	0
1989	15	5	1	1	2	0	0	0	0	0	0	5	0
1990	13	15	1	0	0	0	0	0	0	0	1	3	0
1991	22	19	0	6	0	1	0	0	0	0	0	2	1
1992	1	2	1	0	0	0	0	0	0	0	0	0	0
1993	12	7	0	1	0	0	0	1	0	0	0	0	2
1994	6	12	0	1	0	0	0	0	0	0	0	2	3
1995	4	5	5	0	0	0	0	0	0	0	0	2	4
1996	5	3	3	2	0	0	0	0	0	0	0	1	0
1997	3	2	0	0	0	0	0	0	0	0	0	0	1
1998	3	4	0	0	0	0	0	0	0	0	0	1	0
1999	1	4	0	0	2	0	0	0	0	0	0	0	0
2000	2	9	0	0	0	0	0	0	0	0	1	0	0
2001	10	4	0	1	0	1	0	0	3	0	0	2	0
Totals	250	188	35	24	14	3	3	3	4	1	3	27	12
												In total	567

TABLE A.1e Summary of the number of small mammals captured by species during twenty-four sampling years on the Jackpine Ridge at Taiga Biological Station. The plot was not trapped in 1984.

Years	<i>Clethrionomys gapperi</i>	<i>Sorex cinereus</i>	<i>Peromyscus maniculatus</i>	<i>Blarina brevicauda</i>	<i>Glaucomys sabinus</i>	<i>Tamias minimus</i>	<i>Tamiasciurus hudsonicus</i>
1977	9	0	0	0	0	0	0
1978	5	6	0	0	0	0	1
1979	10	9	0	0	0	0	0
1980	16	2	4	0	0	0	1
1981	1	1	6	0	0	0	0
1982	6	6	6	1	0	0	0
1983	6	0	44	0	0	2	1
1984							
1985	5	0	8	0	0	0	0
1986	23	4	5	0	0	1	0
1987	17	0	11	0	0	1	0
1988	4	5	16	0	0	3	0
1989	11	1	4	0	0	2	0
1990	9	0	0	0	1	1	1
1991	6	4	6	0	0	0	0
1992	0	0	0	0	0	0	1
1993	2	2	0	0	0	1	1
1994	4	1	1	0	0	2	3
1995	1	0	1	0	0	2	2
1996	1	0	1	0	0	0	0
1997	3	0	0	0	0	0	2
1998	4	0	0	0	0	1	1
1999	8	0	0	0	0	2	0
2000	13	0	0	0	1	0	0
2001	4	0	1	0	0	0	0
Totals	168	41	114	1	2	18	14
						In total	358

TABLE A.1f Summary of the number of small mammals captured by species during twenty-five sampling years on the Jackpine Sandplain at Taiga Biological Station.

Years	<i>Clethrionomys gapperi</i>	<i>Sorex cinereus</i>	<i>Peromyscus maniculatus</i>	<i>Microtus pennsylvanicus</i>	<i>Phenacomys intermedius</i>	<i>Synaptomys sp.</i>	<i>Zapus hudsonius</i>	<i>Glaucomys sabrinus</i>	<i>Tamias minimus</i>	<i>Tamiasciurus hudsonicus</i>
1977	1	0	0	0	0	0	0	0	0	0
1978	2	0	0	0	0	0	0	0	0	0
1979	2	4	0	0	0	1	0	0	0	0
1980	3	1	12	0	0	0	0	1	0	1
1981	0	0	9	0	0	0	0	0	0	0
1982	0	0	4	0	0	0	0	0	0	1
1983	1	0	3	0	0	0	1	1	0	0
1984	8	0	15	0	0	0	0	0	1	0
1985	8	0	3	0	0	0	0	0	0	0
1986	10	1	2	0	0	0	1	0	0	1
1987	11	0	3	0	0	0	0	2	4	0
1988	3	0	4	0	0	0	0	2	9	0
1989	18	0	1	1	0	0	0	0	1	0
1990	5	0	5	0	0	0	0	2	2	0
1991	5	4	5	0	0	0	0	0	7	0
1992	0	0	4	0	0	0	0	0	1	0
1993	10	1	6	0	0	0	1	1	0	0
1994	7	3	9	0	0	0	2	0	2	0
1995	2	1	10	0	0	0	0	0	5	0
1996	7	0	9	0	0	0	0	0	1	0
1997	1	0	8	0	0	0	0	0	1	0
1998	1	2	2	0	1	0	0	0	6	0
1999	1	0	9	0	0	0	0	0	5	0
2000	3	1	9	0	0	0	0	1	1	0
2001	8	0	11	0	0	0	1	0	2	0
Totals	117	18	143	1	1	1	6	10	48	3
									In total	348

TABLE A.2a Annual biomass (g) accumulations of small mammal species in the Alder-Tamarack Bog during twenty-four sampling years at Taiga Biological Station.

Years	<i>Clethrionomys gapperi</i>	<i>Sorex cinereus</i>	<i>Peromyscus maniculatus</i>	<i>Microtus pennsylvanicus</i>	<i>Blarina brevicauda</i>	<i>Synaptomys sp.</i>	<i>Sorex arcticus</i>	<i>Microsorex hoyi</i>	<i>Tamiasciurus hudsonicus</i>	<i>Glaucomys sabrinus</i>
1977	264.2	14.4	0	0	0	0	0	0	0	0
1978	198.2	30.4	0	0	0	0	0	0	0	0
1979	54.2	29.9	14.9	67.2	21.0	22.5	6.9	0	0	0
1980	256.9	31.3	0	24.8	0	39.1	0	0	0	0
1981	183.1	9.3	0	0	0	0	0	0	0	0
1982	17.3	61.9	0	0	18.9	0	0	0	0	0
1983	97.2	6.6	0	0	0	0	0	0	0	0
1984										
1985	155.9	12.9	0	0	0	0	0	0	0	0
1986	397.4	47.6	0	20.0	0	0	0	0	0	0
1987	187.4	17.0	0	109.7	0	0	0	3.6	0	0
1988	64.2	66.4	18.4	17.4	43.0	0	21.1	0	0	0
1989	217.6	9.6	0	22.8	0	0	0	0	227.7	0
1990	200.7	89.7	0	17.5	0	0	9.4	0	574.2	0
1991	82.3	55.3	0	69.2	0	14.0	4.5	0	0	0
1992	26.5	15.3	0	0	0	0	0	0	0	0
1993	98.9	48.6	0	132.3	0	0	0	0	0	0
1994	0	49.8	0	95.9	0	0	0	0	0	0
1995	40.2	62.9	0	28.8	0	0	0	0	0	0
1996	19.2	2.8	0	161.0	0	0	0	0	0	0
1997	0	14.3	0	29.2	0	0	0	0	0	0
1998	37.8	45.3	15.9	0	0	0	18.4	3.6	182.9	0
1999	50.4	37.9	0	0	0	0	0	0	0	120.4
2000	0	15.0	0	0	0	0	0	0	0	0
2001	0	27.6	0	17.5	0	0	0	0	0	0
Totals (g)	2649.6	801.8	49.2	813.3	82.9	75.6	60.3	7.2	984.8	120.4

TABLE A.2b Annual biomass (g) accumulations of small mammal species in the **Aspen Upland** during twenty-four sampling years at Taiga Biological Station. The plot was not trapped in 1984.

Years	<i>Clethrionomys</i> <i>gapperi</i>	<i>Sorex</i> <i>cinereus</i>	<i>Peromyscus</i> <i>maniculatus</i>	<i>Microtus</i> <i>pennsylvanicus</i>	<i>Blarina</i> <i>brevicauda</i>	<i>Microsorex</i> <i>hoyi</i>	<i>Synaptomys</i> <i>sp.</i>	<i>Phenacomys</i> <i>intermedius</i>	<i>Zapus</i> <i>hudsonius</i>	<i>Sorex</i> <i>arcticus</i>	<i>Tamiasciurus</i> <i>hudsonicus</i>	<i>Tamias</i> <i>minimus</i>	<i>Glaucomys</i> <i>sabrinus</i>
1977	56.2	0	0	0	0	0	0	0	0	0	0	0	0
1978	215.9	20.5	0	0	0	0	0	0	0	9.5	0	44.7	115.8
1979	276.2	13.1	0	0	0	0	0	0	0	0	0	0	0
1980	235.9	8.4	182.6	43.0	0	0	0	0	0	0	0	0	0
1981	116.7	3.1	88.3	0	0	0	0	0	0	0	0	0	0
1982	57.3	24.7	131.4	0	15.8	0	0	0	0	0	0	0	229.2
1983	220.6	9.6	96.4	27.0	0	0	0	0	0	0	184.5	0	0
1984													
1985	355.9	42.7	38.5	0	0	0	0	0	0	0	0	45.4	0
1986	628.7	32.1	45.0	0	0	0	24.5	0	0	0	0	84.7	85.0
1987	550.4	12.0	98.9	46.6	0	0	0	0	0	0	0	127.4	0
1988	401.4	17.6	143.0	24.9	0	2.8	0	0	0	0	0	170.4	0
1989	481.3	10.7	50.9	21.5	16.3	0	0	21.7	0	0	0	45.0	0
1990	370.7	8.4	76.0	33.7	0	0	24.4	0	0	0	0	0	0
1991	347.3	19.3	70.9	64.6	0	0	0	10.8	35.6	0	0	0	0
1992	240.4	0	85.4	76.7	0	0	0	24.8	0	0	0	0	132.1
1993	472.5	21.8	62.7	14.9	0	0	0	0	17.7	0	194.1	0	0
1994	185.8	33.9	47.4	23.1	0	0	0	0	35.1	0	0	44.9	0
1995	101.0	34.5	121.7	0	0	0	0	0	18.5	0	0	168.6	107.3
1996	83.1	14.3	43.3	0	0	0	0	0	0	0	0	0	0
1997	0	14.3	142.1	0	0	0	0	0	0	0	0	0	0
1998	72.1	14.2	44.4	0	0	0	0	0	0	0	226.4	44.6	0
1999	54.7	7.2	35.2	0	66.2	0	0	0	0	0	0	0	122.3
2000	141.8	31.7	104.2	0	0	0	0	0	0	0	0	0	0
2001	142.2	3.1	74.8	0	0	0	0	0	0	0	0	88.6	136.4
Totals (g)	5808.1	397.2	1783.1	376.0	98.3	2.8	48.9	57.3	106.9	9.5	605.0	864.3	928.1

TABLE A.2c Annual biomass (g) accumulations of small mammal species in the **Blackspruce Bog** during twenty-five sampling years at Taiga Biological Station.

Years	<i>Clethrionomys gapperi</i>	<i>Sorex cinereus</i>	<i>Peromyscus maniculatus</i>	<i>Microtus pennsylvanicus</i>	<i>Synaptomys sp.</i>	<i>Microsorex hoyi</i>	<i>Sorex arcticus</i>	<i>Zapus hudsonius</i>	<i>Tamiasciurus hudsonicus</i>	<i>Tamias minimus</i>
1977	29.9	0	0	0	0	0	0	0	0	0
1978	15.8	0	0	0	0	0	0	0	0	0
1979	18.6	17.6	0	0	0	0	0	0	0	0
1980	195.7	8.6	0	57.4	0	0	0	0	0	0
1981	0	5.3	29.4	0	0	0	0	0	0	0
1982	0	10.0	27.4	0	0	0	0	0	0	0
1983	0	0	125.1	0	0	0	0	0	0	0
1984	256.6	17.2	108.6	55.7	0	0	0	0	0	0
1985	0	18.6	13.6	0	0	0	0	0	0	0
1986	111.5	27.3	0	0	0	0	0	0	0	0
1987	321.1	14.9	0	0	0	2.9	0	0	0	43.2
1988	158.8	12.3	0	0	15.3	0	0	0	0	0
1989	142.9	5.9	0	0	16.5	0	0	0	0	0
1990	152.1	19.0	0	0	0	0	0	0	0	0
1991	144.8	21.7	0	0	0	0	5.3	0	197.6	0
1992	15.4	0	0	0	0	0	0	0	0	0
1993	166.8	20.7	0	0	0	0	0	0	0	0
1994	68.2	3.3	0	0	0	0	0	0	0	0
1995	51.0	3.4	0	15.5	0	0	0	0	0	0
1996	72.0	0	0	0	0	0	0	0	0	0
1997	49.0	3.3	12.4	0	0	0	0	14.4	189.8	0
1998	0	24.7	0	0	0	0	5.3	0	0	0
1999	76.7	11.6	0	0	0	0	0	0	0	0
2000	36.1	6.3	0	0	0	0	0	0	0	0
2001	37.7	3.3	0	17.8	0	0	0	0	0	0
Totals (g)	2120.7	255.0	316.5	146.4	31.8	2.9	10.6	14.4	387.4	43.2

TABLE A.2d Annual biomass (g) accumulations of small mammal species in the Ecotone during twenty-four sampling years at Taiga Biological Station. The plot was not trapped in 1984.

Years	<i>Clethrionomys gapperi</i>	<i>Sorex cinereus</i>	<i>Peromyscus maniculatus</i>	<i>Microtus pennsylvanicus</i>	<i>Blarina brevicauda</i>	<i>Synaptomys sp.</i>	<i>Zapus hudsonius</i>	<i>Condylura cristata</i>	<i>Microsorex hoyi</i>	<i>Sorex arcticus</i>	<i>Tamiasciurus hudsonicus</i>	<i>Tamias minimus</i>	<i>Glaucomys sabrinus</i>
1977	124.7	6.4	0	17.8	0	0	0	0	0	0	0	0	0
1978	144.1	55.7	0	0	0	0	0	0	0	16.3	230.0	45.4	0
1979	134.0	27.3	0	42.0	34.4	22.8	0	0	0	0	0	0	0
1980	390.5	38.5	93.3	69.3	21.1	0	0	0	0	0	0	0	0
1981	150.4	9.6	47.6	0	0	0	0	0	0	0	0	0	0
1982	108.7	66.9	57.1	0	54.6	0	0	40.9	0	0	0	0	112.4
1983	148.1	18.7	40.8	17.0	0	0	0	0	0	0	0	87.8	0
1984													
1985	292.1	21.9	34.2	0	0	0	0	0	0	0	0	0	0
1986	657.3	55.8	0	0	0	0	0	0	0	0	0	90.5	0
1987	409.4	49.8	28	71.2	0	0	0	0	2.9	0	0	45.3	0
1988	228.4	82.8	77.4	12.7	73.9	0	20.9	0	4.4	0	0	134.5	0
1989	308.4	14.2	16.7	24.3	33.7	0	0	0	0	0	0	221.7	0
1990	205.5	50.6	11.5	0	0	0	0	0	0	0	0	90.0	120.9
1991	369.1	65.7	0	89.1	0	13.6	0	0	0	0	176.5	89.6	0
1992	18.9	3.3	15.2	0	0	0	0	0	0	0	0	0	0
1993	240.4	25.8	0	17.6	0	0	0	0	2.5	0	334.1	0	0
1994	89.2	38.0	0	20.2	0	0	0	0	0	0	617.6	89.8	0
1995	76.0	19.5	64.0	0	0	0	0	0	0	0	677.5	91.5	0
1996	81.0	13.5	42.8	30.9	0	0	0	0	0	0	0	48.6	0
1997	56.6	7.1	0	0	0	0	0	0	0	0	199.4	0	0
1998	64.7	12.3	0	0	0	0	0	0	0	0	0	46.0	0
1999	24.8	10.0	0	0	42.8	0	0	0	0	0	0	0	0
2000	32.0	35.1	0	0	0	0	0	0	0	0	0	0	128.9
2001	141.5	10.5	0	22.1	0	21.3	25.5	0	0	0	0	95.8	0
Totals (g)	4495.8	739.0	528.6	434.2	260.5	57.7	46.4	40.9	9.8	16.3	2235.1	1176.5	362.2

TABLE A.2e Annual biomass (g) accumulations of small mammal species in the **Jackpine Ridge** during twenty-four sampling years at Taiga Biological Station. The plot was not trapped in 1984.

Years	<i>Clethrionomys gapperi</i>	<i>Sorex cinereus</i>	<i>Peromyscus maniculatus</i>	<i>Blarina brevicauda</i>	<i>Tamiasciurus hudsonicus</i>	<i>Tamias minimus</i>	<i>Glaucomys sabrinus</i>
1977	126.2	0	0	0	0	0	0
1978	86.7	18.8	0	0	201.8	0	0
1979	182.3	29.4	0	0	0	0	0
1980	299.6	5.5	49.2	0	183.6	0	0
1981	23.3	2.9	114.2	0	0	0	0
1982	160.4	23.6	103.7	19.5	0	0	0
1983	168.0	0	641.0	0	197.5	95.8	0
1984							
1985	64.9	0	130.9	0	0	0	0
1986	352.9	11.3	75.0	0	0	47.5	0
1987	384.0	0	154.0	0	0	0	0
1988	98.9	19.9	229.1	0	0	132.7	0
1989	211.5	5.2	47.7	0	0	87.7	0
1990	188.8	0	0	0	189.3	0	86.2
1991	85.9	11.4	67.1	0	0	45.6	0
1992	0	0	0	0	192.4	0	0
1993	40.0	6.1	0	0	174.2	49.5	0
1994	92.6	3.0	18.0	0	519.5	86.1	0
1995	24.4	0	12.1	0	415.7	80.6	0
1996	26.0	0	18.8	0	0	0	0
1997	57.3	0	0	0	353.0	0	0
1998	97.4	0	0	0	210.7	38.5	0
1999	166.4	0	0	0	0	84.3	0
2000	206.9	0	0	0	0	0	134.1
2001	68.5	0	11.5	0	0	0	0
Totals (g)	3212.9	137.1	1672.3	19.5	2637.7	748.3	220.3

TABLE A.2f Annual biomass (g) accumulations of small mammal species in the **Jackpine Sandplain** during twenty-five sampling years at Taiga Biological Station.

Years	<i>Clethrionomys gapperi</i>	<i>Sorex cinereus</i>	<i>Peromyscus maniculatus</i>	<i>Microtus pennsylvanicus</i>	<i>Zapus hudsonius</i>	<i>Synaptomys sp.</i>	<i>Phenacomys intermedius</i>	<i>Tamiasciurus hudsonicus</i>	<i>Tamias minimus</i>	<i>Glaucomys sabrinus</i>
1977	22.8	0	0	0	0	0	0	0	0	0
1978	40.2	0	0	0	0	0	0	201.8	0	0
1979	27.2	15.9	0	0	0	22.6	0	0	0	0
1980	61.1	3.2	199.8	0	0	0	0	183.6	0	0
1981	0	0	153.8	0	0	0	0	0	0	0
1982	0	0	75.9	0	0	0	0	0	0	0
1983	37.1	0	38.9	0	14.3	0	0	197.5	95.8	0
1984	198.9	0	238.3	0	0	0	0	0	0	0
1985	194.2	0	54.8	0	0	0	0	0	0	0
1986	233.2	2.6	19.5	0	11	0	0	0	47.5	0
1987	239.3	0	45.2	0	0	0	0	0	0	0
1988	79.9	0	53.8	0	0	0	0	0	132.7	0
1989	347.7	0	18.6	22.5	0	0	0	0	87.7	0
1990	114.7	0	69.1	0	0	0	0	189.3	0	86.2
1991	112.1	12.9	56.2	0	0	0	0	0	45.6	0
1992	0	0	94.2	0	0	0	0	192.4	0	0
1993	183.9	3.1	93.1	0	13.3	0	0	174.2	49.5	0
1994	128.1	9.3	135.2	0	29.8	0	0	519.5	86.1	0
1995	58.9	3.4	127.3	0	0	0	0	415.7	80.6	0
1996	172.2	0	147.8	0	0	0	0	0	0	0
1997	19.3	0	129	0	0	0	0	353.0	0	0
1998	27.2	9.1	16.7	0	0	0	30.5	210.7	38.5	0
1999	20.7	0	123.8	0	0	0	0	0	84.3	0
2000	71.0	2.7	124	0	0	0	0	0	0	134.1
2001	130.7	0	167.1	0	15	0	0	0	0	0
Totals (g)	2520.4	62.2	2182.1	22.5	83.4	22.6	30.5	2637.7	748.3	220.3

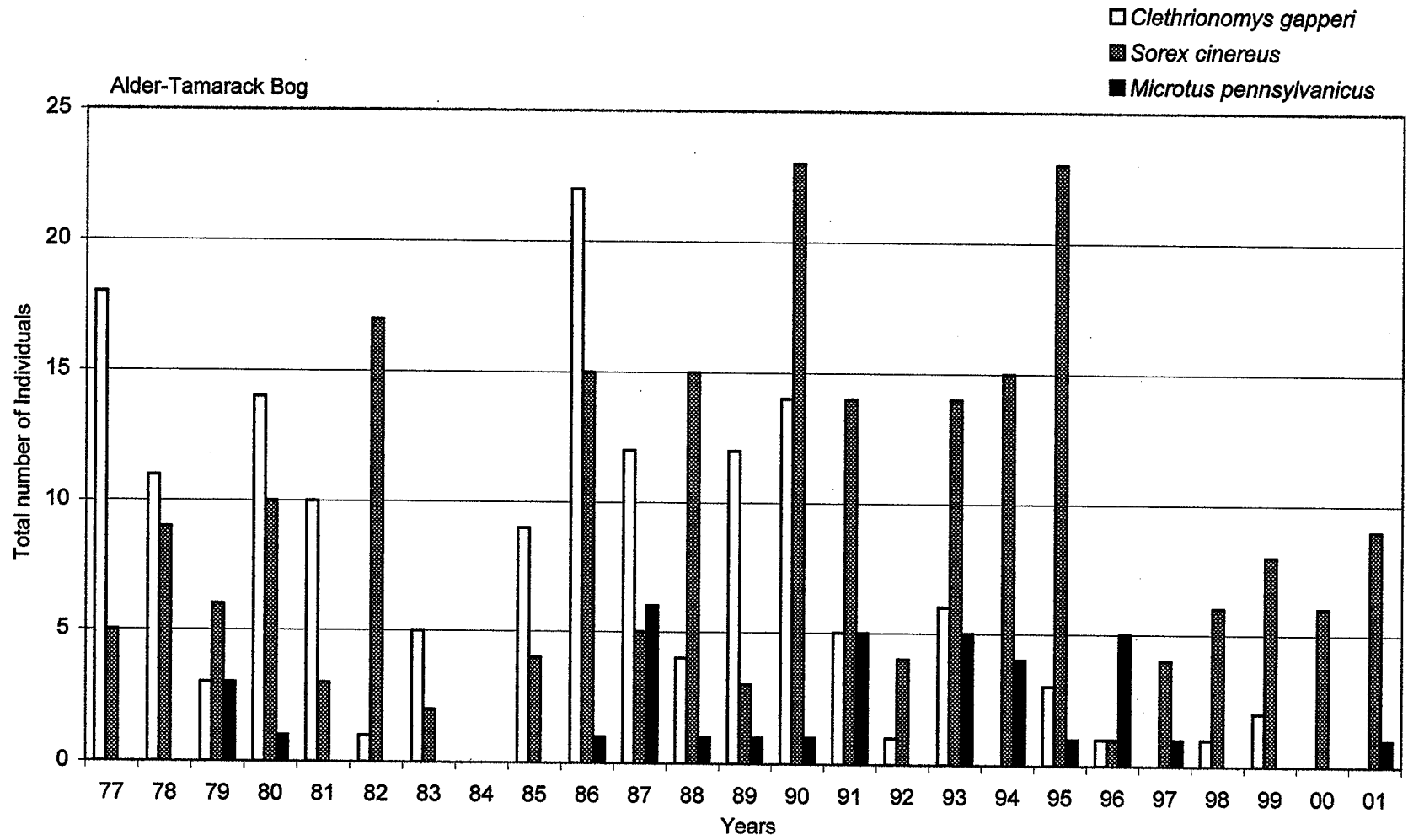


FIGURE A.1a Frequency distribution of the three main small mammal species captured during twenty-four annual trapping seasons on the Alder-Tamarack Bog.

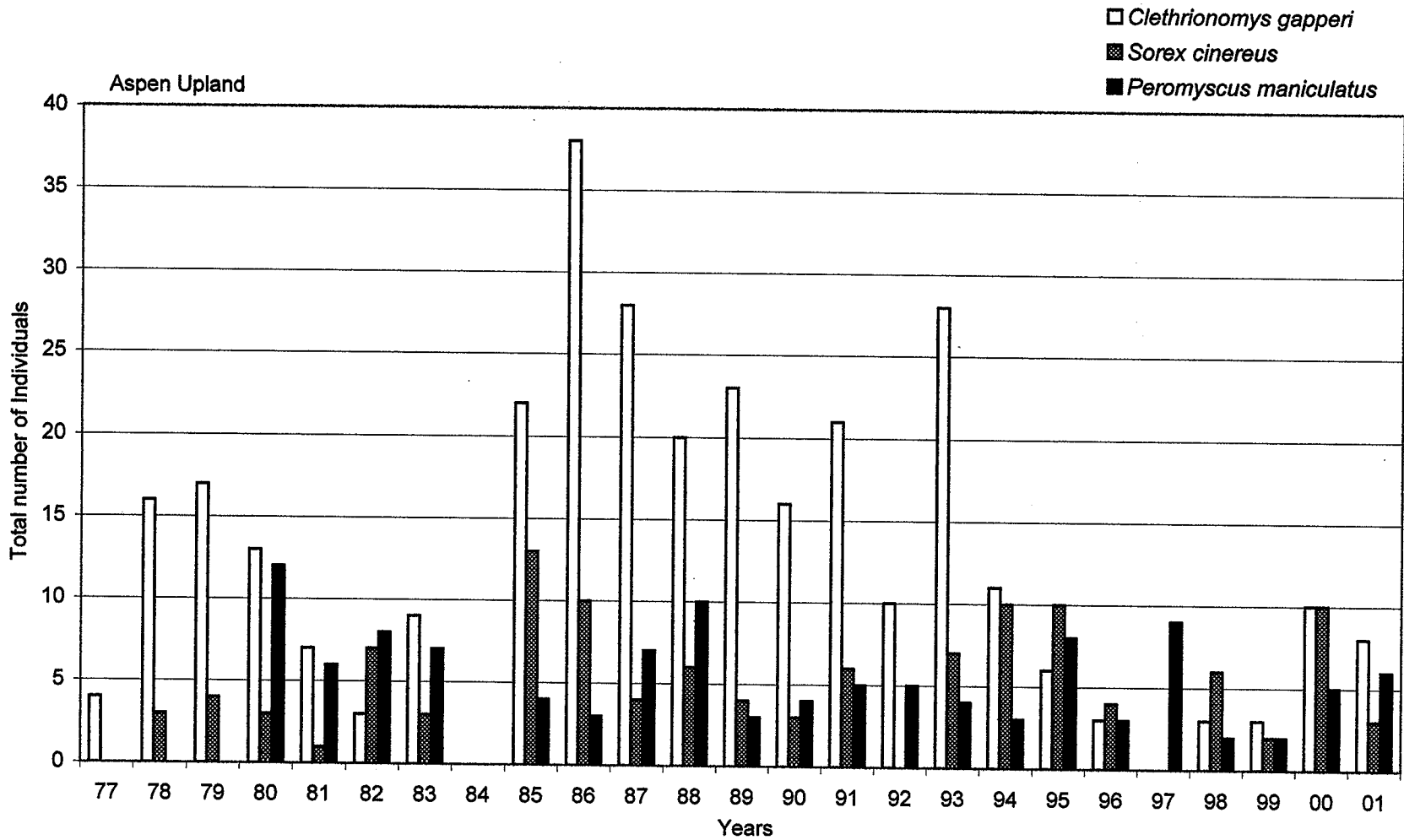


FIGURE A.1b Frequency distribution of the three main small mammal species captured during twenty-four annual trapping seasons on the Aspen Upland.

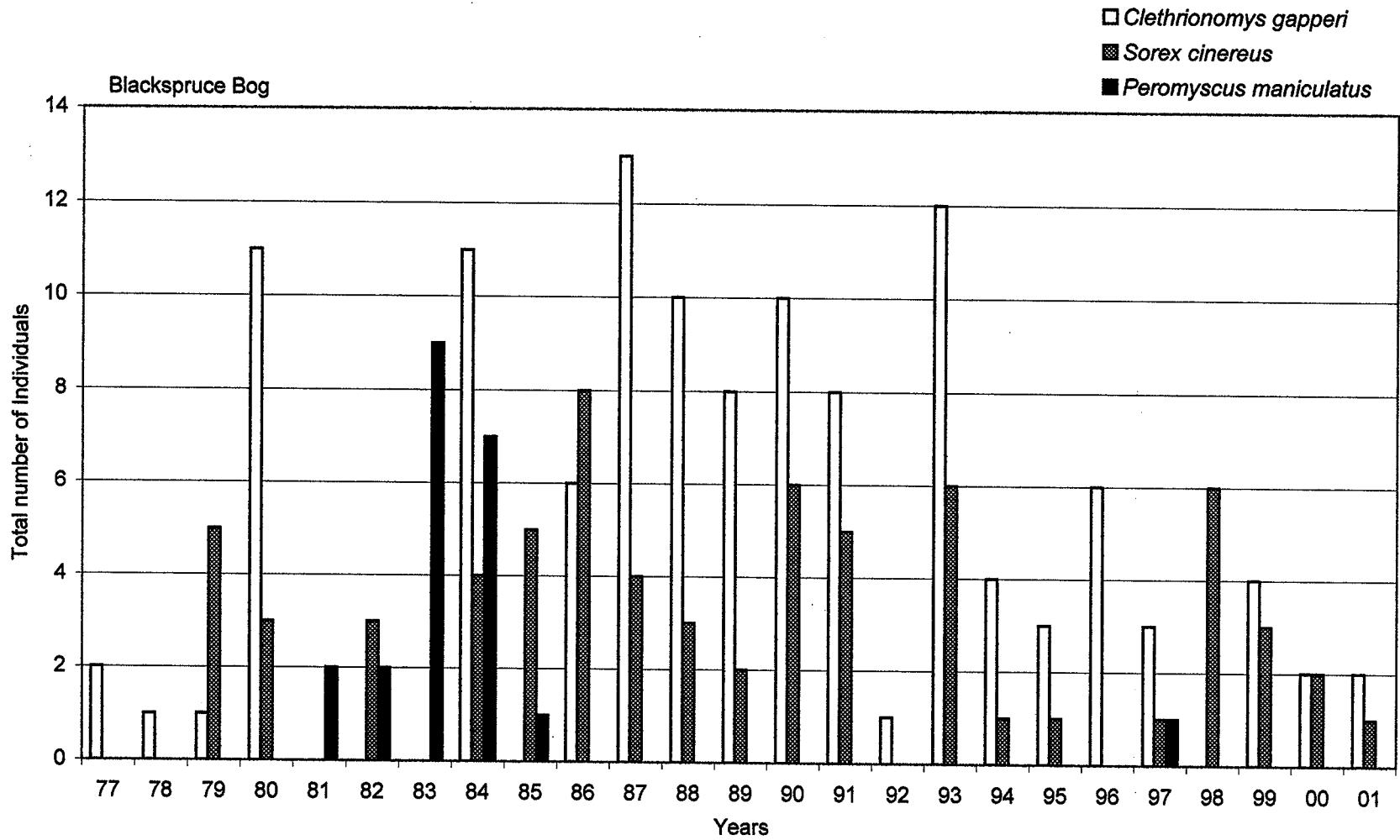


FIGURE A.1c Frequency distribution of the three main small mammal species captured during twenty-five annual trapping seasons on the Blackspruce Bog.

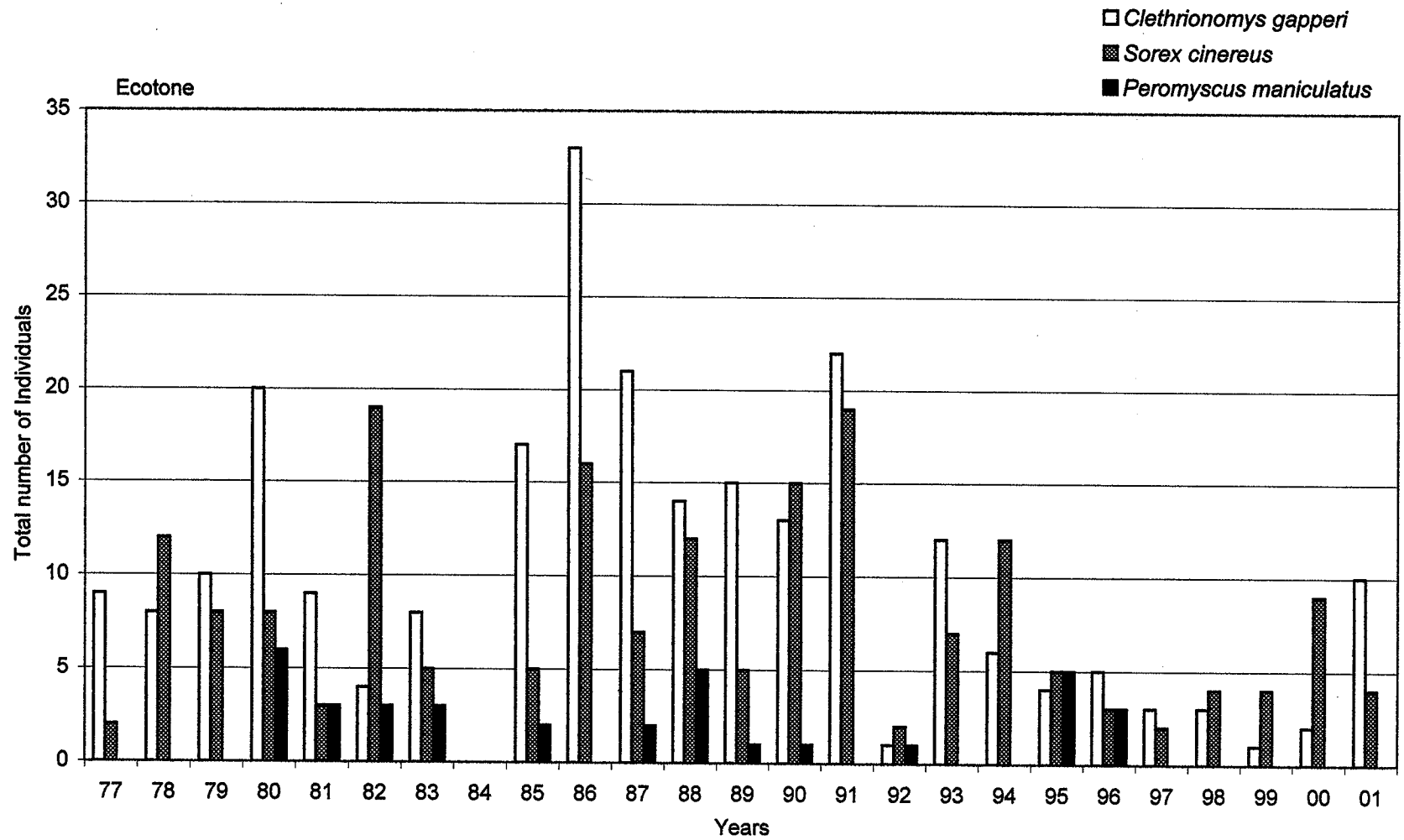


FIGURE A.1d Frequency distribution of the three main small mammal species captured during twenty-four annual trapping seasons on the Ecotone.

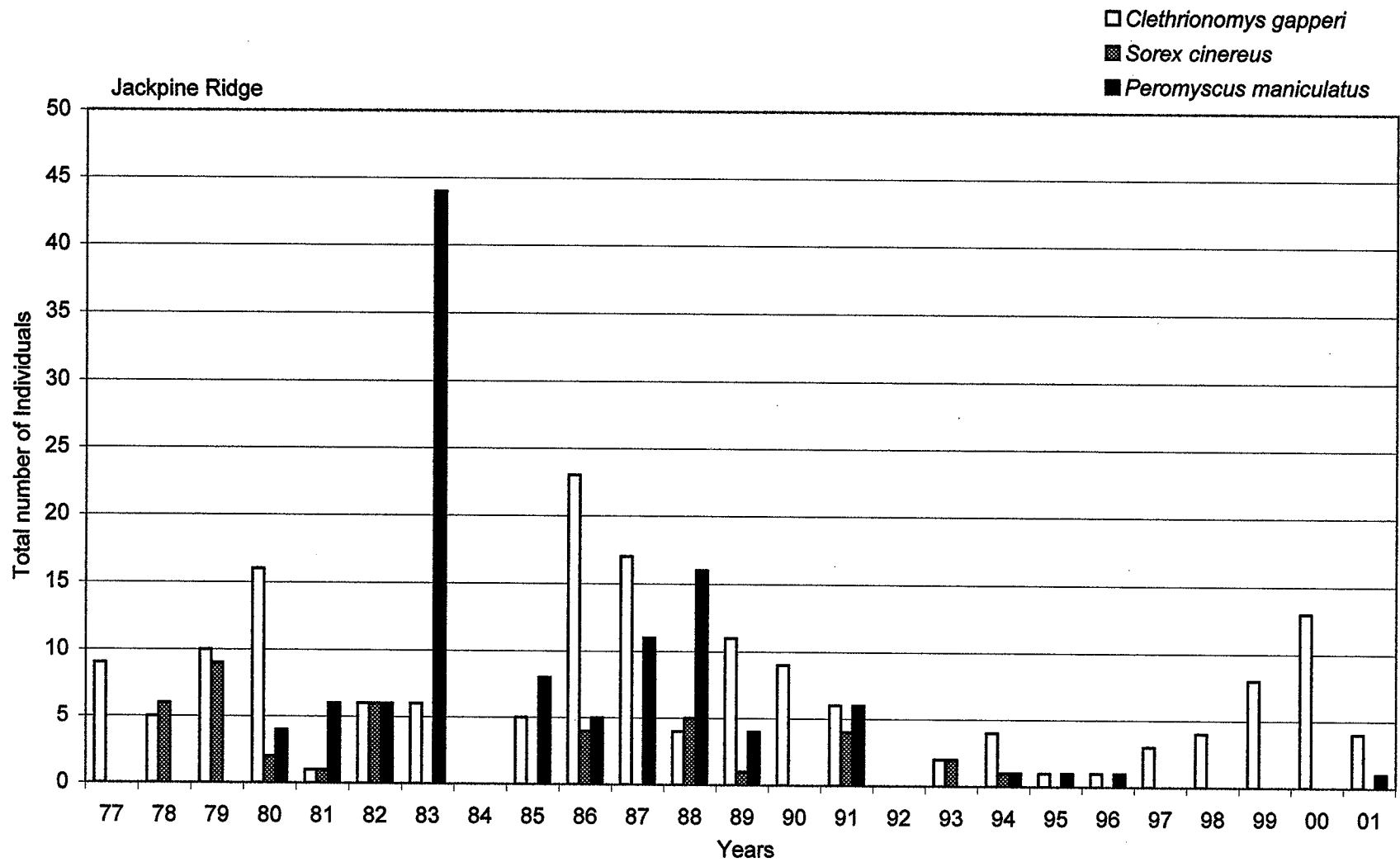


FIGURE A.1e Frequency distribution of the three main small mammal species captured during twenty-four annual trapping seasons on the Jackpine Ridge.

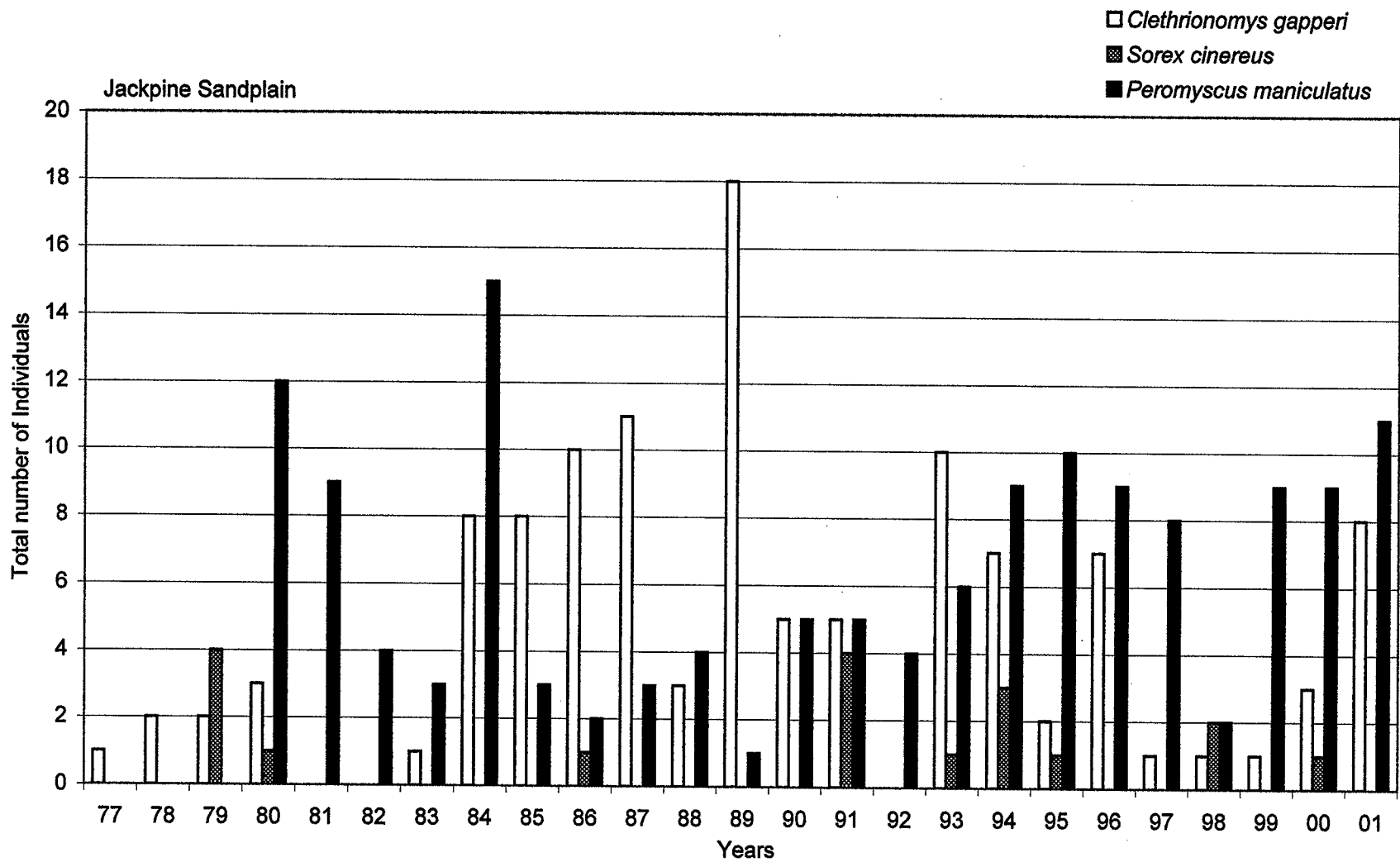


FIGURE A.1f Frequency distribution of the three main small mammal species captured during twenty-five annual trapping seasons on the Jackpine Sandplain.

Appendix A.1

Pre- and post-fire descriptions of six small mammal habitats

Alder-Tamarack Bog (ATB)

Pre-fire conditions (prior 1980):

The ATB plot (51° 02' 43.1" N, 095° 21' 50.8" W) with a GPS altitude reading at 322 metres is located adjacent to the Ecotone plot along Aikens Lake Road (see Section 1. in Fig. 3). The Alder-Tamarack Bog is congruent with the Ecotone plot along one-half of the Bog's outer "J" trapping line (i.e., from J5 to J10). Pre-fire descriptions were provided by several sources (W. Pruitt, pers. comm.) and from stratified vegetation maps (Taiga Biological Station, unpubl. files) made one year prior to the 1980 fire. The pre-fire stratified vegetation maps were based on black-and-white aerial photographs confirmed by ground truthing. The maps described the pre-fire ATB habitat as an "intermediate bog-forest community" with wide-spaced trees. However, the tree cover of this community was more consistent with the "common bog community" classification described in the vegetation map key - found around lakes and between ridges, made up of smaller widely spread black spruce (*Picea mariana*) and more numerous larger tamarack species (*Larix laricina*). The ground cover of this common bog community consisted of *Sphagnum* hummocks and wet hollows. The hummocks supported low shrubs such as *Ledum groenlandicum*, *Chamaedaphne calyculata* and *Kalmia polifolia*, while the wet hollows supported *Carex* spp.

The Alder-Tamarack Bog vegetation was sampled in July and August of 1976 by Penny (1978). Pre-fire vegetation data recorded by Penny (1978) indicated the dominant ground cover variables were: *Sphagnum* spp. mosses and litter/organic debris. Low shrubs consisted of *Ledum groenlandicum*,

Chamaedaphne calyculata and *Gaultheria hispidula*. The tall shrub layer included *Alnus* and *Salix spp.* The herbaceous cover was mostly *Smilacina trifolia*, *Trientalis borealis* and *Viola sp.* Abundant gramineae and cyperaceae species were also noted.

Post-fire conditions on the ATB plot:

A vegetation survey by Martin (1983) of the Alder-Tamarack plot indicated "relatively no change" from the 1978 pre-fire vegetation data. Important ground cover variables in the 1982 survey were *Sphagnum spp.*, litter/organic debris and water. The low shrubs included *Ledum groenlandicum* and *Chamaedaphne calyculata*. The herbaceous layer contained *Smilacina trifolia*, *Viola sp.* and *Trientalis borealis*. Tall shrubs consisted of a dense uniform cover of *Alnus rugosa* and *Betula glandulosa* extending over the entire plot.

The 2000 vegetation survey indicated *Sphagnum spp.*, litter/organic debris and standing water as important ground cover variables. The low shrub layer contained *Ledum groenlandicum*, *Chamaedaphne calyculata* and *Oxycoccus microcarpos*. Tall shrubs were primarily *Alnus rugosa*, *Betula glandulosa* and *Salix spp.* The herbaceous cover was thinly spread throughout the plot and consisted mainly of *Smilacina trifolia*, *Viola sp.* and *Trientalis borealis*, along with several other species recorded at very low percent cover values. *Carex spp.* was noted in abundance on the Alder-Tamarack Bog.

Upper canopy changes within the ATB:

Following the 1980 fire Martin (1983) remarked on the lack of visible evidence of any fire damage suffered by this plot. The sphagnum/water substrate provided moisture conditions that precluded fire in this hydric bog community. As well, the relatively well-spaced tree canopy in the fairly humid environment of the Alder-Tamarack Bog may have had difficulties in supporting the spread of fire.

A survey of the upper canopy by Martin (1983) recorded approximately 122 living mature trees producing a stratum of predominantly *Larix laricina* (118 trees), with four mature living *Picea mariana*. There were about 44 standing dead trees in the Alder-Tamarack Bog in 1982 (only one of these was *Picea mariana*). The 2000 upper canopy survey found little evidence of any significant changes occurring within this layer. *Larix laricina* still dominates the landscape with (80 live trees/50 dead trees) and *Picea mariana* has remained at four mature living trees and one dead. However, a relatively dense undergrowth of *Picea mariana* saplings 1-3 m tall was observed during the 2000 survey with many fewer *Larix laricina* seedlings and saplings noted. As well, the plot supports an extensive tall shrub cover of *Alnus rugosa* and *Betula glandulosa* (1.5 – 2.5 m) in height which forms a thick lower canopy over the entire Alder-Tamarack Bog. No *Pinus banksiana* were observed growing on the plot.

Aspen Upland (ASP)

Pre-fire conditions (prior 1980):

The ASP plot (51° 02' 35.9" N, 095° 22' 03.6" W) with a GPS altitude reading of 321 metres is located within a mixed deciduous-coniferous forest. Pre-fire stratified vegetation maps revealed this area as having "at least 30% and up to 70% of the tree cover" deciduous in nature - with the dominant tree being *Populus tremuloides*. Trees such as *Picea mariana*, *Pinus banksiana*, *Abies balsamifera* and *Betula papyrifera* were also found within this forest community near the lake, with grasses, rushes and sedges as common ground cover species.

Pre-fire vegetation data collected by Penny (1978) indicated ground cover to include mosses of *Pleurozium*, *Dicranum* and *Polytrichum spp.* along with *Cladonia spp.* lichens. Abundant leaf litter/organic debris was also noted. The low shrub layer consisted of *Vaccinium spp.*, *Diervilla lonicera*, *Rosa sp.*, *Potentilla tridentata* and several others. Tall shrubs included *Amelanchier alnifolia*. The herbaceous layer consisted of *Fragaria virginiana*, *Aster spp.* and *Galium boreale* along with numerous other less frequent species.

The micro-topography of the Aspen Upland was described as a heterogeneous mixture of elevated rock ridges traversing the plot interspersed with areas of soil-filled depressions, varying in thickness from 1-2 cm to over 25 cm in depth (Penny 1978). These physical variations of the landscape and differences in moisture gradients dampened the impact of the 1980 fire within the plot.

Post-fire conditions on the ASP plot:

The 1980 fire was “intermittent over this area since ridges covered with crustose lichens escaped burning” (Martin 1983). The physical behaviour of the fire was restricted primarily to the ground – leaving much of the mature vegetation standing (Wheatley 1993). Several of the mature isolated *Pinus banksiana* on the plot were however completely consumed, as the fire spread throughout the grasses onto these dry, resinous, fuel sources.

The 1982 vegetation survey on the Aspen Upland indicated crustose lichens, litter/organic debris and bare rock as the main ground cover variables. Low shrubs included mainly *Diervilla lonicera*, *Vaccinium spp.* and *Potentilla tridentata*. The herbaceous layer contained *Fragaria virginiana*, *Apocynum sp.* and *Vicia americana* along with abundant grass and sedge cover. Major changes among the post-fire vegetation appeared to be limited to some parts of the upper canopy on the plot. Minor changes included the accumulation of charcoal debris on the ground and burned grasses and forbs which recovered rapidly following the fire.

The 2000 vegetation survey observed important ground cover variables that included: litter/organic debris, mosses such as *Pleurozium*, *Polytrichum* and *Dicranum spp.* and crustose rock lichens. The low shrub layer was diverse and contained abundant *Diervilla lonicera*, *Vaccinium spp.* and *Arctostaphylos uva-ursi*. Tall shrubs were *Salix spp.*, *Amelanchier alnifolia*, *Prunus pensylvanica* and *Alnus rugosa* and *A. crispa*. The herbaceous layer consisted of many species, with *Maianthemum canadense*, *Fragaria virginiana* and *Clintonia borealis*

providing much of the cover. The Aspen Upland had a variety of abundant gramineae and cyperaceae species with *Schizachne purpurascens*, *Danthonia spicata* and *Carex spp.* being important contributors.

Upper canopy changes within the ASP:

The upper canopy survey of the Aspen Upland in 1982 recorded approximately 499 mature trees of a deciduous-coniferous mixture with many standing dead *Populus tremuloides* "snags". Almost ¾'s of the recorded trees were *Populus tremuloides*, followed with descending numbers of *Picea mariana*, *Pinus banksiana*, *Picea glauca* and finally *Abies balsamea*. A large portion of the plot in 1982 was covered with a young tree and shrub canopy made up of *Populus tremuloides*, *Salix spp.*, *Alnus spp.* and *Amelanchier alnifolia* members. Today, many of the standing snags recorded in 1982 have since fallen over (uncertainty lies in whether these trees succumbed to the effects of the fire and/or simply reached senescence), toppled during periods of strong winds.

The living *Populus tremuloides* stands on the plot today are noticeably two-tiered. There is a distinct upper canopy of mature *P. tremuloides* reaching 25-30 metres in height made up of a few individuals loosely grouped together, and a lower tier, 8-10 metres tall, of numerous young densely packed *Populus tremuloides* trees distributed throughout the plot in tight clumps. Currently growing on the Aspen Upland are dense, widely spread units of jack pine saplings 3.5-5.5 metres in height along the rock ridges, including smaller pockets of black spruce saplings 1.5-3 metres tall, in low areas of the plot which went

unrecorded in 1982. *Picea mariana*, *Picea glauca* and *Abies balsamea* occurred in descending order of abundance in the 2000 vegetation survey. The tall shrub layer has broadened its distribution, especially *Amelanchier alnifolia* and *Prunus pensylvanica* since the 1982 survey.

The Aspen Upland in many ways is essentially similar in overall vegetative characteristics as before the 1980 fire (W. Pruitt, pers. comm.). Eventually though, the abundant young jack pine flourishing within this plot may gain a more prominent foothold and re-shape the deciduous landscape.

Blackspruce Bog (BSB)

Pre-fire conditions (prior 1980):

The BSB plot (51° 02' 21.6"N, 095° 21' 44.7" W) with a GPS altitude recording of 322 metres is located along the east bank of the Blind River (see Section 1. in Fig. 3). The stratified vegetation maps made prior to the 1980 fire indicated the area as being "mature spruce bog community" characterized by large black spruce trees relatively close spaced with occasional tamarack trees. The ground flora was made up of *Sphagnum* hummocks supporting *Carex* species. W. Pruitt, (pers. comm.) described the Blackspruce Bog as "a shade-filled environment having a thick, dense canopy of *Picea mariana* with an almost entirely-filled *Sphagnum* spp. undergrowth". The lower shrub layer (along with the numerous sphagnum hummocks) also included abundant ericaceous species such as *Ledum* and *Chamaedaphne*, with trees spaced 3-5 feet apart on average (K. Johnson, pers. comm.). Penny (1978) recorded the ground cover as being

composed predominantly of mosses such as *Sphagnum*, *Pleurozium* and *Dicranum spp.* covered with a relatively small proportion of litter/organic debris.

The low-shrub layer consisted mostly of *Ledum groenlandicum*, *Vaccinium vitis-idaea* and *Gaultheria hispidula*. Tall shrubs were not recorded. *Smilacina trifolia* was the dominant member of the herbaceous layer on the BSB.

Post-fire conditions on the BSB plot:

The fire of 1980 on the Blackspruce Bog had access to all vegetation layers due in part to the morphology of *Picea mariana* (with its low dense network of branches reaching the ground level), and to the mature state of the stand itself. Stardom (1977) noted in his vegetation stand descriptions of the TBS area that as black spruce-alder bogs mature, the substrate increases in height above the water table, allowing additional black spruce to invade the area with a consequential increase in transpiration rates, and further drying out of the bog.

Martin (1983) observed (in reference to the fire damage on the Blackspruce Bog), "that destruction of the site was virtually complete despite expected favourable moisture conditions". She noted that only vegetation found within the lower, moister areas of the bog, along the compressed trapping grid pathways survived and provided residual species for regeneration. The sphagnum substrate of the BSB was either completely burned or shortly thereafter, succumbed to the effects of intense heat. Shortly after the 1980 fire the BSB contained wind-disseminated *Epilobium*, along with resprouting clumps of *Ledum* and *Salix* that survived damage by having their roots buried deeply in

the sphagnum layer. The ground surface layer was composed of brown, steam-killed sphagnum, charcoal-covered bare ground, and bowls or depressions of accumulated rainwater (K. Johnson, pers. comm.).

Two-years post-fire, Martin (1983) noted a substantial decrease (approximately ten-fold) in living *Sphagnum spp.*, along with much remaining evidence of the accumulated charcoal-covered litter/organic debris on the BSB forest floor. *Ledum groenlandicum* and *Smilacina trifolia* contributed most to the lower shrub and herbaceous layers, respectively.

A vegetation survey of the Bog in 2000-01 showed mean ground cover variables to include predominantly *Sphagnum spp.*, fallen trees, and smaller amounts of litter/organic debris. No visible evidence of the burned *Sphagnum* is apparent now. The low shrub vegetation consists mostly of *Ledum groenlandicum*, *Vaccinium vitis-idaea* and *Oxycoccus microcarpos*. No tall shrubs were recorded on the Blackspruce Bog. *Smilacina trifolia* and *Eriophorum spissum* were the major contributors to the herbaceous and grass/sedge layers, respectively.

Upper canopy changes within the BSB:

Within the BSB the upper canopy was almost completely engulfed by fire, leaving only charred trunks and branches of standing and fallen *Picea mariana* (Martin 1983). Though the majority of the upper canopy perished in the intense fire, only 3% of the woody debris recorded on the forest floor was from fallen

trees in 1982. Several months after the burn, fire-damaged trees began to fall over on the BSB from strong wind and/or rain storms (K. Johnson, pers. comm.).

In the year 2000, 31% of the mean ground cover included fallen trees. A survey of the upper canopy by Martin (1983) indicated approximately 1,925 standing dead trees on the Blackspruce Bog plot, two-years post-fire. Today, less than 10% or approximately 165 of the original fire-killed trees remains standing. Therefore, about 90% of the fire-killed *Picea mariana* form a "jack-straw" or criss-cross pattern arrangement (in some places up to a metre in height) throughout the plot. The many fallen trees that over-lap one another either produce shelters or barriers to the different species of wildlife. The Blackspruce Bog has the distinction of harbouring the greatest volume of coarse woody debris in comparison to the other six plots.

The plot today is carpeted by a dense layer of *Picea mariana* seedlings, ranging from 10 cm to 1.5 m tall that cover approximately 25% of each trap station quadrat. The less frequent *Pinus banksiana* seedlings and saplings present are of similar age to the *Picea mariana* vegetation, yet, are taller and range between 50 cm to 3.5 m in height, covering about 10% of each trap station quadrat. The mature pre-fire black spruce community of twenty years ago has been replaced by an open landscape of silvery-gray, mostly branchless, standing dead *Picea mariana* - with a dense undergrowth of *Ledum groenlandicum*, *P. mariana* and *P. banksiana* seedlings. Occasionally, an infrequent *Larix laricina* or *Populus tremuloides* seedling may be observed in one or more of the quadrats.

Ecotone (ECO)

Pre-fire conditions (prior 1980):

The Alder-Jackpine Ecotone plot (Ecotone) for simplicity (51° 02' 41.7" N, 095° 21' 44.5" W), represents a continuum of two different habitats (i.e., alder and tamarack bog, with elevated aspen and jack pine mixed forest) that merge at the lower end of a gently sloping rock incline. The microtopography of the Ecotone is highly variable with a drop in elevation of approximately three metres from the top of the ridge, to Aikens Lake Road at the bottom of the plot. Within this plot is a mixture of soil development levels from exposed rock surfaces with small depressions of accumulated organic debris, to shallow mineral soils (< 25cm deep), to wet organic *Sphagnum spp.* mats, several metres in thickness.

The pre-fire stratified vegetation maps indicated that this particular plot straddled two vegetation communities - a low, wet area or "intermediate bog-forest community" with invading alder, tamarack, and willows in association with wet grasses and sedges. The elevated ridge section of the plot during pre-fire time was considered an "intermediate jack pine forest" with flowering shrubs such as *Arctostaphylos uva-ursi*, *Ledum groenlandicum* and *Vaccinium spp.* Ground cover was provided primarily by mosses and lichens. On the edge of the bog community (where the two habitat types meet) there may be willows with occasional birch and aspen trees that occur higher up along the ridge sides.

Pre-fire vegetation data by Penny (1978) indicated the important ground cover variables of the Ecotone were: organic litter/debris and mosses, such as *Sphagnum*, *Pleurozium* and *Dicranum spp.* Low shrubs consisted of *Ledum*

groenlandicum, *Chimaphila umbellata*, *Rubus idaeus* and *Ribes spp.*, and several others. Ferns and allies included *Lycopodium spp.* The herbaceous layer contained *Viola spp.*, *Smilacina trifolia* and *Galium boreale*. Tall shrubs included *Amelanchier alnifolia* and *Alnus spp.*

Post-fire conditions on the ECO plot:

The post-fire vegetation survey in 1982 revealed the important ground variables to include mosses such as *Sphagnum* and *Polytrichum spp.*, litter/organic debris and bare rock. The low shrub layer contained *Vaccinium spp.*, *Diervilla lonicera*, *Rubus idaeus* and *Ledum groenlandicum*. In the herbaceous layer were *Epilobium angustifolium*, *Clintonia borealis* and *Aralia nudicaulis*, including many other species at lower percentages. Cyperaceae was an important contributor as well.

During the 2000 survey the important ground cover variables included: litter/organic debris, fallen logs, and mosses such as *Sphagnum*, *Pleurozium* and *Dicranum spp.* The predominant low shrubs were *Ledum groenlandicum*, *Vaccinium spp.* and *Rubus spp.* Tall shrubs consisted of *Alnus rugosa*, *Salix spp.* and *Betula glandulosa* mainly. The herbaceous layer contained *Aralia nudicaulis*, *Epilobium angustifolium* and *Maianthemum canadense*, along with numerous other species with low percentage cover values. The Ecotone also contained a wide variety of abundant gramineae and cyperaceae species. The tall shrubs of *Alnus rugosa* and *Betula glandulosa* are restricted to row seven and the lower portions of the plot.

Upper canopy changes within the ECO:

The Ecotone pre-fire tree strata, particularly along the ridge top, was a mature mixed forest of large *Pinus banksiana*, *Picea mariana* and *Populus tremuloides*. The 1980 fire was confined mainly to the top and upper sides of the ridge coming close to the southeast corner of the Alder-Tamarack Bog plot (W. Pruitt, pers. comm.). Martin (1983) reported that "fire appears to have been less intense on this plot since a few upper canopy trees have survived". The lower part of the Ecotone adjacent to the Alder-Tamarack Bog plot and alongside Aikens Lake Road was an extremely damp habitat with open water, and therefore able to escape much of the fire.

A survey of the upper canopy two years after the fire revealed approximately 345 standing mature trees on the Ecotone, with over three-quarters of these trees being dead *Picea mariana*, *Pinus banksiana*, *Populus tremuloides* and *Larix laricina*, in descending order of frequency. The remaining trees (about 44 of these) were a mixture of the above, and noted as "living" two-years post-fire (Martin 1983). Ten years following the initial survey Wheatley (1993) reported that the "plot now has many downed trees and no standing mature trees".

The 1982 upper canopy survey observed a distinct tiered-arrangement of trees growing on the slope of the Ecotone. *Pinus banksiana* was found growing along the A to J lines, from row one up to row six, of the small mammal trapping grid. *Picea mariana* and *Populus tremuloides* occurred along the A to J lines, up to row eight. *Larix laricina* was found between rows eight to ten on the Ecotone.

Tall shrubs such as *Alnus rugosa* and *Betula glandulosa* did not make a substantial appearance until row seven on the plot.

The 2000 survey of the upper canopy revealed that the elevated part of the Ecotone along the ridge top and upper sides had dense pockets of jack pine saplings 3-5 metres tall. On the top of the ridge were several open areas covered with lichens, mosses, and much coarse woody debris in the form of fallen trees and branches. Several sections of the Ecotone have very dense "jackstraw" arrangements of fallen coniferous trees, particularly along the top ridge. Farther down the slopes, the deadfall is noticeably reduced due in part to the moist habitat and perhaps more rapid rate of decay, but also due to the increased presence of *Populus tremuloides* which does not seem to form dense "jackstraw" patterns of logs like the surrounding conifers.

Today, only about a dozen mature "snags" remain standing on the Ecotone plot, the rest have been reclaimed by the forest over the years since the burn. As well, there is a tiered-arrangement to the young tree vegetation, but not as defined as indicated from previous surveys. Dense growth of *Picea mariana*, *Pinus banksiana*, *Populus tremuloides* and *Larix laricina* saplings can be found growing together throughout most of the plot, but at different densities depending on ground moisture levels. *Pinus banksiana* appears to have the most definitive boundary and is almost nonexistent past row six.

Jackpine Ridge (JPR)

Pre-fire conditions (prior 1980):

The Jackpine Ridge plot (51° 02' 27.1" N, 095° 21' 43.4" W) with a GPS altitude reading of 326 metres is located on top of a ridge of volcanic origin, approximately several hundred metres northwest above the Blackspruce Bog plot. The pre-fire stratified vegetation maps described the habitat as an "intermediate jackpine community" – an area of small rock ridges with intervening low lying areas. The plot was primarily a mature *Pinus banksiana* forest with *Picea mariana* present in the depressed areas between the rock ridges. Mosses and lichens formed most of the ground cover, particularly *Cladonia spp.*, with little exposure of bare rock. Prior to burning, the JPR was a relatively mesic habitat with a fairly open canopy (W. Pruitt, pers. comm.). Pre-fire vegetation observed at similar elevations across the river from the JPR plot reported a relatively uniform, mature, *Pinus banksiana* forest with trees approximately 10-18 inches in diameter, and about 84 years in age; the odd aspen and birch were noted as well (K. Johnson, pers. comm.).

Pre-fire vegetation data recorded by Penny (in Martin 1983) indicated that only 4% of the plot was bare rock, 28% litter/organic debris, and almost 70% of the ground cover comprised of mosses and lichens. The mosses included *Pleurozium*, *Dicranum* and small amounts of *Polytrichum spp.*; lichens were predominantly *Cladonia spp.* The herbaceous cover contribution was extremely low, being mostly made up of *Aralia sp.* Low shrubs covered approximately 5% of

the plot and included species such as *Arctostaphylos uva-ursi*, *Chimaphila umbellata*, *Diervilla lonicera*, *Linnaea borealis* and *Vaccinium* spp.

Post-fire conditions on the JPR plot:

The 1980 fire was particularly severe on the Jackpine Ridge plot that rises approximately four to five metres above the Blackspruce Bog and consists of an undulating plain of small rock ridges, with low, occasionally damp areas in-between. The northeast edges of the plot face a relatively sharp rock incline which comes up from the Blind River. This combination of a steeply sloped rock face along with mature, resinous conifers growing upon it, apparently produced a "chimney-like" effect during the intense burning of the plot (W. Pruitt, pers. comm.).

K. Johnson (pers. comm.) reported up to 60-70% bare rock during the early post-fire years on the ridge, with about 27% litter/organic debris. A vegetation survey by Martin (1983) two-years post-fire indicated percentage covers of 15.5% bare rock, 48.2% litter and about 12.6% mosses of predominantly *Ceratodon purpureus* and *Polytrichum* spp. Lichens and many of the earlier mosses recorded by Penny were noticeably absent. The herbaceous layer was consisted mainly of *Aralia* sp. and several post-fire colonizing species such as *Epilobium angustifolium* and *Polygonum cilinode*. The low shrub layer contained primarily *Vaccinium* spp., along with small amounts of *Rubus* spp., *Ribes glandulosum*, *Ledum groenlandicum*, *Linnaea borealis* and several others (mainly species favouring more moist habitats) that perhaps managed to survive

the burn. During the 1984-85 season however, severe rain and wind storms washed many of the seedlings and organic debris off the ridge rock surfaces which set back recovery on the plot by several years (K. Johnson, pers. comm.).

Two to three years after the burn many of the *Pinus banksiana* fire-damaged trees (some still possibly supporting rodent-edible cones) began to fall over. Also during this time many big seed-producing, early post-fire colonizing plant species were noted on the ridge, including *Epilobium*, *Geranium* and *Corydalis*. Additionally many berry-producing species also began to return to the JPR which included *Rosa*, *Vaccinium*, *Fragaria* and *Rubus idaeus*.

The vegetation survey in 2000 observed mean percentage covers of 31% bare rock, 81.4% litter/organic debris and 20.5% fruticose lichens. Mosses recorded during the pre-fire period such as *Pleurozium* and *Dicranum spp.* were present, however, in amounts of less than 1% within the many of the quadrats. *Polytrichum spp.* was the most abundant moss within the quadrats, with a mean cover value of nearly 40%. Low shrubs contributed less than 5% of the vegetation cover on the Jackpine Ridge with small clumped distributions of *Diervilla lonicera*, *Vaccinium myrtilloides*, *Linnaea borealis* and several other species that were present during pre-fire times. Tall shrubs included scattered *Prunus pensylvanica* and *Salix spp.* The scant herbaceous layer consisted of only three to four thinly spread species: *Maianthemum canadense*, *Goodyera repens*, *Epilobium angustifolium* and *Apocynum androsaemifolium*. Small infrequent clumps of *Carex foenea* and *Oryzopsis spp.* were found in areas able to accumulate a substrate of organic debris.

Upper canopy changes within the JPR:

The pre-fire tree stratum contained "a fairly dense upper canopy of *Pinus banksiana*, *Picea mariana* and *Picea glauca*, all of which was lost in the fire" (Martin 1983). A survey of the Jackpine Ridge's upper canopy by Martin (1983) showed a fairly evenly distributed forest of mainly mature standing dead *Picea* spp. Approximately 368 out of the 434 trees recorded within the plot boundaries were *Picea* spp., with the remainder being mostly *Pinus banksiana*.

Today, only about 14 of these tall *Pinus banksiana* "snags" remain standing upright within the plot. At present, dense stands of young *Pinus banksiana* 3.0-5.5 metres in height occupy much of the plot and account for almost 50% of the overhead coverage above the small mammal trapping quadrats. Smaller pockets of *Picea mariana* seedlings and saplings (50 cm-2.5 metres tall) are found scattered throughout the plot along with the occasional young *Populus tremuloides*. Infrequent species on the Jackpine Ridge are *Larix laricina* and *Betula papyrifera*. No *Picea glauca* were observed during the 2000 vegetation survey.

The Jackpine Ridge twenty years post-fire represents an elevated landscape of dense jack pine saplings and rolling rock ridges that have been cleared of their charred debris by many years of seasonal rainfall. Lichens and mosses are slowly regaining a minute resemblance to their pre-fire conditions but have many years to fill previously occupied niches. Little soil development has occurred except in low areas or cracks in the rock substrate that have allowed moisture and organic debris to accumulate. The fire behaviour on this plot was

crown fire with complete vegetation destruction, on top of a rock pan. The habitat experienced intense temperatures with much of its substrate burnt bare; leaving a desolate landscape that will take decades to regenerate.

Jackpine Sandplain (JPSP)

Pre-fire conditions (prior 1980):

The Jackpine Sandplain (51° 02' 55.1"N, 095° 21' 01.2"W) with a GPS altitude recording of 336 metres is a relatively uniform habitat both in terms of its distribution of plant species and in its microtopography. The plot occurs on a markedly flat landscape (with the exception of one or two *Marmota monax* mounds found within its boundaries) with well-drained sandy soils supporting a dominant *Pinus banksiana* community.

Pre-fire 1976 vegetation from Penny (1978) indicated primarily a moss and lichen ground cover of *Pleurozium* and *Dicranum spp.* with fruticose lichens of *Cladonia spp.*, and in association with abundant litter/organic debris fallen from mature jack pines. The thin herbaceous layer included *Maianthemum canadense* and *Pyrola rotundifolia* with a small presence of graminoids. The low shrub layer contained *Vaccinium myrtilloides*, *Arctostaphylos uva-ursi* and *Linnaea borealis* in decreasing amounts. No tall shrubs were indicated in the survey by (Penny 1978). The pre-fire habitat of the JPSP was described as being primarily lichen ground cover with little herbaceous species cover; chanterelles and other mushrooms were also noted. The forest was fairly widely-spaced with about 50%

of the ground shaded by the overhead jack pine canopy (K. Johnson, pers. comm.).

Post-fire conditions on the JPSP plot:

Many visible changes occurred within the ground vegetation following the 1980 fire. Keleher (in Martin 1983) reported that "lichens and most mosses are now absent". K. Johnson (pers. comm.) observed that much of the lichen surface was burned down to its sand substrate and subsequently the remaining ash was washed away by rains.

Martin (1983) described the Sandplain as having "sparse ground vegetation", and indicated litter/organic debris and bare soil/sand as being the dominant ground cover variables - along with a notable absence of lichens and mosses. Post-fire additions to the litter layer included many arboreal lichens scattered throughout the plot from fallen branches. The presence of *Polytrichum* sp. moss was also noted following the fire. The herbaceous cover consisted of a thinly spread layer of few species such as *Apocynum androsaemifolium*, *Maianthemum canadense* and *Galium boreale*; some *Carex* spp. and graminoids were recorded as well. Low shrubs included *Vaccinium myrtilloides*, *Arctostaphylos uva-ursi* and *Cornus canadensis*, with small amounts of several other species. Martin (1983) also noted that *Vaccinium vitis-idaea* and *Ledum groenlandicum* were pre-fire species not found in her 1982 survey. In the tall shrub layer *Alnus crispa* was reported in the plot.

Mean percent cover values of vegetation from the 2000 survey of the JPSP showed ground cover as being predominantly litter/organic debris, fruticose soil lichens, dead wood (logs), and mosses such as *Polytrichum*, *Dicranum* and *Pleurozium spp.* - in descending order of percent cover. The herbaceous layer included such species as *Maianthemum canadense*, *Apocynum androsaemifolium* and *Melampyrum lineare*, was both thin and sparse. Members of the wintergreen family (many now placed in family: Ericaceae) found on the Jackpine Sandplain plot included: *Chimaphila umbellata*, *Pyrola asarifolia* and *P. rotundifolia*. A few species (though uncommon) from the orchis family (Orchidaceae) were also present, and included: *Cypripedium acaule* and *Goodyera repens*. The weakly scattered graminoid species present consist of *Oryzopsis pungens* and *O. asperifolia*. Low shrubs consist mainly of *Arctostaphylos uva-ursi*, *Vaccinium myrtilloides*, *V. vitis-idaea* and *Cornus canadensis*. An infrequent tall shrub found on the plot is *Alnus crispa*.

Upper canopy changes within the JPSP:

The Jackpine Sandplain pre-fire descriptions were provided by several sources (W. Pruitt, pers. comm.) and from stratified vegetation maps (Taiga Biological Station, unpubl. files) made one year prior to the 1980 fire. The vegetation map typified the Sandplain as having almost pure *Pinus banksiana*, ...“ over 85% of the trees are jackpine with less than 15% blackspruce”. “Deciduous trees are uncommon”. The *Pinus banksiana* layer dominated this community with a tree stratum of approximately 20-25 metres tall. The plot was

relatively open - due in part to the lack of dense jackpine sapling growth and to the lack of fire-killed, wind-fallen trees found over much of the Sandplain today. Many changes in the upper canopy have occurred throughout the Jackpine Sandplain during the past twenty years.

Following the fire of 1980, approximately one-third to one-half of the mature *Pinus banksiana* upper canopy remained. Upper canopy maps of the Jackpine Sandplain plot were produced (based on the small mammal trapping grid) during the years 1982 and 2000. The location and species identity of all mature trees (both living and standing dead) were recorded on the maps. The 18-year hiatus allowed for several comparisons to be made among trees contributing to the upper canopy today, with those in place shortly after the fire period. The upper canopy map (see Martin 1983) may serve as an index for pre-fire canopy conditions with three tree species recorded: *Pinus banksiana*, *Picea mariana* and *Abies balsamea* in decreasing order of abundance.

Today, none of the *Abies balsamea* trees and saplings, nor mature *Picea mariana* have been observed on the plot. In 1982, the upper canopy contained many fire-killed trees - standing dead that had yet to succumb to strong winds, fungal agents and insects. Since that time, and as the years have progressed, these trees are being increasingly recruited by the forest floor. The Sandplain is currently represented by an almost pure stand of tall *Pinus banksiana* (many with basal fire-scarred trunks) and by more living trees than standing dead, along with a robust population of jackpine saplings 3-5 metres tall invading the plot.

Appendix A.2

Boreal forest origin and history of fire at TBS

Boreal forest origins:

The boreal forest has often been described as a geologically young (Wright 1971) and ecologically dynamic biome (see Payette 1992). In Alaska and western Canada the boreal forest developed during the early Holocene, about 10,000 years ago (Ritchie 1984). In the east it is a much younger forest, about 4,000 - 8,000 years old as a result of late deglaciation (Webb 1987). The area surrounding Taiga Biological Station was underneath glacial Lake Agassiz 9,000 years ago (Teller 1984). Approximately 7,500 years ago Lake Agassiz had drained into Hudson Bay, allowing forests to continue their northward migration until shortly after 6,000 years ago (Shay 1984). Forest boundaries within Manitoba have subsequently shifted over the past 3,000 years in association with the arrival of cooler and wetter conditions. Farmer et al. (1983) described boreal plant species as "glacial transients" that migrated at a rate of approximately 200 km/1,000 yrs, southward and northward, during periods of glacial encroachment and recession. Continued minor shifts in the major vegetation regions of Manitoba have taken place over the last several centuries (Shay 1984).

The boreal forest has also been characterized as a "floristically poor" biome because of its harsh climate and cold soils with only nine or ten tree species found throughout the North American range (Rowe and Scotter 1973; Takhtajan 1986). Many of the forest communities are monospecific, while a noticeable proportion are composed of mixtures of tree species. This lack in boreal flora diversity appears to be the result of sustained, severe climatic controls that occurred during the Quaternary (Payette 1992). Carelton and

Maycock (1978) proposed that the paucity of tree species was not simply due to a climatic limitation, but also from the unpredictable nature of the outbreak of fire.

The study area surrounding Taiga Biological Station is predominantly evergreen, dominated by black spruce (*Picea mariana*), and jack pine (*Pinus banksiana*), both of which occupy a continuum of habitat extremes. Black spruce grows in a wide range of ecological conditions from areas of low-lying terrain filled with peatlands to well-drained sandplains and elevated rock outcrops. Along the margins of the Blind River, a tributary of Wallace Lake, black spruce often formed extensive monotypic communities among the sphagnum bogs prior to the large burn of 1980. Jack pine is more common in the drier upland sites and often forms even-aged stands over large areas of burn on outwash sandplains. Young *Pinus banksiana* are commonly found in burned areas of the lowland sphagnum-filled bogs. Other characteristic coniferous species surrounding TBS include white spruce (*Picea glauca*), tamarack (*Larix laricina*), and balsam fir (*Abies balsamea*); where tree species presence depends on soil moisture availability (Ritchie 1961). Broadleaved trees such as trembling aspen (*Populus tremuloides*), white birch, (*Betula papyrifera*), and balsam poplar (*Populus balsamifera*), are interspersed throughout the area, particularly where recent fires have occurred.

The type of boreal forest that develops on a landscape is therefore dependent on the local climate, physiography, landform, soil, permafrost and fire regime found within an area (Bourgeau-Chavez et al. 2000). Historically, wildfire seems to have always dominated the boreal zone. Past evidence of this long-

term association between fire and forest exists in the fire-scarred trunks of standing trees (Clark 1990) and in the charcoal-accumulated, stratigraphic deposits found in peat beds (Heinselman 1963) and lake sediments (Swain 1973). Fire, perhaps because of its sheer rawness and creative potential in initiating change across the boreal landscape, has been provided with many bold descriptors: "a significant factor" (Ahlgren and Ahlgren 1960), "a natural force" (Mutch 1970), "a tremendous force" (Bendell 1974), "a major natural disturbance" (Ohmann and Grigal 1981), and finally, "a modifying agent" (McIntosh 1983) - all in reference to fire's relationship with forest ecosystems.

Fire is ubiquitous in the boreal forest and is "inextricably woven into the patterns" (in reference to the mature forest patterns found across Canada's north) (Rowe and Scotter 1973). Indeed, fire is an essential part of forest ecosystems and in a natural system should be regarded as a resource (Hendrickson 1972). Hendrickson suggested that the acceptance of fire as a normal, recurrent, environmental event should be a non-issue. The primary focus should be on not whether a particular vegetation tract will burn, but rather "how susceptible it is to fire"?

Fire history, behaviour, and ecological effects:

The fire regime refers to the fire history that characterizes an ecosystem. The elements of a fire regime include fire frequency, fire intensity, size of burn, depth of burn, and fire season (Heinselman 1980; Van Wagner 1983; Bonan and Shugart 1989). Fire regimes in the North American boreal forest vary from short-

interval crown fires and/or high-intensity surface fire regimes, to very long-interval crown and/or surface fire regimes. Heinselman (1978) included seven kinds of fire regimes for forest ecosystems (in terms of the severity and length of the return interval) in order to identify important differences in the way fire influences ecosystems. In his earlier work, Heinselman (1973) referred to the *natural fire rotation* as the average time required for a natural fire regime to burn over an area equivalent to the total area of an ecosystem. Van Wagner (1978) described a similar concept, the *fire cycle* (the average interval between fires at any single point), from the distribution of present stand ages in a natural forest. For example, if the mean age of randomly sampled stands is 100 years, then the fire rotation time is also 100 years (Cogbill 1985).

Fire rotation time is relatively short from 50 – 100 years in much of Alaska and western Canada's boreal forest, but may increase to 500 years or more in eastern Canada with increased precipitation (Viereck 1983). The Great Lakes-St. Lawrence-Acadian forests have several distinct fire regimes: "jack pine barrens" on sandplains had regimes of light surface fires with cycles as short as 15 - 30 years while large peatlands in Minnesota supporting black spruce had crown fire regimes at cycles of 150 – 200 years (Heinselman 1978). Abundant documentation of boreal fire regimes can be found in (Lutz 1956; Heinselman 1973; Swain 1973; Rowe and Scotter 1973; Carroll and Bliss 1982). Since each physiographic site tends to have its own return interval some areas may not burn during a given fire cycle, whereas other areas may burn more than once (Heinselman 1978; Rowe 1983).

Zackrisson (1977) suggested the expression of fire rotation to include both fires caused by lightning and those started by humans, since the development of the forest ecosystem cannot be considered to remain uninfluenced by people. The calculated fire rotation is valuable as an historical factor showing the extent to which fire has affected the development of the landscape as a whole. However, it does not reflect the degree of disturbance in a particular biome (Heinselman 1973). Recent human activities in North American boreal forests have likely modified fire regimes (Campbell and Flannigan 2000).

The Wallace-Aikens Lakes region is composed largely of conifer stands resulting from fires during the following years: 1895, 1929, 1948, 1976 and 1980 (Section I, Fig. 2). A lightning-initiated fire in 1976 consumed approximately 40 km² of 81-year-old timber northeast and northwest of Wallace Lake. Four years later in the spring of 1980, an improperly tended campfire on the north shore of Wallace Lake led to the development of a major forest fire. Eventually, by the time summer was over, about 600 km² of both 51-year-old and 85-year-old forest in the Wallace-Aikens Lake area had burned (Schaefer and Pruitt 1991). The history of recorded fires indicates that the interval of occurrence for fires in the Wallace-Aikens Lake region ranges from 19-34 years.

Heinselman (1978) and Campbell and Flannigan (2000) noted that fire occurrence records over a short time (even several centuries) provide little assurance that they are representative of long-term trends. The effects of fire, whether short-term or long-term are complex. The degree of perturbation fire has on the boreal ecosystem depends on several elements including the nature of

the forest burned, the size and intensity of the burn, the distribution of unburned sites in relation to the burn, and the geographic landscape of the area under consideration (Rowe and Scotter 1973).

To understand fire's evolutionary role in ecosystem development, knowledge of life history attributes is required (Keeley 1978). Plants are assumed to adjust to fire regimes through the evolution of functional adaptations and reproductive strategies to cope with fire (Rowe 1983; Zasada et al. 1992). Specific components of the fire regime - fire frequency and burning pattern (i.e., patchy or extensive) exert the greatest selective force on the reproductive strategies of plants. The primary success of modern boreal forest tree species has been evident in their ability to accommodate to extremes of environmental change. Together, the breeding systems of boreal conifers along with their associated high levels of genetic variability and plasticity constitute the "raw material for continued adaptation to changing environments" (Farmer et al. 1983).

Fire climate:

During the period 1970 to 1980 in the west-central part of Canada, climatic anomalies produced prolonged periods of dry weather. Subsequently, a dramatic increase in the numbers of forest fires occurred with northwestern Ontario's 1980 fire season being recognized as particularly severe. During the month of May 1980, a stable, high pressure system existed over central North America for an extended period, effectively blocking the flow of atmospheric moisture into areas

of Ontario and Manitoba. The effects of low precipitation and continued warm, dry weather, in combination with fast-drying forest fuels, lead to conditions extremely susceptible to severe forest fire problems (Stocks and Street 1983). Flannigan and Harrington (1988) found that the distribution of precipitation (i.e., frequency of dry spells) rather than precipitation amount was the critical factor in the relationship between a meteorological variable and area burned.

The Wallace-Aikens Lake area fire was first reported on May 20, 1980 in the early hours of the morning and officially extinguished on June 30, 1980, at noon. The Fire Weather Index (FWI), which is a numerical rating of fire intensity at the time of ignition, was classified at "58" (Wildfire Report 1980). Any rating above 10 (i.e., FWI > 10) falls in the "high – extreme" category (Wein and MacLean 1983). *Winnipeg Free Press* articles from May 21, 23, and 31, 1980 described weather conditions during the early days of the burn...

"fires yesterday in the tinder-dry forests of Manitoba and Northwest Ontario led to the evacuation of hundreds of people from towns and summer cottages. Firefighting efforts have been hampered by extreme heat and high winds".

"Record setting temperatures and high winds are ravaging huge tracts of land in Manitoba and Northwestern Ontario. Firefighters can expect some record highs of 38⁰C again today".

"the bone-dry weather of April has been followed by below normal precipitation for the month of May, only 7.2 mm has fallen so far with normal precipitation for the month of May being 93 mm (data recorded at the Winnipeg Airport weather station)".

According to the newspaper articles, some fire-prone areas in Manitoba had experienced more than nine consecutive days of above 30⁰ C temperatures with winds stronger than usual for the month of May. Suppression costs of over a quarter of a million dollars were assessed for labour, transportation, property and equipment (however this did not include the costs for military aircraft and personnel) involved in fighting the Wallace Lake fire (Wildfire Report 1980).

Schaefer and Pruitt (1991) found that resistance to fire at TBS was strongly habitat-dependent (i.e., semi-open bogs, upland communities, or mixed deciduous forests) each responded with a varying susceptibility to burning. The six small mammal study plots at TBS represent habitats that express a continuum of fire-damaged environments. They are recognized by their ecological characteristics including: vegetation, soil, and land form, that present essentially a uniform environment. Together they make up a mosaic of diverse ecosystems at TBS, from pure, even-aged, *Pinus banksiana* stands on well-drained sandy soils, to mixed forests on thin mineral soils overlying bedrock, to *Picea mariana* stands on poorly drained organic wetlands.

TABLE B.1a Comparison of the relative abundances (numbers captured/100 trap nights) of **Alder-Tamarack Bog** small mammal species during different time intervals at Taiga Biological Station. The overall relative abundance during 24 sampling-years is included \pm 1S.D.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)	Overall	S.D.
<i>Clethrionomys gapperi</i>	3.56	2.60	4.27	1.00	0.22	2.14	6.358
<i>Sorex cinereus</i>	2.22	2.40	4.07	4.67	1.89	3.07	6.372
<i>Peromyscus maniculatus</i>	0.11	0.07	0.07	0.00	0.00	0.04	0.338
<i>Microtus pennsylvanicus</i>	0.33	0.07	0.67	1.00	0.39	0.50	1.978
<i>Blarina brevicauda</i>	0.11	0.07	0.13	0.00	0.06	0.07	0.509
<i>Microsorex hoyi</i>	0.00	0.00	0.07	0.00	0.00	0.03	0.282
<i>Sorex arcticus</i>	0.11	0.00	0.27	0.07	0.11	0.11	0.761
<i>Synaptomys sp.</i>	0.11	0.13	0.00	0.07	0.00	0.06	0.482
<i>Glaucomys sabrinus</i>	0.00	0.00	0.00	0.00	0.06	0.01	0.204
<i>Tamiasciurus hudsonicus</i>	0.00	0.00	0.27	0.00	0.06	0.07	0.658
Number of trap nights	900	1500	1500	1500	1800	7200	
Total relative abundance	6.55	5.34	9.82	6.81	2.79		
Without sciurids	6.55	5.34	9.55	6.81	2.67		

TABLE B.1b Comparison of the relative abundances (numbers captured/100 trap nights) of the **Aspen Upland** small mammal species during different time intervals at Taiga Biological Station. The overall relative abundance during 24 sampling-years is included \pm 1S.D.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)	Overall	S.D.
<i>Clethrionomys gapperi</i>	3.67	3.60	8.33	5.07	1.50	4.43	9.778
<i>Sorex cinereus</i>	0.78	1.80	1.80	2.20	1.39	1.65	3.605
<i>Peromyscus maniculatus</i>	0.00	2.47	1.80	1.67	1.50	1.61	3.158
<i>Microtus pennsylvanicus</i>	0.00	0.27	0.40	0.67	0.00	0.28	1.239
<i>Blarina brevicauda</i>	0.00	0.07	0.07	0.00	0.17	0.07	0.658
<i>Microsorex hoyi</i>	0.00	0.00	0.07	0.00	0.00	0.01	0.204
<i>Sorex arcticus</i>	0.11	0.00	0.00	0.00	0.00	0.01	0.204
<i>Synaptomys sp.</i>	0.00	0.00	0.13	0.07	0.00	0.04	0.338
<i>Phenacomys intermedius</i>	0.00	0.00	0.07	0.13	0.00	0.04	0.338
<i>Zapus hudsonius</i>	0.00	0.00	0.00	0.40	0.06	0.10	0.624
<i>Glaucomys sabrinus</i>	0.11	0.13	0.07	0.13	0.06	0.10	0.550
<i>Tamias minimus</i>	0.11	0.07	0.67	0.33	0.17	0.28	1.274
<i>Tamiasciurus hudsonicus</i>	0.00	0.07	0.00	0.07	0.06	0.04	0.338
Number of trap nights	900	1500	1500	1500	1800	7200	
Total relative abundance	4.78	8.48	13.41	10.74	4.91		
Without sciurids	4.56	8.21	12.67	10.21	4.62		

TABLE B.1c Comparison of the relative abundances (numbers captured/100 trap nights) of the **Blackspruce Bog** small mammal species during different time intervals at Taiga Biological Station. The overall relative abundance during 25 sampling-years is included \pm 1S.D.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)	Overall	S.D.
<i>Clethrionomys gapperi</i>	0.44	1.22	3.13	1.87	0.94	1.57	4.392
<i>Sorex cinereus</i>	0.56	0.83	1.53	0.87	0.72	0.92	2.385
<i>Peromyscus maniculatus</i>	0.00	1.17	0.00	0.00	0.06	0.29	2.242
<i>Microtus pennsylvanicus</i>	0.00	0.28	0.00	0.07	0.06	0.09	0.737
<i>Microsorex hoyi</i>	0.00	0.00	0.07	0.00	0.00	0.01	0.200
<i>Sorex arcticus</i>	0.00	0.00	0.00	0.07	0.06	0.03	0.277
<i>Synaptomys sp.</i>	0.00	0.00	0.07	0.00	0.00	0.01	0.200
<i>Zapus hudsonius</i>	0.00	0.00	0.00	0.00	0.06	0.01	0.200
<i>Tamias minimus</i>	0.00	0.00	0.07	0.00	0.00	0.01	0.200
<i>Tamiasciurus hudsonicus</i>	0.00	0.06	0.00	0.00	0.17	0.05	0.374
Number of trap nights	900	1800	1500	1500	1800	7200	
Total relative abundance	1.00	3.56	4.87	2.88	2.07		
Without sciurids	1.00	3.50	4.80	2.88	1.90		

TABLE B.1d Comparison of the relative abundances (numbers captured/100 trap nights) of the **Ecotone** small mammal species during different time intervals at Taiga Biological Station. The overall relative abundance during 24 sampling-years is included \pm 1S.D.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)	Overall	S.D.
<i>Clethrionomys gapperi</i>	3.00	3.87	6.40	3.00	1.33	3.47	7.912
<i>Sorex cinereus</i>	2.44	2.67	3.67	3.00	1.44	2.61	5.305
<i>Peromyscus maniculatus</i>	0.00	1.13	0.60	0.40	0.17	0.49	1.888
<i>Microtus pennsylvanicus</i>	0.44	0.27	0.33	0.53	0.17	0.33	1.474
<i>Blarina brevicauda</i>	0.22	0.27	0.40	0.00	0.11	0.19	1.139
<i>Microsorex hoyi</i>	0.00	0.00	0.13	0.07	0.00	0.04	0.338
<i>Sorex arcticus</i>	0.22	0.07	0.00	0.00	0.00	0.04	0.448
<i>Synaptomys sp.</i>	0.11	0.00	0.00	0.07	0.06	0.04	0.338
<i>Zapus hudsonius</i>	0.00	0.00	0.07	0.00	0.17	0.06	0.637
<i>Condylura cristata</i>	0.00	0.07	0.00	0.00	0.00	0.01	0.204
<i>Glaucomys sabrinus</i>	0.00	0.07	0.07	0.00	0.06	0.04	0.338
<i>Tamias minimus</i>	0.11	0.13	0.93	0.40	0.22	0.38	1.329
<i>Tamiasciurus hudsonicus</i>	0.11	0.00	0.00	0.67	0.06	0.17	1.063
Number of trap nights	900	1500	1500	1500	1800	7200	
Total relative abundance	6.65	8.55	12.60	8.14	3.79		
Without sciurids	6.43	8.35	11.60	7.07	3.45		

TABLE B.1e Comparison of the relative abundances (numbers captured/100 trap nights) of **Jackpine Ridge** small mammal species during different time intervals at Taiga Biological Station. The overall relative abundance during 24 sampling-years is included \pm 1S.D.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)	Overall	S.D.
<i>Clethrionomys gapperi</i>	2.67	2.27	4.27	0.87	1.83	2.33	5.718
<i>Sorex cinereus</i>	1.67	0.60	0.67	0.47	0.00	0.57	2.562
<i>Peromyscus maniculatus</i>	0.00	4.53	2.40	0.53	0.06	1.57	9.355
<i>Blarina brevicauda</i>	0.00	0.07	0.00	0.00	0.00	0.01	0.204
<i>Glaucomys sabrinus</i>	0.00	0.00	0.07	0.00	0.06	0.03	0.282
<i>Tamias minimus</i>	0.00	0.13	0.53	0.33	0.17	0.25	0.944
<i>Tamiasciurus hudsonicus</i>	0.11	0.13	0.07	0.47	0.17	0.19	0.830
Number of trap nights	900	1500	1500	1500	1800	7200	
Total relative abundance	4.45	7.73	8.01	2.67	2.29		
Without sciurids	4.34	7.47	7.34	1.87	1.89		

TABLE B.1f Comparison of the relative abundances (numbers captured/100 trap nights) of **Jackpine Sandplain** small mammal species during different time intervals at Taiga Biological Station. The overall relative abundance during 25 sampling-years is included \pm 1S.D.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)	Overall	S.D.
<i>Clethrionomys gapperi</i>	0.56	1.11	3.13	1.60	1.17	1.51	0.436
<i>Sorex cinereus</i>	0.44	0.06	0.07	0.60	0.17	0.27	0.107
<i>Peromyscus maniculatus</i>	0.00	2.56	1.00	2.27	2.67	1.70	0.519
<i>Microtus pennsylvanicus</i>	0.00	0.00	0.07	0.00	0.00	0.01	0.014
<i>Synaptomys sp.</i>	0.11	0.00	0.00	0.00	0.00	0.02	0.022
<i>Phenacomys intermedius</i>	0.00	0.00	0.00	0.00	0.06	0.01	0.012
<i>Zapus hudsonius</i>	0.00	0.06	0.07	0.20	0.06	0.08	0.033
<i>Glaucomys sabrinus</i>	0.00	0.11	0.40	0.07	0.06	0.13	0.070
<i>Tamias minimus</i>	0.00	0.06	1.07	1.00	0.89	0.60	0.236
<i>Tamiasciurus hudsonicus</i>	0.00	0.11	0.07	0.00	0.00	0.04	0.022
Number of trap nights	900	1800	1500	1500	1800	7200	
Total relative abundance	1.11	4.07	5.88	5.74	5.08		
Without sciurids	1.11	3.79	4.34	4.67	4.13		

TABLE B.2a Summary of distribution and abundance of all small mammal species captured (**sciurids omitted**) by habitat at Taiga Biological Station. Species diversity and evenness measures are based on the Shannon Index of diversity. Habitat names have been abbreviated (ATB= Alder-Tamarack Bog; ASP= Aspen Upland; BSB= Blackspruce Bog; ECO= Ecotone; JPR= Jackpine Ridge; JPSP= Jackpine Sandplain).

Species	ATB	ASP	BSB	ECO	JPR	JPSP
<i>Clethrionomys gapperi</i>	154	319	118	250	168	117
<i>Sorex cinereus</i>	221	119	69	188	41	18
<i>Peromyscus maniculatus</i>	3	116	22	35	114	143
<i>Microtus pennsylvanicus</i>	36	20	7	24	0	1
<i>Blarina brevicauda</i>	5	5	0	14	1	0
<i>Microsorex hoyi</i>	2	1	1	3	0	0
<i>Sorex arcticus</i>	8	1	2	3	0	0
<i>Synaptomys sp.</i>	4	3	1	3	0	1
<i>Phenacomys intermedius</i>	0	3	0	0	0	1
<i>Zapus hudsonius</i>	0	7	1	4	0	6
<i>Condylura cristata</i>	0	0	0	1	0	0
Total caught	433	594	221	525	324	287
Total trap nights	7200	7200	7500	7200	7200	7500
Relative abundance	6.01	8.25	2.95	7.29	4.50	3.83
Species richness	8	10	8	10	4	7
Species diversity	1.146	1.245	1.153	1.277	0.988	1.027
Evenness	0.55	0.54	0.55	0.55	0.71	0.53
Total biomass	4539.9	8685.3	2935.7	6629.2	5044.6	4896.5
Relative biomass	63.06	120.64	38.64	92.07	70.06	65.65

TABLE B.2b Summary of distribution and abundance of all small mammal species captured (**sciurids included**) by habitat at Taiga Biological Station.

Species	ATB	ASP	BSB	ECO	JPR	JPSP
<i>Glaucomys sabrinus</i>	1	8	0	3	2	10
<i>Tamias minimus</i>	0	20	1	27	18	48
<i>Tamiasciurus hudsonicus</i>	5	3	4	12	14	3
Sciurids caught	6	31	5	42	34	61
Mammals captured in total	439	625	226	567	358	348
Total trap nights	7200	7200	7500	7200	7200	7500
Relative abundance	6.10	8.68	3.01	7.88	4.97	4.64
Species richness	10	13	10	13	7	10
Species diversity	1.208	1.424	1.245	1.508	1.290	1.422
Evenness	0.52	0.56	0.54	0.59	0.66	0.62
Total biomass	5645.1	11082.7	3366.3	10403.0	8650.9	8433.5
Relative biomass	78.41	153.93	44.39	144.48	120.14	112.81

TABLE B.3a Summary of the Alder-Tamarack Bog small mammal community (sciurids omitted) by grouped intervals in years at Taiga Biological Station.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)
<i>Clethrionomys gapperi</i>	32	39	64	15	4
<i>Sorex cinereus</i>	20	36	61	70	34
<i>Peromyscus maniculatus</i>	1	1	1	0	0
<i>Microtus pennsylvanicus</i>	3	1	10	15	7
<i>Blarina brevicauda</i>	1	1	2	0	1
<i>Microsorex hoyi</i>	0	0	1	0	1
<i>Sorex arcticus</i>	1	0	4	1	2
<i>Synaptomys sp.</i>	1	2	0	1	0
Total caught	59	80	143	102	49
Total trap nights	900	1500	1500	1500	1800
Relative abundance	6.55	5.34	9.55	6.81	2.67
Species richness	7	6	7	5	6
Species diversity	1.127	0.966	1.138	0.913	1.026
Evenness	0.58	0.54	0.59	0.57	0.57
Total biomass	723.8	915.2	1580.5	824.5	495.9
Relative biomass	80.43	61.01	105.36	54.97	27.55

TABLE B.3b Summary of the Alder-Tamarack Bog small mammal community (sciurids included) by grouped intervals in years at Taiga Biological Station.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)
<i>Clethrionomys gapperi</i>	32	39	64	15	4
<i>Sorex cinereus</i>	20	36	61	70	34
<i>Peromyscus maniculatus</i>	1	1	1	0	0
<i>Microtus pennsylvanicus</i>	3	1	10	15	7
<i>Blarina brevicauda</i>	1	1	2	0	1
<i>Microsorex hoyi</i>	0	0	1	0	1
<i>Sorex arcticus</i>	1	0	4	1	2
<i>Synaptomys sp.</i>	1	2	0	1	0
<i>Glaucomys sabrinus</i>	0	0	0	0	1
<i>Tamiasciurus hudsonicus</i>	0	0	4	0	1
Total caught	59	80	147	102	51
Total trap nights	900	1500	1500	1500	1800
Relative abundance	6.55	5.34	9.82	6.81	2.79
Species richness	7	6	8	5	8
Species diversity	1.127	0.966	1.232	0.913	1.178
Evenness	0.58	0.54	0.59	0.57	0.57
Total biomass	723.8	915.2	2382.4	824.5	799.2
Relative biomass	80.43	61.01	158.82	54.97	44.40

TABLE B.4a Summary of the Aspen Upland small mammal community (scurids omitted) by grouped intervals in years at Taiga Biological Station.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)
<i>Clethrionomys gapperi</i>	37	54	125	76	27
<i>Sorex cinereus</i>	7	27	27	33	25
<i>Peromyscus maniculatus</i>	0	37	27	25	27
<i>Microtus pennsylvanicus</i>	0	4	6	10	0
<i>Blarina brevicauda</i>	0	1	1	0	3
<i>Microsorex hoyi</i>	0	0	1	0	0
<i>Sorex arcticus</i>	1	0	0	0	0
<i>Synaptomys sp.</i>	0	0	2	1	0
<i>Phenacomys intermedius</i>	0	0	1	2	0
<i>Zapus hudsonius</i>	0	0	0	6	1
Total caught	45	123	190	153	83
Total trap nights	900	1500	1500	1500	1800
Relative abundance	4.56	8.21	12.67	10.21	4.62
Species richness	3	5	8	7	5
Species diversity	0.535	1.206	1.070	1.369	1.265
Evenness	0.49	0.75	0.51	0.70	0.79
Total biomass	591.4	1697.9	3140.7	2166.4	1088.9
Relative biomass	65.71	113.19	209.38	144.52	60.49

TABLE B.4b Summary of the Aspen Upland small mammal community (scurids included) by time intervals in years at Taiga Biological Station.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)
<i>Clethrionomys gapperi</i>	37	54	125	76	27
<i>Sorex cinereus</i>	7	27	27	33	25
<i>Peromyscus maniculatus</i>	0	37	27	25	27
<i>Microtus pennsylvanicus</i>	0	4	6	10	0
<i>Blarina brevicauda</i>	0	1	1	0	3
<i>Microsorex hoyi</i>	0	0	1	0	0
<i>Sorex arcticus</i>	1	0	0	0	0
<i>Synaptomys sp.</i>	0	0	2	1	0
<i>Phenacomys intermedius</i>	0	0	1	2	0
<i>Zapus hudsonius</i>	0	0	0	6	1
<i>Glaucomys sabrinus</i>	1	2	1	2	2
<i>Tamias minimus</i>	1	1	10	5	3
<i>Tamiasciurus hudsonicus</i>	0	1	0	1	1
Total caught	47	127	201	161	89
Total trap nights	900	1500	1500	1500	1800
Relative abundance	4.78	8.48	13.41	10.74	4.91
Species richness	5	8	10	10	8
Species diversity	0.718	1.341	1.240	1.544	1.466
Evenness	0.45	0.64	0.54	0.67	0.70
Total biomass	751.9	2157.0	3653.2	2813.4	1707.2
Relative biomass	83.55	143.80	243.57	187.65	94.85

TABLE B.5a Summary of the Blackspruce Bog small mammal community (scurids omitted) by grouped intervals in years at Taiga Biological Station.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)
<i>Clethrionomys gapperi</i>	4	22	47	28	17
<i>Sorex cinereus</i>	5	15	23	13	13
<i>Peromyscus maniculatus</i>	0	21	0	0	1
<i>Microtus pennsylvanicus</i>	0	5	0	1	1
<i>Microsorex hoyi</i>	0	0	1	0	0
<i>Sorex arcticus</i>	0	0	0	1	1
<i>Synaptomys sp.</i>	0	0	1	0	0
<i>Zapus hudsonius</i>	0	0	0	0	1
Total caught	9	63	72	43	34
Total trap nights	900	1800	1500	1500	1800
Relative abundance	1.00	3.56	4.80	2.88	1.90
Species richness	2	4	4	4	6
Species diversity	0.687	1.279	0.762	0.816	1.129
Evenness	0.99	0.92	0.55	0.59	0.63
Total biomass	81.9	929.2	1000.5	516.1	408.0
Relative biomass	9.10	51.62	66.69	34.41	22.66

TABLE B.5b Summary of the Blackspruce Bog small mammal community (scurids included) by grouped intervals in years at Taiga Biological Station.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)
<i>Clethrionomys gapperi</i>	4	22	47	28	17
<i>Sorex cinereus</i>	5	15	23	13	13
<i>Peromyscus maniculatus</i>	0	21	0	0	1
<i>Microtus pennsylvanicus</i>	0	5	0	1	1
<i>Microsorex hoyi</i>	0	0	1	0	0
<i>Sorex arcticus</i>	0	0	0	1	1
<i>Synaptomys sp.</i>	0	0	1	0	0
<i>Zapus hudsonius</i>	0	0	0	0	1
<i>Tamias minimus</i>	0	0	1	0	0
<i>Tamiasciurus hudsonicus</i>	0	1	0	0	3
Total caught	9	65	73	43	37
Total trap nights	900	1800	1500	1500	1800
Relative abundance	1	3.62	4.87	2.88	2.07
Species richness	2	5	5	4	7
Species diversity	0.687	1.339	0.824	0.816	1.319
Evenness	0.99	0.83	0.51	0.59	0.68
Total biomass	81.9	929.2	1043.7	713.7	597.8
Relative biomass	9.10	51.62	69.57	47.57	33.20

TABLE B.6a Summary of the Ecotone small mammal community
(sciurids omitted) by grouped intervals in years at Taiga Biological Station.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)
<i>Clethrionomys gapperi</i>	27	58	96	45	24
<i>Sorex cinereus</i>	22	40	55	45	26
<i>Peromyscus maniculatus</i>	0	17	9	6	3
<i>Microtus pennsylvanicus</i>	4	4	5	8	3
<i>Blarina brevicauda</i>	2	4	6	0	2
<i>Microsorex hoyi</i>	0	0	2	1	0
<i>Sorex arcticus</i>	2	1	0	0	0
<i>Synaptomys sp.</i>	1	0	0	1	1
<i>Zapus hudsonius</i>	0	0	1	0	3
<i>Condylura cristata</i>	0	1	0	0	0
Total caught	58	125	174	106	62
Total trap nights	900	1500	1500	1500	1800
Relative abundance	6.43	8.35	11.60	7.07	3.45
Species richness	6	7	7	6	7
Species diversity	1.210	1.290	1.145	1.173	1.349
Evenness	0.68	0.66	0.59	0.65	0.69
Total biomass	625.5	1721.3	2439.8	1168.1	674.5
Relative biomass	69.49	114.75	162.65	77.88	37.48

TABLE B.6b Summary of the Ecotone small mammal community
(sciurids included) by grouped intervals in years at Taiga Biological Station.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)
<i>Clethrionomys gapperi</i>	27	58	96	45	24
<i>Sorex cinereus</i>	22	40	55	45	26
<i>Peromyscus maniculatus</i>	0	17	9	6	3
<i>Microtus pennsylvanicus</i>	4	4	5	8	3
<i>Blarina brevicauda</i>	2	4	6	0	2
<i>Microsorex hoyi</i>	0	0	2	1	0
<i>Sorex arcticus</i>	2	1	0	0	0
<i>Synaptomys sp.</i>	1	0	0	1	1
<i>Zapus hudsonius</i>	0	0	1	0	3
<i>Condylura cristata</i>	0	1	0	0	0
<i>Glaucomys sabrinus</i>	0	1	1	0	1
<i>Tamias minimus</i>	1	2	14	6	4
<i>Tamiasciurus hudsonicus</i>	1	0	0	10	1
Total caught	60	128	189	122	68
Total trap nights	900	1500	1500	1500	1800
Relative abundance	6.65	8.55	12.60	8.14	3.79
Species richness	8	9	9	8	10
Species diversity	1.339	1.386	1.35	1.495	1.605
Evenness	0.64	0.63	0.61	0.72	0.7
Total biomass	900.9	1921.5	3142.7	3244.7	1193.2
Relative biomass	100.09	120.60	209.51	216.32	66.30

TABLE B.7a Summary of the Jackpine Ridge small mammal community
(**sciurids omitted**) by grouped intervals in years at Taiga Biological Station.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)
<i>Clethrionomys gapperi</i>	24	34	64	13	33
<i>Sorex cinereus</i>	15	9	10	7	0
<i>Peromyscus maniculatus</i>	0	68	36	8	2
<i>Blarina brevicauda</i>	0	1	0	0	0
Total caught	39	112	110	28	35
Total trap nights	900	1500	1500	1500	1800
Relative abundance	4.34	7.47	7.34	1.87	1.89
Species richness	2	4	3	3	2
Species diversity	0.666	0.910	0.899	1.061	0.133
Evenness	0.96	0.66	0.82	0.97	0.19
Total biomass	443.4	1806.7	1778.3	360.6	655.6
Relative biomass	49.27	120.45	118.56	24.04	36.42

TABLE B.7b Summary of the Jackpine Ridge small mammal community
(**sciurids included**) by grouped intervals in years at Taiga Biological Station.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)
<i>Clethrionomys gapperi</i>	24	34	64	13	33
<i>Sorex cinereus</i>	15	9	10	7	0
<i>Peromyscus maniculatus</i>	0	68	36	8	2
<i>Blarina brevicauda</i>	0	1	0	0	0
<i>Glaucomys sabrinus</i>	0	0	1	0	1
<i>Tamias minimus</i>	0	2	8	5	3
<i>Tamiasciurus hudsonicus</i>	1	2	1	7	3
Total caught	40	116	120	40	42
Total trap nights	900	1500	1500	1500	1800
Relative abundance	4.45	7.73	8.01	2.67	2.29
Species richness	3	6	6	5	5
Species diversity	0.767	1.052	1.164	1.557	0.739
Evenness	0.7	0.59	0.65	0.97	0.46
Total biomass	645.2	2283.6	2321.7	1924.2	1476.2
Relative biomass	71.69	152.25	154.79	128.28	82.01

TABLE B.8a Summary of the Jackpine Sandplain small mammal community (scurids omitted) by grouped intervals in years at Taiga Biological Station.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)
<i>Clethrionomys gapperi</i>	5	20	47	24	21
<i>Sorex cinereus</i>	4	1	1	9	3
<i>Peromyscus maniculatus</i>	0	46	15	34	48
<i>Microtus pennsylvanicus</i>	0	0	1	0	0
<i>Synaptomys sp.</i>	1	0	0	0	0
<i>Phenacomys intermedius</i>	0	0	0	0	1
<i>Zapus hudsonius</i>	0	1	1	3	1
Total caught	10	68	65	70	74
Total trap nights	900	1800	1500	1500	1800
Relative abundance	1.11	3.79	4.34	4.67	4.13
Species richness	3	4	5	4	5
Species diversity	0.943	0.748	0.766	1.117	0.884
Evenness	0.86	0.54	0.48	0.81	0.55
Total biomass	128.7	1270.3	1257.1	1060.8	1206.8
Relative biomass	14.30	70.57	83.81	70.71	67.05

TABLE B.8b Summary of the Jackpine Sandplain small mammal community (scurids included) by grouped intervals in years at Taiga Biological Station.

Species	(77-79)	(80-85)	(86-90)	(91-95)	(96-01)
<i>Clethrionomys gapperi</i>	5	20	47	24	21
<i>Sorex cinereus</i>	4	1	1	9	3
<i>Peromyscus maniculatus</i>	0	46	15	34	48
<i>Microtus pennsylvanicus</i>	0	0	1	0	0
<i>Synaptomys sp.</i>	1	0	0	0	0
<i>Phenacomys intermedius</i>	0	0	0	0	1
<i>Zapus hudsonius</i>	0	1	1	3	1
<i>Glaucomys sabrinus</i>	0	2	6	1	1
<i>Tamias minimus</i>	0	1	16	15	16
<i>Tamiasciurus hudsonicus</i>	0	2	1	0	0
Total caught	10	73	88	86	91
Total trap nights	900	1800	1500	1500	1800
Relative abundance	1.11	4.07	5.88	5.74	5.08
Species richness	3	7	8	6	7
Species diversity	0.943	1.019	1.333	1.433	1.243
Evenness	0.86	0.52	0.64	0.8	0.64
Total biomass	128.7	1974.6	2683.1	1724.9	1949.4
Relative biomass	14.30	109.70	178.87	114.98	108.31

TABLE B.9 Characteristics of the small mammal communities (scurids omitted) in six habitats at Taiga Biological Station. The Shannon Index of diversity and evenness for the small mammals are compared across sites during different time intervals .

Habitat	Species diversity	Species richness	Evenness	Relative abundance	Relative biomass
Alder-Tamarack Bog					
77 - 79	1.13	7	0.58	6.55	80.43
80 - 85	0.97	6	0.54	5.34	61.01
86 - 90	1.14	7	0.59	9.55	105.36
91 - 95	0.91	5	0.57	6.81	54.97
96 - 01	1.03	6	0.57	2.67	27.55
Aspen Upland					
77 - 79	0.53	3	0.49	4.56	65.71
80 - 85	1.21	5	0.75	8.21	113.19
86 - 90	1.07	8	0.51	12.67	209.40
91 - 95	1.37	7	0.70	10.21	144.52
96 - 01	1.27	5	0.79	4.62	60.50
Blackspruce Bog					
77 - 79	0.69	2	0.99	1.00	9.10
80 - 85	1.28	4	0.83	3.56	51.62
86 - 90	0.76	4	0.55	4.80	66.69
91 - 95	0.82	4	0.59	2.88	34.40
96 - 01	1.13	6	0.63	1.90	22.66
Ecotone					
77 - 79	1.21	6	0.68	6.43	69.49
80 - 85	1.29	7	0.66	8.35	114.75
86 - 90	1.14	7	0.59	11.60	162.65
91 - 95	1.17	6	0.65	7.07	77.88
96 - 01	1.35	7	0.69	3.45	37.48
Jackpine Ridge					
77 - 79	0.67	2	0.96	4.34	49.27
80 - 85	0.91	4	0.66	7.47	120.45
86 - 90	0.90	3	0.82	7.34	118.56
91 - 95	1.06	3	0.97	1.87	24.04
96 - 01	0.13	2	0.19	1.89	36.42
Jackpine Sandplain					
77 - 79	0.94	3	0.86	1.11	14.30
80 - 85	0.75	4	0.54	3.79	70.57
86 - 90	0.77	5	0.48	4.34	83.80
91 - 95	1.12	4	0.81	4.67	70.71
96 - 01	0.88	5	0.55	4.13	67.05

TABLE B.10 Characteristics of the small mammal communities (scurids included) in six habitats at Taiga Biological Station. The Shannon Index of diversity and evenness for the small mammals are compared across sites during different time intervals .

Habitat	Species diversity	Species richness	Evenness	Relative abundance	Relative biomass	
Alder-Tamarack Bog	77 - 79	1.13	7	0.58	6.55	80.43
	80 - 85	0.97	6	0.54	5.34	61.01
	86 - 90	1.23	8	0.59	9.82	158.82
	91 - 95	0.91	5	0.57	6.81	54.97
	96 - 01	1.18	8	0.57	2.79	44.40
Aspen Upland	77 - 79	0.72	5	0.45	4.78	83.55
	80 - 85	1.34	8	0.64	8.48	143.80
	86 - 90	1.24	10	0.54	13.41	243.57
	91 - 95	1.54	10	0.67	10.74	187.65
	96 - 01	1.47	8	0.70	4.91	94.85
Blackspruce Bog	77 - 79	0.69	2	0.99	1.00	9.10
	80 - 85	1.34	5	0.78	3.62	51.62
	86 - 90	0.82	5	0.51	4.87	69.57
	91 - 95	0.82	4	0.59	2.88	47.57
	96 - 01	1.32	7	0.68	2.07	33.20
Ecotone	77 - 79	1.34	8	0.64	6.65	100.09
	80 - 85	1.39	9	0.63	8.55	120.60
	86 - 90	1.35	9	0.61	12.60	209.51
	91 - 95	1.49	8	0.72	8.14	216.32
	96 - 01	1.60	10	0.70	3.79	66.30
Jackpine Ridge	77 - 79	0.77	3	0.70	4.45	71.69
	80 - 85	1.05	6	0.59	7.73	152.25
	86 - 90	1.16	6	0.65	8.01	154.79
	91 - 95	1.56	5	0.97	2.67	128.28
	96 - 01	0.74	5	0.46	2.29	82.01
Jackpine Sandplain	77 - 79	0.94	3	0.86	1.11	14.30
	80 - 85	1.02	7	0.52	4.07	109.70
	86 - 90	1.33	8	0.64	5.88	178.87
	91 - 95	1.43	6	0.80	5.74	114.98
	96 - 01	1.24	7	0.64	5.08	108.31

TABLE C.1 A comparison of vegetation surveys across six sites at Taiga Biological Station completed during different periods of time. Three of the most dominant habitat variables (in descending order of mean percent coverage) were selected from each survey.

(a)

Alder-Tamarack Bog	1976	1982	2000
Ground Cover	Sphagnum sp. Litter/organic debris Dicranum sp.	Sphagnum sp. Standing water Litter/organic debris	Sphagnum sp. Litter/organic debris Standing water
Ferns And Allies	Equisetum sylvaticum	Equisetum sylvaticum	Equisetum sylvaticum Lycopodium annotinum Dryopteris cristata
Low Shrubs (<1m)	Chamaedaphne calyculata Ledum groenlandicum Gaultheria hispidula	Ledum groenlandicum Chamaedaphne calyculata Oxycoccus microcarpos	Ledum groenlandicum Chamaedaphne calyculata Oxycoccus microcarpos
Tall Shrubs (>1m)	Alnus sp. Salix spp.	Alnus sp. Betula glandulosa Salix spp.	Alnus rugosa Betula glandulosa Salix spp.
Trees	Larix laricina Picea mariana	Larix laricina Picea mariana	Larix laricina Picea mariana Betula papyrifera
Herbaceous Cover	Smilicina trifolia Trientalis borealis Viola sp.	Smilicina trifolia Viola sp. Trientalis borealis	Smilicina trifolia Potentilla palustris Trientalis borealis
Grasses/Rushes/ Sedges	Cyperaceae Gramineae	Cyperaceae	Carex disperma Carex aquatilis Calamagrostis canadensis

(b)

Aspen Upland	1976	1982	2000
Ground Cover	Litter/organic debris Lichens Pleurozium spp.	Litter/organic debris Lichens Bare rock	Litter/organic debris Bare rock Lichens
Ferns And Allies			Equisetum sylvaticum Lycopodium spp. Dryopteris cristata
Low Shrubs (<1m)	Diervilla lonicera Rosa acicularis Rubus pubescens	Diervilla lonicera Vaccinium spp. Potentilla tridentata	Diervilla lonicera Vaccinium myrtilloides Arctostaphylos uva-ursi
Tall Shrubs (>1m)	Amelanchier alnifolia	Amelanchier alnifolia Alnus crispa Salix spp.	Salix spp. Amelanchier alnifolia Prunus pensylvanica
Trees	Populus tremuloides Picea mariana Pinus banksiana	Populus tremuloides Picea mariana Pinus banksiana	Populus tremuloides Pinus banksiana Picea mariana
Herbaceous Cover	Fragaria virginiana Aster umbellatus Galium boreale	Fragaria virginiana A. androsaemifolium Vicia americana	Maianthemum canadense Aralia nudicaulis Fragaria virginiana
Grasses/Rushes/ Sedges	Gramineae	Gramineae Cyperaceae	Schizachne purpurascens Danthonia spicata Oryzopsis asperifolia

TABLE C.1 vegetation surveys continued.

(c)

Blackspruce Bog	1976	1982	2000
Ground Cover	Pleurozium spp. Sphagnum spp. Litter/organic debris	Sphagnum spp. Moss spp. Dead wood, logs	Sphagnum spp. Dead wood, logs Litter/organic debris
Ferns And Allies			
Low Shrubs (<1m)	Ledum groenlandicum Vaccinium vitis-idaea Oxycoccus microcarpos	Ledum groenlandicum Vaccinium vitis-idaea Oxycoccus microcarpos	Ledum groenlandicum Vaccinium vitis-idaea Oxycoccus microcarpos
Tall Shrubs (>1m)			
Trees	Picea mariana	Picea mariana Pinus banksiana Populus tremuloides	Picea mariana Pinus banksiana Larix laricina
Herbaceous Cover	Smilacina trifolia	Smilacina trifolia Epilobium angustifolium	Smilacina trifolia
Grasses/Rushes/ Sedges		Eriophorum spissum	Eriophorum spissum

(d)

Ecotone	1976	1982	2000
Ground Cover	Litter/organic debris Sphagnum spp. Pleurozium spp.	Litter/organic debris Sphagnum spp. Moss spp.	Litter/organic debris Sphagnum spp. Dead wood, logs
Ferns And Allies	Lycopodium spp.	Lycopodium spp. Equisetum sylvaticum	Equisetum sylvaticum Lycopodium spp. Dryopteris cristata
Low Shrubs (<1m)	Ledum groenlandicum Chimaphila umbellata Rubus idaeus	Diervilla lonicera Ledum groenlandicum Rubus idaeus	Ledum groenlandicum Cornus canadensis Vaccinium spp.
Tall Shrubs (>1m)	Amelanchier alnifolia Alnus sp.	Alnus spp. Betula glandulosa Salix spp.	Alnus rugosa Salix spp. Betula glandulosa
Trees	Pinus banksiana Populus tremuloides	Populus tremuloides Picea mariana Larix laricina	Picea mariana Populus tremuloides Pinus banksiana
Herbaceous Cover	Smilacina trifolia Viola spp. Clintonia borealis	Epilobium angustifolium Clintonia borealis Viola spp.	Aralia nudicaulis Epilobium angustifolium Maianthemum canadense
Grasses/Rushes/ Sedges	Gramineae Cyperaceae	Cyperaceae	Carex disperma Schizachne purpurascens Carex aquatilis

TABLE C.1 vegetation surveys continued.

(e)

Jackpine Ridge	1976	1982	2000
Ground Cover	Litter/organic debris Lichens Pleurozium spp.	Litter/organic debris Bare rock Ceratonotus purpureus	Litter/organic debris Polytrichum spp. Bare rock
Ferns And Allies		Dryopteris cristata	Lycopodium complanatum Polypodium virginianum
Low Shrubs (<1m)	Diervilla lonicera Chimaphila umbellata Linnaea borealis	Chimaphila umbellata Linnaea borealis Ledum groenlandicum	Chimaphila umbellata Linnaea borealis Diervilla lonicera
Tall Shrubs (>1m)		Salix spp.	Salix spp. Prunus pensylvanica
Trees	Picea glauca	Populus tremuloides Pinus banksiana Picea mariana	Pinus banksiana Picea mariana Populus tremuloides
Herbaceous Cover	Aralia spp.	Polygonum cilinoides	Maianthum canadense Epilobium angustifolium Goodyera repens
Grasses/Rushes/ Sedges		Cyperaceae	Carex foenea Oryzopsis asperifolia Oryzopsis pungens

(f)

Jackpine Sandplain	1976	1982	2000
Ground Cover	Pleurozium spp. Lichens Dicranum spp.	Litter/organic debris Bare soil/sand Dead wood, logs	Litter/organic debris Lichens Dead wood, logs
Ferns And Allies		Lycopodium complanatum	Lycopodium complanatum
Low Shrubs (<1m)	Vaccinium myrtilloides Arctostaphylos uva-ursi Linnaea borealis	Vaccinium spp. Arctostaphylos uva-ursi Linnaea borealis	Vaccinium spp. Arctostaphylos uva-ursi Cornus canadensis
Tall Shrubs (>1m)		Alnus crispa	Alnus crispa Salix spp. Amelanchier alnifolia
Trees	Pinus banksiana Picea mariana	Pinus banksiana Picea mariana Abies balsamea	Pinus banksiana Picea mariana Populus tremuloides
Herbaceous Cover	Maianthum canadense Pyrola spp.	Maianthum canadense Solidago spp. Campanula rotundifolia	Maianthum canadense Melampyrum lineare Solidago hispida
Grasses/Rushes/ Sedges	Gramineae	Cyperaceae Gramineae	Oryzopsis pungens Oryzopsis asperifolia Cyperaceae

TABLE C.2**Field data sheets for the 2000-01 vegetation survey**

TABLE C.3 Distribution of logs found on the Aspen Upland and Ecotone plots. A log is any coarse woody debris ≥ 28.5 cm on the Aspen Upland and ≥ 34.5 cm on the Ecotone in circumference (based on the median value obtained from all coarse woody debris found in each separate plot).

Aspen Upland

(a) *Sorex cinereus*

	0 captures	1 capture	2 captures	3 captures	≥ 4 captures
Maximum	58.00	93.00	77.00	69.00	69.00
Median	38.00	36.50	42.75	34.50	37.75
Minimum	30.00	28.50	29.00	29.00	29.00
Mean	39.92	41.80	43.08	41.06	44.88
S.D.	8.88	14.55	9.99	14.10	16.06
Var	78.86	211.64	99.80	198.67	257.76
N = (logs)	24	30	24	8	8
n = (quadrats)	33	33	23	5	6
Mean logs/quadrat	0.73	0.91	1.04	1.60	1.33

Aspen Upland

(b) *Clethrionomys gapperi*

	0 captures	1 capture	2 captures	3 captures	4 captures	5 captures	6 captures	≥ 7 captures
Maximum	48.00	77.00	52.00	53.00	69.00	58.00	45.00	93.00
Median	32.75	42.00	42.50	34.25	45.75	44.25	38.50	41.00
Minimum	29.00	29.50	30.00	29.00	32.00	30.00	28.50	30.50
Mean	35.08	45.35	40.86	36.75	46.35	43.75	37.30	42.09
S.D.	7.19	14.11	8.31	7.98	12.20	12.18	7.80	13.48
Var	51.74	199.02	69.06	63.60	148.82	148.33	60.82	181.76
N = (logs)	6	17	7	14	10	10	5	23
n = (quadrats)	13	18	14	12	13	14	6	10
Mean logs/quadrat	0.46	0.94	0.50	1.17	0.77	0.71	0.83	2.30

TABLE C.3 Distribution of the **median logs** (cm) found at trapping stations with different rates of capture continued.

Ecotone

(c) *Sorex cinereus*

	0 captures	1 capture	2 captures	3 captures	≥4 captures
Maximum	81.50	86.00	68.00	75.00	78.00
Median	47.75	47.50	49.00	43.00	46.75
Minimum	35.50	34.50	35.00	35.00	34.50
Mean	48.61	50.93	49.90	49.00	48.81
S.D.	10.24	15.13	11.97	14.47	14.02
Var	104.76	228.80	143.21	209.27	196.62
N = (logs)	62	23	15	15	8
n = (quadrats)	34	17	16	14	19
Mean logs/quadrat	1.82	1.35	0.94	1.07	0.42

Ecotone

(d) *Clethrionomys gapperi*

	0 captures	1 capture	2 captures	3 captures	4 captures	5 captures	6 captures	≥7 captures
Maximum	65.50	81.50	69.50	69.50	86.00	57.00	62.00	76.00
Median	45.00	50.25	46.00	42.50	53.50	48.00	41.00	42.00
Minimum	36.00	35.50	34.50	35.00	35.00	34.50	35.00	37.00
Mean	47.63	51.81	48.87	46.00	55.50	47.75	43.75	49.59
S.D.	9.22	11.53	11.52	10.48	18.75	7.67	8.74	14.57
Var	85.08	132.89	132.80	109.85	351.68	58.77	76.46	212.31
N = (logs)	12	26	31	23	11	6	10	11
n = (quadrats)	16	21	20	17	9	6	6	5
Mean logs/quadrat	0.75	1.24	1.55	1.35	1.22	1.00	1.67	2.20

TABLE C.4 Distribution of all coarse woody debris (cm) found at trapping stations with different rates of capture on the Aspen Upland and Ecotone plots.

Aspen Upland

(a) *Sorex cinereus*

	0 captures	1 capture	2 captures	3 captures	≥4 captures
Maximum	58.00	93.00	77.00	69.00	65.00
Median	26.25	29.50	26.50	32.00	30.50
Minimum	12.00	12.50	9.50	16.50	23.00
Mean	28.82	32.90	30.99	34.27	37.25
S.D.	11.51	15.78	13.67	14.23	18.87
Var	132.47	249.16	186.98	202.61	356.23
N = (logs)	58	65	52	13	4
n = (quadrats)	33	33	23	5	6
Mean logs/quadrat	1.76	1.97	2.26	2.60	0.67

Aspen Upland

(b) *Clethrionomys gapperi*

	0 captures	1 capture	2 captures	3 captures	4 captures	5 captures	6 captures	≥7 captures
Maximum	48.00	77.00	52.00	53.00	69.00	58.00	45.00	93.00
Median	27.50	26.75	23.00	28.00	28.00	30.00	23.00	34.75
Minimum	11.00	9.50	12.00	13.00	12.50	13.00	14.50	12.00
Mean	26.21	33.40	27.68	28.71	33.00	32.29	25.19	37.07
S.D.	10.10	16.14	11.87	10.42	14.62	15.45	9.81	15.11
Var	102.09	260.40	140.87	108.63	213.69	238.76	96.29	228.28
N = (logs)	14	42	19	29	23	19	16	30
n = (quadrats)	13	18	14	12	13	14	6	10
Mean logs/quadrat	1.08	2.33	1.36	2.42	1.77	1.36	2.67	3.00

TABLE C.4 Distribution of **all coarse woody debris** (cm) found at trapping stations with different rates of capture continued.

Ecotone

(c) *Sorex cinereus*

	0 captures	1 capture	2 captures	3 captures	≥4 captures
Maximum	81.50	86.00	68.00	75.00	78.00
Median	35.50	33.75	32.50	36.50	34.50
Minimum	14.50	16.00	14.00	13.50	12.50
Mean	36.89	37.67	34.81	38.52	34.87
S.D.	14.44	16.50	15.45	17.57	18.74
Var	208.54	272.38	238.80	308.70	351.19
N = (logs)	123	50	37	25	15
n = (quadrats)	34	17	16	14	19
Mean logs/quadrat	3.62	2.94	2.31	1.79	0.79

Ecotone

(d) *Clethrionomys gapperi*

	0 captures	1 capture	2 captures	3 captures	4 captures	5 captures	6 captures	≥7 captures
Maximum	65.50	81.50	69.50	69.50	86.00	57.00	62.00	76.00
Median	28.00	40.75	34.50	33.00	29.25	29.00	37.00	39.00
Minimum	12.50	16.00	13.00	13.50	16.00	18.00	15.00	19.50
Mean	32.41	42.15	37.31	34.34	37.50	33.56	37.90	42.18
S.D.	15.79	16.47	15.04	12.80	21.26	12.38	11.71	15.78
Var	249.39	271.23	226.23	163.81	452.16	153.34	137.12	248.91
N = (logs)	27	40	60	56	24	17	15	17
n = (quadrats)	16	21	20	17	9	6	6	5
Mean logs/quadrat	1.69	1.90	3.00	3.29	2.67	2.83	2.50	3.40

TABLE C.5a Summary of *Clethrionomys gapperi* ATB habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

	LOW SHRUBS (< 1m)		TALL SHRUBS (>1m)	
<i>Andromeda glaucophylla</i>				
<i>Arctostaphylos uva-ursi</i>	15			
<i>Chamaedaphne calyculata</i>	17			
<i>Chimaphila umbellata</i>	17			
<i>Cornus canadensis</i>	16			
<i>Diervilla lonicera</i>	16	1		
<i>Gaultheria hispidula</i>		1		
<i>Juniperus communis</i>		1		
<i>Kalmia polifolia</i>		46		
<i>Ledum groenlandicum</i>				
<i>Linnaea borealis</i>				
<i>Lonicera dioica</i>				
<i>Lonicera villosa</i>		1		
<i>Oxycoccus microcarpos</i>		3		
<i>Potentilla tridentata</i>				
<i>Ribes glandulosum</i>				
<i>Ribes oxycanthoides</i>				
<i>Ribes triste</i>				
<i>Rosa acicularis</i>				
<i>Rubus chamaemorus</i>				
<i>Rubus idaeus</i>				
<i>Rubus pubescens</i>			1	
<i>Shepherdia canadensis</i>			1	
<i>Spiraea alba</i>				
<i>Symphoricarpos albus</i>				
<i>Vaccinium angustifolium</i>				
<i>Vaccinium caespitosum</i>				
<i>Vaccinium myrtilloides</i>				
<i>Vaccinium vitis-idaea</i>				
<i>Alnus crispa</i>				
<i>Alnus rugosa</i>			24	
<i>Amelanchier alnifolia</i>			20	
<i>Betula glandulosa</i>				
<i>Cornus stolonifera</i>				
<i>Prunus pensylvanica</i>				
<i>Rhamnus alnifolia</i>				
<i>Salix</i> spp.				2
<i>Viburnum edule</i>				
			25	16
			30	15
			21	39

TABLE C.5a Summary of *Clethrionomys gapperi* ATB habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

TREES			
Abies balsamea % cover			
Abies balsamea basal area			
Abies balsamea seedlings			
Betula papyrifera % cover			
Betula papyrifera basal area			
Betula papyrifera seedlings			
Larix laricina % cover	10	2	2
Larix laricina basal area	9	1	2
Larix laricina seedlings	15	3	1
Picea glauca % cover	7	1	1
Picea glauca basal area			
Picea glauca seedlings			
Picea mariana % cover	5		1
Picea mariana basal area			
Picea mariana seedlings			
Pinus banksiana % cover			
Pinus banksiana basal area			
Pinus banksiana seedlings			
Populus balsamifera % cover			
Populus balsamifera basal area			
Populus balsamifera seedlings			
Populus tremuloides % cover			
Populus tremuloides basal area			
Populus tremuloides seedlings			
Snag basal area			1
Actaea rubra			2
Antennaria neglecta			
Apocynum androsaemifolium			1
Aquilegia canadensis			
Aralia nudicaulis			
Aster ciliolatus			
Aster puniceus			
Aster umbellatus			
Bidens cernua			
Caltha palustris			
Campanula aparinoides			
Campanula rotundifolia			
Clintonia borealis			
Comandra pallida			
	7	1	24
	2	2	
	4	1	1

TABLE C.5a Summary of *Clethrionomys gapperi* ATB habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

GRASSES / RUSHES / SEDGES										Alder-Tamarack Bog		
Agropyron trachycaulum											<i>Clethrionomys</i> captures/quadrat	No. of quadrats/capture category
Agrostis scabra	2	3	3	14							0 captures	29
Calamagrostis canadensis	2	4	1	11							1 capture	30
Carex aquatilis	2	3	1	10							2 captures	19
Carex aurea	1	2		13							3 captures	12
Carex canescens	2	6	1	13							≥ 4 captures	10
Carex disperma					1							
Carex foenea												
Carex intumescens												
Carex paupercula												
Carex spp.												
Cinnia latifolia												
Danthonia spicata												
Eriophorum spissum												
Glyceria grandis												
Graminoids												
Juncus dudleyi												
Oryzopsis asperifolia												
Oryzopsis pungens												
Schizachne purpurascens												
Scripus cyperinus												
											Total	100

TABLE C.5b Summary of *Sorex cinereus* habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats. Quadrats are grouped according to their capture rate(s) from 0 to ≥ 4 small mammals recorded at each trap marker. The trap markers are located within the centre of each surveyed vegetation quadrat (100 trap markers/plot).

Alder-Tamarack Bog 4m ² quadrats - <i>Sorex cinereus</i> capture summary		GROUND COVER															FERNS AND ALLIES																										
Number of Captures	Bare rock	Bare soil/sand	Standing water	Litter/organic debris	Dead wood, logs	Dead wood, branches	Lichens, crustose soil	Lichens, crustose rock	Lichens, crustose bark	Lichens, foliose soil	Lichens, foliose rock	Lichens, foliose bark	Lichens, fruticose soil	Lichens, fruticose rock	Lichens, fruticose bark	Arboreal lichens	Mushrooms/gilled	Mushrooms/pored	Fungi, jelly	Fungi, bracket	Black Rock fungus	Calliigon sp.	Ceratodon purpureus	Climacium dendroides	Dicranum spp.	Hedwigia ciliata	Moss spp.	Pleurozium schreberi	Polytrichum spp.	Sphagnum spp.	Dryopteris cristata	Equisetum sylvaticum	Gymnocarpium dryopteris	Lycopodium annotinum	Lycopodium clavatum	Lycopodium complanatum	Lycopodium dendroideum	Polypodium virginianum					
0	0	0	13	38	7	7	0	0	1	0	0	2	1	0	3	0	1	0	0	0	0	0	0	0	1	0	0	1	0	74	11												
1			26	46	2	4		1			2				2							1			1			1	83	7													
2			17	33	5	4		1			2	1			2							1					1	79	7														
3			14	32	3	4		1			2				3		1					1		1				78	1	8		1											
≥ 4			16	36	3	4		1			2	1		1								1		2			2	80	8														

TABLE C.5b Summary of *Sorex cinereus* ATB habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

TREES	
Abies balsamea % cover	
Abies balsamea basal area	
Abies balsamea seedlings	
Betula papyrifera % cover	
Betula papyrifera basal area	
Betula papyrifera seedlings	
Larix laricina % cover	12 3 3
Larix laricina basal area	10 2 2
Larix laricina seedlings	9 2 2
Picea glauca % cover	15 2 2
Picea glauca basal area	12 1 2
Picea glauca seedlings	
Picea mariana % cover	2
Picea mariana basal area	1 1
Picea mariana seedlings	4 1 1
Pinus banksiana % cover	
Pinus banksiana basal area	
Pinus banksiana seedlings	
Populus balsamifera % cover	
Populus balsamifera basal area	
Populus balsamifera seedlings	
Populus tremuloides % cover	
Populus tremuloides basal area	
Populus tremuloides seedlings	
Snag basal area	4
Actaea rubra	
Antennaria neglecta	1
Apocynum androsaemifolium	
Aquilegia canadensis	1
Aralia nudicaulis	
Aster ciliolatus	
Aster puniceus	
Aster umbellatus	
Bidens cernua	
Caltha palustris	
Campanula aparinoides	
Campanula rotundifolia	
Clintonia borealis	
Comandra pallida	2

TABLE C.5b Summary of *Sorex cinereus* ATB habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

HERBACEOUS LAYER	
Corydalis sempervirens	
Cyrtopodium acaule	
Epilobium angustifolium	
Fragaria virginiana	
Galium boreale	
Galium trifidum	
Galium triflorum	
Geocalon lividum	
Goodyera repens	
Halenia deflexa	
Hieracium scabrusculum	
Lathyrus ochroleucus	
Lathyrus venosus	
Lysimachia thyrsiflora	
Maianthemum canadense	
Melampyrum lineare	
Montropa uniflora	
Petasites palmatus	
Polygonum cilinoides	
Potentilla palustris	1
Prenathes alba	
Pyrola asarifolia	
Pyrola rotundifolia	
Pyrola virens	
Ranunculus lapponicus	
Sanicula marilandica	
Scutellaria galericulata	
Smilacina trifolia	4
Solidago hispida	
Solidago uliginosa	
Stellaria longifolia	
Streptopus roseus	
Taraxacum officinale	
Trientalis borealis	
Vicia americana	
Viola adunca	
Viola pallens	1
	2
	5
	8
	1
	2
	2
	3
	5
	1
	2
	1

TABLE C.5b Summary of *Sorex cinereus* ATB habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

GRASSES / RUSHES / SEDGES										Alder-Tamarack Bog		
Agropyron trachycaulum												
Agrostis scabra												
Calamagrostis canadensis	1	2	1	11						2	0 captures	9
Carex aquatilis												
Carex aurea												
Carex canescens	2	3	1	9							1 capture	25
Carex disperma												
Carex foenea	2	4	1	13							2 captures	32
Carex intumescens												
Carex paupercula	2	4	2	13							3 captures	16
Carex spp.	2	3	2	14							≥4 captures	18
Cinnia latifolia												
Danthonia spicata												
Eriophorum spissum												
Glyceria grandis												
Graminoids												
Juncus dudleyi												
Oryzopsis asperifolia												
Oryzopsis pungens												
Schizachne purpurascens												
Scripus cyperinus												
<i>S. cinereus</i> captures/quadrat												
Total												100
												No. of quadrats/capture category

TABLE C.5c Summary of *Clethrionomys gapperi* habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats. Quadrats are grouped according to their capture rate(s) from 0 to ≥ 6 small mammals recorded at each trap marker. The trap markers are located within the centre of each surveyed vegetation quadrat (100 trap markers/plot).

Aspen Upland 4m ² quadrats - <i>Clethrionomys gapperi</i> capture summary																																														
	GROUND COVER													FERNS AND ALLIES																																
Number of Captures	Bare rock	Bare soil/sand	Standing water	Litter/organic debris	Dead wood, logs	Dead wood, branches	Lichens, crustose soil	Lichens, crustose rock	Lichens, crustose bark	Lichens, foliose soil	Lichens, foliose rock	Lichens, foliose bark	Lichens, fruticose soil	Lichens, fruticose rock	Lichens, fruticose bark	Arboreal lichens	Mushrooms/gilled	Mushrooms/pored	Fungi, jelly	Fungi, bracket	Black Rock fungus	Calliigon sp.	Ceratodon purpureus	Climacium dendroides	Dicranum spp.	Hedwigia ciliata	Moss spp.	Pleurozium schreberi	Polytrichum spp.	Sphagnum spp.	Dryopteris cristata	Equisetum sylvaticum	Gymnocarpium dryopteris	Lycopodium annotinum	Lycopodium clavatum	Lycopodium complanatum	Lycopodium dendroideum	Polypodium virginianum								
0	14	2	75	9	4	11	1	6	1	8	3	1								6		1	7	1	9	10				1																
1	18		76	15	5	12	1	1	4	2	9	8	2							7			4	1	2	9	5			1											1					
2	9	2	80	11	3	8	1	4	1	4	1	1								6		1	2	1	4	3	1			2																
3	5	1	76	13	3	1	3	1	1	2	4		1							3		1	4	1	2	7	5	2		4																
4	13	1	80	19	4	1	7	1	1	6	2	7	5	2						8			3	3	6	5	3	1	1												1					
5	22		75	11	6	17	1	5	1	10	6	2			1					12			5	2	4	9			3																	
≥ 6	9	2	85	21	5	8	1	3	2	5	1	2								6		1	5	1	1	6	5	1	4																	

TABLE C.5c Summary of *Clethrionomys gapperi* ASP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

	LOW SHRUBS (<1m)										TALL SHRUBS (>1m)									
<i>Andromeda glaucophylla</i>																				
<i>Arctostaphylos uva-ursi</i>	10																			
<i>Chamaedaphne calyculata</i>		1	11																	
<i>Chimaphila umbellata</i>																				
<i>Cornus canadensis</i>		4	12																	
<i>Diervilla lonicera</i>		3	11	2				1												
<i>Gaultheria hispidula</i>																				
<i>Juniperus communis</i>		4	12	2																
<i>Kalmia polifolia</i>																				
<i>Ledum groenlandicum</i>																				
<i>Linnaea borealis</i>																				
<i>Lonicera dioica</i>																				
<i>Lonicera villosa</i>																				
<i>Oxycoccus microcarpos</i>																				
<i>Potentilla tridentata</i>																				
<i>Ribes glandulosum</i>																				
<i>Ribes oxycanthoides</i>																				
<i>Ribes triste</i>																				
<i>Rosa acicularis</i>																				
<i>Rubus chamaemorus</i>																				
<i>Rubus idaeus</i>																				
<i>Rubus pubescens</i>																				
<i>Shepherdia canadensis</i>																				
<i>Spiraea alba</i>																				
<i>Symphoricarpos albus</i>																				
<i>Vaccinium angustifolium</i>																				
<i>Vaccinium caespitosum</i>																				
<i>Vaccinium myrtilloides</i>																				
<i>Vaccinium vitis-idaea</i>																				
<i>Alnus crispa</i>																				
<i>Alnus rugosa</i>																				
<i>Amelanchier alnifolia</i>																				
<i>Betula glandulosa</i>																				
<i>Cornus stolonifera</i>																				
<i>Prunus pensylvanica</i>																				
<i>Rhamnus alnifolia</i>																				
<i>Salix spp.</i>																				
<i>Viburnum edule</i>																				

TABLE C.5c Summary of *Clethrionomys gapperi* ASP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

TREES										
Abies balsamea % cover										
Abies balsamea basal area										
Abies balsamea seedlings										
Betula papyrifera % cover										
Betula papyrifera basal area										
Betula papyrifera seedlings										
Larix laricina % cover	2									
Larix laricina basal area										
Larix laricina seedlings										
Picea glauca % cover	2									
Picea glauca basal area		1	10	1	1	17	2	1		
Picea glauca seedlings										
Picea mariana % cover			2	26	2					
Picea mariana basal area										
Picea mariana seedlings										
Pinus banksiana % cover										
Pinus banksiana basal area										
Pinus banksiana seedlings										
Populus balsamifera % cover										
Populus balsamifera basal area										
Populus balsamifera seedlings										
Populus tremuloides % cover										
Populus tremuloides basal area										
Populus tremuloides seedlings										
Snag basal area										
Actaea rubra										
Antennaria neglecta										
Apocynum androsaemifolium										
Aquilegia canadensis										
Aralia nudicaulis										
Aster ciliolatus										
Aster puniceus										
Aster umbellatus										
Bidens cernua										
Caltha palustris										
Campanula aparinoides										
Campanula rotundifolia										
Clintonia borealis										
Comandra pallida										

TABLE C.5c Summary of *Clethrionomys gapperi* ASP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

HERBACEOUS LAYER										
<i>Corydalis sempervirens</i>										
<i>Cypripedium acaule</i>										
<i>Epilobium angustifolium</i>	2	8	2							
<i>Fragaria virginiana</i>	4	9	2							
<i>Galium boreale</i>	2	6	3							
<i>Galium trifidum</i>	3	4	1							
<i>Galium triflorum</i>										
<i>Geocaulon lividum</i>										
<i>Goodyera repens</i>										
<i>Halenia deflexa</i>				1						
<i>Hieracium scabriusculum</i>				2						
<i>Lathyrus ochroleucus</i>				1	1	1	2			
<i>Lathyrus venosus</i>						1				
<i>Lysimachia thyrsiflora</i>										
<i>Maianthemum canadense</i>						10	5			3
<i>Melampyrum lineare</i>						7	3			3
<i>Montropa uniflora</i>										
<i>Petasites palmatus</i>										
<i>Polygonum cilinooides</i>										
<i>Potentilla palustris</i>										
<i>Prenathes alba</i>										
<i>Pyrola asarifolia</i>									1	
<i>Pyrola rotundifolia</i>										
<i>Pyrola virens</i>										1
<i>Ranunculus lapponicus</i>										
<i>Sanicula marilandica</i>										
<i>Scutellaria galericulata</i>										
<i>Smilacina trifolia</i>										
<i>Solidago hispida</i>									2	
<i>Solidago uliginosa</i>								1		
<i>Stellaria longifolia</i>									2	1
<i>Streptopus roseus</i>								1		
<i>Taraxacum officinale</i>									1	2
<i>Trientalis borealis</i>									2	1
<i>Vicia americana</i>									1	1
<i>Viola adunca</i>										1
<i>Viola pallens</i>										1

TABLE C.5c Summary of *Clethrionomys gapperi* ASP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

GRASSES/RUSHES/SEDGES											Aspen Upland											
Agropyron trachycaulum	Agrostis scabra	Calamagrostis canadensis	Carex aquatilis	Carex aurea	Carex canescens	Carex disperma	Carex foenea	Carex intumescens	Carex paupercula	Carex spp.	Cinnia latifolia	Danthonia spicata	Eriophorum spissum	Glyceria grandis	Graminoids	Juncus dudleyi	Oryzopsis asperifolia	Oryzopsis pungens	Schizachne purpurascens	Scripus cyperinus	<i>Clethrionomys</i> captures/quadrat	No. of quadrats/capture category
								1	1		10				2	3	3	7		0 captures	13	
1								1			3						3	1	7		1 capture	17
	1											4	1				2	1	9		2 captures	16
					3			2									1	1	7		3 captures	11
		1						1									2		5		4 captures	13
		1						2				2					2	2	4		5 captures	13
		1		1							1	1	1			2	1	6	1	≥ 6 captures	17	
																					Total	100

TABLE C.5d Summary of *Sorex cinereus* ASP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

	LOW SHRUBS (<1m)										TALL SHRUBS (>1m)									
<i>Andromeda glaucophylla</i>																				
<i>Arctostaphylos uva-ursi</i>	4																			
<i>Chamaedaphne calyculata</i>		3	11	1																
<i>Chimaphila umbellata</i>					3	1														
<i>Cornus canadensis</i>																				
<i>Diervilla lonicera</i>		4	11	1		1														
<i>Gaultheria hispida</i>																				
<i>Juniperus communis</i>		3	15	1		1														
<i>Kalmia polifolia</i>																				
<i>Ledum groenlandicum</i>																				
<i>Linnaea borealis</i>																				
<i>Lonicera dioica</i>																				
<i>Lonicera villosa</i>																				
<i>Oxycoccus microcarpos</i>																				
<i>Potentilla tridentata</i>						2														
<i>Ribes glandulosum</i>																				
<i>Ribes oxycanthoides</i>																				
<i>Ribes triste</i>																				
<i>Rosa acicularis</i>									3											
<i>Rubus chamaemorus</i>																				
<i>Rubus idaeus</i>																				
<i>Rubus pubescens</i>									2											
<i>Shepherdia canadensis</i>																				
<i>Spiraea alba</i>									1											
<i>Symphoricarpos albus</i>										1										
<i>Vaccinium angustifolium</i>																				
<i>Vaccinium caespitosum</i>										1										
<i>Vaccinium myrtilloides</i>										12										
<i>Vaccinium vitis-idaea</i>																				
<i>Alnus crispa</i>										1										
<i>Alnus rugosa</i>										1										
<i>Amelanchier alnifolia</i>										3										
<i>Betula glandulosa</i>																				
<i>Cornus stolonifera</i>																				
<i>Prunus pensylvanica</i>																				
<i>Rhamnus alnifolia</i>										3										
<i>Salix spp.</i>																				5
<i>Viburnum edule</i>																				

TABLE C.5d Summary of *Sorex cinereus* ASP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

TREES	
Abies balsamea % cover	
Abies balsamea basal area	
Abies balsamea seedlings	
Betula papyrifera % cover	
Betula papyrifera basal area	
Betula papyrifera seedlings	
Larix laricina % cover	1
Larix laricina basal area	
Larix laricina seedlings	
Picea glauca % cover	1
Picea glauca basal area	
Picea glauca seedlings	1 12 1
Picea mariana % cover	2 10 2
Picea mariana basal area	
Picea mariana seedlings	1 11 1
Pinus banksiana % cover	16 1
Pinus banksiana basal area	
Pinus banksiana seedlings	3 1 7 1 1 16 2
Populus balsamifera % cover	5 2 21 2 1 7 1
Populus balsamifera basal area	
Populus balsamifera seedlings	
Populus tremuloides % cover	17 3
Populus tremuloides basal area	
Populus tremuloides seedlings	20 2
Snag basal area	20 2 1
Actaea rubra	
Antennaria neglecta	
Apocynum androsaemifolium	1
Aquilegia canadensis	5 2 2
Aralia nudicaulis	
Aster ciliolatus	2 7 1 1
Aster puniceus	1 5 2 2 1
Aster umbellatus	
Bidens cernua	
Caltha palustris	
Campanula aparinoides	
Campanula rotundifolia	1 3
Clintonia borealis	1 5
Comandra pallida	1 4
	5 1

TABLE C.5d Summary of *Sorex cinereus* ASP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

HERBACEOUS LAYER									
Corydalis sempervirens									
Cypripedium acaule	3	6	1						
Epilobium angustifolium	3	6	2						
Fragaria virginiana	3	4	2						
Galium boreale	2	9	3						
Galium trifidum									
Galium triflorum									
Geocaulon lividum									
Goodyera repens									
Halenia deflexa	1	1							
Hieracium scabrusculum	1								
Lathyrus ochroleucus	2								
Lathyrus venosus	2								
Lysimachia thyrsiflora	8	4							
Maianthemum canadense	6	3							
Melampyrum lineare	5	2							
Montropa uniflora	5	2							
Petasites palmatus	2								
Polygonum cilinooides	3								
Potentilla palustris									
Prenathes alba									
Pyrola asarifolia	1								
Pyrola rotundifolia									
Pyrola virens									
Ranunculus lapponicus									
Sanicula marilandica									
Scutellaria galericulata									
Smilacina trifolia									
Solidago hispida	1								
Solidago uliginosa	2								
Stellaria longifolia									
Streptopus roseus		1							
Taraxacum officinale									
Trientalis borealis	2								
Vicia americana	1								
Viola adunca	1								
Viola pallens									

TABLE C.5e Summary of *Clethrionomys gapperi* BSB habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

	LOW SHRUBS (<1m)		TALL SHRUBS (>1m)	
<i>Andromeda glaucophylla</i>				
<i>Arctostaphylos uva-ursi</i>	9			
<i>Chamaedaphne calyculata</i>		1		
<i>Chimaphila umbellata</i>				
<i>Cornus canadensis</i>				
<i>Diervilla lonicera</i>				
<i>Gaultheria hispidula</i>		2		
<i>Juniperus communis</i>		53		
<i>Kalmia polifolia</i>		4		
<i>Ledum groenlandicum</i>		51		
<i>Linnaea borealis</i>		2		
<i>Lonicera dioica</i>		59		
<i>Lonicera villosa</i>		1		
<i>Oxycoccus microcarpos</i>		61		
<i>Potentilla tridentata</i>			13	
<i>Ribes glandulosum</i>			14	
<i>Ribes oxycanthoides</i>			9	
<i>Ribes triste</i>				
<i>Rosa acicularis</i>				
<i>Rubus chamaemorus</i>			4	
<i>Rubus idaeus</i>			5	
<i>Rubus pubescens</i>				
<i>Shepherdia canadensis</i>				
<i>Spiraea alba</i>				
<i>Symphoricarpos albus</i>				
<i>Vaccinium angustifolium</i>				
<i>Vaccinium caespitosum</i>				
<i>Vaccinium myrtilloides</i>				
<i>Vaccinium vitis-idaea</i>			23	
<i>Alnus crispa</i>				
<i>Alnus rugosa</i>			27	
<i>Amelanchier alnifolia</i>				
<i>Betula glandulosa</i>				
<i>Cornus stolonifera</i>				
<i>Prunus pennsylvanica</i>				
<i>Rhamnus alnifolia</i>				
<i>Salix</i> spp.				
<i>Viburnum edule</i>				
			23	
			27	
			23	
			26	

TABLE C.5e Summary of *Clethrionomys gapperi* BSB habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

TREES	
Abies balsamea % cover	
Abies balsamea basal area	
Abies balsamea seedlings	
Betula papyrifera % cover	
Betula papyrifera basal area	
Betula papyrifera seedlings	
Larix laricina % cover	1
Larix laricina basal area	
Larix laricina seedlings	
Picea glauca % cover	
Picea glauca basal area	
Picea glauca seedlings	
Picea mariana % cover	25
Picea mariana basal area	3
Picea mariana seedlings	23
Pinus banksiana % cover	9
Pinus banksiana basal area	2
Pinus banksiana seedlings	
Populus balsamifera % cover	
Populus balsamifera basal area	
Populus balsamifera seedlings	
Populus tremuloides % cover	
Populus tremuloides basal area	
Populus tremuloides seedlings	
Snag basal area	1
Actaea rubra	
Antennaria neglecta	
Apocynum androsaemifolium	
Aquilegia canadensis	
Aralia nudicaulis	
Aster ciliolatus	
Aster puniceus	
Aster umbellatus	
Bidens cernua	
Caltha palustris	
Campanula aparinoides	
Campanula rotundifolia	
Clintonia borealis	
Comandra pallida	
	24
	3
	21
	12
	2
	24
	3
	25
	12
	2
	28
	4
	25
	9
	2

TABLE C.5e Summary of *Clethrionomys gapperi* BSB habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

HERBACEOUS LAYER	
Corydalis sempervirens	
Cyrtopodium acaule	
Epiobium angustifolium	
Fragaria virginiana	
Galium boreale	
Galium trifidum	
Galium triflorum	
Geocaulon lividum	
Goodyera repens	
Halenia deflexa	
Hieracium scabriusculum	
Lathyrus ochroleucus	
Lathyrus venosus	
Lysimachia thyrsiflora	
Maianthemum canadense	
Melampyrum lineare	
Montropa uniflora	
Petasites palmatus	
Polygonum cilinooides	
Potentilla palustris	
Prenathes alba	
Pyrola asarifolia	
Pyrola rotundifolia	
Pyrola virens	
Ranunculus lapponicus	
Sanicula marilandica	
Scutellaria galericulata	
Smilacina trifolia	7
Solidago hispida	
Solidago uliginosa	8
Stellaria longifolia	
Streptopus roseus	10
Taraxacum officinale	
Trientalis borealis	
Vicia americana	
Viola adunca	
Viola pallens	7

TABLE C.5e Summary of *Clethrionomys gapperi* BSB habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

GRASSES / RUSHES / SEDGES		Blackspruce Bog	
Agropyron trachycaulum			
Agrostis scabra			
Calamagrostis canadensis			
Carex aquatilis			
Carex aurea			
Carex canescens			
Carex disperma			
Carex foenea			
Carex intumescens			
Carex paupercula			
Carex spp.			
Cinnia latifolia			
Danthonia spicata			
Eriophorum spissum	1	0 captures	35
Glyceria grandis			
Graminoids			
Juncus dudleyi			
Oryzopsis asperifolia	1	1 capture	35
Oryzopsis pungens			
Schizachne purpurascens			
Scripus cyperinus	2	2 captures	17
		≥ 3 captures	13
		Total	100

TABLE C.5f Summary of *Sorex cinereus* habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats. Quadrats are grouped according to the capture rate(s) from 0 to ≥ 3 small mammals recorded at each trap marker. The trap markers are located within the centre of each surveyed vegetation quadrat.

Blackspruce Bog 4m ² quadrats - <i>Sorex cinereus</i> capture summary																																									
GROUND COVER																																									
FERNS AND ALLIES																																									
Number of Captures	Bare rock	Bare soil/sand	Standing water	Litter/organic debris	Dead wood, logs	Dead wood, branches	Lichens, crustose soil	Lichens, crustose rock	Lichens, crustose bark	Lichens, foliose soil	Lichens, foliose rock	Lichens, foliose bark	Lichens, fruticose soil	Lichens, fruticose rock	Lichens, fruticose bark	Arboreal lichens	Mushrooms/gilled	Mushrooms/pored	Fungi, jelly	Fungi, bracket	Black Rock fungus	Calliergon sp.	Ceratodon purpureus	Climacium dendroides	Hedwigia ciliata	Dicranum spp.	Moss spp.	Pleurozium schreberi	Polytrichum spp.	Sphagnum spp.	Dryopteris cristata	Equisetum sylvaticum	Gymnocarpium dryopteris	Lycopodium annotinum	Lycopodium clavatum	Lycopodium complanatum	Lycopodium dendroideum	Polypodium virginianum			
0				26	31	4		1				1	2	1						1						1			4	79											
1				25	31	3		1				1	3	1		1				1						1			5	76											
2				25	33	3						1	2	2		1				1						1			4	77											
≥ 3				23	31	4		1				1	3	1					1								1	3	84												

TABLE C.5f Summary of *Sorex cinereus* BSB habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

	LOW SHRUBS (<1m)				TALL SHRUBS (>1m)			
<i>Andromeda glaucophylla</i>								
<i>Arctostaphylos uva-ursi</i>	9							
<i>Chamaedaphne calyculata</i>		1	3	55				
<i>Chimaphila umbellata</i>								
<i>Cornus canadensis</i>								
<i>Diervilla lonicera</i>								
<i>Gaultheria hispidula</i>								
<i>Juniperus communis</i>			2	54				
<i>Kalmia polifolia</i>		1	1	56				
<i>Ledum groenlandicum</i>			8	47				
<i>Linnaea borealis</i>								
<i>Lonicera dioica</i>								
<i>Lonicera villosa</i>								
<i>Oxycoccus microcarpos</i>					13			
<i>Potentilla tridentata</i>								
<i>Ribes glandulosum</i>								
<i>Ribes oxycanthoides</i>								
<i>Ribes triste</i>								
<i>Rosa acicularis</i>								
<i>Rubus chamaemorus</i>					4			
<i>Rubus idaeus</i>								
<i>Rubus pubescens</i>					5			
<i>Shepherdia canadensis</i>								
<i>Spiraea alba</i>								
<i>Symphoricarpos albus</i>								
<i>Vaccinium angustifolium</i>								
<i>Vaccinium caespitosum</i>								
<i>Vaccinium myrtilloides</i>								
<i>Vaccinium vitis-idaea</i>							24	
<i>Alnus crispa</i>								
<i>Alnus rugosa</i>								
<i>Amelanchier alnifolia</i>								
<i>Betula glandulosa</i>								
<i>Cornus stolonifera</i>								
<i>Prunus pennsylvanica</i>								
<i>Rhamnus alnifolia</i>								
<i>Salix spp.</i>								
<i>Viburnum edule</i>								
	13							25
								25
								25
								29

TABLE C.5f Summary of *Sorex cinereus* **BSB** habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

TREES	
Abies balsamea % cover	
Abies balsamea basal area	
Abies balsamea seedlings	
Betula papyrifera % cover	
Betula papyrifera basal area	
Betula papyrifera seedlings	
Larix laricina % cover	1
Larix laricina basal area	
Larix laricina seedlings	
Picea glauca % cover	
Picea glauca basal area	
Picea glauca seedlings	
Picea mariana % cover	26
Picea mariana basal area	3
Picea mariana seedlings	22
Pinus banksiana % cover	10
Pinus banksiana basal area	2
Pinus banksiana seedlings	
Populus balsamifera % cover	
Populus balsamifera basal area	
Populus balsamifera seedlings	
Populus tremuloides % cover	
Populus tremuloides basal area	
Populus tremuloides seedlings	
Snag basal area	1
Actaea rubra	
Antennaria neglecta	
Apocynum androsaemifolium	
Aquilegia canadensis	
Aralia nudicaulis	
Aster ciliolatus	
Aster puniceus	
Aster umbellatus	
Bidens cernua	
Caltha palustris	
Campanula aparinooides	
Campanula rotundifolia	
Clintonia borealis	
Comandra pallida	
	24
	4
	25
	10
	2
	27
	3
	26
	7
	2
	23
	4
	23
	11
	2
	2
	1
	2

TABLE C.5f Summary of *Sorex cinereus* BSB habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

HERBACEOUS LAYER	
Corydalis sempervirens	
Cyrtopodium acaule	
Epiobium angustifolium	
Fragaria virginiana	
Galium boreale	
Galium trifidum	
Galium triflorum	
Geocaulon lividum	
Goodyera repens	
Halenia deflexa	
Hieracium scabriusculum	
Lathyrus ochroleucus	
Lathyrus venosus	
Lysimachia thyrsiflora	
Maianthemum canadense	
Melampyrum lineare	
Montropa uniflora	
Petasites palmatus	
Polygonum cilioides	
Potentilla palustris	
Prenathes alba	
Pyrola asarifolia	
Pyrola rotundifolia	
Pyrola virens	
Ranunculus lapponicus	
Sanicula marilandica	
Scutellaria galericulata	
Smilacina trifolia	0
Solidago hispida	0
Solidago uliginosa	0
Stellaria longifolia	0
Streptopus roseus	2
Taraxacum officinale	
Trientalis borealis	
Vicia americana	
Viola adunca	
Viola pallens	

TABLE C.5f Summary of *Sorex cinereus* BSB habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

GRASSES/RUSHES/SEDGES		Blackspruce Bog	
Agropyron trachycaulium			
Agrostis scabra			
Calamagrostis canadensis			
Carex aquatilis			
Carex aurea			
Carex canescens			
Carex disperma			
Carex foenea			
Carex intumescens			
Carex paupercula			
Carex spp.			
Cinnia latifolia			
Danthonia spicctata			
Eriophorum spissum	1	0 captures	55
Glyceria grandis			
Graminoids			
Juncus dudleyi			
Oryzopsis asperifolia	1	1 capture	28
Oryzopsis pungens		2 captures	11
Schizachne purpurascens			
Scripus cyperinus	1	≥ 3 captures	6
		Total	100
		<i>S. cinereus</i> captures/quadrat	
		No. of quadrats/capture category	

TABLE C.5g Summary of *Clethrionomys gapperi* habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats. Quadrats are grouped according to the capture rate(s) from 0 to ≥ 3 small mammals recorded at each trap marker. The trap markers are located within the centre of each surveyed vegetation quadrat (100 trap markers/plot).

Ecotone 4m ² quadrats - <i>Clethrionomys gapperi</i> capture summary		GROUND COVER											FERNS AND ALLIES																													
Number of Captures	Bare rock	Bare soil/sand	Standing water	Litter/organic debris	Dead wood, logs	Dead wood, branches	Lichens, crustose soil	Lichens, crustose rock	Lichens, crustose bark	Lichens, foliose soil	Lichens, foliose rock	Lichens, foliose bark	Lichens, fruticose soil	Lichens, fruticose rock	Lichens, fruticose bark	Arboreal lichens	Mushrooms/gilled	Mushrooms/pored	Fungi, jelly	Fungi, bracket	Black Rock fungus	Calliergon sp.	Ceratodon purpureus	Climacium dendroides	Dicranum spp.	Hedwigia ciliata	Moss spp.	Pleurozium schreberi	Polytrichum spp.	Sphagnum spp.	Dryopteris cristata	Equisetum sylvaticum	Gymnocarpium dryopteris	Lycopodium annotinum	Lycopodium clavatum	Lycopodium complanatum	Lycopodium dendroideum	Polypodium virginianum				
0			12	68	15	5		1			2	6		2			1					1	1	5			5	2	38	1	6		5									
1	1		8	64	18	5		2			3	3		3						1				2			3	1	43	1	7		4			1						
2	1		7	72	19	6		2			2	3		2						1		1		3			13	2	28	1	4		3									
3			5	72	21	6		2	1		2	7		3						1				2			10	5	19		3											
4	1			76	23	7		2	1		2	2		3						1				2	6		21	4	2		4		2									
5			2	69	25	13		2			3	4		3					1					6			11	8	27		3		4									
≥ 6	1			79	28	6		2	1		2	4		3									1	1	3			18	3	4		2		1	3							

TABLE C.5g Summary of *Clethrionomys gapperi* ECO habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

TREES										
Abies balsamea % cover										
Abies balsamea basal area										
Abies balsamea seedlings										
Betula papyrifera % cover	2	8	2	1	2					
Betula papyrifera basal area						17	2	3	8	1
Betula papyrifera seedlings										
Larix laricina % cover	4	7	1	1		14	2	3	7	1
Larix laricina basal area										
Larix laricina seedlings										
Picea glauca % cover	6	11	1		3	18	2	4	10	2
Picea glauca basal area										
Picea glauca seedlings										
Picea mariana % cover	3	6			1	21	3	5	21	3
Picea mariana basal area										
Picea mariana seedlings										
Pinus banksiana % cover	5	5	1			17	2	7	10	2
Pinus banksiana basal area										
Pinus banksiana seedlings										
Pinus banksiana % cover	4	11		1		21	3	3	18	2
Pinus banksiana basal area										
Pinus banksiana seedlings										
Populus balsamifera % cover	2	7	1		4	26	2	4	6	4
Populus balsamifera basal area										
Populus balsamifera seedlings										
Populus tremuloides % cover										
Populus tremuloides basal area										
Populus tremuloides seedlings										
Snag basal area										
Actaea rubra										
Antennaria neglecta										
Apocynum androsaemifolium										
Aquilegia canadensis										
Aralia nudicaulis										
Aster ciliolatus										
Aster puniceus										
Aster umbellatus										
Bidens cernua										
Caltha palustris										
Campanula aparinoides										
Campanula rotundifolia										
Clintonia borealis										
Comandra pallida										

TABLE C.5g Summary of *Clethrionomys gapperi* ECO habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

GRASSES / RUSHES / SEDGES										Ecotone												
Agropyron trachycaulum	Agrostis scabra	Calamagrostis canadensis	Carex aquatilis	Carex aurea	Carex canescens	Carex disperma	Carex foenea	Carex intumescens	Carex paupercula	Carex spp.	Cinnia latifolia	Danthonia spicata	Eriophorum spissum	Glyceria grandis	Graminoids	Juncus dudleyi	Oryzopsis asperifolia	Oryzopsis pungens	Schizachne purpurascens	Scripus cyperinus	<i>Clethrionomys</i> captures/quadrat	No. of quadrats/capture category
		3	6		1	9												1	1		0 captures	16
		1	1			11			1										1		1 capture	21
						6			1								1	2	1		2 captures	20
					1	2											1	1	3		3 captures	17
						3				1	1						3	2			4 captures	9
		1			1	4					1							1	1		5 captures	6
						2											1	3			≥ 6 captures	11
																					Total	100

TABLE C.5h Summary of *Sorex cinereus* habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats. Quadrats are grouped according to the capture rate(s) from 0 to ≥ 6 small mammals recorded at each trap marker. The trap markers are located within the centre of each surveyed vegetation quadrat (100 trap markers/plot).

Ecotone 4m ² quadrats - <i>Sorex cinereus</i> capture summary											GROUND COVER											FERNS AND ALLIES																						
Number of Captures	Bare rock	Bare soil/sand	Standing water	Litter/organic debris	Dead wood, logs	Dead wood, branches	Lichens, crustose soil	Lichens, crustose rock	Lichens, crustose bark	Lichens, foliose soil	Lichens, foliose rock	Lichens, foliose bark	Lichens, fruticose soil	Lichens, fruticose rock	Lichens, fruticose bark	Arboreal lichens	Mushrooms/gilled	Mushrooms/pored	Fungi, jelly	Fungi, bracket	Black Rock fungus	Calliargon sp.	Ceratodon purpureus	Climacium dendroides	Dicranum spp.	Hedwigia ciliata	Moss spp.	Pleurozium schreberi	Polytrichum spp.	Sphagnum spp.	Dryopteris cristata	Equisetum sylvaticum	Gymnocarpium dryopteris	Lycopodium annotinum	Lycopodium clavatum	Lycopodium complanatum	Lycopodium dendroideum	Polypodium virginianum						
0	1		78	28	7		2	1		2	9	3							1		1			5			15	6	6		1		2	1										
1	1	6	71	23	6		2	1		2	3	2							1		1	1	1	4	1		11	3	16	1	3		1											
2		10	63	18	5		2			2	2	2												3			8	4	36		9		6				1							
3	1	3	69	14	5		1			2	1	2											1	1			7		32	1	6		3	1										
4	1	8	53	8	7		1			3	1	2							1					1			2	68	2	8		5												
5		1	73	19	5		1			2	1	2												1	5		6	31	6		1	1												
≥ 6		44	76	6	5	1	2			2	1	2												1	1		9	67	6		7													

TABLE C.5h Summary of *Sorex cinereus* ECO habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

HERBACEOUS LAYER										
Corydalis sempervirens										
Cypripedium acaule	4	2	1							
Epilobium angustifolium	4	1	1	1						
Fragaria virginiana	2	2	1							
Galium boreale	5	2								
Galium trifidum	1									
Galium triflorum	5	2								
Geocaulon lividum	1									
Goodyera repens										
Halenia deflexa										
Hieracium scabritusculum										
Lathyrus ochroleucus										
Lathyrus venosus										
Lysimachia thyrsiflora	1									
Maianthemum canadense	5	2								
Melampyrum lineare	2									
Montropa uniflora										
Petasites palmatus										
Polygonum cilinoides										
Potentilla palustris										
Prenathes alba										
Pyrola asarifolia										
Pyrola rotundifolia										
Pyrola virens										
Ranunculus lapponicus										
Sanicula marilandica										
Scutellaria galericulata										
Smilacina trifolia										
Solidago hispida										
Solidago uliginosa										
Stellaria longifolia										
Streptopus roseus										
Taraxacum officinale										
Trientalis borealis	1									
Vicia americana	1									
Viola adunca										
Viola pallens										

TABLE C.5i Summary of *Clethrionomys gapperi* habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats. Quadrats are grouped according to their capture rate(s) from 0 to ≥ 4 small mammals recorded at each trap marker. The trap markers are located within the centre of each surveyed vegetation quadrat (100 trap markers/plot).

Jackpine Ridge 4m ² quadrats - <i>Clethrionomys gapperi</i> capture summary															GROUND COVER										FERNS AND ALLIES																		
Number of Captures	Bare rock	Bare soil/sand	Standing water	Litter/organic debris	Dead wood, logs	Dead wood, branches	Lichens, crustose soil	Lichens, crustose rock	Lichens, crustose bark	Lichens, foliose soil	Lichens, foliose rock	Lichens, foliose bark	Lichens, fruticose soil	Lichens, fruticose rock	Lichens, fruticose bark	Arboreal lichens	Mushrooms/gilled	Mushrooms/pored	Fungi, jelly	Fungi, bracket	Black Rock fungus	Calliargon sp.	Ceratodon purpureus	Climacium dendroides	Hedwigia ciliata	Dicranum spp.	Moss spp.	Pleurozium schreberi	Polytrichum spp.	Sphagnum spp.	Dryopteris cristata	Equisetum sylvaticum	Gymnocarpium dryopteris	Lycopodium annotinum	Lycopodium clavatum	Lycopodium complanatum	Lycopodium dendroideum	Polypodium virginianum					
0	29			83	26	8	12	4	1	5	4	12	3	3		1				1	20	0				1	1	1	38														
1	30	2		81	24	8	12	4	1	5	4	12	7	3		1	1			1	23	0				1	1	1	46														
2	30			81	23	10	17	5	1	4	3	16	3	2		1				1	20	0				1	1	2	42														
3	35			78	22	7	7	3	2	8	3	12	5	3		1	1			1	19	0				2	1	33											1				
≥ 4	34	1		83	28	7	19	19	1	1	8	3	13	5	3			1		1	14	0			1	1	1	31															

TABLE C.5i Summary of *Clethrionomys gapperi* JPR habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

	LOW SHRUBS (<1m)	TALL SHRUBS (>1m)
<i>Andromeda glaucophylla</i>		
<i>Arctostaphylos uva-ursi</i>		
<i>Chamaedaphne calyculata</i>		
<i>Chimaphila umbellata</i>		
<i>Cornus canadensis</i>		
<i>Diervilla lonicera</i>		
<i>Gaultheria hispida</i>	2	
<i>Juniperus communis</i>		
<i>Kalmia polifolia</i>		
<i>Ledum groenlandicum</i>	1	
<i>Linnaea borealis</i>	1	
<i>Lonicera dioica</i>		
<i>Lonicera villosa</i>		
<i>Oxycoccus microcarpos</i>		
<i>Potentilla tridentata</i>		
<i>Ribes glandulosum</i>		
<i>Ribes oxycanthoides</i>		
<i>Ribes triste</i>		
<i>Rosa acicularis</i>		
<i>Rubus chamaemorus</i>		
<i>Rubus pubescens</i>		
<i>Rubus idaeus</i>		
<i>Shepherdia canadensis</i>		
<i>Spiraea alba</i>		
<i>Symphoricarpos albus</i>		
<i>Vaccinium angustifolium</i>		
<i>Vaccinium caespitosum</i>		
<i>Vaccinium myrtilloides</i>		1
<i>Vaccinium vitis-idaea</i>		1
<i>Alnus crispa</i>		
<i>Alnus rugosa</i>		
<i>Amelanchier alnifolia</i>		
<i>Betula glandulosa</i>		
<i>Cornus stolonifera</i>		
<i>Prunus pensylvanica</i>		1
<i>Rhamnus alnifolia</i>		
<i>Salix spp.</i>		5
<i>Viburnum edule</i>		4
		3
		2
		2

TABLE C.5i Summary of *Clethrionomys gapperi* JPR habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

TREES	
Abies balsamea % cover	
Abies balsamea basal area	
Abies balsamea seedlings	
Betula papyrifera % cover	
Betula papyrifera basal area	
Betula papyrifera seedlings	
Larix laricina % cover	1
Larix laricina basal area	
Larix laricina seedlings	
Picea glauca % cover	
Picea glauca basal area	
Picea glauca seedlings	
Picea mariana % cover	7 1
Picea mariana basal area	6 2
Picea mariana seedlings	7 2
Pinus banksiana % cover	8 2
Pinus banksiana basal area	9 2
Pinus banksiana seedlings	
Populus balsamifera % cover	
Populus balsamifera basal area	
Populus balsamifera seedlings	
Populus tremuloides % cover	5 1
Populus tremuloides basal area	4 1
Populus tremuloides seedlings	3 1
Snag basal area	
Actaea rubra	
Antennaria neglecta	
Apocynum androsaemifolium	
Aquilegia canadensis	
Aralia nudicaulis	
Aster ciliolatus	
Aster puniceus	
Aster umbellatus	
Bidens cernua	
Caltha palustris	
Campanula aparinoides	
Campanula rotundifolia	
Clintonia borealis	
Comandra pallida	

TABLE C.5i Summary of *Clethrionomys gapperi* JPR habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

HERBACEOUS LAYER

Corydalis sempervirens
Cyrtopodium acaule
Epilobium angustifolium
Fragaria virginiana
Galium boreale
Galium trifidum
Galium triflorum
Geocaulon lividum
Goodyera repens
Halenia deflexa
Hieracium scabriusculum
Lathyrus ochroleucus
Lathyrus venosus
Lysimachia thyrsiflora
Maianthemum canadense
Melampyrum lineare
Montropa uniflora
Petasites palmatus
Polygonum cilinooides
Potentilla palustris
Prenathes alba
Pyrola asarifolia
Pyrola rotundifolia
Pyrola virens
Ranunculus lapponicus
Sanicula marilandica
Scutellaria galericulata
Smilacina trifolia
Solidago hispida
Solidago uliginosa
Stellaria longifolia
Streptopus roseus
Taraxacum officinale
Trientalis borealis
Vicia americana
Viola adunca
Viola pallens

TABLE C.5i Summary of *Clethrionomys gapperi* JPR habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

GRASSES / RUSHES / SEDGES		Jackpine Ridge	
Agropyron trachycaulum			
Agrostis scabra			
Calamagrostis canadensis			
Carex aquatilis			
Carex aurea			
Carex canescens			
Carex disperma			
Carex foenea			
Carex intumescens			
Carex paupercula			
Carex spp.			
Cinna latifolia			
Danthonia spicata			
Eriophorum spissum			
Glyceria grandis			
Graminoids			
Juncus dudleyi			
Oryzopsis asperifolia			
Oryzopsis pungens			
Schizachne purpurascens			
Scripus cyperinus			
	<i>Clethrionomys</i> captures/quadrat		No. of quadrats/capture category
	0 captures		22
	1 capture		31
	2 captures		23
	3 captures		11
	≥ 4 captures		13
	Total		100

TABLE C.5j Summary of *Peromyscus maniculatus* habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats. Quadrats are grouped according to their capture rate(s) from 0 to ≥ 4 small mammals recorded at each trap marker. The trap markers are located within the centre of each surveyed vegetation quadrat (100 trap markers/plot).

		Jackpine Ridge 4m ² quadrats - <i>Peromyscus maniculatus</i> capture summary																																														
		GROUND COVER														FERNS AND ALLIES																																
Number of Captures		Bare rock	Bare soil/sand	Standing water	Litter/organic debris	Dead wood, logs	Dead wood, branches	Lichens, crustose soil	Lichens, crustose rock	Lichens, crustose bark	Lichens, foliose soil	Lichens, foliose rock	Lichens, foliose bark	Lichens, fruticose soil	Lichens, fruticose rock	Lichens, fruticose bark	Arboreal lichens	Mushrooms/gilled	Mushrooms/pored	Fungi, jelly	Fungi, bracket	Black Rock fungus	Calliargon sp.	Ceratodon purpureus	Climacium dendroides	Hedwigia ciliata	Dicranum spp.	Moss spp.	Pleurozium schreberi	Polytrichum spp.	Sphagnum spp.	Dryopteris cristata	Equisetum sylvaticum	Gymnocarpium dryopteris	Lycopodium annotinum	Lycopodium clavatum	Lycopodium complanatum	Lycopodium dendroideum	Polypodium virginianum									
0	28			82	26	9	11	4	1	5	4	14	5	3		1					1	20	0			1	1	1	42																			
1	30	3		83	21	8	12	3	2	5	3	10	3	2		1					1	18	0			2	1	1	42																			
2	31			81	25	6	13	4	1	6	3	13	4	2		1	1				1	17	0			1	1	2	35																			
3	43			76	25	9	24	2	3	7	2	17	7	2		1	1				1	27	0			1		1	36																	1		
≥ 4	31			83	36	7	23	4		6	5	15	8	6				1			2	22	0			1		1	42																			

TABLE C.5j Summary of *Peromyscus maniculatus* JPR habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

	LOW SHRUBS (<1m)	TALL SHRUBS (>1m)
<i>Andromeda glaucophylla</i>		
<i>Arctostaphylos uva-ursi</i>		
<i>Chamaedaphne calyculata</i>		
<i>Chimaphila umbellata</i>		
<i>Cornus canadensis</i>		
<i>Diervilla lonicera</i>	1	
<i>Gautheria hispidula</i>		
<i>Juniperus communis</i>		
<i>Kalmia polifolia</i>		
<i>Ledum groenlandicum</i>	1	
<i>Linnaea borealis</i>	1	
<i>Lonicera dioica</i>		
<i>Lonicera villosa</i>		
<i>Oxycoccus microcarpos</i>		
<i>Potentilla tridentata</i>		
<i>Ribes glandulosum</i>		
<i>Ribes oxycanthoides</i>		
<i>Ribes triste</i>		
<i>Rosa acicularis</i>		
<i>Rubus chamaemorus</i>		
<i>Rubus pubescens</i>		
<i>Rubus idaeus</i>		
<i>Shepherdia canadensis</i>		
<i>Spiraea alba</i>		
<i>Symphoricarpos albus</i>		
<i>Vaccinium angustifolium</i>		
<i>Vaccinium caespitosum</i>		
<i>Vaccinium myrtilloides</i>		1
<i>Vaccinium vitis-idaea</i>		
<i>Alnus crispa</i>		
<i>Alnus rugosa</i>		
<i>Amelanchier alnifolia</i>		
<i>Betula glandulosa</i>		
<i>Cornus stolonifera</i>		
<i>Prunus pensylvanica</i>		1
<i>Rhamnus alnifolia</i>		
<i>Salix spp.</i>		3
<i>Viburnum edule</i>		
		3
		5
		3
		3
		2
		1
		1
		1
		4

TABLE C.5j Summary of *Peromyscus maniculatus* JPR habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

TREES	
Abies balsamea % cover	
Abies balsamea basal area	
Abies balsamea seedlings	
Betula papyrifera % cover	
Betula papyrifera basal area	
Betula papyrifera seedlings	
Larix laricina % cover	
Larix laricina basal area	
Larix laricina seedlings	
Picea glauca % cover	
Picea glauca basal area	
Picea glauca seedlings	
Picea mariana % cover	8
Picea mariana basal area	2
Picea mariana seedlings	11
Pinus banksiana % cover	46
Pinus banksiana basal area	6
Pinus banksiana seedlings	
Populus balsamifera % cover	
Populus balsamifera basal area	
Populus balsamifera seedlings	
Populus tremuloides % cover	5
Populus tremuloides basal area	1
Populus tremuloides seedlings	
Snag basal area	
Actaea rubra	
Antennaria neglecta	
Apocynum androsaemifolium	
Aquilegia canadensis	
Aralia nudicaulis	
Aster ciliolatus	
Aster puniceus	
Aster umbellatus	
Bidens cernua	
Caltha palustris	
Campanula aparinoides	
Campanula rotundifolia	
Clintonia borealis	
Comandra pallida	
	6
	2
	6
	7
	1
	1
	13
	2
	1
	1
	10
	1
	36
	4
	4
	67
	6
	5
	1
	2
	1
	5
	1
	2
	6
	1

TABLE C.5j Summary of *Peromyscus maniculatus* JPR habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

HERBACEOUS LAYER
Corydalis sempervirens
Cypripedium acaule
Epitobium angustifolium
Fragaria virginiana
Galium boreale
Galium trifidum
Galium triflorum
Geocaulon lividum
Goodyera repens
Halenia deflexa
Hieracium scabriusculum
Lathyrus ochroleucus
Lathyrus venosus
Lysimachia thyrsiflora
Maianthemum canadense
Melampyrum lineare
Montropa uniflora
Petasites palmatus
Polygonum cilinoides
Potentilla palustris
Prenathes alba
Pyrola asarifolia
Pyrola rotundifolia
Pyrola virens
Ranunculus lapponicus
Sanicula marilandica
Scutellaria galericulata
Smilacina trifolia
Solidago hispida
Solidago uliginosa
Stellaria longifolia
Streptopus roseus
Taraxacum officinale
Trientalis borealis
Vicia americana
Viola adunca
Viola pallens

2

TABLE C.5j Summary of *Peromyscus maniculatus* JPR habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

GRASSES / RUSHES / SEDGES		Jackpine Ridge
Agropyron trachycaulum		
Agrostis scabra		
Calamagrostis canadensis		
Carex aquatilis		
Carex aurea		
Carex canescens		
Carex disperma		
Carex foenea		
Carex intumescens		
Carex paupercula		
Carex spp.		
Cinnia latifolia		
Danthonia spiciflora		
Eriophorum spissum		
Glyceria grandis		
Graminoids		
Juncus dudleyi		
Onyropsis asperifolia		
Onyropsis pungens		
Schizachne purpurascens		
Scripus cyperinus		
<i>P. maniculatus</i> /quadrat		
	0 captures	41
	1 capture	28
	2 captures	15
	3 captures	12
	≥ 4 captures	4
	Total	100

TABLE C.5k Summary of *Clethrionomys gapperi* habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats. Quadrats are grouped according to their capture rate(s) from 0 to ≥ 4 small mammals recorded at each trap marker. The trap markers are located within the centre of each surveyed vegetation quadrat (100 trap markers/plot).

		GROUND COVER																FERNS AND ALLIES																							
Number of Captures	Bare rock	Bare soil/sand	Standing water	Litter/organic debris	Dead wood, logs	Dead wood, branches	Lichens, crustose soil	Lichens, crustose rock	Lichens, crustose bark	Lichens, foliose soil	Lichens, foliose rock	Lichens, foliose bark	Lichens, fruticose soil	Lichens, fruticose rock	Lichens, fruticose bark	Arboreal lichens	Mushrooms/gilled	Mushrooms/pored	Fungi, jelly	Fungi, bracket	Black Rock fungus	Calliergon sp.	Ceratodon purpureus	Climacium dendroides	Dicranum spp.	Hedwigia ciliata	Moss spp.	Pleurozium schreberi	Polytrichum spp.	Sphagnum spp.	Dryopteris cristata	Equisetum sylvaticum	Gymnocarpium dryopteris	Lycopodium annotinum	Lycopodium clavatum	Lycopodium complanatum	Lycopodium dendroideum	Polypodium virginianum			
0	1	1	81	22	7		1	1	1	1	31	1	3	1	1					1					3		2	15										1			
1	1	1	77	25	9			1			2	22		4	1					1					4		3	10													
2			77	20	7			1			2	19		3	1	1	1			1					6		7	18											1		
3			83	19	6			1			1	25		1											9		8	7												3	
4			78	28	9			2	1		2	25		2			2								4		6	21													
≥ 5			65	28	8						2	6		3	3	2							1		5		8	5												2	

TABLE C.5k Summary of *Clethrionomys gapperi* JPSP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

	LOW SHRUBS (<1m)		TALL SHRUBS (>1m)	
<i>Andromeda glaucophylla</i>				
<i>Arctostaphylos uva-ursi</i>	22			
<i>Chamaedaphne calyculata</i>		3		
<i>Chimaphila umbellata</i>				
<i>Cornus canadensis</i>				
<i>Diervilla lonicera</i>				
<i>Gaultheria hispidula</i>				
<i>Juniperus communis</i>				
<i>Kalmia polifolia</i>				
<i>Ledum groenlandicum</i>				
<i>Linnaea borealis</i>		3		
<i>Lonicera dioica</i>				
<i>Lonicera villosa</i>				
<i>Oxycoccus microcarpos</i>				
<i>Potentilla tridentata</i>		2		
<i>Ribes glandulosum</i>				
<i>Ribes oxycanthoides</i>				
<i>Ribes triste</i>				
<i>Rosa acicularis</i>				
<i>Rubus chamaemorus</i>				
<i>Rubus pubescens</i>				
<i>Rubus idaeus</i>				
<i>Shepherdia canadensis</i>				
<i>Spiraea alba</i>				
<i>Symphoricarpos albus</i>				
<i>Vaccinium angustifolium</i>				
<i>Vaccinium caespitosum</i>				
<i>Vaccinium myrtilloides</i>			14	3
<i>Vaccinium vitis-idaea</i>			15	5
<i>Alnus crispa</i>			18	5 5
<i>Alnus rugosa</i>			18	7
<i>Amelanchier alnifolia</i>			13	7 2
<i>Betula glandulosa</i>				
<i>Cornus stolonifera</i>				
<i>Prunus pensylvanica</i>				2
<i>Rhamnus alnifolia</i>				
<i>Salix spp.</i>				4
<i>Viburnum edule</i>				

TABLE C.5k Summary of *Clethrionomys gapperi* JPSP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

TREES					
Abies balsamea % cover					
Abies balsamea basal area					
Abies balsamea seedlings					
Betula papyrifera % cover					
Betula papyrifera basal area					
Betula papyrifera seedlings					
Larix laricina % cover					
Larix laricina basal area					
Larix laricina seedlings					
Picea glauca % cover					
Picea glauca basal area					
Picea glauca seedlings					
Picea mariana % cover	1	1	27	4	4
Picea mariana basal area					
Picea mariana seedlings					
Pinus banksiana % cover	5	2	35	5	8
Pinus banksiana basal area					
Pinus banksiana seedlings	2	1	39	5	7
Populus balsamifera % cover					
Populus balsamifera basal area					
Populus balsamifera seedlings					
Populus tremuloides % cover					
Populus tremuloides basal area					
Populus tremuloides seedlings	1				
Snag basal area	1				
Actaea rubra	2				
Antennaria neglecta					
Apocynum androsaemifolium					
Aquilegia canadensis					
Aralia nudicaulis					
Aster ciliolatus					
Aster puniceus					
Aster umbellatus					
Bidens cernua					
Caltha palustris					
Campanula aparinooides					
Campanula rotundifolia					
Clintonia borealis					
Comandra pallida					

TABLE C.5k Summary of *Clethrionomys gapperi* JPSP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

HERBACEOUS LAYER	
Corydalis sempervirens	
Cypripedium acaule	
Epilobium angustifolium	
Fragaria virginiana	1
Gallium boreale	
Gallium trifidum	
Gallium triflorum	
Geocaulon lividum	
Goodyera repens	
Halenia deflexa	
Hieracium scabriusculum	
Lathyrus ochroleucus	
Lathyrus venosus	
Lysimachia thyrsiflora	
Maianthemum canadense	4 1
Melampyrum lineare	4 1
Montropa uniflora	
Petasites palmatus	
Polygonum cilinoides	
Potentilla palustris	
Prenathes alba	
Pyrola asarifolia	1
Pyrola rotundifolia	
Pyrola virens	
Ranunculus lapponicus	
Sanicula marilandica	
Scutellaria galericulata	
Smilacina trifolia	
Solidago hispida	2
Solidago uliginosa	
Stellaria longifolia	
Streptopus roseus	
Taraxacum officinale	
Trientalis borealis	
Vicia americana	
Viola adunca	
Viola pallens	
	3
	2
	1
	2 2
	2 1

TABLE C.5k Summary of *Clethrionomys gapperi* JPSP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

GRASSES / RUSHES / SEDGES		Jackpine Sandplain	
		<i>Clethrionomys</i> captures/quadrat	No. of quadrats/capture category
Agropyron trachycaulum			
Agrostis scabra			
Calamagrostis canadensis			
Carex aquatilis			
Carex aurea			
Carex canescens			
Carex disperma			
Carex foenea			
Carex intumescens			
Carex paupercula			
Carex spp.			
Cinnia latifolia			
Danthonia spicata			
Eriophorum spissum			
Glyceria grandis			
Graminoids			
Juncus dudleyi			
Oryzopsis asperifolia	1	3	0 captures
Oryzopsis pungens		3	1 capture
Schizachne purpurascens		2	2 captures
Scripus cyperinus		2	3 captures
			4 captures
	1	1	≥ 5 captures
		Total	100

TABLE C.5I Summary of *Peromyscus maniculatus* JPSP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

TREES	
Abies balsamea % cover	
Abies balsamea basal area	
Abies balsamea seedlings	
Betula papyrifera % cover	
Betula papyrifera basal area	
Betula papyrifera seedlings	
Larix laricina % cover	
Larix laricina basal area	
Larix laricina seedlings	
Picea glauca % cover	
Picea glauca basal area	
Picea glauca seedlings	
Picea mariana % cover	1
Picea mariana basal area	2
Picea mariana seedlings	24 5
Pinus banksiana % cover	29 4 5
Pinus banksiana basal area	26 5 6
Pinus banksiana seedlings	4 1 36 4 8
Populus balsamifera % cover	23 3 2
Populus balsamifera basal area	
Populus balsamifera seedlings	
Populus tremuloides % cover	
Populus tremuloides basal area	
Populus tremuloides seedlings	1 1
Snag basal area	1
Actaea rubra	
Antennaria neglecta	
Apocynum androsaemifolium	1
Aquilegia canadensis	
Aralia nudicaulis	1
Aster ciliolatus	
Aster puniceus	
Aster umbellatus	
Bidens cernua	
Caltha palustris	
Campanula aparinoides	
Campanula rotundifolia	1
Clintonia borealis	
Comandra pallida	

TABLE C.5I Summary of *Peromyscus maniculatus* JPSP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

HERBACEOUS LAYER	
Corydalis sempervirens	
Cypripedium acaule	
Epilobium angustifolium	1
Fragaria virginiana	
Galium boreale	
Galium trifidum	
Galium triflorum	
Geocaulon lividum	
Goodyera repens	
Halenia deflexa	
Hieracium scabritusculum	
Lathyrus ochroleucus	
Lathyrus venosus	
Lysimachia thyrsiflora	
Maianthemum canadense	3 1
Melampyrum lineare	4 1
Montropa uniflora	6 1
Petasites palmatus	3 2
Polygonum cilinoides	1
Potentilla palustris	
Prenathes alba	
Pyrola asarifolia	1
Pyrola rotundifolia	
Pyrola virens	
Ranunculus lapponicus	
Sanicula marilandica	
Scutellaria galericulata	
Smilacina trifolia	
Solidago hispida	1
Solidago uliginosa	1
Stellaria longifolia	
Streptopus roseus	
Taraxacum officinale	
Trientalis borealis	
Vicia americana	
Viola adunca	2
Viola pallens	

TABLE C.5I Summary of *Peromyscus maniculatus* JPSP habitat variables (i.e. mean percent cover) found within 100 vegetation quadrats.

GRASSES / RUSHES / SEDGES		Jackpine Sandplain	
Agropyron trachycaulum			
Agrostis scabra			
Calamagrostis canadensis			
Carex aquatilis			
Carex aurea			
Carex canescens			
Carex disperma			
Carex foenea			
Carex intumescens			
Carex paupercula			
Carex spp.			
Cinnia latifolia			
Danthonia spicata			
Eriophorum spissum			
Glyceria grandis			
Graminoids			
Juncus dudleyi			
Oryzopsis asperifolia	1	2	0 captures
Oryzopsis pungens	1	3	1 capture
Schizachne purpurascens		3	2 captures
Scripus cyperinus		3	3 captures
<i>P. maniculatus</i> /quadrat		3	≥ 4 captures
			Total
			100
			No. of quadrats/capture category

TABLE C.6 Summary of the most common small mammal captures by trap-type and gender in six habitats over twenty-five sampling years at Taiga Biological Station. Trap-types may include Museum Specials (MS), Schuylers (SCH), New Museum Specials (NMS) and Unknown Traps (UKT). Gender may include Females (F), Males (M) and Unknown Sex (UKS). (Numbers in parentheses are percentages of the total).

(a) Alder-Tamarack Bog

Clethrionomys gapperi

	F	M	UKS	Total
MS	34 (22.08)	52 (33.77)	9 (5.84)	95 (61.69)
SCH	8 (5.19)	17 (11.04)	5 (3.25)	30 (19.48)
UKT	15 (9.74)	12 (7.79)	2 (1.30)	29 (18.83)
	57 (37.01)	81 (52.60)	16 (10.39)	154

Alder-Tamarack Bog

Sorex cinereus

	F	M	UKS	Total
MS	31 (14.03)	45 (20.36)	41 (18.55)	117 (52.94)
SCH	32 (14.48)	41 (18.55)	22 (9.95)	95 (42.98)
UKT	3 (1.36)	2 (0.90)	4 (1.81)	9 (4.07)
	66 (29.86)	88 (39.82)	67 (30.32)	221

Alder-Tamarack Bog

Microtus pennsylvanicus

	F	M	UKS	Total
MS	10 (27.78)	14 (38.89)	1 (2.78)	25 (69.44)
SCH	6 (16.67)	5 (13.89)	—	11 (30.56)
	16 (44.44)	19 (52.78)	1 (2.78)	36

TABLE C.6 Summary of the most common small mammal captures continued.

(b) Aspen Upland

Clethrionomys gapperi

	F	M	UKS	Total
MS	93 (29.15)	117 (36.68)	20 (6.27)	230 (72.10)
NMS	1 (0.31)	—	—	1 (0.31)
SCH	43 (13.48)	29 (9.09)	4 (1.25)	76 (23.82)
UKT	2 (0.63)	2 (0.63)	8 (2.51)	12 (3.76)
	139 (43.57)	148 (46.39)	32 (10.03)	319

Aspen Upland

Sorex cinereus

	F	M	UKS	Total
MS	28 (23.73)	16 (13.56)	22 (18.64)	66 (55.93)
NMS	—	—	1 (0.85)	1 (0.85)
SCH	16 (13.56)	16 (13.56)	18 (15.25)	50 (42.37)
UKT	—	—	1 (0.85)	1 (0.85)
	44 (37.29)	32 (27.12)	42 (35.59)	118

Aspen Upland

Peromyscus maniculatus

	F	M	UKS	Total
MS	30 (25.86)	38 (32.76)	1 (0.86)	69 (59.48)
NMS	—	1 (0.86)	1 (0.86)	2 (1.72)
SCH	16 (13.79)	22 (18.97)	1 (0.86)	39 (33.62)
UKT	—	—	6 (5.17)	6 (5.17)
	46 (39.66)	61 (52.59)	9 (7.76)	116

Aspen Upland

Microtus pennsylvanicus

	F	M	UKS	Total
MS	11 (57.89)	3 (15.79)	—	14 (73.64)
SCH	2 (10.53)	2 (10.53)	1 (5.26)	5 (26.32)
	13 (68.42)	5 (26.32)	1 (5.26)	19

TABLE C.6 Summary of the most common small mammal captures continued.

(c) Blackspruce Bog

Clethrionomys gapperi

	F	M	UKS	Total
MS	33 (28.45)	45 (38.79)	4 (3.45)	82 (70.69)
SCH	10 (8.62)	21 (18.10)	1 (0.86)	32 (27.59)
UKT	1 (0.86)	1 (0.86)	—	2 (1.72)
	44 (37.93)	67 (57.76)	5 (4.31)	116

Blackspruce Bog

Sorex cinereus

	F	M	UKS	Total
MS	20 (28.99)	11 (15.94)	9 (13.04)	40 (57.97)
SCH	13 (18.84)	7 (10.14)	9 (13.04)	29 (42.03)
	33 (47.83)	18 (26.09)	18 (26.09)	69

Blackspruce Bog

Peromyscus maniculatus

	F	M	UKS	Total
MS	10 (45.45)	4 (18.18)	1 (4.55)	15 (68.18)
SCH	2 (9.09)	3 (13.64)	—	5 (22.73)
UKT	1 (4.55)	1 (4.55)	—	2 (9.09)
	13 (59.09)	8 (36.36)	1 (4.55)	22

Blackspruce Bog

Microtus pennsylvanicus

	F	M	UKS	Total
MS	1 (14.29)	2 (28.57)	1 (14.29)	4 (57.14)
SCH	1 (14.29)	1 (14.29)	1 (14.29)	3 (42.86)
	2 (28.57)	3 (42.86)	2 (28.57)	7

TABLE C.6 Summary of the most common small mammal captures continued.

(d) Ecotone

Clethrionomys gapperi

	F	M	UKS	Total
MS	66 (26.40)	93 (37.20)	9 (3.60)	168 (67.20)
SCH	24 (9.60)	36 (14.40)	2 (0.80)	62 (24.80)
UKT	9 (3.60)	7 (2.80)	4 (1.60)	20 (8.00)
	99 (39.60)	136 (54.40)	15 (6.00)	250

Ecotone

Sorex cinereus

	F	M	UKS	Total
MS	22 (11.70)	43 (22.87)	31 (16.49)	96 (51.06)
SCH	21 (11.17)	39 (20.74)	27 (14.36)	87 (46.28)
UKT	—	1 (0.53)	4 (2.13)	5 (2.66)
	43 (22.87)	83 (44.15)	62 (32.98)	188

Ecotone

Peromyscus maniculatus

	F	M	UKS	Total
MS	11 (31.43)	12 (34.29)	2 (5.71)	25 (71.43)
SCH	4 (11.43)	2 (5.71)	1 (2.86)	7 (20.00)
UKT	—	3 (8.57)	—	3 (8.57)
	15 (42.86)	17 (48.57)	3 (8.57)	35

Ecotone

Microtus pennsylvanicus

	F	M	UKS	Total
MS	7 (29.17)	9 (37.50)	1 (4.17)	17 (70.83)
SCH	2 (8.33)	2 (8.33)	2 (8.33)	6 (25.00)
UKT	1 (4.17)	—	—	1 (4.17)
	10 (41.67)	11 (45.83)	3 (12.50)	24

TABLE C.6 Summary of the most common small mammal captures continued.

(e) Jackpine Ridge

Clethrionomys gapperi

	F	M	UKS	Total
MS	49 (29.34)	53 (31.74)	9 (5.39)	111 (66.47)
NMS	3 (1.80)	1 (0.60)	—	4 (2.40)
SCH	29 (17.37)	19 (11.38)	3 (1.80)	51 (30.54)
UKT	1 (0.60)	—	—	1 (0.60)
	82 (49.10)	73 (43.71)	12 (7.19)	167

Jackpine Ridge

Sorex cinereus

	F	M	UKS	Total
MS	7 (17.07)	6 (14.63)	11 (26.83)	24 (58.54)
SCH	4 (9.76)	5 (12.20)	6 (14.63)	15 (36.59)
UKT	1 (2.44)	—	1 (2.44)	2 (4.88)
	12 (29.27)	11 (26.83)	18 (43.90)	41

Jackpine Ridge

Peromyscus maniculatus

	F	M	UKS	Total
MS	46 (40.00)	30 (26.09)	1 (0.87)	77 (66.96)
SCH	13 (11.30)	18 (15.65)	—	31 (26.96)
UKT	4 (3.48)	3 (2.61)	—	7 (6.09)
	63 (54.78)	51 (44.35)	1 (0.87)	115

TABLE C.6 Summary of the most common small mammal captures continued.

(f) Jackpine Sandplain
Clethrionomys gapperi

	F	M	UKS	Total
MS	45 (38.46)	39 (33.33)	2 (1.71)	86 (73.50)
NMS	3 (2.56)	1 (0.85)	—	4 (3.42)
SCH	13 (11.11)	12 (10.26)	1 (0.85)	26 (22.22)
UKT	—	1 (0.85)	—	1 (0.85)
	61 (52.14)	53 (45.30)	3 (2.56)	117

Jackpine Sandplain
Sorex cinereus

	F	M	UKS	Total
MS	1 (5.56)	2 (11.11)	4 (22.22)	7 (38.89)
SCH	3 (16.67)	3 (16.67)	3 (16.67)	9 (50.00)
UKT	—	—	2 (11.11)	2 (11.11)
	4 (22.22)	5 (27.78)	9 (50.00)	18

Jackpine Sandplain
Peromyscus maniculatus

	F	M	UKS	Total
MS	44 (30.77)	51 (35.66)	1 (0.70)	96 (67.13)
NMS	2 (1.40)	2 (1.40)	—	4 (2.80)
SCH	18 (12.59)	17 (11.89)	—	35 (24.48)
UKT	—	—	8 (5.59)	8 (5.59)
	64 (44.76)	70 (48.95)	9 (6.29)	143

TABLE C.7 Mean body mass (g) \pm 1 S.D. of male and female small mammal species captured in two different trap-types across six sites during twenty-five annual trapping seasons at Taiga Biological Station. Overall mean weights of the separate genders also include individuals with unrecorded trap types from each plot. Traps are MS = Museum Specials and SCH = Schuylers.

(a)							
Alder-Tamarack Bog							
Species	Trap	Female	S. D.	N	Male	S. D.	N
<i>Clethrionomys gapperi</i>	MS	18.97	5.76	34	16.65	3.78	51
	SCH	17.88	5.94	8	16.88	1.17	16
	Overall	18.01	5.21	57	16.58	3.86	79
<i>Sorex cinereus</i>	MS	3.71	0.87	31	3.55	0.65	47
	SCH	3.37	0.62	30	3.44	0.65	37
	Overall	3.51	0.76	64	3.50	0.65	84
<i>Microtus pennsylvanicus</i>	MS	26.12	5.43	10	21.39	8.24	14
	SCH	28.13	10.41	6	16.52	4.86	5
	Overall	26.88	7.40	16	20.11	7.69	19

(b)							
Aspen Upland							
Species	Trap	Female	S. D.	N	Male	S. D.	N
<i>Clethrionomys gapperi</i>	MS	21.35	7.23	92	16.26	4.47	114
	SCH	21.41	7.81	43	17.74	5.26	27
	Overall	21.37	7.39	135	16.54	4.65	141
<i>Sorex cinereus</i>	MS	3.36	0.56	28	3.19	0.31	16
	SCH	3.29	0.47	16	3.14	0.54	16
	Overall	3.33	0.53	44	3.17	0.43	32
<i>Peromyscus maniculatus</i>	MS	15.88	2.11	30	14.81	2.41	39
	SCH	16.26	4.23	16	15.27	3.22	21
	Overall	16.01	2.98	46	14.97	2.70	60
<i>Microtus pennsylvanicus</i>	MS	20.04	8.44	11	18.27	4.29	3
	SCH	---	---	---	26.60	10.04	2
	Overall	20.04	8.44	11	21.60	7.43	5

(c)							
Blackspruce Bog							
Species	Trap	Female	S. D.	N	Male	S. D.	N
<i>Clethrionomys gapperi</i>	MS	17.75	7.17	34	17.02	5.09	45
	SCH	22.91	7.00	10	18.20	5.56	21
	Overall	18.93	7.38	44	17.40	5.23	66
<i>Sorex cinereus</i>	MS	3.43	0.54	20	3.59	0.63	11
	SCH	3.62	0.73	13	3.77	0.69	7
	Overall	3.50	0.62	33	3.66	0.64	18
<i>Peromyscus maniculatus</i>	MS	15.59	3.33	10	12.07	0.31	3
	SCH	15.10	0.28	2	12.87	0.96	3
	Overall	15.73	3.00	13	12.29	0.84	8
<i>Microtus pennsylvanicus</i>	MS	16.00	---	1	16.65	1.63	2
	SCH	32.50	---	1	23.70	---	1
	Overall	24.25	11.67	2	19.00	4.23	3

TABLE C.7 Mean body mass (g) \pm 1 S.D. of male and female small mammal species continued.

(d)							
Ecotone							
Species	Trap	Female	S. D.	N	Male	S. D.	N
<i>Clethrionomys gapperi</i>	MS	18.82	5.61	73	17.09	4.45	97
	SCH	21.20	6.90	23	16.54	4.83	33
	Overall	19.44	5.92	99	17.02	4.54	132
<i>Sorex cinereus</i>	MS	3.66	1.12	22	3.54	0.80	42
	SCH	3.56	1.04	20	3.46	0.68	37
	Overall	3.61	1.07	42	3.51	0.74	79
<i>Peromyscus maniculatus</i>	MS	14.43	2.41	12	15.83	3.98	15
	SCH	15.50	4.46	4	13.80	1.84	2
	Overall	14.91	2.88	16	15.79	3.85	17
<i>Microtus pennsylvanicus</i>	MS	21.71	8.27	7	15.68	6.07	8
	SCH	22.90	2.40	2	15.90	2.40	2
	Overall	21.56	6.94	10	15.72	5.41	10

(e)							
Jackpine Ridge							
Species	Trap	Female	S. D.	N	Male	S. D.	N
<i>Clethrionomys gapperi</i>	MS	21.88	7.54	47	18.02	4.91	51
	SCH	21.61	6.83	28	18.22	4.72	19
	Overall	21.76	7.27	78	18.09	4.83	72
<i>Sorex cinereus</i>	MS	3.64	0.68	8	3.38	1.01	6
	SCH	4.00	1.22	4	3.68	0.94	5
	Overall	3.76	0.86	12	3.52	0.94	11
<i>Peromyscus maniculatus</i>	MS	14.68	2.98	45	14.12	2.41	29
	SCH	15.76	2.96	12	13.71	1.99	18
	Overall	14.93	2.98	62	13.89	2.25	50

(f)							
Jackpine Sandplain							
Species	Trap	Female	S. D.	N	Male	S. D.	N
<i>Clethrionomys gapperi</i>	MS	24.46	6.63	45	19.04	5.37	39
	SCH	25.45	7.34	13	18.76	5.14	11
	Overall	24.24	6.95	61	19.01	5.21	52
<i>Sorex cinereus</i>	MS	3.30	—	1	3.15	0.78	2
	SCH	4.27	1.25	3	3.00	0.14	2
	Overall	4.03	1.13	4	3.08	0.46	4
<i>Peromyscus maniculatus</i>	MS	15.97	3.75	43	14.52	2.34	50
	SCH	16.16	3.36	18	15.18	2.77	17
	Overall	15.95	3.58	63	14.70	2.43	69

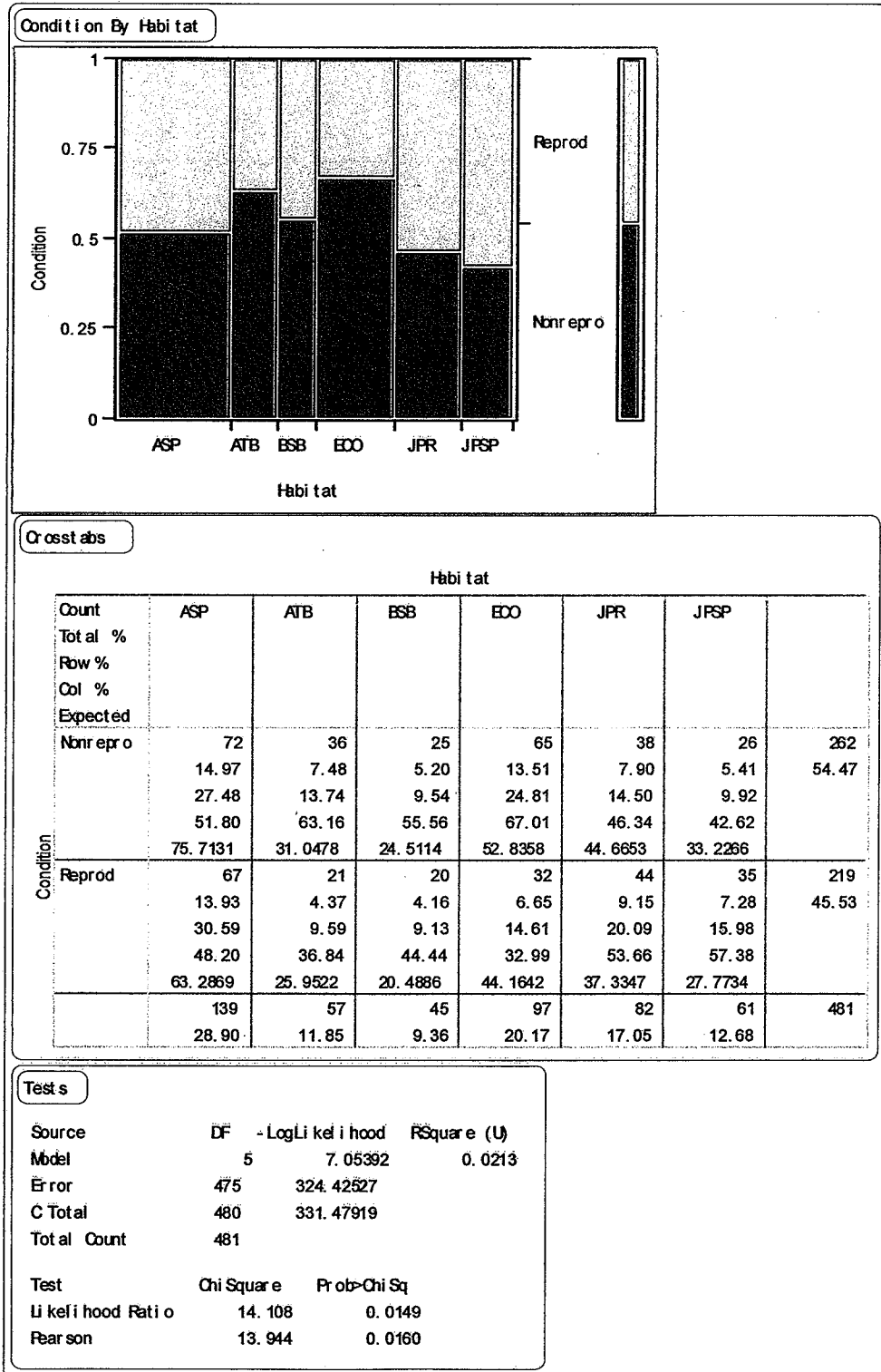


TABLE C.8 A comparison of female *Clethrionomys* reproductive conditions across six sites at Taiga Biological Station combined over twenty-five years of sampling-effort.

TABLE C.9 The frequency of capture-combinations for three of the most common small mammal species found at each trapping station (100 trap markers/plot) across six sites, at Taiga Biological Station. The capture-combinations are derived from twenty-five years of small mammal data recorded from each habitat. Species that are less frequently captured have been omitted.

(a) Alder-Tamarack Bog

No captures recorded	1
All three species captured	17
<i>Clethrionomys gapperi</i> and <i>Microtus pennsylvanicus</i>	2
<i>Clethrionomys gapperi</i> and <i>Sorex cinereus</i>	46
<i>Microtus pennsylvanicus</i> and <i>Sorex cinereus</i>	6
<i>Clethrionomys gapperi</i> alone	5
<i>Sorex cinereus</i> alone	22
<i>Microtus pennsylvanicus</i> alone	1
Total number of trapping stations	100

(b) Aspen Upland

No captures recorded	3
All three species captured	31
<i>Clethrionomys gapperi</i> and <i>Peromyscus maniculatus</i>	17
<i>Clethrionomys gapperi</i> and <i>Sorex cinereus</i>	29
<i>Peromyscus maniculatus</i> and <i>Sorex cinereus</i>	7
<i>Clethrionomys gapperi</i> alone	10
<i>Sorex cinereus</i> alone	1
<i>Peromyscus maniculatus</i> alone	2
Total number of trapping stations	100

(c) Blackspruce Bog

No captures recorded	15
All three species captured	6
<i>Clethrionomys gapperi</i> and <i>Peromyscus maniculatus</i>	5
<i>Clethrionomys gapperi</i> and <i>Sorex cinereus</i>	23
<i>Peromyscus maniculatus</i> and <i>Sorex cinereus</i>	3
<i>Clethrionomys gapperi</i> alone	32
<i>Sorex cinereus</i> alone	13
<i>Peromyscus maniculatus</i> alone	3
Total number of trapping stations	100

TABLE C.9 The frequency of capture-combinations for three of the most common small mammal species found continued.

(d) Ecotone

No captures recorded	2
All three species captured	10
<i>Clethrionomys gapperi</i> and <i>Peromyscus maniculatus</i>	12
<i>Clethrionomys gapperi</i> and <i>Sorex cinereus</i>	45
<i>Peromyscus maniculatus</i> and <i>Sorex cinereus</i>	0
<i>Clethrionomys gapperi</i> alone	16
<i>Sorex cinereus</i> alone	11
<i>Peromyscus maniculatus</i> alone	4
Total number of trapping stations	100

(e) Jackpine Ridge

No captures recorded	10
All 3 species captured	14
<i>Clethrionomys gapperi</i> and <i>Peromyscus maniculatus</i>	35
<i>Clethrionomys gapperi</i> and <i>Sorex cinereus</i>	10
<i>Peromyscus maniculatus</i> and <i>Sorex cinereus</i>	2
<i>Clethrionomys gapperi</i> alone	17
<i>Sorex cinereus</i> alone	4
<i>Peromyscus maniculatus</i> alone	8
Total number of trapping stations	100

(f) Jackpine Sandplain

No captures recorded	13
All 3 species captured	7
<i>Clethrionomys gapperi</i> and <i>Peromyscus maniculatus</i>	30
<i>Clethrionomys gapperi</i> and <i>Sorex cinereus</i>	2
<i>Peromyscus maniculatus</i> and <i>Sorex cinereus</i>	1
<i>Clethrionomys gapperi</i> alone	12
<i>Sorex cinereus</i> alone	3
<i>Peromyscus maniculatus</i> alone	32
Total number of trapping stations	100

TABLE C.10 Observed capture combinations based on presence-absence data from 100 trapping stations over twenty-five years representing interspecific associations involving three of the most common small mammal species within the Alder-Tamarack Bog.

(a)

		<i>Clethrionomys</i> present		<i>Clethrionomys</i> absent	
		<i>M. pennsylvanicus</i> Present	<i>M. pennsylvanicus</i> Absent	<i>M. pennsylvanicus</i> Present	<i>M. pennsylvanicus</i> Absent
<i>S. cinereus</i>	Present	17	46	6	22
	Absent	2	5	1	1

n = 100 trap markers

(b)

		<i>C. gapperi</i>	
		Present	Absent
<i>S. cinereus</i>	Present	63	28
	Absent	7	2

n = 100 trap markers

(c)

		<i>M. pennsylvanicus</i>	
		Present	Absent
<i>S. cinereus</i>	Present	23	68
	Absent	3	6

n = 100 trap markers

(d)

		<i>C. gapperi</i>	
		Present	Absent
<i>M. pennsylvanicus</i>	Present	19	7
	Absent	51	23

n = 100 trap markers

TABLE C.11 Six conditional tables representing interspecific associations based on presence-absence data from 100 trap markers using three of the most common small mammal species within the Alder-Tamarack Bog.

a) <i>Clethrionomys gapperi</i> present				b) <i>Clethrionomys gapperi</i> absent			
		<i>M. pennsylvanicus</i>				<i>M. pennsylvanicus</i>	
		Present	Absent			Present	Absent
<i>S. cinereus</i>	Present	17	46	<i>S. cinereus</i>	Present	6	22
	Absent	2	5		Absent	1	1

c) <i>Microtus pennsylvanicus</i> present				d) <i>Microtus pennsylvanicus</i> absent			
		<i>C. gapperi</i>				<i>C. gapperi</i>	
		Present	Absent			Present	Absent
<i>S. cinereus</i>	Present	17	6	<i>S. cinereus</i>	Present	46	22
	Absent	2	1		Absent	5	1

e) <i>Sorex cinereus</i> present				f) <i>Sorex cinereus</i> absent			
		<i>C. gapperi</i>				<i>C. gapperi</i>	
		Present	Absent			Present	Absent
<i>M. pennsylvanicus</i>	Present	17	6	<i>M. pennsylvanicus</i>	Present	2	1
	Absent	46	22		Absent	5	1

TABLE C.12 Observed capture combinations based on presence-absence data from 100 trapping stations over twenty-five years representing interspecific associations involving three of the most common small mammal species within the Aspen Upland.

(a)

		Clethrionomys present		Clethrionomys absent	
		<i>P. maniculatus</i>		<i>P. maniculatus</i>	
		Present	Absent	Present	Absent
<i>S. cinereus</i>	Present	31	29	7	1
	Absent	17	10	2	3

n = 100 trap markers

(b)

		<i>C. gapperi</i>	
		Present	Absent
<i>S. cinereus</i>	Present	60	8
	Absent	27	5

n = 100 trap markers

(c)

		<i>P. maniculatus</i>	
		Present	Absent
<i>S. cinereus</i>	Present	38	30
	Absent	19	13

n = 100 trap markers

(d)

		<i>C. gapperi</i>	
		Present	Absent
<i>P. maniculatus</i>	Present	48	9
	Absent	39	4

n = 100 trap markers

TABLE C.13 Six conditional tables representing interspecific associations based on presence-absence data from 100 trap markers using three of the most common small mammal species within the **Aspen Upland**.

a) <i>Clethrionomys gapperi</i> present				b) <i>Clethrionomys gapperi</i> absent			
		<i>P. maniculatus</i>				<i>P. maniculatus</i>	
		Present	Absent			Present	Absent
<i>S. cinereus</i>	Present	31	29	<i>S. cinereus</i>	Present	7	1
	Absent	17	10		Absent	2	3

c) <i>Peromyscus maniculatus</i> present				d) <i>Peromyscus maniculatus</i> absent			
		<i>C. gapperi</i>				<i>C. gapperi</i>	
		Present	Absent			Present	Absent
<i>S. cinereus</i>	Present	31	7	<i>S. cinereus</i>	Present	29	1
	Absent	17	2		Absent	10	3

e) <i>Sorex cinereus</i> present				f) <i>Sorex cinereus</i> absent			
		<i>C. gapperi</i>				<i>C. gapperi</i>	
		Present	Absent			Present	Absent
<i>P. maniculatus</i>	Present	31	7	<i>P. maniculatus</i>	Present	17	2
	Absent	29	1		Absent	10	3

TABLE C.14 Observed capture combinations based on presence-absence data from 100 trapping stations over twenty-five years representing interspecific associations involving three of the most common small mammal species within the **Blackspruce Bog**.

(a)

		Clethrionomys present		Clethrionomys absent	
		<i>P. maniculatus</i>		<i>P. maniculatus</i>	
		Present	Absent	Present	Absent
<i>S. cinereus</i>	Present	6	23	3	13
	Absent	5	32	3	15

n = 100 trap markers

(b)

		<i>C. gapper</i>	
		Present	Absent
<i>S. cinereus</i>	Present	29	16
	Absent	37	18

n = 100 trap markers

(c)

		<i>P. maniculatus</i>	
		Present	Absent
<i>S. cinereus</i>	Present	9	36
	Absent	8	47

n = 100 trap markers

(d)

		<i>C. gapper</i>	
		Present	Absent
<i>P. maniculatus</i>	Present	11	6
	Absent	55	28

n = 100 trap markers

TABLE C.15 Six conditional tables representing interspecific associations based on presence-absence data from 100 trap markers using three of the most common small mammal species within the **Blackspruce Bog**.

a) <i>Clethrionomys gapperi</i> present				b) <i>Clethrionomys gapperi</i> absent			
		<i>P. maniculatus</i>				<i>P. maniculatus</i>	
		Present	Absent			Present	Absent
<i>S. cinereus</i>	Present	6	23	<i>S. cinereus</i>	Present	3	13
	Absent	5	32		Absent	3	15

c) <i>Peromyscus maniculatus</i> present				d) <i>Peromyscus maniculatus</i> absent			
		<i>C. gapperi</i>				<i>C. gapperi</i>	
		Present	Absent			Present	Absent
<i>S. cinereus</i>	Present	6	3	<i>S. cinereus</i>	Present	23	13
	Absent	5	3		Absent	32	15

e) <i>Sorex cinereus</i> present				f) <i>Sorex cinereus</i> absent			
		<i>C. gapperi</i>				<i>C. gapperi</i>	
		Present	Absent			Present	Absent
<i>P. maniculatus</i>	Present	6	3	<i>P. maniculatus</i>	Present	5	3
	Absent	23	13		Absent	32	15

TABLE C.16 Observed capture combinations based on presence-absence data from 100 trapping stations over twenty-five years representing interspecific associations involving three of the most common small mammal species within the **Ecotone**.

(a)

		Clethrionomys present		Clethrionomys absent	
		<i>P. maniculatus</i>		<i>P. maniculatus</i>	
		Present	Absent	Present	Absent
<i>S. cinereus</i>	Present	10	45	0	11
	Absent	12	16	4	2

n = 100 trap markers

(b)

		<i>C. gapperi</i>	
		Present	Absent
<i>S. cinereus</i>	Present	55	11
	Absent	28	6

n = 100 trap markers

(c)

		<i>P. maniculatus</i>	
		Present	Absent
<i>S. cinereus</i>	Present	10	56
	Absent	16	18

n = 100 trap markers

(d)

		<i>C. gapperi</i>	
		Present	Absent
<i>P. maniculatus</i>	Present	22	4
	Absent	61	13

n = 100 trap markers

TABLE C.17 Six conditional tables representing interspecific associations based on presence-absence data from 100 trap markers using three of the most common small mammal species within the **Ecotone**.

a) <i>Clethrionomys gapperi</i> present				b) <i>Clethrionomys gapperi</i> absent			
		<i>P. maniculatus</i>				<i>P. maniculatus</i>	
		Present	Absent			Present	Absent
<i>S. cinereus</i>	Present	10	45	<i>S. cinereus</i>	Present	0	11
	Absent	12	16		Absent	4	2

c) <i>Peromyscus maniculatus</i> present				d) <i>Peromyscus maniculatus</i> absent			
		<i>C. gapperi</i>				<i>C. gapperi</i>	
		Present	Absent			Present	Absent
<i>S. cinereus</i>	Present	10	0	<i>S. cinereus</i>	Present	45	11
	Absent	12	4		Absent	16	2

e) <i>Sorex cinereus</i> present				f) <i>Sorex cinereus</i> absent			
		<i>C. gapperi</i>				<i>C. gapperi</i>	
		Present	Absent			Present	Absent
<i>P. maniculatus</i>	Present	10	0	<i>P. maniculatus</i>	Present	12	16
	Absent	45	11		Absent	4	2

TABLE C.18 Observed capture combinations based on presence-absence data from 100 trapping stations over twenty-five years representing interspecific associations involving three of the most common small mammal species within the Jackpine Ridge.

(a)

		Clethrionomys present		Clethrionomys absent	
		<i>P. maniculatus</i>		<i>P. maniculatus</i>	
<i>S. cinereus</i>	Present	14	10	2	4
	Absent	35	17	8	10

n = 100 trap markers

(b)

		<i>C. gapperi</i>	
		Present	Absent
<i>S. cinereus</i>	Present	24	6
	Absent	52	18

n = 100 trap markers

(c)

		<i>P. maniculatus</i>	
		Present	Absent
<i>S. cinereus</i>	Present	16	14
	Absent	43	27

n = 100 trap markers

(d)

		<i>C. gapperi</i>	
		Present	Absent
<i>P. maniculatus</i>	Present	49	10
	Absent	27	14

n = 100 trap markers

TABLE C.19 Six conditional tables representing interspecific associations based on presence-absence data from 100 trap markers using three of the most common small mammal species within the **Jackpine Ridge**.

a) <i>Clethrionomys gapperi</i> present				b) <i>Clethrionomys gapperi</i> absent			
		<i>P. maniculatus</i>				<i>P. maniculatus</i>	
		Present	Absent			Present	Absent
<i>S. cinereus</i>	Present	14	10	<i>S. cinereus</i>	Present	2	4
	Absent	35	17		Absent	8	10

c) <i>Peromyscus maniculatus</i> present				d) <i>Peromyscus maniculatus</i> absent			
		<i>C. gapperi</i>				<i>C. gapperi</i>	
		Present	Absent			Present	Absent
<i>S. cinereus</i>	Present	14	2	<i>S. cinereus</i>	Present	10	4
	Absent	35	8		Absent	17	10

e) <i>Sorex cinereus</i> present				f) <i>Sorex cinereus</i> absent			
		<i>C. gapperi</i>				<i>C. gapperi</i>	
		Present	Absent			Present	Absent
<i>P. maniculatus</i>	Present	14	2	<i>P. maniculatus</i>	Present	35	8
	Absent	10	4		Absent	17	10

TABLE C.20 Observed capture combinations based on presence-absence data from 100 trapping stations over twenty-five years representing interspecific associations involving three of the most common small mammal species within the **Jackpine Sandplain**.

(a)

		<i>Clethrionomys</i> present		<i>Clethrionomys</i> absent	
		<i>P. maniculatus</i>		<i>P. maniculatus</i>	
		Present	Absent	Present	Absent
<i>S. cinereus</i>	Present	7	2	1	3
	Absent	30	12	32	13

n = 100 trap markers

(b)

		<i>C. gapperi</i>	
		Present	Absent
<i>S. cinereus</i>	Present	9	4
	Absent	42	45

n = 100 trap markers

(c)

		<i>P. maniculatus</i>	
		Present	Absent
<i>S. cinereus</i>	Present	8	5
	Absent	62	25

n = 100 trap markers

(d)

		<i>C. gapperi</i>	
		Present	Absent
<i>P. maniculatus</i>	Present	37	33
	Absent	14	16

n = 100 trap markers

TABLE C.21 Six conditional tables representing interspecific associations based on presence-absence data from 100 trap markers using three of the most common small mammal species within the **Jackpine Sandplain**.

		a) <i>Clethrionomys gapperi</i> present		b) <i>Clethrionomys gapperi</i> absent	
		<i>P. maniculatus</i>		<i>P. maniculatus</i>	
		Present	Absent	Present	Absent
<i>S. cinereus</i>	Present	7	2	1	3
	Absent	30	12	32	13

		c) <i>Peromyscus maniculatus</i> present		d) <i>Peromyscus maniculatus</i> absent	
		<i>C. gapperi</i>		<i>C. gapperi</i>	
		Present	Absent	Present	Absent
<i>S. cinereus</i>	Present	7	1	2	3
	Absent	30	32	12	13

		e) <i>Sorex cinereus</i> present		f) <i>Sorex cinereus</i> absent	
		<i>C. gapperi</i>		<i>C. gapperi</i>	
		Present	Absent	Present	Absent
<i>P. maniculatus</i>	Present	7	1	2	1
	Absent	2	3	12	13

TABLE C.22 Median body mass (g) of small mammals captured in two different trap-types (MS = Museum Special; SCH = Schuyler) showed that differences in body mass were not significant. The Wilcoxon test uses a chi-square distribution approximation. Wilcoxon rank-sum test results indicated $P > 0.10$ in all cases.

(a) Alder-Tamarack Bog						
<i>Clethrionomys gapperi</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.3138	1	0.5753	Median weight (g)	17.52	17.21
				Number	94	28
				Std. Dev.	4.57	4.65
<i>Sorex cinereus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	2.4966	1	0.1141	Median weight (g)	3.53	3.38
				Number	110	81
				Std. Dev.	0.68	0.59
<i>Microtus pennsylvanicus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.2302	1	0.6314	Median weight (g)	23.36	22.85
				Number	24	11
				Std. Dev.	7.46	10.02
(b) Aspen Upland						
<i>Clethrionomys gapperi</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	1.3663	1	0.2424	Median weight (g)	18.18	19.52
				Number	219	74
				Std. Dev.	6.39	7.23
<i>Sorex cinereus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.0894	1	0.7649	Median weight (g)	3.25	3.22
				Number	65	47
				Std. Dev.	0.46	0.47
<i>Peromyscus maniculatus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.2443	1	0.6211	Median weight (g)	15.26	15.74
				Number	68	38
				Std. Dev.	2.35	3.63
<i>Microtus pennsylvanicus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	1.5873	1	0.2077	Median weight (g)	19.66	25.57
				Number	14	3
				Std. Dev.	7.62	7.32

TABLE C.22 Wilcoxon rank-sum test results of median body mass (g) of small mammals continued.

(c) Blackspruce Bog

<i>Clethrionomys gapperi</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	2.3871	1	0.1223	Median weight (g)	17.44	19.72
				Number	78	31
				Std. Dev.	6.10	6.35

<i>Sorex cinereus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	1.0039	1	0.3164	Median weight (g)	3.41	3.58
				Number	40	28
				Std. Dev.	0.53	0.64

<i>Peromyscus maniculatus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	1.1932	1	0.2747	Median weight (g)	14.71	13.28
				Number	15	5
				Std. Dev.	2.99	1.68

(d) Ecotone

<i>Clethrionomys gapperi</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.0214	1	0.8838	Median weight (g)	17.98	18.52
				Number	161	55
				Std. Dev.	5.17	6.21

<i>Sorex cinereus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.5388	1	0.4629	Median weight (g)	3.57	3.44
				Number	91	78
				Std. Dev.	0.90	0.74

<i>Peromyscus maniculatus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.0756	1	0.7833	Median weight (g)	15.04	15.42
				Number	25	6
				Std. Dev.	3.53	3.46

<i>Microtus pennsylvanicus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.6876	1	0.4070	Median weight (g)	18.49	20.40
				Number	15	5
				Std. Dev.	7.58	4.49

TABLE C.22 Wilcoxon rank-sum test results of median body mass (g) of small mammals continued.

(e) Jackpine Ridge

<i>Clethrionomys gapperi</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.2631	1	0.6080	Median weight (g)	19.41	19.73
				Number	105	50
				Std. Dev.	6.61	6.52

<i>Peromyscus maniculatus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.9527	1	0.3290	Median weight (g)	14.40	14.67
				Number	75	31
				Std. Dev.	2.80	2.66

<i>Sorex cinereus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.3876	1	0.5336	Median weight (g)	3.40	3.45
				Number	22	15
				Std. Dev.	0.69	0.92

(f) Jackpine Sandplain

<i>Clethrionomys gapperi</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.0029	1	0.9573	Median weight (g)	21.88	22.29
				Number	85	25
				Std. Dev.	6.61	7.02

<i>Peromyscus maniculatus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.7503	1	0.3864	Median weight (g)	15.19	15.68
				Number	93	35
				Std. Dev.	3.14	3.08

<i>Sorex cinereus</i>	χ^2	d.f.	p-value	Trap type	MS	SCH
	0.9799	1	0.3222	Median weight (g)	3.19	3.69
				Number	7	8
				Std. Dev.	0.43	0.95

TABLE C.23 Number of observed and (expected) male and female small mammals captured in two trap-types (MS = Museum Special; SCH = Schuyler) across six sites at Taiga Biological Station. The null hypothesis is that there is no association between trap-type and gender ($df = 1$; $P < 0.05$ indicates that there is no significant difference between male and female susceptibility to trap-type in almost all cases).

(a) Alder-Tamarack Bog						
<i>Clethrionomys gapperi</i>		Female	Male	Total	χ^2	p-value
	MS	34 (32.54)	52 (53.46)	86		
	SCH	8 (9.46)	17 (15.54)	25		
	Total	42	69	111		
<i>Sorex cinereus</i>		Female	Male	Total	χ^2	p-value
	MS	31 (32.13)	45 (43.87)	76		
	SCH	32 (30.87)	41 (42.13)	73		
	Total	63	86	149		
<i>Microtus pennsylvanicus</i>		Female	Male	Total	χ^2	p-value
	MS	10 (10.97)	14 (13.03)	24		
	SCH	6 (5.03)	5 (5.97)	11		
	Total	16	19	35		
(b) Aspen Upland						
<i>Clethrionomys gapperi</i>		Female	Male	Total	χ^2	p-value
	MS	93 (101.28)	117 (108.72)	210		
	SCH	43 (34.72)	29 (37.28)	72		
	Total	136	146	282		
<i>Sorex cinereus</i>		Female	Male	Total	χ^2	p-value
	MS	28 (25.47)	16 (18.53)	44		
	SCH	16 (18.53)	16 (13.47)	32		
	Total	44	32	76		
<i>Peromyscus maniculatus</i>		Female	Male	Total	χ^2	p-value
	MS	30 (29.51)	38 (38.49)	68		
	SCH	16 (16.49)	22 (21.51)	38		
	Total	46	60	106		
<i>Microtus pennsylvanicus</i>		Female	Male	Total	χ^2	p-value
	MS	11 (10.11)	3 (3.89)	14		
	SCH	2 (2.89)	2 (1.11)	4		
	Total	13	5	18		
(c) Blackspruce Bog						
<i>Clethrionomys gapperi</i>		Female	Male	Total	χ^2	p-value
	MS	33 (30.77)	45 (47.23)	78		
	SCH	10 (12.23)	21 (18.77)	31		
	Total	43	66	109		
<i>Sorex cinereus</i>		Female	Male	Total	χ^2	p-value
	MS	20 (20.06)	11 (10.94)	31		
	SCH	13 (12.94)	7 (7.06)	20		
	Total	33	18	51		
<i>Peromyscus maniculatus</i>		Female	Male	Total	χ^2	p-value
	MS	10 (8.84)	4 (5.16)	14		
	SCH	2 (3.16)	3 (1.84)	5		
	Total	12	7	19		

TABLE C.23 The chi-square statistic for the number of male and female small mammals captured in two trap-types continued.

(d) Ecotone

		Female	Male	Total	χ^2	p-value
<i>Clethrionomys gapperi</i>						
	MS	66 (73.33)	93 (72.09)	159	0.041	0.8395
	SCH	24 (24.66)	36 (35.34)	60		
	Total	90	129	219		
<i>Sorex cinereus</i>						
	MS	22 (22.36)	43 (42.64)	65	0.018	0.8921
	SCH	21 (20.64)	39 (39.36)	60		
	Total	43	82	125		
<i>Peromyscus maniculatus</i>						
	MS	11 (11.90)	12 (11.10)	23	0.676	0.4108
	SCH	4 (3.10)	2 (2.90)	6		
	Total	15	14	29		
<i>Microtus pennsylvanicus</i>						
	MS	7 (7.20)	9 (8.80)	16	0.051	0.8222
	SCH	2 (1.80)	2 (2.20)	4		
	Total	9	11	20		

(e) Jackpine Ridge

		Female	Male	Total	χ^2	p-value
<i>Clethrionomys gapperi</i>						
	MS	49 (53.04)	53 (48.96)	102	2.003	0.1569
	SCH	29 (24.96)	19 (23.04)	48		
	Total	78	72	150		
<i>Sorex cinereus</i>						
	MS	7 (6.50)	6 (6.50)	13	0.188	0.6646
	SCH	4 (4.50)	5 (4.50)	9		
	Total	11	11	22		
<i>Peromyscus maniculatus</i>						
	MS	46 (41.91)	30 (34.10)	76	3.077	0.0794
	SCH	13 (17.10)	18 (13.91)	31		
	Total	59	48	107		

(f) Jackpine Sandplain

		Female	Male	Total	χ^2	p-value
<i>Clethrionomys gapperi</i>						
	MS	45 (44.70)	39 (39.30)	84	0.019	0.8901
	SCH	13 (13.30)	12 (11.70)	25		
	Total	58	51	109		
<i>Peromyscus maniculatus</i>						
	MS	44 (45.31)	51 (49.69)	95	0.268	0.6047
	SCH	18 (16.69)	17 (18.31)	35		
	Total	62	68	130		

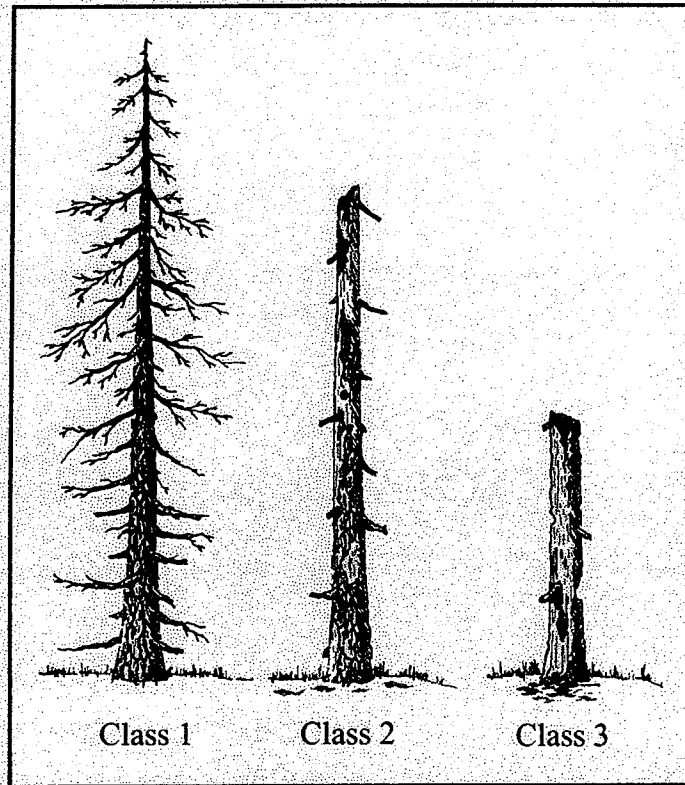


FIG. C.1a Three structural classes of dead trees (after Bull et al. 1997).

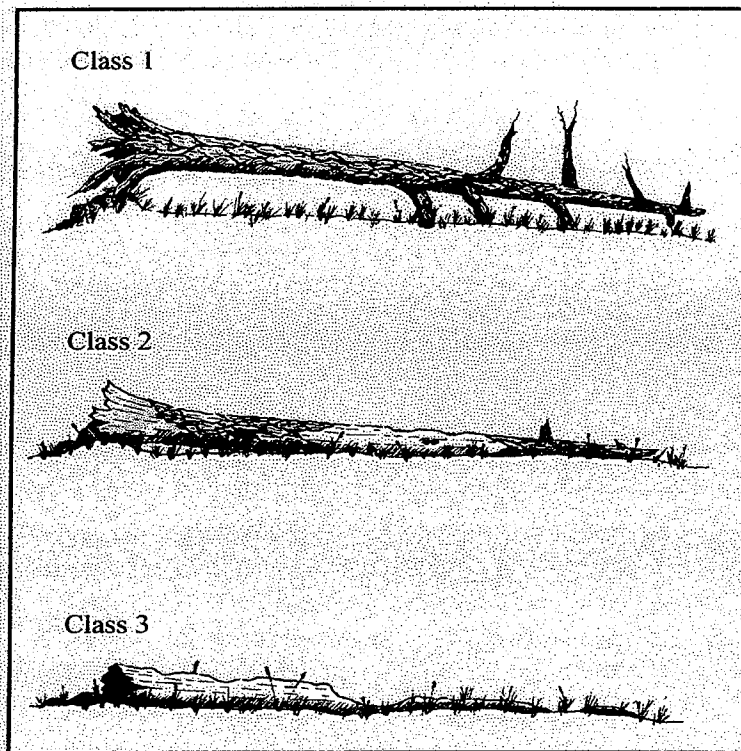


FIG. C.1b Three structural classes of logs (after Bull et al. 1997).

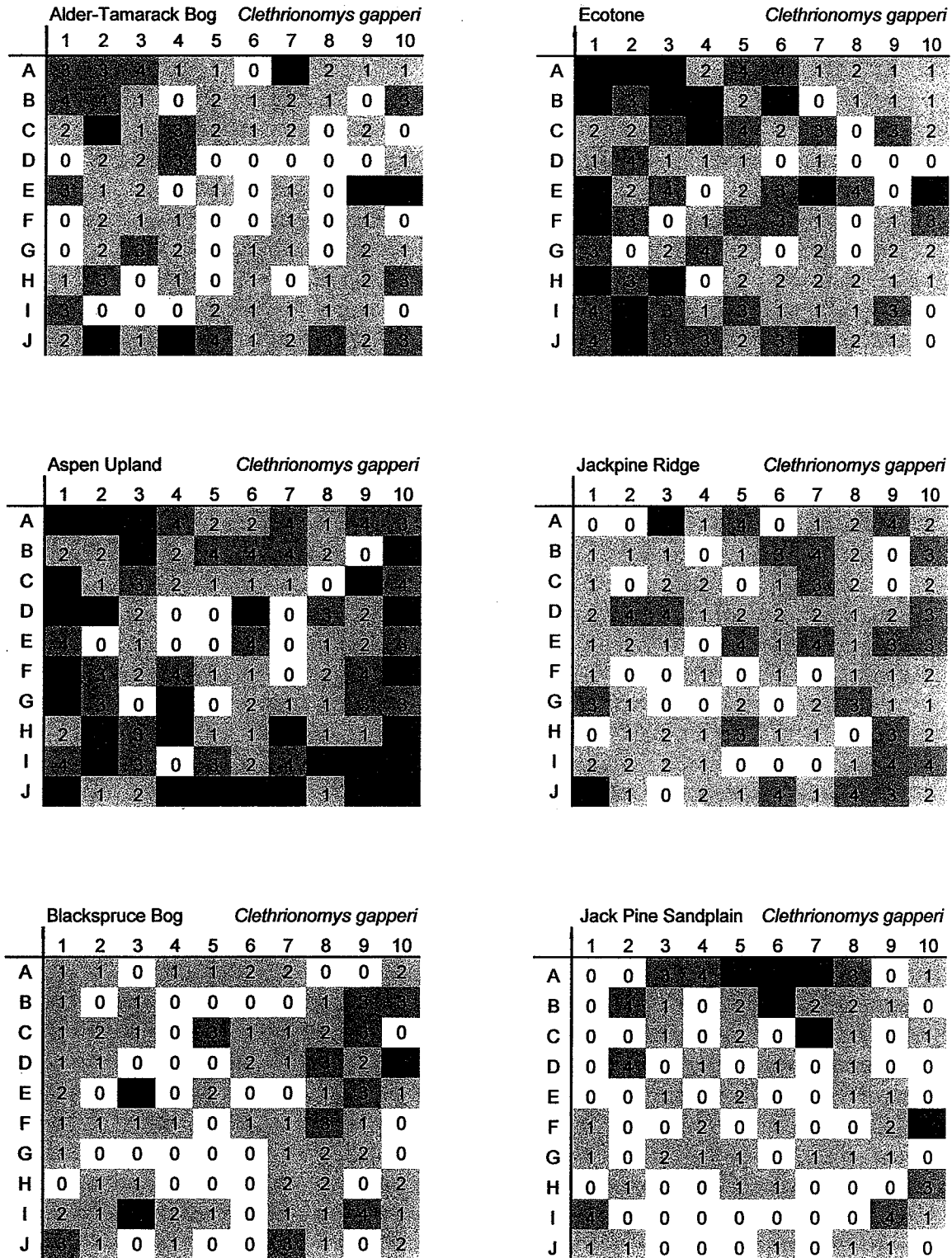


FIG. C.2a Comparison of the cumulative captures of *Clethrionomys gapperi* (1977-2001) at each trapping station across six habitats at Taiga Biological Station. Darker patches represent areas with higher capture rates.

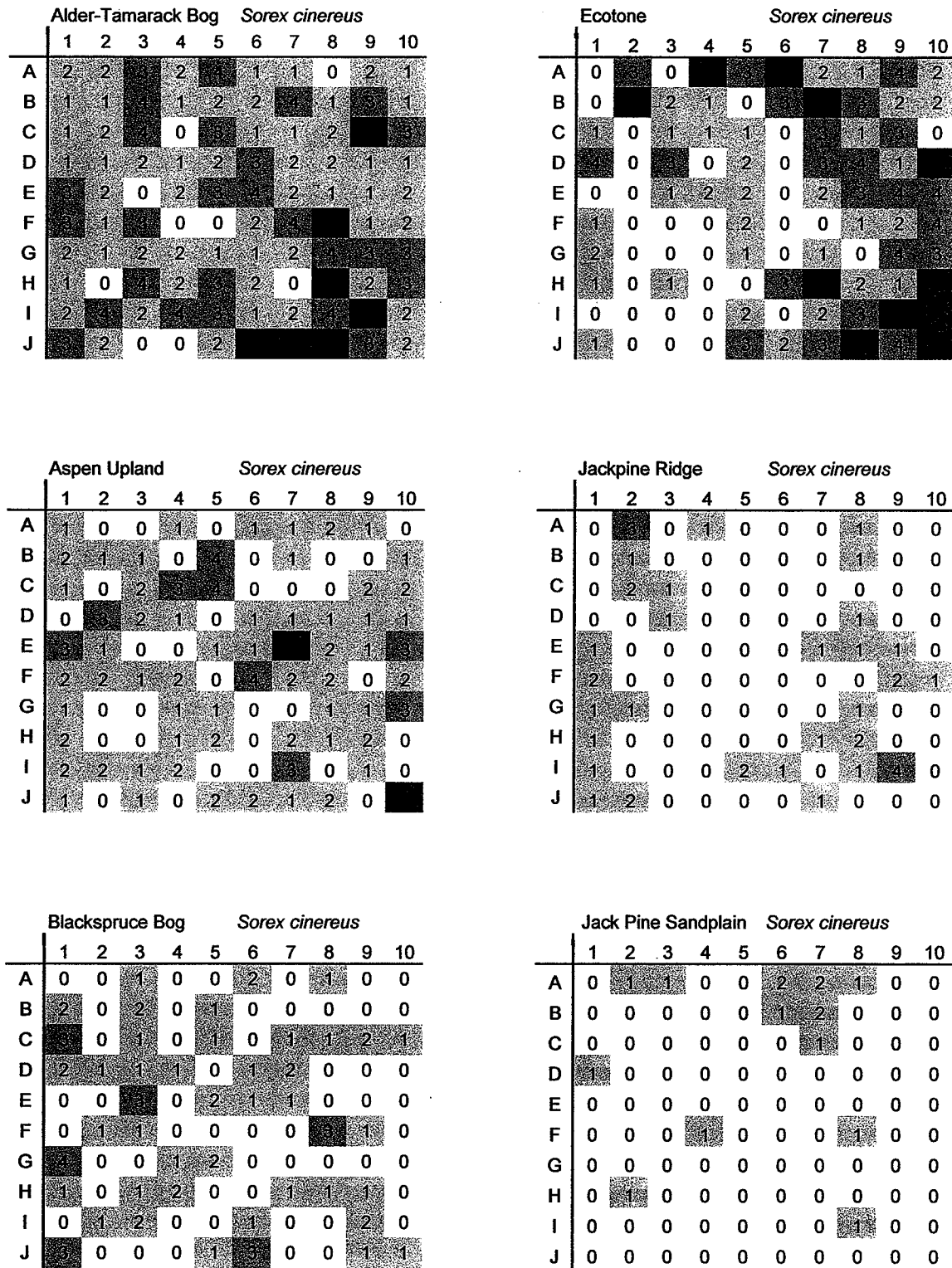


FIG. C.2b Comparison of the cumulative captures of *Sorex cinereus* (1977-2001) at each trapping station across six habitats at Taiga Biological Station. Darker patches represent areas with higher capture rates.

Alder-Tamarack Bog *Peromyscus maniculatus*

	1	2	3	4	5	6	7	8	9	10
A	0	0	0	0	0	0	0	0	1	0
B	0	0	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0	0	0
D	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0
I	1	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	1	0

Ecotone *Peromyscus maniculatus*

	1	2	3	4	5	6	7	8	9	10
A	1	0	0	0	0	0	0	0	0	1
B	0	0	1	1	0	0	0	0	0	0
C	0	2	0	0	0	1	0	0	0	0
D	1	1	0	0	0	0	0	0	0	0
E	1	2	1	0	1	0	0	0	0	0
F	1	0	1	0	0	1	0	0	0	0
G	2	2	0	0	0	1	0	0	0	0
H	0	1	1	1	0	0	0	0	0	0
I	2	2	0	0	2	0	0	0	0	0
J	0	0	1	0	0	0	0	0	0	0

Aspen Upland *Peromyscus maniculatus*

	1	2	3	4	5	6	7	8	9	10
A	0	1	1	1	0	0	0	0	2	0
B	2	0	2	0	0	3	1	2	0	0
C	0	0	0	1	0	0	1	2	1	2
D	0	0	1	0	0	0	1	1	1	1
E	0	1	0	0	1	2	1	0	0	1
F	0	0	0	0	1	0	1	1	2	3
G	0	1	1	0	1	0	2	0	0	0
H	1	1	0	0	0	2	0	0	0	0
I	1	1	0	0	0	0	2	3	1	2
J	1	1	0	0	0	0	0	1	2	1

Jackpine Ridge *Peromyscus maniculatus*

	1	2	3	4	5	6	7	8	9	10
A	0	0	2	1	2	1	0	0	0	0
B	2	0	2	0	0	1	1	0	0	0
C	0	0	0	0	1	1	1	0	1	2
D	1	1	2	0	0	3	0	1	0	1
E	1	1	0	0	0	0	0	0	1	0
F	2	0	1	1	0	1	0	1	0	2
G	1	0	0	0	0	0	2	0	1	1
H	0	0	2	0	1	0	0	1	2	0
I	2	1	2	1	0	1	1	0	0	0
J	0	0	0	2	0	1	1	0	2	0

Blackspruce Bog *Peromyscus maniculatus*

	1	2	3	4	5	6	7	8	9	10
A	0	0	0	0	0	0	1	1	2	0
B	0	0	0	2	0	0	0	0	0	0
C	0	0	1	0	0	0	0	0	0	1
D	0	0	0	0	0	1	0	1	0	0
E	0	0	0	0	0	0	0	0	0	0
F	0	2	0	0	0	0	0	0	0	0
G	0	0	0	0	0	1	1	0	1	0
H	0	0	0	0	0	0	0	1	0	0
I	0	1	0	0	0	0	0	0	0	1
J	0	0	0	0	0	0	0	0	0	0

Jackpine Sandplain *Peromyscus maniculatus*

	1	2	3	4	5	6	7	8	9	10
A	1	2	0	0	0	1	0	2	1	0
B	0	1	1	2	0	0	0	2	2	0
C	1	2	1	1	0	2	1	1	2	1
D	1	2	0	2	0	1	1	1	0	1
E	2	0	1	0	0	1	1	0	0	0
F	2	0	2	1	1	0	0	0	0	0
G	2	2	0	0	1	0	0	1	1	1
H	1	2	0	1	2	0	0	0	1	1
I	0	0	0	1	1	2	0	2	1	0
J	1	2	2	1	0	2	0	1	0	0

FIG. C.2c Comparison of the cumulative captures of *Peromyscus maniculatus* (1977-2001) at each trapping station across six habitats at Taiga Biological Station. Darker patches represent areas with higher capture rates.

Alder-Tamarack Bog *Microtus pennsylvanicus*

	1	2	3	4	5	6	7	8	9	10
A	0	0	0	1	0	0	1	1	0	1
B	0	0	0	1	1	1	2	1	0	2
C	0	2	0	0	0	0	0	0	2	0
D	0	0	0	0	0	0	0	0	0	0
E	2	0	0	0	0	0	0	0	0	0
F	1	0	1	2	0	0	0	0	0	0
G	0	0	1	0	1	0	1	1	1	0
H	0	0	1	0	0	2	1	1	0	1
I	0	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	0	0

Ecotone *Microtus pennsylvanicus*

	1	2	3	4	5	6	7	8	9	10
A	0	0	0	0	0	0	1	0	0	1
B	0	0	1	0	0	0	1	1	0	0
C	0	0	0	0	0	0	0	0	1	0
D	0	0	0	0	0	0	0	1	0	0
E	0	0	0	0	2	0	0	0	1	1
F	0	0	0	0	0	0	0	2	2	1
G	0	0	0	0	0	0	1	1	0	0
H	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	2	0	0

Aspen Upland *Microtus pennsylvanicus*

	1	2	3	4	5	6	7	8	9	10
A	0	0	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0	2	0
C	1	1	0	0	0	0	0	0	1	0
D	0	2	0	1	0	0	0	0	0	0
E	0	2	0	0	0	0	0	0	0	0
F	1	0	1	0	1	0	0	1	0	0
G	0	0	0	1	0	0	0	0	0	0
H	0	1	0	1	0	0	1	1	0	0
I	0	0	0	0	0	0	0	0	0	1
J	0	0	0	0	0	0	0	0	0	0

Jackpine Ridge *Microtus pennsylvanicus*

	1	2	3	4	5	6	7	8	9	10
A	0	0	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0	0	0
D	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	0	0

Blackspruce Bog *Microtus pennsylvanicus*

	1	2	3	4	5	6	7	8	9	10
A	0	0	0	0	0	0	0	0	0	0
B	0	0	0	1	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0	0	0
D	1	0	0	0	0	0	0	0	0	0
E	0	1	0	0	0	0	0	0	0	0
F	0	0	0	0	1	0	0	0	0	0
G	0	0	1	0	1	0	0	0	0	0
H	0	0	1	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	0	0

Jackpine Sandplain *Microtus pennsylvanicus*

	1	2	3	4	5	6	7	8	9	10
A	0	0	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0	0	0
D	0	0	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	1	0	0	0
F	0	0	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0	0	0
H	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0
J	0	0	0	0	0	0	0	0	0	0

FIG. C.2d Comparison of the cumulative captures of *Microtus pennsylvanicus* (1977-2001) at each trapping station across six habitats at Taiga Biological Station. Darker patches represent areas with higher capture rates.

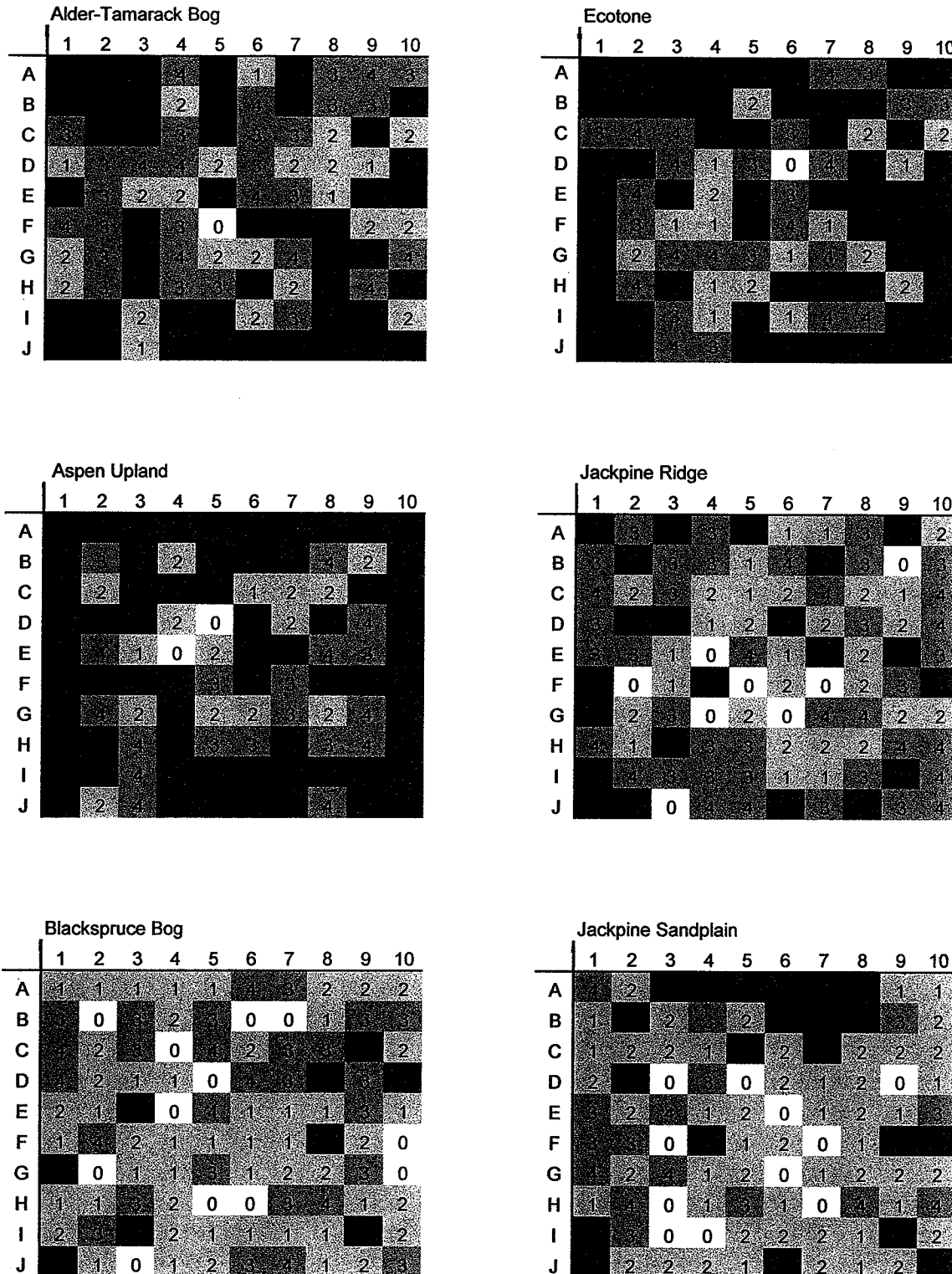


FIG. C.2e Cumulative captures of all small mammal species combined (without sciurids) across six sites at Taiga Biological Station. Total gridded area of each habitat forms a one-acre sized study plot containing 100 trapping stations per habitat. Darker patches represent areas with higher capture rates.

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