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Department of Forest Sciences

The University of British Columbia
Vancouver, Canada

Date June 23, 1999
Abstract

I examined diet, home range size, habitat use, and rest sites of short-tailed weasels (Mustela erminea) in the mixedwood boreal forest of Alberta. Of the 8 food groups identified in 585 scats, Arvicolidae, mainly red-backed voles (Clethrionomys gapperi), were the primary prey of weasels. In summer, weasels supplemented their diet with birds and eggs. Male weasels are 2-3 times larger than females and included red squirrels (Tamiasciurus hudsonicus) in their summer and fall diets. Despite relatively high abundance of deer mice in my study area, this species was not exploited substantially by weasels.

I radio-collared 7 female and 10 male short-tailed weasels. Female (n=4) and male (n=4) weasels had home range sizes of 65.5-94.8 ha and 122.6-204.6 ha, respectively. Male and female weasels showed similar trends in their use of birch, shrub, aspen, and jack pine habitats but differed in their use of other habitats. Male weasels preferred habitats associated with high abundance of red squirrels (black spruce and larch) and under-utilized habitats associated with low abundance of red squirrels (3-year-old regenerating aspen cutblocks). Female weasels showed the opposite trend. They preferred habitats associated with high abundance of voles (3-year-old regenerating aspen cutblocks) and under-utilized black spruce and larch habitats.

Weasels used a variety of rest sites and most of these sites were associated with their prey. Squirrel middens and the bases of trees or snags were the most common rest sites used by male weasels. Most rest sites used by female weasels were in residual logging material. In cutblocks, female weasels preferentially used areas with slash. Abundant small mammals, in particular C. gapperi, appeared to be a factor promoting the use of slash by females.

To ensure suitable habitat is provided for male weasels, forest managers should retain patches of coniferous trees that are old enough to produce cones. These patches support red squirrels that are prey to male weasels and whose middens are their preferred resting sites. Forest managers should retain forest stands (undisturbed by timber harvesting) adjacent to 3-year-old regenerating aspen cutblocks to ensure occupation of by females. The retention of logging slash in these cutblocks had high densities of red-backed voles and also provided rest sites for females.
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Introduction

Short-tailed weasels (Mustela erminea) have a large circumpolar range from Europe, through Asia, to North America and Greenland. In North America, short-tailed weasels range from the mid-United States north to the Arctic islands of Canada (Fagerstone 1987). In Alberta, the weasel is found throughout the province (Smith 1993). In the mid-1880's, they were introduced to New Zealand (King 1989).

The short-tailed weasel is the second smallest member of the family Mustelidae. There are 67 species in the family with the genus Mustela containing a contentious 13 to 16 species (King 1989). In general, members of the family Mustelidae can be characterized by sexual dimorphism, a long thin body with short legs, and anal scent glands (King 1989). In North America, other members of the subgenus include the least weasel (Mustela nivalis) and long-tailed weasel (Mustela frenata). The short-tailed weasel has been studied extensively in Europe and Asia but not in North America. In North America, short-tailed weasels are smaller than their European and Asian counterparts. Their size is closer to that of the European least weasel. Short-tailed weasels increase in size with latitude (Ralls and Harvey 1985). In North America, the length of females ranges from 19-29 cm and the length of males from 22-34 cm (Hall 1981). The weight of females and males ranges from 28-85 g and 70-206 g, respectively (Hall 1981, Fitzgerald 1977, Simms 1979a).

Short-tailed weasels have a life expectancy of 1 to 1.5 years but older animals, up to 7-8 years, have been trapped in Russia, Holland, and New Zealand (King 1989). Short-tailed weasels are preyed upon by raptors and mammalian predators such as domestic cats, coyotes, foxes, and long-tailed weasels (Fagerstone 1987). This species is sexually dimorphic with the males 2-3 times larger than females (Smith 1993). Short-tailed weasels reproduce via delayed implantation and have 1 litter per year, usually April (Deanesley 1935), averaging 6 young in North America (Hamilton 1933). The young are raised solely by the mother (King 1989).

Weasels are carnivores specializing on small mammals such as voles and mice (Hamilton 1933, Aldous and Manweiler 1942, Simms 1979b, Raymond et al. 1984). Experiments conducted on captive short-tailed weasels in Europe revealed that males consume, on average, 19-32% of body weight per day and females 12-27% of body weight daily (Muller 1970). Populations of weasels have been observed to fluctuate closely with those of their prey and small mammal density is considered a strong controlling agent of weasel density (Criddle and Criddle 1925, Debrot 1981, Raymond and Bergeron 1982, Korpimaki et al. 1991). However, some
researchers argue that weasels control the cyclic densities of small mammals (Pearson 1971, Fitzgerald 1977, Henttonen et al. 1987).

In North America, weasels use a variety of habitat types from coniferous and deciduous forests (Soper 1946) to grasslands (Simms 1979b). Weasels are active both day and night and throughout the year (Samson and Raymond 1995). During winter, weasels are white with a black-tipped tail. During spring, their pelage changes to light brown dorsally with white fur extending along the abdomen from the chin to the inside of the hind legs (King 1989).

Throughout their range, weasels are harvested for their fur. In Alberta, short-tailed weasels, least weasels, and long-tailed weasels are trapped from early November to late February with their pelts in prime condition mid-November to late January. During the winter of 1996-97, 5326 pelts were harvested at $6.73 per pelt contributing $35 844 to the Alberta economy (Alberta Environmental Protection 1999).

I studied short-tailed weasels within the forest management area of Alberta Pacific Forest Industries, Inc. (AlPac), the world’s largest single-line kraft pulp mill, in the mixedwood boreal forest of Alberta. In 1987-88, the Alberta government leased more than 220 000 km$^2$ of mixedwood boreal forest to the pulp and paper industry. AlPac was granted the deciduous timber rights to 61 000 km$^2$ of the mixedwood boreal forest. Annually, AlPac harvests approximately 3 million m$^3$ of trees. Since the allocation of Alberta’s mixedwood to the pulp and paper industry, several reports have concluded that the current inventory of wildlife and habitat is inadequate to assess the impacts of large scale timber harvesting or to develop wildlife management strategies (e.g., Samail 1988, Dancik et al. 1990, Alberta Forestry, Lands and Wildlife 1991, Navratil and Chapman 1991).

There are few data on the ecology of the short-tailed weasel in North America. For the boreal regions of Canada, there are no data on use of habitat, density, or home range size of short-tailed weasels (Thompson et al. 1989). Sensitivity of weasels to habitat changes caused by logging has not been reported in the literature. Also, little information is available on the effects of silvicultural practices on weasel behaviour. To address the general lack of information pertaining to Alberta’s wildlife, several research initiatives have been established throughout the mixedwood boreal forest of Canada. This includes the Sustainable Forest Management Network (SFMN), a Network of Centres of Excellence, founded in 1995 at the University of Alberta. The SFMN is a nation-wide effort to better understand the social, economic, and ecological dynamics of the boreal mixedwood forest. My thesis complements the research of Drs. R.A. Moses and S. Boutin from the University of Alberta. In 1993, they established an on-going study at Owl River,
Alberta, to examine the response of small mammal populations to partial-cut and clear-cut logging in aspen-dominated boreal mixedwoods (Moses and Boutin 1998). As part of this study, Weaver (1996) examined the effects of timber harvesting in the boreal forest on deer mice and red-backed voles. In 1995, I initiated my project on weasels in the same study area at Owl River.

The objectives of my study are to: 1) describe the diet of the short-tailed weasel and differences in the diets of males and females; 2) describe the use of habitats by male and female weasels; 3) describe the structures used by weasels for resting; and 4) examine the use of slash by female weasels in 3-year old cutblocks, containing naturally regenerating aspen (*Populus tremuloides*); and 5) propose recommendations for managing habitat of weasels in mixedwood boreal forests.
Study Area

My study area (54°58’N, 111°55’W), is located at Owl River, approximately 60 km north-east of Lac La Biche, Alberta (Fig. 1), in the southern portion of the mixedwood boreal forest. The mixedwood boreal forest is circumpolar. In Canada, it extends from north-eastern British Columbia, through Alberta and Saskatchewan, to south-eastern Manitoba (Fig. 1). The province of Alberta contains approximately 40% or 290 000 km² of Canada’s mixedwood boreal forest (Rowe 1972).

Figure 1. Distribution of the mixedwood boreal forest in western Canada (altered from Stelfox 1995) and the location of my study area (★) at Owl River, Alberta.

The mixedwood boreal region is a predominately forested landscape and is characterized by a complex mosaic of stands varying in age, composition, and structure, interspersed with rivers, lakes, bogs, and fens. The dominant coniferous tree species are white spruce and black spruce (Picea glauca and Picea mariana), with balsam fir (Abies balsamea), jack pine (Pinus banksiana) and larch (Larix laricina) also present (Rowe 1972). Dominant deciduous species are aspen (Populus tremuloides) and poplar (Populus balsamifera), and lesser amounts of white birch (Betula papyrifera) (Rowe 1972). Although relatively pure stands of all these tree species exist, the most common later seral stand types are those comprised of a mix of species, most often trembling aspen, balsam poplar, and white spruce.
My study area is located within the Forest Management Area of AlPac. It is comprised of 2 townships (Township 69 Range 13 W4M and Township 70 Range 13 W4M), each approximately 10 km by 10 km. The study area was harvested for aspen and poplar in winter 1993/94. During my study, the cutblocks were densely vegetated with naturally regenerating aspen and poplar saplings, wild rose (*Rosa* spp.), herbs, and grasses. The area is dominated by jack pine stands (1930 origin), black spruce-larch mixed stands (1880 origin), and mature mixed and pure stands of aspen and balsam poplar (1930-1950 origin). Large wet shrubby areas of dwarf birch (*Betula pumila* var. *glandulifera*), alder (*Alnus* spp.), and willow (*Salix* spp.) are also present. Pure stands of white spruce and mixed deciduous-coniferous stands are relatively sparse. There are several small lakes in the area. Some agricultural land occurs adjacent to the southern edge of the study area.

The mean daily temperature for this region is 3.9 to 10.9°C in summer (May-September) and -1.1 to -22.4°C in winter (October-April). The annual mean precipitation is 432.3 mm including 131.5 cm of snow. Major snowfall months are November to April with a mean monthly snowfall of 11.9 to 25.0 cm (Environment Canada 1998).

The dominant disturbance regime in the mixedwood boreal forest is fire (Rowe 1961, Johnson 1992). Other disturbances include oil and gas exploration, white spruce saw-timber operations, windstorms, and pathogens.

Alberta Phase 3 Forest Inventory (Alberta Forest Service 1985) and Alberta Vegetation Inventory mapping (Alberta Forestry, Lands and Wildlife 1991) of the study area was completed by AlPac and the Government of Alberta based on 1:15 000 aerial photographs. Attributes associated with the mapping include canopy species composition, percent canopy closure, estimated decade of origin, and the location of wetlands, bodies of water, burns, clearcuts, and oil and gas development (e.g., seismic exploration lines and natural gas pipeline right-of-ways).
Chapter 1
Diet of Short-tailed Weasels in the Mixedwood Boreal Forest

Introduction

Mustelids in North America have a diverse range of diets. Some species are omnivorous such as the striped skunk (*Mephitis mephitis*). Others are primarily carnivorous such as the American marten (*Martes americana*), fisher (*Martes pennanti*) and wolverine (*Gulo gulo*). The short-tailed weasel (*Mustela erminea*) is described as a small mammal specialist with a preference for voles, such as *Microtus* and *Clethrionomys* species, but they also eat other mammals (e.g., mice, lemmings, shrews, squirrels, chipmunks, rabbits, muskrats, and groundhogs), birds, eggs, insects, and earthworms (Aldous and Manweiler 1942, Osgood 1963, Maher 1967, Northcott 1971, Fitzgerald 1977, Simms 1979b, Raymond *et al.* 1984).

Weasels are formidable hunters for their size. Their long and thin bodies make them effective predators of small mammals because they can pursue their prey amongst the complex structure near the ground and can enter rodent holes and runways. Some researchers argue that hunting efficiency of weasels drives the cycles of microtine populations (Pearson 1971, Fitzgerald 1977, Henttonen *et al.* 1987). Regardless, weasel populations respond numerically to changes in the abundance of small mammals, particularly voles (Criddle and Criddle 1925, Debrot 1981, Raymond and Bergeron 1982, Delattre 1983, King 1983a, Korpimaki *et al.* 1991, Boutin *et al.* 1995). During years of low vole abundance, weasel numbers decline due to poor breeding success (Erlinge 1981, 1983). The number and survival of offspring depend on food abundance, particularly small mammals, and large numbers of young weasels die in years with few prey (King 1983b). This observation suggests that despite the weasel’s diverse diet, small mammals, especially voles, are their most important food.

Sexual dimorphism in mustelids is considered a means for partitioning prey resources (Brown and Lasiewski 1972). Because male weasels are 2-3 times heavier than females (Smith 1993), partitioning of food resources is expected between sexes. However, researchers have found little difference between diets of males and females other than that males tend to include large prey in their diet (Erlinge 1979a, Simms, 1979b, Erlinge 1981). It seems unlikely that significant partitioning of food resources occurs.

Knowledge of weasel diets would aid understanding of ecological relationships in the mixedwood boreal forest but there is little information concerning their food habits. Logging
practices affect small mammal abundance. Irruptions of deer mice (*Peromyscus maniculatus*) and declines in southern red-backed vole (*Clethrionomys gapperi*) populations following timber harvesting have been documented in the mixedwood boreal forest (Moses and Boutin 1998) and in other forest types (Sullivan and Krebs 1981, Martell 1983). If weasels depend on voles, logging practices in the mixedwood boreal forest could have a negative affect on their breeding success. Knowledge of weasel food habits may also assist in explaining patterns of habitat use of weasels at both the patch and stand levels.

My objectives are to describe the diet of the short-tailed weasel in the southern portion of the mixedwood boreal forest in Alberta, compare diets of male and female weasels, and examine food selectivity by weasels.

**Methods**

**Weasel Trapping and Scat Collection**

I live-trapped weasels from July-August 1995 and from February-December 1996 at Owl River, Alberta (Townships 69 and 70, Range 13, W4M). Small mammal trapping accompanied the weasel trapping in May-October 1995-96. I trapped weasels using wooden box traps modified from King (1973) and insulated with cotton. Bacon or carcasses of white lab mice (*Mus musculus*) provided food for weasels during their confinement. Incidental captures of weasels were also made in Longworth traps deployed for small mammals. I sexed, weighed, and ear-tagged weasels that I caught. Prior to the breeding season, I assumed all weasels were adults. During the post-breeding season (summer and fall), I could not distinguish adults and juveniles. I collected scats from the traps. Between trap sessions, the small mammal and weasel traps were visited frequently by weasels and marked with scats. I collected these scats as well. Occasionally, I found scats on large rocks or logs. I assumed all scats to be short-tailed weasel because the least weasel (*Mustela nivalis*) is rare in the area.

I trapped weasels in continuous aspen-dominated mature forest (60-70 years old), regenerating aspen cutblocks (harvested winter 1993/94), and 50 m into aspen forest adjacent to cutblocks. There were 3 types of cutblock sampled: 1) clearcut, all standing trees removed from the cutblock and the slash (limbs and tops from felled trees) burned; 2) dispersed retention, 1-2% of the trees left uncut and the slash dispersed along access roads in the cutblock; and 3) aggregated retention, 10% of the cutblock left unharvested as uniformly distributed, 40-m diameter patches of undisturbed trees and associated ground cover, and slash dispersed along
access roads in the cutblock. Each habitat type was replicated twice for a total of 8 sites. Small mammal trapping occurred in all of these sites except the aspen forest adjacent to cutblocks. In 1996, 5 additional dispersed retention cutblocks were added to the study sites but, small mammal trapping did not occur in these 5 cutblocks.

Processing Scats

I heated scats at 200°C for 20 min to eliminate the possibility of parasite transmission. I then washed scats using warm water to remove unidentifiable matter and left them to air dry. Each scat was assumed to be one food item. This is a reasonable assumption because “the stomach capacity of most weasels is only 10-20 g whereas the average weight of a small rodent would be about 20-30 g” (King 1989: page 64). The only exceptions were in those cases where the scat contained feathers or egg shell in addition to hair, such scats were assumed to contain 2 food items.

Food Identification

I identified mammal remains from guard hairs and teeth. When teeth were present, I identified the food item from its teeth, otherwise identification was done using guard hairs. I selected 5-8 guard hairs from each scat and attempted to identify guard hairs using whole mounts. If identification was not possible, then I made scale impressions using clear nail polish. A thin layer of nail polish was applied to a microscope cover slip and the hairs were then placed on the cover slip with their ends extended over the edge of the slip. After the nail polish dried, I removed the hairs and inverted the cover slip onto a microscope slide for identification.

I identified teeth using museum specimens and Smith (1993). I identified hairs using Moore et al. (1974), Adorjan and Kolenosky (1969), and Thompson et al. (1987). I identified teeth and hair to the lowest taxon possible. Teeth were identified to species except for shrews which were identified to genus (i.e., Sorex spp.). Shrews also were identified to genus from hair samples. Hair samples for voles (Clethrionomys gapperi, Microtus pennsylvanicus, Phenacomys intermedius) and northern bog lemming (Synaptomys borealis) were difficult to differentiate and were identified to family (Arvicolidae). Teeth of voles and lemmings were distinguishable to species.
Diet and Energy Contribution of Food Groups

I calculated diet in terms of: 1) number of each prey type eaten; and 2) weight for each prey type eaten. Diet expressed in terms of prey weight removes the imbalance between large and small items and reveals prey most energetically profitable to eat (King 1989). The energy contribution of each prey type is related to the average weight of the prey (King 1989). I used the mean weights of adults given in Smith (1993) to calculate the average weight of each prey type. For Soricidae, because I did not distinguish species, I averaged the mean weights of all species present on range maps (Smith 1993) encompassing my study area.

Abundance of Small Mammals

Estimates of abundance for small mammals were provided from a small mammal project conducted by Dr. Rich Moses and Dr. Stan Boutin of the University of Alberta. Small mammals were live-trapped using Longworth traps. Traps were spaced at 25-m intervals in 6-ha grids. The number of traps varied between trapping sites and ranged from 126 to 140. In 1995, each grid was trapped for 3 consecutive nights every 2 weeks from May through August, and for 2 weeks in September. In 1996, each grid was sampled 3 times, once in May, July, and September. Every small mammal captured was marked with a numbered ear tag. The species caught were Microtus pennsylvanicus, Clethrionomys gapperi, Phenacomys intermedius, Peromyscus maniculatus, Zapus hudsonius, and Sorex spp. For each grid, estimates of abundance and error were calculated for each trap session using the programme CAPTURE (Otis et al. 1978). Only the estimates of abundance for C. gapperi and P. maniculatus were used in my analyses. The sample sizes of the remaining species were considered too small to provide estimates of abundance.

Results

Sample Size

In 1995, 26 female and 29 male weasels were captured. In 1996, 31 female and 32 male weasels were captured. In total, 712 scats were collected but only 585 of the scats were used (204 from 1995, 381 from 1996). The remainder were discarded because they either crumbled during washing (60 scats) or were composed of white lab mice used for bait (67 scats). From these samples, I identified 7 food groups (Table 1.1). More than one food item was found in 33
Table 1.1. Food groups identified and their percent occurrence in weasel scats for 1995 and 1996 collected at Owl River, Alberta. Values in parentheses indicate number of tooth samples for a species.

<table>
<thead>
<tr>
<th>Food group</th>
<th>Scats from Jul-Aug 1995</th>
<th>Scats from Feb-Dec 1996</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Percentage</td>
</tr>
<tr>
<td>Arvicolida</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern red-backed vole (Clethrionomys gapperi)</td>
<td>(34)</td>
<td>(28)</td>
</tr>
<tr>
<td>Meadow vole (Microtus pennsylvanicus)</td>
<td>(4)</td>
<td>(12)</td>
</tr>
<tr>
<td>Heather vole (Phenacomys intermedius)</td>
<td>(7)</td>
<td>(8)</td>
</tr>
<tr>
<td>Northern bog lemming (Synaptomys borealis)</td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Cricetida</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deer mouse (Peromyscus maniculatus)</td>
<td>13 (2)</td>
<td>5.9</td>
</tr>
<tr>
<td>Zapodidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meadow jumping mouse (Zapus hudsonius)</td>
<td>3 (1)</td>
<td>1.4</td>
</tr>
<tr>
<td>Soricidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shrew (Sorex spp.)</td>
<td>7 (1)</td>
<td>3.2</td>
</tr>
<tr>
<td>Sciuridae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red squirrel (Tamiasciurus hudsonicus)</td>
<td>15</td>
<td>6.8</td>
</tr>
<tr>
<td>Least chipmunk (Eutamias minimus)</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Birds</td>
<td>22</td>
<td>10.0</td>
</tr>
<tr>
<td>Eggs</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>220</td>
<td></td>
</tr>
</tbody>
</table>
scats so in total, 618 food items (Table 1.1) were identified. Teeth samples were obtained from 119 scats (50, 1995; 69, 1996). Southern red-backed vole, meadow vole, heather vole, northern bog lemming, deer mouse, meadow jumping mouse, and shrew were identified from the teeth (Table 1.1). In 1995, 29 scats were known to be from female weasels and 72 scats from males. In 1996, 68 and 151 scats were known to be from female and male weasels, respectively.

Seasonal Diet

A seasonal plot of food group occurrences for 1996 (February 18-December 8) (Fig. 1.1) shows that, during spring and summer, weasels included birds (May 5-September 22) and eggs (May 24-September 7) in their diet (Fig. 1.1). The period during which red squirrels were eaten also was seasonally constrained (April 30-November 9). Meadow jumping mice were limited to late summer and early fall (July 25-September 29). The other diet items (Arvicolidae, deer mouse, and shrews) were eaten over most of the period during which scats were collected.

Occurrence of Food Groups in Diet

In 1995, Arvicolidae was the most common food group identified, comprising 159 of 220 food group occurrences (72.2%) (Table 1.1). Each of the remaining food groups comprised 10% or less of the diet (bird, red squirrel, deer mouse, shrew, meadow jumping mouse, and least chipmunk). In 1996, Arvicolidae was again the most common food group identified, comprising 242 of 398 food group occurrences (60.8%) (Table 1.1). Each of the remaining food groups comprised 12% or less of the diet. Eggs was the only food group found in 1996 that did not occur in 1995.

Based on tooth samples, Arvicolidae is dominated by the southern red-backed vole (Table 1.1). The southern red-backed vole accounted for 73.9% of the tooth samples for Arvicolidae in 1995 and 56.0% in 1996.

When the 1996 data were partitioned into periods of no-bird consumption (February 18-May 4, September 23-December 8) and bird consumption (May 5-September 22), the percentage of Arvicolidae in the diet changed noticeably from 55.8% when feeding on birds to 80.2% when birds were not a part of the diet (Fig. 1.2). During the period of bird consumption, eggs also were higher in occurrence, 3.8% versus 0%, and red squirrels were also a greater proportion of the diet, 14.1% versus 5.3%.
Figure 1.1. The seasonal occurrence of food groups in the diet of short-tailed weasels and the distribution of scats collected and analyzed (n=381 scats) based on 2-week intervals, from February-December 1996, in the mixedwood boreal forest of central Alberta. Numbers in parentheses are the number of occurrences in each food group. The number of food group occurrences (n=388) came from 371 scats because 17 scats contained 2 food groups.
Figure 1.2. Diets of short-tailed weasels, bird consumption (May 5-September 22) and no-bird consumption (February 18-May 4, September 23-December 8) 1996, in the mixedwood boreal forest of central Alberta. n=312 food group occurrences for bird consumption period, n=76 food group occurrences for no-bird consumption period. Numbers above bars are the number of occurrences in each food group. The number of food group occurrences (n=388) came from 371 scats because 17 scats contained 2 food groups.
Body Weights of Males and Females

In 1995, female weasels (July 7-August 22) averaged 65.7 g (adults and juveniles, range 56-80 g, n=26) and male weasels (July 12-August 22) averaged 165.5 g (adults and juveniles, range 98-217 g, n=29). In the longer trapping period of 1996, seasonal variation in weight was evident. Females weighed considerably less during winter and spring (February 14-May 14, average 52.4 g, adults, range 48-60 g, n=9) compared to summer (May 25-September 30, average 72.6 g, adults and juveniles, range 56-104 g, n=26). Male weasels showed the same trend, but with less difference between seasons, averaging 156.5 g (adults, range 118-187 g, n=10) during winter and spring (February 14-May 15) and averaging 163.5 g (adults and juveniles, range 104-262 g, n=30) during summer (May 21- September 30).

Diets of Males and Females

The occurrence of food groups was not significantly different between sexes ($\chi^2 = 6.43$, df = 6, $P > 0.25$) from July through August 1995 (Fig. 1.3). Despite a non-significant finding, male weasels show a tendency to eat larger prey (red squirrel and least chipmunk) than do females. In February through December 1996, the occurrences of food groups between the sexes was significantly different ($\chi^2 = 18.97$, df = 5, $P < 0.005$, Fig. 1.4). Male weasels exploited red squirrels more often than did females (Bonferroni-adjusted Z-test, $P \leq 0.05$).

Weight Contribution of Food Groups to Female and Male Diets

The average weight contributed to the diet by each food group was calculated using Smith (1993) (Tables 1.2 and 1.3). Based on the average weight of each food group, the total weight of prey potentially consumed by male weasels was 2-3 times greater than that for female weasels in 1995 and 1996.

Arvicolidae and red squirrels were the largest sources of potential weight in female and male diets, respectively. Arvicolidae made the largest weight contribution to the diets of females providing 97.0% and 77.0% of the weight potentially consumed in July to August 1995 and February to December 1996, respectively (Fig. 1.5a, Fig. 1.6a). In 1995, each of the remaining food groups (deer mouse, shrew, and birds) provided 2.0% or less of the potential weight consumed. In 1996, red squirrels provided 13.0% of the potential weight and each of the remaining food groups (deer mouse, shrew, and birds) 4.0% or less.
Figure 1.3. Diets of male and female short-tailed weasels, July-August 1995, in the mixedwood boreal forest of central Alberta. The occurrence of food groups did not differ between females and males ($\chi^2 = 6.43$, df = 6, $P > 0.25$); n=29 food group occurrences for females; n=72 food group occurrences for males. Numbers above bars are the number of occurrences in each food group. The number of food group occurrences (n=101) came from 98 scats because 3 scats contained 2 food groups.
Figure 1.4. Diets of male and female weasels, February-December 1996, in the mixedwood boreal forest of central Alberta. The occurrence of food groups differed between male and female diets ($\chi^2 = 18.97$, df = 5, $P < 0.005$); n=68 food group occurrences for females; n=151 food group occurrences for males. * indicates significant difference between sexes (Bonferroni-adjusted Z-test, $P \leq 0.05$). Numbers above bars are the number of occurrences in each food group. The number of food group occurrences (n=219) came from 210 scats because 9 scats contained 2 food groups.
Table 1.2. The average weight calculated for each food group and the amount of weight potentially consumed by male and female short-tailed weasels, July to August 1995, in the mixedwood boreal forest of central Alberta.

<table>
<thead>
<tr>
<th>Food group</th>
<th>Average weight for each food group (g)</th>
<th>Proportion of food group in female diet</th>
<th>Potential weight of food consumed by females (g)</th>
<th>Proportion of food group in male diet</th>
<th>Potential weight of food consumed by males (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arvicolidae</td>
<td>29.1</td>
<td>0.79</td>
<td>2310.9</td>
<td>0.67</td>
<td>1942.5</td>
</tr>
<tr>
<td>Deer mouse</td>
<td>24.0</td>
<td>0.07</td>
<td>48.0</td>
<td>0.06</td>
<td>133.3</td>
</tr>
<tr>
<td>Meadow jumping mouse</td>
<td>18.1</td>
<td>0.00</td>
<td>0.0</td>
<td>0.01</td>
<td>25.1</td>
</tr>
<tr>
<td>Shrew</td>
<td>6.9</td>
<td>0.07</td>
<td>13.9</td>
<td>0.03</td>
<td>19.3</td>
</tr>
<tr>
<td>Red squirrel</td>
<td>231.3</td>
<td>0.00</td>
<td>0.0</td>
<td>0.13</td>
<td>2891.3</td>
</tr>
<tr>
<td>Least chipmunk</td>
<td>47.6</td>
<td>0.00</td>
<td>0.0</td>
<td>0.01</td>
<td>66.0</td>
</tr>
<tr>
<td>Birds</td>
<td>5.0</td>
<td>0.07</td>
<td>10.0</td>
<td>0.10</td>
<td>48.6</td>
</tr>
<tr>
<td>Eggs</td>
<td>3.0</td>
<td>0</td>
<td>0.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2382.8</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>5126.1</strong></td>
</tr>
</tbody>
</table>

1 Proportions from Fig. 1.3

Table 1.3. The average weight calculated for each food group and the amount of weight potentially consumed by male and female short-tailed weasels, February to December 1996, in the mixedwood boreal forest of central Alberta.

<table>
<thead>
<tr>
<th>Food group</th>
<th>Average weight for each food group (g)</th>
<th>Proportion of food group in female diet</th>
<th>Potential energy of food consumed by females (g)</th>
<th>Proportion of food group in male diet</th>
<th>Potential energy of food consumed by males (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arvicolidae</td>
<td>29.1</td>
<td>0.69</td>
<td>2013.9</td>
<td>0.50</td>
<td>1447.2</td>
</tr>
<tr>
<td>Deer mouse</td>
<td>24.0</td>
<td>0.04</td>
<td>105.9</td>
<td>0.03</td>
<td>79.5</td>
</tr>
<tr>
<td>Meadow jumping mouse</td>
<td>18.1</td>
<td>0.00</td>
<td>0.0</td>
<td>0.01</td>
<td>12.0</td>
</tr>
<tr>
<td>Shrew</td>
<td>6.9</td>
<td>0.13</td>
<td>91.9</td>
<td>0.15</td>
<td>105.7</td>
</tr>
<tr>
<td>Red squirrel</td>
<td>231.3</td>
<td>0.01</td>
<td>340.1</td>
<td>0.18</td>
<td>4135.8</td>
</tr>
<tr>
<td>Least chipmunk</td>
<td>47.6</td>
<td>0.00</td>
<td>0.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Birds</td>
<td>5.0</td>
<td>0.12</td>
<td>58.8</td>
<td>0.07</td>
<td>33.1</td>
</tr>
<tr>
<td>Eggs</td>
<td>3.0</td>
<td>0.00</td>
<td>0.0</td>
<td>0.07</td>
<td>19.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2610.6</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>5833.2</strong></td>
</tr>
</tbody>
</table>

1 Proportions from Fig. 1.4
Figure 1.5. The percentage of each food group based on weight of prey for (a) female and (b) male short-tailed weasels, July and August 1995, in the mixedwood boreal forest of central Alberta. The contribution of each food group to weasel diet is calculated as number of occurrences multiplied by average weight of prey. n=29 food group occurrences for females, n=72 food group occurrences for males.
Figure 1.6. The percentage of each food group based on weight of prey for (a) female and (b) male short-tailed weasels, February to December 1995, in the mixedwood boreal forest of central Alberta. The contribution of each food group to weasel diet is calculated as number of occurrences multiplied by average weight of prey. n=68 food group occurrences for females, n=151 food group occurrences for males.
Red squirrels made the largest weight contribution to male diets providing 56.4% and 70.9% of the weight potentially consumed in July-August 1995 and February-December 1996, respectively (Fig. 1.5b, Fig. 1.6b). In both years, Arvicolidae was a relatively large contributor with 37.9% in 1995 and 24.8% in 1996. Each of the remaining food groups (deer mouse, shrew, meadow jumping mouse, least chipmunk, birds, and eggs) accounted for less than 3.0% in 1995 and 1996.

Small Mammal Prey Selection

Small mammal trapping was used as an estimate of prey availability. In 1995 (July 5-August 23), the ratio of red-backed vole to deer mouse, for all sites sampled, ranged from 0:1 to 2.8:1 with an average of 0.75:1. In 1996 (May 7-September 27), the ratio of red-backed vole to deer mouse, for all sites, ranged from 0:1 to 1.9:1 with an average of 0.60:1. I used tooth samples in scats to examine selection of small mammal prey. Because there was no significant difference between males and females for the occurrence of Arvicolidae in their diet, I combined data for male and female scats. To test the hypothesis that weasels prefer red-backed voles to deer mice, I used the highest vole to mouse ratio as estimates of food availability (2.8 vole:1 mouse; 1.9 vole:1 mouse, in 1995 and 1996, respectively). Even with this cautious estimate of vole availability, in 1995 (July-August), weasels preferred red-backed voles to deer mice ($\chi^2 = 7.82$, df = 1, $P < 0.01$, n=36; 34 voles, 2 mice). In 1996 (May-September), weasels preferred red-backed voles to deer mice ($\chi^2 = 4.01$, df = 1, $P < 0.05$, n=30; 25 voles, 5 mice).

Discussion

Diet Composition

Scat analysis revealed that short-tailed weasels consume several food groups. Arvicolidae (voles and lemmings) occurred most often with deer mouse, meadow jumping mouse, shrew, red squirrel, least chipmunk, birds and eggs occurring less frequently. Other North American studies of short-tailed weasels have reported similar diet compositions. These studies also have observed rabbits, muskrat, groundhog, fish, insects, crayfish, and earthworms in the diet (Aldous and Manweiler 1942, Osgood 1963, Maher 1967, Northcott 1971, Fitzgerald 1977, Simms 1979b, Raymond et al. 1984). All of these food groups, except crayfish, are found in my study area. Possible reasons for their absence in the weasel scats of my study are: 1) during my study, small
mammal populations were relatively high (R. Moses pers. comm.) and these less frequently consumed foods may be less desirable or more costly to obtain, so are consumed only when preferred items are unavailable; 2) because these food items account for < 1% of the diet in published studies, it is possible that the large prey may represent opportunistic scavenging that is rarely detected by scat analysis; or 3) the method used for washing and analyzing scats biased against the recovery of insects, earthworms, and fish.

The primary food group, Arvicolidae, comprised between 55.8% to 80.2% of the diet. The most common Arvicolidae in the diet is red-backed vole which accounted for 73.9% and 56.0% of the tooth samples collected in 1995 and 1996, respectively. A high proportion of voles in the weasel diet is not unusual and has been observed in North America and Europe. In North America, small mammals (eg., voles and mice) dominate the diet of short-tailed weasels: *Microtus pennsylvanicus* (35.7%, Hamilton 1933; 88.8%, Simms 1979b; 82.6%, Raymond et al. 1984), mice and voles (58.7%, Aldous and Manweiler 1942), and *Zapus* sp. (27.8%, Northcott 1971). In Europe, voles, lagomorphs and birds are dominant prey, including, *Arvicola* spp. (67%, Klimov 1940; 41.1%, Lavrov 1956; 91.4%, Debrot 1981), *Microtus* spp. (53.3%, Lavrov 1956; 46.8%, Korpimaki et al. 1991), *Arvicola* spp. and *Microtus* spp. (80%, Erlinge 1981), *Microtus* spp. and *Clethrionomys* spp. (49%, Brugge 1977), lagomorphs (38.7%, Potts and Vickerman 1974; 55.9%, Tapper 1976), and birds (37.6%, Day 1968). In New Zealand, where weasels were introduced, birds are the dominant prey (43%, King and Moody 1982). Voles are generally the greatest component of the weasel’s diet. When not so, as in diets dominated by lagomorphs and birds, then voles and other small mammal species collectively comprise the bulk of the remaining diet.

Seasonal Variation in Diet

Studies show considerable variation in the dominant prey species of short-tailed weasels suggesting that this species of weasel may feed on different prey depending upon prey availability (Simms 1979b, Debrot 1981). This could lead to seasonal variation in diet because abundance of prey species changes seasonally. I have shown that weasels are opportunists taking advantage of new food resources during summer. Arvicolidae, deer mouse, and shrew were exploited during summer and winter with relatively higher proportions occurring in the winter diet. Birds, eggs, red squirrels, and meadow jumping mouse were exploited only during summer. The same seasonal widening and narrowing of diet has been observed in Europe and New
Zealand where birds and lagomorphs were incorporated into the summer diet of short-tailed weasels (Erlinge 1981, King and Moody 1982).

In general, seasonal variation in diet may be explained by changes in resource availability and changes in hunting behaviour. The appearance of birds and egg shells in the summer diet corresponds with the breeding season of resident and migratory birds (Semenchuk 1992). The continued appearance of egg shells in weasel scats past the main incubation season of birds may be from cached eggs, abandoned nests, or late breeding birds. The period of red squirrel consumption corresponds to the breeding periods and post-juvenile dispersal of red squirrels (Banfield 1974, Rusch and Reeder 1978). Weasels are most likely killing juveniles because juveniles are more vulnerable or there is a greater risk of injury associated with attacking adults. Adult squirrels can weigh as much or more (Smith 1993) than the largest adult male weasel captured in my study area. Weasels can kill species larger than themselves, but such behaviour is unnecessary when food resources are not limited.

Seasonal changes in diet may also be influenced by changes in seasonal hunting behaviour (Nams and Beare 1982). During winter, weasels may spend more time hunting below the snow and less time in trees relative to summer. This behaviour could account for the higher proportion of subnivian dwelling prey (i.e., voles and mice) and fewer tree dwelling prey (i.e., red squirrels and birds) in the winter diet.

The brief and late seasonal occurrence of meadow jumping mice in the diet is difficult to explain due to a paucity of information on the species. Possible explanations for the short appearance of meadow jumping mice in the diet may be: 1) meadow jumping mice enter hibernation in late September or early October and do not emerge until late spring (Banfield 1974); 2) low densities of meadow jumping mice throughout the remainder of the year and weasel indifference to sparse prey as documented by Erlinge (1981); 3) meadow jumping mice may be difficult to capture; or 4) weasels may not hunt in habitats occupied by meadow jumping mice. Distaste for this species by short-tailed weasels is not documented and unlikely because Northcott (1971) found meadow jumping mice to be a large component of the diet.
Diet Variation Between Sexes

A slight difference in male and female diet, based on prey size, was observed. Female weasels concentrated almost exclusively on small mammals and birds. Male weasels took the same prey, as well as eggs and larger prey, such as red squirrels. It is not uncommon for males to consume larger prey (Erlinge 1979a, Simms 1979b, Erlinge 1981, King and Moody 1982). The phenomenon is attributed to differences in body size among sexes. Differences in weights of sexes that I measured are consistent with other reports that show strong sexual dimorphism; males are up to 3 times the body weight of females (Smith 1993). The weasel’s size in relation to the size of its prey is an indicator of potential injury risked when hunting. Male weasels are much larger and therefore exposed to less risk of injury than are females when attacking larger species (King 1991). However, body size also limits access to particular microhabitats. For example, Simms (1979b) observed a close relationship between female body size and size of dominant prey. Females were optimally sized for vole predation but males were not because their larger size limits access to vole tunnels. These observations suggest that females would have less incentive to hunt alternative large prey when small mammals are readily accessible.

The appearance of eggs only in the diets of males is puzzling. The difference in egg consumption between sexes may be explained by: 1) weasel anatomy; 2) hunting habits; or 3) sample size. The smaller size of females may limit their ability to grasp and break eggs with their teeth. As a result, females may not eat eggs or their method of consumption may differ from males and perhaps the probability of ingesting shell is low. Hunting habits may explain the presence of eggs in the diets of males because males may spend more time hunting squirrels in trees and thus are more likely to encounter birds’ nests. King and Moody (1982) suggested that egg consumption by weasels is underestimated because weasels may be capable of sucking the contents from eggs without ingesting the shell. Teer (1964) observed such behaviour by long-tailed weasels (Mustela frenata) eating duck eggs and it is conceivable that short-tailed weasels would be capable of the same behaviour. An underestimate of eggs eaten by females is possible. The sample size for females was considerably smaller than that for males and therefore the chances of detecting uncommon foods, such as egg shells, in scats would be less.
Contribution of Energy by Food Groups to Female and Male Diets

Calculating the weasel’s diet in terms of the weight of each food group indicates which foods are most energetically profitable for consumption (King 1989). Caution must be taken when interpreting these findings because “the results are greatly influenced by how much one assumes a weasel to eat off a single carcass” (King 1989: page 64). For example, weasels favour the brains of mice and voles and are known, during years of high prey abundance, to eat only the brain and discard the rest (King 1989). Also, the risk of injury and energy required to catch large prey could negate the potential energy gained by eating large prey. Prey abundance, at the time of my study, is also likely to influence my results. At the time of my study, red squirrel was potentially the most profitable species eaten by males (spring-fall) although males consumed far fewer red squirrels than Arvicolidae. For female weasels, Arvicolidae was the most abundant and potentially the most profitable species eaten. These findings indicate that the larger prey species in male and female diets (red squirrels and Arvicolidae, respectively) are potentially the most profitable foods consumed by weasels.

Prey Selectivity

In my study, the preference of short-tailed weasels for red-backed voles over deer mice is consistent with other observations. Simms (1979b) noted that despite relatively high numbers of deer mice in his study area, they were rarely preyed upon by short-tailed weasels. Nams’ (1981) study of radio-tagged weasels in habitat enclosures found that weasels offered a choice between red-backed voles and deer mice, ate red-backed voles more frequently. The catchability of these 2 species may explain the weasel’s preference for red-backed voles. The climbing of trees or ‘freezing’ responses of mice to weasel presence are often successful tactics for escaping weasels (King 1989). Erlinge (1975) observed that voles were more easily caught than mice by the least weasel (*Mustela nivalis*). If this is true for the short-tailed weasel, lower energy costs and greater capture success would favour hunting in microhabitats used by red-backed voles as observed by Nams (1981).
Chapter 2
Home Range Size and Habitat Use of Short-tailed Weasels in the Mixedwood Boreal Forest

Introduction

Short-tailed weasels (*Mustela erminea*) are solitary mammals except during mating and breeding seasons (King 1989). Home ranges are spaced with little overlap between individuals of the same sex (Erlinge 1977a), a common spacing pattern among Mustelidae (Powell 1979). Weasels exhibit intraspecific aggression and dominance within and between sexes (Erlinge 1977b). However, defense of home ranges is thought to rely primarily on scent marking, as well as visual and acoustic signals during close contacts, rather than physical encounters (Erlinge 1977a).

There are only a few estimates of the home range size of short-tailed weasels. In North America (southern Ontario), home ranges are 20-25 ha for males and 10-15 ha for females (Simms 1979b). In Russia and Europe, home ranges are 28.6-160 ha for males and 3.7-12 ha for females (Nyholm 1959, Vaisfeld 1972). In New Zealand, home ranges of males and females are 130-324 ha and 54-135 ha, respectively (Alterio 1998). Home ranges of males expand temporarily during the spring breeding season presumably so that males encounter greater numbers of females (Erlinge 1977a, Sandell 1986). Sizes of home ranges may also be related to prey abundance. Erlinge (1977c) observed the expansion of a female home range when small rodents were sparse. Jedrzejewski *et al.* (1995) also observed the expansion of home ranges for male least weasels (*Mustela nivalis*) from 11-37 ha during rodent outbreak years to 117-216 ha during rodent crash years.

Sexual selection pressures are thought to encourage differences in home range size between male and female mustelids. The smaller body size of female short-tailed weasels has been hypothesized to minimize the energy required for daily maintenance and optimize resource exploitation and hunting efficiency, both particularly important during the breeding season. As well, the larger body size of males has been hypothesized to increase breeding potential and access to females through greater mobility and territory defense (Erlinge 1979a, Powell 1979, Simms 1979a, Moors 1980). Male weasels have large home ranges to attain sufficient resources and meet the higher energy demands associated with their large body size.

There are few data describing the use of habitat by short-tailed weasels in mixedwood boreal forests. In North America, weasels have been observed in: coastal coniferous forest and logged (successional) habitats (Sullivan and Sullivan 1980); mixed hardwood stands consisting
of aspen and birch (Aldous and Manweiler 1942), coniferous forest and meadows (Fitzgerald 1977); riparian and upland coniferous and deciduous forest (Doyle 1990); arctic tundra (MacLean et al. 1974); upland and lowland sedge habitats (Maher 1967); the deciduous, mixed forest and early succession stands (logged areas < 5 years old) of eastern Canada (Samson and Raymond 1995); and early successional communities of grass and shrubs (Simms 1979a). The diversity of observations suggests that weasels are versatile in their use of habitats.

In this chapter, I describe the home range sizes of male and female short-tailed weasels and the use of habitats within their home ranges. In particular, I examine the habitat use of weasels in areas where timber has been harvested and assess the effect of radiotags on the condition of weasels.

**Methods**

**Radio-tagging and Telemetry**

I radio-tagged 10 male weasels and 7 female weasels using Holohil® PD2C and MD2C transmitters weighing 4-5 g for males and 2-3 g for females, < 4% of total adult body weight. I held weasels in-hand when attaching collars rather than anesthetizing them as recommended by King (1989). Because my primary interest is the use of timber harvested areas, I only collared weasels live-trapped in cutblocks harvested in winter 1993/94 and containing regenerating aspen (Populus tremuloides). I assessed the effect of radiotags on weasel condition, by comparing weights of tagged and untagged weasels live-trapped during the same period.

I monitored weasels for various periods between March and December 1996. I located them by radio-triangulation (White and Garrott 1990) from fixed telemetry stations. I recorded at least 3 bearings from separate stations. I checked the accuracy of triangulation in the field on AVI (Alberta Vegetation Inventory) maps. After I approached the site to confirm activity (i.e., resting versus foraging), specific location, and habitat type, I flagged the site and returned later to locate it using a hand-held GPS (Global Positioning System). GPS data were corrected to ± 1 m.

Due to equipment problems, my telemetry sampling was erratic, particularly for males. In general, I located male weasels every 2-4 days and females every 1-2 days. Male weasels often damaged their transmitters and 2 weeks without locations were not uncommon. I attempted to obtain the locations over the 24-hr day, but despite my efforts, daylight locations dominate my data set.
Home Range Definition

I define home range as the area traversed by an individual during its normal activities of food gathering and resting within the period when sampling occurred. Home range is commonly defined as “that area traversed by the individual in its normal activities of food gathering, mating and caring of young” (Burt 1943: page 351). Burt (1943) also stressed that the home range is the area where an animal normally moves and should not include excursions outside its normal area. In my study, I did not follow female weasels during their breeding season. Therefore, the caring of young by female weasels is not applicable to my definition of home range.

Home Range and Utilization Distributions

I generated home ranges for weasels with 20 or more locations with a minimum of 12 hours between locations. I calculated home ranges using a fixed kernel density estimator (Seaman and Powell 1996). The advantages of a kernel estimator are: 1) it is non-parametric and does not make any assumptions as to the shape of the area (White and Garrott 1990); and 2) it has received some testing (Worton 1995; Seaman and Powell 1996). Fixed kernel estimators provide more accurate estimates of home range area compared with adaptive kernel estimators (Seaman and Powell 1996). The selection of a smoothing parameter is important (Worton 1995) with least squares cross validation essential for accurate estimates (Seaman and Powell 1996).

I calculated home ranges using the program The Home Ranger Version 1.0a (Hovey 1997). I calculated home ranges using volume contours and an adjusted “h” based on the cross-validation of least squares. To accommodate my definition of home range, I excluded areas of excursion by using a 95% utilization distribution. Utilization distribution is a function describing the probability of finding the animal at a particular location on a plane (White and Garrott 1990). This means that 95% of the animal’s locations were within the 95% volume contour. The remaining 5% of locations were considered excursions from the area of normal activity and excluded. The choice of 95% is arbitrary. I chose 95% because it is commonly used by other studies and useful for comparative purposes.
Habitat Use and Geographical Information Systems (GIS)

I used GIS to examine habitat use. I classified habitats based on the dominant forest cover types described by the Alberta Vegetation Inventory (AVI) mapping system. AVI maps are derived from digitized aerial photographs (1:15,000) and limited ground-truthing. I ground-truthed my study area extensively to ensure habitats were not classified incorrectly due to errors in interpretation and digitizing of aerial photographs. I imported a digitized AVI map into ArcView GIS Version 3.1 (ESRI 1996). I converted home range UTM (Universal Transverse Mercator) coordinate outputs from The Home Ranger into vector polygons using Arc/Info Version 7.1 (ESRI 1997). I overlaid the home range polygons on the AVI map in Arcview GIS. I then used a raster analysis with a resolution of 0.1 m x 0.1 m to determine the area of overlap between each AVI habitat type and a weasel’s home range. At this stage, I excluded water bodies (e.g., lakes) found within a home range.

Habitat Use - Ivlev’s Electivity Index

To examine habitat use, I compared habitat use and availability in a home range using Ivlev’s electivity index (Krebs 1989). Ivlev’s electivity index varies from -1 to +1, with values of > 0 to +1 indicating preference and values < 0 to -1 indicating avoidance (Krebs 1989). I defined availability as the area of each habitat type in a weasel’s home range. I defined use as the number of telemetry locations in each habitat type. I determined 95% confidence intervals for each electivity index using bootstrapping (n=1000). Ivlev’s electivity indices with bootstrapping were calculated using a program developed by Dave Huggard (University of British Columbia, unpublished). The index values are sensitive to errors in the accuracy of the availability measure (e.g., home range calculations) and GIS maps.

Results

Home Range Size

Four females and 4 males had the minimum requirement of 20 locations for determination of home range size (Table 2.1). On average, male home ranges (122.6-204.6 ha) were 1.8 times larger than female home ranges (65.5-94.8 ha) (Table 2.1). On average, males were 2.2 times heavier than females (Table 2.1).
Table 2.1. Size of fixed-kernel home ranges for female (n=4) and male (n=4) short-tailed weasels, based on the 95% utilization distribution, in the mixedwood boreal forest of central Alberta.

<table>
<thead>
<tr>
<th>Weasel</th>
<th>Sampling Period</th>
<th>Maximum weight (g)</th>
<th>Number of locations</th>
<th>Home range size (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female 1</td>
<td>Aug-Oct</td>
<td>84</td>
<td>27</td>
<td>82.6</td>
</tr>
<tr>
<td>Female 2</td>
<td>Aug-Dec</td>
<td>85</td>
<td>57</td>
<td>94.8</td>
</tr>
<tr>
<td>Female 3</td>
<td>Aug-Oct</td>
<td>104</td>
<td>75</td>
<td>65.5</td>
</tr>
<tr>
<td>Female 4</td>
<td>Aug-Nov</td>
<td>75</td>
<td>39</td>
<td>76.8</td>
</tr>
<tr>
<td>Male 1</td>
<td>Mar-May</td>
<td>218</td>
<td>26</td>
<td>134.5</td>
</tr>
<tr>
<td>Male 2</td>
<td>May-Nov</td>
<td>151</td>
<td>25</td>
<td>122.6</td>
</tr>
<tr>
<td>Male 3</td>
<td>May-Oct</td>
<td>220</td>
<td>20</td>
<td>204.6</td>
</tr>
<tr>
<td>Male 4</td>
<td>Jun-Nov</td>
<td>184</td>
<td>34</td>
<td>131.3</td>
</tr>
</tbody>
</table>

Habitat Use

I identified 11 habitat types, based on dominant AVI forest and non-forest cover, in the home ranges of 4 female and 4 male weasels (Table 2.2). White spruce, balsam poplar, gas pipeline, and anthropogenic cover habitats accounted for < 4% of a home range area or occurred in < 2 home ranges (Tables 2.3 and 2.4).

Habitat Selection

Based on Ivlev’s index values (Tables 2.3 and 2.4), male and female weasels differed in their use of habitats (Tables 2.5). Female weasels showed a consistent preference for cutblock habitat. Females tended to under-utilize larch, black spruce, and aspen habitats and completely avoid jack pine. The use of shrub, birch, and white spruce habitats was not consistent, being preferred and avoided depending upon the individual female.

Male weasels tended to prefer black spruce, larch, birch, and scrub habitats and under-utilized aspen and cutblock habitats. Males avoided jack pine and white spruce habitats.
Table 2.2. Type, age, and percent canopy cover of habitats in the home ranges of 4 female and 4 male weasels, based on 95% utilization distributions, at Owl River, Alberta, in 1995 and 1996.

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Dominant plant species</th>
<th>Age (yrs)</th>
<th>% Crown closure of trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>aspen</td>
<td><em>Populus tremuloides</em></td>
<td>60-90</td>
<td>80-100</td>
</tr>
<tr>
<td>poplar</td>
<td><em>Populus balsamifera</em></td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>birch</td>
<td><em>Betula papyrifera</em></td>
<td>45-55</td>
<td>70-80</td>
</tr>
<tr>
<td>white spruce</td>
<td><em>Picea glauca</em></td>
<td>130</td>
<td>60-100</td>
</tr>
<tr>
<td>black spruce</td>
<td><em>Picea mariana</em></td>
<td>115-140</td>
<td>50-100</td>
</tr>
<tr>
<td>larch</td>
<td><em>Larix laricina</em></td>
<td>115-140</td>
<td>50-90</td>
</tr>
<tr>
<td>jack pine</td>
<td><em>Pinus banksiana</em></td>
<td>65-100</td>
<td>70-100</td>
</tr>
<tr>
<td>shrub(^1)</td>
<td><em>Salix spp.</em>, <em>Betula pumila</em></td>
<td>unknown</td>
<td>-</td>
</tr>
<tr>
<td>herbaceous grassland</td>
<td>-</td>
<td>unknown</td>
<td>-</td>
</tr>
<tr>
<td>gas pipeline(^2)</td>
<td>-</td>
<td>unknown</td>
<td>-</td>
</tr>
<tr>
<td>anthropogenic cover(^3)</td>
<td>-</td>
<td>unknown</td>
<td>-</td>
</tr>
<tr>
<td>cutblock(^4)</td>
<td><em>Populus tremuloides</em>, <em>Populus balsamifera</em></td>
<td>3</td>
<td>-</td>
</tr>
</tbody>
</table>

\(^1\) crowns of most shrubs interlocking
\(^2\) right-of-way for buried gas pipeline
\(^3\) cultivated lands including perennial forage crops, annual crops, and oil and gas development
\(^4\) harvested for aspen and poplar in winter 1993/94

Changes in Body Weight

I examined the body weight of 4 radio-tagged and 4 untagged females (Fig. 2.1) and 4 radio-tagged and 4 untagged males (Fig. 2.2). In most cases, weasels showed a trend to reach maximum weight mid-summer (June-August) followed by a gradual loss of weight beginning August-early September. Weights of radio-tagged and untagged weasels were not substantially different and showed similar changes over the seasons.

Discussion

There are 2 features to my study that may bias my results. My results may be biased by the high proportion of daylight locations in my data set. However, in summer, North American and European weasels are predominantly diurnal in activity (Erlinge 1979b, Debrot *et al.* 1985, Samson and Raymond 1995). In my study, it is also possible, that the behaviour of weasels was compromised by radio-tagging and do not accurately represent the population. White and Garrott (1990) stress the importance of testing the effect of radio-tagging on study animals. In my study,
Table 2.3. Habitat types in home ranges (95% utilization distribution) of 4 female short-tailed weasels, the number of telemetry locations in each habitat type, and Ivlev's electivity index for habitat preference and avoidance with bootstrapped 95% confidence intervals, in the mixedwood boreal forest of central Alberta. * indicates that upper and lower confidence intervals do not contain zero and the selectivity is "significant" at P=0.05. For each weasel, habitats are ordered in decreasing magnitude of the electivity index.

<table>
<thead>
<tr>
<th>Weasel</th>
<th>Habitat type</th>
<th>Proportion of home range</th>
<th>Proportion of telemetry locations</th>
<th>Electivity index</th>
<th>Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female 1</td>
<td>cutblock</td>
<td>0.296</td>
<td>0.667</td>
<td>0.386*</td>
<td>0.239 - 0.467</td>
</tr>
<tr>
<td>n=27</td>
<td>larch</td>
<td>0.113</td>
<td>0.074</td>
<td>-0.208 - 1.000</td>
<td>0.242</td>
</tr>
<tr>
<td></td>
<td>aspen</td>
<td>0.456</td>
<td>0.259</td>
<td>-0.275* - 0.608</td>
<td>-0.056</td>
</tr>
<tr>
<td></td>
<td>jack pine</td>
<td>0.113</td>
<td>0.000</td>
<td>-1.000 - 1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>black spruce</td>
<td>0.019</td>
<td>0.000</td>
<td>-1.000 - 1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>birch</td>
<td>0.004</td>
<td>0.000</td>
<td>-1.000 - 1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>shrub</td>
<td>0.010</td>
<td>0.000</td>
<td>-1.000 - 1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>gas pipeline</td>
<td>0.017</td>
<td>0.000</td>
<td>-1.000 - 1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td>Female 2</td>
<td>cutblock</td>
<td>0.366</td>
<td>0.561</td>
<td>0.211*</td>
<td>0.090 - 0.303</td>
</tr>
<tr>
<td>n=57</td>
<td>shrub</td>
<td>0.073</td>
<td>0.088</td>
<td>0.093 - 0.349</td>
<td>0.414</td>
</tr>
<tr>
<td></td>
<td>aspen</td>
<td>0.312</td>
<td>0.263</td>
<td>-0.085 - 0.328</td>
<td>0.083</td>
</tr>
<tr>
<td></td>
<td>black spruce</td>
<td>0.164</td>
<td>0.088</td>
<td>-0.302* - 0.806</td>
<td>-0.017</td>
</tr>
<tr>
<td></td>
<td>larch</td>
<td>0.059</td>
<td>0.000</td>
<td>-1.000 - 1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>poplar</td>
<td>0.026</td>
<td>0.000</td>
<td>-1.000 - 1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td>Female 3</td>
<td>cutblock</td>
<td>0.490</td>
<td>0.733</td>
<td>0.199*</td>
<td>0.122 - 0.256</td>
</tr>
<tr>
<td>n=75</td>
<td>birch</td>
<td>0.010</td>
<td>0.013</td>
<td>0.186 - 1.000</td>
<td>0.627</td>
</tr>
<tr>
<td></td>
<td>black spruce</td>
<td>0.130</td>
<td>0.147</td>
<td>0.061 - 0.321</td>
<td>0.272</td>
</tr>
<tr>
<td></td>
<td>aspen</td>
<td>0.203</td>
<td>0.080</td>
<td>-0.435* - 0.768</td>
<td>-0.161</td>
</tr>
<tr>
<td></td>
<td>larch</td>
<td>0.060</td>
<td>0.013</td>
<td>-0.642 - 1.000</td>
<td>-0.208</td>
</tr>
<tr>
<td></td>
<td>shrub</td>
<td>0.079</td>
<td>0.013</td>
<td>-0.712* - 1.000</td>
<td>-0.330</td>
</tr>
<tr>
<td></td>
<td>white spruce</td>
<td>0.028</td>
<td>0.000</td>
<td>-1.000 - 1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td>Female 4</td>
<td>shrub</td>
<td>0.180</td>
<td>0.282</td>
<td>0.222 - 0.077</td>
<td>0.416</td>
</tr>
<tr>
<td>n=39</td>
<td>white spruce</td>
<td>0.038</td>
<td>0.051</td>
<td>0.152 - 1.000</td>
<td>0.545</td>
</tr>
<tr>
<td></td>
<td>cutblock</td>
<td>0.306</td>
<td>0.333</td>
<td>0.043 - 0.261</td>
<td>0.228</td>
</tr>
<tr>
<td></td>
<td>larch</td>
<td>0.232</td>
<td>0.231</td>
<td>-0.002 - 0.386</td>
<td>0.215</td>
</tr>
<tr>
<td></td>
<td>black spruce</td>
<td>0.095</td>
<td>0.051</td>
<td>-0.299 - 1.000</td>
<td>0.148</td>
</tr>
<tr>
<td></td>
<td>aspen</td>
<td>0.119</td>
<td>0.051</td>
<td>-0.396 - 1.000</td>
<td>0.039</td>
</tr>
<tr>
<td></td>
<td>jack pine</td>
<td>0.030</td>
<td>0.000</td>
<td>-1.000 - 1.000</td>
<td>-1.000</td>
</tr>
</tbody>
</table>
Table 2.4. Habitat types in home ranges (95% utilization distribution) of 4 male short-tailed weasels, the number of telemetry locations in each habitat type, and Ivlev’s electivity index for habitat preference and avoidance with bootstrapped 95% confidence intervals, in the mixedwood boreal forest of central Alberta. * indicates that the upper and lower confidence intervals do not contain zero and the selectivity is "significant" at $P=0.05$. For each weasel, habitats are ordered in decreasing magnitude of the electivity index.

<table>
<thead>
<tr>
<th>Weasel</th>
<th>Habitat type</th>
<th>Proportion of home range</th>
<th>Proportion of telemetry locations</th>
<th>Electivity index</th>
<th>Confidence interval lower</th>
<th>Confidence interval upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male 1</td>
<td>birch</td>
<td>0.075</td>
<td>0.231</td>
<td>0.509*</td>
<td>0.012</td>
<td>0.673</td>
</tr>
<tr>
<td></td>
<td>shrub</td>
<td>0.050</td>
<td>0.115</td>
<td>0.397</td>
<td>-1.000</td>
<td>0.645</td>
</tr>
<tr>
<td></td>
<td>black spruce</td>
<td>0.113</td>
<td>0.231</td>
<td>0.345</td>
<td>-0.187</td>
<td>0.580</td>
</tr>
<tr>
<td></td>
<td>larch</td>
<td>0.111</td>
<td>0.192</td>
<td>0.269</td>
<td>-0.485</td>
<td>0.515</td>
</tr>
<tr>
<td></td>
<td>aspen</td>
<td>0.336</td>
<td>0.192</td>
<td>-0.271</td>
<td>-0.627</td>
<td>0.016</td>
</tr>
<tr>
<td></td>
<td>herbaceous</td>
<td>0.087</td>
<td>0.038</td>
<td>-0.383</td>
<td>-1.000</td>
<td>0.144</td>
</tr>
<tr>
<td></td>
<td>grassland cutblock</td>
<td>0.175</td>
<td>0.000</td>
<td>-1.000</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>jack pine</td>
<td>0.045</td>
<td>0.000</td>
<td>-1.000</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>white spruce</td>
<td>0.006</td>
<td>0.000</td>
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<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>anthropogenic</td>
<td>0.004</td>
<td>0.000</td>
<td>-1.000</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>cover</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male 2</td>
<td>black spruce</td>
<td>0.118</td>
<td>0.240</td>
<td>0.339</td>
<td>-0.194</td>
<td>0.543</td>
</tr>
<tr>
<td></td>
<td>larch</td>
<td>0.263</td>
<td>0.480</td>
<td>0.292*</td>
<td>0.031</td>
<td>0.442</td>
</tr>
<tr>
<td></td>
<td>cutblock</td>
<td>0.270</td>
<td>0.240</td>
<td>-0.060</td>
<td>-0.543</td>
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<tr>
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<td>aspen</td>
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<td>0.040</td>
<td>-0.505*</td>
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<td>-0.007</td>
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<td>shrub</td>
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<td>-1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>anthropogenic</td>
<td>0.041</td>
<td>0.000</td>
<td>-1.000</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>cover</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>jack pine</td>
<td>0.018</td>
<td>0.000</td>
<td>-1.000</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>birch</td>
<td>0.015</td>
<td>0.000</td>
<td>-1.000</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>white spruce</td>
<td>0.008</td>
<td>0.000</td>
<td>-1.000</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>poplar</td>
<td>0.003</td>
<td>0.000</td>
<td>-1.000</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td>Male 3</td>
<td>birch</td>
<td>0.006</td>
<td>0.100</td>
<td>0.882</td>
<td>-1.000</td>
<td>0.951</td>
</tr>
<tr>
<td></td>
<td>larch</td>
<td>0.068</td>
<td>0.200</td>
<td>0.492</td>
<td>-0.153</td>
<td>0.709</td>
</tr>
<tr>
<td></td>
<td>black spruce</td>
<td>0.048</td>
<td>0.100</td>
<td>0.353</td>
<td>-1.000</td>
<td>0.679</td>
</tr>
<tr>
<td></td>
<td>shrub</td>
<td>0.037</td>
<td>0.050</td>
<td>0.147</td>
<td>-1.000</td>
<td>0.679</td>
</tr>
<tr>
<td></td>
<td>cutblock</td>
<td>0.277</td>
<td>0.350</td>
<td>0.116</td>
<td>-0.297</td>
<td>0.330</td>
</tr>
<tr>
<td></td>
<td>jack pine</td>
<td>0.062</td>
<td>0.050</td>
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<td>0.413</td>
</tr>
<tr>
<td></td>
<td>aspen</td>
<td>0.467</td>
<td>0.150</td>
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<td>-1.000</td>
</tr>
<tr>
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<td>cover</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>white spruce</td>
<td>0.011</td>
<td>0.000</td>
<td>-1.000</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
</tbody>
</table>

continued next page ....
Table 2.4. continued …

<table>
<thead>
<tr>
<th>Weasel</th>
<th>Habitat type</th>
<th>Proportion of home range</th>
<th>Proportion of telemetry locations</th>
<th>Electivity index</th>
<th>Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male 4</td>
<td>birch</td>
<td>0.007</td>
<td>0.029</td>
<td>0.624</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>shrub</td>
<td>0.014</td>
<td>0.059</td>
<td>0.624</td>
<td>-1.000</td>
</tr>
<tr>
<td>n=34</td>
<td>larch</td>
<td>0.223</td>
<td>0.471</td>
<td>0.358*</td>
<td>0.138</td>
</tr>
<tr>
<td></td>
<td>black spruce</td>
<td>0.084</td>
<td>0.176</td>
<td>0.355</td>
<td>-0.177</td>
</tr>
<tr>
<td></td>
<td>cutblock</td>
<td>0.242</td>
<td>0.176</td>
<td>-0.157</td>
<td>-0.609</td>
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<tr>
<td></td>
<td>aspen</td>
<td>0.230</td>
<td>0.088</td>
<td>-0.445*</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>jack pine</td>
<td>0.185</td>
<td>0.000</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>herbaceous</td>
<td>0.010</td>
<td>0.000</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td></td>
<td>grassland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>white spruce</td>
<td>0.006</td>
<td>0.000</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
</tbody>
</table>

Table 2.5. Summary of habitat types preferred and avoided by female and male weasels based on Tables 2.3 and 2.4. Each “✓” represents 1 individual among 4 male and 4 female weasels.

<table>
<thead>
<tr>
<th>Habitat types</th>
<th>Prefer(^1)</th>
<th>Avoid(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>females</td>
<td>males</td>
</tr>
<tr>
<td>cutblock</td>
<td>✓✓✓✓</td>
<td>✓</td>
</tr>
<tr>
<td>shrub</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>birch</td>
<td>✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>white spruce</td>
<td>✓</td>
<td>✓✓✓</td>
</tr>
<tr>
<td>black spruce</td>
<td>✓</td>
<td>✓✓✓</td>
</tr>
<tr>
<td>larch</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>aspen</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
<tr>
<td>jack pine</td>
<td>✓✓</td>
<td>✓✓</td>
</tr>
</tbody>
</table>

\(^1\)Bolded “✓” indicates statistical significance.
Figure 2.1. Weights of 4 radio-tagged female weasels (Females 1-4) and 4 untagged female weasels (Females 5-8), live-trapped from February-November 1996, in the mixedwood boreal forest of central Alberta.
Figure 2.2. Weights of 4 radio-tagged male weasels (Males 1-4) and 4 untagged male weasels (Males 5-8), live-trapped from February-November 1996, in the mixedwood boreal forest of central Alberta.
weight profiles indicate that the weasels did not suffer nutritionally, however, I do not know if
the normal hunting behaviour of weasels was compromised by the presence of a radio-collar. For
example, the increased diameter of a weasel’s neck caused by a radio-collar may have limited
the size of mouse and vole tunnels that could be explored. Because I did not detect effects of
radio-collars on body weight, the results of my study can be explained reasonably by sexual
dimorphism and dietary habits of male and female weasels. Simms (1979b) found that home
ranges in southern Ontario range from 20-25 ha for males and 10-15 ha for females. My data
show much larger home ranges for male and female weasels in the mixedwood boreal forest. My
data are similar to home range sizes recorded in New Zealand for Mustela erminea (Alterio
1998).

The variability in size of home ranges documented in the literature may reflect
differences in prey abundance as suggested by Jedrzejewski et al. (1995) and Erlinge (1977c). In
the boreal forest, North American populations of voles have been observed to oscillate (Adamcik
et al. 1979, Boutin et al. 1995). In my study area, between 1995 and 1996, a decline in small
mammal numbers was observed (Moses pers. comm.). During that period, I observed a
concurrent increase in the distance traveled between live-trapping stations by ear-tagged weasels
(personal observation). The longer distances traveled by weasels suggests that home range sizes
may have increased between 1995 and 1996. This suggests that the home range sizes presented
in my study should not be considered static but rather a reflection of the abundance of prey
present during the period that weasels were monitored.

Differences in the home range sizes of male and female short-tailed weasels have been
My data show the same differences between the sexes. Differences in weight alone account for a
large portion of the difference between male and female home ranges for many mammalian
species (Harestad and Bunnell 1979). In Chapter 2, I documented that males were 2-3 times
heavier than females. This difference in body weight was true for the weasels used in this
analysis and corresponds to the difference in average home range size between male and female
weasels.

Weasels use a variety of habitats (Aldous and Manweiler 1942, Maher 1967, MacLean et
1995). My data show the same diversity of habitat use, as well as differences in habitat use by
males and females. Many studies have explained the use of habitats by the presence and
Weasels use shrub (Simms 1979a) and birch (Aldous and Manweiler 1942) habitats. Bateman (1968) found marten to favour birch habitats with abundant meadow voles (Microtus pennsylvanicus). In my study, shrub and birch habitats were generally favoured by weasels. A positive association with these habitats is evident for males and relatively weak for females. In the mixedwood boreal forest, these habitats are also favourable for voles (Roy et al. 1995), an important primary food of the short-tailed weasel (Chapter 2).

The use of coniferous forest by weasels has been documented by Fitzgerald (1977) and Sullivan and Sullivan (1980). In my study, I also detected the use of coniferous or cone-bearing forest by weasels. I found black spruce and larch habitats were preferred by male weasels but under-utilized by female weasels. These habitats are used by the cone-dependent red squirrel (Rusch and Reeder 1978), an important food in the diet of male weasels (Chapter 2). My data suggests that male weasels were using these habitats for hunting red squirrels. Jack pine habitat occurred in weasel home ranges but it was avoided by male and female weasels. Jack pine habitats may be avoided because of a depauperate prey base. Voles have high moisture requirements (Getz 1968, McManus 1974) and jack pine habitat may be too dry to support substantial numbers of voles. This habitat type also has been identified as an inferior conifer habitat for red squirrels (Rusch and Reeder 1978). The avoidance of white spruce habitat by males is not understood because this habitat is favoured by red squirrels (Rusch and Reeder 1978) and supports red-backed voles (Banfield 1974). It is possible that avoidance of white spruce is due to effects of small sample size, white spruce was sparse in home ranges (0.6-1.1 % of home range size) and the number of telemetry locations for males was small.

Weasels use deciduous and aspen habitats (Aldous and Manweiler 1942, Samson and Raymond 1995) and logged areas (< 5 years old) in eastern Canada (Samson and Raymond 1995). In my study area, weasels use these habitat types (mature aspen forest and 3-year-old regenerating aspen cutblocks). Male weasels under-utilized both habitat types. The under-utilization of aspen and cutblock habitats can be explained, in part, by abundance of red squirrels. In my study area, red squirrels were absent from cutblocks (personal observation). The abundance of red squirrels in aspen habitats is also low relative to cone-producing habitats (e.g., black spruce and larch) (Rusch and Reeder 1978). I found that female weasels preferred cutblocks but under-utilized aspen. This can be explained by small mammal abundance. In my study area (summer 1996), populations of voles (Clethrionomys gapperi and Microtus...
*pennsylvanicus* and deer mice (*Peromyscus maniculatus*), on average, were more abundant in 3-year-old cutblocks compared to aspen forest (Moses and Boutin unpublished data). In the mixedwood boreal forest, the habitat use of short-tailed weasels appears to correspond to the abundance of their principal prey.
Weasels are poor excavators and rely on natural cavities and the holes of burrowing mammals for rest sites (King 1989). Fitzgerald (1977) observed that short-tailed weasels (*Mustela erminea*) use subnivian nests of montane voles (*Microtus montanus*) in the Sierra Nevada, California. In Alaska and the Northwest Territories, the least weasel (*Mustela nivalis*) and short-tailed weasel used winter nests of lemmings (MacLean *et al.* 1974, Maher 1967). In both cases, the nests were located beneath the snow among dense grass and lined with the fur of the weasel’s prey. Elsewhere, least weasels and long-tailed weasels (*Mustela frenata*), close relatives of short-tailed weasels, use dens excavated by the Franklin’s ground squirrel (*Spermophilus franklini*), pocket gophers (*Geomys bursarius*), and eastern moles (*Scalopus aquaticus*) (Polderboer *et al.* 1941). The least weasel has also been observed to use nests of the Drummond’s vole (*Microtus pennsylvanicus drummondii*) (Criddle 1947).

 Availability of suitable rest sites is important for short-tailed weasels particularly during winter. During cold months, their long and slender shape (Brown and Lasiewski 1972), high metabolism (Casey and Casey 1979), and minimal fat storage (King 1989) makes thermal regulation difficult. When at rest, weasels depend on the insulating properties of their nests to keep warm (King 1989). The availability of rest sites may be crucial during periods of low prey abundance when weasels must hunt over large areas, particularly in winter. In this chapter, I describe rest sites used by short-tailed weasels in the mixedwood boreal forest of Alberta and compare rest site structures used by males and females.

**Methods**

Radio-tagging and Telemetry

I radio-tagged 10 male weasels and 7 female weasels using Holohil® PD2C and MD2C transmitters weighing 4-5 g for males and 2-3 g for females, < 4 % of total adult body weight. I held weasels in-hand when attaching collars rather than anaesthetizing them as recommended by King (1989). Because my primary interest was the use of timber harvested areas, I only collared weasels live-trapped in cutblocks harvested during winter 1993/94 and containing naturally regenerating aspen (*Populus tremuloides*).
I monitored the 10 males and 7 females for various periods between March and December 1996. I located them by radio-triangulation (White and Garrott 1990) from fixed telemetry stations. I recorded at least three bearings from separate stations. I checked the accuracy of triangulation in the field on AVI (Alberta Vegetation Inventory) maps. After I determined a general location, I approached the site to confirm activity (i.e., resting versus foraging), specific location, and habitat type. I flagged the site and returned later to locate it using a hand-held GPS (Global Positioning System). The GPS data were corrected to ± 1 m.

Due to equipment problems, my telemetry sampling was erratic, particularly for males. In general, I located male weasels every 2-4 days and females every 1-2 days. Male weasels often damaged their transmitters and 2-week periods without locations were not uncommon. I attempted to obtain the locations over the 24-hr day, but despite my efforts, daytime locations dominate my data set.

Resting Activity

I define rest sites as places used by weasels for the purpose of rest or prey consumption; that is, the weasel was not actively hunting. Hunting or traveling activity was indicated by changes in the volume of the radio signal. When inactive, the signal volume remained constant. I identified an inactive location using Zone of Receiver (i.e., when the signal could be heard on the receiver without an external antenna). I moved to the edge of the signal range where reception was most sensitive to changes in the weasel’s location. I listened to the signal for 15 min. If a change in signal strength was not observed, I deemed the weasel inactive. Often, I returned to the site after a minimum of 30 min to confirm the weasel’s inactivity.

Results

Rest Site Structures

I obtained 104 inactive locations and identified 79 rest sites. The number of inactive locations and rest sites differ because some rest sites were used more than once. Each weasel had more than 1 rest site. The weasels used a wide variety of rest sites and in all cases, the weasels were below ground. I classified rest sites into 7 structural types described in Table 3.1.
Table 3.1. Classification and descriptions of rest site structures in the mixedwood boreal forest of central Alberta.

<table>
<thead>
<tr>
<th>Rest site structure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squirrel midden</td>
<td>A squirrel midden is an area of red squirrel (<em>Tamiasciurus hudsonicus</em>) activity where the ground is covered by cone scales near the base of a tree and with multiple openings to a tunnel system.</td>
</tr>
<tr>
<td>Animal tunnel</td>
<td>Tunnels used by snowshoe hares (<em>Lepus americanus</em>) through moss and root systems; or tunnel openings of the least chipmunk (<em>Eutamias minimus</em>) without any associated habitat structure.</td>
</tr>
</tbody>
</table>
| Residual logging material | 1) Slash: the tops and branches of felled trees dispersed along the main road and spurs through the cutblock.  
                              | 2) Soil and woody debris (WD): fallen branches and/or logs assumed not to have resulted from logging activity.  
                              | 3) Root bulb: the upturned roots of a harvest tree stump plugged with dirt.                                                                 |
| Natural deadfall           | Fallen branches and/or logs assumed not to have resulted from logging activity (includes *Salix* spp. and other unidentified species).       |
| Base of tree or snag      | Animal excavated opening visible at the base of a tree, snag, or base of multi-stemmed *Salix* spp. or *Alnus* spp.                           |
| Moss hummock              | Mound of moss sometimes covering a system of roots with visible animal excavations.                                                          |
| Upturned roots of tree    | The exposed soil-plugged roots of a windfall aspen.                                                                                         |

Use of Rest Site Structures

For the 10 male weasels, I obtained 63 inactive locations and identified 42 individual rest sites (Table 3.2). Squirrel midden was the most common rest site structure used by males (55% of the rest sites; n=23), followed by the base of tree or snag (24% of the rest sites; n=10). The remaining rest site structures (n=9) each accounted for 7% or less of the sites (animal tunnel, natural deadfall, moss hummock, and upturned roots of tree). Forty-one rest sites of males were in forested habitats and 1 rest site was in a cutblock.

For the 7 female weasels, I obtained 41 inactive locations and identified 37 individual rest sites (Table 3.2). Residual logging material was the most common rest site structure used by females (41% of the sites; n=15), followed by base of tree or snag (30% of the sites; n=11), and natural deadfall (16% of the sites; n=6). The remaining rest site structures (n=5) each accounted
Table 3.2. Number of individual resting sites, their associated habitat types, and the total number of observations of 7 female and 10 male short-tailed weasels, March-December 1996, in the mixedwood boreal forest of central Alberta.

<table>
<thead>
<tr>
<th>Rest site structure</th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of rest sites</td>
<td>Number of observations</td>
</tr>
<tr>
<td>squirrel midden</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>animal tunnel</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>residual logging material</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>base of tree or snag</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>natural deadfall</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>moss hummock</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>upturned roots of tree</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td>41</td>
</tr>
</tbody>
</table>

\(^1\) Tree species listed are the dominant canopy species.
for 5% or less of the sites (squirrel midden, upturned roots of tree, and moss hummock). Eighteen rest sites of females were in forested habitats and 19 were in cutblocks.

Based on Bonferroni-adjusted Z-tests (P < 0.05), the proportion of squirrel midden rest sites used by males was significantly greater than that used by females. The proportion of residual logging material rest sites used by females was significantly greater than that used by males (Fig. 3.1). I detected no difference between males and females in their use of the remaining structures.

Figure 3.1. Rest sites used by male and female short-tailed weasels, March-December 1996, in the mixedwood boreal forest of central Alberta. * indicate significant difference between sexes (Bonferroni-adjusted Z-test, P ≤ 0.05); n=37 rest sites for females; n=42 rest sites for males. Numbers above bars are the number of occurrences for each rest site structure.
Discussion

Weasels used a variety of structures as rest sites. Most (78/79) of the rest site structures identified in my study were associated with the prey of weasels: red squirrels, voles, lemmings, mice, and chipmunks (Chapter 2). This is not surprising because weasels are poor excavators and rely on other animals, including their prey species, to provide cavities that can be used as rest sites (MacLean et al. 1974, Fitzgerald 1977). In my study area, residual logging material, the bases of trees or snags, natural deadfalls, and upturned roots of trees were all identified as structures associated with the nests of red-backed voles and deer mice (Weaver 1996, R.L. Weaver pers. comm.). Middens and tunnels are constructed by red squirrels and least chipmunks (Rezendes 1993). Tunnels through moss hummocks in black spruce and larch stands may be used by northern bog lemmings (Synaptomys borealis) and other small mammal species. Weasels also used rest site structures not associated with prey identified in my study (Chapter 2) as in the case of an animal tunnel used by snowshoe hares (Lepus americanus).

Sexual dimorphism and related differences in diet (Chapter 2) can account for differences in the use of rest site structure between males and females. Because males are 2-3 times larger than females (Chapter 2), their access to smaller rest site structures is constrained as suggested by Simms' (1979) observation of limited access by males to hunting micro-habitats (e.g., vole tunnels). The males' larger size also enables them to hunt red squirrels (Chapter 2) and likely results in an increased chance of male weasels exploring and resting in squirrel middens.

Short-tailed weasels use more than one rest site (Nyholm 1959). My data support this finding. The availability of an adequate number of rest sites is important when prey abundance is low and weasels must hunt over large areas (King 1989). In winter, the availability of rest sites is especially important because when at rest, the maintenance of body heat requires twice as much energy as in summer (Casey and Casey 1979). The weasel's long and slender shape (Brown and Lasiewski 1972), high metabolism (Casey and Casey 1979), and minimal fat storage (King 1989) makes thermal regulation difficult. Hence when at rest, the weasel must rely largely upon the insulating properties of its nest to keep warm (King 1989).

My results suggest that logging has implications for the availability of rest sites used by males. Although all 10 male weasels that I studied used cutblocks, only 1 of the 42 rest sites was in a cutblock. Males can use the bases of trees and snags but logging usually removes snags and the longevity of standing trees left in cutblocks is uncertain due to windthrow. The removal of standing trees and snags by logging could reduce the availability of rest sites for males, as well
as remove habitat for red squirrels, an important prey of male weasels (Chapter 2). Logging has less severe implications for rest sites used by females. One half of the rest sites used by females were in cutblocks and many of these were in residual logging material.
Chapter 4
Use of Slash in Cutblocks by Female Short-tailed Weasels

Introduction

Downed wood provides important structure in habitats of mustelids and small mammals. It provides secure travel corridors and in winter, subnivian access and thermal cover. The importance of downed wood for mustelids, particularly marten and fisher, has been well documented (Baker 1992, Corn and Raphael 1992, Lofroth 1993, Buskirk and Powell 1994, Buskirk and Ruggiero 1994). For small mammals, downed wood can function as travel routes (Maser et al. 1979, Maser and Trappe 1984; Carter 1993); provide a food source of fungal fruiting bodies (Maser and Trappe 1984, Rhoades 1986); and nest sites (Weaver 1996). Higher abundance of southern red-backed voles (Clethrionomys gapperi) has been associated with downed wood (Nordyke and Buskirk 1991). Little has been reported on use of downed wood by short-tailed weasels (Mustela erminea). Gyug (1993) reported that short-tailed weasels used cutblocks with slash more than those with none. Because of their shape and size, it is likely that the benefits of slash to small mammals may also apply to the short-tailed weasel (e.g., travel routes). As well, higher small mammal abundance could attract weasels to downed wood as foraging sites.

My objective in this chapter is to determine if female weasels preferentially use slash in cutblocks and whether small mammal abundance can account for this behaviour. If females use slash, timber harvesting practices provide residual downed wood, which could be managed to suit the needs of wildlife. Residual downed wood can be dispersed, piled or removed from a site. Management of downed wood could mitigate some of the effects of timber harvesting on habitat for wildlife.

Methods

Radio-tagging and Telemetry

I used 4 female weasels in this analysis (Females 1-4 described in Chapter 3). I used Holohil® MD2C transmitters weighing 2-3 g, < 4% of an adult female's body weight. I held weasels in-hand when attaching collars rather than anaesthetizing them as recommended by King (1989). I followed the 4 females between July and December 1996 and located them by
radio-triangulation (White and Garrott 1990) from fixed telemetry stations. I recorded at least 3 bearings from separate stations. Accuracy of triangulation was checked in the field on AVI (Alberta Vegetation Inventory) maps. After I determined a general location, I approached the site to confirm activity (i.e., resting versus foraging), specific location, and habitat. I flagged the site and returned later to locate it using a hand-held GPS (Global Positioning System). The GPS data were corrected to ± 1 m. I attempted to obtain the locations over the 24-hr day, but despite my efforts, daytime locations dominate my data set.

Slash

I defined slash as piles of logging debris, the tops and branches of felled trees, dispersed along the main road and spurs passing through a cutblock. I determined the area of slash in 4 cutblocks used by Females 1-4. The cutblocks were all harvested for trembling aspen (*Populus tremuloides*) during winter, 1993-94, using dispersed retention (Chapter 1: page 7-8). At the time of my study, the cutblocks were approximately 3-years-old and vegetated with naturally regenerating aspen saplings, grasses, forbs, and shrubs. Approximately 35-68 m of main road and spurs occurred per hectare of cutblock.

In May 1997, I walked the perimeter of each slash pile taking UTM (Universal Transverse Mercator) coordinates via hand-held GPS every 5 sec or approximately every 2-5 m. The GPS point data were corrected to ± 1 m. I converted the point data into vector polygons using Arc/Info Version 7.1 (ESRI 1997) and imported the vector polygons into ArcView version 3.1 (ESRI 1996). I calculated the area of slash available for use within each female’s home range using a raster overlay of home range and slash polygons with a 0.1 m x 0.1 m raster resolution.

Small Mammal Population Estimates

I live-trapped small mammals in two cutblocks, Sites 1 and 2, that 3 female weasels (Females 2-4) were known to use. I placed 4 Multi-capture Tin Cat® live traps 25 m apart in a diamond configuration with an additional trap placed in the centre (5 traps in total). I placed 6 diamonds in each cutblock, 3 diamonds in areas of slash and 3 diamonds in areas of no-slash. I trapped each cutblock for 3 nights from October 4-6, 1996. I identified each small mammal to
species and then sexed, weighed, and marked it with picric acid. I recorded the number of marked and unmarked animals.

I used the Schumacher and Eschmeyer Method to estimate small mammal population sizes with confidence limits (Krebs 1989). This method estimates the population size for a closed population (i.e., population size is constant without recruitment or loss). It is appropriate for my study because the trapping occurred over a short period. The Schumacher and Eschmeyer Method distinguished 2 types of individuals: 1) marked individuals caught on 1 or more nights; and 2) unmarked individuals not caught previously. I determined population sizes for 4 areas: 1) Site 1 areas of slash; 2) Site 1 areas of no-slash; 3) Site 2 areas of slash; and 4) Site 2 areas of no-slash. In each case, data from the 3 sampling diamonds were pooled. I calculated confidence limits for each population estimate using a Poisson distribution as recommended for cases in which total number of recaptures is < 50 (Krebs 1989).

**Results**

**Slash Area and Use of Slash by Weasels**

I tested selective use of slash in cutblocks using the Log-likelihood statistic (Zar 1984). Availabilities of slash and no-slash for each weasel are based on their respective areas within a female’s home range (Table 4.1). I used both active (i.e., hunting or traveling) and inactive (i.e., resting or consuming prey) observations in the analyses. All 4 females preferred slash areas over no-slash areas (P < 0.001, Table 4.2).

Table 4.1. Cutblock area found within the home range of each female weasel and areas within the cutblock designated as slash or no-slash based on GIS analyses.

<table>
<thead>
<tr>
<th>Weasel</th>
<th>Home range size (ha)</th>
<th>Cutblock area (ha)</th>
<th>No-slash area (ha)</th>
<th>Slash area (ha)</th>
<th>% slash in cutblock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female 1</td>
<td>82.6</td>
<td>24.43</td>
<td>22.40</td>
<td>2.03</td>
<td>8.3</td>
</tr>
<tr>
<td>Female 2</td>
<td>94.8</td>
<td>34.70</td>
<td>32.59</td>
<td>2.11</td>
<td>6.1</td>
</tr>
<tr>
<td>Female 3</td>
<td>65.5</td>
<td>32.09</td>
<td>28.16</td>
<td>3.93</td>
<td>12.2</td>
</tr>
<tr>
<td>Female 4</td>
<td>76.8</td>
<td>23.53</td>
<td>21.21</td>
<td>2.41</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Activity in Slash by Females

Collectively, observations of inactive females in areas of slash and no-slash collectively account for only a small proportion of the data, 11% and 18%, respectively (Table 4.2). When
standardized by area, Females 1 and 3 had greater activity in slash, Female 2 had greater inactivity in areas of no-slash, and Female 4 was not found inactive (Table 4.3).

Table 4.2. Selective use of slash within cutblocks by female short-tailed weasels in the mixedwood boreal forest of central Alberta, based on log-likelihood statistics. Values in parenthesis are the number of inactive observations in slash and no-slash areas.

<table>
<thead>
<tr>
<th>Weasel</th>
<th>Observed locations in slash</th>
<th>Observed locations in no-slash</th>
<th>Expected locations in slash</th>
<th>Expected locations in no-slash</th>
<th>Log-likelihood statistic</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female 1</td>
<td>11 (4)</td>
<td>7 (0)</td>
<td>1.5</td>
<td>16.5</td>
<td>31.82</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Female 2</td>
<td>14 (0)</td>
<td>18 (5)</td>
<td>2</td>
<td>30</td>
<td>36.09</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Female 3</td>
<td>21 (2)</td>
<td>34 (7)</td>
<td>6.7</td>
<td>48.3</td>
<td>24.10</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Female 4</td>
<td>7 (0)</td>
<td>6 (0)</td>
<td>1.3</td>
<td>11.7</td>
<td>15.55</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Table 4.3. Inactivity of female short-tailed weasels standardized by slash and no-slash cutblock area in the mixedwood boreal forest of central Alberta.

<table>
<thead>
<tr>
<th>Weasel</th>
<th>Number of inactive locations in slash per ha of slash</th>
<th>Number of inactive location in no-slash per ha of no-slash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female 1</td>
<td>1.97</td>
<td>0.00</td>
</tr>
<tr>
<td>Female 2</td>
<td>0.00</td>
<td>0.15</td>
</tr>
<tr>
<td>Female 3</td>
<td>0.51</td>
<td>0.25</td>
</tr>
<tr>
<td>Female 4</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Small Mammal Abundance Estimates

I caught 3 species of small mammals: *Clethrionomys gapperi*, *Microtus pennsylvanicus*, and *Peromyscus maniculatus* (Table 4.4). I captured relatively few *M. pennsylvanicus* with individuals appearing in traps on the last trap night only. Although statistically significant at Site 1 only, when all species were pooled, the data showed a trend for greater estimates of small mammals in areas of slash (Fig. 4.1). At Site 1, I estimated small mammal abundance as 46 ± 5 animals and 97 ± 10 animals for no-slash and slash areas, respectively. These abundance estimates were significantly different ($\chi^2 = 18.18$, df = 1, P < 0.001). At Site 2, I estimated small mammal abundance as 43 ± 6 animals and 58 ± 9 animals for no-slash and slash areas, respectively. These abundance estimates were not significantly different ($\chi^2 = 2.22$, df = 1, P > 0.10).
Table 4.4. Small mammal species captured and the number of captured and recaptured animals in areas of slash and no-slash for Sites 1 and 2 from October 4-6, 1996 in the mixedwood boreal forest of central Alberta.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Species</th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>no. captured</td>
<td>no. recaptured</td>
<td>no. captured</td>
</tr>
<tr>
<td>no-slash</td>
<td>C. lethrionomys gapperi</td>
<td>33</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Peromyscus maniculatus</td>
<td>33</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Microtus pennsylvanicus</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>slash</td>
<td>C. lethrionomys gapperi</td>
<td>42</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Peromyscus maniculatus</td>
<td>35</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Microtus pennsylvanicus</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 4.1. Total small mammal abundance estimates (C. lethrionomys gapperi, Peromyscus maniculatus, Microtus pennsylvanicus) with confidence limits, based on the Schumacher and Eschmeyer Method (Krebs 1989), October 4-6 1996. Areas of slash and no-slash were in regenerating aspen cutblocks (harvested winter 1993/94) in the mixedwood boreal forest of central Alberta. * indicate significant difference between areas of no-slash and slash in Sites 1 and 2 (Chi-square, P < 0.05).
Abundance estimates for *C. gapperi* showed the same trend for greater numbers in areas of slash with statistical significance at Site 1 (Fig. 4.2) but not Site 2. Abundance estimates of *P. maniculatus* differed little between areas of no-slash and slash (Fig. 4.2). At Site 1, *C. gapperi* abundance estimates were significantly different ($\chi^2 = 26.25$, df =1, $P < 0.001$). At Site 2, *C. gapperi* abundance estimates were not significantly different ($\chi^2 = 3.59$, df =1, $P > 0.05$). At Site 1 and Site 2, *P. maniculatus* abundances were not significantly different (Site 1, $\chi^2 = 0.90$, df =1, $P > 0.25$; Site 2, $\chi^2 = 0.30$, df =1, $P > 0.50$).

Figure 4.2. Abundance estimates of *Clethrionomys gapperi* and *Peromyscus maniculatus* with confidence limits based on the Schumacher and Eschmeyer Method (Krebs 1989), October 4-6 1996. Areas of no-slash and slash areas in regenerating aspen cutblocks (harvested winter 1993/94) in the mixedwood boreal forest of central Alberta. * indicates significant difference between areas of no-slash and slash in Sites 1 and 2 (Chi-square, $P < 0.05$).
Discussion

In the mixedwood boreal forest of Alberta, females weasels preferentially used areas of slash in cutblocks during summer and fall. My results are consistent with the behaviour of weasels in southern British Columbia during winter (Gyug 1993). There are 3 reasons why female weasels may selectively use areas with slash: (1) the amount of food; (2) the number of rest sites; and (3) availability of travel corridors. My data suggest that food abundance, specifically *Clethrionomys gapperi*, and number and type of rest sites (Chapter 3) are 2 factors that may explain the preferential use of slash by female weasels.

I think that food resources promoted use of slash because slash has a higher abundance of prey (Chapter 2). In my study area, small mammals, including *C. gapperi*, tend to be more abundant in slash than no-slash. Higher abundance of *C. gapperi* and other prey in slash would reduce hunting effort for weasels and make these areas attractive as foraging and resting sites.

Other studies have found positive associations between *C. gapperi* and downed wood (Nordyke and Buskirk 1991) providing support for trends evident in my data. In the mixedwood boreal forest, Roy *et al.* (1995) found both *P. maniculatus* and *C. gapperi* were positively associated with downed woody material. Roy *et al.* (1995) also concluded that *P. maniculatus* populations are flexible in their habitat requirements while *C. gapperi* populations are less so and “select areas of dense shrubs with abundant downed woody material.” The flexible habitat requirements of *P. maniculatus* explains their even distribution throughout the cutblock. *C. gapperi*’s positive association with downed wood explains the trend for greater abundance in slash.

Weaver (1996), in my study area, found that *C. gapperi* and *P. maniculatus* nested beneath slash, rotting downed wood, and the base of stumps and snags in cutblocks. Female weasels rested in slash and so, rest site availability is another reason for slash use by female weasels. Weasels rely on natural cavities or the nests of other species for rest sites (King 1989). Hence, I expect more resting activity by female weasels in slash due to a greater availability of nests associated with the higher abundance of small mammals. It does not appear, however, that slash is necessary for female weasels to find suitable rest sites in cutblocks because female weasels also rested in portions of cutblocks without slash.
Arvicolidae (voles and lemmings) were the principal prey of male and female weasels (February-December) in the mixedwood boreal forest of central Alberta. The red-backed vole was the primary vole species predated by weasels. During summer, diets of weasels were supplemented with birds and eggs. During summer and fall, the large size of male weasels allowed them to prey on red squirrels. Despite relatively high populations of deer mice in my study area, weasels did not take advantage of this potential prey. This dietary pattern has implications to forest management because of the different short-term responses of red-backed vole and deer mouse populations to timber harvesting. Following timber harvest in my study area, small mammal communities dominated by red-backed voles shifted to communities dominated by deer mice with a complete absence of red-backed voles from harvested areas during their breeding season. The shift occurred in dispersed retention cutblocks (1-2% canopy cover and slash retention) and clearcuts (no retention of canopy cover or slash) during the first year following harvesting of aspen (Moses and Boutin 1998). During the second year following harvesting, populations of red-backed voles recovered. In the short-term (1 year post-harvest), the principal prey of short-tailed weasels was decreased and this may have temporarily diminished the habitat quality of cutblocks for short-tailed weasels.

In the mixedwood boreal forest of central Alberta, the home range sizes of female and male weasels were 65.5-94.8 ha and 122.6-204.6 ha, respectively. Differences in the home range sizes of males and females can be attributed to sexual dimorphism, males are 2-3 times heavier than females. Within their home ranges, male and female weasels showed similar trends in the use of some habitat types. Generally, both sexes were indifferent to aspen forest habitat, generally preferred birch and shrub habitats, but avoided jack pine habitat. Male and female weasels differed in use of other habitats and these differences can be explained largely by differences in diet. Male weasels preferred habitats associated with high abundance of red squirrels (black spruce and larch habitats) and under-utilized habitats associated with low abundance of red squirrels (3-year-old regenerating aspen cutblocks). Female weasels showed the opposite trend. They preferred habitats associated with high vole abundance (3-year-old regenerating cutblocks) and under-utilized black spruce and larch habitats.

Weasels used a variety of rest site structures and most of these sites were associated with their prey. The most common rest sites used by male weasels were squirrel middens. The second most common rest sites of males were bases of trees and snags. In contrast, residual
logging materials were the most common rest sites used by females and these structures were associated with voles and mice.

The minor use of cutblocks by males for resting suggests that logging may diminish the availability of their preferred rest sites. Female weasels made substantial use of cutblocks and preferred areas with slash which were used for resting, hunting, and possibly travel routes. Small mammal abundance, in particular red-backed voles, suggests that prey abundance is a factor promoting the use of slash by females. At the time of my study (3 years post-harvest), slash was not essential for providing suitable rest sites because female weasels also rested in portions of cutblocks without slash. Dense vegetation throughout cutblocks provided alternative sources of security and thermal cover. However, slash may facilitate movements of weasels by providing travel routes less hindered by dense vegetation while providing security cover. Based on my findings, slash supports a high abundance of small mammals and appears to be a beneficial attribute in 3-year-old regenerating aspen cutblocks.

Management Recommendations

Female and male weasels exploited several resources in aspen-harvested landscapes and these resources can be provided through appropriate forest practices (Table 5.1). These forest practices help to maintain the availability of food and rest site structures for short-tailed weasels. Red-backed voles and deer mice are the predominant species of small mammals in aspen forests. Red-backed voles are most important because they are the principal prey of weasels (Chapter 1) and vole abundance is positively correlated with reproductive success of weasels (Erlinge 1981, Erlinge 1983, King 1983b). Populations of red-backed voles declined during the first year after forest harvesting. To minimize this decline of red-backed voles, I concur with Moses and Boutin (1998) and recommend aggregated dispersion (or “high residual”) in cutblocks. Slash and standing trees are retained with this prescription. Slash is dispersed along haul roads and spurs of cutblocks and approximately 10% of total canopy cover (basal area) is retained in undisturbed 40-m diameter patches distributed uniformly throughout cutblocks. Dispersed retention (retention of 1-2% of canopy cover) has limited utility as habitat for male weasels. Because rest sites of males are associated with squirrel middens and the bases of trees and snags, aggregated retention can maintain habitat suitable for males if the forest patches are large enough.
<table>
<thead>
<tr>
<th>Resource required by short-tailed weasels</th>
<th>Landscape and stand features providing the resource</th>
<th>Management recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females home range: 65.5-94.8 ha</td>
<td>3-year-old aspen cutblocks with adjacent forest</td>
<td>Retain forest along the borders of 3-year-old aspen cutblocks. Cutblocks should be no wider than 1000m. Ages at which cutblocks do not function as habitat for weasels is not known.</td>
</tr>
<tr>
<td>food: red-backed voles</td>
<td>residual logging material and early seral vegetation, and mature aspen stands</td>
<td>Retain logging slash. Logging slash covering a minimum of 6% of the cutblock area should be piled along haul roads and spurs.</td>
</tr>
<tr>
<td>rest sites: downed woody material</td>
<td>residual logging material</td>
<td>Retain logging slash. Logging slash covering a minimum of 6% of the cutblock area should be piled along haul roads and spurs.</td>
</tr>
<tr>
<td>Males home range: 122.6-204.6 ha</td>
<td>stands of cone-bearing trees (black spruce, larch)</td>
<td>Retain patches of cone-bearing trees. Minimum patch size should be 35 ha so it can support at least 1 male. Patches should be less than 1250 m apart to ensure overlap of male home ranges with female home ranges.</td>
</tr>
<tr>
<td>food: 1) red-backed voles</td>
<td>1) residual logging material and early seral vegetation; and mature aspen stands</td>
<td>1) Retain logging slash. Logging slash covering a minimum of 6% of the cutblock area should be piled along haul roads and spurs.</td>
</tr>
<tr>
<td>2) red squirrels</td>
<td>2) stands of cone-bearing trees (black spruce, larch)</td>
<td>2) Retain patches of cone-bearing trees. A 35-ha patch that provides space for a male weasel should be sufficient to support red squirrels.</td>
</tr>
<tr>
<td>rest sites: squirrel middens and bases of trees and snags</td>
<td>stands of cone-bearing conifer trees (black spruce, larch)</td>
<td>Retain patches of cone-bearing trees. A 35-ha patch that provides space for a male weasel should be sufficient to support red squirrels.</td>
</tr>
</tbody>
</table>
Female weasels have different habitat requirements than males and are less vulnerable to logging. Slash and other logging debris (e.g., soil and woody debris, and root bulbs) are readily used by females for rest sites and they provide habitat for red-backed voles. At least 6% of the cutblock area should be covered in slash and this slash should be distributed linearly along main roads and spurs to ensure it occurs in home ranges of several females. In my study area, females tended to centre their home ranges in cutblocks anchored to forest stands undisturbed by timber harvesting. Based on the diameter of average home range size of females (79.9 ha), cutblocks should not exceed a width of 1000 m (assuming a home range of circular shape) and bordered by forest stands undisturbed by forest harvesting. This would ensure that all females residing in cutblocks would have access to the forest edges of cutblocks (especially if the goal is to maximize females on the landscape). Males are much larger than females and have different habitat requirements that are more difficult to provide through the primary silvicultural prescription applied in my study area. Males are strongly associated with forest stands occupied by red squirrels that offer food and rest sites. To ensure adequate habitat for males, at least during early seral stages, stands of coniferous trees capable of producing cones should be retained across the landscape. Based on average size of cone-bearing stands (black spruce and larch) in male home ranges, these stands should be a minimum of 35 ha so they can support at least 1 male. Based on the diameter of average home range size of males (assuming a home range of circular shape), these stands should be less than 1250 m apart to ensure home ranges of males overlap with those of females. Forest stands should meet habitat requirements of both male and female weasels.

These recommendations are based solely on my findings for weasels. Many more species inhabit the forest and some likely would suffer if the recommendations were applied everywhere. A balanced approach, managing for multiple species, will be more appropriate for sustaining wildlife in the mixedwood boreal forest. Also, the numbers provided are based on a 1-year study. It is known that weasel home ranges fluctuate with prey abundance. Declines in abundance of prey may result in the expansion of home range sizes reported in my study. This would likely result in larger patches of cone-bearing trees (larch and black spruce) needed by males. Also, due to the mixedwood boreal forest’s diverse landscape, the habitats studied are not representative of the entire mixedwood boreal forest. Recommendations suitable for this area may not be appropriate for other areas such as those dominated by older mixedwood stands.
Research Needs

Basic knowledge of some aspects of the natural history of weasels is unknown. To my knowledge, there is no literature describing maternal dens of short-tailed weasels and I was unable to determine the characteristics of maternal den sites. The majority of my research was conducted between March and December, hence, I did not examine the rest sites used by weasels during much of the winter when thermoregulation is most challenging for this species. As well, I was unable to describe habitat use and food habits for weasels during winter. I did not examine the use of habitat by weasels in an unharvested landscape. Information about the behaviour of weasels in an unharvested landscape would make responses of weasels to disturbance easier to assess.

I showed that weasels, especially females, used cutblocks, but I was unable to determine whether females were able to successfully reproduce in cutblocks. During my study, I caught only 1 lactating female. The low trapability of breeding females makes it difficult to address the reproductive success of females. Nevertheless, the reproductive success of females is important for assessing the viability of weasels populations in disturbed landscapes. Although I obtained results useful to forest managers, long-term studies are required. Because my study was only 1 year in duration and restricted to two seral stages (3-year-old cutblocks and late seral forest), I do not know how long or how well cutblocks function as habitat for weasels. Over time, the loss of habitat elements, such as downed wood and slash through decay and standing trees through windthrow, may reduce the suitability of cutblocks as habitat for weasels. Further research is required to assess the habitat relationships of short-tailed weasels in mixedwood boreal forests.
Literature Cited


King, C.M. 1983a. The relationships between beech (Nothofagus sp.) seedfall and populations of mice (Mus musculus), and the demographic and dietary responses of stoats (Mustela erminea), in three New Zealand forests. J. Anim. Ecol. 52:141-166.


