Ecology and summer/fall habitat selection of American marten in northern Idaho

Scott Dean Tomson

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Ecology and Summer/Fall Habitat

Selection of American Marten in Northern Idaho

By:

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B.A., DePauw University, 1988

Presented in partial fulfillment of the requirements for the degree of

Master of Science

The University of Montana

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Dean
I live-trapped, radio-collared, and radio-tracked 32 American martens (Martes americana) during 3 summer/fall seasons (1994-96) in the Cabinet Mountains of northern Idaho. Objectives were to: 1) evaluate habitat selection at the home range within study area, location within home range, and location within stand (microhabitat) spatial scales, 2) gain a better understanding of marten population characteristics, and 3) examine community interactions (especially with regard to prey species). Males were captured more commonly than females (26M, 12F). Martens were located using triangulation approximately 3 times weekly during daylight hours. Nineteen of 20 animals with sufficient locations to allow for home range and habitat selection analyses were adults (> 1 yr. old). Average minimum convex polygon (95% contour) home range for adult males was 1.56 km² (SD = 0.70, range = 0.54 - 3.00). Adult female average home range was 1.16 km² (SD = 0.83, range = 0.42 - 2.20). At the home range within study area and location within home range scales, martens preferred mature stands with average dbh ≥ 22.9 cm. I determined the significance of this preference for each year and for all years combined using compositional analysis methods. Significant preference (α ≤ 0.01) for the mature class over immature and seedling/sapling classes was most common at the home range within study area scale. At the microhabitat scale, I found martens selected for resting sites (n = 38) in areas with significantly more snags than non-used paired plots located at a random azimuth 50 m from the use plot center. Live trees and cavities in snags were the most frequently used resting sites. Cavity rest sites (n = 8) were exclusively in dead, large diameter, subalpine firs (Abies lasiocarpa).

The median age of the martens I captured was 1 year (range <1 - 7, n = 22). I documented a total of 13 mortalities not associated with capture and handling. Four martens were too decomposed to ascertain cause of death. Cranial or thoracic trauma, likely predator induced, was evident in 7 deaths and starvation was likely in at least 2 cases. Minimum densities of 0.33 marten/km² and 0.23 marten/km² were estimated for the study area during the 1995 and 1996 summer/fall seasons respectively.

Small mammal abundance and diversity were significantly higher in mature forests (avg. dbh ≥ 22.9 cm) than regenerating stands (avg. dbh ≤ 10.1 cm). Differences in available prey, in association with increased access to structures that provide shelter from weather and predators, may be reasons why martens in this population showed significant preference for mature stands.
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INTRODUCTION

The American marten (*Martes americana*), along with the wolverine (*Gulo gulo*), lynx (*Lynx lynx*), and fisher (*Martes pennanti*) comprise a group of species now commonly referred to as forest carnivores. Members of the group are priorities for research and conservation efforts because of their large area requirements, association with late successional forests, and the relative lack of information available for conservation planning (Ruggiero et al. 1994). My study, conducted in the Cabinet Mountains of northeastern Idaho, focused on the American marten.

Distribution of the marten in North America has been impacted by fur harvesting and habitat loss due to fire and logging (Dodds and Martell 1971, Koehler et al. 1975, Soutiere 1979). Historically, martens occurred from the tundra/taiga ecotone south to the northern Appalachians, upper Great Lake states and Rocky Mountains and from the Atlantic to the Pacific Ocean (Hagmeier 1956). The marten is absent from historic range in Illinois, Indiana, New Jersey, North Dakota, Ohio, Pennsylvania, and West Virginia (Clark et al. 1987, Thompson 1991). No dramatic declines in marten populations have been detected in the northern Rocky Mountains of the United States. In Idaho, martens currently occur in association with forested land in the southeast corner as well as north and east of the Snake River Valley (Leptich 1990). The species is not considered threatened or endangered and is managed as a furbearer by the state.

Forest Service compliance with the National Forest Management Act necessitates selection of Management Indicator Species (MIS) within planning areas. Monitoring the selected species allows managers to gauge impacts of management activities on forest communities. The marten was chosen as a MIS for old-growth habitat quality on many
Region 1 National Forests, including the Idaho Panhandle National Forest in north Idaho (USDA Forest Service 1987). Old-growth forest communities, especially those at lower elevations, in the northwestern United States have been substantially impacted by logging (Harris 1984). Thomas et al. (1993a, 1993b) suggest population viability of marten, lynx, and fisher to be at medium to high risk due to the reduction of old-growth in the Pacific Northwest. The current lack of information regarding these species restricts the ability of land managers to implement adequate conservation strategies. Few studies have addressed marten habitat use in the northern Rocky Mountains of the U.S., and fewer still have been conducted in humid continental forests such as those found in northern Idaho. The result is a paucity of information regarding marten habitat requirements in the forests of this region. My ultimate goal was to improve knowledge of specific aspects of marten ecology in northern Idaho. This knowledge may help to prevent future population declines of martens and other old-growth dependent species in the region.

Working for the Idaho Department of Fish and Game in cooperation with the U.S. Forest Service, I conducted a study of marten ecology on the Panhandle National Forest in northern Idaho. This study was initiated in 1994 by the Idaho Department of Fish and Game to: 1) evaluate marten summer/fall habitat selection at the home range within study area, location within home range, and location within stand (microhabitat) spatial scales, 2) gain a better understanding of marten population characteristics, and 3) examine community interactions (especially in regard to prey species). These objectives follow recommendations made in The Scientific Basis for Conserving Forest Carnivores (Ruggerio et al. 1994).
STUDY AREA

The study site (Fig. 1) was located on the Sandpoint Ranger District of the Idaho Panhandle National Forest in northern Idaho. Geographically, the area marks the western boundary of the Cabinet Mountains and falls within the Shining Mountains ecoprovince, described as a humid continental highland (Demarchi 1994). Elevation ranges from 640 to 2133m at the highest peak. Climate is subcontinental with cold winters and warm, dry summers. Annual precipitation at higher elevations, over ¾ of which falls as snow, approaches 203cm. Lower elevation forests receive approximately 76cm (USDA Forest Service 1987).

Seventy-four percent of the core area is composed of stands dominated by subalpine fir (Abies lasiocarpa) and Englemann spruce (Picea engelmannii) forests. These forests are typified by dense understory shrub communities of menziesia (Menziesia ferruginea), alder (Alnus sinuata), and huckleberry (Vaccinium spp.). Western red cedar (Thuja plicata) and hemlock (Tsuga heterophylla) stands cover 7% of the total and together Douglas-fir (Pseudotsuga menziesii), grand fir (Abies grandis), larch (Larix occidentalis), and white pine stands (Pinus monticola) occupy 15%. Only 1% of the region is natural meadows or rock. The mean slope for this area is 35%; the most common aspect is south although all aspects are represented fairly equally. Roughly 48% of this area is occupied by mature stands with an average diameter at breast height (dbh) ≥ 22.0cm. Intermediate stands averaging 12.0 to 21.9cm dbh comprise 28% of the area. Regenerating stands averaging 0 to 11.9cm dbh make up the remaining 23%.

Historically, martens were trapped in this area for their pelts. At the present, harvest
Fig 1. Map of study area, Trestle Peak, Idaho.
efforts are minimal to non-existent. I was not aware of any trapping activity in the area over the course of my fieldwork.

METHODS

Marten Capture

Martens were live-trapped over 4 periods during the course of this study. Most trapping occurred during late spring and early summers (June 1- August 15) of 1994 -96. Minimal trapping was conducted in late November and December 1994 and during September 1996 to retrieve collars. I trapped in a variety of habitats throughout the study area in an attempt to capture and mark as many animals within the area as possible. My goal was not to estimate density through mark recapture, thus, traps were not placed in a grid or along a transect. Effort varied across sites and undisturbed traps were usually moved after 5 days. Martens were captured in live traps (no. 105, Tomahawk Live Trap Co., Tomahawk, WI) baited with putrid chicken, deer meat, or sardines. Traps were placed near downed logs and along streams in cubbies constructed of loose bark and other vegetative matter. This procedure camouflaged the traps, reduced the possibility of bait being accessed from the side or rear of the trap, and provided the animal shade and protection from precipitation. When traps were set in the snow they were covered on 4 sides with waxed cardboard to provide insulation and protection from moisture. The majority of trapping was conducted in spruce/fir community types within 400 m of roads.

Traps were checked daily. A solution of ketamine hydrochloride (0.1 ml @ 100 mg/ml) and xylazine (0.05 ml @ 100 mg/ml) was administered intramuscularly with a hand-held syringe to immobilize the animals. Immobilized martens were weighed,
measured, sexed, and examined to determine overall physical condition. I determined age subjectively as adult or juvenile by sagittal crest development (Marshall 1951), body size, and tooth wear. One first upper premolar was extracted with a tooth elevator for later aging of cementum annuli (Matson and Matson 1993). Most animals were ear tagged (National Band and Tag Co., Newport, KY) prior to release and fitted with a 52 g radio collar (ATS Corp., Isanti, MN) adjusted to roughly 1.5 cm larger than neck circumference and at least 1 cm smaller than head circumference. Animals were then returned to the traps and released after full recovery from anesthesia. Average time from drug injection to release was 1 h.

Telemetry

Radio collared martens were located from the ground during the summer and fall using a hand held, three-element Yagi or directional ‘H’ antenna. Both triangulation and walk-in monitoring was conducted. Walk-in monitoring involved following the radio signal of a resting marten until the marten was observed or until close range triangulation could be conducted to locate the resting site of an unsighted marten. Aerial telemetry was employed only to locate martens that moved large distances or to pinpoint mortality signals. Relocations were separated by at least 12 h to ensure independence (Katnik et al. 1994). Animals were monitored at various time intervals over a 12 h (0800 - 2000) period to reduce daily activity pattern bias. A minimum of 3 azimuths from known locations within the study area were used in triangulations (Samuel and Fuller 1995). I attempted to obtain all azimuths within 1 h to minimize error caused by animal movement. In addition, azimuths were taken from locations that minimized distance between the transmitter and
receiver. I critically evaluated signal strength and correspondence of several azimuths to ensure that "bad" signals were discarded (White and Garrott 1990). Azimuths from strong, non-deflected signals were plotted in the field resulting in an approximation of the animal's location. Locations from weak, inconsistent signals were discarded. I plotted triangulation and walk-in locations on USGS 7.5 minute topographic maps and later added universal transverse mercator (UTM) coordinates, along with activity, date, and time information, to a GIS data base.

Size of error polygons increase with increasing distance between the receiver and transmitter and departure of tracking angles from ninety degrees (Kenward 1987). I conducted telemetry with consideration to these factors to avoid incorrect assumptions concerning macrohabitat use. In addition, I assessed error through field testing. Collars were hidden by a field assistant on the ground and in trees throughout the study area over a 1 month period. This design accounted for variability in topography, weather conditions, and rest site type. Collar locations were verified by GPS and plotted on USGS 7.5 minute topographic maps. I used triangulation methods identical to those used in locating martens to plot collar locations. The distance between these locations and actual locations were used to determine average telemetry error (mean = 150 m, S.D. = 71.2, n = 25).

I conducted walk-in telemetry on resting martens to gather specific habitat information. Martens to be "walked-in" on were chosen before telemetry was begun each day to eliminate observer bias regarding proximity to roads, topography, etc. Plots were taken only when the marten was seen or when a strong signal was received with the antenna and cable disconnected from the receiver. I found that the collar was within approximately 50
m when such a signal was obtained. When martens were unseen, close range triangulation was conducted to determine the location of the non-visible marten.

Home Range

I used walk-ins and triangulation locations to assess seasonal marten home range size during the snow-free season (June 1 - October 31) over three consecutive years (1994-96). The program Calhome (Baldwin et al. 1992) was used to plot 95% minimum convex polygon (MCP) ranges for martens during each study season. I determined the minimum number of points necessary to estimate range area by plotting range area against a number of points randomly selected from a marten's total locations (Fig. 2). Each subsample of points was randomly selected from the entire population of points. This procedure was repeated for a random sample of 4 martens (3M, 1F). The minimum number of locations was defined by the point on the curve where 3 additional points produced < 10% increase in range area (Odum and Kuenzler 1955). Correlation between number of locations and home range size was tested for each of these 4 martens using Spearman's Rho. Number of locations was positively correlated with home range size in all 4 cases. In addition, I created a scatter plot to assess the relationship between number of locations and home range size for all martens with greater than 12 locations (Fig. 3). Due to the limited number of martens with ≥ 18 locations, I reported average home range size for martens with adequate locations and yearly average home ranges for all martens with ≥ 12 locations. Home ranges of martens monitored for consecutive years were constructed for each year. In addition, I calculated overall home range size using all locations from all years.
Fig. 2. Results of randomly selected locations from 4 martens to determine adequate number of relocations necessary to assess home range size.

* Legend indicates martens used in test (3M, 1F)

** MCP - minimum convex polygon
Fig. 3. Scatter plot of correlation between number of relocations and home range size for martens in the Trestle Peak study area.

* $R^2 = 0.80$.

** MCP - minimum convex polygon
Habitat Assessment

To address marten microhabitat selection, I collected habitat data at marten rest sites and at paired random locations (following Jones, 1988) using a modified USFS stand exam technique (USDA Forest Service, 1985). Use plots were taken at: 1) areas where martens were observed visually; and 2) areas where walk-ins resulted in a rest site approximation by close range triangulation on an unsighted marten. Paired plots were located 50m at a random azimuth from the center of used plots. I chose this distance to restrict the analysis to a microhabitat scale yet ensure that data were not replicated within the plot pairs. The concentric, nested plot arrangement consisted of a plot center, a 7.5m radius fixed plot, and a variable plot. The variable plot was determined by a 20 basal area factor (BAF) measure taken from plot center. This procedure involved the use of a 20 BAF prism or a logger's tape and limiting distance chart. All trees more than 12.7cm dbh falling within the limiting distances were included in the plot. Categorical data on species, crown class, crown ratio, and tree class were recorded for all trees in the variable plot. Collection of these data followed USDA Forest Service stand examination procedures. A diameter tape was used to measure dbh to the nearest centimeter for all trees in the variable plot. In addition, ages and heights were determined for 1 tree in the plot within each of 3 diameter classes (12.0 - 21.9cm, 22.0 - 37.9cm and > 38.0cm) for each species present. An increment borer was used to extract a core from the tree at breast height. The rings were counted on this core to determine tree age. Tree heights were estimated with a clinometer.

At plot center the following data were recorded:

1) slope percent from clinometer reading,
2) aspect,
3) topographic site (ridge, valley, etc.),
4) canopy cover from 1 spherical densiometer reading (Strickler 1959).

Data were collected in the 7.5m radius circular plot on the basis of:
1) habitat type (Cooper et al. 1987),
2) number of snags and snag class (Gale 1973, Maser et al. 1979).
3) site characteristics,
   a. even aged/uneven aged,
   b. interior forest/forest edge (within plot)/opening/riparian.

Coarse woody debris was measured along an 8m transect defined by a random azimuth taken from plot center. The diameter of all logs on the ground greater than 12.7cm diameter were measured at the intercept and classified by decay class (Maser et al. 1979).

All habitat data were collected in each plot pair during the season in which the marten was located at the use plot for that pair.

GIS Database

I developed a GIS database using Pamap version 4.2 (Essential Planning Systems, Canada) to facilitate analysis of marten habitat selection at home range and landscape scales. Approximately 95% of all marten locations I recorded fell within the boundaries of the Trestle Peak, ID USGS 7.5 minute quadrangle map. I restricted my analyses to this quadrangle due to GIS limitations and the fact that I would lose virtually no data. A digital timber stand polygon map and associated stand data for the Trestle Peak quadrangle, created on the Sandpoint Ranger District of the Idaho Panhandle National Forest, was imported into the GIS. This database provided timber stand information such as average dbh, major species, and stand basal area. These data were acquired through on
the ground data collection or regression analyses based on the data collected. All data were collected and analyzed by the USDA Forest Service.

The importation of a USGS digital elevation model (DEM) allowed access to data on slope, aspect, and elevation. Road and hydrologic coverages were obtained from the USFS. I imported all marten UTM point locations into the GIS in ASCII format. In addition, marten 95% MCP home range polygons were imported.

Statistical Analyses

Selection for Diameter Classes

I used a compositional analysis (Aitchison 1986) to test 2 hypotheses regarding different scales of marten habitat selection in relation to average stand dbh. Compositional analysis of habitat from radio tracking data (Aebischer and Robertson 1992, Aebischer et al. 1993) was developed in response to a suite of problems associated with earlier techniques for assessing habitat use. This method treats the individual animal rather than radio location as the sampling unit, thereby reducing problems associated with non-independence of animal locations and allowing for separation of within and between-animal variation. Furthermore, relative habitat use can be evaluated from most to least and tested to determine statistically significant differences between habitats (Aebischer et al. 1993).

Several approaches have been used to define study area boundaries (areas of available habitat) in studies of this nature because determining availability often involves arbitrary decisions (Johnson 1980, Porter and Church 1987). I chose to use a modification of a 100% MCP around marten (n = 15) locations for all years (Fig. 4). Three martens with
Fig. 4. Study area boundary as defined by marten 100% minimum convex polygon home ranges 1994-96.
* Border represents Trestle Peak 7.5 minute quadrangle
** 3 home ranges were not included in study area
sufficient location data were excluded from this grouping, and from any habitat analyses, because their ranges were isolated from the others and trapping was not conducted in the area separating these martens. Including these animals would have greatly expanded the study area and induced potential bias to the compositional analysis. In digitizing the study area boundary, I was constrained by the extent of my map to the north and east. To the south and west, I modified the 100% MCP to maintain a consistent buffer of approximately 300m around outermost marten locations. By design, this delineation provided an area of potential use around the locations but excluded large areas in which marten may not have been. My objective was to ensure biological reality while reducing the risk of both type I and type II errors when evaluating habitat preference.

I used the variable average dbh from the USFS timber database to categorize stands in the study area into 1 of 3 size categories. I assigned stands averaging from 0 to 11.9cm dbh to Class 1 (small diameter). Class 2 stands (intermediate diameter) ranged from 12.0 to 21.9cm dbh. Stands averaging 22.0cm dbh and greater were considered Class 3 (large diameter). Within the last 15 years, stand exams or walk through exams have occurred in 55% of the stands in the study area. Information generated from regression analysis based on actual data accounted for an additional 23% of the total. The remaining stands were classified through aerial photo interpretation by the USDA Forest Service. I verified accuracy of stand classification using aerial photos, data from walk-in locations, or ocular inspection for all stands in the study area.

One of my objectives was to determine whether martens selected diameter class when establishing home ranges within the study area. I determined the proportion of each diameter class in the overall study area by overlaying GIS coverages for stand polygons
and the study area polygon. In the same manner, I determined the proportion of each diameter class within the home range of each marten in the study area. All martens with 12 or more locations were included in this analysis (n = 15). Twelve locations provided a suitable measure of proportional habitat utilization. Aebischer and Robertson (1992) stressed maximizing the number of tagged animals to adequately represent the population. Twelve locations as a minimum allowed me to increase the number of animals included in this analysis. I used compositional analysis methodology (see Aebischer and Robertson 1992 and Aebischer et al. 1993 for a complete review) to score the habitat classes in relation to preference and to determine if differences in preference between classes were significant. This test was conducted for each of the 3 years and for all years combined.

I evaluated use of stands within the home range in respect to dbh class in a similar manner. Proportions of marten home ranges within each dbh class were compared to proportions of individual marten locations within each dbh class. Again, dbh classes were ranked in relation to use and tests for significance between classes were run. I conducted tests for the 3 years independently and for all years. Means of all locations and home range proportions were used for martens with greater than 1 year of locations in the multi-annual analysis.

To address telemetry error, I ran separate tests using only locations that were further than my estimated mean telemetry error from another dbh class. I determined distances of each marten location to the 3 dbh classes by overlaying point and surface coverages in the GIS. Due to high, localized fragmentation within the study area, some martens had few points further than 150m from another dbh class. For these tests I included only animals with > 40% of total locations greater than 150m from another diameter class.
I used a t test for 2 independent samples to compare percentages of small diameter habitat within home ranges of martens killed by predators (n = 3) and martens known to be surviving at the termination of the study (n = 5). Only martens with greater than 12 locations were used in the analysis. The objective of this analysis was to determine whether predated martens had home ranges comprised of significantly more small diameter habitat.

Selection for Old Growth

A chi-square test for homogeneity was used to determine if martens preferred stands classified as old growth according to USDA Forest Service criteria (Appendix). I tested all marten locations within the study area (n = 477) against random points generated for the study area (n = 350).

Selection for Roads, Streams, Slope and Aspect

Home Range within Study Area Scale

I used Mann-Whitney U tests to determine if selection of home ranges was significant in relation to distance to roads and streams and preference for slope and aspect. I used this nonparametric technique due to the non-normality and variance characteristics of these data. Random points (n=350) falling within the study area were generated and imported into a GIS coverage (Fig. 5). Distances to roads and streams and slope and aspect data for all points were generated from GIS coverages. I did not distinguish
Fig. 5. Random points generated within study area boundary for analytical purposes.
* Border represents Trestle Peak 7.5 minute quadrangle
between road types and considered only perennial streams. I ran a Mann-Whitney U test for 2 independent samples to test for differences between all random locations on the study area and random locations within individual marten home ranges (Fig. 6) for all 4 variables. Martens with locations during more than 1 year were tested for each year. A Bonferroni correction was made due to the repetitive nature of these tests. The resultant significance level was 0.002 (\( \alpha = 0.05/22 \) tests).

**Locations within Home Range Scale**

I generated 20 random points within each marten home range to test against known marten locations. I used 20 random points because the average number of locations for all martens was approximately 20. The random points were exported into a GIS coverage and a database containing attribute information was created. A Mann-Whitney U test for 2 independent samples was used to test for differences between random and actual locations within each marten’s home ranges across the 4 variables. I did not pool locations for martens monitored for more than 1 year in this test. This approach allowed me to evaluate selection by each marten on a year to year basis. I used a Bonferroni corrected significance level of 0.002 to evaluate the data.

I performed an additional test on the stream data due to the results of the Mann-Whitney tests. I calculated a mean value for distance to stream for random points and actual locations for each marten during each year. The difference of each of these means was taken and a mean and standard deviation of these differences was calculated. I constructed a 95% and 99% confidence interval around these means to test for a
Fig. 6. All actual marten locations 1994-96, Trestle Peak Quadrangle, Idaho
* Border represents Trestle Peak 7.5 minute quadrangle
significant difference between the 2 populations of points.

**Microhabitat Selection**

I used a 2 stage random sampling technique to examine marten microhabitat selection. Radio collared martens in the study area represented a random sample from the population of martens. Random walk-in locations at rest sites of tagged martens comprised the second stage of random samples. By this design, habitat data were collected from a random subset of rest sites from a random subset of martens within the population. I determined the difference between the paired and actual plot values for each variable for all marten locations and calculated a mean and standard deviation of the differences for each variable. The resulting mean was tested to determine if there was a significant difference at $\alpha = 0.05$ between the plot values. I compared plots in respect to: total trees, total live trees, total dead trees, canopy cover, number of snags, number of dead tops, dbh (4 classes), and coarse woody debris (3 size classes). I tested for correlation among these variables using Spearman’s rank correlation coefficient.

**Survival**

I used the program Micromort (Heisey 1992) to calculate survival estimates for the population of martens I studied. I calculated number of radio days for each marten and summed these days to get total radio days for use in the analysis. Martens that shed collars or went off the air were considered censures and only days monitored were used. In cases in which I recovered a collar after an absence from the field, (winter non-monitoring period) I assumed the marten survived for $\frac{1}{2}$ the days between the last day
located and the time the collar was recovered.

I performed 2 separate analyses in which I calculated annual survival and mortality percentages by year and over the 3 year study duration. In the first analysis, I considered only martens I found dead as mortalities and classed these as predations or unknown non-human caused. Censured martens were not considered mortalities. In the second analysis, I assumed that all censured martens were mortalities. I grouped censures and unknown non-human caused mortalities and considered predations separately.

Small Mammal Trapping

I used snap trap grids to evaluate marten selection for habitats with higher abundance of small mammals. Grids were laid out in paired arrangements. Mature stands and adjacent regenerating stands (trees < 1m in height) within known marten home ranges comprised the pairs. This design allowed me to address questions concerning differences in small mammal distribution and abundance between mature forests and early successional sites in the same general area. I conducted trapping at 2 locations in 1995 and 1996 during June, July, and August. The grid layout of these areas was consistent during each year. In 1996 an additional area of paired grids was trapped. Traps were separated by 5 m in grids of 25 traps (5x5). Trapping was conducted for three consecutive nights. Traps were checked and baited every 24 hours. The species of each animal captured was determined and recorded.

I conducted a test for a significant difference in overall abundance of small mammals between mature and regenerating sites. I determined the difference in total captures for all species between each pair of forest types during each trapping period at each of the 3
locations and calculated a mean difference, standard deviation and 95% confidence interval for all pairs. Mature and regenerating stands at the 3 locations comprised the pairs. Total numbers of captures over a 3 night period were used in the analysis. I conducted no tests for variation between nights.

Paired t-tests were conducted to test for differences in abundance of deer mice (*Peromyscus maniculatus*), red-backed voles (*Clethrionomys gapperi*), and western jumping mice (*Zapus princeps*) at 3 paired (mature and regenerating) sites. A separate test for each of the 3 species was conducted. I used the total number of captures per species at each location for each 3 night period. I did not run tests to compare variation between nights.

**RESULTS**

**Study Animals and Trapping**

A total of 38 (26M, 12F) martens were captured in 1712 trap nights (Table 1). Many of these individuals were captured more than once. Overall capture rate (recaptures included) was 4.3 martens/100 trap nights. The success rate for new individuals captured varied by year. During the 1994 summer, I documented 2.4 new captures/100 nights. Late fall success was similar, with 2.4 new captures/100 nights. In the summer of 1995, success dropped to 1.2 new captures/100 nights. Conversely, the 1996 summer showed a marked increase with 5 new captures/100 trap nights.

Five mortalities were associated with the capture or handling of study animals. All but 1 of these occurred during the 1994 field season. M45 was captured 4 times during the summer of 1994. Captures 3 and 4 occurred on consecutive days. On the fourth capture
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Table 1. Capture history of all martens trapped over the study duration 1994-96.

* Mortality* indicates natural mortality of unknown cause

** Marten ID: M-male, F-female; numbers indicate radio frequency and capture year

*** 6.7% Capture mortality rate = (5/73) x 100%
this marten was unresponsive in the trap and later died. F3738 was captured once during
the course of the study and did not recover from the standard injection of
ketamine/xylazine. This marten was 5 years old. Based on age, tooth wear, and body
weight this marten apparently was in a weakened condition prior to capture. M6794 was
initially captured and collared in July 1994. Upon his second capture in November 1994 he
was given the standard injection of ketamine/xylazine. The intent was to replace his ear
tags and remove the radio collar for the winter. Although this animal initially showed
signs of normal recovery, he did not fully regain consciousness and died 4 h after capture.
This animal was approximately 2½ years old at time of death. F6194 was initially
was recaptured and fitted with a new collar. Her condition seemed good at that time, but
she was found dead in a trap on June 26, 1995. The cause of death was apparently trap
stress. The cementum annuli-determined age of this marten was approximately 2 years.
M8594 was collared in late July 1994. He was found dead in late October 1994
presumably due to an infection caused by a poorly fitted collar. This animal was collared
as a juvenile and was less than 1 year old at time of death.

Non-target captures were infrequent. Red squirrels (*Tamiasciurus hudsonicus*, n = 7),
Columbian ground squirrels (*Spermophilus columbianus*, n = 2), a northern flying squirrel,
(*Glaucomys sabrinus*), a bushy-tailed woodrat (*Neotoma cinerea*), and a subadult female
fisher accounted for all such captures. One of the red squirrels was partially consumed
while in the trap. Two other red squirrels and the flying squirrel did not survive capture.
The surviving small mammals were released without handling. The fisher was
immobilized, sexed, measured, ear tagged, and released upon recovery.
Survival

Thirteen mortalities (5F, 8M) were documented during the study. At least 7 of these mortalities involved predation, but the carcass was fed upon in only 2 cases. Four (2M, 2F) of the martens killed by predators were known to occupy established territories and all 7 were ≥1 and ≤3 years of age according to cementum analysis.

Of the 13 known, non-human caused mortalities, 8 took place after June 1996. Five (3M, 2F) of 9 animals captured in 1996 were killed or died of starvation or disease in the summer of 1996. I assume 2 males (M6196, M6496) were dispersers because they moved long distances (approximately 10 km from capture sites) during the 2 weeks they were monitored. Both of these martens were found dead on the ground. I suspect starvation or disease in the deaths of these animals because they were found huddled in areas of cover. Furthermore, their bodies were not contorted and they did not appear to have undergone a struggle. The bodies were too decomposed for necropsy.

M9196 was captured 3 times in less than a month. I received a mortality signal approximately 10 days after his final capture. The marten had been located and was active approximately 24 hours earlier. I found the animal in an open clearcut the following day; he appeared to have undergone a struggle and his body was contorted and the neck was likely broken. Hemorrhaging had occurred in the thoracic area but the body was not fed upon. F5596 and F3596 were recovered less than 24 hours after their mortality signals were received. Necropsies performed at Washington State University (WSU) indicated cranial and thoracic trauma, most likely induced by predation, were the causes of death in these 2 instances. Neither of these martens was fed upon. M7994 and M7095 were captured and collared in 1994 and 1995 respectively. Both animals were found dead less
than 24 hours after their mortality signals were picked up in July 1996. M7994 was approximately 20km from the location of his original capture. His body was mostly consumed, making necropsy impossible. M7095 was found within his usual home range. The body was not fed upon but was in a contorted position. Hemorrhaging and puncture wounds were indicative of predation (WSU necropsy). F6795 was captured and collared in 1995. Her body was recovered less than 24 hours after receiving a mortality signal in August 1996. The body cavity of this marten was fed upon by a relatively small animal. Necropsy (WSU) showed hemorrhaging and puncture wounds in the thorax. Predation is the likely cause of death in this case. It is possible that M5596 was feeding on this animal; he was located within 300m of the carcass just prior to recovery. The remains of F7394, M7694 and M9794 were recovered during the summer of 1994. Each of these martens had puncture marks in the skull and only M9794 was consumed. Necropsy was not possible due to the condition of the carcasses however, predation is likely in each of these cases as evidenced by the bone breakage.

Overall, marten's skulls were punctured or crushed in 6 predation episodes. The punctures in 2 skulls matched the intercanine width of a coyote. The remaining skulls were destroyed accidentally after necropsy at the WSU lab, preventing this determination. The facts that coyotes were abundant in the study area, the methods of kill as described by necropsy were similar in all instances, and that punctures in 2 skulls match coyote canines strongly suggest that coyotes were responsible for the predations I documented.
Using a Micromort survival analysis in which censured animals were not considered mortalities, I predicted an overall (3 year average) survival rate of 55.5% (95% C. I. Lower = 39.7%, Upper= 77.4%) for the population of martens I studied. The overall predation rate was 29.6% (L = 12.6%, U = 46.8%) and the overall rate of other mortality (non-human caused natural) was 14.9% (L = 1.4%, U = 28.2%). Individual years varied dramatically in regard to survival. In 1994, I estimated annual survival at 50.0% (L = 43.6%, U = 98.6%) with mortality due to predation at 37.5% (L = 25.3%, U = 70.7%) and other mortality at 12.5% (L = 0%, U = 35.4%). In 1995, survival was 100% with no mortality. I estimated 1996 survival at 24.3% (L = 9.1%, U = 64.8%) with predation mortality accounting for an estimated 47.3% (L = 17.9%, U = 76.7%) and other mortality at 28.4% (L = 1.5%, U = 55.3%).

In a separate Micromort analysis, I treated all censure as mortality. Overall annual survival based on these criteria was estimated at 39.3% (L = 25.8%, U = 59.8%). I estimated annual predation caused mortality to be 25.6% (L = 10.4%, U = 40.7%) with other mortality (excluding capture mortality) accounting for 35.1% (L = 18.6%, U = 51.7%). As in the previous analysis, yearly estimates varied. In 1994, survival was estimated at 50.0% (L = 19.6%, U = 89.8%) with predation caused mortality at 34.8% (L =3.4%, U = 66.2%) and other mortality at 23.2% (L = 0%, U= 51.2%). The 1995 survival estimate was highest at 71.5% (L = 48.9%, U = 100%). No mortalities were associated with predation and other mortality was estimated to be 28.5% (L = 1.4%, U = 55.7%). In 1996, the survival estimate dropped to 28.5% (L = 4.5%, U = 45.1%). Predation caused mortality was an estimated 40.0% (L = 12.7, U = 65.3) and other mortality was estimated to be 46.8% (L = 20.0%, U = 73.5%).
No significant difference was detected ($\alpha = 0.05$) between percentages of small diameter habitat within home ranges of martens killed by predators and surviving martens. This analysis must be interpreted with caution, however, as sample sizes were very small.

**Home Range**

At least 12 locations were obtained during the summer of 1994 on 9 martens (5M, 4F) resulting in a total of 160 locations (Table 2). Average home range size for adult male martens as estimated by the minimum convex polygon (MCP) 95% contour was 1.8km$^2$ ($n = 5$, range = 0.5 - 3.0km$^2$). Juvenile M8594 had a 95% MCP of 1.1km$^2$. Adult female home range (95% MCP) was 1.30km$^2$ ($n = 4$, range = 0.4 - 2.4km$^2$). In 1995, a total of 218 relocations were recorded on 9 martens (8M, 1F) including 2 martens monitored in 1994 (M5294, M8894). Each animal had at least 20 relocations during this period. Average home range size for males in 1995 was 1.8km$^2$. F6795 had a 2.5km$^2$ home range during 1995. The summer of 1996 resulted in a total of 125 relocations for 9 martens (7M, 2F). Of these animals, 4 (M3795, M3995, M7695 and F6795) were also monitored in 1995 and 1 (M5294) was monitored in 1994 and 1995. Twelve or more relocations were recorded for each of these individuals. The average home range for males in 1996 was 1.9km$^2$ while the 2 monitored females had an average home range size of 0.8km$^2$.

Eighteen locations were determined to be the minimum number needed to accurately assess home range size (see Fig. 3). (Note: I report animals with > 12 in the previous paragraph due to the small number of martens with sufficient locations.) MCP 95% home ranges of the 9 male martens with at least 18 locations averaged 1.64km$^2$ (SD = 0.8, range = 0.5 - 3.0). Only 2 females had at least 18 locations during the course of a season. The
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<tr>
<td>M7095</td>
<td>1995</td>
<td>20</td>
<td>71 ha</td>
</tr>
<tr>
<td>M7396</td>
<td>1996</td>
<td>12</td>
<td>311 ha</td>
</tr>
<tr>
<td>M7694</td>
<td>1994</td>
<td>&lt;5</td>
<td></td>
</tr>
<tr>
<td>M7695</td>
<td>1995</td>
<td>20</td>
<td>144 ha</td>
</tr>
<tr>
<td>M7695</td>
<td>1996</td>
<td>14</td>
<td>155 ha</td>
</tr>
<tr>
<td>M7994</td>
<td>1994</td>
<td>&lt;5</td>
<td></td>
</tr>
<tr>
<td>M8594</td>
<td>1994</td>
<td>20</td>
<td>223 ha</td>
</tr>
<tr>
<td>M8894</td>
<td>1994</td>
<td>16</td>
<td>164 ha</td>
</tr>
<tr>
<td>M8894</td>
<td>1995</td>
<td>28</td>
<td>418 ha</td>
</tr>
<tr>
<td>M89</td>
<td>1994</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>M9194</td>
<td>1994</td>
<td>12</td>
<td>108 ha</td>
</tr>
<tr>
<td>M9196</td>
<td>1996</td>
<td>&lt;5</td>
<td></td>
</tr>
<tr>
<td>M9794</td>
<td>1994</td>
<td>&lt;5</td>
<td></td>
</tr>
<tr>
<td>M9795</td>
<td>1995</td>
<td>30</td>
<td>294 ha</td>
</tr>
<tr>
<td>M9796</td>
<td>1996</td>
<td>14</td>
<td>105 ha</td>
</tr>
</tbody>
</table>

Table 2. Number of locations and home range size of all martens monitored 1994-96.
average 95% MCP home range of these females was 1.8km² (SD = 0.63, range = 1.30-2.2). No significant difference (α = 0.05) in home range size was detected between males and females with at least 18 locations or between males and females with ≥ 12 locations.

I documented changes in location of home ranges for martens 2 monitored for more than 1 season. In each of these instances, I suspect shifts in home range are related to the deaths of neighboring males. M5294 showed a dramatic shift in his range during the 1996 season. The “new” home range encompassed large parts of the previous home ranges of M7095 and M3195 (Figures 7a, 7b). Both of these males died earlier in 1996. In 1995, M8894 expanded his home range to encompass a large part of the home range of M6794. This male died in November 1994.

Intersexual home ranges were not exclusive among this population of martens. Most female home ranges were used by at least 1 male during the periods of monitoring. On several instances, as with M9795 and F6795, a male and female were located near each other. This proximity was documented in October and November, well past the breeding season.

Home ranges of male martens monitored during this study show fairly definite boundaries in most cases (Figs. 8 and 9). However, the home range overlap of juvenile M8594 and adult M5294 in 1994 was substantial (Fig. 9). This suggests that adult male territoriality may be reduced toward juvenile males. Furthermore, males in the eastern section of the study area exhibited overlapping ranges in 1995 (Fig. 8) and 1996.
Fig. 7a. M5294 95% MCP home ranges, Trestle Peak Quadrangle, ID 1994-96.

Fig. 7b. 1996 home range of M5294 in relation to previous home ranges of M3195 and M7095.
Fig. 8. Home ranges of all martens in 1995. Note overlap of M9795 and F6795 and of M3795 and M7695.

Fig. 9. Home ranges of all martens in 1994. Note overlap of M5294 and JM8594 (juvenile) and of M6794 and F6494.

*In Fig. 8 and Fig. 9 black represents small diameter class; green represents intermediate diameter class; blue-green represents large diameter class.
Density

In 1995, 10 collared martens were known residents of the study area. Male home ranges were tightly spaced. This spacing suggests that all males in this area were collared. The possibility exists that 1 or more females in this area were not captured. At any rate, I estimated the minimal density for this area at 0.3 marten/km$^2$ in 1995.

During the 1996 summer, 15 collared martens occupied the study area for a short time. Dispersal and mortality reduced the number of collared individuals within this area to 7 by mid-August. The minimum density of resident adult martens for the study area during 1996 m was 0.2 marten/km$^2$.

Age

Over the course of this study, the ages (time of capture) of 22 martens were determined. Nineteen of these martens were classified as between 1 and 3 years old (Table 2). The remaining animals were classed as a juvenile, a 5 year old, and a 7 year old. The median age of martens captured was 1 year (range $<$1 - 7, $n = 22$). This information, in association with mortality data, provides evidence that few martens in this population survive for more than 3 years.

Habitat Use

I evaluated habitat selection at 2 spatial scales using compositional analysis methodology. The following 2 sections outline the results of these analyses. I report the number of individuals that exhibited the highest preference for each diameter class as well as the overall preference of the population of martens during each season and overall. The
significance values pertain to the habitat preference of the population of martens evaluated over a given period. All cases in which one habitat is said to be preferred over another are not significant, thus the information regarding preference where no significance was detected must be interpreted accordingly. For ease of interpretation I will refer to the three diameter classes as large (≥22.0cm dbh), intermediate (12.0 - 21.9cm dbh), and small (0 - 11.9cm dbh).

Locations from triangulation on strong, non-deflected signals were used in this analysis. I was able to acquire signals of this type approximately 90% of the time on the martens I monitored. Thus, it was not necessary to throw out a large number of locations and I do not feel my results are biased due to many instances in which I could not get a good location on a marten. In addition, this analysis is based on resting and active locations. Resting locations comprise 53% of the total with active and intermittently resting and active locations accounting for 25% and 23% respectively.

**Home Range within Study Area Scale**

Habitat composed of large diameter trees was preferred most in relation to the other 2 habitat classes by 9 of the 15 (11M, 4F) martens included in the analysis of home range selection within the study area across all years. Small and intermediate habitat each ranked the highest in terms of preference in 3 cases. Evaluation of all martens over the 3 year period showed the large diameter class to be most preferred followed by intermediate and small. No significant difference in preference between intermediate and small classes was detected at α ≤ 0.05. I use tables 3a, 3b, 3c, and 3d to illustrate the sequential process of the compositional analysis methods.
Table 3a. Percentage of 3 average stand diameter classes within the MCP (minimum convex polygon) home range of M3195 and within the study area. Calculation of the difference between logratios is demonstrated using the Small category as the denominator; i.e. ln(Intermed MCP/Small MCP).

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Intermed</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCP Area%</td>
<td>1</td>
<td>30</td>
<td>69</td>
</tr>
<tr>
<td>Study Area%</td>
<td>27</td>
<td>28</td>
<td>45</td>
</tr>
<tr>
<td>Logratios MCP</td>
<td>3.40</td>
<td>4.26</td>
<td></td>
</tr>
<tr>
<td>Logratios Total</td>
<td>0.04</td>
<td>0.51</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>3.36</td>
<td>3.75</td>
<td></td>
</tr>
</tbody>
</table>

Table 3b. Logratio differences between home range and study area diameter class compositions for M3195. Values correspond with row while the columns represent the denominator used in the comparison. Classes are ranked based on the sign value (converted to 0 or 1). The row with the most ones represents the most preferred habitat. This ranking procedure was repeated for all martens included in the analysis.

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Intermed</th>
<th>Large</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>-3.36</td>
<td>-3.75</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Intermed</td>
<td>3.36</td>
<td>-0.38</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Large</td>
<td>3.75</td>
<td>0.38</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

* Indicates significantly higher preference for row habitat over column habitat. $\alpha \leq 0.05$

** Indicates significantly lower preference for row habitat over column habitat
Table 3c. Mean values of logratio differences for all martens included in the analysis. Confidence intervals are constructed to test if logratio differences are significantly different from 0. Significant values are in bold.
(S = small; I = intermediate; L = large)

<table>
<thead>
<tr>
<th></th>
<th>L/S</th>
<th>S/I</th>
<th>L/I</th>
<th>S/L</th>
<th>I/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.32</td>
<td>-0.32</td>
<td>0.93</td>
<td>-1.25</td>
<td>-0.93</td>
</tr>
<tr>
<td>StdDev</td>
<td>1.80</td>
<td>1.80</td>
<td>1.36</td>
<td>1.48</td>
<td>1.36</td>
</tr>
<tr>
<td>0.05 C.I.</td>
<td>0.75</td>
<td><strong>0.62</strong></td>
<td>0.75</td>
<td><strong>0.57</strong></td>
<td><strong>0.62</strong></td>
</tr>
<tr>
<td>0.01 C.I.</td>
<td>0.99</td>
<td><strong>0.81</strong></td>
<td>0.99</td>
<td><strong>0.75</strong></td>
<td><strong>0.81</strong></td>
</tr>
</tbody>
</table>

Table 3d. Summary of compositional analysis of home range within study area habitat preference for all martens (n = 15) 1994-96.
*Indicates significantly higher preference for row habitat over column habitat.
**Indicates significantly lower preference for row habitat over column habitat.

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Intermed</th>
<th>Large</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>-0.32</td>
<td>-1.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermed</td>
<td>0.32</td>
<td>-0.93</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Large</td>
<td>1.25</td>
<td>0.93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>0</td>
<td>0**</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Intermed</td>
<td>1</td>
<td>0**</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Large</td>
<td>1*</td>
<td>1*</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>
In 1994, 6 martens (5M, 1F) were included in the analysis. Three of these martens showed the highest preference for large diameter stands. The intermediate diameter class was most preferred by the remaining 3 individuals. Results for all 6 martens from 1994 showed the large diameter class to be most preferred followed by the intermediate and small classes, respectively. The large and intermediate classes showed a significantly higher preference than the small class at $\alpha \leq 0.05$. No difference in preference between the large and intermediate class was detected at this level of significance.

Five of 9 martens (8M, 1F) monitored in 1995 showed the highest preference for large diameter habitat. The small class was ranked highest for 3 individuals and intermediate was most preferred in 1 case. Across all martens, large diameter habitat was most preferred and small diameter least preferred. The large diameter class showed a significantly higher preference than the intermediate class. When compared to the smallest diameter class, preference for the large class was significantly greater. No difference in preference between small and intermediate classes was detected at the 0.05 level.

During the 1996 monitoring period, 5 of 7 martens (5M, 2F) preferred the large diameter class most. The other 2 classes were most preferred in 1 case each. Ranking of classes across individuals indicated the highest preference for large diameter followed by the small, then intermediate classes respectively. The largest class was significantly different from the other 2 classes at $\alpha < 0.01$. No significant difference between small and intermediate classes was shown at the 0.05 level.

**Locations within Home Range Scale**

Locations within home ranges for all 15 martens across all years included 7 cases in
which large diameter habitat was the most preferred. The intermediate class was highest in preference ranking for 6 individuals. Two martens preferred the small class over the other 2 classes. Across all martens, large diameter had the highest ranking and small diameter the least. Large diameter habitat was significantly higher in preference than small diameter ($\alpha \leq 0.01$). No significant difference between large and intermediate or between intermediate and small was detected at $\alpha \leq 0.05$.

The large and intermediate classes had the highest preferences for 3 and 2 martens, respectively, in 1994. Overall, large diameter was most preferred followed in order by small and intermediate. No significant difference in preference between any of the classes was detected.

During the 1995 monitoring period, intermediate and large diameter classes each ranked highest for 4 martens. The small class received the highest ranking in 1 case. Again large diameter was ranked highest overall with intermediate second and small third. The large diameter class ranked significantly higher than the small class ($\alpha \leq 0.05$). No significant difference was shown between large and intermediate classes or between intermediate and small.

The intermediate class ranked highest for 3 of 7 martens monitored in 1996. Two martens showed the highest preference for each of the remaining 2 classes. Large diameter habitat ranked highest overall followed by intermediate and small. No significant difference was shown between any classes.

Seven martens (5M, 2F) had a sufficient number of locations >150 m from another dbh class to warrant analysis. Tests including only these points showed all 7 martens preferred the large diameter class over the other 2 classes. For all individuals combined,
large diameter ranked highest and small diameter lowest. Preference for large diameter habitat in relation to the other classes was significant at $\alpha \leq 0.01$. No difference was detected between classes intermediate and small.

**Selection for Old Growth**

I found marten use of old growth to be significantly greater than random ($\chi^2 = 40.4$, df $= 1$, $\alpha \leq 0.01$). Approximately 42% of all marten locations occurred in stands classified as old growth according to USDA Forest Service criteria whereas only 16% of the overall study area was considered old growth by the same classification. This classification is based on factors such as stand age, tree size, number of large trees per acre and decadence (number of snags, down woody material and dead tops). The majority (57%) of all locations occurring in old growth involved resting martens. The remainders were either active (23%) or intermittently resting and active (20%). These findings are similar to all locations of which 53% were resting episodes, with active and intermittent activities comprising 25% and 22%, respectively.

**Other Stand Scale Habitat Selection**

I documented 28 (6% of total locations) instances in which my triangulation placed martens in non-forested openings. One individual (M9795) accounted for 25% of these locations. In all 28 cases, martens were $\leq 160$ m from a forested stand (mean = 66 m, range 8 - 160 m). All but 2 of the nearest stands were large diameter class and the remainders were intermediate diameter class.

My study area was primarily comprised of subalpine fir and spruce stands (74%).
Although I captured martens in lower elevation areas dominated by cedar and hemlock, my analyses of habitat selection pertain primarily to spruce/subalpine fir forests. In total, 368 of 478 locations (77%) fell in stands in which subalpine fir was the major species. Western hemlock stands accounted for 36 locations (8%). Although locations occurred in cedar, Douglas-fir, grand fir, larch, spruce and white pine stands, these types accounted for < 4% of total locations.

**Streams, Roads, Slope and Aspect**

**Home Range Scale**

I detected no cases in which a marten’s use of aspect or slope at the home range scale differed significantly from random point values (Mann-Whitney U test, Bonferroni corrected $\alpha \leq 0.002$). Two martens did exhibit significant preference for gentler slopes than expected at $\alpha \leq 0.05$. At $\alpha \leq 0.05$ actual distance to road (ADR) was significantly greater than random distance to road (RDR) for marten M7095. Conversely, ADR was significantly less than RDR for M7695. No martens showed significant non-random use in relation to road distance at the Bonferroni corrected $\alpha$ level.

Five of the 22 tests comparing individual marten locations to random points within each respective marten’s home range indicated a significant difference in distance to stream. In each of these instances, actual distance was significantly less than random distance at $\alpha \leq 0.05$. At the Bonferroni corrected $\alpha$ level, no significance was shown for this variable. In a separate test involving differences of actual and random means (see Methods), marten locations were significantly closer to streams than random points ($\alpha \leq 0.01, n = 22$).
Study Area Scale

Comparison of random locations within individual home ranges to all random points within the study area showed a significant difference between used and available slope values for 4 martens ($\alpha \leq 0.05$, n=22). No significance was detected at the Bonferroni corrected confidence level.

A significant difference in distance to road was detected in 13 cases where random locations within marten home ranges were tested against random locations within the study area ($\alpha \leq 0.05$, n = 22). Three martens exhibited use significantly different from random for each of 2 years. Overall, 7 martens had locations significantly closer to roads than expected by random chance at $\alpha \leq 0.05$. Four cases were significantly closer to roads than expected at the Bonferroni corrected significance level. The remaining 3 animals showed use of areas within the study area significantly further from roads than expected. No home ranges were significantly further from roads than expected at the corrected significance level.

In tests comparing random locations within marten home ranges to random locations within the study area, a significant difference in relation to distance to stream ($\alpha \leq 0.05$, n = 22) was found for 8 martens in 10 total instances. Six of these cases indicated selection of home ranges closer to streams than expected for the overall study area. One individual (M5294) accounted for 3 of these cases. The remaining 3 individuals’ random points within home ranges were significantly further from streams than random points within the study area. At the Bonferroni corrected confidence level, 3 cases involving 2 martens were found to be significant. The 2 situations involving the same individual showed significantly closer distances to streams than expected. The remaining marten’s random
points were significantly further from streams than expected.

**Microhabitat Selection**

I conducted tests on 38 walk-in locations involving 12 martens over the course of this study. Used plots had significantly more total trees and dead trees within the variable plot than did random plots ($\alpha \leq 0.01$), and used plots had more snags and dead top trees within the 7.5m radius fixed plot ($\alpha \leq 0.01$). I tested for correlation between snags (7.5m radius plot) and the remaining 3 significant variables using Spearman’s Rho and found that each variable was positively correlated with snags ($\alpha \leq 0.01$). No significant difference between the 2 plot types was detected for total live trees or for the 4 dbh classes and 3 coarse woody debris classes.

Martens used a variety of rest site types including live trees, cavities in snags, cavities in downed logs, and talus fields (Fig. 10). Live trees (41%) and snags (24%) comprised 65% of the rest sites I located ($n = 37$). Of the 14 rest sites located in live trees, 6 were in subalpine fir, 5 in spruce, and the remaining 3 in western hemlock. Eight rest sites were located in snag cavities. All of these snags were subalpine firs. A branch on a spruce snag was used during 1 resting episode. The average dbh of live trees used as rest sites was 54.9cm. Snags used for resting were smaller at 41.9cm. The 3 downed logs used as rest sites had an average diameter of 48.0 cm. The average dbh of all trees selected as actual rest sites was 47.2cm. This figure is slightly larger than the plot average dbh for trees in all condition classes of 42.3cm. The average for all trees in the random plots was 43.3cm.

At least 1 downed log $> 12.7$cm diameter was found in 79% of the transects conducted at rest site plots and 70% of the transects in random plots. The mean for all rest site plots
Fig. 10. Marten rest site types documented in Trestle Creek study area 1994-96.
was 1.5 logs and the grand mean diameter for logs at all sites was 22.3cm. Paired random plots had a mean of 1.6 logs with a mean diameter of 18.6cm. Densiometer readings averaged 31.5% across all used rest site plots. The average for random plots was slightly lower at 27.1%. A variety of habitat types were used for resting, however, phases of the subalpine fir series (queencup beadelily, twisted stalk, beargrass, and menziesia, comprised 72% of the total. At rest site locations, deciduous shrub canopy cover > 1 m in height was often greater than 70%. The major species comprising this cover were sitka alder (Alnus sinuata), menziesia (Menziesia ferruginea) and mountain ash (Sorbus pennsylvanica).

Small Mammal Densities

Deer mice, Gapper’s red-backed voles and western jumping mice were the 3 principle prey species captured on small mammal trapping grids. Incidental captures of microtine voles (Microtus spp.), red-tailed and yellow-pine chipmunks (Tamias ruficaudus and T. amoenus, respectively), and shrews (Sorex spp.) were recorded. Gapper’s red-backed voles were found at significantly higher frequencies in mature stands than in regenerating stands (α ≤0.001). No red backed voles were captured in regenerating sites is compared to 45 captures in mature, forested habitats (Fig. 11). No significant difference was detected between the 2 habitats regarding the abundance of deer mice or jumping mice. In terms of total small mammals captured in the respective habitats, mature stands had significantly higher numbers (α ≤ 0.05). In 7 of 10 trapping sessions, mature, forested habitats tallied more overall captures (Fig. 12).
Fig. 11. Total small mammal captures by species in forested and open habitats 1995-96.
Fig. 12. Total small mammals captured during each trapping period in each habitat type 1995-96.
DISCUSSION

The habitat requirements of a species may vary both spatially and temporally (Wiens 1986). For this reason, spatial and temporal variation should be incorporated into analyses of habitat selection. Failure to address these scale issues may result in inappropriate conclusions regarding habitat use (Wiens 1989, Ruggiero et al. 1994). Ruggiero et al. (1994:140) stated, "questions about kinds, amounts and arrangements of environments required by populations and species should be asked at the stand, home range, landscape, physiographic province and regional scales and in the context of seasonal, yearly and longer time frames". I addressed marten habitat selection at the microsite, locations within home range, and home range within study area scales during summer/fall months (June 1-October 31) 1994-96.

Home Range within Study Area Scale Selection

Martens are generally considered habitat specialists (Bissonette et al. 1988) occurring primarily in mature, mesic coniferous habitats (Soutiere 1979, Steventon and Major 1982, Raine 1983, Bateman 1986). Thompson and Harestad (1994) summarized the results of 10 studies of habitat selection and found use/availability ratios of $\geq 1$ only when succession reached the "mature" stage. Each study found use/availability ratios for "overmature" stands $> 1$. My findings regarding marten selection for mature conifer forests are consistent with this information. At the home range within study area scale, martens in this population preferred large diameter stands. Large diameter stands were preferred most across all 3 years combined and within each year. In all analyses except 1994 this preference was significantly higher than the other 2 classes. Conversely the smallest
diameter class was least preferred at this scale in all analyses. Preference for this class was significantly less than the large class in all cases. Intrasexual territoriality and questions concerning mechanisms driving the establishment of home range boundaries, such as maximization of access to mates, may confound interpretations of marten habitat selection at this scale. Nonetheless, forest successional stage is apparently an important component of marten home range selection.

Locations within Home range Scale Selection

Martens also showed a preference for large diameter stands when using stands within their respective home ranges, however, this preference was not as consistently significant as in the larger scale analyses. For all years combined, and in 1995, there was no significant difference in preference between large and intermediate classes and during 2 years (1994, 1996) there was no significant difference in preference for any of the classes.

Several factors may contribute to these results. Martens likely select for certain habitat characteristics at the home range scale so that a home range encompasses an area which satisfies all life requirements. If this is the case, selection within the home range may be undetectable or non-significant due to relatively uniform use (Ruggerio et al 1998). Secondly, radio telemetry does not allow for determination of activity other than resting or not resting. A marten may need certain habitats but not spend a great deal of time in them (i.e. travel corridors). Therefore, statements pertaining to preference for a particular habitat at this scale of analysis could be misleading. Finally, telemetry error could confound results at this scale. In some cases, the distance of a marten location to a stand in another diameter class was less than my telemetry error. This was especially true when
martens occupied fragmented areas comprised of a mosaic of cutting units and older stands. Criteria attributed to a point are more likely to be incorrect in a patchy habitat than in homogenous areas, especially if telemetry error is fairly large (Bissonette et al. 1994). I addressed this concern by conducting a test using only locations further than my mean telemetry error from another stand diameter class. The results were consistent with the overall results in that large diameter stands were preferred most at the stand level. Of the 7 martens included in this test, all exhibited the strongest preference for large diameter stands and this preference was significant in relation to intermediate and small stands. Telemetry error may have effected the outcome of the overall analysis. Large diameter stands may be preferred to a greater degree than my findings show. In any case, large diameter stands are preferred most by martens in this population at the stand level.

**General Habitat Use**

Martens are often associated with older, mesic coniferous stands (Buskirk and Powell 1994). The presence of complex physical structure near the ground in older stands appears to be the primary reason such stands are so frequently used. According to Buskirk and Powell (1994), this complex physical structure provides protection from predators, access to prey, and protective thermal micorenvironments, especially during winter. I found that areas with old growth characteristics are important during summer months, as well.

Martens avoid openings such as clearcuts and meadows, especially during winter months (Koehler and Hornocker 1977, Soutiere 1979, Simon 1980, Spencer et al. 1983). Martens may use openings in the summer months if they provide adequate cover and food
(Streeter and Braun 1968, Kohler et al. 1975). Six percent of my triangulation locations placed martens in non-forested openings. In these cases, the martens were an average of 66 m from a forested stand. Based on the large openings present in the study area, I would expect this distance to be greater if martens were not avoiding areas far from forest cover. This information shows that martens in this region use ecotones and openings to some degree, however, forays are not made great distances from timbered stands, even during summer months.

Marten use of the forest within my study area was not significantly different from random in relation to slope and aspect. In this region, where moisture is abundant and habitat change is not dramatic across all aspects, lack of selection for any particular aspect during summer and fall is not surprising. In the case of slope, topography in my study area was not extreme such that a large percentage of rocky, non-forested stands existed. I assume that slope would effect marten behavior primarily in cases where changes in slope cause the habitat to change greatly.

As with slope and aspect, marten locations were not significantly different than random points in relation to distance to roads. I frequently observed marten scats along skid trails and hiking trails, indicating that these man-made features are often used as travel routes. Although sign was not common on more heavily traveled roads, these features were not barriers to marten movements. Furthermore, I located marten resting sites near primary, Forest Service gravel roads several times. The motorized traffic in this area did not appear to disturb the animals, at least not to the degree that they avoided areas near roads.

Marten locations within home ranges were significantly closer to streams than random points within the same home range ($\alpha < 0.01$). No significant difference in distance to
water was found between random points within each marten home range and random points within the entire study area. Martens used stream corridors and riparian areas within home range territories frequently. Rest sites were often near streams or springs and active martens frequently traveled along riparian corridors. Buskirk et al. (1989) documented preference of riparian areas for rest sites and Spencer et al. (1983) reported martens used these areas for foraging. Miller and Getz (1976) and Raphael (1988) stated that abundance and diversity of small mammal species may often be higher in areas with high soil moisture (i.e. riparian areas). In addition to enhanced foraging opportunities, riparian areas may be sought by martens in the summer due to cooler temperatures and the access to water.

Microhabitat Scale Selection

Determination of selection at the microhabitat scale requires gathering data that has small measurement error relative to the size of the feature being studied (Buskirk and Ruggiero 1994). Furthermore, questions regarding habitat heterogeneity and the spatial scale of an animal’s habitat perception should be considered but are often difficult to answer. I used only walk-in locations and selected 50m as the distance between marten rest sites and paired unused plot centers in an attempt to address these issues. I assumed that a marten can perceive differences in it’s surroundings at this scale and that there is a detectable level of heterogeneity in the habitat variables I measured. The forests I conducted analyses in are heterogeneous at a small scale in terms of snags and trees with dead tops trees. In addition, martens selected for areas with higher concentrations of dead and dying trees. Martens may be simply selecting for snags within the forest with certain
characteristics (i.e. cavities of certain size). The fact that higher abundances of snags were present at marten rest sites may simply be due to the nature of snag distribution. In either case, decaying, large diameter snags are important summer rest sites for martens in this region. Although I found no significant difference between paired sites for the other variables these habitat characteristics could still be important to martens. The distribution of these conditions or characteristics may be such that differences are not detectable at a 50m scale.

Martens in this population used snags, live trees, down logs, talus slopes, and underground rest sites. These findings coincide with other research conducted on summer marten rest site selection. I did not detect frequent use of red squirrel middens, although high use of middens has been reported elsewhere (Finley 1969, Buskirk 1984). Spencer (1987) found martens in the Sierra Nevada range of California used live trees, snags, downed logs, and talus for non-subnivean rest sites; snags were the most preferred rest sites in relation to availability and the selected snags were almost exclusively large diameter fir snags (mean = 102.1cm dbh). Campbell (1979) also reported selection for large diameter spruce and fir snags during snow free months in Wyoming. All 7 of the rest sites I documented in standing snag cavities occurred in subalpine firs. Although the diameters of these trees (mean = 41.4cm dbh, range = 29.2 - 67.6cm) were smaller than those reported by Spencer (1987) in California, these snags were large in relation to what was available in my study area. The exclusive use of fir snags is likely due to the fact that fir snags tend to retain bark longer than other species, which speeds decay and cavity formation in the bole (Raphael 1980). Research conducted in the Rocky Mountains of Wyoming in the winter indicated downed logs, talus fields, and snags to be important
marten rest structures (Buskirk et al. 1989, Wilbert 1992). Coffin (1994) documented marten use of talus slopes, snags, downed woody material and red squirrel tree nests as resting sites in southwest Montana. However, Fager (1991), Kujala (1993), and Coffin (1994) did not find martens in southwest Montana preferred areas with abundant snags, or to use snags often when selecting winter rest sites. These findings may be due to seasonal differences in rest site selection. Martens are known to use subnivean rest sites, often associated with coarse woody debris, in winter to minimize thermoregulatory demands (Buskirk et al. 1989). Spencer (1987) reported only subnivean sites were used during periods of continuous snow cover.

Rest sites in cavities or other enclosed areas provide martens protection from weather and from potential predators (Buskirk and Powell 1994). Martens I observed (n = 14) tended to rest in the open in live tree branches only during warm, sunny days. On colder days and during periods of rain, rest sites were almost exclusively in enclosed areas. These protected areas were used during warm days as well, suggesting that they are used for security in addition to shelter from the elements. Martens using rest sites in talus fields and underground cavities never fled during my presence in the area. When in snag cavities, martens occasionally left the cavity and ran while I observed, however many remained in the cavity and watched me. In almost all cases, martens on branches in live trees left the area after a short time. Spencer (1987) observed similar behavior when approaching resting martens in the Sierra Nevada, California. Resting martens appeared to take 2-3 minutes to fully wake up, especially those I observed in cavities. Although martens have few morphological or physiological adaptations to reduce thermoregulatory costs (Taylor and Buskirk 1994), they may lower their metabolic rate slightly during
resting. The sluggishness I observed in waking martens is potentially due to a lowered metabolic rate. Based upon this observed vulnerability in waking martens it is understandable why these animals would prefer enclosed rest sites, even during warm weather.

**Home Range**

In comparison to findings from previous studies, marten home ranges in my study were quite small. Mech and Rogers (1977) reported an average 100% MCP home range of 15.6km² from data on 3 male martens in Minnesota (mean # of locations = 18.0). In Alaska, Buskirk (1983) found male martens to have an average 100% MCP home range of 7.1km² (n = 10, mean # of locations = 37.9). Coffin (1994) documented average male 100% MCP home ranges in southwest Montana of 19.4km² (n = 6, mean # of locations = 27.5). Burnett (1981), working in northwest Montana reported the only average home ranges smaller than those I recorded. Data from 4 male martens (mean # of locations = 13.3) in Burnett’s study area indicated an average 100% MCP home range of 0.9km² whereas the average 100% MCP for all males in my study area with ≥ 18 locations (n = 9) was 1.9km².

Buskirk and McDonald (1989) examined variation in home range sizes reported from 9 studies and found no geographic or climate related patterns. Sampling duration was found to be positively correlated with home range size. They suggested that long periods of sampling may result in multiple home ranges being included in a single depicted home range perimeter. The fact that I only collected data over short, seasonal sampling periods may partially explain why the home ranges I observed were much smaller than most. In
addition, it is possible that habitat quality in my study area is superior to the habitat in other areas where home ranges have been measured. Buskirk and McDonald (1989) hypothesized a strong relationship between home range size and site conditions in territorial terrestrial carnivores which are habitat specialists and have low reproductive rates (e.g., marten). Unfortunately, I was unable to make comparisons between habitat conditions in my area of study and other areas in which marten home range sizes have been reported. Prey densities were fairly high across my study area. In addition, martens took advantage of the abundant huckleberry crop available in this area during summer. Most scats encountered during late summer contained huckleberries. These facts, in association with the tight spacing and overlap of some male home ranges, suggested high quality habitat in terms of resource abundance. Powell (1994) predicted that martens should exhibit higher intrasexual overlap of ranges at higher prey densities. The overlapping male home ranges I documented occurred in areas of contiguous, older forests. Higher prey densities in the contiguous forests may have influenced the observed overlap of territories.

Density

The minimum density estimates from my study area are similar to other minimum densities reported in managed forests. Phillips (1994) found 0.7 marten/km² in an area closed to trapping and timber harvest in Maine and 0.1 marten/km² in an industrial forest open to marten harvest. Soutiere (1979), also in Maine, determined minimum densities of 0.4 and 1.2 marten/km² in selectively cut and undisturbed areas respectively. Francis and Stephenton (1972) reported densities of 1.2-1.9 marten/km² in Ontario. Thompson and
Colgan (1987) documented a decline in minimum density across 4 consecutive years. They thought this decline from 2.4 to 0.8 marten/km² was due to a prey base decline.

Age

Martens are a relatively long-lived species (Strickland et al. 1982) and have been reported to live at least 15 years in captivity (Markley and Bassett 1942, Ritchie 1953). Strickland (1978) determined a mean age of 2.7 years for 1300 trapped martens in Ontario. Similarly, harvest data from Montana reveals that greater than 90% of the animals are less than 2 years old (Coffin 1994). The median age in my study area of 1 year (mean age = 1.9 years) may be slightly biased by a high capture rate of young individuals. Assuming equal or nearly equal catchability between old and young individuals, it appears from my data that martens in the population I studied do not often survive for more than 3 years.

Survival

Survival of martens in the population I studied is relatively low, (see Micromort data in Results) due in part to predation. Overall, I documented 7 deaths (3M, 4F) from predation and 3 more that were assumed to be from predation. I suspect coyotes in most or all of these predations. Information related to predation on martens is rather sparse and largely anecdotal. Fishers (DeVos 1951, Phillips 1994), red foxes (Thompson 1994), coyotes (Phillips 1994) and great horned owls (Baker 1992, Thompson 1994) kill martens. Opinions regarding the effects of predation on marten populations are varied. Strickland et al. (1982) noted that marten’s natural enemies are few and that climbing ability removes
martens from most terrestrial predators. DeVos (1951) believed that actual predation on martens was rare. However, Hawley and Newby (1957) and Buskirk and Powell (1994) suggested that martens avoid open areas due to increased risk of avian predation and that intraspecific and interspecific competition for food or other resources is a mortality factor in regard to martens (Marshall 1951, Clem 1975). The fact that only 2 of the predated martens I found were fed upon supports this theory. Thompson et al. (1989) suggested that logged forests may contain higher populations of potential marten predators than unlogged forests. Thompson (1994) tested this hypothesis and found significantly higher rates of predation in logged forests than in areas with no timber harvest. I detected no significant difference in the percentage of small diameter habitat within the home ranges of martens killed by predators and surviving martens. I feel my sample sizes were too small to adequately address this question. Furthermore, I believe to adequately address this question I would need to assess fragmentation at a larger scale. Although I cannot divide my study area into distinct harvested and non-harvested sites, the predation I documented occurred almost exclusively in the highly fragmented areas (Appendix). Although I cannot divide my study area into distinct harvested and non-harvested sites, predation occurred almost exclusively in the highly fragmented areas (Appendix). I believe this fact is due to the higher occurrence of coyotes in these areas and the increased probability of a marten being caught in an area where it cannot climb a tree to escape a predator. Questions such as these are important and warrant further investigation.

A study conducted in Sweden on European pine martens (*Martes martes*) and red fox (*Vulpes vulpes*) (Storch et al. 1990) determined that marten numbers increased in response to a fox decline caused by an epizootic of sarcoptic mange. These researchers
hypothesized that martens had begun using open areas to exploit a field vole (*Microtus agrestis*) prey source left vacant due to the fox decline. This expansion of habitat, they believed, resulted in a higher marten population. Field research provided evidence that martens continued to avoid open areas and, subsequently, the prey available there.

Because fox predation on pine martens was documented (Pulliainen 1981) and foxes can have a regulating effect on other mustelids (Latham 1952), it was hypothesized by Storch et al. (1990) that marten populations may have increased due to reduced predation by foxes and better access to food-rich forest patches vacated by foxes. These investigators stated several reasons why martens still avoided clearcuts after the reduction in foxes and suggested that in areas where martens live permanently without predators, treeless areas should be used more frequently (Storch et al. 1990). A study of the European pine marten on the island of Minorca, Spain where no marten predators are present supports this hypothesis. Clevenger (1994) found martens on this island to use a variety of habitats including coastal shrublands and open areas. This observation supported the hypothesis that martens' avoidance of openings is related to the increased threat of predation in such areas.

**Prey Distribution and Abundance**

My findings on prey distribution and abundance were consistent with previous research, especially regarding the red-backed vole and deer mouse habitat associations. Mature, forested sites accounted for all captures of Gapper's red-backed voles. No significant difference was detected in abundance of deer mice or jumping mice at forested and regenerating sites. Red-backed voles are considered specialists associated with mesic,
mature forested habitats (Ramirez and Hornocker 1981, Allen 1983) due in part to their
dependence on downed woody material (Tevis 1956, Merrit 1976). Conversely, deer
mice have been considered habitat generalists, tolerant of a wide range of ecological
conditions (Scrivner and Smith 1984, Clark and Stromberg 1987). The western jumping
mouse feeds primarily on grass seeds and fungi (Jones et al. 1978) and utilizes areas with
dense herbaceous or grassy vegetation along moist streamsides in more mature stands
(Scrivner and Smith 1984, Raphael 1988). The abundant grasses and herbaceous
vegetation on my regenerating grids evidently provided adequate habitat for western
jumping mice because no difference between site types was detected for this species.
Significantly higher small mammal abundance in my forested sites was likely influenced by
the higher soil moisture, abundance of CWD, and increased structural complexity
compared to regenerating sites. Raphael (1988) recorded the highest small mammal
capture rates at sites with these attributes in a subalpine forest in southeastern Wyoming.
In regard to diversity in my sampling units, 7 species (shrews were only classed as Sorex)
were captured overall. Six of these species occurred in forested areas whereas only 4
were captured at regenerating sites. Hargis and Bissonette (1995) conducted intensive
small mammal trapping to evaluate the effects of forest fragmentation on martens and
marten prey in Utah. They found species richness was highest in forested areas whereas
the highest densities were recorded in clearcuts. These findings differ from my data in that
regenerating clearcuts in my study area had lower overall densities than mature forests.
This could possibly be related to the cyclic nature of small mammal populations. Hargis
and Bissonette (1995) found significantly more red-backed voles in forests and
significantly more deer mice in clearcuts. According to these findings, small mammal
communities in forests are notably different than communities in clearcuts. Corn et al. (1988) pointed out a similar dichotomy and stressed the need for research regarding the effects of forest management on small mammal communities.

Microtines, especially red-backed voles, are widely recognized as staple marten prey in the northwestern United States (Murie 1961, Weckwirth and Hawley 1962, Koehler and Hornocker 1977). Martens consume deer mice as well but often less than expected based on their numerical abundance (Koehler and Hornocker 1977, Thompson and Colgan 1987). Francis and Stephenton (1972) suggested that martens make little use of deer mice because they are not preferred or because they are difficult to catch. I found that red-backed voles are much more abundant in forested areas. This fact may play a role in the preference martens exhibit for mesic, forested stands. The difficulty lies in determining to what degree martens’ preference for forested stands is affected by small mammal distribution. Martens may prefer older forests for other reasons, such as security from predators, and simply use the prey base available to them in those areas. A combination of factors, including food resource abundance, probably drive marten selection for these habitats.

Conclusions

Martens in the population I studied preferred mature stands with larger diameter trees over immature or seedling/sapling stands at both the within home range and home range within study area levels. This preference was significant (α < 0.05) in more cases at the home range within study area scale than at the within home range scale. Thus, how older stands are distributed across the landscape is important in regard to marten home range
selection. The abundance of large diameter live trees, snags, and downed logs in mature stands appeared to influence marten preference for these stands. Larger diameter live trees and large subalpine fir snags were the most commonly used rest sites. Cavities within snags and downed logs were used frequently, even during periods of warm weather. At the microhabitat scale, areas with significantly higher numbers of snags were selected by martens.

Like Buskirk and Powell (1994), I believe martens' selection for older stands is related to food availability and the protection from predators and weather that snags and CWD offer. Red-backed voles, a primary marten prey species (Murie 1961, Weckwirth and Hawley 1962, Koehler and Hornocker 1977), were only present in forested stands. Furthermore, forested stands had significantly higher densities of small mammals than non-forested stands. These factors may be partially responsible for the observed preference martens have for mature forests. Observation of marten scats during summer suggested heavy use of huckleberries during this time period. These berries were more abundant in open areas that martens used infrequently, which implies that marten selection for forested areas is driven by factors other than access to food alone.

My documentation of at least 6 predation episodes over a relatively short duration indicates that martens are susceptible to predation. I believe, as others have suggested, that martens' avoidance of openings and use of stands with near ground structural complexity is driven, to some degree, by predator avoidance behavior. I documented more predation in the fragmented region of my study area (see Appendix). Potentially, there are more predators such as coyotes in these areas (Buskirk and Ruggiero 1994). In addition, martens with home ranges in fragmented habitats are more likely to be caught
traveling through an area lacking the escape structures found in unfragmented areas comprised of mature stands. For both of these reasons, martens likely prefer contiguous patches of mature forest where they are less prone to predation. More research is necessary to address how predators affect marten populations.

Riparian areas were frequently used by martens in the study area. This use could be attributed to higher concentrations of small mammals in such areas or may simply be due to the habitat characteristics of the older, uncut forests which frequently remain in riparian zones. Roads did not appear to have a negative effect on marten movements. Trails were often traveled as evidenced by marten scats along such routes. I did not find slope or aspect to influence martens' use of the study area.

The home range estimates for martens in my study areas were smaller than most previously reported home ranges. My estimates were only for the snow free period and did not include a large number of points for each marten. The small home range sizes I observed may be influenced by these factors. However, prey species were abundant in the study area, as evidenced by my trapping efforts. In addition, huckleberries provided an easily accessible and locally abundant seasonal food source during the 3 years of my study. For these reasons I feel the Trestle Creek study area provided high quality habitat for martens and that the small home ranges I documented are reflective of such habitat.

The slight reduction I observed in minimum marten density from 0.3 marten/km² in 1995 to 0.2 marten/km² in 1996 suggests that marten populations may be subject to fluctuations. This suggestion is strengthened by the fact that at least 8 non-capture caused mortalities were documented in 1996. The years 1994 and 1995 accounted for only 3 and 1 such deaths, respectively. High seasonal mortality, in association with a mean age for
martens in the population I studied of 1.9 years, indicates that these populations have the potential to undergo periodic highs and lows. It is possible that the mortality and subsequent reduction in marten density I witnessed in 1996 was driven by a decline in small mammal prey. Such interrelated cycles have been reported in past marten studies (Hawley and Newby 1957, Weckwerth and Hawley 1962). My small mammal trapping data was not adequate, nor was my study long enough, to determine if such a cycle was occurring however, my limited small mammal trapping did show a reduction in small mammals from 1995 to 1996.

Management Implications

To ensure that marten populations remain intact in north Idaho, land managers should understand several aspects of marten ecology. Primarily, martens prefer older spruce\fir habitats with abundant large diameter snags and CWD. Marten selection for these habitats is stronger at the home range scale than at the stand within home range level. Consequently, the arrangement of older stands across the landscape is important in managing for martens. Martens in my study area did not use openings frequently and were never found far from a forest edge. Maintaining connectivity between patches of optimal habitat is important to the persistence of marten populations. Simply providing mature spruce\fir stands is not adequate if these stands are too isolated from similar habitats. Fragmentation may also be detrimental to marten populations in that it favors habitat-generalist predators (Buskirk and Ruggiero 1994).

Snags and structural complexity near the ground are important to martens for a variety of reasons. If timber harvesting is conducted in such a manner that this structure is left in
place, marten populations should not be as negatively affected, especially if some overstory is left unharvested. The decadence characteristics of a stand (snags, CWD) seem to be more important to martens than the very old, large diameter trees we typically associate with old growth. Many of the spruce\fir stands I found martens using had an average age of around 150 years. Thus, these stands were not exceptionally old but did have a high degree of decadence in the form of snags and CWD. Harvest rotations should not need to undergo dramatic changes to address martens' habitat requirements in spruce\fir forests such as these as long as adequate amounts of forest in this age category are available across the landscape and these stands can attain an “old growth” condition in terms of decadence over this time span. A 150-year rotation may not be adequate to meet these needs in other forest types in this area or in similar forests in different geographic regions.

Finally, should we consider the marten as a good MIS for old growth in north Idaho? Martens did not completely avoid younger stands but I did not find them in such stands often. Old growth stands were used more than expected in relation to their availability and it seems that certain structures missing in younger stands are very important to martens as resting structures. I have shown that martens prefer older stands out I have not shown that they are dependent upon them. I do not feel that my study was comprehensive enough, or long enough, for me to reach a definitive conclusion regarding the martens’ value as an old growth MIS.
Literature Cited


Latham, R.M. 1952. The fox as a factor in the control of weasel populations. J. Wildl. Manage. 16:516-518.


APPENDIX

Northern Idaho Old Growth Criteria (USFS) 1
Mortality Locations in relation to Fragmentation 4
<table>
<thead>
<tr>
<th>OLD GROWTH TYPE</th>
<th>FOREST TYPE(S)</th>
<th>HABITAT TYPE GROUP(S)</th>
<th>LARGE TREE AGE</th>
<th>TREES/AC &gt;DBH</th>
<th>DBH VARIATION 2/</th>
<th>SNAGS &gt;9 IN. DBH 1/</th>
<th>DEAD/ BROKEN TOP &gt;9 IN. DBH 1/</th>
<th>PERCENT DECAY &gt;9 IN. DBH 1/</th>
<th>PERCENT DOWN WOODY &gt;9 IN. DBH 2/</th>
<th>TREE CANOPY LAYERS</th>
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1/These values are the weighted means and the range of means across plots within forests, forest types, or habitat type groups.
2/These are low, moderate and high probabilities of abundant large down woody material or variation in diameters based on stand condition expected to occur most frequently.
<table>
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<tr>
<th>OLD GROWTH TYPE</th>
<th>FOREST TYPE(S)</th>
<th>HABITAT TYPE GROUP(S)</th>
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<th>ASSOCIATED CHARACTERISTICS</th>
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1/These values are the weighted means and the range of means across plots within forests, forest types, or habitat type groups.

2/These are low, moderate and high probabilities of abundant large down woody material or variation in diameters based on stand condition expected to occur most frequently.
**TABLE 1 NORTH IDAHO ZONE OLD GROWTH CHARACTERISTICS (Continued)**

<table>
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<tr>
<th>DESCRIPTION</th>
<th>MINIMUM CRITERIA</th>
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<td>SAF,MAF</td>
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1/These values are the weighted means and the range of means across plots within forests, forest types, or habitat type groups.

2/These are low, moderate and high probabilities of abundant large down woody material or variation in diameters based on stand condition expected to occur most frequently.
Appendix 2. Locations of mortalities (red) and possible mortalities (yellow) imposed onto aerial photos of study area.