

**SCALE DEPENDENT ANALYSES OF HABITAT SELECTION BY MARTEN
IN THE SUB-BOREAL SPRUCE BIOGEOCLIMATIC
ZONE, BRITISH COLUMBIA**

by

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MARTEN IN THE SUB-BOREAL SPRUCE BIOGEOCLIMATIC ZONE,

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ABSTRACT

Winter habitat selection by radio-collared marten (*Martes americana*) in the Sub-Boreal Spruce (SBS) Biogeoclimatic Zone was examined at landscape, stand and patch scales between January 1988 and September 1991. Capture data indicate that the moist cold subzone of the SBS was more productive as marten winter habitat than the lower elevation dry cool subzone. Landscape scale habitat use for 7 adult marten (4 males, 3 females) revealed that marten preferentially included mature to old growth seral stage habitat types of mesic to hygric moisture regimes within their home ranges. Three male marten included substantial areas of young forest seral stage habitat types which may provide them with access to alternate prey during periods of high prey population cycles. Stand scale analyses indicate that, within individual home ranges, marten do not prefer any particular habitat types but do avoid some habitat types, particularly young seral stages, xeric habitat types and wetlands. This apparent lack of preference at the stand scale is likely a consequence of landscape level selectivity. Marten exhibited selectivity at the stand scale for habitats types classified by their structural features. These habitat preferences were related to the abundance of coarse woody debris, deciduous canopy closure, high shrub and low shrub closure, and abundance and size of trees and snags. At the stand scale, marten did not prefer any particular class of coniferous canopy closure. Within habitat types, marten were selective at the patch scale. Structural characteristics at marten sites were significantly different from the prevailing characteristics of the habitat types that these sites were in.

Selectivity occurred for all structural attributes examined with the exception of mean snag diameter. My results have implications for forest management, in particular forest harvesting types, rates and cutblock sizes, site preparation tactics, and stand tending practices. If marten are to be maintained in an area, forest management practices must be implemented that promote a distribution of seral stages (including old growth) with structural features necessary for marten winter habitat.

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INTRODUCTION

Marten (*Martes americana*) are found throughout forested regions of much of Canada, Alaska, and portions of the western and northeastern contiguous United States (Hagmeier 1956, Strickland et al. 1982). Their distribution in the south has been reduced due to loss of suitable habitat (Strickland et al. 1982). The northern limit of their range coincides closely with the treeline (Strickland et al. 1982). Marten inhabit most of the forested biogeoclimatic zones of British Columbia (Pojar and Meidinger 1991). Marten are harvested by trappers annually in every ecoprovince, with the majority of the harvest occurring in the Southern Interior Mountains, Sub-Boreal Interior, and Northern Boreal Mountains ecoprovinces (Demarchi and Lea 1989, MOELP unpub. data). Marten are, economically, the most important of the 17 furbearer species managed in British Columbia. In the 1984/85 trapping season, a record of 45,000 martens were harvested, worth \$2,700,000 (Stordeur 1986). This represented 36 percent of the overall fur harvest value.

Winter is a critical season for martens. At this time, habitat selection is most pronounced, foraging opportunities are most limited, mobility is restricted, and thermoregulatory costs are greatest (Raine 1983, Hargis and McCullough 1984, Buskirk et al. 1988). Martens generally prefer coniferous or mixed-wood forests and tend to be associated with old forest conditions (Strickland et al. 1982, Strickland and Douglas 1987). These preferences are often linked to structural features of habitat such as coarse woody debris (CWD), trees, snags and vegetation cover (Allen 1982). In the

United States, marten have been used as an old growth indicator species (Wischnofsky 1978 in Harcombe 1984, Irwin and Cole 1987) due to their restricted habitat requirements. Marten will, however, use younger seral conditions providing specific habitat needs are met. There is evidence that marten inhabiting these younger seral conditions have larger home ranges and lower population densities than do marten in older seral stages (Soutiere 1979).

Sensitivity of marten to habitat changes caused by logging and silvicultural practices has been reported consistently in extensive literature (British Columbia - Kelly 1982; Maine - Soutiere 1979, Steventon and Major 1982; Minnesota - Mech and Rogers 1977; Newfoundland - Snyder and Bissonette 1987; Ontario - Thompson 1986; Wyoming - Clark and Campbell 1977, Campbell 1979). The age at which regenerating clearcuts are used by marten varies among studies. In Wyoming, marten did not use clearcuts for at least a year after cutting (Clark and Campbell 1977). In Maine, marten rarely used clearcuts less than 15 years old but were found in partially harvested stands (Soutiere 1979). Snyder and Bissonette (1987) reported that 23 year old regenerating stands were insufficient to support marten in Newfoundland, whereas Thompson (1986) found that marten used clearcuts during winter after only ten years in Ontario.

Little information is available on the effects of silvicultural practices, but they undoubtedly play an important role in influencing marten use of regenerating clearcuts and second growth forests. Stordeur (1986) provides the following speculations on the ramifications of current silvicultural practices in British Columbia. "Clean" site

preparations, the removal of logging debris and the regenerating understory, will affect marten negatively by removing cover, hunting habitat, and den sites. Pre-commercial thinning in plantations is likely to be beneficial because woody downfall is created and the open canopy promotes understory plants. These factors contribute to abundant prey. The degree of spacing will be important in determining the value of canopy closure for marten habitat. Commercial thinning, essentially logging in established stands, is unlikely to adversely affect marten. Forest fertilization increases understory vegetation, possibly augmenting prey populations. The effect of herbicides on marten habitat use is unknown but may be adverse if numbers of prey species decline on herbicide treated sites.

Fires alter cover and may temporarily alter the edaphic nature of a site. Wildfires may act beneficially, by creating a mosaic of habitat types which support a diversity of prey. In Alaska, Magoun and Vernam (1986) concluded that marten are adapted to wildfire driven ecosystems. Burns were used by marten but cover provided by wind-thrown trees was a critical component of their habitat. Prescribed fire, as a site preparation technique, has the potential to reduce the value of a clearcut for marten by eliminating cover, snags, logs and other habitat features important to marten.

Clearcut logging occurs throughout forests of British Columbia. In 1986, 210,397 ha of forests were logged, 88 percent of which was clearcut (Vance 1990). This portion of the land base reverts to very young successional states and joins a growing area under intensive silviculture. The sub-boreal forests of British Columbia

dominate the central interior of B.C. and are important timber producing regions (Meidinger et al. 1991). The rate of cut in the Sub-Boreal Spruce (SBS) Biogeoclimatic Zone and associated silvicultural activities could have serious implications for some wildlife, particularly old forest associated species such as marten. Several studies have indicated that provision or maintenance of habitat for marten need not always be incompatible with logging practices (Koehler et al. 1975, Soutiere 1979, Steventon and Major 1982, Snyder and Bissonette 1987). However, foresters and wildlife habitat managers often lack the information necessary to assess the suitability of habitat for marten or to predict impacts of forest harvesting on marten habitat (Harcombe 1984). This problem arises mainly from a lack of understanding of habitat needs of marten, and a lack of tools for managers to assess, prevent, and mitigate serious impacts to marten habitat. The development of effective, reliable habitat management tools for marten requires a sound knowledge of their habitat ecology.

Turner (1989) noted that the geographical scale at which studies are conducted can strongly influence their conclusions, and that observations of landscape function such as the movement of organisms among landscape components also depends on scale. For these reasons, it is important to examine patterns of habitat use by marten at a variety of scales. Johnson (1980) discussed the concept of selection order in habitat use studies. He proposed that animals may select habitats or components of habitats on a hierarchical basis. First order selection is defined as the geographical range of the species. Few would argue with the statement, given their distribution, that marten are

strongly tied to coniferous forests (Hagmeier 1956). Within this geographical range, second order selection refers to the selection of home range. Third order selection refers to the selection of individual habitats or habitat assemblages within the home range. Johnson (1980) terms fourth order selection as the selection of food items at particular feeding sites but this argument could be extended to any habitat component that a species uses or requires. The latter three levels (in the case of marten) are similar to the scales used to describe forest landscape dynamics - landscape, stand and patch (Pickett and Thompson 1978, Harris 1984, Hunter 1990, Morrison et al. 1992). At each level in the hierarchy, it is important to identify the entity that is being selected. Marten have been reported to select or use preferentially a variety of habitat types, conditions or attributes (Koehler et al. 1975, Campbell 1979, Soutiere 1979, Steventon and Major 1982, Spencer et al. 1983, Snyder and Bissonette 1987, Corn and Raphael 1992, Wilbert 1992). Most of these studies have examined habitat use at only one scale (e.g. Koehler et al. 1975) or have used the same measure (often percent habitat use measured at one scale) as the measure of habitat use for all scales (e.g. Spencer et al. 1983, Martin and Barrett 1991, Wilbert 1992). A thorough analysis of marten habitat use and selection necessitates the identification of which habitat types and/or components are available, used and selected at each scale.

In this study, my objectives are to 1) describe winter habitat selection of marten in the Sub-Boreal Spruce Biogeoclimatic Zone at the landscape (second order), stand (third order) and patch (fourth order) scales; and 2) to describe the relationships between this selection and important components or attributes of these habitats. I

hypothesize that at the landscape scale marten will establish home ranges to preferentially include particular habitat types. Habitat types selected for are expected to reflect the old forest conditions with which marten have been associated with in winter. At the stand scale, I hypothesize that marten will demonstrate habitat selection within the home range that will be a function of the structural attributes of habitat. Within stands, I hypothesize that marten will select patches on the basis of their structural features. These relationships could form the basis of a habitat suitability index (HSI) model capable of assessing tracts of land for their suitability as marten winter habitat (Lofroth and Banci 1990).

Chapter 1 describes habitat selection by radio-collared marten in the intensive study area at the landscape scale. Chapter 2 describes selection of habitat types and structural attributes by marten at the stand scale. Chapter 3 examines selection of habitat by marten as a function of structural attributes at a patch scale. In Chapter 4, I summarize my results, discuss their implications to habitat management for marten in forestry operations, and describe research needs.

STUDY AREA

My study area is located in the Bulkley Valley near Smithers, British Columbia, within the Sub-Boreal Spruce (SBS) Biogeoclimatic Zone (Pojar and Meidinger 1991) (Fig. 1). Climate of the SBS can be characterized as cold sub-boreal continental humid type, with severe, snowy winters and relatively warm, moist, short summers with light to intense rainfalls of short duration (Pojar et al. 1984). Snowfall accounts for 25-50% of all precipitation. The study area contains both the SBSdk (dry cool) and SBSmc (moist cold) subzones of the SBS (Pojar et al. 1991) (Fig. 2).

The SBSdk occurs at the lower elevations (from 550 m to 1100 m) and contains the major settlements of the Bulkley Valley. The climate of the SBSdk is milder than the SBSmc with drier summers (mean summer precipitation 443 to 513 mm) and winter snowfalls that are considerably less and of shorter duration than in the SBSmc. Mean annual temperature is 2.1 to 4.0 C. Dominant tree species are hybrid white spruce (*Picea glauca x engelmannii*), lodgepole pine (*Pinus contorta*), trembling aspen (*Populus tremuloides*) and black cottonwood (*Populus balsamifera*). Minor species include black spruce (*Picea mariana*), subalpine fir (*Abies lasiocarpa*) and paper birch (*Betula papyrifera*). The most abundant forest types are pine-spruce or pine-spruce-aspen mixtures.

The SBSmc lies between 750 m and 1300 m in elevation and is the main timber producing area of the SBS (Pojar et al. 1984). Mean annual temperature varies from 0.4 to 2.1 C. The snowpack is greater and lasts considerably longer than that of

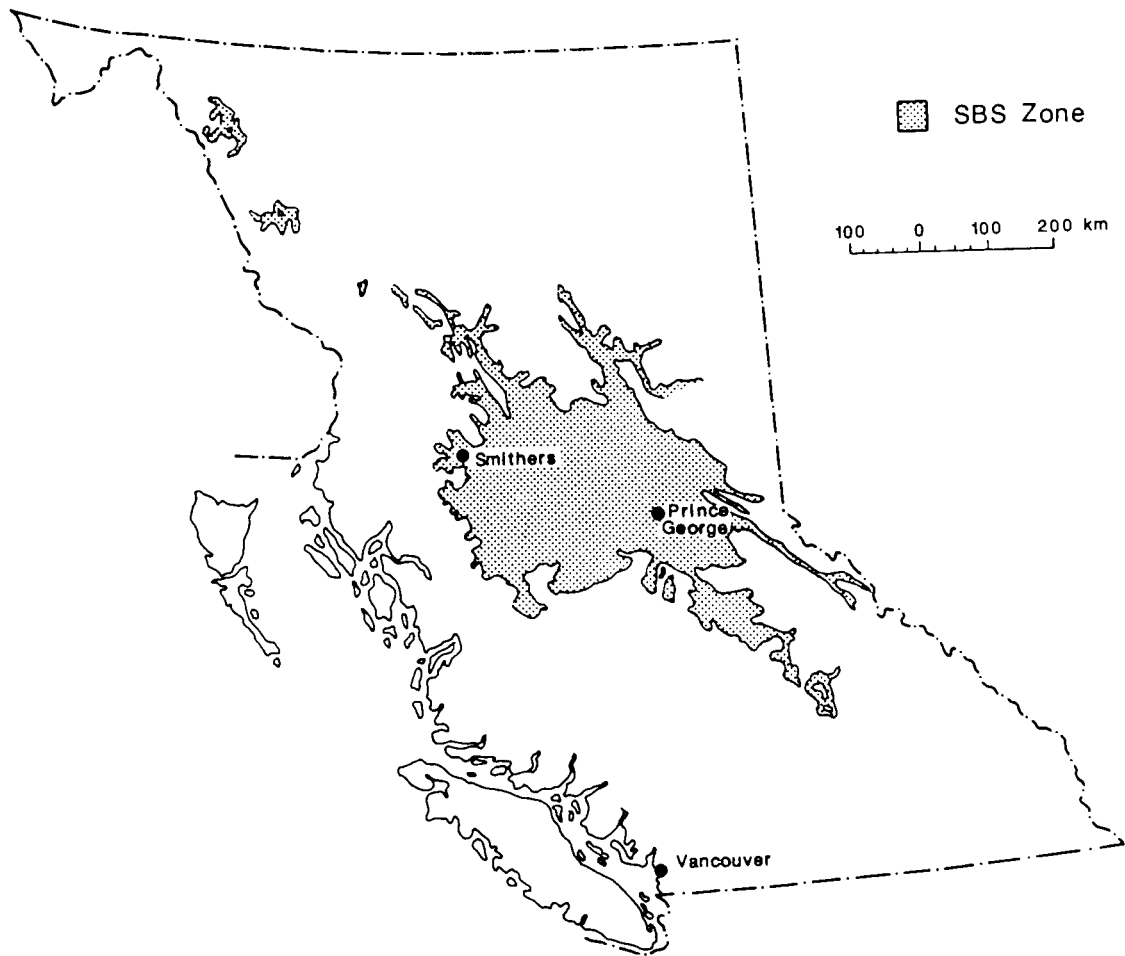


Figure 1. Distribution of the Sub-Boreal Spruce Biogeoclimatic Zone in British Columbia.

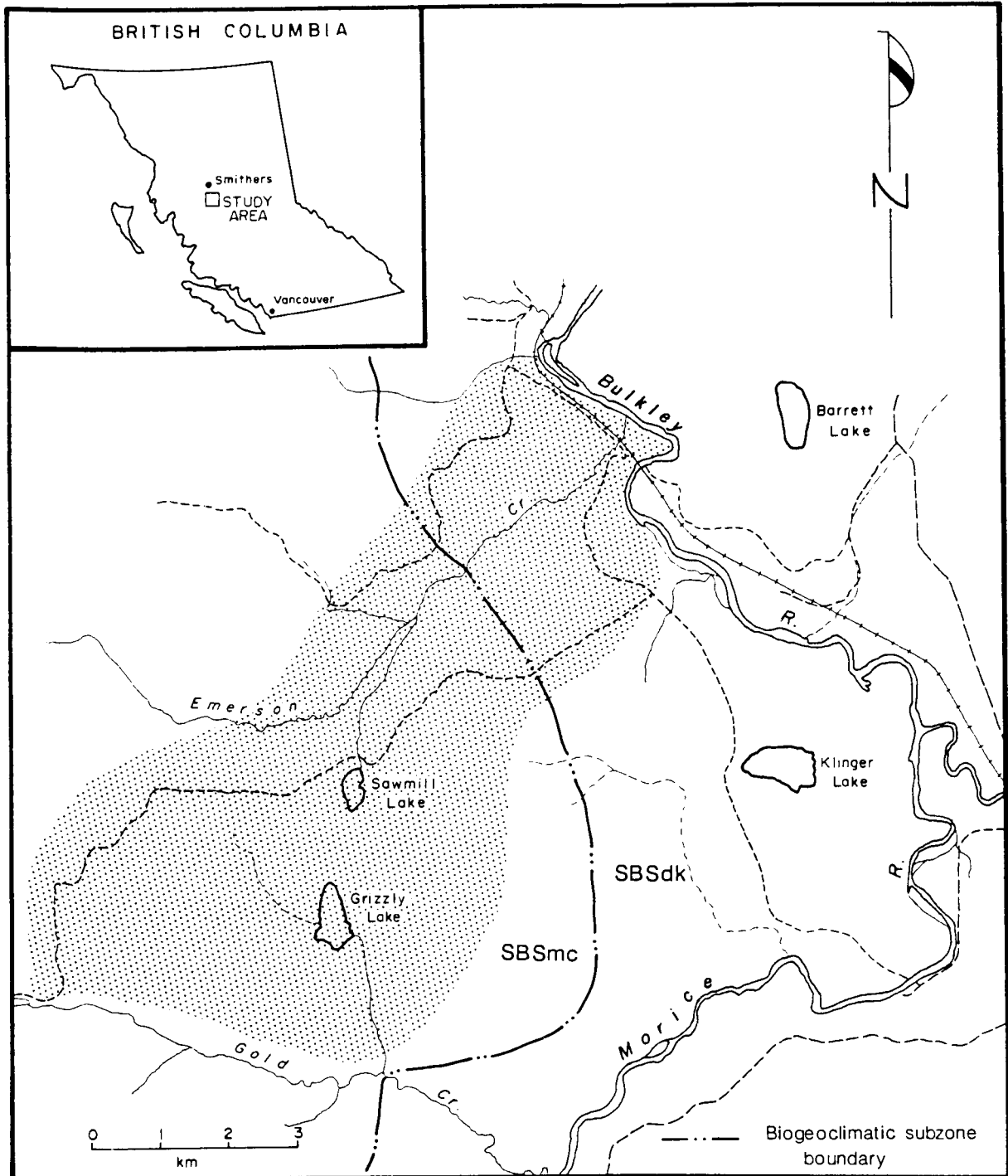


Figure 2. Location of the Emerson Creek study area and biogeoclimatic subzone boundary.

the SBSdk (Pojar et al. 1984). Dominant conifers are subalpine fir, hybrid white spruce, and lodgepole pine. Trembling aspen is a common seral species.

Fire history analyses suggest that stands in the SBS have been burned at least once every 300 years and most stands once every 100 years. Due to the effectiveness of modern fire suppression techniques, fire is unlikely to continue to be such a major influence in this biogeoclimatic zone (Pojar et al. 1984).

The study area encompasses 59.1 km² and is located in the Emerson Creek watershed, 10 km west of Houston and 50 km southeast of Smithers (Fig. 2). It is bounded on the north by the height of land on the north side of Emerson Creek, on the west by the north fork of Gold Creek, on the east by private agricultural land and on the south by Gold Creek. Two small lakes (Grizzly and Sawmill) are located near the center of the study area. Elevation ranges from 700 m to 1200 m.

This area has been influenced by wildfire until recent times. There is evidence of fires as recent as 50 years ago (B.C. Ministry of Forests unpub. data). It also has a history of logging. Selective logging and onsite milling occurred over a large portion of the study area in the mid-1960's. During this time, numerous winter roads and skid trails were built that still provide access to parts of the study area. Recent logging (1987-1991) has resulted in three large clearcuts ranging from 100 to 500 ha in size. The main road through the area, a popular and well used route, provides access to the Telkwa Mountains for recreational snowmobile and ATV enthusiasts.

Habitat mapping of the study area was completed by the B.C. Ministry of Forests, Forest Science Section (Smithers) on 1:10,000 colour aerial photographs. This

information was transferred to a 1:10,000 map base and digitized (PAMAP Systems) by B.C. Ministry of Forests staff in Smithers. Habitats were described using the Biogeoclimatic Ecosystem Classification (BEC) system (Pojar et al. 1991). BEC is a hierarchical system that combines regional, local and chronological features with climatic, vegetation and site classifications. For the purposes of my study, habitat type descriptions were simplified to include only climatic features (subzone), site information (site series) and chronological features (seral stage). Site information is referred to as site unit within text and tables because some of the site series were combined to form one site unit. Site series were combined when there were minor vegetation and structural differences between them. Seral classification is adapted from that of Hamilton (1988) and is outlined in Table 1. Seral stages were also separated into seral associations on the basis of dominant vegetation. This level of classification was not considered in my study. Appendix A contains the detailed ecosystem classification for the study area.

Approximately 83% of the study area is within the SBSmc subzone (4889 ha) with the remainder in the SBSdk subzone (1020 ha) (Table 2). Mesic to hygric habitat types dominate both of these subzones (SBSdk - 887 ha; SBSmc - 4393 ha). Within the SBSdk subzone, young forest seral stage habitat types comprise almost half of the area, with herb-shrub and mature forest seral stage habitat types comprising most of the rest (Table 2). Relatively small portions of the SBSmc subzone are comprised of lakes, clearings, herb-shrub, and pole-sapling seral stage habitat types. Young forest, mature forest and old growth seral stage habitat types dominate this subzone (Table 2).

Table 1. Seral stage classification of habitats in the Emerson Creek study area (adapted from Hamilton 1988).

SERAL STAGE	SERAL CLASSIFICATION
0	Nonvegetated
1	Herb-Shrub
2	Pole-Sapling
3	Young Forest
4	Mature Forest
5	Old Growth

Table 2. Habitat types occurring in the Emerson Creek study area.

HABITAT TYPE			SYMBOL	AREA (ha)	PERCENT OF STUDY AREA
Subzone	Site Unit	Seral Stage			
SBSdk	Dry Pine	Young Forest	dk DP 3	22	0.4
		Herb-Shrub	dk RP 1	85	1.4
	Rose Peavine	Pole-Sapling	dk RP 2	39	0.7
		Young Forest	dk RP 3	248	4.2
		Mature Forest	dk RP 4	190	3.2
		Thimbleberry Forb	Herb-Shrub	dk TF 1	23
	Thimbleberry Forb	Pole-Sapling	dk TF 2	19	0.3
		Young Forest	dk TF 3	142	2.4
		Mature Forest	dk TF 4	75	1.3
		Horsetail Flat	Mature Forest	dk HF 4	1
	Cottonwood Bottomland	Herb-Shrub	dk CB 1	28	0.5
		Pole-Sapling	dk CB 2	1	< 0.1
		Young Forest	dk CB 3	21	0.3
		Mature Forest	dk CB 4	16	0.3
	Nonforested Wetland	Herb-Shrub	dk NW 1	3	0.1
	Cultivated Land	Herb-Shrub	dk CU 1	96	1.6
	Clearing	Herb-Shrub	dk C 1	11	0.2
SBSdk TOTAL				1020	17.3
SBSmc	Dry Pine	Herb-Shrub	mc DP 1	9	0.1
		Pole-Sapling	mc DP 2	8	0.1
		Young Forest	mc DP 3	218	3.7
		Mature Forest	mc DP 4	45	0.8
	Huckleberry Moss	Herb-Shrub	mc HM 1	266	4.5

Table 2. Continued.

HABITAT TYPE			SYMBOL	AREA (ha)	PERCENT OF STUDY AREA
Subzone	Site Unit	Seral Stage			
SBSmc	Huckleberry Moss	Pole-Sapling	mc HM 2	192	3.2
		Young Forest	mc HM 3	1028	17.4
		Mature Forest	mc HM 4	396	6.7
		Old Growth	mc HM 5	682	11.5
	Thimbleberry Oakfern	Herb-Shrub	mc TO 1	156	2.6
		Pole-Sapling	mc TO 2	39	0.7
		Young Forest	mc TO 3	189	3.2
		Mature Forest	mc TO 4	177	3.0
		Old Growth	mc TO 5	419	7.1
	Devil's Club	Herb-Shrub	mc DC 1	83	1.4
		Pole-Sapling	mc DC 2	9	0.2
		Young Forest	mc DC 3	3	< 0.1
		Mature Forest	mc DC 4	97	1.6
		Old Growth	mc DC 5	635	10.8
	Horsetail Flat	Herb-Shrub	mc HF 1	3	< 0.1
		Mature Forest	mc HF 4	22	0.4
		Old Growth	mc HF 5	42	0.7
	Cottonwood Bottomland	Herb-Shrub	mc CB 1	2	< 0.1
		Young Forest	mc CB 3	5	0.1
		Mature Forest	mc CB 4	14.7	0.2
	Glow Moss	Young Forest	mc GM 3	1	< 0.1
		Mature Forest	mc GM 4	14	0.2
		Old Growth	mc GM 1	1	< 0.1

Table 2. Continued.

HABITAT TYPE			SYMBOL	AREA (ha)	PERCENT OF STUDY AREA
Subzone	Site Unit	Seral Stage			
SBSmc	Forested Wetland	Young Forest	mc FW 3	1	< 0.1
		Mature Forest	mc FW 4	26	0.5
	Nonforested Wetland	Herb-Shrub	mc NW 1	55	0.9
	Clearing	Herb-Shrub	mc C 1	1	< 0.1
	Lake	Nonvegetated	mc L 0	50	0.9
SBSmc TOTAL				4889	82.7
STUDY AREA TOTAL				5909	100.0

CHAPTER 1

HABITAT SELECTION BY MARTEN AT A LANDSCAPE SCALE

Introduction

Hansen (1989) stated that "in simplest terms, a landscape can be visualized as containing just two patch types: those offering suitable habitats for a species and those that are unsuitable". He further stated that "a landscape patch is likely to be suitable habitat if it offers the type of resources the animal can use and if these are distributed at space and time scales that correspond to the spatial and temporal scaling of the animal". It is important to note that what may be a landscape scale for a species with a small home range may be something very different for one with a large home range. Thus, landscape should be defined in the context of the study animal. The examination of landscape scale habitat use by marten entails the study of home range size, location and composition within a broad or regional context (e.g. watersheds). Use of the landscape by marten may also be reflected in relative productivity of broad ecological types.

The majority of research on habitat use by marten has been conducted at the stand scale - specifically examination of the use of particular habitat types (Soutiere 1979, Steventon and Major 1982, Spencer et al. 1983, Buskirk 1984, Hargis and McCullough 1984, Snyder and Bissonette 1987). However, some studies have used a broader approach. Buskirk and MacDonald (1989) reviewed home range sizes of

marten in North America and determined that between-site differences existed for male marten and that these needed to be investigated in light of contributing ecological factors. Slough (1989) described general home range composition of introduced marten in the Yukon Territory. Steventon and Major (1982) examined use of habitat in the context of landscape (in this case their study area) and found inconclusive results for 3 radio-collared marten. A number of researchers (Soutiere 1979, Steventon and Major 1982, Bissonette et al. 1989) examined marten use of the landscape using a coarse-grained habitat classification of harvested and residual (uncut) stands of softwood or mixed-wood forests. Some of these studies in part rely on stand scale analyses and this must be considered when interpreting or assessing their results.

My objective is to examine habitat selection by marten at the landscape scale. That is, given the range of ecologically defined habitats types available within a specific area, are particular types preferred or avoided? Landscape scale selection would likely occur if one biogeoclimatic subzone provided more suitable habitat or was more productive for marten than other subzones (*sensus* Hansen 1989). This selection would also be revealed by composition of habitat types within marten home ranges compared to availability of habitat types within the landscape.

I hypothesize that the climatic, vegetation and structural differences between the two subzones will be reflected in their productivity as marten habitat. I expect that there will be a greater density of marten in the SBSmc subzone than the SBSdk subzone. The SBSmc subzone, particularly the mature forest and old growth seral stages, is more typical of older, coniferous dominated forests that have been

traditionally thought to provide winter habitat for marten. Also, I expect marten to disproportionately include in their home ranges some habitat types and avoid or minimize the inclusion of others. Specifically, because at a stand scale marten have often been reported as preferring mesic, mature and old growth habitat types (Koehler et al. 1975, Steventon and Major 1982, Spencer et al. 1983), I hypothesize that these preferences will be reflected at the landscape scale of habitat use. I hypothesize that marten will avoid including young seral stages (herb-shrub and pole-sapling) within home ranges. Although many habitat types may be included within a home range, I expect that the habitat types preferred at the landscape scale will account for most of the area within home ranges.

Materials and Methods

Marten were live-trapped in Tomahawk traps (24x25x66 cm) baited with combinations of meat scraps, fish, jam and commercial marten lure. Traps were placed every 250 m along roads and skid trails throughout the study area. Captured marten were run into a handling cone (Archibald and Jessup 1984) and weighed. They were immobilized with a 2:1 mixture of ketamine hydrochloride and xylazine hydrochloride (both 100 mg/ml) at a combined dosage of 2 mg/100 g body weight.

Marten were ear-tagged with individually numbered metal ear tags in both ears for future identification (Model 1005-1, National Band and Tag Co.) and equipped with radio collars (Model SMRC-5, Lotek Engineering Inc.). Radio collar life was a

maximum of 5-6 months which spanned most of a winter sampling season. During the 1987/88 and 1988/89 trapping sessions, adult resident marten were collared. Resident marten were defined as those that had been in the study area for at least three months. In the 1989/90 trapping season, radio collars were placed on all adult marten that were live-trapped. Adults were distinguished from juveniles by weight, size of sagittal crest, size of baculum and tooth wear. Sex was determined by palpation for the baculum and examination for nipples. A premolar tooth was removed for aging by cementum analysis (Dix and Strickland 1986). Weight, body length, hind and fore limb length, hind foot length, neck girth and chest girth were measured. Marten were released at the point of capture once they had completely recovered from the immobilization drugs, usually within 1 hour.

Marten were monitored throughout the winter season, starting in December and ending in April. Marten were monitored on a daily basis when possible. Monitoring was done with Telonics TR-2 receiver/scanners and 4 element Yagi antennas. Permanent telemetry stations were established throughout the study area. Bearings were recorded on a UTM coordinate system and locations were calculated using the Maximum Likelihood Estimator (MLE) method with "Locate II" (Nams 1990). Harmonic mean home ranges (Dixon and Chapman 1980), exclusive of outliers (Ackerman et al. 1989), were derived for radio-collared marten for which there were a suitable number of locations (Clark et al. 1989). Home ranges of marten were calculated using "Program Home Range" (Ackerman et al. 1989). Home ranges were overlaid on the study area habitat map using a geographic information system

(PAMAP Systems), and the resultant habitat type composition of each home range was determined. Habitat compositions of home ranges were compared to that of the mapped intensive study area using Chi-square goodness of fit tests and Bonferroni use/availability statistics (Neu et al. 1974). All significances are reported at the $P \leq 0.05$ level. Habitat analyses were limited to those habitat types which comprised at least 1% of the study area.

Results

Forty-one trapping sessions (ranging from 3 to 18 days in length) were conducted from October 1987 to December 1990. These totalled 10820 trap nights, 1905 in the SBSdk and 8915 in the SBSmc. Fifty-one different marten were captured on 265 different occasions throughout the duration of the study. Three of these marten escaped from the handling cone before they could be immobilized, and hence no information exists for them. Forty-seven marten were live-trapped in the SBSmc subzone compared to only 7 trapped in the SBSdk subzone (Fig. 1.1). Three marten were trapped in both subzones. Of those trapped in the SBSmc subzone 25 (53%) were adults (16 (34%) males, 9 (19%) females), 17 (36%) were subadults (13 (28%) males, 4 (9%) females) and 5 (11%) were unclassified. Of those captured within the SBSdk subzone, 4 (57%) were adults (1 (14%) male, 3 (43%) females), 2 (29%) were subadults (both male) and 1 (14%) was unclassified. The age class/sex composition of

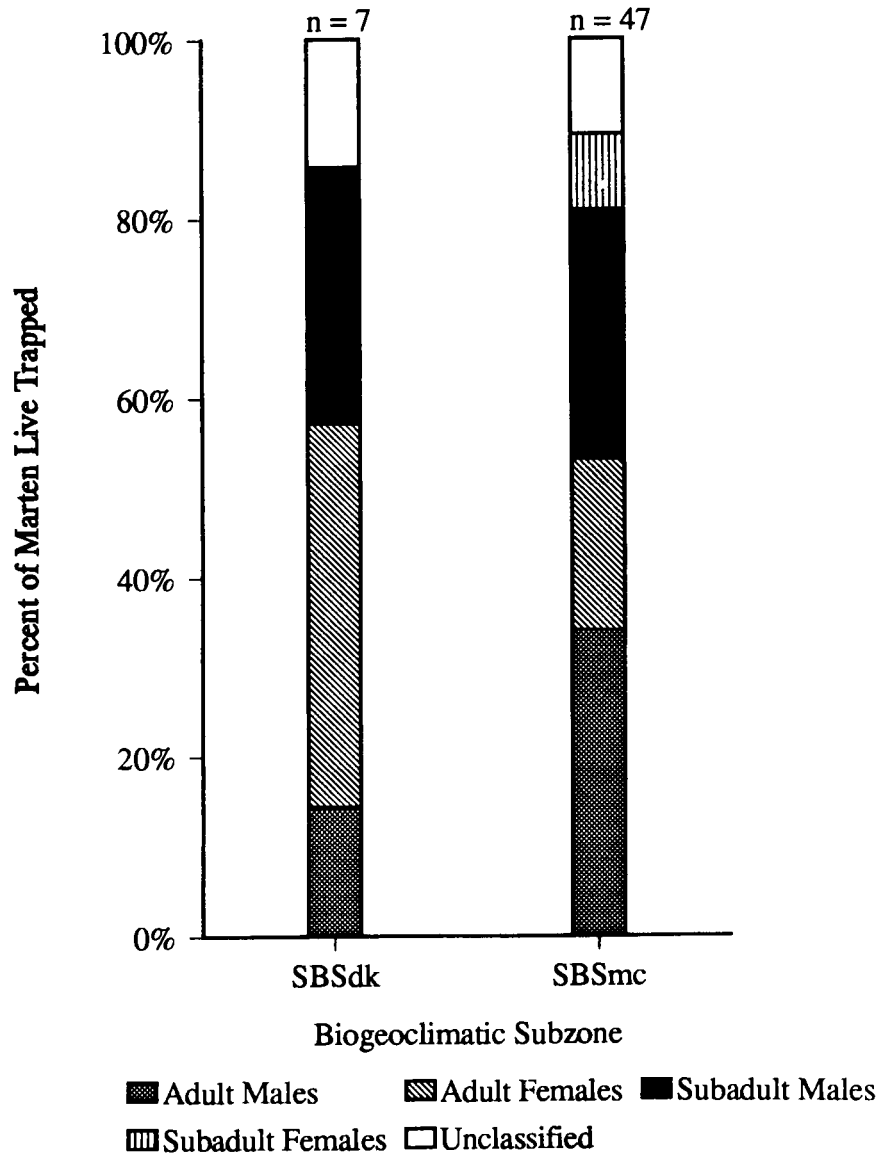


Figure 1.1. Age class and sex composition of marten live captured in each biogeoclimatic subzone.

captured marten was significantly different ($\chi^2 = 16.07$; 1,3 df; $0.005 < P < 0.001$) between subzones, however the small sample from the SBSdk limits comparisons. Capture success (captures/100 trap nights) was approximately 8 times greater in the SBSmc subzone than in the SBSdk subzone for both total captures (3.87 vs 0.47, $t = -3.17$, $P < 0.01$) and number of different individual marten captured (2.73 vs 0.35, $t = -2.13$, $P < 0.01$) (Fig. 1.2).

Eighteen marten were instrumented with radio collars (Table 1.1). Three marten were fitted with radio collars in more than one winter field season. Few locations were obtained for many of the radio-collared marten due to a variety of circumstances. Seventeen of the 48 marked marten were harvested by trappers (5 of these were currently or had been instrumented with radio collars). Most of these were trapped within 5 km of the study area, however three marten were trapped 51, 82, and 82 km (straight line distance) from the study area. Radio collar failures also accounted for loss of information. Ten marten were monitored intensively. A suitable number of locations to allow home range analyses (Clark et al. 1989 suggest 30-40 locations for marten) was obtained for 7 of these animals (Table 1.1). The number of locations obtained for each radio-collared marten ranged from 2 (M88176) to 91 (M88105). Home range sizes averaged 5.25 km^2 for males ($n = 4$, mean number of locations = 69) and 3.16 km^2 for females ($n = 3$, mean number of locations = 46) and 4.35 km^2 overall (mean number of locations = 59) (Table 1.1).

Use-availability analyses (Neu et al. 1974) revealed that only 6 of 19 habitats comprised proportionately more of marten home ranges than they did of the study area

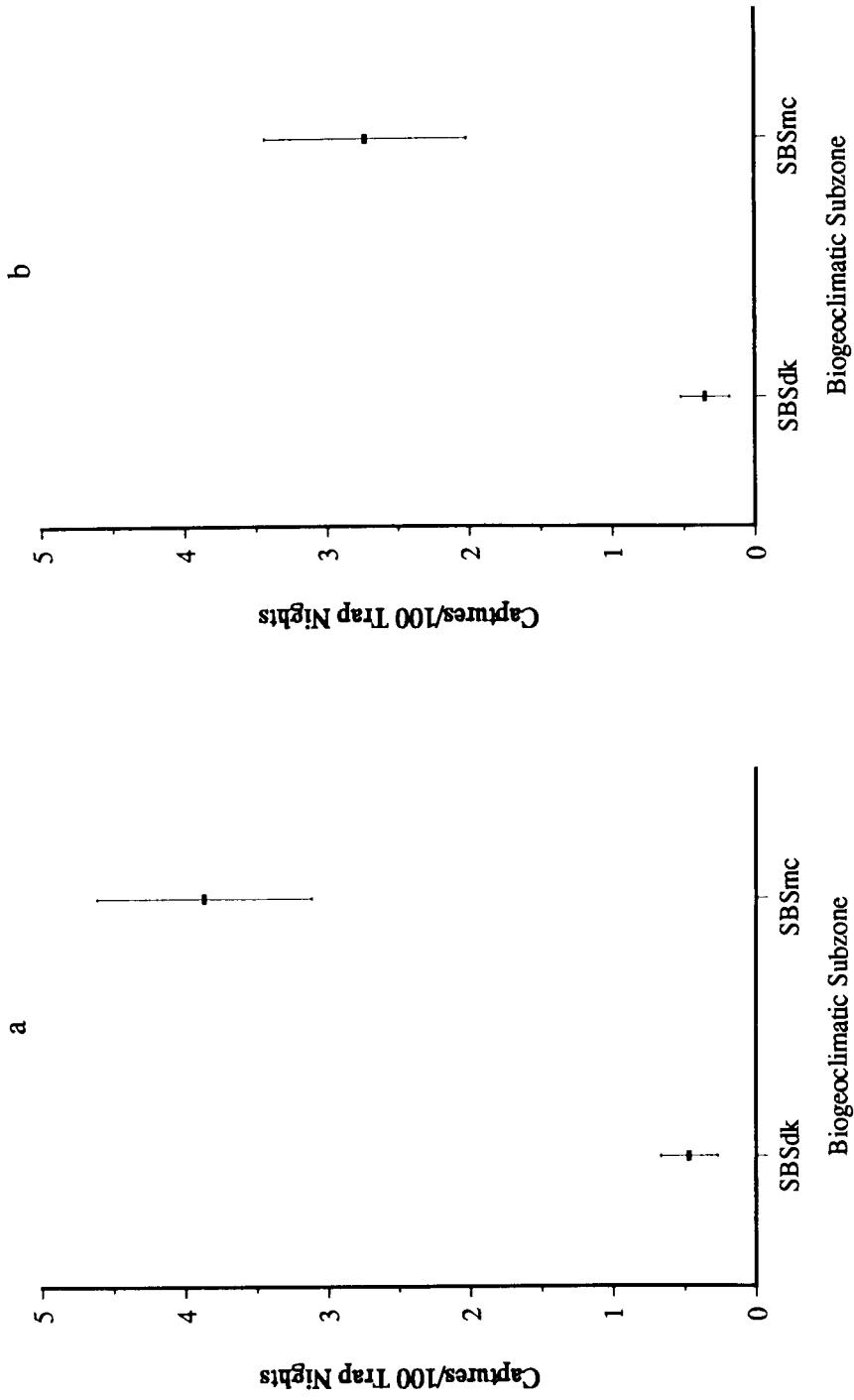


Figure 1.2. Mean number (+/- SE) of marten captures/100 trap nights (a) and mean number of individual marten captured/100 trap nights (b) in each biogeoclimatic subzone.

Table 1.1. Home range size, age class, sex and number of locations for radio-collared marten.

MARTEN	AGE CLASS	SEX	LOCATIONS	HOME RANGE SIZE (km ²) ^a
M88105	Adult	Male	91	6.27
M88107	Adult	Male	6	4.72 ^b
M88108	Adult	Male	78	4.05
M88121	Adult	Male	7	4.09 ^b
M88122	Adult	Male	9	2.95 ^b
M88152	Adult	Male	49	6.12
M89160	Adult	Male	5	8.36 ^b
M89161	Adult	Male	9	8.53 ^b
M89172	Adult	Male	58	4.55
M88106	Adult	Female	21	2.11 ^b
M88112	Adult	Female	39	3.82
M89159	Subadult	Female	4	bc
M89164	Adult	Female	9	7.92 ^b
M89170	Adult	Female	55	4.41
M89173	Adult	Female	15	2.26 ^b
M89175	Adult	Female	44	1.25
M89176	Adult	Female	2	bc
M89177	Adult	Female	15	10.05 ^{bd}

a - excludes outlier locations (Ackerman et al. 1989)

b - not used in home range and habitat use analyses due to low number of locations

c - not enough locations to calculate home range

d - all but 2 locations are outside of the mapped intensive study area

(Table 1.2). Of these, three were mature forest seral stage and three were old growth seral stage. No early seral stage habitats were found in significantly greater proportion in marten home ranges than they are in the study area. All of the SBSdk habitats comprised significantly less of marten home ranges than they comprised of the study area for 6 of the 7 martens. Four additional habitats were represented significantly less within more than half of the home ranges than they were within the study area. These habitats were all young forest seral stage or younger. On average, 72.2% of the area of marten home ranges were mature forest and old growth (Table 1.3). Marten home ranges are composed primarily of mesic (mc HM) to hygric (mc DC) habitats ranging in successional stage from young forest to old growth (Fig. 1.3).

Discussion

Differences in capture rates between the two subzones likely reflect differences in density of marten. Brainerd (1990) suggested that lower value/suboptimal habitats may act as sinks (Pulliam and Danielson 1991) for dispersing juveniles. My trapping results do not indicate a larger proportion of juveniles trapped in the SBSdk, the subzone with the lowest capture rates, however sample sizes for this subzone are small. Capture success in the SBSmc (3.87) is greater than those of De Vos (1952) (2.04), De Vos and Guenther (1952) (2.64), and Raphael (1986) (1.41), and less than those of Baker (1993) (4.06), Miller et al. (1955) (7.04), Newby and Hawley (1954) (11.1), and Weckwerth and Hawley (1962) (11.9). Capture rates indicate that the

Table 1.2. Habitat preferences of radio-collared marten in winter at the landscape scale (based on Bonferroni Z statistics at $P \leq 0.05$ level of significance; "-" = used less than available, "0" = used in proportion to availability, "+" = used more than available). Selectivity is the proportion of radio-collared marten with that preference type.

HABITAT TYPE	MARTEN							SELECTIVITY		
	M88105	M88108	M88112	M88152	M89170	M89172	M89175	-	0	+
	n = 83	n = 62	n = 37	n = 45	n = 53	n = 54	n = 43			
dk CU 1	-	-	-	-	-	-	-	7/7	0/7	0/7
dk RP 1	-	-	-	-	-	-	-	7/7	0/7	0/7
dk RP 3	-	-	-	-	-	-	0	6/7	1/7	0/7
dk RP 4	-	-	-	-	-	-	+	6/7	0/7	1/7
dk TF 3	-	-	-	-	-	-	0	6/7	1/7	0/7
dk TF 4	-	-	-	-	-	-	+	6/7	0/7	1/7
mc DC 1	0	0	0	0	0	-	0	1/7	6/7	0/7
mc DC 4	0	0	0	0	0	0	-	1/7	6/7	0/7
mc DC 5	+	0	0	0	+	-	-	2/7	3/7	2/7
mc DP 3	-	0	-	0	-	0	-	4/7	3/7	0/7
mc HM 1	-	-	-	0	-	-	0	5/7	2/7	0/7
mc HM 2	0	-	0	0	-	0	-	3/7	4/7	0/7

Table 1.2. Continued.

HABITAT TYPE	MARTEN							SELECTIVITY		
	M88105	M88108	M88112	M88152	M89170	M89172	M89175	-	0	+
mc HM 3	-	0	-	0	-	0	-	4/7	3/7	0/7
mc HM 4	0	0	0	0	0	0	+	0/7	6/7	1/7
mc HM 5	+	+	0	0	+	0	-	1/7	3/7	3/7
mc TO 1	0	0	-	0	-	-	0	3/7	4/7	0/7
mc TO 3	-	0	-	0	-	0	-	4/7	3/7	0/7
mc TO 4	0	-	0	0	0	0	0	1/7	6/7	0/7
mc TO 5	+	0	+	0	+	0	-	1/7	3/7	3/7

Table 1.3. Home range composition of radio-collared marten in winter at the landscape scale. Numbers represent the percentage of home range comprised by each habitat type.

HABITAT TYPE	M88105	M88108	M88112	M88152	M89170	M89172	M89175	MEAN
dk CU 1								0.0
dk RP 1								0.0
dk RP 3							10	1.4
dk RP 4							21	3.0
dk TF 3							1	0.1
dk TF 4							14	2.0
mc DC 1	1	1	1	1	2		1	1.0
mc DC 4	5	2	8	5	4	6		4.3
mc DC 5	26	13	22	6	32	2		14.4
mc DP 3		2		2		2		0.8
mc HM 1	1	1	1	2			13	2.6
mc HM 2	1		1	2		2		0.9
mc HM 3	1	20		24		27	3	10.7
mc HM 4	8	7	11	13	5	15	20	11.3
mc HM 5	25	25	23	9	27	10		17.0

Table 1.3. Continued.

HABITAT TYPE	M88105	M88108	M88112	M88152	M89170	M89172	M89175	MEAN
mc TO 1	2	3		1			4	1.4
mc TO 3		4		7		7		2.6
mc TO 4	3		2	7	2	12	12	5.4
mc TO 5	21	17	25	11	27	4		15.0

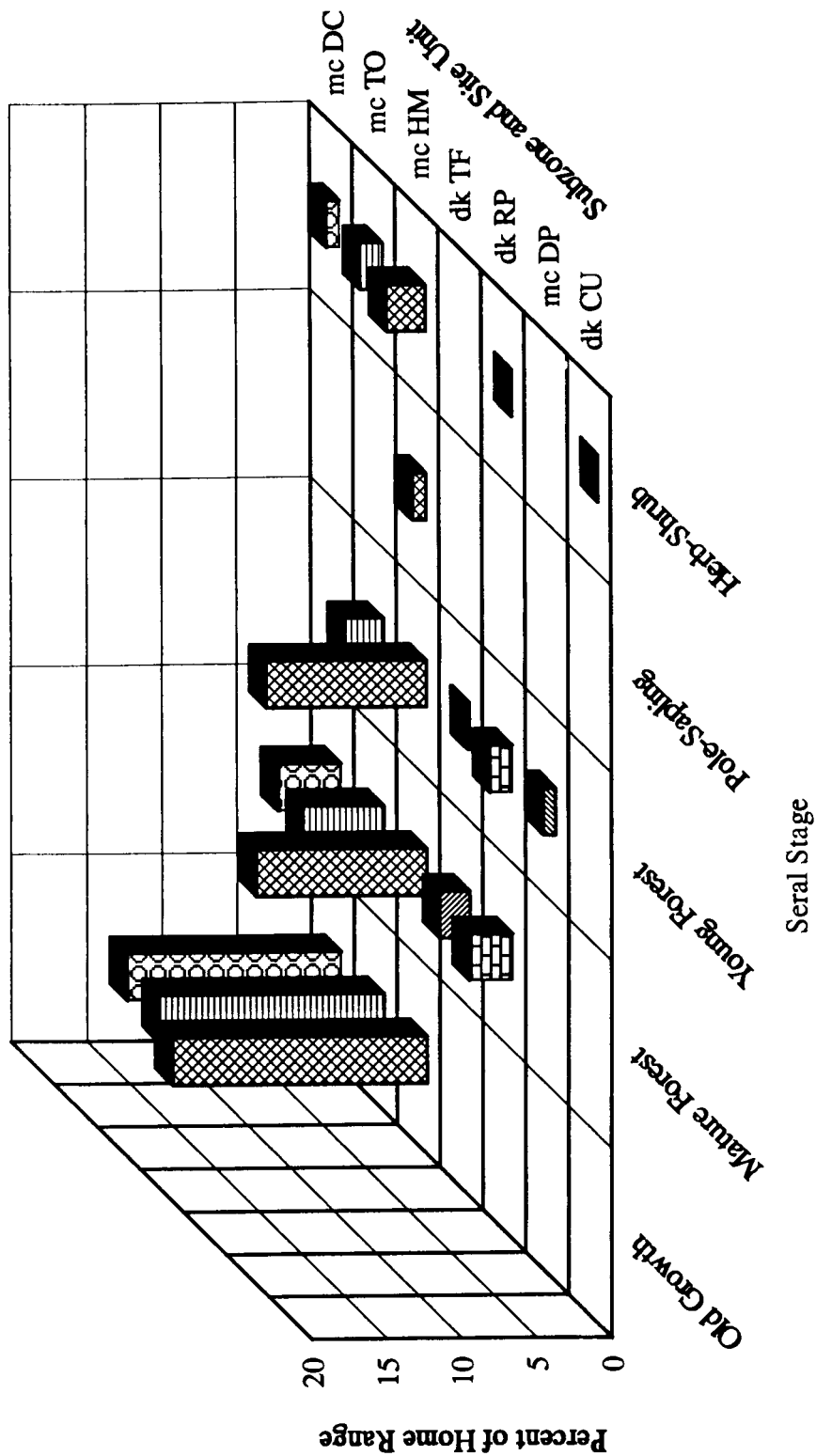


Figure 1.3. Mean habitat type composition of radio-collared marten home ranges (n=7) in winter in the Emerson Creek study area.

abundance of marten in the Emerson Creek study area is within the range observed elsewhere in North America.

Home range sizes of marten in the Emerson Creek study area are within the range of mean sizes of 2.0 - 15.7 km² for adult males and 0.8 - 8.4 km² for females reported in the literature (Strickland and Douglas 1987), but near the low end of this range. Females' home ranges were slightly larger than half the size of males' home ranges, a finding consistent with the literature (Strickland and Douglas 1987). Six of the 7 home ranges were contained entirely within the SBSmc subzone. The seventh home range (M89175) straddled the boundary between the 2 subzones. The only marten whose entire home ranges were contained entirely within the SBSdk subzone were 2 adult females (M89173 and M89177). Both had too few locations to adequately determine their home range size. However, based on available data, their home ranges were 2.26 km² and 10.05 km² respectively. Home range estimates typically increase with additional locations (Clark et al. 1989). This suggests that given adequate sample sizes, home range estimates for both marten would be larger than those of marten in the SBSmc. This observation is consistent with Soutiere's (1979) thesis that marten inhabiting younger seral stages generally occur at lower densities and have larger home ranges than those inhabiting older seral stages. The SBSdk subzone is generally composed of younger forests with a much larger component of deciduous forest than the SBSmc. Because of the differences in densities and home range sizes, it appears that the SBSmc subzone provides winter habitat that is more suitable for marten than the SBSdk subzone.

Results of my use-availability analyses are, for the most part, consistent with studies that examined stand scale habitat use by marten (Soutiere 1979, Snyder and Bissonette 1987, Bissonette et al. 1989, Slough 1989). My results indicate, however, that in spite of social and other factors affecting home range establishment, marten prefer to include some habitat types and avoid including others when establishing home ranges. At Emerson Creek, habitats "preferred" at a landscape or home range scale are mesic to hygric site units of mature forest or old growth seral stages. Habitats that are consistently or commonly "avoided" include all of the early seral stage SBSdk habitats and a number of the early seral stage habitats in the SBSmc subzone.

Although only a few habitat types comprised most of each marten's home range, there were a large number of habitat types contained within their home range (mean = 11 habitat types). This diversity could provide opportunities for marten faced with seasonal and annual variation in ecological conditions. There was considerable variability in preference for some of the mid-seral stage habitat types (e.g. mc DP 3, mc HM 2, mc HM 3, mc TO 3). Marten which made greatest use of these habitat types were large adult males. These habitat types had the greatest densities of snowshoe hare (*Lepus americanus*) sign (MOELP unpub. data) and my habitat use data were collected at a high in the hare cycle. Remains of snowshoe hare were present in 9.8% of marten scats collected in the study area (Park 1991). Marten are sexually dimorphic, with males substantially larger than females (Strickland and Douglas 1987). Perhaps the large size of males increases their capability of killing large prey such as

snowshoe hare and allows them to exploit these younger seral stages. Raphael (1986) states that although large areas of homogenous mature forest may support more marten in a given area at one point in time, a diversity of forest communities may support more marten over the long term. Inclusion of a number of habitats within a home range, regardless of their abundance in the landscape may be a reflection of this strategy. A diversity of habitats within home ranges may allow marten to extend their behavioral flexibility to take advantage of increased foraging opportunities such as cyclic events in prey populations.

Ruggiero (1991) notes that when a population is substantially more abundant in a given habitat than any other, it is "closely associated" with that habitat and this should be interpreted to indicate an ecological requirement for persistence. Marten are clearly more abundant in the SBSmc subzone and within that subzone their home range composition "closely associates" them with mature forest to old growth seral stages of mesic to hygric moisture regimes. I conclude that habitat selection occurs at the landscape scale for marten and that this is reflected in density of marten and habitat composition of their home ranges.

CHAPTER 2

HABITAT SELECTION BY MARTEN AT A STAND SCALE

Introduction

Marten inhabit a broad range of North American forest ecosystems (Strickland and Douglas 1987). Within these ecosystems, habitat selectivity by marten has been demonstrated by a number of researchers (Campbell 1979, Soutiere 1979, Burnett 1981, Kelly 1982, Steventon and Major 1982, Taylor and Abrey 1982, Raine 1983, Spencer et al. 1983, Buskirk 1984, Hargis and McCullough 1984, Wynne and Sherburne 1984, Bateman 1986, Magoun and Vernam 1986, Thompson 1986, Fredrickson 1990, Fager 1991, Baker 1992). Most of these studies have reported that marten use a variety of habitats, but tend to prefer old forest conditions characterized by mesic sites, dense canopy closure, abundant coarse woody debris (CWD) and abundant snags. These habitat attributes are important to marten because they are associated with the habitat's capability to provide shelter, access to foraging sites and food.

Voles are one of the principal prey of marten (Strickland and Douglas 1987) and mesic sites support denser vole populations than do other sites (Koehler et al. 1975, Corn et al. 1988). Small mammal abundance has also been positively correlated with high closure of low shrubs, which may be related to site productivity and the subnivean (beneath the snow) spaces provided by snow-preserved shrubs. Marten prefer

forests with 30% to 80% canopy closure (Koehler et al. 1975, Spencer et al. 1983, Buskirk 1984). High canopy closure provides suitable thermal cover (Kelly 1982) and security from aerial predators (Allen 1982, Strickland and Douglas 1987). It is important that coniferous rather than deciduous trees provide the canopy closure so that the integrity of the canopy is maintained all winter.

Coarse woody debris is related to a number of marten's life requisites. Small mammals use coarse woody debris as security and thermal cover. Winter hunting sites of marten for small mammalian prey are subnivean and coarse woody debris provides access to and about these sites (Clark and Campbell 1977, Steventon and Major 1982, Hargis and McCullough 1984). Access to winter hunting sites may also be provided by the interstitial spaces created when large shrubs (> 2 m) are bent over and partially buried by snow. Not only is coarse woody debris important for foraging, but it also provides resting sites (Clark and Campbell 1977, Steventon and Major 1982, Spencer et al. 1983, Buskirk 1984, Spencer 1987, Buskirk et al. 1989, Martin and Barrett 1991, Corn and Raphael 1992, Wilbert 1992). Few studies quantify coarse woody debris characteristics, however, data from Spencer et al. (1983) and Corn and Raphael (1992) suggest that marten prefer sites with at least 100 m³/ha of coarse woody debris. Snags and large live trees are also important for the provision of resting sites (Wilbert 1992). Spencer et al. (1983) found that marten preferred habitats with > 40 m²/ha basal area of trees and > 12 m²/ha basal area of snags and Wilbert (1992) reported that diameters of trees which had resting sites within their boles were \geq 23 cm.

In Chapter 1, I demonstrated that habitat selection by marten occurs at the

landscape scale. However, does selectivity occur at a finer scale (*sensus* Johnson 1980)? To test the generality of the trends reported in the literature and their applicability to the SBS zone, I examined habitat use and selectivity by marten at the stand scale. The first objective of this chapter is to describe marten's use of habitat types at the stand scale. That is, given the range of habitat types available within a marten's home range are there particular types that are avoided or preferred? I will test the following null hypothesis:

1. H_0 : Marten will not exhibit habitat type selectivity within their home range, i.e. they will use habitat types in proportion to their availability.

Habitat types are products of anthropogenic classifications which conveniently group vegetation communities into similar categories. This classification scheme is based on criteria defined by the researcher and may be appropriate for some purposes but not others. If responses of animals do not conform with these criteria or they conform at some scales and not others then the classification scheme may be effectively transparent to the study species, and habitat analyses would suggest animals are indifferent in their use of habitat, at least as the researcher classified it. Perhaps animals are sensitive to other more utilitarian criteria, such as structural features. Affinities for particular structural features may span vegetation classifications and account for more of the variation in habitat use.

The second objective of this chapter is to examine habitat preferences in regard

to a number of structural habitat attributes including characteristics of coarse woody debris, snags, trees, and vegetation strata. I will test the following null hypotheses:

2. H_0 : Marten electivity indices for different classes of coarse woody debris abundance will not be significantly different from zero.
3. H_0 : Marten electivity indices for different classes of vegetation strata closure will not be significantly different from zero.
4. H_0 : Marten electivity indices for different classes of basal area or stocking of trees will not be significantly different from zero.
5. H_0 : Marten electivity indices for different classes of basal area, stocking or diameter of snags will not be significantly different from zero.

Materials and Methods

Marten were captured and instrumented with radio collars as described in Chapter 1. Radio-collared marten were monitored daily in an attempt to obtain one relocation/marten/day. Marten activity was classified on the basis of signal strength characteristics over the duration of time required to obtain the telemetry fix. Marten were considered as immobile if and only if no variability in signal was heard during the relocation process. I assumed these locations represent resting sites. Marten were considered as mobile if signal strength varied during the fix. I assumed these locations represent travel and foraging sites.

Marten locations were calculated using the maximum likelihood estimator technique with Locate II (Nams 1990). Locations were limited to those with error areas of < 1 ha and were recorded in UTM grid coordinates to the nearest metre. Harmonic measure home ranges, exclusive of outliers (Ackerman et al. 1989), were calculated as described in Chapter 1. Marten locations were overlaid on the habitat map of the intensive study area using a geographic information system (PAMAP Systems) and habitat types were assigned to locations on this basis. Locations in map polygons comprised of habitat complexes were weighted by habitat types proportionately to the areal extent of each habitat type (e.g. 0.6 locations to habitat A, 0.4 locations to habitat B). Habitat summaries of marten home ranges were obtained as described in Chapter 1.

Habitat attribute data were collected for all habitat types found within the study area. The study area was gridded at 100 m intervals. This grid was then grouped into blocks of 25 grid intersection points. Blocks were randomly sampled and habitat attribute data was collected at each of the 25 points in the selected blocks. Coarse woody debris volumes were estimated using methods for assessing fuel loading for prescribed fire (Van Wagner 1968, Brown 1974, Trowbridge et al. 1987). Coarse woody debris was classified as either hard or soft. I defined CWD as hard when less than 1/4 of the diameter of the log was rotten enough to be easily removed by scuffing it with the observer's foot. All other CWD was considered soft. Mensuration data for live trees and snags were obtained by conducting variable radius cruise plots at each sample point. Percent closure was estimated (Luttmerding et al. 1990) for coniferous

canopy, deciduous canopy, high shrub (2-10 m), and low shrub (0-2 m) strata.

Sampling was continued until at least 5 sample points were collected for each habitat type. A few habitat types were so uncommon that they were missed by this sampling method. These were sampled by randomly selecting, from the habitat map, polygons in which these habitat types occurred. Sample points were located within these polygons using the original sampling grid. For the most part, sampling intensity of each habitat type was proportional to the habitat's relative abundance within the study area.

Use-availability analyses were done using Chi-square goodness of fit tests and Bonferroni Z statistics (Neu et al. 1974). All habitat analyses were performed only on those habitats that comprised at least 1% of the home range being examined. This was done in an effort to eliminate interpretation problems associated with high use-availability ratios resulting from spurious locations in very rare habitat types. Habitat types were classed as being used significantly less than available (avoided), used in proportion to availability, or used significantly greater than available (preferred) within a marten's home range. These analyses were performed to test my null hypothesis that, within their home ranges, marten use habitat types in proportion to their availability. All significances are reported at the $P \leq 0.05$ level.

Marten use of habitats as a function of habitat attributes was examined by grouping habitats with similar features for each analyses (i.e. grouping habitats with similar mean coarse woody debris volumes for the coarse woody debris analyses). Vanderploeg and Scavia's relativized electivity indices (Lechowicz 1982) were calculated for each radio-collared marten's use of attribute classes. Chi-square

goodness of fit tests were conducted on these indices to test for differences between observed and expected electivity index values for habitat attribute classes. T-tests were conducted on pooled data to test for differences from no preference (electivity index value = 0) for each habitat attribute class. All significances are reported at the $P \leq 0.05$ level. Significantly negative electivity index values are referred to as "avoidance" and significantly positive electivity index values are referred to as "preference" throughout the remainder of this chapter. Spearman rank correlations were calculated to examine relationships between attribute classes and electivity indices.

Results

Use-availability analyses revealed that no habitat types were used significantly more than expected at either immobile or mobile locations (Tables 2.1 and 2.2). Most marten used 6 habitat types significantly less than available within their home ranges at mobile locations (Table 2.1). These were young seral stage habitat types (dk TF 1, mc NW 1), nonvegetated habitat types (mc L 0), xeric habitat types (mc DP 3, mc DP 4) and wetlands (mc FW 4). In addition to these, 7 habitat types were used significantly less than expected by at least some marten. These included 4 habitat types which were young forest seral stage or younger (mc DC 1, mc HM 2, mc HM 3, mc TO 1), and 3 mature forest seral stage habitat types (mc DC 4, mc HM 4, mc TO 4). Seventeen habitat types were used in proportion to their abundance by a majority of marten. These included all available seral stages in mesic to hygic site units.

Table 2.1. Habitat preferences of radio-collared marten in winter at the stand scale for mobile locations (based on Bonferroni Z statistics at $P \leq 0.05$ level of significance; "-" = used less than available; "0" = used in proportion to availability; "+" = used more than available). Blanks indicate that none of that habitat type occurred within that marten's home range. Selectivity is the proportion of radio-collared marten with that preference type.

HABITAT TYPE	MARTEN							SELECTIVITY		
	M88105 n = 58	M88108 n = 44	M88112 n = 23	M88152 n = 27	M89170 n = 37	M89172 n = 31	M89175 n = 32	-	0	+
dk RP 3							0	0/1	1/1	0/1
dk RP 4							0	0/1	1/1	0/1
dk TF 1							-	1/1	0/1	0/1
dk TF 4							0	0/1	1/1	0/1
mc DC 1			0	-	0			1/3	2/3	0/3
mc DC 4	0	-	0	-	0	0		2/6	4/6	0/6
mc DC 5	0	0	0	0	0	0		0/6	6/6	0/6
mc DP 3		-		-		0		2/3	1/3	0/3
mc DP 4			-	-		0		2/3	1/3	0/3
mc FW 4	-	-			-			3/3	0/3	0/3
mc HF 4						0		0/1	1/1	0/1
mc HF 5	0	0						0/2	2/2	0/2
mc HM 1				0			0	0/2	2/2	0/2

Table 2.1. Continued.

HABITAT TYPE	MARTEN								SELECTIVITY		
	M88105	M88108	M88112	M88152	M89170	M89172	M89175	-	0	+	
mc HM 2			0	0		-		1/3	2/3	0/3	
mc HM 3	0	0		0		0	-	1/5	4/5	0/5	
mc HM 4	0	0	-	0	-	0	0	2/7	5/7	0/7	
mc HM 5	0	0	0	0	0	0		0/6	6/6	0/6	
mc L 0	-	-		0				2/3	1/3	0/3	
mc NW 1	-	-		0				2/3	1/3	0/3	
mc TO 1	-	0		0			0	1/4	3/4	0/4	
mc TO 3		0		0		0		0/3	3/3	0/3	
mc TO 4	0		-	0	-	0	0	2/6	4/6	0/6	
mc TO 5	0	0	0	0	0	0		0/6	6/6	0/6	

Table 2.2. Habitat preferences of radio-collared marten in winter at the stand scale for immobile locations (based on Bonferroni Z statistics at $P \leq 0.05$ level of significance; "-" = used less than available; "0" = used in proportion to availability; "+" = used more than available). Blanks indicate that none of that habitat type occurred within that marten's home range. Selectivity is the proportion of radio-collared marten with that preference type.

HABITAT TYPE	MARTEN								SELECTIVITY		
	M88105 n = 25	M88108 n = 18	M88112 n = 14	M88152 n = 18	M89170 n = 16	M89172 n = 23	M89175 n = 11	-	0	+	
dk RP 3							0	0/1	1/1	0/1	
dk RP 4							0	0/1	1/1	0/1	
dk TF 1							-	1/1	0/1	0/1	
dk TF 4							-	1/1	0/1	0/1	
mc DC 1			0	0	0			0/3	3/3	0/3	
mc DC 4	0	-	0	-	0	0		2/6	4/6	0/6	
mc DC 5	0	0	0	0	0			1/6	5/6	0/6	
mc DP 3		-		-		0		2/3	1/3	0/3	
mc DP 4			0	0		0		0/3	3/3	0/3	
mc FW 4	-	-			-			3/3	0/3	0/3	
mc HF 4						-		1/1	0/1	0/1	
mc HF 5	-	0						1/2	1/2	0/2	
mc HM 1				0			0	0/2	2/2	0/2	

Table 2.2. Continued.

HABITAT TYPE	MARTEN										SELECTIVITY		
	M88105	M88108	M88112	M88152	M89170	M89172	M89175	-	0	+			
mc HM 2			-	0		-		2/3	1/3	0/3			
mc HM 3	-	0		0		0	-	3/5	2/5	0/5			
mc HM 4	0	0	0	0	-	0	-	2/7	5/7	0/7			
mc HM 5	0	0	0	-	0	0		1/6	5/6	0/6			
mc L 0	-	-		-				3/3	0/3	0/3			
mc NW 1	-	-		-				3/3	0/3	0/3			
mc TO 1	-	-		0			0	2/4	2/4	0/4			
mc TO 2						0		0/1	1/1	0/1			
mc TO 3		0		0		0		0/3	3/3	0/3			
mc TO 4	-		-	0	-	0	0	3/6	3/6	0/6			
mc TO 5	0	0	0	0	0	0		0/6	6/6	0/6			

Marten appeared to have stricter criteria for use of habitat types at immobile locations than they did for mobile locations (Table 2.2). Nine habitat types were used significantly less than their availability by most radio-collared marten. These included 5 habitat types of young forest seral stage or younger (dk TF 1, mc DP 3, mc HM 2, mc HM 3, mc NW 1), 1 nonvegetated habitat type (mc L 0), and 3 habitat types of mature forest seral stage (dk TF 4, mc FW 4, mc HF 4). Seven habitat types were used significantly less than expected by at least some marten. These included 1 habitat type of herb-shrub seral stage (mc TO 1), 3 habitat types of mature forest seral stage (mc DC 4, mc HM 4, mc TO 4) and 3 habitat types of old growth seral stage (mc DC 5, mc HF 5, mc HM 5). Eleven habitat types were used in proportion to their abundance by a majority of marten. Based on the above results I reject null hypothesis 1 and conclude that marten exhibit habitat selectivity within their home ranges, albeit by avoidance.

Tables 2.3 and 2.4 present percent use of habitat types by radio-collared marten. Mean percent habitat use for mobile locations (Table 2.3) (for those habitat types within more than one radio-collared marten's home range) by seral stage are: nonvegetated - 1.2%; herb-shrub - 3.0%; pole-sapling - 6.8%; young forest - 5.4%; mature forest - 5.5%; old growth - 20.5%. Mean percent habitat use for immobile locations (Table 2.4) are: nonvegetated - 0.0%; herb-shrub - 6.4%; pole-sapling - 12.8%; young forest - 6.0%; mature forest - 3.9%; old growth - 19.2%). These data indicate that a large portion of marten radio locations are found within old growth seral stages and that there is little difference in percentage use of particular habitat

Table 2.3. Percent habitat use by mobile radio-collared marten in winter at the stand scale. Numbers represent the percent of locations within each habitat.

HABITAT TYPE	M88105 n = 58	M88108 n = 44	M88112 n = 23	M88152 n = 27	M89170 n = 37	M89172 n = 31	M89175 n = 32	MEAN
dk RP 3							5.0	5.0*
dk RP 4							30.0	30.0*
dk TF 1							0.0	0.0*
dk TF 4							10.6	10.6*
mc DC 1			1.3	0.0	0.5			0.6
mc DC 4	4.3	0.0	11.7	0.0	4.1	10.3		5.1
mc DC 5	25.2	13.2	23.5	5.9	39.2	1.4		18.1
mc DP 3		0.0		0.0		0.3		0.1
mc DP 4			0.0	0.0		4.1		1.4
mc FW 4	0.0							0.0*
mc HF 4						3.1		3.1*
mc HF 5	1.7							1.7*
mc HM 1				3.7			10.0	6.9
mc HM 2			3.9	9.6				6.8
mc HM 3	1.6			15.2		24.5	0.0	10.3

Table 2.3. Continued.

HABITAT TYPE	M88105	M88108	M88112	M88152	M89170	M89172	M89175	MEAN
mc HM 4	4.1	6.3	0.4	10.4	0.0	20.3	24.4	9.4
mc HM 5	33.4	46.8	30.9	16.3	19.2	11.4		26.3
mc L 0	0.0	0.0		3.7				1.2
mc NW 1	0.0	0.0		7.4				2.5
mc TO 1	0.0	2.0		3.0			2.5	1.9
mc TO 2						2.1		2.1*
mc TO 3		2.4		4.1		11.0		5.8
mc TO 4	5.0		0.0	5.9	0.0	10.0	16.3	6.2
mc TO 5	19.0	10.0	23.9	12.6	33.2	4.5		17.2

* sample size = 1

Table 2.4. Percent habitat use by immobile radio-collared marten in winter at the stand scale. Numbers represent the percent of locations within each habitat.

HABITAT TYPE	M88105 n = 25	M88108 n = 18	M88112 n = 14	M88152 n = 18	M89170 n = 16	M89172 n = 23	M89175 n = 11	MEAN
dk RP 3							16.4	16.4*
dk RP 4							38.2	38.2*
dk TF 1							0.0	0.0*
dk TF 4							0.0	0.0*
mc DC 1			1.4	2.2	0.6			1.4
mc DC 4	3.2	0.0	10.0	0.0	5.6	4.8		3.9
mc DC 5	29.6	13.3	32.1	4.4	39.4	0.0		19.8
mc DP 3		0.0		0.0		6.8		2.3
mc DP 4			2.9	2.2		6.4		3.8
mc FW 4	0.0							0.0*
mc HF 4						0.8		0.8*
mc HF 5	0.0							0.0*
mc HM 1				5.6			36.4	21.0
mc HM 2			0.0	25.6				12.8
mc HM 3	0.0			16.7		21.6	0.0	9.6

Table 2.4. Continued.

HABITAT TYPE	M88105	M88108	M88112	M88152	M89170	M89172	M89175	MEAN
mc HM 4	4.0	11.1	4.3	8.3	0.0	11.2	0.0	5.6
mc HM 5	28.8	21.1	7.9	1.1	24.4	12.8		16.0
mc L 0	0.0	0.0		0.0				0.0
mc NW 1	0.0	0.0		0.0				0.0
mc TO 1	0.0	0.0		3.3			9.1	3.1
mc TO 2						1.6		1.6*
mc TO 3		3.9		5.6		9.2		6.2
mc TO 4	0.0		0.0	1.7	0.0	11.2	0.0	2.2
mc TO 5	33.2	12.2	38.6	13.3	30.0	3.2		21.8

* sample size = 1

types between immobile and mobile locations ($\chi^2_{(5)} = 10.96, 0.05 \leq P \leq 0.1$).

Chi-square goodness of fit tests were used to determine if significant differences exist between expected and observed use for the attributes of coarse woody debris (CWD), trees, snags and vegetation strata. Figures 2.1 through 2.12 show relationships between habitat attributes and preferences for 7 radio-collared marten. Marten exhibited increasing preferences for habitats with increasing amounts of CWD > 20 cm in diameter (Fig. 2.1; $r_s = 0.62, P \leq 0.01$ - immobile locations; $r_s = 0.46, P \leq 0.05$ - mobile locations). They avoided habitats with no CWD at immobile locations and preferred habitats with > 200 m³/ha CWD at both immobile and mobile locations. Mean electivity indices for mobile locations were negative (although nonsignificant) for all habitats with < 200 m³/ha CWD. Radio-collared marten also demonstrated a generally increasing preference for habitats with increasing volumes of hard CWD (Fig. 2.2; $r_s = 0.50, P \leq 0.01$ - immobile locations; $r_s = 0.48, P \leq 0.01$ - mobile locations). At immobile locations, they avoided habitats with no hard CWD and preferred habitats with 101-200 m³/ha hard CWD. At mobile locations, radio-collared marten preferred habitats with > 100 m³/ha hard CWD. Mean electivity index values for habitats with ≤ 100 m³/ha hard CWD were negative, but not significantly different from zero. Marten preferences for CWD generally follow the pattern of percent habitat use (Figs. 2.1 and 2.2). However, although use of habitats with 101-200 m³/ha CWD > 20 cm dbh was at least 10% less than use of habitats with 1-100 m³/ha, the mean electivity index was greater, an indication of the relative importance of these habitat classes (Fig 2.1). This figure indicates that more than 70% of marten habitat use is in

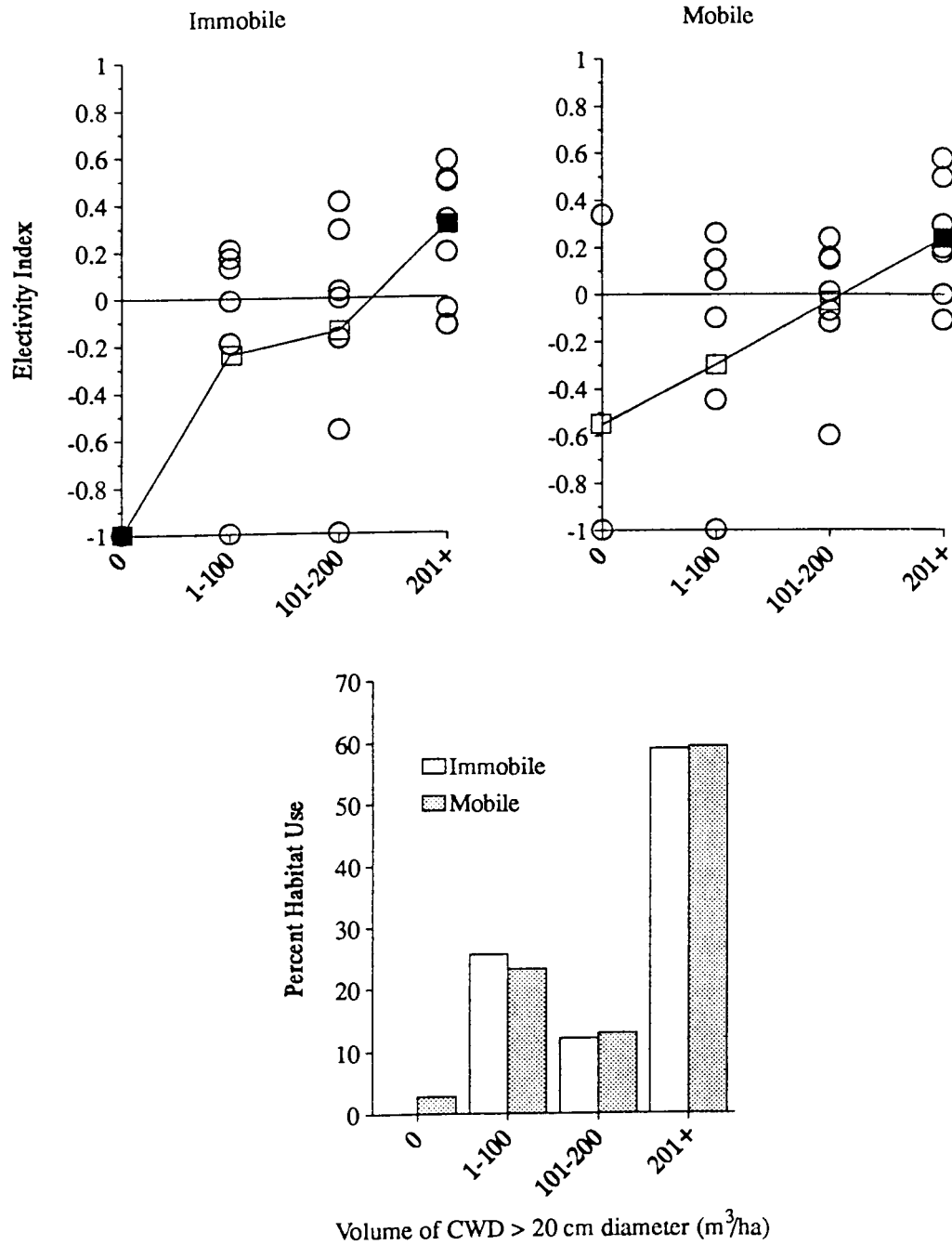


Figure 2.1. Marten electivity indices and percent habitat use at immobile and mobile locations for classes of coarse woody debris (> 20 cm diameter) volume (m^3/ha). Open circles indicate electivity values for individual martens. Squares indicate electivity values for pooled data. Filled squares indicate electivity values different ($P \leq 0.05$) from zero.

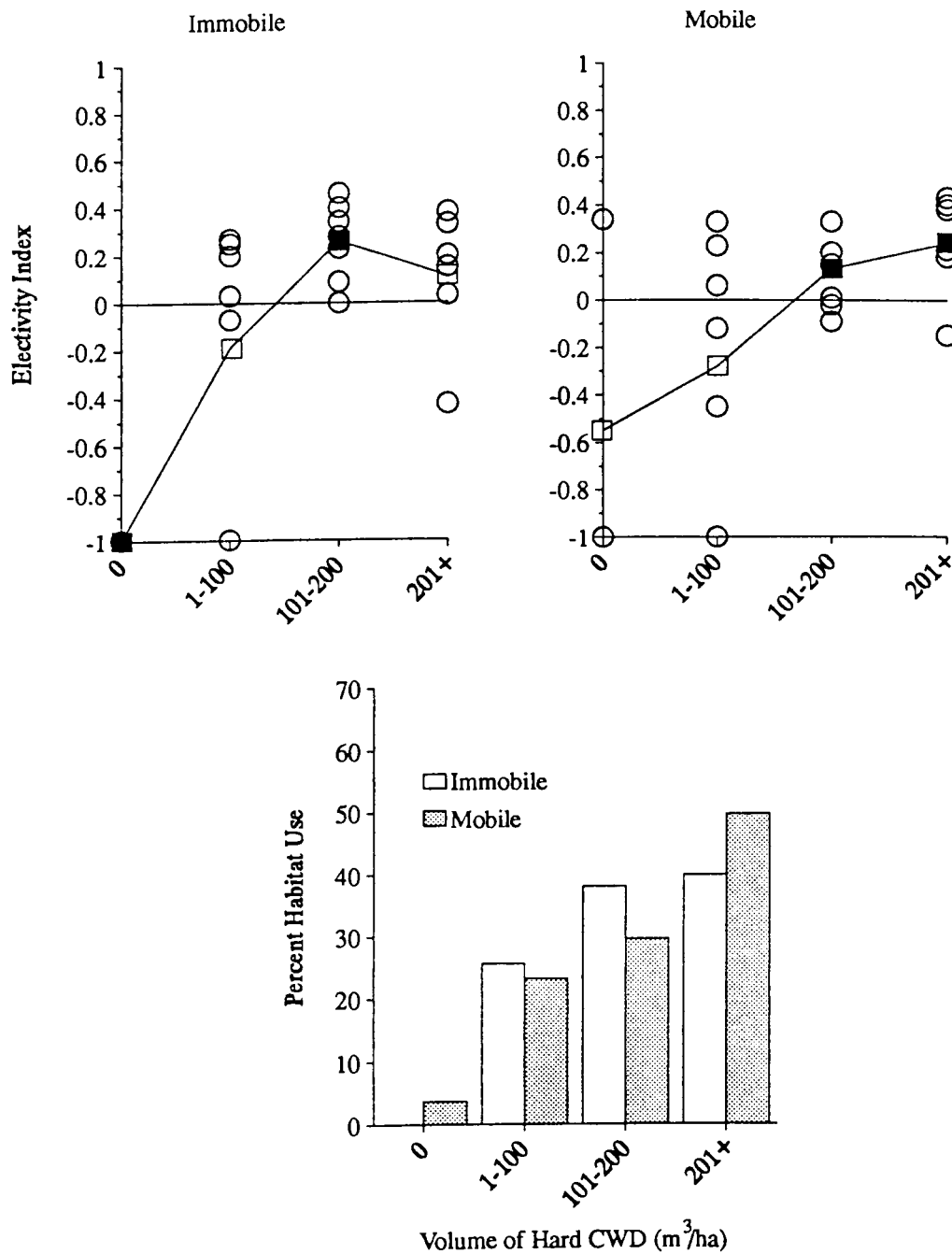


Figure 2.2. Marten electivity indices and percent habitat use at immobile and mobile locations for classes of hard coarse woody debris volume (m^3/ha). Open circles indicate electivity values for individual marten. Squares indicate electivity values for pooled data. Filled squares indicate electivity values different ($P \leq 0.05$) from zero.

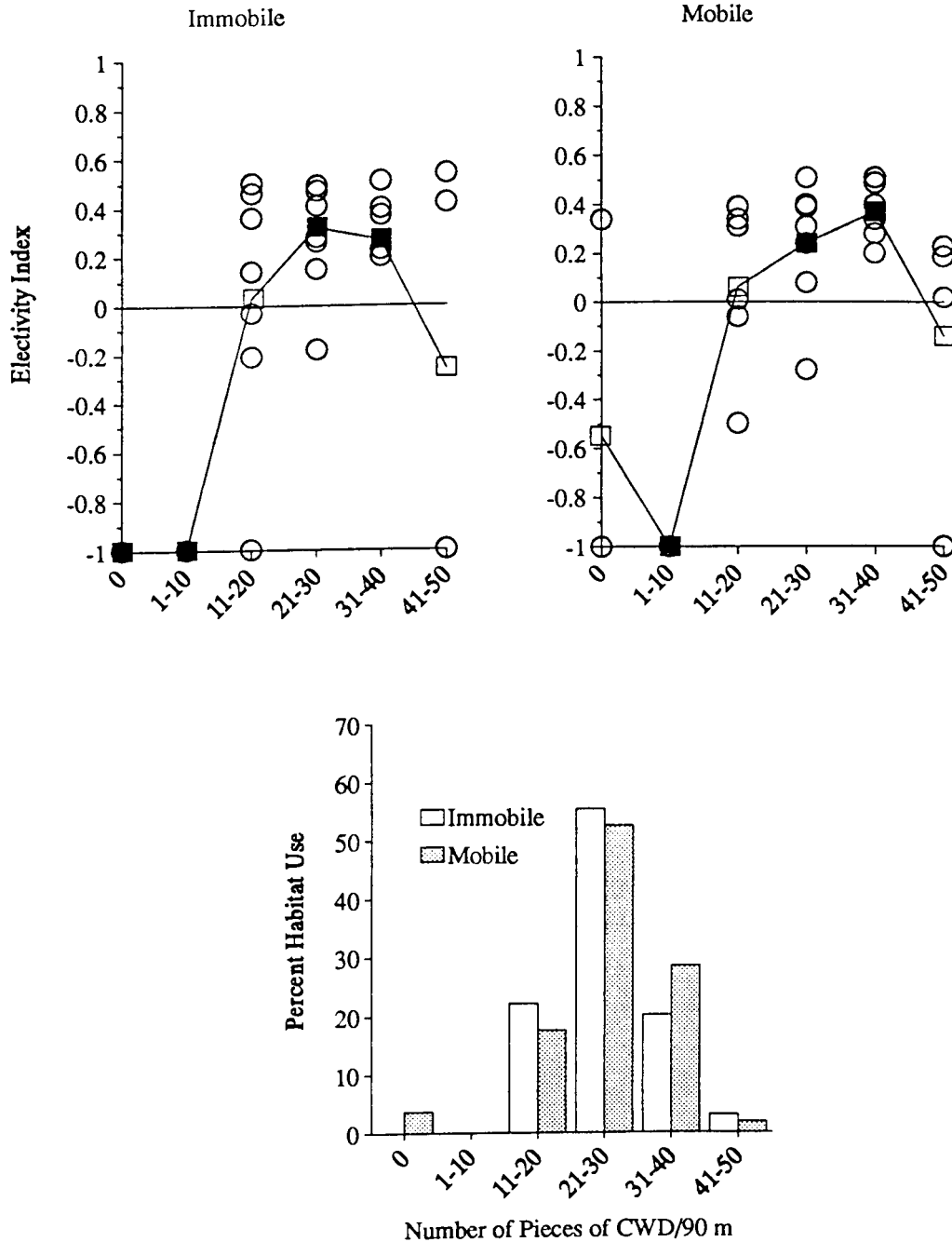


Figure 2.3. Marten electivity indices and percent habitat use at immobile and mobile locations for classes of coarse woody debris piece tallies. Open circles indicate electivity values for individual marten. Squares indicate electivity values for pooled data. Filled squares indicate electivity values different ($P \leq 0.05$) from zero.

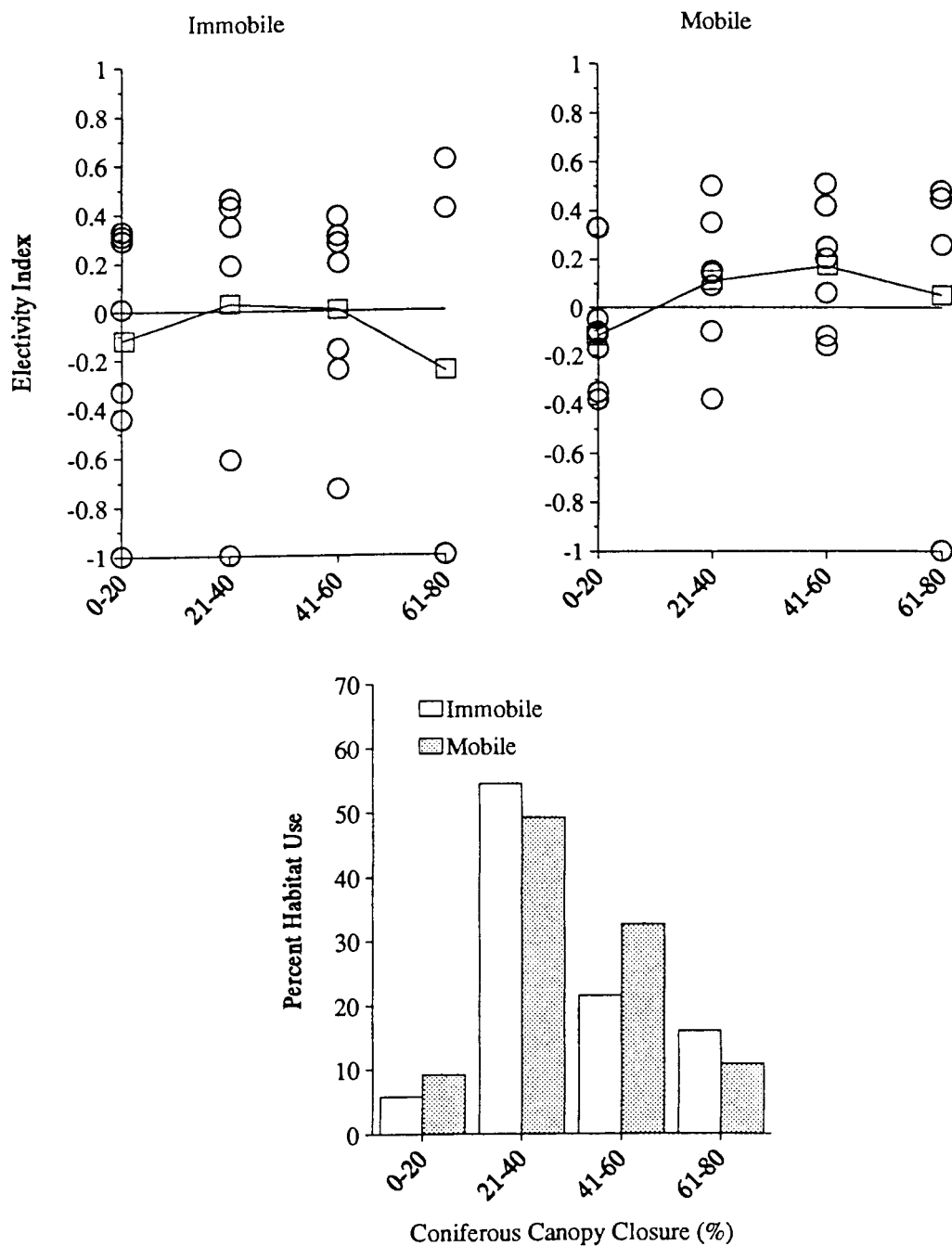


Figure 2.4. Marten electivity indices and percent habitat use at immobile and mobile locations for classes of coniferous canopy closure. Open circles indicate electivity values for individual marten. Squares indicate electivity values for pooled data. Filled squares indicate electivity values different ($P \leq 0.05$) from zero.

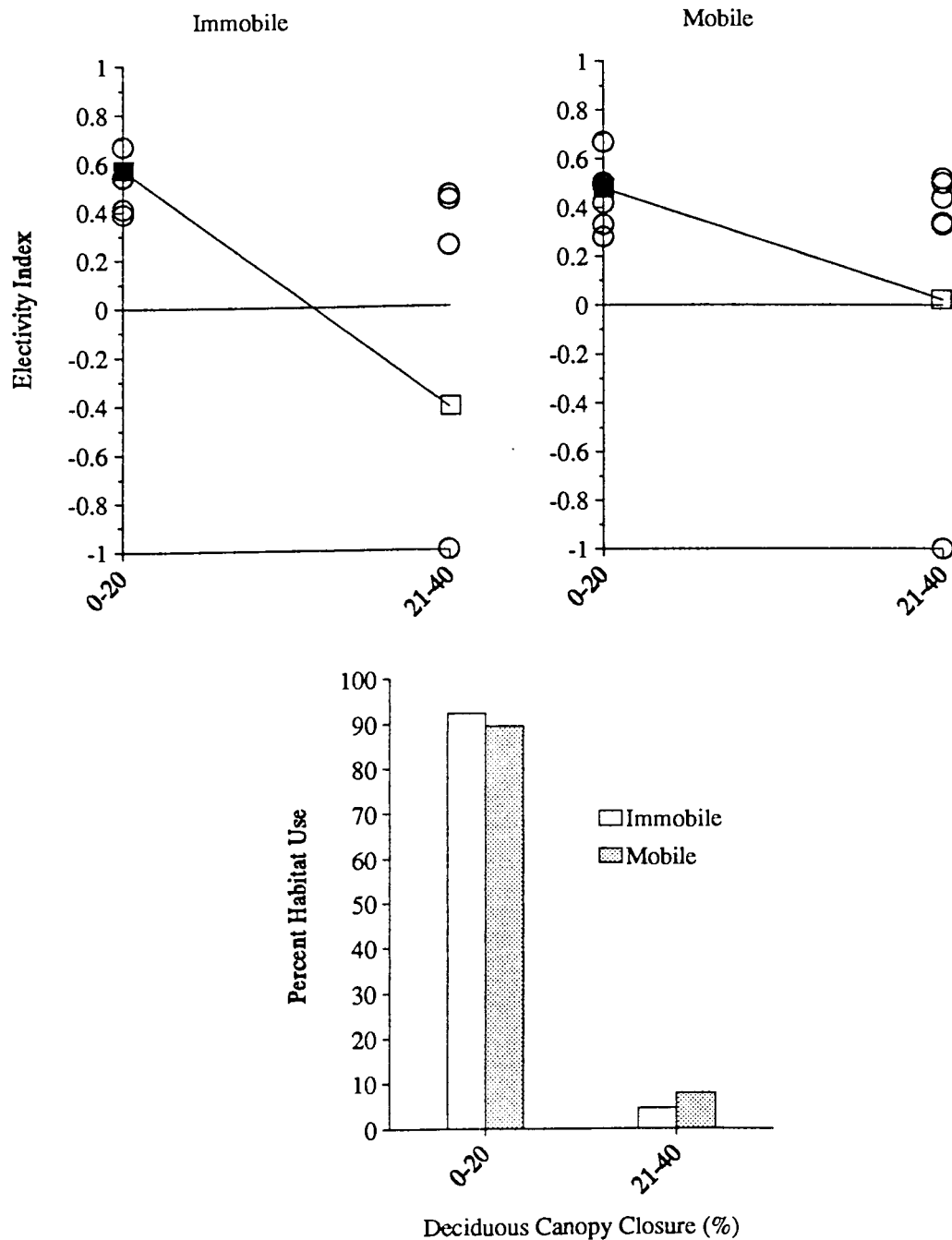


Figure 2.5. Marten electivity indices and percent habitat use at immobile and mobile locations for classes of deciduous canopy closure. Open circles indicate electivity values for individual marten. Squares indicate electivity values for pooled data. Filled squares indicate electivity values different ($P \leq 0.05$) from zero.

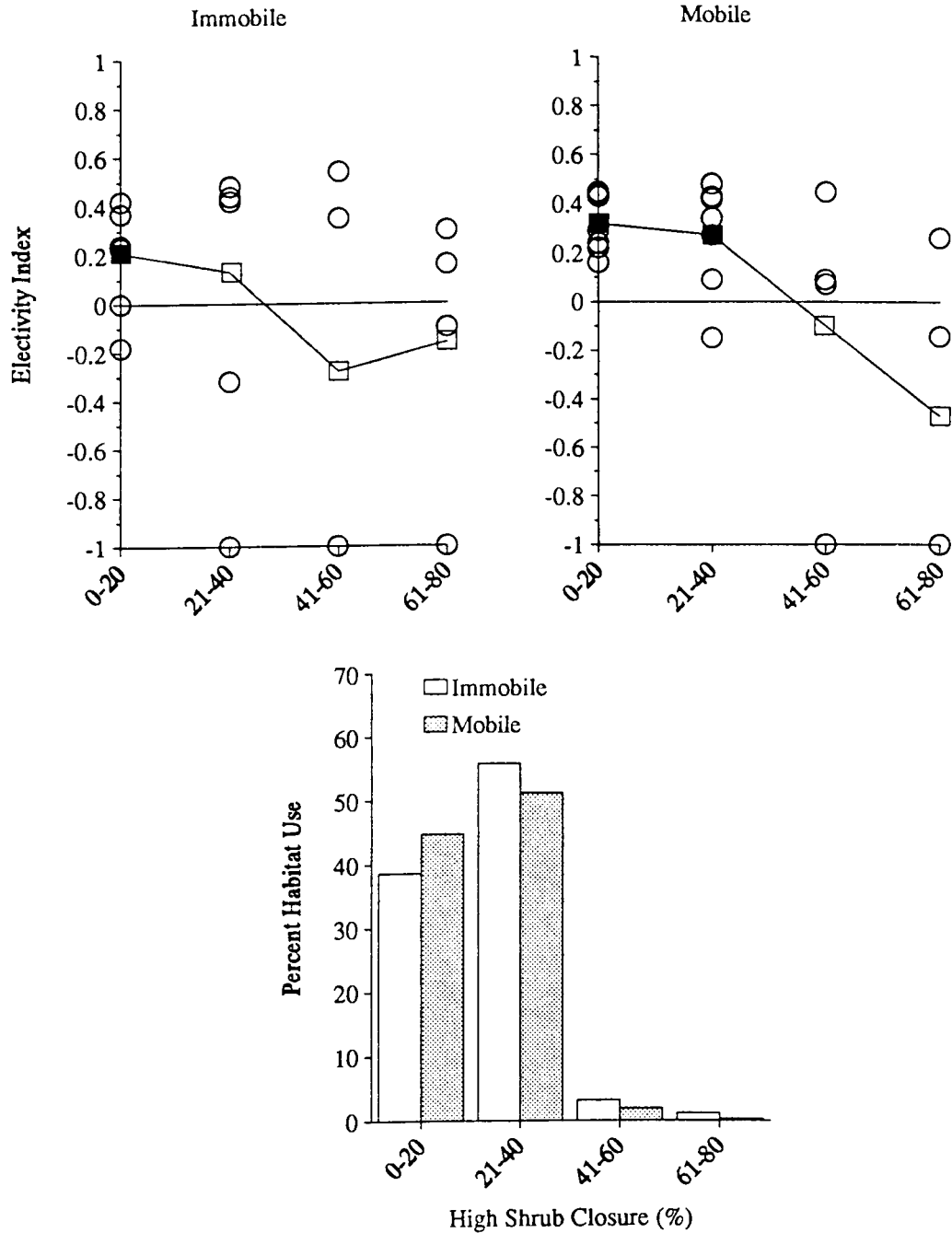


Figure 2.6. Marten electivity indices and percent habitat use at immobile and mobile locations for classes of high shrub (2-10 m) closure. Open circles indicate electivity values for individual marten. Squares indicate electivity values for pooled data. Filled squares indicate electivity values different ($P \leq 0.05$) from zero.

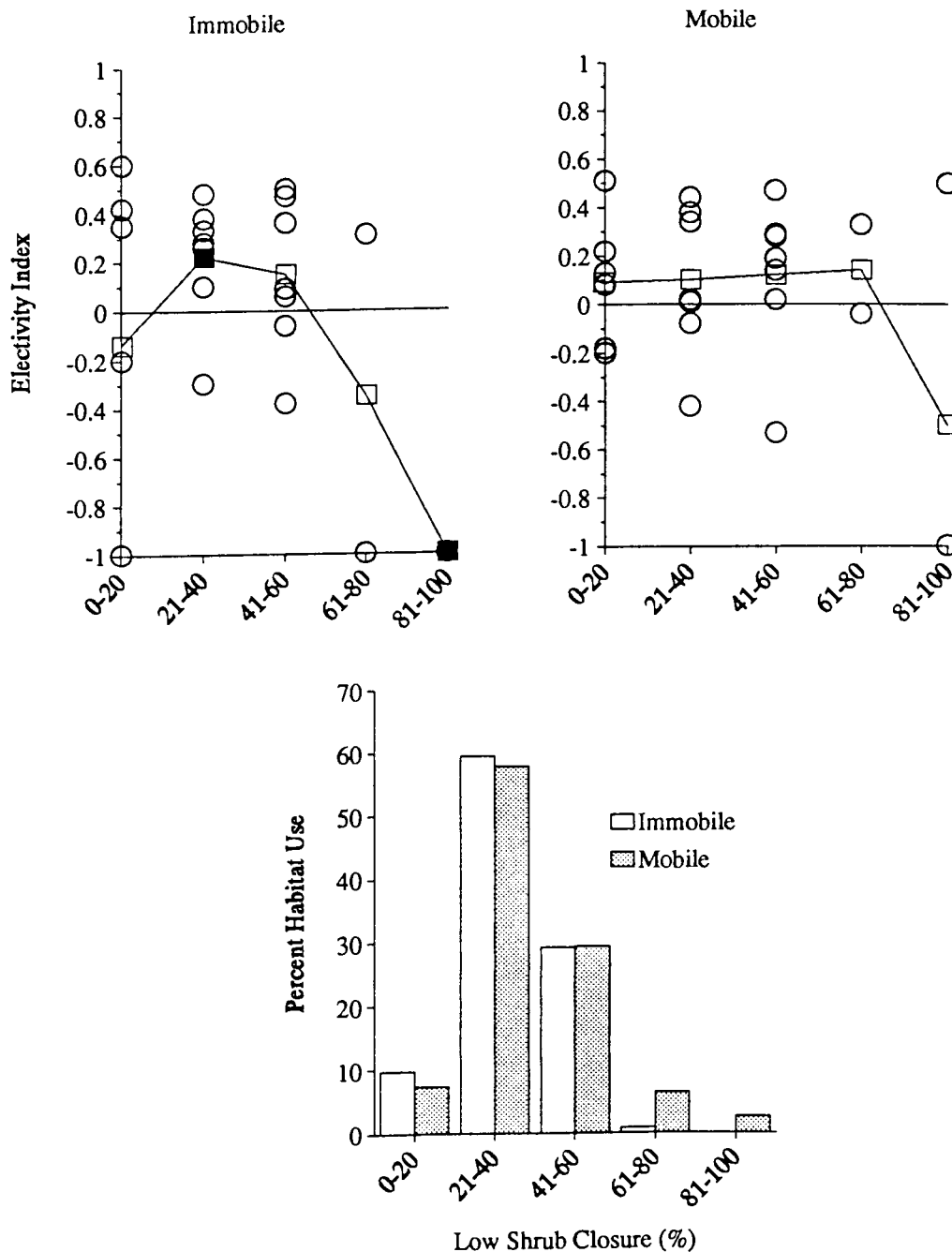


Figure 2.7. Marten electivity indices and percent habitat use at immobile and mobile locations for classes of low shrub (0-2 m) closure. Open circles indicate electivity values for individual martens. Squares indicate electivity values for pooled data. Filled squares indicate electivity values different ($P \leq 0.05$) from zero.

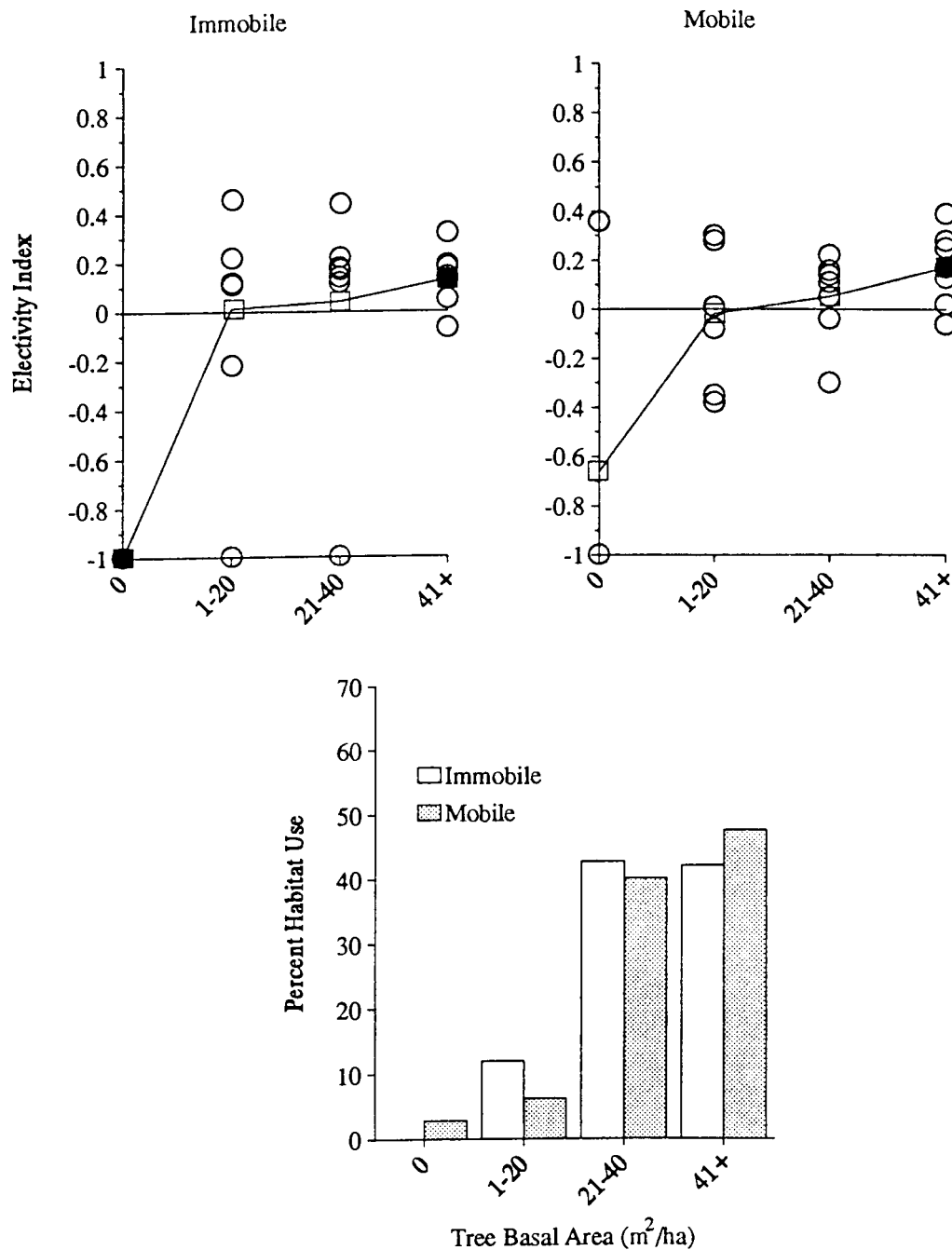


Figure 2.8. Marten electivity indices and percent habitat use at immobile and mobile locations for classes of tree basal area (m²/ha). Open circles indicate electivity values for individual marten. Squares indicate electivity values for pooled data. Filled squares indicate electivity values different ($P \leq 0.05$) from zero.

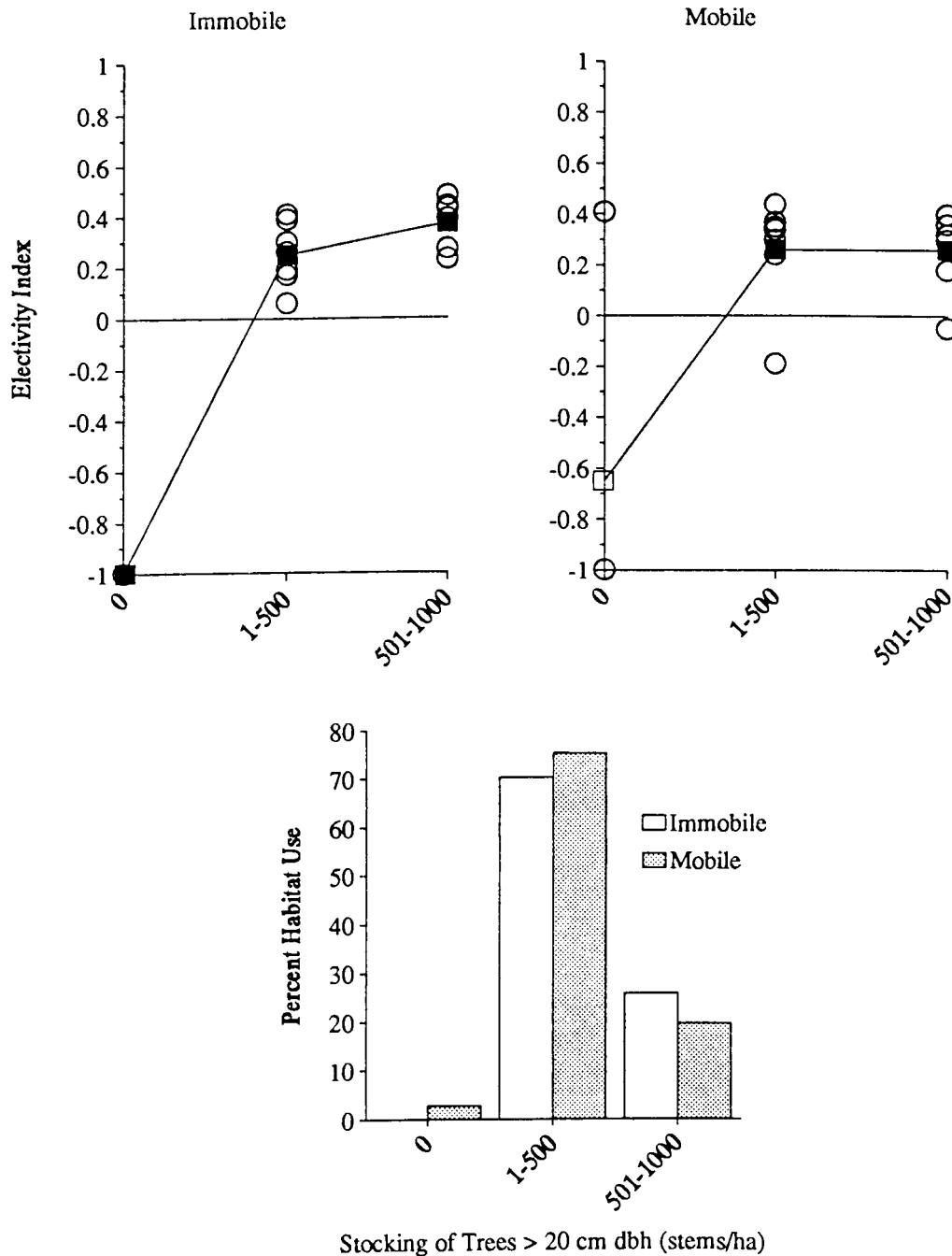


Figure 2.9. Marten electivity indices and percent habitat use at immobile and mobile locations for classes of tree (> 20 cm dbh) stocking (stems/ha). Open circles indicate electivity values for individual marten. Squares indicate electivity values for pooled data. Filled squares indicate electivity values different ($P \leq 0.05$) from zero.

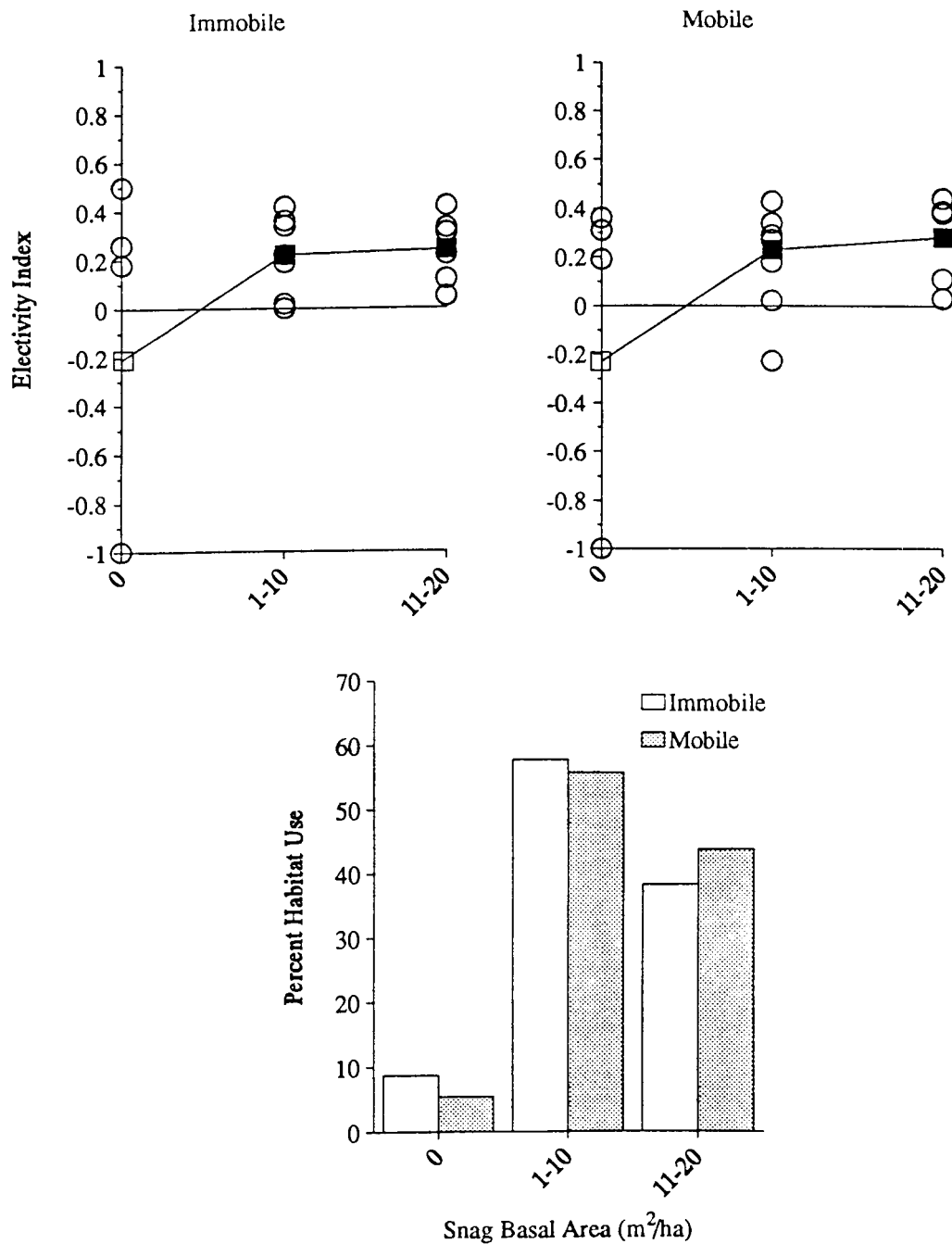


Figure 2.10. Marten electivity indices and percent habitat use at immobile and mobile locations for classes of snag basal area (m^2/ha). Open circles indicate electivity values for individual marten. Squares indicate electivity values for pooled data. Filled squares indicate electivity values different ($P \leq 0.05$) from zero.

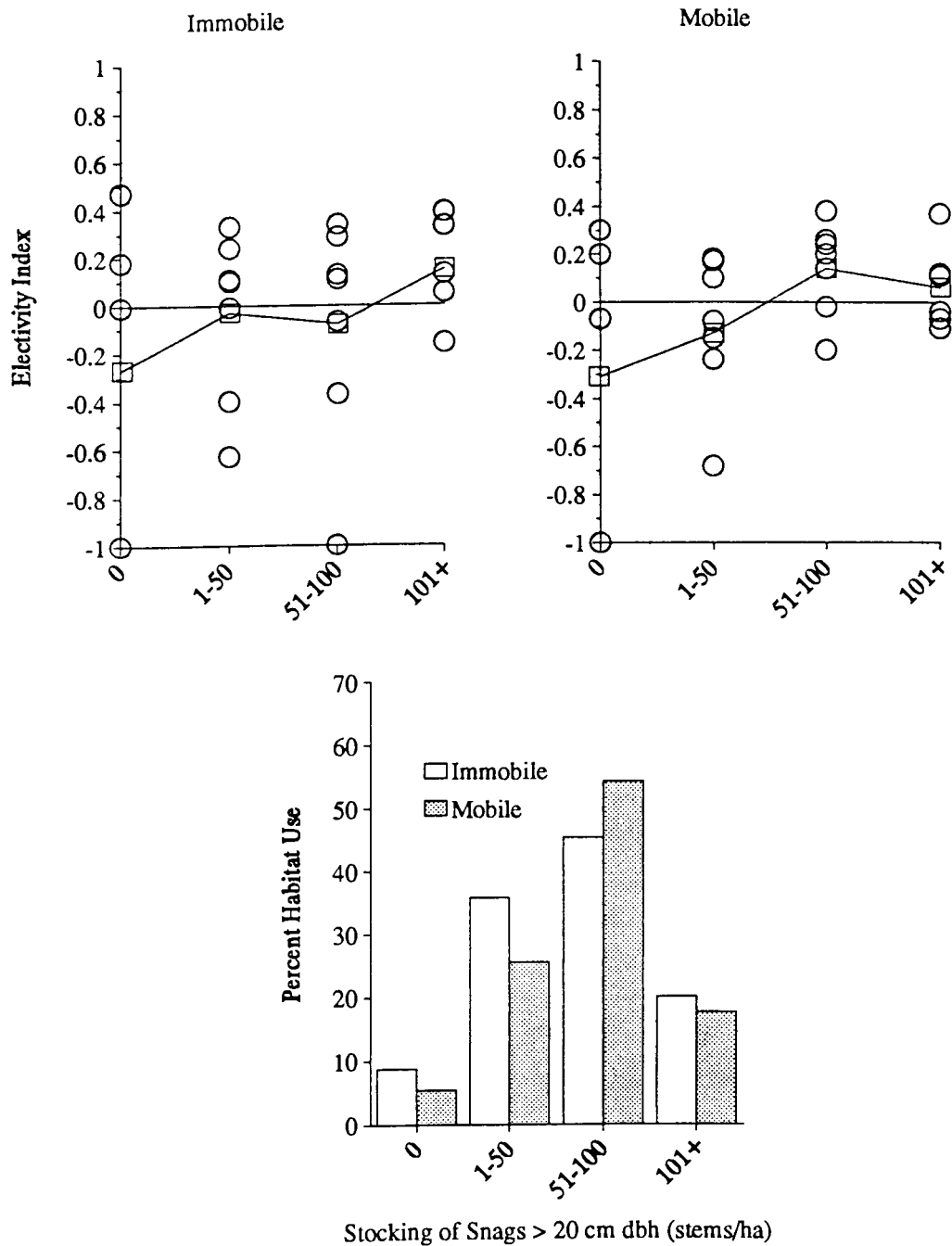


Figure 2.11. Marten electivity indices and percent habitat use at immobile and mobile locations for classes of snag (> 20 cm dbh) stocking (stems/ha). Open circles indicate electivity values for individual marten. Squares indicate electivity values for pooled data. Filled squares indicate electivity values different ($P \leq 0.05$) from zero.

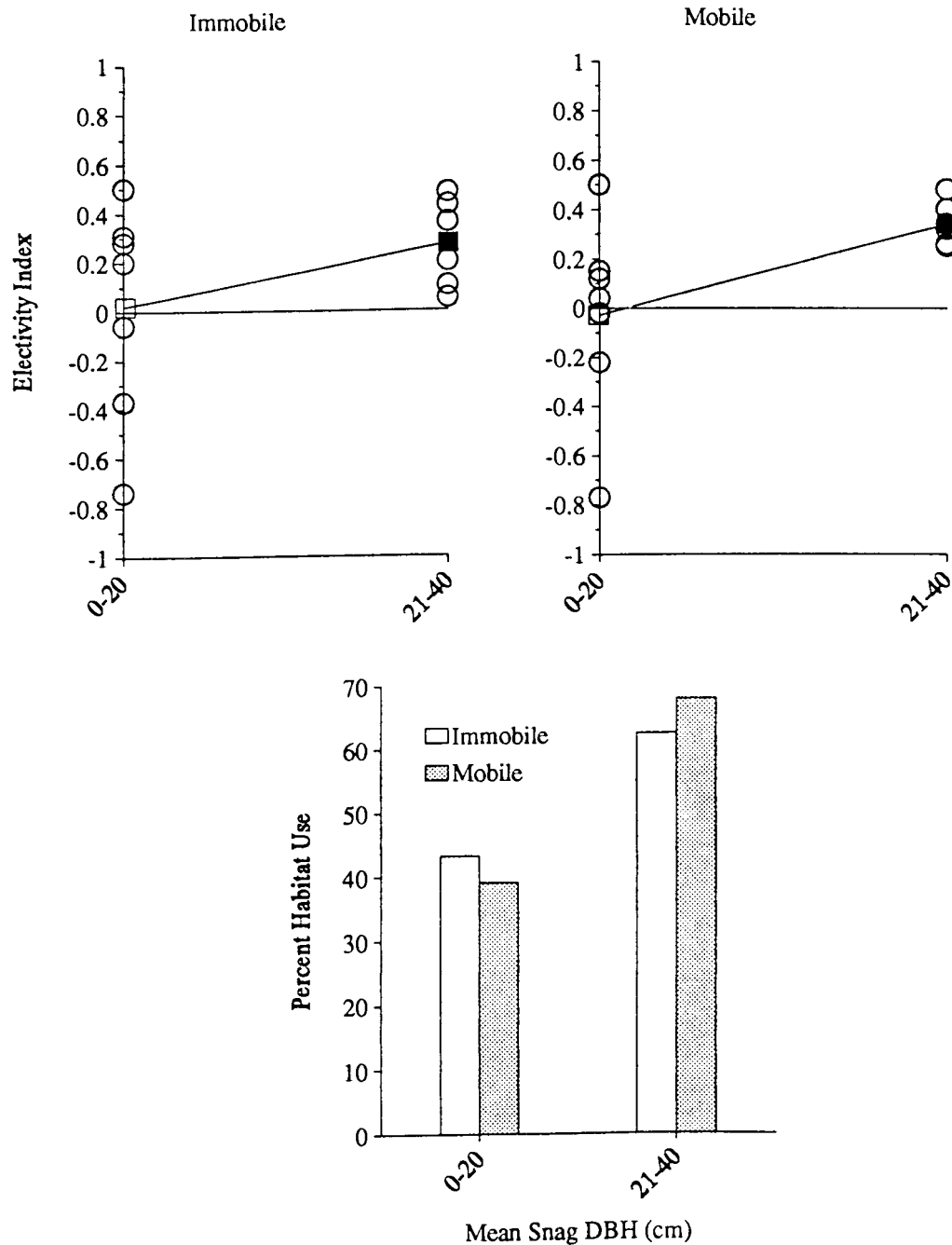


Figure 2.12. Marten electivity indices and percent habitat use at immobile and mobile locations for classes of mean snag dbh (cm). Open circles indicate electivity values for individual marten. Squares indicate electivity values for pooled data. Filled squares indicate electivity values different ($P \leq 0.05$) from zero.

habitats with $> 100 \text{ m}^3/\text{ha}$ CWD. These levels of CWD are represented predominantly by habitats with 11-40 pieces of CWD per habitat assessment plot (Fig. 2.3). Marten generally avoided habitats with less than 11 pieces CWD per plot and preferred those habitats with 21-40 pieces CWD per plot. Habitats with 21-40 pieces CWD per plot represented more than 70% of all marten habitat use. Spearman rank correlation coefficients were positive for immobile ($r_s = 0.44$, $P \leq 0.001$) and mobile locations ($r_s = 0.38$, $P \leq 0.05$). Null hypothesis 2 is rejected for all three coarse woody debris variables that I examined.

Marten unexpectedly demonstrated little relationship between electivity indices and coniferous canopy closure (Fig. 2.4; $r_s = 0.04$; $P \leq 1.0$ - immobile locations; $r_s = 0.37$, $P \leq 0.1$ - mobile locations). Mean electivity indices were negative for habitats with 0-20% coniferous canopy closure and positive for habitats with 21-60% coniferous canopy closure, however none were significantly different from zero. Mean electivity indices for habitats with 61-80% closure were also not significantly different from zero. In spite of this lack of selectivity less than 10% of locations were in habitats with 0-20% coniferous canopy closure and approximately 75% of all locations were in habitats with 21-60% coniferous canopy closure (Fig. 2.4).

Marten preferred habitats that had a small deciduous component and most of their use was in habitats with 0-20% deciduous canopy closure (at both immobile and mobile locations) (Fig. 2.5; $r_s = -0.74$, $P \leq 0.01$ - immobile locations; $r_s = -0.30$, $P \leq 1.0$ - mobile locations). Marten electivity indices for habitats with 21-40% deciduous canopy closure were not significantly different from zero. No radio-collared marten

used habitats or had more than 1% of its home range comprised of habitat types with greater than 40% deciduous canopy closure.

Radio-collared marten preferred and mostly used habitats with 0-40% high shrub closure (Fig. 2.6). Spearman rank correlation coefficients were negative for both immobile ($r_s = -0.21$, $P \leq 1.0$) and mobile locations ($r_s = -0.45$, $P \leq 0.05$), but significant only for mobile locations. Marten made little use of habitats with greater than 40% high shrub closure. Mean electivity indices were not significantly different from zero for these habitats.

Marten preferred habitats with 21-40% low shrub closure at immobile locations and avoided habitats with 81-100% low shrub closure (Fig 2.7). At mobile locations, mean electivity index values were not significantly different from zero for all conditions of low shrub closure. Spearman rank correlation coefficients were negative but not significant ($r_s = -0.31$, $P \leq 1.0$ - immobile locations; $r_s = -0.06$, $P \leq 1.0$ - mobile locations). Null hypothesis 3 is rejected for the deciduous canopy, high shrub and low shrub vegetation strata but not for coniferous canopy strata.

Radio-collared marten avoided habitats without trees when resting (Fig. 2.8) and preferred habitats with basal areas of $> 40 \text{ m}^2/\text{ha}$ at all locations. There was a positive correlation between electivity indices and tree basal area ($r_s = 0.41$, $P \leq 0.05$ - immobile locations; $r_s = 0.43$, $P \leq 0.05$ - mobile locations). Most habitat use by marten occurred in habitats with $> 20 \text{ m}^2/\text{ha}$ basal area of trees (Fig 2.8). Marten avoided habitats with no trees $> 20 \text{ cm dbh}$ at immobile locations and preferred those with 1-500 and 501-1000 stems/ha at all locations (Fig. 2.9). Mean electivity indices for

habitats with 501-1000 stems/ha were the same as or greater than the mean electivity indices for habitats with 1-500 stems/ha despite that the former class represented much lower habitat use (Fig 2.9). Spearman rank correlation coefficients were positive for both immobile ($r_s = 0.76$, $P \leq 0.001$) and mobile locations ($r_s = 0.24$, $P \leq 1.0$) but significant only for immobile locations. Null hypothesis 4 is rejected for both live tree variables that I examined.

Marten preferred habitats with 1-10 and 11-20 m²/ha basal area of snags (Fig. 2.10). The majority of habitat use (80-90%) was in habitats of these two classes (Fig. 2.10). The correlations between snag basal area and electivity indices, however, were not significant ($r_s = 0.18$, $P \leq 1.0$ - immobile locations; $r_s = 0.27$, $P \leq 1.0$ - mobile locations). Marten had mean electivity index values that were not significantly different from zero for all stocking levels of snags > 20 cm dbh (Fig. 2.11) and correlation coefficients were nonsignificant ($r_s = 0.22$, $P \leq 1.0$ - immobile locations; $r_s = 0.24$, $P \leq 1.0$ - mobile locations). However, marten made most use of habitats with 51-100 stems/ha of snags > 20 cm dbh and made little use of habitats without snags of this size (Fig. 2.11). Marten preferred habitats where mean snag dbh was 21-40 cm and showed no preference or avoidance for those habitats where mean snag dbh was 0-20 cm (Fig. 2.12). The former habitats accounted for most of the marten use (Fig. 2.12). Correlation between snag dbh and electivity indices were positive for both location types but significant for mobile locations only ($r_s = 0.27$, $P \leq 1.0$ - immobile locations; $r_s = 0.62$, $P \leq 0.05$ - mobile locations). Null hypothesis 5 is rejected for snag basal area and mean snag diameter but not for snag stocking.

Discussion

At the stand scale, radio-collared marten did not prefer particular habitat types within their home range, but they avoided many. Although some habitats were used more than available within marten home ranges, these differences were not significant. While travelling or foraging, most radio-collared marten avoided habitat types that were xeric, young seral stages, lakes, or wetlands. More habitat types were avoided for resting sites than for travel and foraging sites. At resting sites, marten also avoided using some older seral stage habitat types (eg. mc HF 4, mc HF 5). These tendencies are generally consistent with other studies, although some of my specific results differ. Hargis and McCullough (1984) found that, on the basis of snow tracking, marten exhibited no preference for particular habitat types while travelling, but preferred forests, ecotones and frozen streams for resting, access and foraging. They measured availability over their entire study area but not within individual marten home ranges. Bateman (1986), using methods similar to those of Hargis and McCullough (1984), reported that marten preferred conifer forests with high overstory density and balsam fir (*Abies balsamea*) - white birch (*Betula papyrifera*) stands. Campbell (1979) noted that marten used mature spruce-fir types significantly more than other forest types. Both Burnett (1981) and Fager (1991) observed a preference for mesic coniferous types and Fager (1991) noted an avoidance of xeric types. Burnett (1981) did not evaluate availability but reported his findings on the basis of rankings of habitat use data alone, whereas Fager (1991) compared habitat characteristics of radio and track

locations to random points in his study area. Clearcuts were avoided by marten in coastal British Columbia (Baker 1992), Maine (Soutiere 1979, Steventon and Major 1982), and Newfoundland (Fredrickson 1990). Second growth forests were preferred by marten in coastal British Columbia (Baker 1992) and mature softwood and mixedwood forests were preferred in Maine (Soutiere 1979, Steventon and Major 1982). These authors' analyses all consisted of use-availability comparisons within individual marten home ranges. Spencer et al. (1983) in California and Raine (1983) in Manitoba also demonstrated habitat selection by marten in their respective study areas. Some differences between the above studies and my findings may occur because of differences in methodology, complexity of habitat classification, the number of habitat types and sample size per habitat type, and the criteria used to determine availability. Differences could also occur because of ecological differences among the study areas. Regardless of differences in methodologies and ecosystems, marten in my study area typically avoided habitat types that marten in other studies also avoided.

Perhaps many of the authors that report habitat preferences for marten at what appears to be a stand scale (Burnett 1981, Hargis and McCullough 1984, Bateman 1986, Fager 1991) are actually measuring these relationships at a landscape scale. The lack of selection or preference for particular habitat types at the stand scale by marten in my study area may be a consequence of selection occurring at the landscape scale (Chapter 1). Marten, by establishing home ranges, have already included those habitat types which they prefer to use and simply avoid or use very little those habitat types that are included within the home range and are of little value to them. At Emerson

Creek, mesic to hygric habitats in the Mature Forest and Old Growth seral stages were preferred at the landscape scale. These same habitat types account for a large percentage of marten locations at the stand scale. If selection occurs at the landscape scale, the likelihood of detecting selection at the stand scale is diminished, especially if the areas of preferred habitat types within home ranges are large relative to home range size.

Radio-collared marten at Emerson Creek showed preferences for habitats characterized by abundant coarse woody debris, little deciduous canopy closure, low to moderate high shrub and low shrub closure, high basal areas of trees and snags, high stocking levels of trees > 20 cm dbh, and large diameter snags. These results concur with findings of other researchers. Spencer et al. (1983) documented marten use of habitat in relation to structural features and noted that marten habitat use was related to densities and sizes of logs, snags, stumps and trees, distance to water, distance to meadows, ground cover, and canopy closure. I extrapolated from their plot data and estimated that marten in their study areas preferred sites with approximately 100 m³/ha coarse woody debris. My results indicate that marten exhibit no preference or avoidance for habitats that have 1-200 m³/ha CWD but preferred those that have > 200 m³/ha. The general form of this relationship holds true for hard CWD as well, however marten preferred habitats that had > 100 m³/ha hard CWD.

Coarse woody debris is critical to the winter ecology of marten by providing access to subnivean resting and foraging sites. Hard CWD tended to be higher above the ground than soft CWD (vertical structure). Because of this characteristic, it could

be more important than soft CWD for subnivean access and foraging activities. Presumably, on a daily basis, many more access sites are required for foraging than are required for resting sites. Burnett (1981) found that 13 of 14 hunting sites investigated were associated with fallen trees. Magoun and Vernam (1991) suggested that log debris may compensate for low or no canopy closure in interior Alaska and hence allow marten to make extensive use of wildfire areas. In winter, snags and logs are used as resting den sites by marten (Martin and Barrett 1991) and CWD plays an important role at resting sites found within mesic forest conditions Fager (1991). Baker (1992) found that coarse woody debris was used for resting den sites in her study area but found no relationship between habitat use and CWD volumes. She attributed this lack of relationship to high levels of CWD from past logging throughout her study area. Results of my selectivity and correlation analyses suggest that CWD is important for winter habitat of marten in the Sub-Boreal Spruce Zone and that hard CWD is particularly important for providing access to foraging sites.

Most previous research has indicated that marten have an affinity for forest stands with dense canopy closure. Hargis and McCullough (1984) stated that marten in their study area preferred areas with 100% closure and avoided areas lacking tree cover. Bateman (1986) noted that marten preferred forests with high overstory density and Buskirk (1984) observed that most resting dens were in forests with greater than 60% canopy closure. Burnett (1981) showed that marten had a strong preference for canopy closure greater than 17% and mean canopy closure at site investigations was 35%. Spencer et al. (1983) showed that marten avoided habitats with 0-20% canopy

closure and preferred those with 40-60% canopy closure. Although the magnitude of canopy closures preferred by marten differed among studies, these must be interpreted in the context of canopy closures available in their respective study areas.

In the SBS Zone marten showed little preference for different classes of coniferous canopy closure at the stand scale, although most of their habitat use occurred in stands with 21-60% closure. However, they avoided habitats with deciduous canopy closure > 20%. This avoidance of deciduous stands and avoidance of habitats without trees is consistent with the notion that coniferous canopy closure is a central feature of marten winter habitat. High use of coniferous habitats by marten, in concert with the electivity values (as small as they are), suggest that habitats with 21-60% coniferous canopy closure are important to marten and provide much of their winter habitat in the SBS Zone.

Marten preferred habitats with 0-40% high shrub closure. The value of these high shrubs lies in the interstitial spaces created in the subnivean zone when the shrubs are bent over by snow press. Areas with low shrubs are also important to marten. The majority of habitats used by marten have 21-60% low shrub closure. Although this may be partly correlated with coniferous canopy closure, the shrub stems would not only support snow and thus create subnivean spaces but also provide winter food for small mammals. Use of habitats with shrubs would provide marten with access to abundant small mammal prey.

Marten in my study area, as in other studies, showed an affinity for habitats with many medium to large diameter trees and snags. They avoided habitats without

trees and preferred those with $> 40 \text{ m}^2/\text{ha}$ basal area. Most of the habitat use was in habitats with $> 20 \text{ m}^2/\text{ha}$ basal area. These basal areas are consistent with those in the northern Sierra Nevada where marten showed preferences for habitats with 40-60 m^2/ha basal area in one study area and $> 60 \text{ m}^2/\text{ha}$ in another study area but avoided areas with $< 20 \text{ m}^2/\text{ha}$ basal area in both study areas (Spencer et al. 1983). Marten in my study area exhibited greater preference for habitats with 501-1000 stems/ha of trees $> 20 \text{ cm}$ dbh, although they used habitats with 1-500 stems/ha more than habitats with the higher stocking. Marten showed a similar preference for high snag basal areas, although they did not avoid habitats without snags. Most habitat use was in habitats with 1-20 m^2/ha basal area of snags and 1-100 stems/ha of snags $> 20 \text{ cm}$ dbh. Marten had a generally increasing (although not significant) preference for habitats with increasing amounts of snags. In addition, they preferred habitats with snags that were an average of 21-40 cm dbh.

Trees and snags are important components of marten habitats throughout North America. Marten use the space along tree trunks, and fallen trees to gain subnivean access (Hargis and McCullough 1984, Thompson 1986) and their daytime resting sites are often large dead, rotten snags (Campbell 1979). This dependency on trees and snags for subnivean access is also evident in marten habitat selection. In some habitats, both tree and snag stocking are significantly greater at resting sites than at random sites (Fager 1991). Spencer et al. (1983) reported preferences for habitats with snag basal areas $> 12 \text{ m}^2/\text{ha}$. Without trees and snags protruding through the snow marten would be denied resting sites and foraging opportunities. Lack of these

structures would diminish habitat quality for marten.

Of a total of 22 resting den sites that I investigated (den sites that were located while still occupied) within my study area, 13 were associated with trees, snags or tall stumps left from previous partial cut logging. Most of these den sites were located within the root bases of these structures. The remaining 9 dens were associated with coarse woody debris. Size of these structures may also be important. Mean den tree diameter was 36.2 cm and mean den snag/stump diameter was 38.4 cm. Perhaps trees and stumps of this size have a root mass large enough to provide marten with suitable den sites. Baker (1992) also found that large stumps and root masses of trees were important components of denning habitat, particularly natal dens.

In the SBS Zone during winter, marten show little preference for individual habitat types at the stand scale, however they demonstrate a marked avoidance of some habitat types, particularly young seral stages, xeric habitat types and wetlands. I conclude that preferred habitat types are selected at the landscape scale during the establishment of home range (Chapter 1) and that, at the stand scale, habitats of lower value included within the home range are avoided in day-to-day activities. More importantly, although preferences for particular habitat types were not detected, marten exhibit habitat selectivity based on habitat attributes. In particular, habitat preferences are most strongly expressed for volume of coarse woody debris, deciduous canopy closure, high and low shrub closure, and characteristics of large trees and snags. At the stand scale, evidence supporting the importance of coniferous canopy closure is equivocal and likely masked by selectivity at the patch scale (see Chapter 3). Although

marten exhibited little preference for any particular class of coniferous canopy closure, coniferous habitats were used substantially by marten and their importance to sustaining marten populations cannot be discounted.

CHAPTER 3

HABITAT SELECTION BY MARTEN AT A PATCH SCALE

Introduction

Marten habitat selection at the patch scale has been examined for resting sites (Buskirk 1984, Spencer 1987, Martin and Barrett 1991, Wilbert 1992) and subnivean access sites used during foraging and resting (Corn and Raphael 1992). These authors concluded that habitat selection occurred if habitat characteristics at sites used by marten (habitat patches) differed from those at random sites (often referred to as availability). Measurement of availability varied among studies. Wilbert (1992) compared patch scale habitat use by marten to random plots, within marten home ranges and to plots in the vicinity of resting sites. Martin and Barrett (1991) measured availability within their study area and within marten home ranges. Spencer (1987) measured availability within home ranges only. Corn and Raphael (1992) measured availability within stands used for travel and within stands used for subnivean activity. The above studies report that marten exhibit selection for a variety of habitat attributes at the patch scale, although results vary depending on the manner which availability was estimated (Martin and Barrett 1991, Wilbert 1992). Corn and Raphael (1992) and Wilbert (1992) estimate availability in ways that are most appropriate to examine habitat selection at the patch scale.

In previous chapters, I presented evidence for habitat selection at the landscape

scale (selection of particular habitat types) and at the stand scale (avoidance of particular habitat types and selection of habitats grouped by their structural attributes). My objective in this chapter is to examine habitat selection by marten at the patch scale.

Usually, landscapes are not homogeneous but rather are assemblages of units with different vegetation or physical features. These are readily discernable in the field or on aerial photographs. Similarities among units are assessed and a classification scheme based on several criteria is used to group units into habitat types. For wildlife studies, this classification scheme and the resultant habitat types are functionally derived and may be specific to a single species or group of species. Once habitat types are defined, they can be described more specifically by measuring characteristics at a sample of locations within the habitat type and from these measurements mean values derived. These mean values reflect the habitat types' prevailing vegetation and physical characteristics.

Some characteristics are nominal, such as lake or forest. Other characteristics are continuous variables which can be measured, such as structural attributes. For these continuous variables, habitat types generally represent conditions that span a range of values. A habitat type has a mean value for a particular structural attribute, but there is variability among sites within the habitat type. Some sites are less than the mean, others are greater than the mean. If marten have affinities for particular structural attributes and if the relationships between structural attributes and life requisites described in Chapter 2 are important, then I expect marten to select patches or sites

within habitats that are atypical of the habitats' prevailing structural attributes. At sites used by marten (marten sites), I expect attribute values should deviate from the mean value for the habitat (habitat mean), especially if this mean value is one for which marten have already demonstrated avoidance at the stand scale. I expect the structural characteristics of marten sites to resemble the structural characteristics of habitats preferred by marten at the stand scale (Chapter 2).

Although marten at Emerson Creek exhibited strong avoidance of particular classes of structural attributes at the stand scale, they made use of these habitats classes some of the time. For example, marten avoided and made limited use of habitats with small amounts of CWD. I expect that the patches selected by marten when they used these habitats would have significantly greater CWD than that typical for these habitats. Furthermore, although marten may not exhibit preferences for habitat attribute classes at the stand scale they could exhibit preferences at the patch scale. Marten in my study area had no obvious preferences for different classes of coniferous canopy closure at the stand scale. These findings contradict the literature in which many authors suggest that this attribute is an important component of marten winter habitat and that habitats with little coniferous canopy closure are of little value to marten during winter. In habitats with typically less than 20% coniferous canopy closure, I expect that marten will demonstrate the importance of coniferous canopy closure by using patches within these habitats where mean coniferous canopy closures are significantly greater than the habitat mean.

I intend to determine whether or not marten select specific patches or sites

within habitats on the basis of the structural attributes of those patches. Thus, for a particular habitat attribute class, is the mean value for that attribute at marten sites different from the mean at random habitat description plots? The null hypotheses are that structural characteristics of marten sites do not differ from the structural characteristics at random habitat description plots.

Materials and Methods

Marten were captured, instrumented with radio collars and monitored as described in previous chapters. Marten locations were overlaid on the 1:10,000 habitat base map using a geographic information system (PAMAP Systems) and from there transferred to 1:10,000 colour aerial photographs. Marten locations were visited on the ground to collect habitat attribute information equivalent to that collected at habitat description plots (described in Chapter 2).

Habitat types were assigned to attribute classes (e.g. CWD Class = 1-100 m³/ha) based on the mean values of the attributes at the habitat description plots. For each habitat attribute class, attributes at marten locations (marten sites) were compared to attributes at random habitat description plots (habitat mean) using Mann-Whitney U-tests. All significances are reported at the $P \leq 0.05$ level. Data for the habitat description plots were restricted to habitat types in which marten locations occurred.

Results

Selection at the patch scale was found for all habitat attributes examined with the exception of mean snag diameters (Tables 3.1 - 3.5). In both 0 m³/ha and 1-100 m³/ha CWD habitats, marten used sites with significantly higher volumes of CWD (> 20 cm diameter) than the habitat means (Table 3.1). Marten showed similar patch scale selection for hard CWD (of all sizes) (Table 3.1). For the upper two classes of CWD (101-200 and 201+ m³/ha), CWD volumes at marten sites were not significantly different from the habitat means. There were more pieces of CWD at marten sites than habitat means for all piece tally classes, however significant differences were found only for one piece tally class (11-20 pieces CWD) (Table 3.1).

Coniferous canopy closures at marten sites were significantly different than the habitat means for 3 of the 4 habitat classes (Table 3.2). Marten sites had significantly greater closure than habitat means for the 0-20% coniferous canopy closure class and had significantly less coniferous canopy closure than the habitat means for the 41-60 and 61-80% closure classes. Deciduous canopy closure was significantly less at marten sites than habitat means for both classes of closure (Table 3.2). Marten sites had significantly more high shrub closure than the habitat means for the 0-20% closure class and significantly less for the 41-60% closure class (Table 3.3). No significant difference could be detected for 61-80% closure class because of inadequate sample size ($n = 1$). Low shrub closure was significantly greater at marten sites than the habitat mean for the 0-20% closure class but significantly less for the 61-80% class

Table 3.1. Mean coarse woody debris attributes at marten sites and random habitat plots for coarse woody debris attribute classes. P values are results of Mann-Whitney U-tests.

	Habitat Attribute Values				
	Marten Sites		Habitat Plots		P Value
	Mean ± SE	(N)	Mean ± SE	(N)	
CWD Class (m³/ha)					
> 20 cm diameter					
0	14.8 ± 11.6	(3)	0.0 ± 0.0	(6)	0.05
1-100	58.3 ± 6.7	(117)	29.7 ± 4.1	(178)	<0.01
101-200	101.2 ± 9.7	(65)	125.2 ± 10.0	(72)	0.08
201+	219.4 ± 12.8	(107)	235.8 ± 11.7	(132)	0.17
Hard CWD Class					
(m³/ha)					
0		(0)		(0)	
1-100	56.2 ± 4.8	(120)	49.2 ± 4.6	(201)	<0.01
101-200	166.1 ± 7.4	(148)	159.4 ± 8.1	(135)	0.54
201+	243.3 ± 33.6	(24)	227.4 ± 16.6	(52)	0.99
Piece Tally Class					
0		(0)		(0)	
1-10	9.5 ± 8.5	(2)	0.2 ± 0.2	(5)	0.08
11-20	19.6 ± 1.1	(92)	16.5 ± 0.8	(160)	0.03
21-30	25.0 ± 1.1	(116)	24.9 ± 1.0	(131)	0.99
31-40	33.3 ± 1.4	(75)	31.2 ± 1.2	(74)	0.58
41-50	52.4 ± 5.5	(7)	40.3 ± 4.3	(18)	0.17

Table 3.2. Mean tree strata closures (%) at marten sites and random habitat plots for tree strata closure classes. P values are results of Mann-Whitney U-tests.

	Habitat Attribute Values				
	Marten Sites		Habitat Plots		P Value
	Mean ± SE	(N)	Mean ± SE	(N)	
Coniferous Canopy Closure Class (%)					
0-20	26.3 ± 3.1	(47)	15.0 ± 2.1	(50)	0.01
21-40	33.0 ± 1.7	(106)	31.1 ± 1.8	(109)	0.41
41-60	40.3 ± 1.8	(115)	48.0 ± 2.9	(48)	0.01
61-80	26.1 ± 3.6	(23)	72.9 ± 4.3	(7)	<0.01
Deciduous Canopy Closure Class (%)					
0-20	5.2 ± 0.7	(255)	8.4 ± 1.0	(161)	<0.01
21-40	13.3 ± 2.4	(36)	31.0 ± 2.8	(53)	<0.01

Table 3.3. Mean shrub closures (%) at marten sites and random habitat plots for shrub closure classes. P values are results of Mann-Whitney U-tests.

	Habitat Attribute Values				
	Marten Sites		Habitat Plots		P Value
	Mean \pm SE	(N)	Mean \pm SE	(N)	
High Shrub (2-10 m) Closure Class (%)					
0-20	18.1 \pm 1.4	(160)	14.1 \pm 2.2	(64)	0.05
21-40	20.4 \pm 1.6	(123)	24.4 \pm 1.9	(143)	0.33
41-60	9.4 \pm 6.8	(7)	50.0 \pm 11.5	(6)	0.06
61-80	60.0	(1)	77.0	(1)	
Low Shrub (0-2 m) Closure Class (%)					
0-20	26.5 \pm 2.6	(32)	11.3 \pm 2.4	(16)	<0.01
21-40	28.9 \pm 1.4	(168)	31.2 \pm 2.0	(114)	0.50
41-60	47.0 \pm 2.7	(71)	49.1 \pm 2.8	(78)	0.52
61-80	42.3 \pm 5.7	(20)	69.2 \pm 6.1	(6)	0.02

Table 3.4. Mean tree attributes at marten sites and random habitat plots for tree attribute classes. P values are results of Mann-Whitney U-tests.

	Habitat Attribute Values				
	Marten Sites		Habitat Plots		P Value
	Mean ± SE	(N)	Mean ± SE	(N)	
Tree Basal Area Class (m²/ha)					
0	12.7 ± 11.7	(3)	0.0 ± 0.0	(4)	0.12
1-20	26.7 ± 9.6	(12)	5.8 ± 2.2	(18)	0.20
21-40	47.7 ± 1.9	(149)	34.6 ± 1.5	(160)	<0.01
41+	45.8 ± 2.1	(124)	43.5 ± 2.2	(81)	0.65
Tree Stocking Class (stems/ha)					
0	46.3 ± 46.3	(3)	0.0 ± 0.0	(4)	0.39
1-500	412.9 ± 18.1	(252)	299.5 ± 16.4	(233)	<0.01
501-1000	403.7 ± 62.2	(33)	575.2 ± 52.2	(26)	0.01

Table 3.5. Mean snag attributes at marten sites and random habitat plots for snag attribute classes. P values are results of Mann-Whitney U-tests.

	Habitat Attribute Values				
	Marten Sites		Habitat Plots		P Value
	Mean \pm SE	(N)	Mean \pm SE	(N)	
Snag Basal Area Class (m²/ha)					
0	0.0 \pm 0.0	(4)	0.0 \pm 0.0	(4)	0.99
1-10	7.5 \pm 0.8	(197)	4.6 \pm 0.5	(205)	0.02
11-20	17.3 \pm 1.6	(88)	10.8 \pm 1.1	(54)	0.02
Snag Stocking Class (stems/ha)					
0	51.5 \pm 42.7	(5)	0.0 \pm 0.0	(12)	0.03
1-50	25.6 \pm 7.9	(90)	19.8 \pm 5.8	(96)	0.48
51-100	120.1 \pm 11.3	(171)	62.4 \pm 6.9	(140)	<0.01
101+	134.4 \pm 26.3	(22)	131.9 \pm 26.3	(15)	0.84
Snag Diameter Class (cm)					
0-20	10.4 \pm 1.0	(172)	9.2 \pm 1.0	(169)	0.31
21-40	28.3 \pm 1.5	(116)	30.7 \pm 1.6	(94)	0.60

(Table 3.3).

Marten selected sites that had greater basal area of trees than the habitat means, however the only significant difference was for the 21-40 m²/ha class (Table 3.4). Stocking of trees (> 20 cm dbh) at marten sites were significantly different than habitat means for the 1-500 and 500-1000 stems/ha classes (Table 3.4). Marten sites had significantly higher tree density tree than the mean for the 1-500 stem/ha class and significantly lower tree density tree for the 501-1000 stem/ha class. Snag basal area was significantly greater at marten sites than the habitat mean for all habitat classes except the 0 m²/ha class (Table 3.5). In the 0 m²/ha snag class habitats, snag basal areas at marten sites were not different than the mean for that class. Stocking of snags (> 20 cm dbh) at marten sites was greater than the habitat means for all classes of snag stocking, however significant differences occurred only for the 0 and 51-100 stems/ha classes (Table 3.5). Mean snag diameters at marten sites did not differ significantly from the habitat means of all classes (Table 3.5).

Discussion

Within habitats types used by marten, marten selected sites or "patches" whose structural characteristics were significantly different from those at random habitat plots. Sites selected by marten had more coarse woody debris than that typical for habitats classed as 100 m³/ha or less CWD. Selectivity appeared to reach a threshold at 101 m³/ha, where although marten prefer habitats with greater than 200 m³/ha (Chapter

2), sites with as little as 101 m³/ha are either adequate or marten will tolerate these levels, possibly to take advantage of other resources. Marten showed an affinity for patches that had more pieces of CWD than typically available, however this was significant for only one CWD class. Associations of marten with CWD are evident elsewhere in their range (Wilbert 1992). Marten are long and thin, with relatively short hair and as a result are thermally inefficient (Brown and Lasiewski 1972).

Consequently, access to thermally efficient resting sites is important. Buskirk et al. (1989) described the importance of CWD to the thermal characteristics of resting sites. CWD is also important to marten for access to the subnivean environment for foraging activities (Steventon and Major 1982, Hargis and McCullough 1984, Bateman 1986, Snyder and Bissonnette 1987, Spencer 1987, Corn and Raphael 1992). The importance of CWD is reflected in the selectivities exhibited by marten in the SBS Zone in British Columbia.

Results of patch scale selection for coniferous canopy closure revealed an interesting pattern, particularly in context of stand scale selection for coniferous canopy closure (Chapter 2). At the stand scale, there were no significant differences in preference for the four classes of coniferous canopy closure. This lack of selectivity is contrary to most literature which shows that marten prefer stands with dense coniferous canopy closure (minimum 20 - 30%) (Koehler et al. 1975, Spencer et al. 1983). Marten at Emerson Creek, when in habitats with a mean coniferous canopy closure of less than 20%, used sites that had a mean closure of 26.3%, a closure greater than the habitat mean. My results at the patch scale are more consistent with

the general pattern in the literature than are those at the stand scale. Marten in my study area also used sites within habitats classed as high coniferous canopy closure (61 - 80%) that had considerable less coniferous canopy closure than the habitat mean. These findings are consistent with those of Spencer et al. (1983) but are contrary to those of Koehler et al. (1975). Perhaps sites with closed coniferous canopies have relatively depauperate understories and as a result may be unproductive for small mammals, the principal winter prey of marten in my study area (Park 1991).

Differences in deciduous canopy, high shrub, and low shrub closure between marten sites and habitat description plots further support my findings of selection of these attributes at the stand scale. Not only do marten prefer stands with little deciduous closure (Chapter 2) but when they are in habitats with a deciduous component, the sites used by marten are atypical, in that they have significantly less deciduous canopy closure than the habitat mean.

Marten selected patches that had a greater tree basal area than typically available in all tree basal area habitat classes. This pattern may simply reflect their preference for habitats with coniferous canopy closure. However, based on results for coniferous canopy closure one might expect that in habitats with high basal areas marten would choose patches with less coniferous canopy closure. Examination of tree stocking reveals that marten choose patches with lower stocking than that typical for the 501-1000 stems/ha habitat class. My interpretation is that marten sites with high basal areas, instead of having many stems/ha and as a result high coniferous canopy closure, have fewer stems/ha of larger size. This characteristic of marten sites could be

related to their preference for an intermediate coniferous canopy closure and also to marten use of the root bases of large trees as subnivean resting sites (Chapter 2, Spencer 1987, Martin and Barrett 1991, Wilbert 1992).

Marten used patches that had significantly more snags and greater basal area of snags than typically available. There were no differences between mean snag diameters at marten sites and habitat means. Wilbert (1992) found that snags used for resting sites were significantly larger in diameter than snags in the immediate vicinity and that snag density was greater at plots centred on resting sites than snag density at random plots in her study area. My results in this chapter, in addition to those in Chapter 2 which indicate marten preferences increase with increasing basal area and size of snags, further support the importance of snags to winter habitat of marten.

I have shown that during winter, use of patches by marten is associated with these patches' structural attributes. Although a particular habitat generally may not meet their needs, marten can travel through the habitat selectively exploiting patches whose attributes are closer to their needs. If this model is true, then the critical limiting factor for marten winter habitat is not so much the prevailing characteristics of the habitat type but rather the inter-patch variation and density of patches which can satisfy the requirements of marten. Habitat types selected for at the landscape scale when marten establish their home ranges presumably have greater densities of high quality patches than those avoided at the landscape and stand scales. I conclude that selection occurs at the patch scale. In some cases patch scale selectivity helps explain discrepancies between patterns of selection for habitat attributes at the stand scale and

patterns reported in the literature (eg. coniferous canopy closure). In other cases patch scale selectivity provides further support of the habitat selection patterns observed at the stand scale.

CHAPTER 4

SUMMARY AND GENERAL DISCUSSION

Summary

I examined winter habitat use and selection by marten in the Sub-Boreal Spruce (SBS) Biogeoclimatic Zone of central British Columbia from January 1988 to September 1991. My objectives were to determine whether marten selected habitat at landscape, stand and patch scales (*sensus* Johnson 1980) and to identify which components of habitat were selected at each scale.

I examined habitat selection at a landscape scale by comparing live-trapping results between two subzones of the SBS zone and by comparing the habitat composition of 7 adult resident marten home ranges with that of the study area. At Emerson Creek, marten were clearly more abundant in coniferous forests (moist cold subzone - SBSmc) than in mixed deciduous-coniferous forests (dry cool subzone - SBSdk). This difference in density is likely a function of differences in climate, vegetation and structural features of these zones. Marten preferred to include mesic to hygric habitat types of mature to old growth seral stages when establishing home ranges. Most marten avoided including early seral stage habitat types in home ranges. However, some marten, mainly adult males, included substantial areas of mid-seral habitat types in their home ranges. I hypothesize that their inclusion is related to the abundance of snowshoe hare in these habitat types and allows marten to exploit cyclic

events in prey populations. Marten are sexually dimorphic, with males significantly larger than females (Strickland and Douglas 1987). Of the various age-sex classes, it is likely that adult males could exploit large prey (such as snowshoe hare) better than smaller age-sex classes. Steventon and Major (1982) and Thompson (1986) both present evidence of adult male marten preying on snowshoe hare.

Marten habitat selection at a stand scale was examined by comparing use and availability of habitat types within marten's home ranges. Selectivities for attributes were examined by comparing use and availability of habitats defined by their structural attributes. Within home ranges, marten generally used habitat types proportional to their availability, particularly those that were preferred at the landscape scale. Marten avoided xeric habitat types, early seral stage habitat types, wetlands and lakes. I concluded that preferences for habitat types were manifested at the landscape scale and that apparently "low value" habitat types contained within home ranges were avoided in day-to-day activities. Although stand scale selection of habitat types was pre-empted by landscape scale selection, marten showed stand scale selection for habitats defined by their structural attributes. Selectivity was positively correlated with coarse woody debris volumes, stocking of trees, stocking of snags and snag size. Marten selected for intermediate to high levels of pieces of coarse woody debris and low levels of deciduous canopy closure, high shrub closure and low shrub closure.

Habitat selection at a patch scale was examined by comparing structural characteristics of 292 sites that marten used with characteristics of 388 random plots. Stratified by classes of structural attributes, characteristic of sites used by marten

differed significantly from the prevailing characteristics of the habitat. Marten selected patches that contained greater volumes of coarse woody debris (CWD) > 20 cm diameter and greater volumes of hard CWD than the habitat means when in 0 and 1-100 m³/ha habitat classes. Marten also selected patches that had more pieces of CWD than the habitat mean when they were in habitat types that typically had few pieces of CWD. Marten selected patches that had a mean coniferous canopy closure of 26% which was greater than the habitat mean for low (0-20) coniferous canopy closure habitats and less than the habitat mean for high (61-80) coniferous canopy closure habitats. They chose patches that had less deciduous canopy closure in all cases, less high shrub closure in habitats that typically had > 40% closure, greater low shrub closure in habitats with typically 0-20% closure, and less low shrub closure in habitats that typically had > 60% closure. When in habitats classed as forested, marten preferred patches that had intermediate (approximately 400 stems/ha) stocking of trees. Marten used sites that had trees when in habitats classed as treeless. Snag basal area and stocking levels at marten sites were greater than habitat means. Snag diameter did not differ between marten sites and habitat means. Through patch scale selection, marten can roam about habitat types and use sites which have structural characteristics different from those typical in the area. This behaviour allows marten to substantially improve their encounter rate of structural resources and exploit the best portions of marginal and low quality habitats.

Affinities of marten for structural characteristics of habitat are summarized in Table 4.1. Highly suitable winter habitats for marten in the Sub-Boreal Spruce zone

Table 4.1. Summary of affinities of marten for structural characteristics by life requisite (Allen 1982). "+" indicates high affinity, "0" indicates moderate affinity, "-" indicates low affinity, a blank indicates a nonexistent condition.

Life Requisite	Habitat Attribute	Attribute Level			
		None	Low	Moderate	High
Resting Sites	CWD Volume	-	-	0	+
	Pieces of CWD	-	-	+	0
	CWD Piece Size		-	0	+
	CWD Decay	+	+	0	-
	Tree Abundance	-	-	+	-
	Tree Size		-	+	+
	Snag Abundance	-	-	+	+
	Snag Size		-	0	+
Food/Foraging Sites	CWD Volume	-	-	0	+
	Pieces of CWD	-	-	+	0
	CWD Piece Size		-	0	+
	CWD Decay	+	+	0	-
	Moisture Regime		-	+	-
	Tree Abundance	-	-	+	-
	Tree Size		-	+	+
	Snag Abundance	-	-	+	+
	Snag Size		-	0	+
	Coniferous Canopy Closure	-	-	+	-
	High Shrub Closure	0	+	0	-
	Low Shrub Closure	0	+	0	-
Security	Coniferous Canopy Closure	-	-	+	+

are mesic to hygric forests of at least young forest seral stage (but generally mature forest or old growth) with high levels of CWD > 20 cm diameter, of which a substantial portion has little decay. These winter habitats also have intermediate coniferous canopy closure (20-60%), little deciduous canopy closure, and little to intermediate high and low shrub closure. They also have relatively high stocking of medium to large diameter snags and intermediate stocking levels of medium to large diameter trees.

Management Implications

Sub-Boreal Spruce forests do not provide suitable winter habitat for marten until they reach the young forest seral stage and do not provide highly suitable winter habitat until the mature forest seral stage. These habitat relationships of marten have implications for forest harvesting, in particular rate of cut. In most SBS forests, the young forest seral stage may not be reached until at least 50 years. If forest management objectives include ensuring viable populations of marten, the amount of suitable habitat available, its location, and spatial arrangement must be addressed. Soutiere (1979) found that when his study area was 50% clearcut (low suitability) and 25% selectively cut (moderate-high suitability) marten densities were reduced by two-thirds. Thompson and Harestad (in press) conducted a broad analysis of forest harvesting impacts on marten populations. They conclude that in most forest types modest amounts of cutting dispersed over the landscape are not detrimental to marten

populations and may even enhance them. Lofroth and Steventon (1990) recommended that no less than 50% of an area remain as suitable winter habitat for marten to maintain minimum viable populations. If highly productive marten populations that can sustain maximum harvests are desired then more conservative forest management regimes may be required. Ensuring that no more than one-third of an area is rendered unsuitable as winter habitat for marten will help achieve this goal. No more than one-third of an area should be in an herb-shrub or pole sapling seral stage and the remaining two-thirds should be divided evenly between young forest, mature forest and old growth seral stages. These recommendations assume harvesting regimes that incorporate three pass systems.

Marten prefer habitats that have 20-60% coniferous canopy closure and avoid habitats with greater or less than this attribute. At Emerson Creek, marten rarely ventured into recent clearcuts during winter (3 of 609 locations) and when they did, it was never very far. Baker (1992) suggested that recent clearcuts represent a greater mortality risk to marten than do forests. As a consequence, consideration needs to be given to harvest type, size, and shape of harvest area and the characteristics of retained forest blocks. Marten will cross openings of up to 100 m, but to allow cutblock size and shape to be governed by this distance will seriously affect future forest conditions. Future forests managed to ensure openings are less than 100 m would be typically edge dominated and have very little interior habitat. Bissonette et al. (1987) recommend that areas need be at least 25 ha in size to be useful to marten. Thus cutblocks should be approximately this size so that upon regrowth they will provide

forest stands suitable for marten. Corridors of forested habitat suitable for marten travel, and preferably other life requisites should be retained to ensure connectivity between patches of marten habitat. Forest managers should retain patches of forests (Franklin 1990, Hopwood 1991) within cut areas, particularly those patches with abundant large snags, trees and CWD. Retaining these patches will likely shorten an area's return time to suitable winter habitat and improve its overall suitability for marten. Marten, in some parts of their geographic distribution, are by necessity adapted to fire driven ecosystems. Although specifics regarding size, shape and configuration of cutblocks, corridors and leave areas are not readily available, managers should strive to use data from natural disturbance processes to guide forest land management. This includes data on disturbance type, intensity, size, frequency and post-disturbance conditions.

Although size and location of cutblocks are important criteria for marten habitat management, processes that alter forest structure also play an important role. Silvicultural operations have the capacity to seriously affect the rate of recovery and eventual suitability of harvested areas as marten winter habitat. Site preparation techniques have implications for coarse woody debris management. In particular broadcast burning, or piling and burning may change CWD in the following ways:

- 1) overall volume of CWD is reduced;
- 2) vertical structure of CWD is decreased because supporting branches are burned off;
- 3) bark retention on CWD is reduced or lost;

- 4) the ability of CWD to retain moisture is reduced (this may be important for small mammals, reptiles, amphibians and colonization by microfauna and flora) and;
- 5) CWD is case hardened which may enhance marten habitat because retention time is extended but it may diminish marten habitat because colonization by microfauna and microflora is impeded.

Site preparation objectives should provide adequate volumes of CWD well distributed over harvest areas for the duration of the rotation. Appropriate volumes may differ among sites, depending on ecological conditions and direction should be sought from similar "natural" ecosystems.

Regeneration stocking targets should be examined in light of marten habitat preferences for intermediate stocking levels and intermediate levels of coniferous canopy closure. High stocking rates serve to decrease stem size for an extended period of time and result in closed canopy forests at an earlier age. This creates a depauperate understory and likely low small mammal populations. Small stems also decrease availability of preferred den sites.

Stand tending operations that promote moderately open canopy, structurally diverse forests with productive shrub understories should be encouraged. Acceptability of trees in thinning, spacing and pruning operations should be reviewed and changes made to ensure adequate numbers of snags (wildlife trees) are provided in future forests.

Ecological conditions differ greatly not only between biogeoclimatic zones but also between finer levels of classification such as subzones. Marten likely depend on the same broad structural features of forests regardless of where they are in British Columbia. However the relative value of these features as marten habitat vary with ecological conditions. The extensive range of marten is testimony that marten are well adapted to survive in a variety of forest types and different environmental conditions (snow accumulation, duration of winter, prey base etc.). In the absence of habitat use information for particular ecological zones, foresters and habitat managers should use "unmanaged forest conditions" as models for managed forests. Indigenous fauna have presumably adapted to these conditions. If attributes of unmanaged forests are encouraged in managed forests, the long term maintenance and viability of marten populations should be ensured.

Research Needs

I was unable to determine the habitat use and preference characteristics of female marten for maternal den sites. The limited literature suggests that snags are important features of these sites, allowing females to keep kits in dry, secure conditions. As with some other ecologically important phenomena, use of maternal dens are critical but infrequent events and thus difficult to observe and quantify. I also was unable to adequately describe warm weather winter resting sites. Only two of these sites were found, both high in tree canopies, one in a mistletoe bundle and one at

the intersection of several leaning trees.

The generality of my findings to other ecological conditions needs to be examined. This has been done to some extent through snow track surveys in other subzones of the SBS, however a wider range of conditions needs to be tested both within the SBS zone and in other biogeoclimatic zones.

The link between habitat suitability and population dynamics is rarely addressed in habitat studies. This aspect needs to be examined so that critical levels of structural attributes can be identified.

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Appendix A. Ecosystems of the Emerson Creek study area, British Columbia.

Biogeoclimatic Subzone	Site Unit	Seral Association	Seral Stages	Site Series	Moisture/Nutrient Regime
SBS Dry Cool (dk)	Rose Peavine	Typic	1-4	01 (07)	mesic/mesotrophic
		Lodgepole Pine	2-4	01 (07)	mesic/mesotrophic
		Mixed Wood	2-4	01 (07)	mesic/mesotrophic
		Aspen Mixed Shrub	3,4	01 (07)	mesic/mesotrophic
		Alder Mixed Herb	3	01 (07)	mesic/mesotrophic
	Dry Pine	Mixed Wood	3	02, 03	subxeric (xeric) /submesotrophic - oligotrophic
	Dry Pine	Aspen Willow Woodland	3	02, 03	subxeric /submesotrophic
	Thimbleberry Forb	Typic Forb	1-4	08	mesic - subhygric /mesotrophic - permesotrophic
	Thimbleberry Forb	Mixed Wood	3,4	08	mesic - subhygric /mesotrophic - permesotrophic
	Thimbleberry Forb	Willow Alder Woodland	3	08	mesic (subhygric) /permesotrophic
	Thimbleberry Forb	Aspen Mixed Shrub	3,4	08	mesic - subhygric /mesotrophic - permesotrophic
	Thimbleberry Forb	Alder Mixed Herb	1	08	subhygric/eutrophic
	Thimbleberry Forb	Birch Mixed Shrub	3	08	subhygric /permesotrophic
Horsetail Flat	Typic	4	09	hygric - subhygric	

Appendix A. (Continued).

Biogeoclimatic Subzone	Site Unit	Seral Association	Seral Stages	Site Series	Moisture/Nutrient Regime
SBS Dry Cool (dk)	Cottonwood Bottomland	Typic	1,3,4	10	subhygric /subeutrophic
		Willow Mixed Shrub	2	10	subhygric /subeutrophic
	Forested Wetland	Typic	4	11,12	hydric/mesotrophic - permesotrophic
	Nonforested Wetland	Typic	1	11,12	subhydric - hydric /mesotrophic - permesotrophic
	Clearing	Typic	1	N/A	N/A
	Cultivated Land	Typic	1	N/A	N/A
SBS Moist Cold (mc)	Huckleberry Moss	Typic Moss	1-5	01	mesic (submesic) /mesotrophic
		Pine Huckleberry	1-4	01 (04)	mesic (submesic) /mesotrophic
		Green Alder	1-5	01 (04)	mesic (submesic) /permesotrophic
		Mixed Wood	2-4	01 (04)	mesic (submesic) /mesotrophic
		Willow Alder Woodland	3	01 (04)	mesic (submesic) /mesotrophic
		Aspen Mixed Shrub	3	01 (04)	mesic (submesic) /mesotrophic
		Hemlock Moss	5	01	mesic/mesotrophic
	Dry Pine	Typic	1-4	02,03	subxeric (xeric) /submesotrophic - oligotrophic

Appendix A. (Continued).

Biogeoclimatic Subzone	Site Unit	Seral Association	Seral Stages	Site Series	Moisture/Nutrient Regime
SBS Moist Cold (mc)	Dry Pine	Mixed Wood	3,4	02,03	subxeric (xeric) /submesotrophic - oligotrophic
		Aspen Willow Woodland	2,3	02,03	subxeric /submesotrophic
	Thimbleberry Oakfern	Typic	1-5	06,07	subhygric /permesotrophic
		Mixed Wood	3,4	06,07	(mesic) subhygric /permesotrophic
		Willow Alder Woodland	3	06,07	(mesic) subhygric /permesotrophic
		Thimbleberry Alder Mixed Shrub	1	06,07	subhygric /permesotrophic
		Alder Nettle	1	06,07	subhygric /subeutrophic
	Devil's Club	Typic	1,3-5	08	subhygric (hygric) /permesotrophic - eutrophic
		Green Alder	4,5	08	subhygric (hygric) /permesotrophic - eutrophic
		Thimbleberry Alder Mixed Shrub	1,2	08	subhygric (hygric) /permesotrophic - eutrophic
	Horsetail Flat	Typic	1,4,5	09	hygric - subhydric /permesotrophic
	Glow Moss	Typic	3-5	10	subhygric /permesotrophic

Appendix A. (Continued).

Biogeoclimatic Subzone	Site Unit	Seral Association	Seral Stages	Site Series	Moisture/Nutrient Regime
SBS Moist Cold (mc)	Cottonwood Bottomland	Typic	4	10	subhygric /subeutrophic
		Willow Mixed Shrub	1,3	10	subhygric /subeutrophic
	Forested Wetland	Typic	3,4	11	hydric /mesotrophic - permesotrophic
	Nonforested Wetland	Typic	1	11	subhydric - hydric /mesotrophic - permesotrophic
	Clearing	Typic	1	N/A	N/A