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Resting Site Characteristics of American Marten in the Northern Lower Peninsula of Michigan

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RESTING SITE CHARACTERISTICS OF AMERICAN MARTEN IN THE NORTHERN LOWER PENINSULA OF MICHIGAN

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This is dedicated to my wife Danya, children Colton and Maylan and my parents. Your support, understanding and encouragement throughout my educational and research requirements truly helped me achieve my goals. Thank you.

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ABSTRACT

RESTING SITE CHARACTERISTICS OF AMERICAN MARTEN IN THE NORTHERN LOWER PENINSULA OF MICHIGAN

by Robert L. Sanders

American marten are usually associated with forests that are characteristically late successional, closed canopy, and diverse in structure; attributes that meet habitat requirements and provide resting site structures. Resting site structures are required habitat components that are used daily and provide protection from predation and inclement weather. I identified resting site characteristics of American marten in the Manistee National Forest in Michigan's Lower Peninsula from May 2011 to December 2013. Twenty five marten (15 male and 10 female) were monitored using radio telemetry to identify what types of resting sites structures were used. I identified 522 unique resting site structures; tree cavities (n = 255, 48.9%), branches (n = 162, 31%), and nests (n = 90, 17.2%) were the three most commonly observed structures being used. During the summer season (April-September) marten used more exposed tree branches (41.8%), while in the winter (October-March) they used more cavities (64.5%). Marten were observed using structures in live trees 86% of the time. Live trees used by marten included oak species (*Quercus spp.)*, maple species (*Acer spp.*), and red pine (*Pinus resinosa*). Trees used as resting sites had significantly larger mean diameter at breast

height (DBH) than the average DBH of non-resting site trees found at resting site locations. The average stand basal area (33.9 m^2/ha) found in resting site plots was significantly larger than that found at control plots 60 meters away. Maintaining complex forest structure, abundant CWD, high percent canopy closure and high basal area should be considered when forest management guidelines are being drafted. Silviculture techniques that promote tree species diversity, older stand age classes, and retention of CWD are all important factors to consider when managing for marten. I recommend using a single-tree selection method for timber harvest in core marten habitat, which should allow loggers to retain larger diameter trees, pockets of higher basal areas around resting site structures, and abundant CWD. Additionally, the single-tree selection approach should promote an uneven-aged forest that will maintain a complex vertical and horizontal forest structure.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

The Little River Band of Ottawa Indians (LRBOI) is a federally recognized Native American Tribe that has rights within the 1836 Ceded territory located in Michigan. Traditionally, tribal members relied on the land and nature to persist in this region. The Anishinaabek people believed they and the natural world live in harmony and are connected. Typically, Anishinaabek communities were organized based on relationships found in the natural environment and would form family groups called "clans". Members were, and still are, associated with clan animals such as deer, bear, sturgeon, or marten, which are species native to the Great Lakes region. Clan members that are associated with American marten are part of the "Waabizheshi Dodem" (Marten Clan). Marten are both ecologically and culturally significant to the LRBOI community.

Marten are a species of concern to the LRBOI community. Restoration and stewardship of native species is a high priority for LRBOI, as is the Native culture, harmony, and connectedness to the natural world. At one time marten thrived throughout the Great Lakes Region, only to be locally extirpated and later reintroduced in Michigan's Lower Peninsula. Therefore, obtaining baseline information regarding this species is a critical step in sustaining a viable American marten population within the 1836 ceded territory.

CHAPTER I

INTRODUCTION

The American marten *(Martes americana)* is a small meso-carnivore that inhabits a large geographic range throughout North America. They range from Alaska to Newfoundland and from Oregon to Maine (Williams et al. 2007). The presence of marten in forest landscapes is used as an indicator of good quality habitat that is comprised of complex forest structure and composition (Buskirk and Powell, 1994; Buskirk and Ruggiero, 1994). Marten are typically associated with old-growth coniferous and mixed coniferous forests, which characteristically offer thick canopy cover, abundant tree cavities, vertical and horizontal forest structure and abundant coarse woody debris (CWD) (Buskirk and Ruggiero 1994; Bowman and Robitaille 1997; Chapin et al. 1997; Potvin et al. 2000). However, marten occupy different habitats across North America, due to compositional differences in forest types (Buskirk and Powell, 1994; Potvin et al., 2000). Because of these differences, marten use a wide-range of habitat attributes across their range. For example, marten in Canada and western United States forests use late-successional coniferous forests but in the eastern United States (i.e., Michigan, Maine, and New Hampshire) marten use mixed coniferous/deciduous and deciduous forest types (Chapin et al., 1997; Potvin et al., 2000, Jensen 2012). In Michigan, historical forest species composition and habitat types have changed drastically over the last 200 years due to European settlement (Whitney 1987, Frelich 2002).

Pre-European settlement forests in Michigan were generally diverse in species composition and consisted of older age classes with both structural and vertical diversity, with conifers (e.g., hemlock, red, white, jack pine) being some of the dominant tree species (Whitney 1987, Pilon 2006). Forest stands would have been comprised of large contiguous blocks that were heterogeneous in nature and unaltered by anthropogenic effects (e.g., timber harvest, development). In addition, the landscape was mixed with small tracts of subdominant tree species that created a mosaic patchwork of species richness and diversity (Whitney 1987, Frelich 2002).

Although forests today are still diverse, they are fragmented across the landscape and consist of entirely different age and physical structure than pre-European settlement forests. Old-growth forests are virtually non-existent, and forests are characteristically even-aged and lack the structural diversity once observed (Whitney 1987). Historically, soil nutrient limited areas would have consisted of tracts of conifer species (i.e., red, white, jack pine), which are now comprised mostly of aspen and second-growth hardwood species (Pilon 2006). As such, the habitat that marten were using prior to European settlement is different from current habitat occupied by marten presently in the LP. This drastic and abrupt change in habitat resulted in marten population declines in Michigan.

Marten were extirpated in Michigan's LP by 1911 and by 1939 in the Upper Peninsula (UP). These extirpations most likely occurred due to synergistic effects of over harvesting and habitat loss resulting from land clearing, logging practices, and forest fires caused by timber slash (Earle et al. 2001; Williams et al. 2007). During the latter part of the 20th century, logging practices shifted to a more conservative sustained-yield approach (i.e., silviculture methods), which resulted in the conversion of more suitable marten habitat (Earle et al. 2001). In 1955, the Michigan Department of Natural Resources (MDNR) and the United States Forest Service (USFS) began reintroduction efforts in the Upper Peninsula, releasing 276 marten between 1955 and 1979 (Williams et al. 2007). The reintroduction effort was considered successful, and in 2000 the Michigan Department of Natural Resources opened a limited trapping season in the Upper Peninsula (Cooley et al. 2002). In 1985 and 1986 the MDNR and USFS began reintroduction efforts in the LP (Williams et al. 2007). Two sites were chosen for reintroduction; 49 (25 males, 24 females) marten were released in the Pigeon River Country State Forest (PRCSF) and 36 (19 males, 17 females) were released in the Manistee National Forest (MNF, Williams et al. 2007). All 85 marten were live trapped and translocated from the Crown Chapleau Game Preserve in Ontario, Canada (Williams et al. 2007).

Marten are habitat specialists that require certain habitat components, within their range, that support resting site structures. Resting site availability is considered an important part of American marten habitat requirements because resting structures are thought to offer protection from predators and thermal protection from inclement weather (Zalewski 1997; Martin and Barrett 1991; Buskirk 1984). Marten are not physiologically adapted for cold weather due to their elongated bodies, small fat reserves, and relatively thin pelt, requiring them to use their environment to reduce thermoregulatory costs (Spencer 1987; Buskirk 1988; Taylor and Buskirk 1994). During winter months when temperatures can drop below a marten's lower critical temperature of 16^{o}C (Buskirk et al. 1988), marten rely on resting sites such as cavities, hollow logs and subnivean sites that minimize temperature loss. Their body temperature, together with the insulating qualities of snow and the materials of the resting site structures, can raise the temperature within the resting site above the ambient air temperature (Buskirk 1984). Additionally, marten can fall prey to many larger predator species (e.g., bobcat, coyote, fox, fisher, humans) and resting sites may provide shelter from not only larger terrestrial carnivores but avian predators (e.g., northern goshawk, great horned owl) as well (Buskirk 1984).

Marten use resting sites daily and vary resting site selection seasonally (Martin and Barrett 1991). While resting sites vary geographically, they typically fall into two categories: enclosed and exposed. Exposed resting sites include platforms and forked tree branches that provide refugia from predators, but offer little protection from the elements. These types of structures are typically used more in summer months (Martin and Barrett 1991, Bull and Heater 2000). Enclosed resting sites consist of snags, stumps, hollow logs, and subnivean sites, and are typically used more often in the winter when snow and cold temperatures persist. Enclosed resting sites offer thermoregulatory properties that help marten stay warm in cold weather (Spencer 1987; Buskirk 1984). Buskirk (1984) and Martin and Barrett (1991) found that resting sites were associated with late-successional coniferous forests with canopy closures of >60%. Forests with dense canopy cover offer protection from predators, foraging opportunities, exposure, and available resting site locations. In areas with old growth forest stands marten have been observed using subnivean sites (Buskirk 1984), which Buskirk and Spencer (1984; 1987) suggest are associated with CWD. However, old-growth forests and thus CWD are limited in Michigan's LP (Whitney 1987), perhaps making subnivean sites less available.

Although research has been conducted describing resting sites across a large geographical range in North America (Buskirk 1984; Spencer 1987; Buskirk et al. 1989; Zalewski 1997), no studies have been conducted in the LP. Marten in the LP appear to be occupying habitat unlike that analyzed in past studies; habitat that consists almost entirely of secondary forest characteristics. The status and habitat needs of marten in the LP are largely unknown due to the limited amount of research to date and the unique habitat this particular population occupies. What research has been conducted on the status of marten in the LP has mainly employed winter track surveys, baited track stations, and live-trapping to conduct mark re-capture studies (Irvine 1989, 1994; Harden 1998; Bostick 2003). Bostick (2003) found that marten populations appeared to be stable in the original release sites but were not expanding to other suitable areas. Nelson (2006) suggested that there are two populations that still exist in the LP. However, little is known about the status of the population(s) in the LP (i.e., is the population increasing, decreasing, or stable?). Further, the unique nature of the habitat being used by marten in the LP limits the usefulness of information from past publications in other geographical areas in developing forest management strategies supportive of a sustainable marten population. Although these studies are insightful they do not address the geographically specific micro-habitat requirements (e.g., resting sites structures) required by marten. Resting sites have been identified as being a key component of high quality marten habitat (Bull and Heater 2000), but there are currently only a limited number of studies that assess habitat requirements of marten in the Great Lakes region (Dumyahn et al. 2007, Buchanan 2008). Therefore, it is important to identify what habitat characteristics, including resting sites, are needed to maintain a viable marten population in the LP.

Identifying important characteristics of resting sites will aid greatly in formulating guidelines that managers can incorporate into forest management plans. The overall objectives of this study were to 1) determine habitat structures important to American marten, 2) identify characteristics influencing resting site use within marten home ranges, and 3) provide forest management recommendations to maintain and improve marten habitat.

CHAPTER II

STUDY AREA

The study area was located in Michigan's Northern Lower Peninsula (LP) in the Manistee National Forest (MNF) and adjacent public and private lands, primarily in Wexford and Lake Counties (Figure 1). Additionally, this area resides within the 1836 ceded territory of the Little River Band of Ottawa Indians (LRBOI). Habitat in the MNF varies widely throughout the forest, and the landscape is highly fragmented with private inholdings. The MNF is managed primarily for timber production, while maintaining a multiple use policy (USDA Forest Service 1996). Historically, Michigan was comprised of approximately thirty-seven million acres of forested land (Kapp 1999). However, when this land was settled timber harvest and logging slash created large wildfires that decimated a large proportion of these forests, which ultimately altered wildlife habitat in Michigan. In 1930, the Civilian Conservation Corps (CCC) reforested a large portion of the degraded landscape. Due to the CCC's past efforts, large tracts of red pine plantations occur throughout the MNF. Although comprised mostly of red pines, these "monoculture" stands also contain remnants of deciduous tree species.

My study area supports a variety of upland forest types comprised of mixed hardwood, aspen, and second-growth conifer stands. Important deciduous species include red oak (*Quercus rubra*), white oak (*Quercus alba*), black oak (*Quercus velutina*) black cherry (*Prunus serotina*), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), aspen (*Populus* spp.), American beech (*Fagus grandifolia*), American basswood (*Tilia* *americana*), white ash (*Fraxinus americana*), iron wood (*Carpinus caroliniana*), yellow birch (*Betula alleghaniensis*), and witch hazel (*Hammamelis virginiana*). Coniferous species include red pine (*Pinus resinosa*), white pine (*Pinus strobus*), jack pine (*Pinus banksiana*), and eastern hemlock (*Tsuga canadensis*).

The climate in Michigan's LP varies seasonally with mild summers and cold winters, which can persist up to 6 months. Average annual temperatures range from 16^{o}C in spring/summer (April – September) to 1^{o}C fall/winter (October – March; National Oceanic and Atmospheric Administration [NOAA] 2002). The mean annual snowfall averages 225 cm, while average annual rainfall is 76 cm (NOAA 2002). The elevation in the LP ranges from 174 m to 520 m. Topography in my study area is relativity flat with elevations ranging from 259 to 304 meters above sea level.

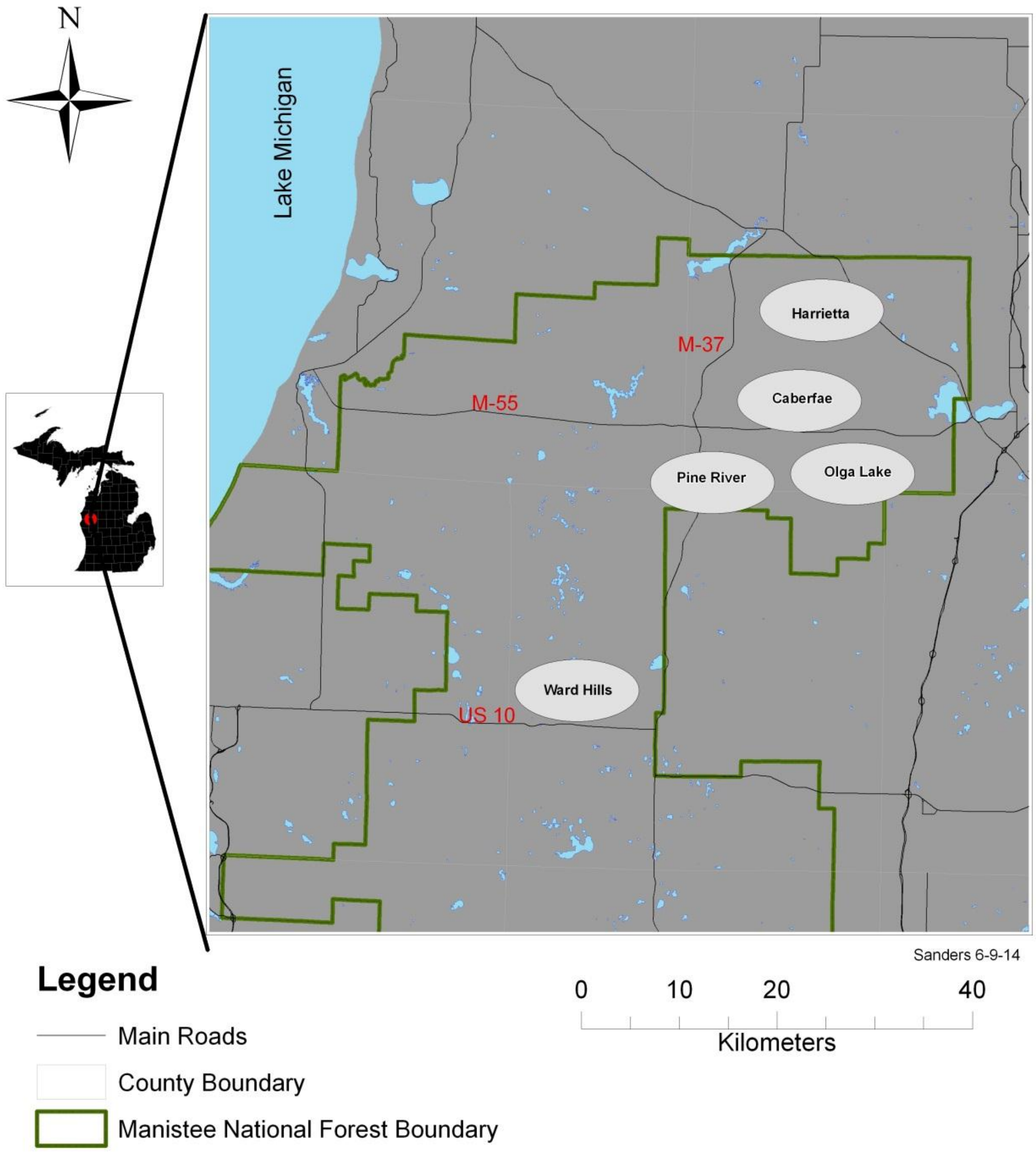

Figure 1. Location of study area in Michigan's Northern Lower Peninsula. The five ellipses represent areas where American marten were monitored in the Manistee National Forest (MNF) from May 2011 through December 2013.

CHAPTER III

METHODS

Capture

I live-trapped marten in 2011 during May and July, 2012 during January, May, July, and December, and 2013 during May, June, July, and August. I captured marten using tomahawk live traps (model 103 & 105, Tomahawk Live Trap Company, Tomahawk, Wisconsin, USA). Traps were baited with smoked pork, beaver, chicken, or venison and an olfactory long distance call lure was applied within three meters of the trap location ("Gusto", F &T Fur Harvest Trading Post, Alpena, MI.). During winter trapping sessions, traps were placed on the ground and covered with straw and one half of a fifty-five gallon barrel. I used this to protect captured marten from inclement weather and extreme cold temperatures. Additionally, traps were covered with natural debris (e.g., pine boughs, bark, moss, leaves, etc.) to make the trap blend in with the natural surroundings. During warmer trapping sessions (i.e., spring/summer seasons) I followed the same trapping procedures but did not use straw or barrels to cover traps. Upon marten captures, traps were wrapped in a canvas blanket to reduce visual stimulation and transported to a portable field lab. The field lab consisted of a truck with a camper top wired with lights and electrical outlets. Marten would then be transferred into a modified open-ended restraining cone (Desmarchelier et al. 2007). The end of the cone was open to allow access to the marten's snout, where a mask was used to pump isoflurane (a gas inhalant anesthetic) to induce anesthesia. Marten temperature, pulse, respiratory rates, and oxygen saturation levels were monitored throughout field immobilization. Body mass and morphometric measures were taken and marten were field aged based on tooth wear and classified as juvenile, sub-adult, or adult. In addition, blood, fecal, urine, ear swabs, and hair samples were collected from each marten for concurrent genetic and health assessment studies. Each marten was implanted subcutaneously with a personal identification tag (AVID Identification Systems Inc., Norco, California) for permanent identification. Marten were fitted with collar-mounted, mortality-sensing VHS radio transmitters that weighed ≤ 20 grams (Modified model RI-2D Holohil Systems Ltd., Ontario, Canada or Advanced Telemetry Systems, Isanti, Minnesota, USA model 1555). After completion of handling and immobilizing, marten were placed in a recovery box and transported back to the trap site where they were monitored until the effects of the anesthesia wore off ($\bar{x}$ = 7.5 ± 3.5 minutes). Marten were released when they demonstrated the ability to run off under their own capacity. Animal capture and handling activities were conducted using protocols established by the Little River Band of Ottawa Indians and Grand Valley State University Institutional Animal Care and Use Committee (protocol #12-05-A) and under the guidance of a licensed veterinarian (Maria Spriggs, DVM, Staff Veterinarian, Mesker Park Zoo and Botanical Garden, Evansville, Indiana).

Radio Telemetry/Resting Sites

Marten were located to identify resting site structures using radio telemetry at least once per week between 0800 and 1700 hours from May 2011 through December

2013. Once resting sites were located, attempts were made to see the marten in the structure. If the marten could not be seen in the structure, it was identified based on the following criteria: telemetry signal, tracks leading up to the structure, scat found at the base of the structure, chew marks around cavities, or vocalizations from within the structure. If the precise structure could not be identified I would just record the location of the marten. Structures were categorized as: hollow log, branch, cavity, nest (i.e., bird, squirrel, corvid, or raptor nests) or subnivean site. Living trees or dead snags with resting sites were identified to species and the diameter at breast height (DBH in cm) was recorded. If a marten was found in a cavity, branch, or nest, the structure's height was measured using a hypsometer (Forestry Pro laser rangefinder/hypsometer, Forestry Suppliers, Jackson, Mississippi, USA). Canopy closure of each site was estimated using a densiometer (spherical densiometer model C, Forestry Suppliers, Jackson, Mississippi, USA) and classified as $\leq 33\%$, 34-66%, or $\geq 67\%$. At each site, I described the habitat type (e.g., red pine stand, red pine mixed with oaks, hardwoods), which was based on tree composition located within a 15-m radius of the site. Temperature, cloud cover (clear, partly cloudy, or overcast), precipitation (rain, snow, sleet, or none), wind speed (m/s), and snow depth (no snow, trace-15 cm, or > 15 cm) were recorded. Resting sites were categorized into two seasons, summer (April-September) and winter (October-March). Locations of all resting sites were determined using Global Position System (GPS), and resting sites were flagged and painted with a letter R. To minimize disturbance to marten while in their resting sites, vegetation data was collected at a later date after marten had left the site.

Vegetation Sampling

For vegetation measurements, a subset of resting site locations was collected. A subset of sites was chosen because of the length of time it took to collect and measure vegetation in these locations. Resting site locations were randomly selected from each radio collared marten. For a subsample of resting site locations (n = 147), a 15-meter radius plot was measured around the resting site structure. A 15-meter plot was chosen so that the microhabitat features could be identified and I assumed that this was an important scale at which marten would select resting site features (Porter et al. 2005). Tree species were identified within each plot and the DBH of all trees ≥ 10 cm was measured. The average basal area (m^2/ha) was calculated for each site from the DBH measurements. The length and diameter was measured on all downed coarse woody debris ≥ 1.0 m long and ≥ 10 cm in diameter, and measured the length and width of all brush piles ≥ 1.0 m^2. One quadrant of the plot was selected randomly and all saplings ≥ 1.0 m tall were counted and identified. For each resting site surveyed, I established an associated control plot where I measured the same attributes as the resting site plots (Porter et al. 2005). Control plots were sampled to look for fine-scale differences between habitat used for resting sites and habitat that was available within the forest stand. Control plots were found by randomly selecting a cardinal direction (0-360^o) and measuring 60 m from the resting site structure. Sixty meters was selected so that there would be 15 meters between the rest site plot and control plot. This eliminated the chance that there would be any overlap between plots when measuring forest vegetation.

Home Range Analysis

Marten resting site locations were used to calculate home range size in my study area. Locations were obtained ≥ 24 hours apart by locating marten in their resting sites and taking a GPS location. Therefore, the only error associated with these locations was the accuracy of the GPS unit (Garmin Oregon 550t). Fixed kernel home range estimator was used to calculate home range size of marten (Worton 1989). This type of estimator takes into account extreme values (i.e., extreme outliers) and represents the actual area marten are utilizing (Powell 2000) better than other methods. In collaboration, ArcGIS (ESRI, ArcGIS Desktop: Release 10. Redlands, California, USA), geospatial modelling environment (www.spatialecology.com/gme/) and R was used to calculate both the 95% and 50% isopleth core area contours. The smoothed cross validation (SCV) parameter for bandwidth was used to estimate home range size (Powell 2000) and a 30 m cell size dimension was selected for the output raster.

Data Analysis

Mann-Whitney U median tests were conducted to compare mean basal area, average volume of CWD, average area of brush piles, and average number of saplings between resting site plots and control plots. I choose non-parametric tests because my data failed normality. Additionally, Mann-Whitney tests were conducted to detect differences between species occurrence and average DBH size between resting and control plots. Species diversity of trees and saplings counted in resting and control plots were calculated using Shannon-Weiner index, where p_i = the proportion of the total

$$H'_{\text{Density}} = p_i \ln p_i,$$

density of species i (Elliott and Hewitt 1997). I also used a chi-squared test to look at resting site selection differences between summer and winter seasons, between sexes, and between deciduous, coniferous and snags species. Data were manipulated using EXCEL and analyzed using Sigma Plot 12. Additionally, the mean and standard deviation will be reported as $\overline{x}$ = ± sd through the document.

Home range estimates were analyzed to look for differences between male and female marten that had ≥ 30 locations (Seaman et al. 1999). I compared differences (α = 0.05) in home range estimates at both the 50% and 95% core area contours between sexes using the Mann-Whitney rank sum analysis (Zar 1984).

CHAPTER IV

RESULTS

Trapping success

I captured 33 marten (19 male and 14 female) between May 2011 and August 2013. I classified 23 marten as adult, six as sub-adult, and four as juvenile. No capture myopathy was observed (i.e., marten death related to capture stress and handling) during any of the trapping sessions but I did document five marten mortalities (3 males and 2 female) during the study period (Table 1).

Resting Sites

I outfitted 25 (15 male and 10 female) marten with radio collars from which 522 individual resting site structures were identified. I had visual confirmation (i.e., I saw the marten using the structure) 71% of the time, whereas 29% of the time I had to rely on other clues to confirm the precise structure being utilized (i.e., scat, tracks, prey remains, chew marks, radio frequency strength or a combination of these). I identified five unique structure types being utilized as resting sites; cavities, branches, nests, hollow logs, and subnivean sites. The three most commonly observed structures were cavities (n = 255, 48.9%), branches (n = 162, 31.0%) and nests (n = 90, 17.2%, Table 2).

Differences in resting site selection were observed between the summer season (April – September) and winter season (October – March, Figure 2). Branches (41.1%)

Table 1. Details of 33 American marten trapped from May 2011 through August 2013 in the Manistee National Forest in Michigan's Lower Peninsula.

Capture year	Capture month	Id	Sex	Age	Body mass (g)	Status as of December 2013	Mortality
2011	January	606M	Male	Adult	978	Alive	
2011	May	314M	Male	Adult	984	Alive	
2011	January	090F	Female	Adult	718	Unknown	
2011	May	058M	Male	Adult	951	Unknown	
2011	July	333M	Male	Adult	814	Dead	Killed by marten
2011	May	290M	Male	Sub-adult	905	Dead	Hit by automobile
2011	May	884F	Female	Adult	684	Unknown	
2011	May	609F	Female	Adult	762	Unknown	
2011	May	522F	Female	Adult	646	Unknown	
2011	May	372M	Male	Adult	1150	Unknown	
2012	January	124M	Male	Adult	894	Alive	
2012	May	798F	Female	Adult	658	Alive	
2012	January	600F	Female	Sub-adult	674	Alive	
2012	May	367F	Female	Adult	805	Alive	
2012	January	009F	Female	Adult	641	Dead	Killed by a canine

2012	January	523M	Male	Adult	897	Alive	
2012	May	889M	Male	Sub-adult	1026	Unknown	
2012	May	365F	Female	Sub-adult	672	Dead	Unknown
2012	January	550M	Male	Sub-adult	873	Unknown	
2012	January	010F	Female	Adult	645	Alive	
2012	May	317M	Male	Adult	1223	Unknown	
2012	January	635M	Male	Adult	1041	Dead	Hit by automobile
2012	January	822F	Female	Adult	730	Unknown	
2013	May	627F	Female	Sub-adult	644	Unknown	
2013	August	100M	Male	Juvenile	840	Alive	
2013	August	057M	Male	Juvenile	792	Alive	
2013	July	078M	Male	Adult	1064	Alive	
2013	July	601M	Male	Adult	1126	Alive	
2013	August	857F	Female	Adult	728	Unknown	
2013	August	619M	Male	Adult	1140	Alive	
2013	May	581M	Male	Adult	892	Unknown	
2013	June	055M	Male	Juvenile	Unknown	Unknown	
2013	July	847F	Female	Juvenile	544	Unknown	
Total			Male Female		$\bar{x} = 977 \pm 126$ $\bar{x} = 682 \pm 63$		5

Table 2. Resting site structures used by American marten (15 male and 10 female) in the summer and winter season in the Manistee National Forest from May 2011 through December 2013. Summer season is defined as April – September and winter season is defined as October – March. Males and females were pooled for analysis.

Resting site structure	Summer Season n	Summer Season %	Winter Season n	Winter Season %	Total resting site structures n	Total resting site structures %
Cavity	129	39.3	126	64.9	255	48.9
Branch	137	41.8	25	12.9	162	31.0
Nests	52	15.9	38	19.6	90	17.2
Hollow log	9	2.7	2	1.0	11	2.1
Subnivean	1	0.3	3	1.5	4	0.8
Total	328	100	194	100	522	100

and cavities (37.8%), were selected most often in summer, while cavities (64.1%) and nests (20.0%) were selected most often in winter (χ^2 = 52.3, df = 2, p < 0.001, Table 2). A significant difference was found when comparing male and female resting site selection (χ^2 = 32.3, df = 2, p < 0.001). Male marten chose more nests and branches than expected while females choose more cavities.

The type of arboreal resting site structures varied by tree species. Cavity (n = 132, 53%) and branch (n = 61, 38%) resting sites were located most often in oak tree species (i.e., black, red, white oak), whereas nest structures used by marten were found more often in red pines (n = 50, 56%, Figure 3). The average heights of cavities (n =

249), branches (n = 159), and nests (n = 90) were, 4.3 ± 2.1, 8.6 ± 3.1, and 12.7 ± 2.5 meters respectively (Table 3).

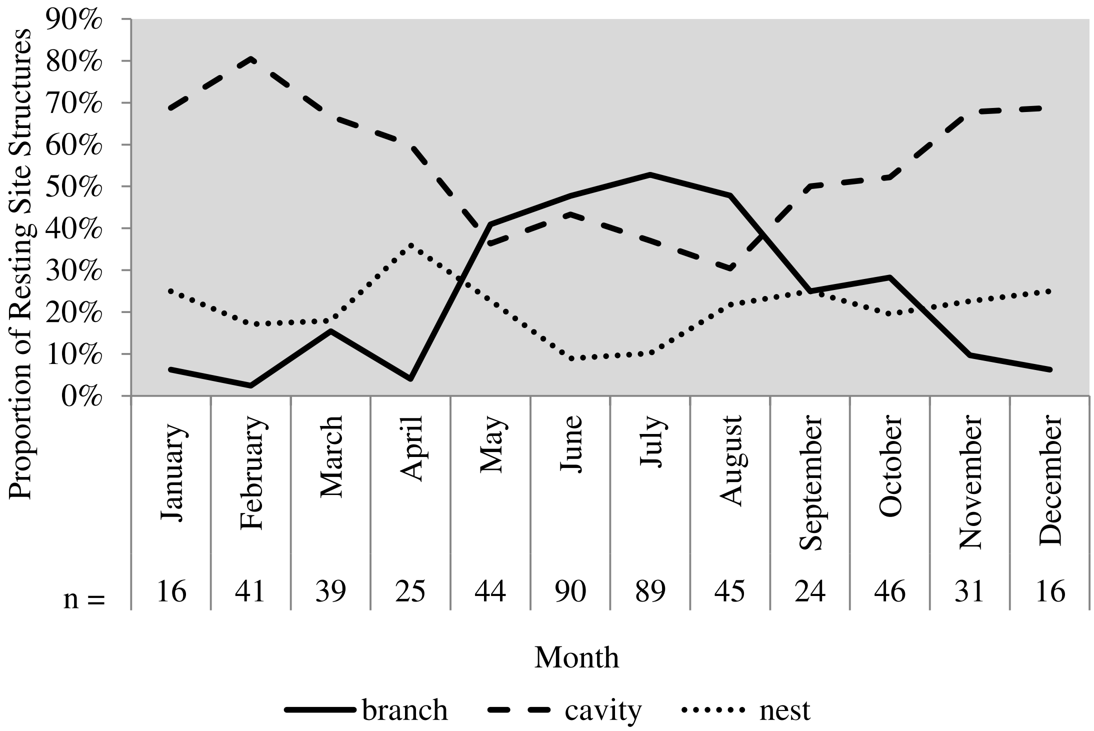

Figure 2. Proportion and types of resting site structures shown by month in the Manistee National Forest during May 2011 through December 2013. Summer season is defined as April – September and winter season is defined as October – March. Hollow log and subnivean resting sites were excluded due to limited number of observations.

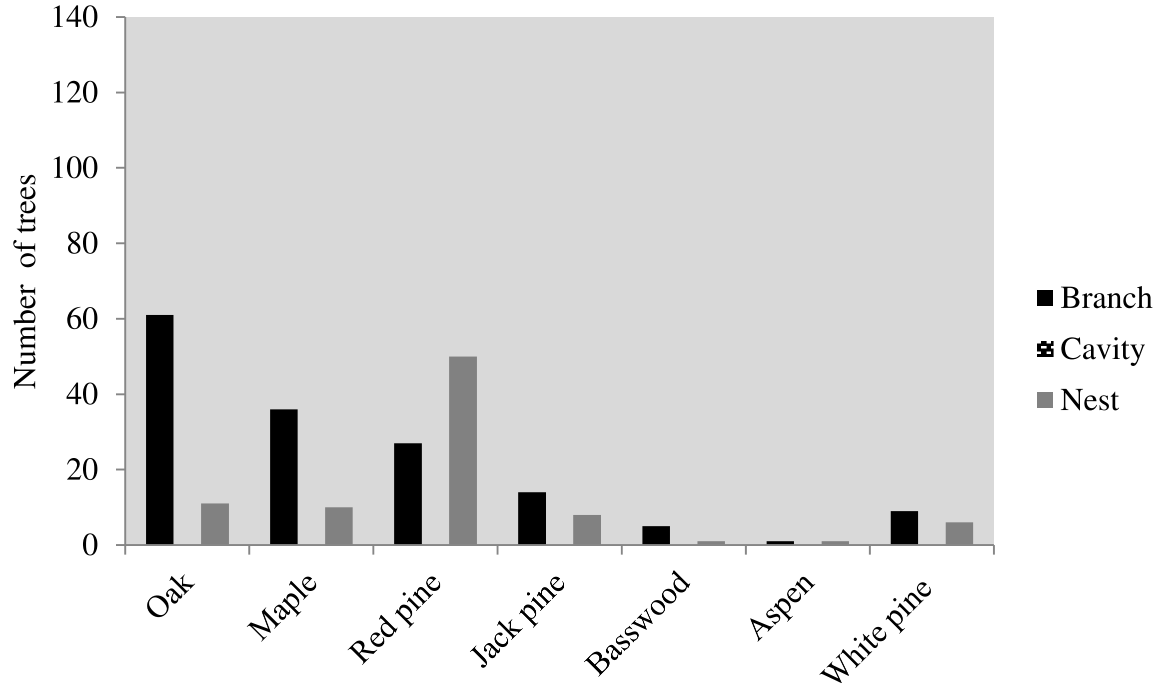

Figure 3. Distribution of resting site structures by tree species found in the Manistee National Forest from May 2011 through December 2013. Tree species < 2% of the total were excluded from the figure.

Table 3. The mean height (m = meters) of arboreal resting site structures and associated tree species in which they were located within the Manistee National Forest during May 2011 through December 2013.

	Resting Site Structures								
	Cavity			Branch			Nest		
Tree species	n	Height (m)	SD (m)	n	Height (m)	SD (m)	n	Height (m)	SD (m)
Oak species[a]	132	4.2	2.7	61	8.1	2.9	11	10.2	3.1
Aspen species[b]	46	7.0	3.2	1	7.9	n/a	1	23.5	n/a
Maple species[c]	44	4.0	3.3	36	7.9	3.0	10	13.3	4.2
Basswood	12	4.2	2.8	5	8.9	5.3	1	19.2	n/a
Black cherry	6	6.6	1.3	3	12.8	n/a	1	6.1	n/a
American beech	3	3.5	1.1	2	11.9	0.4	2	6.2	1.5
Red pine	2	3.5	n/a	27	8.2	4.0	50	14.6	2.3
White pine	2	2.9	0.6	9	8.3	2.5	6	8.0	1.9
Yellow birch	1	2.4	n/a	0	n/a	n/a	0	n/a	n/a
Ash	1	unknown	n/a	1	4.7	n/a	0	n/a	n/a
Jack pine	0	n/a	n/a	14	7.0	3.6	8	12.8	2.2
Total	249	4.3	2.1	159	8.6	3.1	90	12.7	2.5

[a] Oak species include Black, Red, and White oak
[b] Aspen species include Big tooth and Quaking aspen
[c] Maple species include Red and Sugar maple

Marten used forested stands that had a high percent canopy closure. I found 77.9% (n = 395) of sites were located in forest stands that had ≥ 67% canopy closures, 19.7% (n = 100) with closures of between 34 – 66% and only 2.4% (n = 12) with canopy closures of ≤ 33%.

Of the 522 unique resting sites observed, 429 were found in live trees (86.1%) and 69 in snags (13.9%). I found 11 different live tree species were utilized by marten for resting sites. The three most frequently used tree types were oak species (40.6%), maple species (18.4%) and red pine (18.2%). I found that resting sites located in oak species (n = 174) had an average DBH of 53.2 ± 15.4 cm, maple species (n = 79) 45.0 ± 13.2 cm and red pine (n = 78) 29.3 ± 5.9 cm (Table 4). I found that the average DBH of all resting site trees (n = 429, $\bar{x}$ = 42.9 ± 10.3 cm) was significantly larger (U' = 268721, p = < 0.001) then the average DBH (n = 7764, $\bar{x}$ = 21.1 ± 9.0 cm) of non-resting site trees found within the 15-meter established vegetation plot around resting site structures. Snag trees (i.e., standing, dead or dying tree with no leaves) that were used as resting sites were found in nine different tree species (Table 5). The three most commonly observed snags species being utilized by marten were oak snags (43.5%, $\bar{x}$ = 45.1 ± 11.6 cm DBH, n = 30), aspen snags (21.7%, $\bar{x}$ = 34.8 ± 7.7 cm DBH, n = 15), and maple snags (15.9%, $\bar{x}$ = 32.9 ± 8.5 cm DBH, n = 11, Table 5). The average DBH of all resting sites snags (n = 69, $\bar{x}$ = 34.5 ± 8.6 cm) was significantly larger (U' = 3425, p = < 0.001) then the average DBH (n = 767, $\bar{x}$ = 17.6 ± 7.8 cm) of non-resting site snags found within the 15-meter established vegetation plot around used snag structures. Resting site structures, including snags, were found in deciduous trees 63.3% (n = 325), in coniferous trees 21.6%

Table 4. Live tree species used for resting sites and associated type of resting site used by American marten in the Manistee National Forest from May 2011 through December 2013. Diameter at breast height (DBH) is a total average per tree species and measured in centimeters (cm, sd = standard deviation). Percentage is the total for the column.

	Resting Site Structures									Overall Total		
	Cavity			Branch			Nest					
Live tree species	n	DBH (sd)	%	n	DBH (sd)	%	n	DBH (sd)	%	n	DBH (sd)	%
Oak species[a]	107	55.7 (14.7)	54.6	57	49.9 (15.9)	39.0	10	47.7 (15.8)	11.5	174	53.2 (15.4)	40.6
Maple Species[b]	35	46.7 (14.4)	17.9	34	44.0 (12.4)	23.3	10	41.7 (11.0)	11.5	79	45.0 (13.2)	18.4
Red pine	1	39.4 (n/a)	0.5	27	27.8 (5.8)	18.5	50	29.8 (5.7)	57.5	78	29.3 (5.9)	18.2
Aspen Species[c]	31	42.4 (9.0)	15.8	1	33.5 (n/a)	0.7	1	53.3 (n/a)	1.1	33	42.5 (9.1)	7.7
White pine	1	40.9 (n/a)	0.5	9	36.9 (14.3)	6.2	6	25.3 (8.1)	6.9	16	33.1 (12.9)	3.7
Basswood	11	49.6 (8.4)	5.6	4	42.2 (11.1)	2.7	1	41.4 (n/a)	1.1	16	46.9 (9.3)	3.7
Jack pine	0	n/a	0.0	9	26.5 (4.6)	6.2	6	27.9 (3.9)	6.9	15	27.1 (4.2)	3.5

American beech	3	45.9 (8.4)	1.5	2	32.7 (5.6)	1.4	2	25.7 (16.2)	2.3	7	36.3 (12.7)	1.6
Black cherry	5	33.9 (12.4)	2.41	3	35.6 (n/a)	2.1	1	40.4 (n/a)	1.1	9	35.1 (10.4)	2.1
White ash	1	64.5 (n/a)	0.5	0	n/a	0.0	0	n/a	0.00	1	64.5 (n/a)	0.2
Yellow birch	1	58.7 (n/a)	0.5	0	n/a	0.0	0	n/a	0.00	1	58.7 (n/a)	0.2
Total	196	47.8 (11.2)	100	146	36.6 (10.0)	100	87	37.0 (10.1)	100	429	42.9 (10.3)	100

[a] Oak species include black, red, and white oak

[b] Maple species include red and sugar maple species

[c] Aspen species include big tooth and quaking species

Table 5. Snag tree species used for resting sites and associated structure type found in the Manistee National Forest from May 2011 through December 2013. Diameter at breast height (DBH) is a total average per tree species and measured in centimeters (cm, sd = standard deviation). Percentage is a total for the column.

	Resting site structures in Snags											
	Cavity			Branch			Nest			Overall total		
Snag tree species	n	DBH (sd)	%	n	DBH (sd)	%	n	DBH (sd)	%	n	DBH (sd)	%
Oak species[a]	25	46.6 (11.7)	47.2	4	38.7 (10.3)	30.8	1	34.8 (n/a)	33.3	30	45.1 (11.6)	43.5
Aspen species[b]	15	34.8 (7.7)	28.3	0	n/a	0.0	0	n/a	0.0	15	34.8 (7.7)	21.7
Maple species[c]	9	33.0 (8.2)	17.0	2	32.4 (13.9)	15.4	0	n/a	0.0	11	32.9 (8.5)	15.9
Jack pine	0	n/a	0.0	5	19.1 (5.3)	38.5	2	32.4 (7.8)	66.7	7	22.9 (8.4)	10.1
Basswood	1	41.7 (n/a)	1.9	1	31.8 (n/a)	7.7	0	n/a	0.0	2	36.7 (7.0)	2.9
White pine	1	51.8 (n/a)	1.9	0	n/a	0.0	0	n/a	0.0	1	n/a	1.4
Red pine	1	30.1 (n/a)	1.9	0	n/a	0.0	0	n/a	0.0	1	n/a	1.4

White ash	0	n/a	0.0	1	44.4 (n/a)	7.7	0	n/a	0.0	1	n/a	1.4
Black cherry	1	37.3 (n/a)	1.9	0	n/a	0.0	0	n/a	0.0	1	n/a	1.4
Total	53	39.3 (9.2)	100	13	33.3 (9.8)	100	3	33.6 (7.8)	100	69	34.5 (8.6)	100

[a] Oak species include black, red, and white oak trees

[b] Aspen species include big tooth and quaking aspen trees

[c] Maple species include red and sugar maple trees

(n = 111) and in snags 15.0% (n = 77) of the time. From a subsample of resting site plots (n = 147), I found marten were selecting deciduous trees (n = 98) significantly more and coniferous trees (n = 25) significantly less than would be expected based on availability (defined as the total number of trees of each type pooled from the 147 used resting site plots), while no differences were observed when comparing snags ($\chi^2 = 110.3$, df = 2, $p < 0.001$).

I observed marten reusing resting sites on 159 separate occasions throughout the course on this study. Of the 522 individual resting sites, I observed marten re-using 72 (13.7%) of those sites on more than one occasion (Table 6). I found that 450 of the resting sites were used only once, 48 were re-used twice, 13 were re-used three times, five were re-used four times, and two sites were re-used five times. Additionally, four resting sites were re-used six, seven, nine and ten times. I also observed 10 marten re-using resting sites that had been previously occupied by different marten. I observed 20 individual resting site structures being used, on separate occasions, by different marten. The number of times resting sites were re-used varied by individual (Table 6). I found that cavities had the highest percentage of resting site re-use among the five structure types identified (i.e., cavities, nests, branches, hollow logs, and subnivean, Figure 4). Resting sites classified as "re-used" were only counted one time in the total resting sites observed (n = 522).

Vegetation analysis

I identified 15 different overstory tree species from 294 vegetation plots (n = 147 resting site plots, n = 147 control plots). Trees species richness per plot ranged from 3 to

9 species ($\overline{x}$ = 4.95 ± 1.16) in resting site plots and 1 to 8 species ($\overline{x}$ = 4.71 ± 1.17) in control plots and no significant difference was observed. The three tree types found most frequently in the overstory from resting site plots were red pine (n = 3377, 41.7%), white pine (n = 1134, 14.0%), and snags (n = 767, 9.5%, Table 7). I included snags in my analysis, even though I did not identify them down to species, because I felt they represented an important part of the habitat composition associated with vegetation plots. Therefore, for this analysis I classified them as "snags" and included those as part of the live tree species analysis. The average DBH of red pine ($\overline{x}$ = 20.8 ± 6.6 cm) and white ash trees (n = 59, $\overline{x}$ = 19.9 ± 11.7 cm) in resting site plots was significantly lower (p = 0.001) than the average DBH of red pine (n = 2861, $\overline{x}$ = 21.9 ± 6.8 cm) and white ash trees (n = 45, $\overline{x}$ = 29.8 ± 15.0 cm) in control plots (Table 7). Additionally, I found that the average DBH of basswood (n = 121, $\overline{x}$ = 34.9 ± 9.4) and ironwood trees (n = 45, $\overline{x}$ = 15.4 ± 6.2 cm) were significantly larger in resting site plots then control plots (n = 101, ¯ = 32.4 ± 7.7 cm and n = 68, $\overline{x}$ = 13.3 ± 3.5 cm, Table 7). I found that the mean number of trees per resting site plots ≥ 10 cm was 55.2 ± 23.3. Furthermore, I found approximately twice the amount of coniferous trees in resting site plots (n = 4859, $\overline{x}$ = 33.1 ± 26.2) as deciduous trees (n = 2481, $\overline{x}$ = 16.9 ± 10.1). The mean number of snags per resting site plot was 5.2 ± 4.3.

I counted a total of 44,144 sapling trees (trees < 10 cm) and identified 23 sapling species in vegetation plots (n = 147 resting sites and n = 147 control plots, Figure 5). Sapling tree species richness ranged from 1 to 8 species ($\overline{x}$ = 3.30 ± 1.38) in resting site plots and 0 to 8 species ($\overline{x}$ = 3.14 ± 1.44) in control plots. Sugar maple (38%), American

Table 6. American marten ID number, location, number of resting sites found, number of re-used sites observed, and proportion of resting sites re-used by individual marten from May 2011 through December 2013 in the Manistee National Forest in Michigan's Lower Peninsula. Marten with < 5 locations were excluded from this table.

Marten Id #	Sex	Location	# of rest sites	# of re-used sites	Proportion re-used
124M	Male	Olga Lake	60	8	0.13
798F	Female	Olga Lake	47	6	0.13
600F	Female	Caberfae	45	11	0.24
606M	Male	Ward Hills	37	0	0.00
367F	Female	Caberfae	38	3	0.08
314M	Male	Caberfae	35	3	0.09
009F	Female	Ward Hills	33	8	0.24
523M	Male	Caberfae	32	7	0.22
889M	Male	Olga Lake	27	4	0.15
627F	Female	Ward Hills	23	0	0.00
100M	Male	Olga Lake	20	5	0.25
365F	Female	Pine River	18	0	0.00
550M	Male	Ward Hills	17	2	0.12
057M	Male	Olga Lake	15	2	0.13
010F	Female	Caberfae	14	3	0.21
317M	Male	Pine River	10	1	0.10
078M	Male	Ward Hills	11	0	0.00
635M	Male	Ward Hills	9	3	0.33
822F	Female	Ward Hills	9	4	0.44
090F	Female	Ward Hills	7	1	0.14
601M	Male	Harrietta	6	0	0.00
058M	Male	Ward Hills	6	1	0.17
Total			519	72	

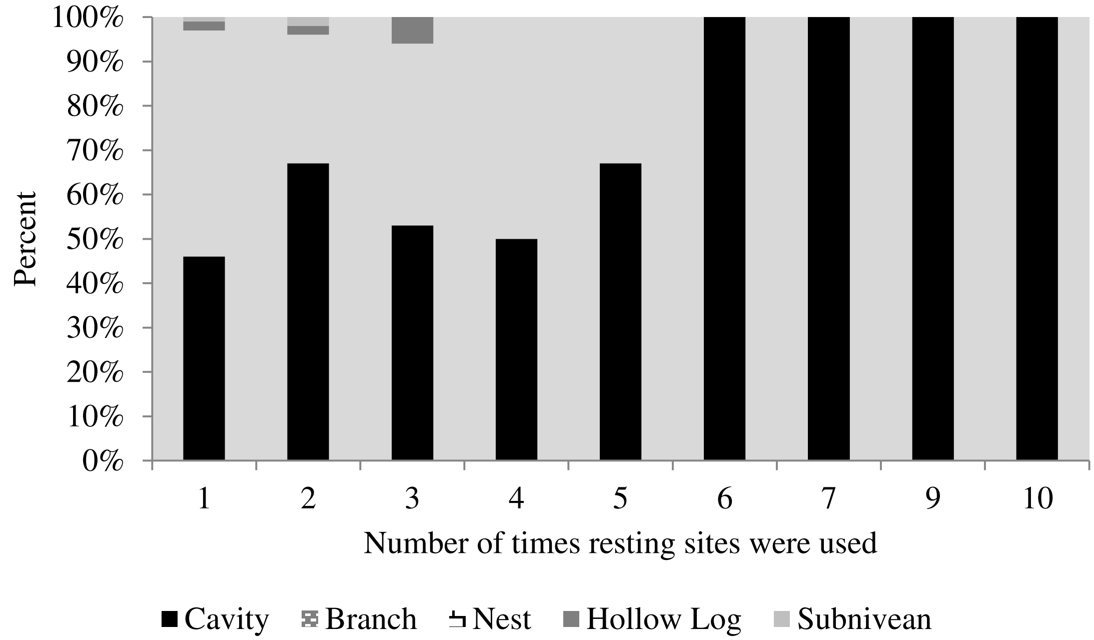

Figure 4. Distribution of resting site structures that were used (1) and re-used (2-10) from May 2011 through December 2013 in the Manistee National Forest in Michigan Lower Peninsula. The x-axis indicates the number of times marten were found using a resting site.

Table 7. Percent community composition and analysis of mean DBH (± sd) of tree species, including snags, in the overstory located at resting site and control plots in the Manistee National Forest in Michigan's Lower Peninsula. P-value represents a significant difference at 0.05 confidence interval between resting site and control plot DBH size.

	Resting Sites (n=147)				Control Sites (n=147)				
Tree Species	n	%	DBH	sd	n	%	DBH	sd	P-Value
Red Pine	3377	41.7	20.8	6.6	2861	38.2	21.9	6.8	**0.001**[b]
White Pine	1134	14.0	17.8	7.4	1013	13.5	17.6	6.9	0.563
Snag	767	9.5	17.6	7.8	831	11.1	17.5	6.8	0.597
White Oak	535	6.6	20.7	9.6	518	6.9	19.8	8.8	0.239
Sugar Maple	415	5.1	27.7	12.4	469	6.3	27.5	12.2	0.871
Red Oak	506	6.2	30.3	15.2	419	5.6	29.3	13.3	0.736
Jack Pine	348	4.3	21.3	5.1	322	4.3	21.9	5.1	0.220
Red Maple	326	4.0	18.5	7.6	318	4.3	19.3	7.3	0.080
American Beech	126	1.6	21.7	13.5	254	3.4	22.2	11.0	0.107
Black Oak	173	2.1	31.7	12.5	133	1.8	29.4	11.3	0.145
Big Tooth Aspen	157	1.9	26.4	12.4	102	1.4	23.4	10.2	0.108
Basswood	121	1.5	34.9	9.4	101	1.4	32.4	7.6	**0.033**[b]
Ironwood	45	0.6	15.4	6.2	68	0.9	13.3	3.5	**0.046**[b]
White Ash	59	0.7	19.9	11.7	45	0.6	29.8	15.0	**0.001**[b]
Black Cherry	15	0.2	25.0	15.5	32	0.4	25.9	16.2	0.784
Total	8104	100	23.3[a]	10.2	7486	100	23.4[a]	9.5	

[a] Presents average of total, [b] Significant at $p < 0.05$

beech (16%), and white oak (10%) were the three most abundant sapling species in the understory, and significantly more sugar maple saplings were found in resting sites plots than in control plots (U' = 414.5, p = 0.030). The overstory Shannon Index between resting and control plots ranged from 0.26 to 1.81 ($\overline{x}$ = 1.08 ± 0.36) and 0.00 to 1.84

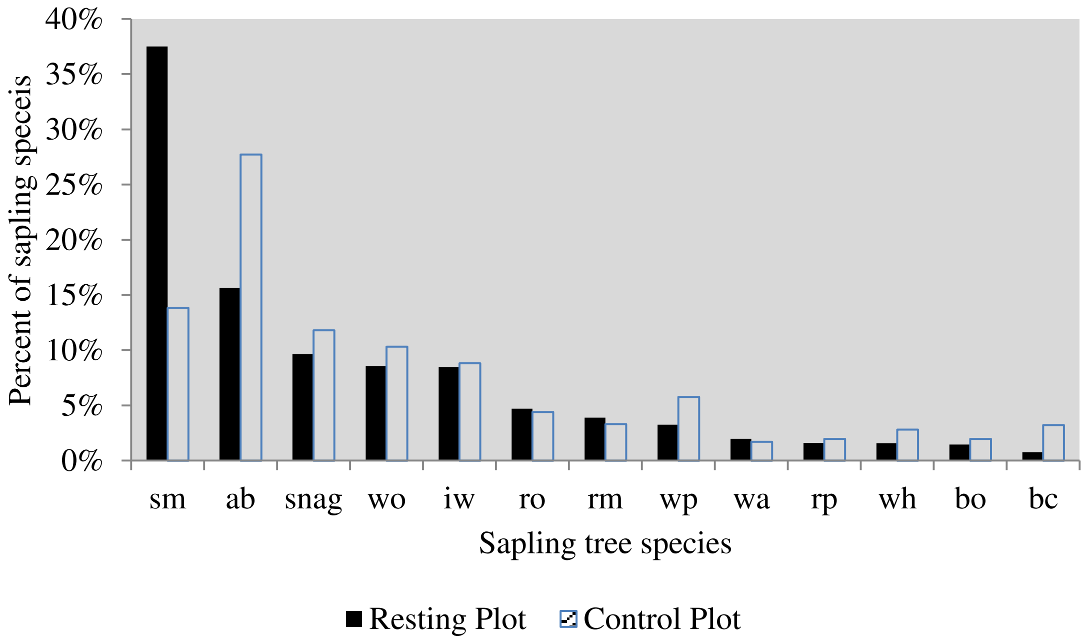

Figure 5. Percent of saplings species found in resting site and control plots. Percentage is the total number of individual species measured. Species that were less than 1% were excluded from analysis. Total number of plots was n = 294 (n = 147 resting plots, n = 147 control plots). Data was collected in 2012 and 2013 in the Manistee National Forest in Michigan's Lower Peninsula. sm = sugar maple, ab = American beech, snag = snag, wo = white oak, iw = iron wood, ro = red oak, rm = red maple, wp = white pine, wa = white ash, rp = red pine, wh = witch hazel, bo = black oak, bc = black cherry.

($\overline{x}$ = 1.04 ± 0.38) respectively. I did not find a significant difference between the diversity index values in overstory tree species between plots (U' = 10521, p = 0.698, n = 147 resting site plots, n = 147 control plots). The Shannon Index for saplings ranged between 0 and 1.62 ($\overline{x}$ = 0.82 ± 0.37) in resting sites plots and 0 to 1.59 ($\overline{x}$ = 0.78 ± 0.42) in control plots. I did not find a significant difference when comparing the sapling species diversity index values between resting and control plots (U' = 10349, p = 0.53).

I found average basal area for resting site plots (n = 147, $\overline{x}$ = 33.92 ± 9.04 m^2 ha) was significantly larger than control plots (n = 147, $\overline{x}$ = 31.10 ± 8.69 m^2 ha, p = 0.007). When comparing the total volume of CWD between resting sites and control plots I found no significant difference (U' = 9567, p = 0.090, n = 147). Additionally, I did not find any significant difference in the total area of brush piles between resting site and control plots (U' = 16318, p = 0.525).

Home-range estimates

From May 2011 through December 2013 I collected 690 GPS locations from 25 marten. Locations were all collected by physically walking in and identifying the precise location of the marten. I collected 62% (n = 427) of locations during the summer season (April – September) and 38% (n = 263) during the winter season (October – March). The number of locations per marten ranged between 1 and 73. Sixteen marten did not meet the minimum (≥ 30 per individual) location requirements to effectively establish a home range estimate and were excluded from further analysis.

A total of nine marten (5 male and 4 female) were used to estimate home range size (Table 8). At the 95% contour interval male marten had an average home range of 22.59 km^2 ± 18.78 km^2 with a range of 7.66 to 54.78 km^2, while females averaged 6.24 km^2 ± 4.01 km^2 with a range of 2.83 to 12.01 km^2. At the 50% contour I found that the average male core area was 5.25 km^2 ± 4.10 km^2 with a range of 2.02 to 11.88 km^2 and females 1.31 km^2 ± 0.69 km^2 with a range of 0.73 to 2.30 km^2. Due to a small sample size I combined data for the entire study period (i.e., May 2011 through December 2013). I did find a significant difference between male and female home range estimates at the 95% contour interval (U' = 1.00, p = 0.03). However, I was unable to distinguish a significant difference between male ($\overline{x}$ = 5.25 ± 4.10) and female ($\overline{x}$ = 1.31 ± 0.69) home range estimates at the 50% core area contour (t = 1.88, p = 0.10).

Table 8. Fixed kernel home range estimates (km^2) at the 95% contour and 50% core area contours of nine radio collared American marten from May 2011 through December 2013 in the Manistee National Forest in Michigan's Lower Peninsula.

			Home range estimates	
Marten ID	Number of Locations	Duration of monitoring	Fixed Kernel (km^2) 95% Contour	Fixed Kernel (km^2) 50% Contour
Male				
124M	73	Feb. 2012 – July 2013	13.15	2.82
314M	40	Oct. 2011 – Aug. 2013	22.68	6.54
523M	53	Feb. 2012 – July 2013	7.66	2.02
606M	41	June 2011 – May 2013	54.78	11.88
889M	38	May 2012 – April 2013	14.71	3.00
$\bar{x}$			22.59 ± 18.78	5.25 ± 4.10
Female				
798F	64	May 2012 – Sept. 2013	12.01	2.30
009F	45	Feb. 2012 – April 2013	5.62	1.21
367F	42	June 2012 – July 2013	2.83	0.73
600F	73	Feb. 2012 – July 2013	4.52	1.00
$\bar{x}$			6.24 ± 4.01	1.31 ± 0.69

CHAPTER V

DISCUSSION

American marten in the Lower Peninsula of Michigan used resting sites that were associated with large diameter trees, high basal areas and high percent canopy closure. Although vegetation and tree composition changes geographically, my findings are similar to other marten studies and certain resting site selection patterns that have been observed. In Bialowieza National Park, Poland, pine marten (*Martes martes*) were observed using arboreal resting sites (mainly cavities and nests) throughout the year > 95% of the time (Zalewski 1997). Bull and Heater (2000) found American marten in Northeastern Oregon selected platforms, cavities, and subnivean sites most often. Typically, cavities are associated with large diameter trees in late successional forests. However, in Michigan, these types of forest characteristics are limited because of past and current forest management strategies and land use practices. Although entire forest stands may not exhibit these characteristic, certain remnant tree species (e.g., old age class oak species possessing cavities and large branch platforms) within forest stands often possess these characteristics in my study area.

Throughout the year marten selected different types of resting site structures, which suggests that temperatures influenced selection preference. Marten have been shown to select arboreal structures, such as branches and witches broom (i.e., abnormal growth of small branches) in warmer months, whereas subnivean sites were used more during colder months (Chapin et al. 1997; Zalewski 1997; Bull and Heater 2000). My data support these findings. For example, I found marten selected branches for resting sites more in summer than winter. This was likely due to the fact that marten, during warmer temperatures, do not have to rely on resting site structures, such as cavities, nests, or subnivean sites, to provide thermoregulatory protection. Additionally, during summer months, deciduous trees support dense canopy cover, which may decrease risks from avian predators and allow marten to use these types of structures. Although not tested, marten, in part, may select resting sites on exposed branches to increase foraging success. These types of resting sites were found an average of eight meters above ground and offered marten a higher vantage point, which may have increased their field of view and ultimately may have increased their ability to detect and locate prey. I found that the use of nests (e.g., squirrel dreys, corvid, or raptor constructions) as resting sites increased during the winter season, which suggests that these types of structures meet certain requirements needed during cooler temperatures. Nests may offer thermoregulatory benefits when temperatures are low, and offer protection from predation. Additionally, nests may also provide a foraging opportunity for marten. Squirrel remains were documented at multiple resting site locations, suggesting that squirrels were an important prey species for marten in my study area. Cavities were used fairly uniformly throughout the year and potentially offer protective properties important to marten survival during periods of extreme temperature. For example, during warmer weather, when temperature and humidity are high, Zalewski (1997) suggested that cavities may be used as a cooling mechanism. Marten possess the ability to reduce body temperature by evaporation through the nasal mucosa during bouts of high temperatures (Baker 1979). However, when humidity levels are high, these mechanisms may not work as efficiently and marten may need to rely on other strategies, such as the use of cooler resting sites to reduce body temperature. In contrast, during cooler temperatures marten rely on certain types of resting site structures (cavities or nests) that offer thermoregulatory protection that provide warmer areas to rest (Buskirk et. al. 1989).

In my study area, cavities were used more in the winter season than in the summer season. Additionally, cavities were used more often than the other resting site structures documented, which suggest that cavities are important resting site structures to marten in my study area. Cavities may provide insulating properties that keep marten warmer during cooler months and cooler during warmer months. Although subnivean resting sites were not documented as often (n = 4), these types of sites, if available, may be important to marten. Coarse woody debris is limited in the LP because of current forest management practices, fuels reduction efforts, and limited old growth forest stands/characteristics. Therefore, although subnivean site use in my study area was low, it is most likely due to the low availability of CWD that is used to create subnivean sites. A number of marten studies have found that CWD is an important forest attribute to this species (Buskirk et. al. 1989; Bull and Heater 2000; Payer and Harrison 2003).

Large-diameter trees are important to marten because they provide specific habitat requirements, such as cavities and large branches that can be used as resting sites (Wynne and Sherburne 1984; Spencer 1987; Raphael and Jones 1997). The use of live large-diameter trees for resting sites in my study area was similar to that reported in other studies. Zalewski (1997) found that three tree species, oak (*Quercus robur*), lime (*Tilia cordata*), and spruce (*Picea abies*), with an average DBH of 59 cm, were used most often for resting sites. Two of those species were deciduous and one coniferous. I found two deciduous species (oak and maple species), with an average DBH of 49.1 cm, and one coniferous species (red pine), with an average DBH of 29.3 cm, used most often. I also found that the mean DBH of trees used as resting sites was significantly larger than the mean DBH of trees located within the 15-meter radius plot around resting sites. This suggests that marten are selecting larger-diameter trees to use as resting sites. Large-diameter trees that support abundant tree cavities are characteristic of mature, late successional forest stands, which are thought to be optimal marten habitat (Ruggiero et al. 1998; Bull and Heater 2000). Cavities in large diameter trees have the potential to provide habitat and refugia for a host of species. Processes like heart rot fungus and woodpecker excavations can increase cavity abundance in forest stands. Pileated woodpeckers (*Dryocopus pileatus*), which are found in my study area, create cavities that are used by a host of vertebrate species. Bonar (2000) found that 38 different vertebrate species used cavities created by pileated woodpeckers in Alberta, Canada.

Marten have been reported to select numerous habitat types throughout their range. In the western United States marten are reported to prefer coniferous forests (Buskirk et al. 1994; Clark et al. 1987), but the availability of deciduous forest types in those studies were limited. In the eastern extent of their range, marten appear to utilize both coniferous and deciduous forest types (Payer and Harrison 2003; Fuller and Harrison 2005). This data suggest that marten in my study area are mostly selecting deciduous trees for resting sites, but also that tree composition around resting sites consisted largely of coniferous tree species. This indicates that marten are selecting resting sites at two scales: microhabitat (e.g., deciduous trees for resting sites) and stand levels (e.g., coniferous forest types surrounding resting sites). Resting site structures and forest cover types surrounding those structures must meet and incorporate fitness implications that are important to marten (Porter et al. 2005).

Similar to other marten studies (Buskirk 1984; Martin and Barrett 1991), I also found that marten re-used resting sites. Fager (1991) found that during the spring in western Montana, marten resting site structures were re-used from one to six times, which is consistent with my findings. The majority of my sites were re-used only once; however, because I only located marten on average once a week, resting site re-use was likely more common than I documented. Some of the resting sites I observed suggested that marten were re-using those sites frequently based on anecdotal evidence, such as fecal matter, prey remains, and chew marks found at some of the resting sites. Still, searching for new resting sites daily may come at a cost to marten in terms of lost opportunities to forage or mate. Therefore, marten may employ some type of learned behavior of where resting sites are located within their home ranges to decrease search time locating new resting sites (Martin and Barrett 1991). Other studies have reported that marten remember where resting sites are located within their home ranges as well (Spencer 1987; Buskirk et al. 1989). Re-use of resting sites appears to be a common learned behavior of American marten across a large proportion of their North American range.

Marten prefer habitat with complex vertical and horizontal structure (Chapin et al. 1997). Additionally, habitat use has been correlated with high basal area and canopy closure (Prayer and Harrison 2003). I did observe a significant difference between the basal areas found within resting site plots and control plots, suggesting marten in the

MNF prefer higher basal areas when selecting resting sites. However, species composition and vertical structure (i.e., layers within a forest stand) between resting and control plots were fairly uniform. The higher basal area associated with resting site plots could be, in part, due to the large DBH of resting site trees. Payer and Harrison (2003) found that marten used areas with higher live tree basal area than unused areas and speculated that unused areas lacked the complex vertical structure marten need in their habitat. Additionally, they found that marten avoided forest stands with basal areas below 18 m^2/ha.

Percent canopy closure at resting sites is also indicative of marten habitat. My results were consistent with other studies (Bowman et al. 1997; Chapin et al. 1997) that showed marten used habitat with a high percent canopy closure. I observed that 77.9% of the resting sites had ≥ 67% canopy closure, which is consistent with marten in Oregon showing strong preference for coniferous forest with a canopy closure ≥ 50% (Bull et al. 2005).

Although American marten populations can be affected by a variety of factors, habitat loss is one of the major influences affecting this species' survival (Stone 2010). Specifically, habitat loss from timber harvest has been reported to negatively affect marten (Fuller and Harrison 2005). Removal of overhead cover, reduction in large diameter coarse woody debris, simplification of structural diversity (both vertical and horizontal), and alteration of tree composition (e.g., conversion of forest types to suboptimal species or age classes through clear cutting) are all factors that can negatively affect American marten population density, home-range size, and mortality rates (Andruskiw et al. 2008; Stone 2010). Therefore, when drafting forest management prescriptions it is important to take into account specific habitat requirements of species. Certain species, like marten, are more susceptible to changes in forest stand structure and composition. Changes in tree DBH size, percent canopy closure and basal area can all affect whether or not marten can occupy a forest stand.

CHAPTER VI

MANAGEMENT IMPLICATIONS

Wildlife managers are faced with many challenges when proposing management prescriptions, including a divergent set of stakeholders that all have differing interests in forest management decisions. Management prescriptions must account for multiple, often competing, uses of resources which can be challenging when managing for marten sustainability. The following recommendations are based on considerations of resting sites only. While resting sites are a critical component of marten habitat, forests must also accommodate foraging, mating, and dispersal activities. This study does not address management for these aspects of marten habitat, although there is undoubtedly some significant overlap between habitat requirements for different purposes.

Overall, maintaining complex forest structure, both vertical and horizontal, abundant CWD, high percent canopy closure, and high basal areas should be considered when forest management guidelines are being drafted to manage habitat for marten and in particular resting site structures. Silviculture techniques that promote tree species diversity, older stand age classes, and retention of CWD are all important factors to consider. I recommend using a single-tree selection method for timber harvest. This type of silviculture system should allow loggers to retain large diameter trees, pockets of higher basal areas around known and potential resting site structures, and abundant CWD. Additionally, the single-tree selection approach could promote an uneven-aged forest that will maintain a complex vertical and horizontal forest structure.

Within the LP it is important for forest managers to retain the appropriate structures to provide marten with suitable resting site locations. Marten appeared to depend on particular tree species for resting site use (in particular, oak species, maple species, and red pine). Cavities and branches that were used as resting site structures generally were found in larger diameter oak and maple species; therefore, I suggest forest management guidelines retain oak and maple species with DBH of ≥ 53.2 cm and 45.0 cm, respectively, in known marten habitat. I also recommend that trees where squirrel, corvid, or raptor nests are present be retained, as these structures offer potential resting site opportunities to marten. Additionally, forest stands that are predominantly composed of coniferous species and are infiltrated with a limited number of hardwood species seem to be important to marten in this study area. Therefore, in red, white, and jack pine stands, I recommend that hardwood tree species be retained or promoted, particularly deciduous trees that have a DBH of ≥ 32.8 cm. This should not only promote species diversity but should ensure future resting site availability.

Marten seem to prefer areas with larger basal areas, which suggest that basal area, in part, could be driving resting site selection and should be incorporated into prescription guidelines. The average basal area around resting sites in my study area was 33.92 m^2 ha (sd = 9.04), however, research has shown marten actively using forests with basal areas of 18 m^2/ha (Payer and Harrison 2003). Although Payer and Harrison (2003) found marten using forest stands with lower basal area thresholds than I observed around my resting site locations, they incorporated other marten activities (i.e., foraging, scent marking) in their data analysis. Therefore, in the LP I recommend maintaining a minimum basal area of 25 m^2/ha, which is one standard deviation below the average basal area, around potential or current resting site structures, with the caveat that marten will likely use forest stands with lower basal areas for different activities. If feasible, I suggest that no timber harvest activities be permitted within a 15 to 20-meter radius around identified resting site structures and potential structures. This should help maintain higher basal areas associated with resting sites.

Although this study did not find a significant difference between CWD found in resting sites plots compared to control plots (see above for possible reasons for this result), biologically CWD maybe an important attribute associated with resting site structures. Numerous other studies have documented the importance of CWD to marten (Bull et al. 2005; Buskirk et al. 1989; Martin et al. 1991). Therefore, I recommend that whole tree chipping be discouraged as a timber harvest method and tree tops and branches (CWD) be put into piles systematically across the harvested area. The retention and construction of small brush piles (10 m^2) of CWD should not only promote resting site opportunities but also provide foraging sites, as *Peromyscus* species are associated with CWD (Bowman et al. 2000).

Providing management agencies with specific clues on how to identify potential marten resting sites would be beneficial. Trees with cavities were used for resting sites by marten frequently in my study area. I observed that the majority of used cavities had bark gnawed off from around the entrance hole, which can be easily detected when marking timber (Figure 6). Marten also seem to select large, mature aspen trees with cavities, when available. Large old aspen trees were not selected as often as other species, likely because they were not as available in my study area. Additionally, I identified some of the snag resting sites as large old aspen trees. Therefore, I feel late successional stage aspen trees are important in providing resting sites opportunities and should be retained and incorporated to diversify forest stands. Also, aspen trees are a relatively short-lived species and they should provide resources such as snags and CWD for future marten generations. I also observed that marten typically selected non-merchantable trees. For instance, red pine trees with multiple or crown tops, (e.g., trees damaged by porcupines), mature trees that have large excavated or decomposed cavities, and large mature "wolf" trees that consisted of many branches were consistently being used as resting sites. I believe that the aforementioned clues can assist foresters/timber markers in identifying potential resting site structures that can be retained in treatment areas. A large portion of my study area consisted of red pine stands that were uniform in age and structure. These stands are economically mature and will likely be slated for timber harvest (P. O'Connell, pers. comm. 2012). Caution should be taken with implementing current red pine management techniques, such as row thinning and seed tree harvest, as thinning below certain thresholds may be detrimental to this species. Additionally, my analysis showed that the majority of saplings near resting sites consisted of deciduous trees, which suggests that these stands may be converting from pure conifer to mixed deciduous through succession. Therefore, it may be beneficial to marten if heavily harvested conifer stands (i.e., white, red jack pines) be replanted with conifer species, which would create a more diverse stand consisting of both deciduous and conifer species. Additionally, more research is needed in the LP to examine the effects of tree removal, especially in red pine stands. Marten cannot tolerate > 30 – 40% open areas inside their home ranges (Chapin et al. 1997, Fuller and Harrison 2005, Payer and Harrison 2003, Dumyahn et al. 2007). Therefore, experimentation with timber

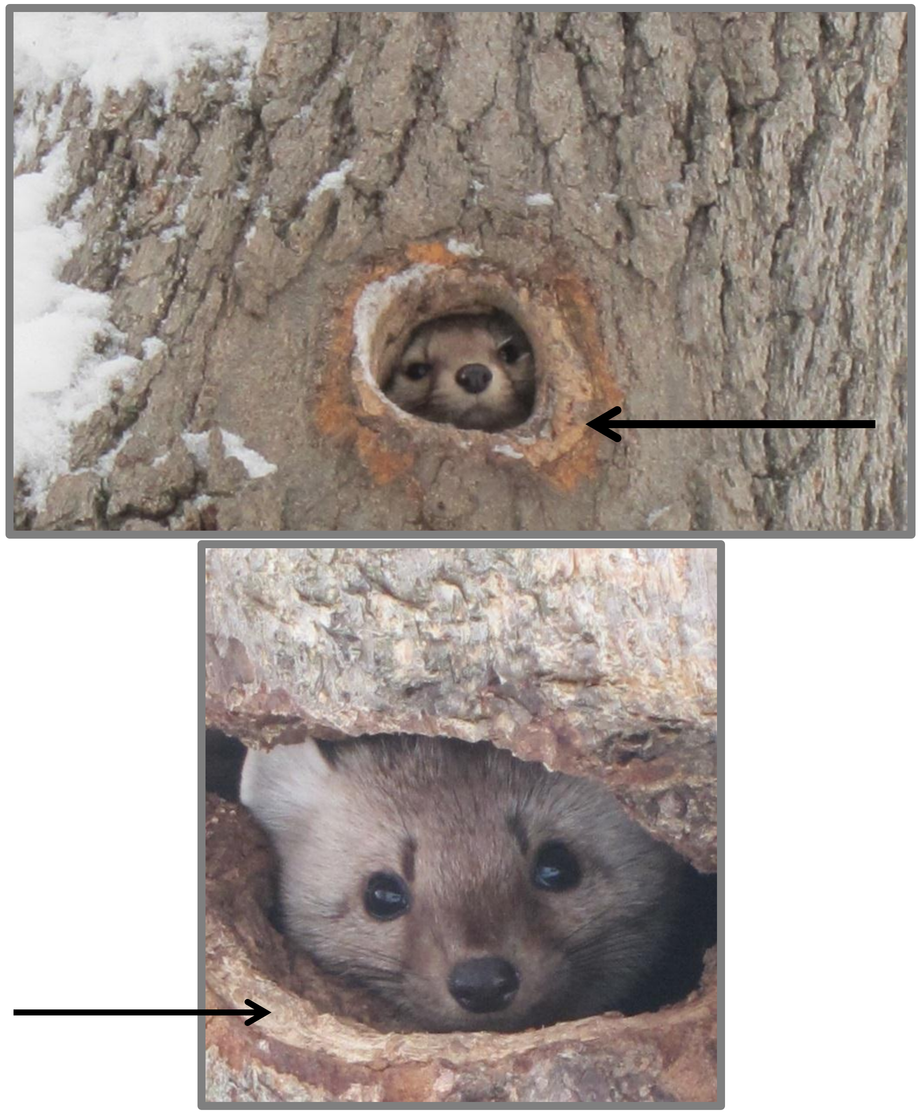

Figure 6. Pictures of used resting site cavities showing chew marks around entrance hole. Pictures were taken in the Manistee National Forest between May 2011 and December 2013.

removal where marten have established home ranges presents good opportunities to explore how timber management techniques and strategies may affect this species.

Managing forests in Michigan’s LP to maintain and improve habitat for the American marten will require the adoption of silvicultural techniques that retain selected large-diameter trees as potential resting sites, encourage the retention and accumulation of coarse woody debris, and retain strategically located pockets of high basal areas associated with likely marten resting sites. Additionally, this marten population would benefit from additional research that focuses on suitable habitat at the landscape level. In particular, habitat that is being utilized by dispersing marten would provide valuable insight into travel corridors and forest connectivity within the LP.

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