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American Marten Denning Behavior in Michigan

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American Marten Denning Behavior in Michigan

Melissa J. Nichols

A Thesis Submitted to the Graduate Faculty of

GRAND VALLEY STATE UNIVERSITY

In

Partial Fulfillment of the Requirements

For the Degree of

Master of Science

Biology Department
Grand Valley State University
Allendale, MI 49401

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Dedication

This is dedicated Justin and my parents. Thank you for always encouraging me to do my best and for helping me to achieve my goals. Without your support I could not have been successful.

Acknowledgments

I would like to start by thanking my committee members Paul Keenlance, Joe Jacquot, and Eric Clark for helping guide me through this process and supporting me through the never-ending twists and turns of this project. I am extremely grateful for all of the support given by the Little River Band of Ottawa Indians and the Sault Ste. Marie Tribe of Chippewa Indians, without your logistical help this project would not have been possible. I would like to thank Grand Valley State University for providing a tuition waiver, graduate assistantship, and financial resources in the form of a Presidential Grant.

From the field to the writing process, the research collaborators in this project were outstanding. The fieldwork could not have been completed without the dedication of Bob Sanders, Maria Spriggs, Danielle Bradke, Tamara Hillman, Rachel Hughart, Aubri Spenski, Angela Kujawa, Brad Silet, Rusty Aikens, and Chris Schumacher. Through thick and thin, mosquitos and -24 degree days, you were the people I knew I could count on. Thank you so much!

Finally, a huge thanks to all of the other folks that had a hand in this collaboration: Dr. Dave Unger, Dr. Jill Witt, Mary Feely, David Haskins, and Pat Laarman. This project was a success due to your support, help, and guidance.

Abstract

Female American marten (*Martes americana*) produce litters of 1-5 kits between late March and early May. Kits remain with their mother for the duration of their first summer in a series of den structures. We located these den structures using radio-telemetry and placed remote-triggered cameras at the entrances to capture information on litter size, female activity patterns, and den visits by males and potential predators. From the summer of 2012 to the summer of 2014 we tracked 13 individual female marten (8 in the Lower Peninsula, 5 in the Upper Peninsula) with 17 litters to 75 unique den sites (60 in the Lower Peninsula, 15 in the Upper Peninsula). We found 58 dens in live trees, 11 in snags, 5 in hollow logs, and 1 subterranean. Of the tracked marten we were able to collect camera activity data for 14 litters produced by 11 female marten at 59 dens. We found that den trees in both the Lower and Upper Peninsulas were significantly larger than the trees surrounding them in a 30-m diameter circular plot. In the Lower Peninsula we found that den trees were in areas with a higher basal area than was found in randomly selected areas. Average litter size was 2.5 ± 0.25 kits (range 1-4, n=14). We recorded 858 activity periods, 68 occurrences of the female delivering prey to kits, 72 instances of males visiting dens, and two instances of potential predators at dens. We found no relationship between litter size and den relocation patterns, documented den reuse four times, and found a range of distances between successive dens (5–3382m, median 407m, n=60 relocations). These findings indicate that den-switching behavior is very complex and is likely due to a combination of outgrowing den space, pest buildup at the den, predator avoidance, and relocation to areas of higher prey density. The retention of large structures that are hollow or contain cavities is essential to maintaining suitable denning habitat for marten.

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Chapter 1

Introduction

The American marten (*Martes americana*, hereafter marten) is a mid-sized carnivore that can be found in the northern portion of North America. Marten have a long, lean body shape with very few fat stores, traits somewhat typical of the *Mustelidae* family to which the species belongs. There is strong sexual dimorphism present, with males weighing up to 65% more than females (Clark et al. 1987). Marten have semi-retractable claws on each foot and are capable of rotating their back feet in order to easily descend trees head first (Clark et al. 1987). Marten are long-lived compared to other animals of their size, however the age structure of marten populations shifts toward young animals when the population is trapped (Buskirk and Ruggiero 1994). The species' historic range included much of the Northeast United States, Michigan's Lower Peninsula (LP), and most of Wisconsin in addition to the present day range that stretches from Alaska to Newfoundland and as far south as New Mexico along the Rocky Mountains (Williams et al. 2007). With such a widespread geographic range the marten is known to inhabit many different forest types across its range.

Long considered an old-growth coniferous forest specialist, recent research is challenging this assumption (Coffin et al. 1997; Potvin et al. 2000; Poole et al. 2004). Marten home ranges tend to be in areas with dense canopy, many large trees, and large amounts of coarse woody debris (CWD) typical of old growth forests (Bull et al. 2005) but studies have found that when presented with stands of mature and over-mature coniferous forest or deciduous and mixed deciduous forest the marten selected for the mixed deciduous locations (Potvin et al. 2000). While many researchers still agree that marten select for old-growth conifer habitat within their home ranges, the forest complexity indicated by the presence of a dense shrub cover, snags, and

coarse woody debris may be better indicators of suitable habitat (Coffin et al. 1997; Ruggiero et al. 1998; Poole et al. 2004). Marten avoid areas with large clearcuts, as these areas provide no cover from aerial predators (Soutiere 1979). In the kit-rearing season, females are suggested to be more selective of habitat due to their higher energy demands and an overall smaller body size as compared to males (Caryl et al. 2012).

The home ranges reported for marten vary based on geographic location, though males always have larger home ranges than females (Gosse et al. 2005). Sanders (2014) used a 95% fixed kernel home range estimator with a minimum of 30 locations per animal and found mean home range sizes for males in the Manistee National Forest (MNF) of Michigan to be $22.59 \text{ km}^2 \pm 18.78 \text{ km}^2$ (n=5, range= 7.66-54.78 km^2) and females $6.24 \text{ km}^2 \pm 4.01 \text{ km}^2$ (n=4, range 2.83-12.01 km^2). Phillips et al. (1998) used 95% minimum convex polygons with a minimum of 24 locations per animal and reported median home range sizes in Maine during spring and summer as 2.58 km^2 for males and 1.95 km^2 for females, whereas Gosse et al. (2005) used the same method in Newfoundland but with a minimum of 20 locations per animal and found the mean home range for males was $23.37 \text{ km}^2 \pm 20.01 \text{ km}^2$ (n=15, range 6.37-67.24 km^2) and for females was $15.02 \text{ km}^2 \pm 11.71 \text{ km}^2$ (n=24, range 4.35-46.50 km^2), and finally Fuller and Harrison (2005) used 95% minimum convex polygons with a minimum of 10 locations over a minimum of 90 days per animal and found males in Maine located in a landscape with partial harvesting had a mean home range size of $6.29 \text{ km}^2 \pm 0.58 \text{ km}^2$ (n=9) and females had a mean home range of $3.1 \text{ km}^2 \pm 0.65 \text{ km}^2$ (n=5) during the spring and summer. Fragmentation levels (Caryl et al. 2012), resource abundance (Gosse et al. 2005), and season (Phillips et al. 1998) all have an effect on home range size therefore home range size could be used as an indicator of habitat suitability.

Marten movement patterns and overall diet composition changes seasonally. Marten generally move more diurnally in the summer compared to winter (Bull and Heater 2000). Having limited fat reserves, it is speculated that marten move nocturnally in winter to better locate their main prey sources that are active at night (Zielinski et al. 1983). Bull (2000) documented marten taking larger prey in the winters such as squirrels as compared to vole-sized prey that dominated scats collected in the summer. This strategy would be energetically favorable if the effort involved in catching larger prey was offset by the energy gains provided by the capture (Bull 2000) and the same strategy could also be used by reproductive females in summer whose energy demands can be five to ten times greater than non reproductive females (Sandell 1990).

Marten were historically found throughout Michigan's LP as far south as Allegan County, however in the late 19th and early 20th centuries the logging industry became established which led to an extremely fragmented landscape unsuitable for marten populations (Whitney 1987). Large red and white pines dominated the pre-settlement forests of the LP with highlands containing a mix of hemlock, white pine, and hardwoods (Whitney 1987). These large, old pines would have provided adequate resting and denning habitat as well as large prey populations to support a healthy marten population. The late 1800s brought the logging trade to the LP and once railways were introduced to the interior of the state, the LP lost the large pine forests that once provided suitable marten habitat. Through a combination of logging and an extreme fire regime, young sugar maples and oaks dominated the remaining forest in the LP and marten were extirpated by 1911 (Whitney 1987; Williams et al. 2007). A similar story took place in the Upper Peninsula (UP) where marten were extirpated by 1939 (Williams et al. 2007). The depression brought reforestation efforts to the state and red pines were planted in great numbers (Whitney

1987). With the establishment of more sustainable forest management practices, marten reintroductions began in the western UP in 1955 and concluded in 1981, introducing a total of 276 marten. The reintroduction into the LP was less successful due to political challenges in bringing marten from Ontario, however between 1985 and 1986, 85 marten were reintroduced into the Pigeon River Country State Forest, the MNF, and the Pere-Marquette State Forest. Finally, between 1989 and 1992, three translocations occurred in the UP to help the dispersal process. Two of these translocations brought a total of 47 marten to the Eastern UP (EUP).

The US Forest Service monitored the LP reintroduction sites and found in 1989 there were marten present and some of the original animals had reproduced (Irvine 1989). By 1994, Irvine estimated that the sites surrounding the original release locations contained self-sustaining marten populations and the reintroduction was a numerical success. Nelson (2006) determined the two LP populations had diverged genetically from the source population in Ontario but also documented inbreeding within both LP populations. Unfortunately, the habitat of the LP is still relatively fragmented and could be preventing marten dispersal. Aune and Schladweiler (1997) studied a marten population in southwestern Montana on the edge of current marten range and proposed that the fragmented habitat that made up their study area was of poor quality and ultimately negatively affected fecundity levels of the population.

Marten demonstrate delayed implantation similar to other mustelids. Females that are older than 1.5 years have more corpora lutea, and in food scarce periods older marten consistently have more corpora lutea than younger marten (Thompson and Colgan 1987; Fortin and Cantin 2005). The breeding season occurs from July to August and is determined by photoperiod (Clark et al. 1987; Amstislavsky and Ternovskaya 2000). The male courtship can last up to fifteen days with each mating lasting approximately ten minutes with multiple copulations throughout

courtship (Brassard and Bernard 1939; Clark et al. 1987). After fertilization occurs, the blastocyst undergoes arrested development for seven to nine months (Clark et al. 1987). Implantation date is dependent on photoperiod and is followed by a 27-day active pregnancy (Jonkel and Weckwerth 1963; Clark et al. 1987). Parturition occurs between mid March and early May with litter sizes between 1 and 5 kits averaging 2.85 kits with a 1:1 sex ratio (Clark et al. 1987; Strickland and Douglas 1987; Hodgman et al. 1994; Jones et al. 1997). Litter size is in the predicted range for 1 kg mammals (Sacher and Staffeldt 1974), but most other mammals in this size range are capable of multiple litters per year, which marten are not, therefore marten reproductive output is lower than expected per year (Buskirk and Ruggiero 1994).

Marten parturition timing is likely an evolutionary strategy to match up kit independence with the food peak that occurs in late summer (Sandell 1990). Newborn kits weigh approximately 28 grams at birth and there is sexual dimorphism visible by three weeks (Brassard and Bernard 1939; Clark et al. 1987). Kits open their eyes sometime between day 35 and 37 and begin crawling at approximately 46 days (Ashbrook and Hansen 1927; Brassard and Bernard 1939). Weaning also begins during the sixth week after birth when the female marten starts providing prey for her kits at the den (Ashbrook and Hansen 1927; Brassard and Bernard 1939). At 15 weeks the kits have upper canines beginning to replace the milk teeth that are pushed out at 17 weeks (Brassard and Bernard 1939), prior to this point it would be very difficult for the kits to hunt on their own. By the late summer kits begin venturing out without their mothers, however dispersal does not occur until a later time and is completed by April (Strickland et al. 1982; Broquet et al. 2006).

Female marten raise kits in a series of dens throughout the summer. The location where parturition occurs is designated as the natal den and this location tends to be in a well-insulated,

very secure structure such as a cavity or underground tunnel that protects the newborn kits from the weather and predators (Bull and Heater 2000). In pine marten (*Martes martes*) females relocated kits from the natal den after five to seven weeks, and the specific amount of time spent in the natal den may be a function of the number of kits in the litter (Kleef and Tydeman 2009). These relocations could be in response to a buildup of feces and pests, because the kits simply outgrow the natal den, and/or as a predator avoidance mechanism (Kleef and Tydeman 2009). Maternal dens, the dens kits are moved to after birth, tend to be in larger cavities that are slightly less secure from predators (Bull and Heater 2000). Cavities are an important resource to denning marten for protection from predators and temperature regulation, however marten cannot excavate their own cavities and so they rely on cavities formed naturally or by other excavators such as pileated woodpeckers (Bonar 2000). Trees affected by fungal decay are therefore important to denning marten as they have natural cavity formation and pileated woodpeckers often choose to excavate cavities in already decaying trees (Bonar 2000; Bull et al. 2005). The need for cavities large enough to house an adult marten and her offspring leads to selection of large diameter trees as den locations (Raphael and Jones 1997). Other structures, such as large diameter hollow logs, rock piles, and underground tunnels, are also used as den sites (Bull and Heater 2000). In addition to the den structure itself, Joyce (2013) found den sites also had greater canopy closure, greater sapling density, and a higher mean tree diameter than randomly selected sites. In addition, Ruggiero et al. (1998) suggests that CWD can be important even when not used as the primary den structure because it provides hiding locations for the female and her offspring should a predator, such as a coyote or fisher, approach the den site suddenly.

The energetic demands on female marten associated with raising kits is at least twice that of non-lactating females and the period just before kit independence can create demands up to

ten times greater than for females not raising kits (Sandel 1990). These energy requirements keep females from remaining with their kits continuously. Henry et al. (1997) used telemetry-based recorders to assess den attendance patterns whereas Kleef and Tydeman (2009) used temperature loggers inside of the dens for the same purpose. Both studies found, prior to weaning, females remained at the den site with their kits for a majority of the day and would leave the den for only short periods of time; after weaning, female marten would leave the den for longer periods of time more frequently (Henry et al. 1997; Kleef and Tydeman 2009). Additionally, both studies found females typically left the den from dusk to midnight (Henry et al. 1997; Kleef and Tydeman 2009). When the mother returned, Henry et al. (1997) noted a period of activity lasting between five and thirty minutes and Kleef and Tydeman (2009) found when a marten returned to the den after a long period away she would remain at the den site for a long period of time. The long periods of time spent away from the den after weaning could be a response to the need to catch enough prey to feed the entire litter as females bring their kits food items even after weaning (Ruggiero and Henry 1993). Thompson and Colgan (1994) determined that activity patterns might be influenced by habitat quality, as the females they studied in more pristine environments were active 35% less than females occupying ranges in fragmented areas.

In addition to females having varying attendance patterns, there is also documentation of males attending maternal dens while kits were present (Ruggiero and Henry 1993). It is suggested that males attend the dens in order to encounter females during the breeding season (Ruggiero and Henry 1993). While at the den, males rarely have negative interactions with kits, however infanticide has been documented (Ruggiero and Henry 1993; Jones et al. 1997; Dubruiel et al. 2013). Since the breeding season occurs prior to kit independence and females are capable of reproducing in consecutive years, it is logical that males would attend the den and

because female home ranges rarely overlap with a multitude of male ranges, it also follows that there is a high probability that the male attending the den is also the father of the litter.

It is crucial to evaluate the reproductive ecology of marten in the MNF and EUP at this time because the health of each population is unclear. The objectives of this study were to describe the den structures used by female marten, to compare the microhabitat surrounding dens to other areas within the marten's home range, to analyze den-switching behavior of females, and to attempt to quantify den attendance via remote-trigger cameras.

Chapter 2

American Marten Den Site Characteristics in Michigan's Northern Lower Peninsula Manuscript

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American Marten Den Site Characteristics in Michigan's Northern Lower Peninsula

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ABSTRACT We sought to determine the habitat variables that could be used to characterize den sites selected by American marten (*Martes americana*) and to describe specific denning structures within the Manistee National Forest in the Lower Peninsula of Michigan. We used radio-telemetry to track female marten during the denning seasons in 2012 to 2014 and analyzed both the denning structure used as well as the habitat surrounding the den. We found that den trees were significantly larger than the trees that surround the den ($p < 0.001$, $n = 60$), that bigger litters used larger den structures ($p = 0.003$, $n = 56$), and that the basal area around den structures was significantly higher than the basal area of a random, paired non-den plot ($p = 0.01$, $t = 2.75$). We used mixed effects logistic regression to create a model predicting whether a site was a den

site or a randomly selected site and the top model included both basal area of the site and the Shannon Weiner diversity of the overstory trees at the site. Overall our study agrees with current research on selection for large, hollow trees as den structures and a lack of selection for habitat features within a stand (Gilbert et al. 1997, Bull and Heater 2000). Because large trees are most common in late-successional forests, we suggest preserving both potential den trees and late-successional forests in order to retain high quality marten habitat.

KEY WORDS American marten, den site selection, *Martes americana*, Michigan

Denning habitat is thought to influence the viability and health of American marten (*Martes americana*, hereafter marten) populations throughout their natural range (Aune and Schladweiler 1997; Bull and Heater 2000). Female marten raise kits in a series of dens throughout the summer with den relocations occurring from May to August with an average of 10.8 (n=9 females with kits, range 5-24 relocations) relocations occurring per summer (Ruggiero et al. 1998). Dens must protect the entire litter from both the elements and predators, therefore dens structures tend to be large-diameter trees, snags, or fallen logs (Bull and Heater 2000) as well as rock crevices (Ruggiero et al. 1998) that contain cavities large enough to house multiple growing marten. While snags have a natural decay pattern favorable to cavity formation, live trees that are affected by heart rot fungi also form hollow cavities suitable for marten dens (Bull and Heater 2000).

There is likely differing habitat selection for den structures and the habitat that surrounds them. As opposed to resting sites, where the structure is only required to hold a single adult marten and possibly protect it from avian predators, den structures must protect largely defenseless kits from predators and unfavorable weather conditions. In this way, there is increased pressure for secure den structures as opposed to resting structures. Previous studies

have found marten resting sites often have higher volumes of coarse woody debris than expected and have attributed the high volumes to increased hunting ease, but few studies have found this association with den sites (Ruggiero et al. 1998, Gosse et al. 2005). Marten may select an extremely secure den structure surrounded by less than ideal habitat as opposed to selecting a less secure den with a surrounding area that would provide additional areas of cover and food (Gilbert et al. 1997). Even so, there is likely a balance between selecting a secure den site and selecting an area that provides cover and additional food resources, however there is little documentation of these preferences (Gilbert et al. 1997, Ruggiero et al. 1998).

Although a few studies have occurred in habitat similar to the Lower Peninsula (LP) of Michigan (Gilbert et al. 1997), research on the denning habits and habitat selection of marten has mainly been conducted in conifer-dominated locations that have stable populations (Martin and Barrett 1991, Coffin et al. 1997, Bull and Heater 2000, Gosse et al. 2005). The LP is less conifer-dominated and is at a lower, less dynamic elevation than most of the natural range of marten. In addition, marten were extirpated from the LP in 1911 due to intense, unregulated trapping and widespread habitat degradation (Williams et al. 2007). By 1986, a total of 85 marten were reintroduced into the LP, with only 36 introduced specifically into the Manistee National Forest (MNF) and Pere-Marquette State Forest (Williams et al. 2007, Figure 1). Almost 30 years following the reintroduction, the MNF marten population still exists but preliminary analysis gives evidence of low genetic diversity and the probability of the population's long-term persistence is now in question (Hillman 2014). Although the long-term persistence likely doesn't affect current den selection, it does put a priority on effectively managing the landscape to reduce the number of stressors affecting the population.

Due to the different habitat availability in the LP of Michigan as well as the question of

long-term persistence, our first objective was to describe the specific denning structures used by female marten in the LP and our second objective was to determine if females select for specific habitat features surrounding a den site compared to other areas within their home range. This is one of the most intense den selection studies to date and appears to be the first of its kind to occur outside of the typical old-growth forest preferred by marten. The overall goal of this study was to provide additional data on marten den site characteristics to habitat managers in order to better preserve this population.

STUDY AREA

The study area was located in Lake and Wexford Counties (44° 12' 16.9092" N, 85° 44' 6.882" W) within the MNF in the northern LP of Michigan (Figure 1). The area is predominantly forested with small sections of private inholdings including both residential and development sites interspersed and no large areas of agriculture or urban development. Red pine (*Pinus resinosa*) stands make up a considerable portion of the study area with large red oaks (*Quercus rubra*), sugar maples (*Acer saccharum*), American beech (*Fagus grandifolia*), and big-tooth aspen (*Populus grandidentata*) contributing to the deciduous forest component. The study site is located in a timber management area and is also used for recreation throughout the year therefore it is subdivided by many two-track roads. The normal annual precipitation is 90.37 cm, the normal average temperature in the summer is 19.4°C, and the normal average temperature in the winter is -4.8°C (NCEI 2015).

METHODS

Live-trapping

Trapping sessions occurred throughout the study as needed. Sessions lasted from one to three weeks. The first session occurred in December 2011 and the last occurred in July 2014. No

trapping sessions were performed in April of any year in order to avoid time of whelping. We used live traps (models 103, 104.5, and 105; Tomahawk Live Trap Company, Tomahawk, Wisconsin, USA) baited with raw meat (chicken, elk liver, beef, smoked pork, beaver, or venison) and a commercial-grade call lure (“Gusto”, Minnesota Trap Line, Pennock, MN). In cold weather, we surrounded traps with straw and sheltered them from the elements using the longitudinal half of a 55-gallon plastic drum. In warmer weather, we covered traps with natural vegetation and debris such as pine needles, moss, bark, and leaves to shelter the animal from sun and precipitation and provide bedding material. We checked traps at least once per 24-hour period.

Upon capture of a marten, we covered the trap in a towel to reduce visual stimulation and subsequent stress to the animal. We transported the covered trap to a mobile field lab erected in the back of a field vehicle and used an open-ended denim cone to confine the marten during initial immobilization (Desmarchelier et al. 2007). The handling cone gave us access to the marten’s nose where we were able to administer isoflurane and oxygen using a mobile anesthesia machine. We used chemical hand-warmers and/or an electric heating pad to raise the marten’s temperature if it began to fall and ethanol applied to the footpads and armpits to lower the marten’s temperature if needed to avoid overheating for the duration of anesthesia. Once the animal was completely immobilized we were able to assess overall condition using a combination of rectal temperature, respiration, and pulse. We weighed and sexed each individual and during the reproductive months we determined if females were lactating. We injected a passive integrated transponder (PIT) tag (Avid Identification Systems, Inc., Norco, California) into each animal. Adult females were fitted with an approximately 20 g VHS radio-collar equipped with a mortality sensor (Modified model RI-2D Holohil Systems Ltd., Ontario,

Canada or model m1505 Advanced Telemetry Systems, Isanti, MN attached on a belt Advanced Telemetry Systems, Isanti, Minnesota). We monitored each animal in a padded recover box until fully recovered from anesthesia, at which time marten were released at the site of capture. For the entire collaborative study, the time spent under anesthesia averaged 24 ± 8 minutes (range 8-51 minutes, $n=121$, Spriggs 2015). All capture and handling procedures were established and approved by the Little River Band of Ottawa Indians, the Grand Valley State University Institutional Animal Care and Use Committee (approval #12-05-A), and the project veterinarian (Maria Spriggs, DVM, Staff Veterinarian, Busch Gardens Tampa, FL). Throughout the study, we had no handling or collar-related mortality and we attribute this success to our thorough anesthetization and collaring procedures.

Radio-Telemetry & Den Monitoring

We began intensively tracking (≥ 2 times per week) radio-collared adult females using the homing method beginning in March of each year. Site fidelity of a female from late March to April indicated the presence of a natal den (where the female gave birth to a litter of kits) and we confirmed natal and maternal dens (any den used after a natal den) through a combination of visualization of kits, site fidelity of the female, and the presence of scat and prey remains. After den-site confirmation, we placed two remotely triggered cameras around the den entrance in order to continuously monitor female den attendance as well as kit emergence. Cameras were also used to quantify litter size and document relocation timing.

Den-Site Analysis

Once each den site was confirmed we assessed the structure type (tree cavity or downed log), the tree species, tree condition (live or snag), and the diameter at breast height (DBH) or log diameter. We recorded the location of each den in UTM coordinates using a handheld GPS

device (Garmin Oregon 550t, within 10m precision). When marten litters were no longer using the den we revisited the site to document other habitat variables without disturbing the animals. We measured a 15-m radius circular plot around each den in which we measured and identified all trees with DBH ≥ 10 cm, and determined the length and diameter of all CWD ≥ 10 cm diameter and 1 m long. CWD was described on a scale from 1-3 with one being the least decayed and 3 being the most decayed, a method taken from Sanders (2014). Within one randomly selected quadrat of the plot, we identified and counted all saplings ≥ 1 m in height. We then selected a comparison vegetation plot within the female's home range that was 60 m from the den tree in a randomly selected direction and measured the same attributes (following Porter et al. 2005). By placing plots 60m from the den tree we ensured that no vegetation was sampled twice.

Analysis

For each vegetation plot we calculated basal area in m^2 per plot, Shannon Weiner diversity (SWD) of the overstory (trees ≥ 10 cm DBH, hereafter 'over SWD'), number of trees in the overstory, SWD of the saplings (trees < 10 cm DBH, hereafter 'sapling SWD'), total volume of CWD, and volume of Class 1 CWD within the plot. We also calculated descriptive statistics on den features using Microsoft Excel. We then converted basal area to m^2 per hectare and CWD to m^3 per hectare.

In order to make management recommendations based on number of potential den trees to preserve, we used 100% minimum convex polygons to determine the area in which a female's dens for an entire summer were located. We then divided that total area by the number of dens used that summer to estimate a minimum den site density. Finally, we took the mean of values collected from all females that were tracked for the entirety of the summer and converted it to

den trees per hectare.

All other statistical analyses were performed in Program R (version 2.12.2, Program R Core Team 2008). We began by checking all data for normality using Shapiro-Wilk. We attempted to transform non-normal data using a square root transformation. Data that were normal were then tested for equal variance using a Bartlett's test. We compared den sites between years for each vegetation variable as well as the number of kits per litter between years and compared the litter size to den structure DBH using Kruskal Wallis tests, as the data did not fit parametric assumptions. Any differences detected with Kruskal Wallis tests were analyzed using a Wilcoxon rank sum with Bonferroni correction. After finding no significant differences in den site characteristics between years we analyzed the years together for all remaining statistics. We compared each den site to its paired randomly selected site for each vegetation variable using either a paired t-test for data meeting parametric assumptions or a Wilcoxon signed-rank test for data not meeting these assumptions. The DBH of den trees was compared to the DBH of the trees ≥ 10 cm DBH that surrounded it in the 15-m radius plot using a Wilcoxon signed-rank test. Finally, we also ran a mixed effects logistic regression for all years combined. Fixed effects in the logistic regression included basal area of the site, total volume of coarse woody debris, and the Shannon Weiner Diversity index of both the overstory and the saplings while the conditional effect was the litter. By using litter instead of marten as the conditional effect we accounted for differences in den selection between years for females tracked in multiple summers. First we checked for multicollinearity among the fixed effects variables and set a conservative limit of $r=0.5$ for correlation. We then created multiple models using non-correlated variables. We used Akaike's Information Criterion (AIC) to rank our models and determine the most parsimonious model (Anderson and Burnham 2002). All models within two

AIC units of the top model were considered supported (Moore and Gillingham 2006). The alpha level for all univariate statistics was set at 0.05.

RESULTS

We tracked a total of eight female marten with young to 60 unique den sites (range of 1-9 per female each summer). One female was tracked in all three years, two were tracked in both 2012 and 2013, three marten were unique to 2012, one marten was unique to 2013, and one marten was unique to 2014 for a total of 12 tracked litters. Two of the marten tracked only in 2012 were lost to predation or collar slip before we could determine their litter sizes. The number of kits per litter was not significantly different between 2012, 2013, and 2014 ($p > 0.05$), and the mean litter size was 2.6 (SE \pm 0.34, range 1-4, $n=10$). We could not determine litter size for two litters due to a lack of camera captures. Dens were found in a combination of live trees, snags, and hollow logs (Table 1). Live trees were the most common den structure ($n=51$), followed by snags ($n=7$), and hollow logs ($n=2$). Of the 51 dens found in live trees, only one was found in a conifer (Table 2). In all years, den trees were significantly larger than the surrounding trees ($p < 0.001$, $n=58$) with a median DBH of 54.1 cm (range 27.4-97.2). We found a significant difference between the DBH of den trees used by different sized litters ($p=0.003$, $n=56$, Table 3) with litters of four kits occupying significantly larger den structures than litters with only a single kit. When we compared the number of hectares a marten used for denning to the number of dens within that space, we found a mean of 8.33 (range 4.55-100.00) hectares of forest per den.

Den site analysis often occurred at the end of the season, ensuring that our randomly selected sites did not include other den trees used during the season. Additionally, the center tree used for our randomly selected sites rarely showed attributes similar to den trees. 61% of the trees used as the center of our randomly selected plots were smaller than all den trees used in this

study and 91% of randomly selected center trees were smaller than all but the smallest three den trees. Of the 39% of randomly selected trees larger than the smallest den tree used in this study, half were pine species under 40cm DBH, a tree type not used as a den in this study. Overall, we feel confident that our randomly selected comparison sites were not centered on den trees.

Overstory SWD, total number of overstory trees, sapling SWD, total CWD volume, and least decayed CWD volume between den sites and randomly selected sites were not significantly different (Table 4). Basal area was significantly higher at den sites compared to random sites ($p=0.01$, $t=2.75$). When preparing our logistic regression, no two variables were correlated beyond our limit of $r=0.5$ (highest $r=0.38$). Six models were considered supported using AIC. The model with the highest AIC ranking had a 22% chance of being the best model for predicting if a location was a den or random site. The highest ranked model included BA and over SWD (Table 5). All supported models included BA, the only variable that was significantly different between den and random sites.

DISCUSSION

We found that den trees were significantly larger than surrounding trees, similar to other studies on marten den structures, even though this habitat is different than that seen in traditional marten studies (Raphael and Jones 1997, Bull and Heater 2000). Large den structures are a necessity to provide room for an entire litter of kits as well as the mother. This would explain why den structures were larger when litter size was four kits compared to one kit. Preference for large den structure has been shown in many previous studies however there is limited evidence for habitat preferences (i.e. basal area, diversity, etc.) at a larger scale such as the stand level (Gilbert et al. 1997).

We found selection of den sites with a higher basal area than the surrounding area, but no

other significant differences in overall habitat characteristics between den sites and randomly selected sites. While the top model we created included basal area and overstory Shannon Weiner diversity, the likelihood that it was the top model was only 22% and the five other supported models included basal area. Due to the lack of support for our top model, we suggest that our measured variables did not do a good job of indicating if a site was a den or random site. A higher basal area around a den site with no difference in the number of trees between den sites and random sites indicates the presence of more large trees around the den site. Additional large trees surrounding the den structure potentially provide the litter with multiple hiding locations (Ruggiero et al. 1998, Joyce 2013). In regards to the lack of differences in other habitat variables between den sites and randomly selected sites, there is the potential females select home ranges mainly comprised of suitable denning habitat in these aspects therefore the only preference that is observable would be the selection for large, hollow denning structures and the basal area (Ruggiero et al. 1998). In a population that does not appear to have increased significantly in size since reestablishment, it seems feasible that females have the opportunity to select high quality home ranges with many areas suitable for denning and few areas completely unsuitable.

Additionally, females could be selecting for habitat features we did not measure in this study. Female marten are possibly selecting for prey availability as opposed to specific habitat features. In many locations, marten primarily consume red-backed voles (*Clethrionomys gapperi*) that are complex habitat specialists (Thompson and Colgan 1990, Hales et al. 2008, Kurta 2011). However, Bull (2000) found that female marten consume significantly fewer red-backed voles than male marten and instead consume significantly more shrews (*Sorex spp.*) and chipmunks (*Tamias spp.*). Preliminary evidence from the MNF shows that females in our study area consume high volumes of gray squirrels (*Sciurus carolinensis*), eastern moles (*Scalopus*

aquaticus), and chipmunks (Kujawa 2014). Squirrels, chipmunks, and moles can all be classified as habitat generalists within the available forest (Kurta 2011); therefore, if martens are selecting den sites based on prey availability but are selecting generalist prey over specialist prey we would not expect to see differences in habitat between den sites and randomly selected sites based on the variables we measured. Another possible habitat feature not measured in this study was the availability of other cavities near the den site. Martens in Michigan's Upper Peninsula have been observed to use other structures surrounding the main den structure as shelter when approached by potential predators (personal observation). Joyce (2013) found that marten den sites were surrounded by more potential den structures than random sites, a variable that would include cavities.

Finally, martens could be selecting for habitat on a much larger scale than was measured in this study. We only considered habitat selection within a stand, but martens could be selecting for the stand itself. There is evidence for the selection of old growth and late-successional stands for resting sites (Slauson and Zielinski 2009) because these forest types have characteristics essential for large prey populations as well as cover for predator avoidance (Gosse et al. 2005). In our study, all of the den sites were paired with a randomly selected site within the same stand, in order to test if martens are selecting on a stand scale future studies would need to compare stands that were used for denning with stands that were unused. Unfortunately, it is often impossible to test if a stand is unused, a proxy could be comparing the habitat of dens to one another to see if martens are all choosing similar habitats.

While overall CWD volume was not significantly different between den and random sites, dens did have a higher mean volume of the least decayed CWD compared to randomly selected sites. The class of least decayed CWD is still relatively intact and could be used as runways or

perches for the litters. Hollow CWD that was still relatively intact would be ideal for protection against predators. Joyce (2013) found that den sites contain more potential denning structures including fallen hollow logs and Ruggiero et al. (1998) found that den sites contain more large diameter CWD than random sites.

The majority of dens were found in large, live, deciduous trees and only one den was found in a conifer species. Although still alive, these deciduous trees offered marten large cavities capable of protecting kits. Snags were solely composed of deciduous species possibly because there were few large coniferous snags in the study area. Ruggiero et al. (1998) found very few dens in live trees compared to snags, hollow logs, or squirrel middens and Raphael and Jones (1997) found more use of live trees than Ruggiero et al. (1998), but no studies found the level of use that was described in our study. This is likely due to the difference in habitat throughout the marten's natural range. The study by Ruggiero et al. (1998) was conducted in Wyoming where forests are dominated by either lodgepole pine or Engelmann spruce-subalpine fir; the study by Raphael and Jones (1997) was conducted in the hemlock-fir forests of the Pacific Northwest indicating that both studies likely had a smaller deciduous component than was available in the MNF. These differences highlight why this study is important for managers in the MNF.

Overall our study agrees with current research on preference for large, hollow trees as den structures and a lack of preference for specific habitat features within a stand (Gilbert et al. 1997, Bull and Heater 2000). Future studies should (1) take prey base into account when comparing den sites to randomly selected sites, (2) consider more habitat variables when comparing the two sites in order to rule out stand level selection and (3) look at a larger scale and compare between used and unused forest stands within each animal's home range.

MANAGEMENT IMPLICATIONS

In order to conserve the American marten population in the Manistee National Forest and other landscapes similar to the LP, managers must conserve areas of late-successional forest that provide suitable habitat for marten denning. Specifically, we recommend leaving a minimum of one large, hollow tree with a DBH \geq 49 cm per 8.4 ha of forest. In addition, we recommend that timber harvest of large trees be avoided from late March to mid May to avoid harvesting den trees containing immobile marten kits. The best management strategy would be an uneven-aged management where large, hollow trees remain on the landscape and mature forest is available to marten populations.

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Figure Captions

Figure 1. Study area map of the Manistee National Forest in Lake and Wexford Counties in MI, USA. Manistee National Forest and Pigeon River Country State Forest are designated by dark grey fill. Den sites are shown as red dots within the Manistee National Forest.

Table 1. Den structures used by female American marten in the LP of Michigan from 2012 to 2014.

Year	Total	Live Tree	Snag	Hollow Log
2012	28	25	2	1
2013	21	18	2	1
2014	11	8	3	0
All	60	51	7	2

Table 2. Species breakdown of American marten den structures found in live trees from 2012 to 2014 in the LP of Michigan. Maple=maple species and Oak=oak species.

Year	Total	Basswood	Big			Maple	Oak	Red Pine
			Black Cherry	Toothed Aspen	Black Walnut			
2012	25	4	1	4	0	5	11	0
2013	18	0	0	1	1	7	9	0
2014	8	0	0	0	0	1	6	1
All	51	4	1	5	1	13	26	1

Table 3. Relationship between the DBH (cm) and number of den structures used by American marten litters of different sizes from 2012 to 2014 in the LP of Michigan.

Number of Kits in Litter	Number of Dens	Median DBH
1	9	39.6
2	7	54.2
3	26	54.55
4	14	69.75

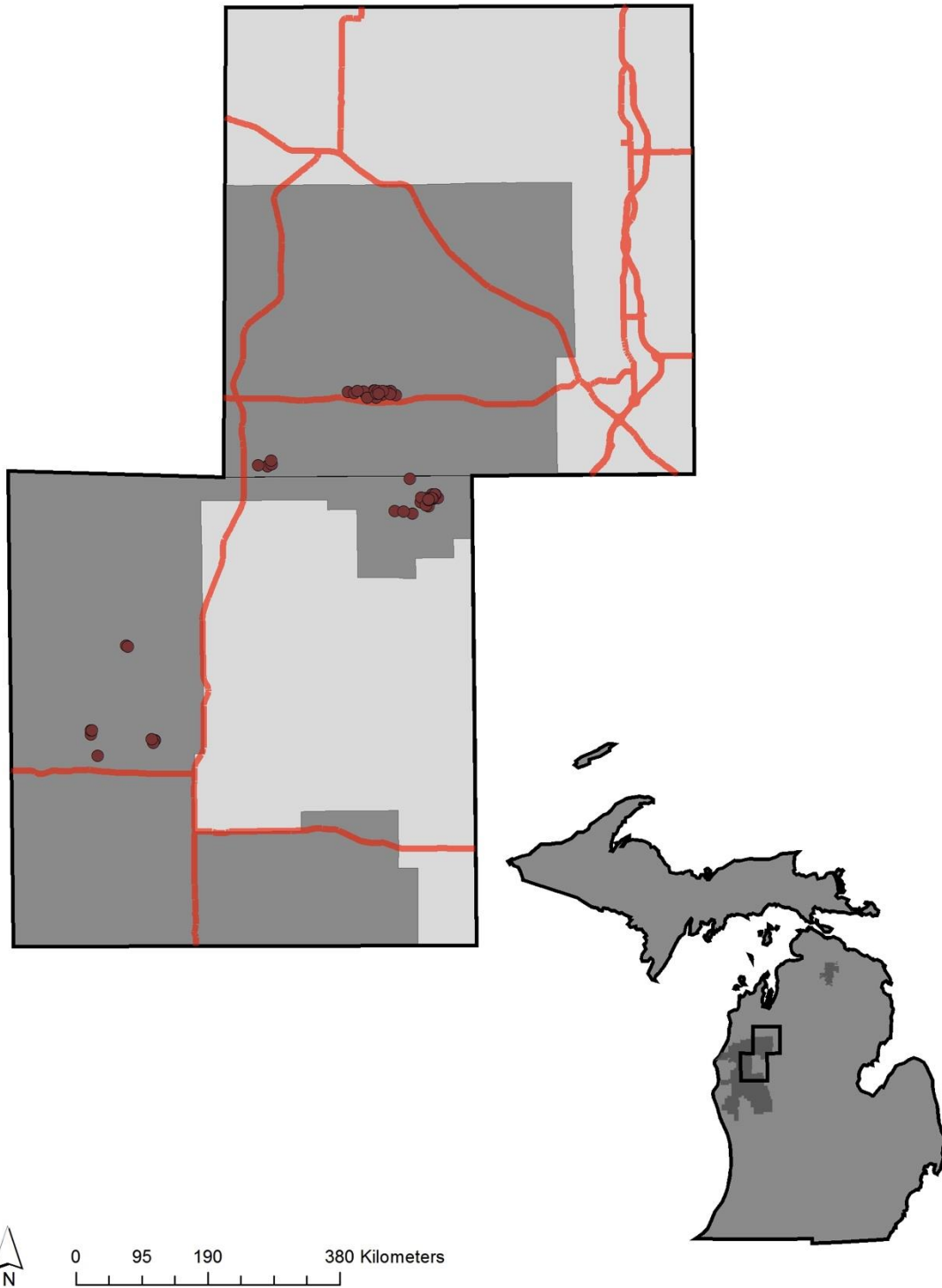
Table 4. Median values for basal area per hectare, the Shannon Weiner Diversity index of trees >10 cm DBH (*over SWD*), the Shannon Weiner Diversity index of saplings <10 cm DBH (*sapling SWD*), volume of coarse woody debris per hectare (*CWD*), and volume of class one coarse woody debris per hectare (*CWD I*) found in plots surrounding American marten den sites and randomly selected sites. p-values represent differences in raw values, not differences in median values.

	Den	Random	p-value
<i>basal area per hectare (m²)</i>	32.74	29.56	0.01
<i>overstory SWD</i>	1.08	1.11	0.88
<i>number of overstory trees</i>	45.5	43	0.44
<i>sapling SWD</i>	0.64	0.67	0.49
<i>total CWD (m³)</i>	13.23	11.32	0.11
<i>least decayed CWD (m³)</i>	3.57	2.41	0.07

Table 5. Supported mixed effects logistic regression models for American marten den site selection in the Lower Peninsula of Michigan from 2012 to 2014. AIC = Akaike's Information Criterion, Δi = AIC rank, ω_i = Akaike weights, *over SWD* = Shannon Weiner Diversity index of trees >10 cm DBH, *sapling SWD* = Shannon Weiner Diversity index of saplings <10 cm DBH, *CWD* = volume of coarse woody debris.

Logistic Regression Model	K	AIC	Δi	ω_i
<i>overstory SWD, basal area</i>	4	150.07	0.000	0.22
<i>basal area</i>	3	150.64	0.57	0.16
<i>overstory SWD, sapling SWD, basal area</i>	5	151.29	1.22	0.12
<i>sapling SWD, basal area</i>	4	151.69	1.61	0.10
<i>basal area, CWD</i>	4	151.70	1.63	0.10
<i>overstory SWD, basal area, CWD</i>	5	151.81	1.74	0.09

Figure 1.



Chapter 3

American Marten Den Site Characteristics in Michigan's Eastern Upper Peninsula

Manuscript

American Marten Den Site Characteristics in Michigan's Eastern Upper Peninsula

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Abstract- This study used a combination of live trapping, radio-telemetry, and trail cameras to evaluate den site selection by reproductive female marten in the Upper Peninsula of Michigan. Mean litter size was 2.4 ± 0.2 kits. We found that marten select for large den structures and use a combination of live trees, snags, fallen logs, and underground areas for denning. We found no significant differences in habitat variables between den sites and randomly selected sites. We conclude that marten were selecting home ranges with quality denning habitat throughout and were selecting specific denning structures within their home range.

Introduction

Currently, *Martes americana* Turton (American marten, hereafter “marten”) can be found throughout the northern portion of North America including most of the Upper Peninsula (UP) of Michigan (Williams et al. 2007). Prior to European settlement, marten could be found throughout the UP and much of the Lower Peninsula (LP; Williams et al. 2007). Marten were extirpated from the UP by 1939 due to a combination of unregulated timber harvest and excessive trapping pressure (Williams et al. 2007). From 1955 to 1981, a total of 276 marten

were reintroduced in the UP, followed by two translocations into the Eastern UP in 1989 and 1992 (Williams et al. 2007). In 2000 the population had recovered enough to restore a harvest season. Earle et al. (2001) indicated approximately half of the professionals in the UP believed marten numbers were increasing or increasing slightly and only 7% reported decreasing numbers of marten. However, in the decade that followed, Skalski et al. (2011) indicated a large decline in marten population size and recommended modifying the harvest strategies in Michigan's UP to avoid a further decline. The Michigan Department of Natural Resources took this advice and modified the bag limit from one marten and three fishers to one animal total. The most recent DNR marten and fisher harvest survey report indicates that while the number of marten harvested remained relatively the same from 2012-2013, harvest effort increased by approximately 33% (Frawley 2014).

Marten are often considered as preferring old growth forests (Buskirk and Ruggiero 1994, Slauson et al. 2007) or even requiring them for denning (Spencer et al. 1983), but that habitat type is largely missing from the Michigan landscape due to historical and current forestry practices. Other research (Bowman and Robitaille 1997, Bull et al. 2005, Fuller and Harrison 2005) has found marten require tall trees with high canopy closure and an abundance of downed logs, habitat features common with, but not limited to, old-growth coniferous forests. Ruggiero et al. (1998) found that habitat needs are more restrictive for female marten raising kits, with den sites having more large coarse woody debris (CWD) than randomly selected sites in the marten's home range.

These den sites make up most of a female's summer locations because kits remain with the mother for the entire summer after birth (Broquet et al. 2006). Throughout the summer, the group will move from the original structure where parturition occurred (the natal den), sometime

between late March and early May (Clark et al. 1987), to a series of other dens (maternal dens) within the mother's home range (Kleef and Tydeman 2009, Ruggiero et al. 1998). Kits are weaned beginning at six weeks of age (Brassard and Bernard 1939) at which point the mother begins delivering prey items to the den sites for consumption by the kits (Kleef and Tydeman 2009). By late summer the kits are largely independent, however dispersal from the maternal home range typically does not occur until the following spring (Buskirk and Ruggiero 1994, Helldin and Lindstrom 1995).

Common den structures include standing live trees, snags, and fallen hollow logs (Ruggiero et al. 1998). Den structures must be able to house the entire litter and therefore structure size is an important attribute and den structures are often significantly larger than randomly selected trees (Bull et al. 2005, Irvine 1994, Ruggiero et al. 1998). Additionally, den sites must offer protection from both the elements and predators because females will leave their kits for long periods of time in order to hunt and rest (Erb et al. 2009, Henry et al. 1997, Jones et al. 1997). Den sites have been found to have more potential den structures (cavities, CWD, etc.) than randomly selected sites (Joyce 2013) and more large CWD that could be used as escape cover for the litter (Ruggiero et al. 1998).

The reasons for the apparent population decline in the UP are currently unclear and research on marten habitat use and demography in the Eastern UP is limited, so the objective of this study was to gain a better understanding of the specific habitat requirements of denning female marten to help ensure the current management strategies are in line with retaining a healthy, harvestable marten population.

Field-site Description

This study occurred in the Hiawatha National Forest in Chippewa and Mackinac counties of Michigan's UP (Figure 1). The study site contained no large developed areas but did include small private inholdings and access roads. The area was made up of a variety of natural communities including but not limited to boreal forest, dry-mesic northern forest, and hardwood-conifer swamps (Albert et al. 2008). The overstory was dominated by *Abies balsamea* L. (Balsam fir), *Picea glauca* (Moench) Voss (White spruce), and *Thuja occidentalis* Linnaeus (Eastern white cedar) with a deciduous component of *Betula papyrifera* Marsh. (Paper birch) and *Populus tremuloides* Michx (Quaking aspen). In June, the normal daily max temperature was 23.7°C and the normal daily min temperature was 8.6°C. There were normally 33 days of precipitation and 94.1 days of snow throughout the year. The winter of 2012-2013 produced 69.5 inches of snow and the winter of 2013-2014 produced 99.1 inches of snow (NCEI 2015).

Methods

Live-Trapping

We used live traps (models 103, 104.5, and 105; Tomahawk Live Trap Company, Tomahawk, Wisconsin, USA) baited with raw meat (chicken, elk liver, beef, smoked pork, beaver, or venison) and a commercial-grade call lure ("Gusto", Minnesota Trap Line, Pennock, MN) to capture marten. In cold weather we covered the traps with hay for insulation and the longitudinal half of a 5-gallon bucket to protect from snow. In warm weather we covered traps with natural material such as pine needles, leaves, or moss to act as a sunshade and provide bedding material. We checked traps a minimum of once every twenty-four hours. We immobilized captured marten using a mobile anesthesia machine administering a mixture of

isoflurane and oxygen (Desmarchelier et al. 2007). We injected each animal with a passive integrated transponder (PIT) tag and attached radio-collars (approximately 20 g, Advanced Telemetry Systems model 1555) to female marten and, during the spring and early summer, checked for signs of lactation. Once the radio-collar was attached we placed the marten in a dark holding chamber to recover from the anesthesia. Once fully recovered we released the marten at the site of capture. For the entire collaborative study, the time spent under anesthesia averaged 24 ± 8 minutes (range 8-51 minutes, n=121, Spriggs 2015). All capturing and handling procedures were established and approved by the Sault Ste. Marie Tribe of Chippewa Indians, the Grand Valley State University Institutional Animal Care and Use Committee (approval #12-05-A), and the project veterinarian (Maria Spriggs, DVM, Staff Veterinarian, Busch Gardens Tampa, FL).

Radio-Telemetry & Den Monitoring

In the summer of 2013 we monitored potentially reproductive females at least twice per week. We did not begin trapping and telemetry early enough to detect natal dens of females, and all confirmed dens are classified as maternal dens. We confirmed the presence of a litter through den-site fidelity of a female, camera capture of kits, presence of prey remains, presence of a latrine, or visual or auditory confirmation of kits. In the summer of 2014 we had a very limited study period that include one week of den monitoring. We attempted to locate all collared females each day of the study period.

We placed one to three trail cameras at each potential den structure to confirm the presence of kits and estimate the number of kits in each litter. We removed the cameras when the mother relocated the litter to a new den structure.

Den-Site Analysis

When a structure was confirmed as a den we recorded the structure type (live tree, snag, fallen hollow log, underground) as well as the diameter at breast height (DBH) of standing den structures and diameter of hollow logs at the den entrance. When the den structure was no longer in use we would return for more detailed analysis. Within a 15m-radius circle centered at the den structure we measured the DBH and recorded the species of each tree that was larger than 10cm DBH. We then measured the length and diameter of CWD longer than one meter and with a diameter greater than 10 cm. In one randomly selected quadrant of the plot we identified all stems ≥ 1 m in height. Next we measured the same attributes in a paired plot located 60 m from the den structure in a randomly selected direction (following Porter et al. 2005).

Analysis

For each den site plot and paired randomly selected plot we calculated the total volume of CWD which we converted to m^3 CWD per hectare, the total basal area per hectare, and the Shannon-Weiner diversity of both the overstory (trees ≥ 10 cm DBH) and stems (trees ≤ 10 cm DBH).

We compared data between years for basal area, coarse woody debris volume, overstory Shannon-Weiner diversity, and stem Shannon-Weiner diversity at den sites as well as the DBH of den trees. We then compared these values between den sites and the paired randomly selected sites. We compared data by first testing for normality of each data set using a Shapiro-Wilk test. We attempted to transform non-normal data using a log transformation. We tested for equal variance using the Bartlett test. Normal data with equal variances were tested using a paired t-test, and data not meeting parametric assumptions were tested using a Mann-Whitney U-test. When comparing between den sites and randomly selected sites we used a paired t-test or

Wilcoxon signed-rank test. All statistical analyses were completed in Program R (version 3.2.1, Program R Core Team 2015).

Results

In 2013 we tracked 3 females to 10 unique den sites and in 2014 we tracked 2 females to 5 unique den sites for a total of 15 den sites and a range of 2 to 4 dens per female. No females were tracked in both years. Throughout the study we monitored litters for 47 days in total. During telemetry and through camera captures we documented litters using structures other than the main den structure for cover at 3 of the 15 den sites. We found no significant differences in habitat variables between years so all statistics were run on data from both years. Mean litter size was 2.4 kits (± 0.2 SE, range 2–3). We found dens in 7 live trees, 4 snags, 3 hollow logs, and 1 subterranean. Of all dens located in live trees, 3 were in conifers [White cedar; *Pinus strobus* L. (White pine); and *Pinus resinosa* Ait. (Red pine)] and four were in deciduous species [quaking aspen; *Populus grandidentata* Michx (Big-tooth aspen); and two in *Quercus rubra* L. (Northern red oak)]. In 2013, all den structures in live trees were found in deciduous species whereas in 2014 they were all found in coniferous species. The median DBH of all standing den trees, including live trees and snags, was 41.9cm (range 26.7-66.4cm, n=11) and standing den trees were significantly larger than the surrounding trees that had a median size of 16.45 cm DBH ($p < 0.001$). Of the 11 dens located in standing trees, only four were the largest tree in the plot, with other den sites having a median of two larger trees in the plot (range 1-10 larger trees). Surrounding trees that were larger than the den were primarily live trees (n=25 of 28 trees). Fourteen larger surrounding trees were coniferous species and 12 were deciduous species. In 2014, the only trees larger than the standing tree dens were coniferous species. Of all randomly

selected plots, 71% were centered on trees smaller than the smallest recorded den tree and 100% were smaller than the fourth smallest recorded den tree. None of the randomly selected center trees that were larger than the smallest den tree were in species used as dens; therefore we are confident that our randomly selected trees were not undocumented den trees. We found no significant differences between den sites and randomly selected sites for basal area, Shannon-Weiner diversity, or total coarse woody debris volume (Table 1).

Discussion

We found evidence that marten prefer large structures to den in and den structures in standing trees were significantly larger in diameter than the surrounding trees, which is in agreement with past studies (Bull et al. 2005, Bull and Heater 2000, Raphael and Jones 1997, Slauson and Zielinski 2009). The den structure serves as physical and thermal protection for the litter and must be able to contain the entire litter for long periods of time. Large trees, snags, and fallen logs are the structures most likely to have large enough cavities or hollow areas created by either heart rot fungi (Berry 1973, Bull et al. 1997), pileated woodpecker cavities (Bonar 2000), or natural decay.

We did not find den sites to be significantly different from randomly selected sites in any measured habitat variable. The lack of significant difference between habitat in den sites and randomly selected sites could indicate that marten select for appropriate den structures as opposed to den site habitat or that marten are choosing sites based on habitat variables we did not measure. Ruggiero et al. (1998) found den sites to have more large CWD than randomly selected sites, and he proposed that the CWD was used for hiding and as escape cover for the litter. While we did not find a relationship between CWD volume and den sites, we did document kits using

multiple structures in the den site as cover. At two of these locations the alternate structure was a snag and in one instance it was a secondary hollow log. Joyce (2013) indicated that marten den sites are surrounded by more potential den structures including cavities, witches brooms, and burrows large enough to contain an adult marten, than randomly selected sites. Although we did not search for alternate cavities around the main den structure, it is possible that there were enough cavities in standing trees surrounding den sites to provide the necessary protection and escape cover for the litter.

Over the two-summer study period we found dens in both coniferous and deciduous species of standing trees. Interestingly, in 2013, all standing tree dens were located in deciduous species while in 2014 all standing tree dens were located in conifers. This pattern suggests that marten will use any structure, regardless of species, as a den as long as it is large enough and provides enough protection from predators (Raphael and Jones 1997, Ruggiero et al. 1998).

We only found one other study that documented underground dens. Bull and Heater (2000) found three natal dens and two maternal dens underground. Of those dens, two were associated with rocks or boulders, two entrances were located in root wads, and one was associated with a red squirrel midden. Our study differs in that the entrance was not associated with rocks, trees, or a squirrel midden; the entrance was approximately 10 cm in diameter and therefore may have been a red squirrel burrow. The use of this relatively undocumented den structure shows that marten will use any structure large enough and secure enough to keep the entire litter safe.

The retention of potential den structures, including large trees with cavities, will help to ensure the retention of a healthy marten population. Future research should reassess the demography and population structure of the marten in the Eastern UP to determine if a decline in population numbers is still apparent.

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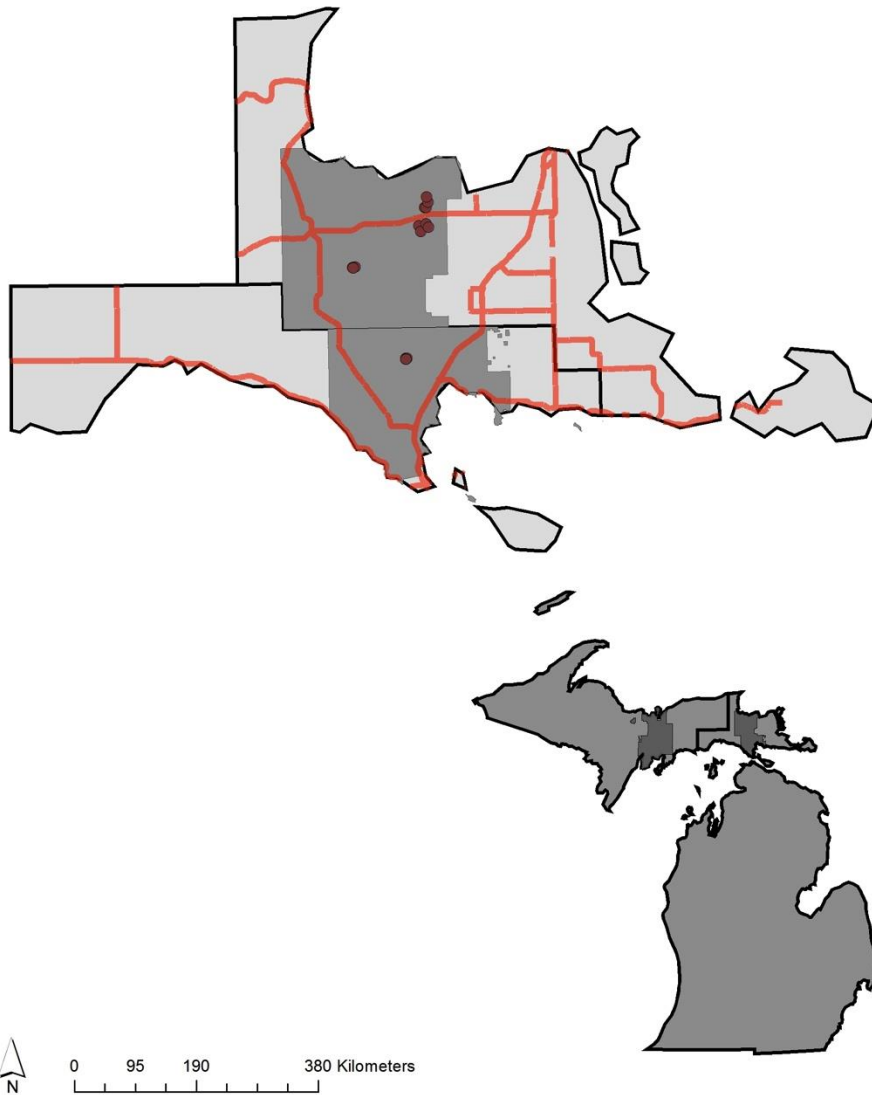
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Table 1. Median values for basal area (m^2 per hectare), the Shannon-Weiner Diversity of the overstory (trees >1m tall and >10 cm DBH), the Shannon-Weiner Diversity of the stems (trees >1m tall and <10 cm DBH), and the total volume of CWD (m^3) found in plots surrounding American marten den sites and randomly selected sites. p-values represent differences in raw values, not differences in median values.

	Range at Den Site	Median Value at Den Site	Range at Random Site	Median Value at Random Site	p-value
Basal Area (m^2 /hectare)	3.4-66.1	26.2	10.0-56.7	25.3	0.5805
Overstory Shannon-Weiner Diversity	0-1.69	1.37	0.60-1.96	1.44	0.4543
Stem Shannon-Weiner Diversity	0.35-1.59	0.97	0.41-1.64	1.05	0.2686
Total CWD volume (m^3)	0.46-4.0	1.70	0.10-4.10	1.81	0.3498

Figure 1. Study area map of Chippewa and Mackinaw Counties in the Upper Peninsula of Michigan, USA. The Hiawatha National Forest is in dark grey and American marten den sites are indicated by red dots.



Chapter 4

Maternal Den Site Activity Patterns of American Marten Manuscript

Maternal Den Site Activity Patterns of American Marten

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Abstract - Female American marten (*Martes americana*) raise their kits in a series of dens throughout the summer after parturition. Even after weaning, females provide their offspring with prey until they are capable of hunting for themselves. We used a combination of radio telemetry and placement of remote-trigger cameras to study the activity patterns and den switching behaviors of marten in Michigan for the summers of 2012 to 2014. We found no relationship between litter size and the number of days spent at each den and documented den reuse four times. We recorded 858 total activity periods. We conclude that den switching is a complex behavior that is likely influenced by den size, fecal buildup outside of the den, prey availability in the immediate vicinity of the den, and predator presence.

Introduction

Female *Martes americana* Turton (American marten, hereafter “marten”) give birth to litters of 1 to 5 kits between mid March and late April each year following a 27-day active pregnancy (Clark et al. 1987, Strickland and Douglas 1987). Kits remain with their mothers for the duration of their first summer in a series of den structures. Weaning has been documented between six and seven weeks of age (Brassard and Bernard 1939). At weaning, kits rely on their mother to

provide them with prey until they are capable of hunting on their own. Even after kits become independent around mid July, the family group stays loosely connected as they share the same home range until kits disperse (Strickland et al. 1982).

Female activity and den attendance appears to change between pre-weaning and weaning of the litter. It has been documented that regardless of kit age, female marten are away from the den from dusk to midnight (Henry et al. 1997), however females take fewer long trips away from the den prior to weaning. In addition to female activity at den sites being recorded, adult males sometimes visit den sites while the kits are present (Jones et al. 1997). This behavior is likely due to the overlap of mating season with kit-rearing season for adult females.

Den switching behavior is also recorded in studies looking at den attendance (Jones et al. 1997, Ruggiero et al. 1998). Female marten relocate litters an average of 10.8 (n=9 females with kits, range 5-24 relocations) times per summer (Jones et al. 1997, Ruggiero et al. 1998), but it is unclear why females relocate their litters throughout the summer. Relocation due to fecal buildup, the litter outgrowing the cavity, or as a means of predator avoidance have all been hypothesized but data has been lacking to test among these hypotheses (Kleef and Tydeman 2009). The objective of this study was to gain a better understanding of female den attendance patterns and determine what prompts den relocations in Michigan.

Field-site Description

We had two study areas, the first in Lake and Wexford Counties in the Manistee National Forest (MNF) of the Lower Peninsula (LP) of Michigan and the second in Chippewa and Mackinac Counties the Hiawatha National Forest (HNF) in the eastern portion of the Upper Peninsula (UP) of Michigan (Fig. 1). Both sites were predominantly forested with small

inholdings and very little urban or suburban development. The MNF contains large tracts of *Pinus resinosa* Ait. (Red pine) plantations as well as maple-oak regenerating forests. The HNF site was dominated by *Abies balsamea* (L.) Mill (Balsam fir), *Thuja occidentalis* Linnaeus (Eastern white cedar), *Pinus strobus* L. (Northern white pine), and *Pinus banksiana* Lamb. (Jack pine). The overall stand age at the HNF site was older than in the MNF site. Both study sites are located in timber management areas that are also used for recreation throughout the year. In the MNF, normal annual precipitation is 90.37 cm and normal average temperature in the summer is 19.4°C. In the HNF, normal annual precipitation is 87.8 cm and normal average temperature in the summer is 17.3°C (NCEI 2015).

Methods

We live-trapped (models 103, 104.5, and 105; Tomahawk Live Trap Company, Tomahawk, Wisconsin, USA) opportunistically for one to three week periods from 2012 to 2014. Trapping sessions never occurred in April to avoid whelping. Traps were baited with a combination of raw meat (chicken, elk liver, beef, smoked pork, beaver, or venison) and a commercial grade call lure (“Gusto”, Minnesota Trap Line, Pennock, MN). In warm weather, we surrounded traps with debris from the site including leaf litter, bark, pine needles, and moss to shelter the trap from precipitation. In colder weather we surrounded traps with hay then covered small traps with the longitudinal half of a five-gallon bucket and large traps with the longitudinal half of a 55-gallon drum. Traps were checked at least once per 24 hours.

Upon capture, marten were transported to a mobile field lab set up in the bed of a field vehicle. Using a mobile anesthesia machine we administered isoflurane and oxygen to immobilize the animal (Desmarchelier et al. 2007). Once the marten was immobilized we

evaluated the overall body condition and response to anesthesia using body temperature, respiration rate, and pulse. For the duration of handling we regulated body temperature using a combination of chemical hand-warmers and heating pads to warm the animal when the body temperature began to fall below normal, and the application of ethanol to the footpads and arm pits to cool the animal when the body temperature began to rise. We weighed and sexed each marten and checked females for signs of lactation during reproductive months. We injected a passive integrated transponder (PIT) tag (Avid Identification Systems, Inc., Norco, California) into each animal. Adult females were fitted with an approximately 20 g VHS radio-collar equipped with a mortality sensor (Modified model RI-2D Holohil Systems Ltd., Ontario, Canada and model 1505 or 1555 attached on a belt Advanced Telemetry Systems, Isanti, Minnesota). When the marten was fully recovered from anesthesia it was released at the site of capture. Time from handling to release was less than one hour (for the entire collaborative study average time was 24 ± 8 minutes, range 8-51 minutes, $n=121$; Spriggs 2015). We had no capture or handling issues for the entirety of the study. All capture and handling procedures were established and approved by the Little River Band of Ottawa Indians, the Sault Ste. Marie Tribe of Chippewa Indians, the Grand Valley State University Institutional Animal Care and Use Committee (approval #12-05-A), and the project veterinarian (Maria Spriggs, DVM, Staff Veterinarian, Busch Gardens Tampa, FL).

We used a combination of radio telemetry and remote trigger cameras to develop den activity patterns for female marten with kits throughout the denning periods of 2012, 2013, and 2014. We attempted to locate radio-collared females at least twice per week during the denning season. Site fidelity of a female from late March to April indicated the presence of a natal den (where the female gave birth to a litter of kits) and we confirmed maternal dens (any den used after a natal

den) through site fidelity of a female, the presence of scat, prey remains, and/or observation of kits.

Once a site was confirmed as a den we placed one to three remote trigger cameras angled toward the den entrance. Camera settings and placement were not standardized throughout the study and the number of cameras placed at a den could vary during the time period the litter was occupying the den. Time between camera triggers ranged from one to five seconds. We did not remove cameras until the litter was documented at a different den. Photo captures were used to quantify litter size, maternal den attendance, den visits by other marten (identified by size, fur color pattern, and radio-collar style), and den visits by potential predators as well as the first date a female brought prey to her kits and the first date kits appeared on camera. Camera captures were grouped together into activity periods using methods adapted from Henry et al. (1997). The first camera capture indicated the beginning of an activity period and a block of five or more minutes with no camera captures indicated the end of an activity period. If a marten was missing from camera captures for less than five minutes we assumed the animal had just stepped out of the frame.

We calculated the mean litter size each summer for each site, for each site overall, and for all litters. We found the number of days spent at each den using any day we captured activity on camera or a day that we successfully tracked the female to a den and placed a camera. Additionally, we calculated the number of activity periods per day of confirmed presence at a den. Prior to running statistical tests we tested samples for normality using Shapiro-Wilk and tested for equal variance using Bartlett's test or Fligner-Killeen test. We compared the number of days spent at dens between years using a Kruskal Wallis test. We used a Spearman Rank test to determine if there is a correlation between the size of a litter and the number of days spent at

each den. We used simple linear regression to compare the days a female was monitored to the number of activity periods recorded. We calculated the length of each activity period and used Shapiro-Wilk to determine if activity periods were normally distributed across all hour blocks during the day. For females with activity in more than 12 hours throughout the day we calculated the mean number of females that had no activity for each hour block. We calculated the number of activity periods that occurred between dusk and midnight. Dusk ranged from just before 2100 in May to just after 2200 in July. For any activity between May and June 15 we used 2100 as our time for dusk and after June 15 we used 2200.

For each den relocation we calculated the straight-line distance travelled between dens. Within each year and study site we compared these distances between each individual female using a Kruskal-Wallis test. If no individual marten differences were found we combined data into years and study sites (i.e., 2013 LP, 2013 UP, etc.). We then compared these years using a two-sample t-test. Differences between individuals or years were analyzed with post-hoc Wilcoxon Rank Sum tests using a Bonferroni correction. All statistical analyses were performed in Program R (version 3.2.1, Program R Core Team 2015).

Results

From 2012 to 2014 we collected camera activity data for 14 litters produced by 11 female martens at 59 dens ($\bar{X} = 4.21 \pm 0.73$ dens per female per summer, Table 1). Including confirmed dens with no camera activity data and den reuse, we calculated the distance between dens for 60 den switches by 12 female martens (Table 2). In the UP we monitored 5 females for a single year, in the LP we monitored 5 females for a single year, 1 female for 2 years, and 1 female for all 3 years. Not all females could be monitored for an entire season, we lost contact with 1 female in

2012 and had 2 mortalities, 1 female was depredated at the end of May in 2013, and 1 female died of unknown causes possibly linked to malnourishment and parasites in the lungs (Spriggs 2015).

Over the 3-year study we documented and monitored 35 kits (Table 1). The average litter size for the study was 2.5 kits (+/- 0.25 SE, range 1-4). The average litter size in the LP over three years was 2.56 (+/- 0.38 SE, range 1-4) while the average litter size in the UP over 2 years was 2.4 (+/- 0.24, range 2-3). These numbers represent minimum possible values, as it was always possible that we did not get photographic evidence of all kits or kit mortality occurred prior to camera placement or kit emergence. Litter size in the LP in 2012 was significantly larger than litter size in the LP in 2013 (LP 2012= 3.33 ± 0.33 ; LP 2013= 1.75 ± 0.48 ; $p=0.04$), but no other years or sites significantly differed ($p > 0.05$).

We monitored litters for 3 to 39 days ($\bar{X} = 15.3 \pm 2.8$ days) and recorded 858 total activity periods. The majority of all camera events occurred in June (66.4%), followed by May (26.6%). By July, kits were leaving the den with their mother more often and denning behavior diminished with the entire litter moving together to rest sites. Activity periods ranged from 1 second to 83 minutes 19 seconds. Eighty-seven activity periods were recorded by a secondary or tertiary camera, accounting for 10.1% of all occurrences. Start times of activity were normally distributed among all 24 hours. Ten of the 14 females with recorded activity had activity periods beginning in more than 12 different hour blocks. For each hour block, the mean number of females with no activity periods was 1.41 ± 0.24 (range 0-4, $n=10$). All ten had activity from 0101-0300, 0401-0600, and 1700-1900. From 2101-2200 four of the females had no activity periods start and from 0701-1000 three of the females had no activity periods start. The number of days spent at a den ranged from 1 to 20 days ($\bar{X} = 3.6 \pm 0.5$ days). We captured more activity

periods the longer we successfully monitored a female (Table 1, Fig. 2, $R=0.621$, $F=22.3$, $p=0.0005$). We found no relationship between litter size and number of days spent at each den and found no differences in number of days spent at dens between years. We documented 3 litters reusing 4 dens throughout the study. Den reuse occurred 6 to 28 days after the original occupation of the den ($\bar{X} = 17.25 \pm 5.0$ days, $n=4$). Litters remained at reused dens for 1 to 2 days ($\bar{X} = 1.75 \pm 0.25$ days) before leaving.

The earliest we first observed kits on camera was May 22 in 2012, May 25 in 2013, and May 21 in 2014 (Table 3). We captured 68 occurrences of the female delivering prey to kits, with the earliest observation each year on May 29, 2012; May 5, 2013; and May 23, 2014. Finally, we had a total of 89 activity captures of male marten visiting dens, however only 72 of these activity captures were likely unique events. The earliest male activity recorded was on April 21, 2013. In both 2012 and 2014 the earliest male activity recorded was on May 24. In 2014, this was the only day we recorded a male visiting a den, in 2012 the last occurrence was on June 28 and in 2013 the last occurrence was on July 26. We recorded 2 instances of potential predators at dens, one *Canis latrans* Say (Coyote) and one *Procyon lotor* L. (Raccoon).

The median distance moved per female per summer ranged from 64m to 2470m (Table 2). For all den switches, the minimum distance between dens was 5m and the maximum was 3382m with a median distance between dens of ($n=60$, Table 2). In 2012 we found differences between the distances between dens for individual females in the LP ($p=0.025$) but post hoc multiple comparisons did not highlight what caused this statistical difference. No other years and study sites had significant differences between females. When we combined data into years and study sites we found significant differences between LP 2013 and LP 2014 ($p=0.007$), the mean distance between dens in LP 2013 was 766m and the mean distance between dens in LP 2014

was 159m. Due to small sample size in the UP we combined years and found the mean distance between dens to be 491m with the median distance between dens of 297m.

Discussion

By May 5 we saw evidence of females delivering prey to the litter and by the end of May kits were exploring outside of the den. These developmental stages align with a parturition date between late March and mid April (Clark et al. 1987, Henry et al. 1997, Jones et al. 1997). Henry et al. (1997) found that females were often away from the den from dusk to midnight, but we did not find conclusive evidence of this trend, as activity periods were normally distributed throughout the day. While 4 females did not have activity start from 2101-2200, 6 did and 3 females were lacking activity from 0700-1000. Activity periods did appear less frequent from 2101-2200 however there was not enough evidence that females always leave the den at dusk. It is possible that females are leaving the den to hunt, therefore differences in prey availability in Wyoming versus Michigan could account for this attendance pattern. Females in both the LP and UP were found to consume multiple prey species including *Peromyscus leucopus* (Rafinesque) (White-footed mice), *Sciurus carolinensis* (Gmelin) (Gray squirrels), and *Scalopus aquaticus* L. (Eastern moles) (Kujawa et al. 2014). Most studies from the western United States find that marten are *Clethrionomys gapperi* (Vigors) (Red-backed vole) specialists (Bull 2000; Hargis and McCullough 1984) and as Red-backed voles are primarily nocturnal it is logical that females would leave the den at night in order to effectively hunt. While Red-backed voles are available as prey in the HNF (E. Clark, Sault Ste. Marie Tribe of Chippewa Indians, Sault Ste. Marie, MI, USA, pers. comm.), small mammal studies in MNF have captured no Red-backed voles (J. Jacquot, Grand Valley State University, Allendale, MI, USA, pers. comm.). Overall, a more

generalized diet is seen in Michigan and a lack of consistent activity patterns is understandable as the female could effectively hunt during the day as well as at night.

The average litter size was similar to numbers reported in other research (Jones et al. 1997, Strickland and Douglas 1987). The difference in litter size in the LP between 2012 and 2013 could be due to an unseasonably warm winter in 2011 and colder winter in 2012. Energetic stress is a major factor in determining litter sizes in other mammals (Tannerfeldt and Angerbjörn 1998), and a warmer winter could have led to less energetically stressed females producing larger litters.

We found no evidence of a relationship between litter size and den relocation patterns. If litters were relocated due to size restraints of the denning structure we would expect to see no den reuse. In the mean 17.25 days between original use of a den and the reuse, kits have enough time to grow a significant amount. Although den reuse was relatively uncommon throughout the study, the four instances we recorded indicate that den size is not the leading factor contributing to den relocation patterns. If relocation were due to fecal buildup, larger litters likely would have relocated dens more often than smaller litters because feces would have built up faster. Although we found no relationship between litter size and den relocation, we also found limited support for the predator avoidance mechanism described by Kleef and Tydeman (2009). We only recorded two instances of potential predators attempting to get into dens and it is reasonable to assume that marten would view the presence of humans at the den as a predator threat, but relocation did not occur immediately after our presence at dens. Further, the median straight-line distance travelled between dens was only 407m, a distance easily travelled by predators. We propose that in addition to the factors outlined by Kleef and Tydeman (2009), the availability of prey resources immediately surrounding the den site may also affect relocation. For example, White-

footed mice have a reported average home range size of 0.1 ha (Lackey et al. 1985) and density is dependent on the habitat (Anderson et al. 2003), with some overlap of home ranges. Den relocation may occur when the female marten has depleted the prey base directly surrounding the den, as a move of 100m would put the marten into new small mammal territory. This theory could also explain differences between the distances individual females move and differences in distances between years because the small mammal populations fluctuate yearly and can differ dramatically between two forest patches (Wolff 1996; Anderson et al. 2003). GPS tracking of females to determine where she hunts and small mammal trapping around den sites immediately following a den switch could lead to a better understanding of this hypothesis. The hypotheses as to why marten switch dens are likely not mutually exclusive, rather the behavior is complex and dependent on a multitude of factors.

We documented a large number of male visits to dens from April to July. Although males are not known to help rear kits (Clark et al. 1987), Jones et al. (1997) recorded male presence at 6 of 36 monitored dens and Ruggiero and Henry (1993) mentioned that male marten often frequent known den sites during the breeding season in order to encounter females. Since the breeding season and kit-rearing season overlap and marten are capable of breeding every year, copulation often occurs when kits are present at the den (Ruggiero and Henry 1993). Male attendance early in the kit-rearing season when females are likely not receptive to copulation could be a way for males to keep track of potential mates within their home range or could be a part of the courtship process.

Previous studies on attendance have used a variety of methods for monitoring. Henry et al. (1997) used telemetry based recorders positioned at the den, Erb et al. (2009) monitored using temperature sensors attached to marten collars, and Jones et al. (1997) was one of the first studies

to capture den activity on camera. Over 3 years, Jones et al. (1997) found a total of 31 dens occupied by 8 different martens, monitored 16 of those dens and captured marten activity at 12 of the monitored dens. Over five years, Henry et al. (1997) found a total of 26 dens occupied by 9 different martens and 13 litters. Although we were able to collect information on when females were active outside of their dens, we recommend combining camera data, telemetry activity monitors, PIT tag readers, and/or temperature sensors (Jones et al. 1997) to better document when females come and go from the den.

By combining methods there would be a better chance at accurate collection. Cameras provide data that other methods cannot, such as prey delivery, kit transfer, and male attendance, but are unreliable for obtaining accurate den attendance patterns, especially when the den entrance is not at ground level. Additionally, while one camera captured 90% of activity periods, it was not necessarily the camera we placed first so we recommend placing multiple cameras at each den to improve the likelihood of good camera placement. Placing one camera close to the den and one farther away could help collect different types of information (closer camera placement makes identifying prey easier while more distant camera placement allows for wider angles). By using multiple monitoring methods researchers could gain a much better understanding of how martens are moving during the reproductive months and when females are in their dens versus away. In addition, future studies should attempt to measure cavity size in a practical, non-destructive manner in order to better understand den relocation and the relationship between litter size and den size. Researchers would also be able to locate alternate den entrances if cavity size was measured.

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1 Table 1. Den and activity data for female American marten in Michigan from 2012 to 2014.

Site	Year	Marten	Number of Kits	Number of Dens with Camera Activity	First Day Litter Monitored	Number of Days Monitored	Number of Activities Captured	Activities Per Day	Median Days Per Den
LP	2012	367	3	8	May 23	25	76	3.0	2.5
LP	2012	600	3	7	May 25	20	36	1.8	2
LP	2012	798	4	2	May 29	22	119	5.4	11.5
LP	2012	822	3	2	May 25	5	31	6.2	9
LP	2013	365	1	4	May 7	22	65	3.0	2
LP	2013	600	2	4	April 19	19	124	6.5	5.5
LP	2013	798	3	10	April 18	39	146	3.7	1
UP	2013	5128	3	3	May 30	14	21	1.5	4.5
UP	2013	6002	2	4	June 19	18	131	7.3	4.5
UP	2013	6552	Unknown	2	July 3	4	4	1.0	2
LP	2014	627	2	2	May 14	6	5	0.8	2.5
LP	2014	798	4	7	May 8	14	81	5.8	3
UP	2014	3121	3	2	June 22	3	3	1.0	1
UP	2014	9710	2	3	June 23	3	10	3.3	1

Table 2. Straight-line distances between successive dens of female American marten in Michigan from 2012 to 2014.

Site	Year	Marten	Unique Dens	Den Switches	Minimum Distance (m)	Maximum Distance (m)	Median Distance (m)
LP	2012	009	2	1	148	148	n/a
LP	2012	367	6	5	59	565	347
LP	2012	600	8	9	310	1143	811
LP	2012	798	7	6	198	3382	2470
LP	2012	822	3	2	66	326	196
LP	2013	365	6	6	40	1134	209
LP	2013	367	3	2	402	637	520
LP	2013	600	3	2	1099	1590	1344
LP	2013	798	9	8	220	2085	748
UP	2013	5128	4	4	203	258	256
UP	2013	6002	3	2	335	1320	828
UP	2013	6552	2	1	1262	1262	n/a
LP	2014	627	4	3	42	362	236
LP	2014	798	7	6	5	377	64
UP	2014	3121	2	1	798	798	n/a
UP	2014	9710	3	2	91	518	305

Table 3. Activity data for American marten reproductive females and their kits in Michigan from 2012 to 2014.

Site	Year	Marten	First Day Litter Monitored	First Appearance of Kits Outside of Den	First Documentation of Female Delivering Prey
LP	2012	367	May 23	May 23	June 13
LP	2012	600	May 25	May 22	June 5
LP	2012	798	May 29	June 10	June 11
LP	2012	822	May 25	May 29	May 29
LP	2013	365	May 7	May 29	May 29
LP	2013	600	April 19	June 7	June 8
LP	2013	798	April 18	May 25	May 5
UP	2013	5128	May 30	May 31	June 22
UP	2013	6002	June 19	June 19	June 19
UP	2013	6552	July 3	July 3	n/a
LP	2014	627	May 14	May 24	n/a
LP	2014	798	May 8	May 21	May 23
UP	2014	3121	June 22	June 22	June 22
UP	2014	9710	June 23	June 23	June 23

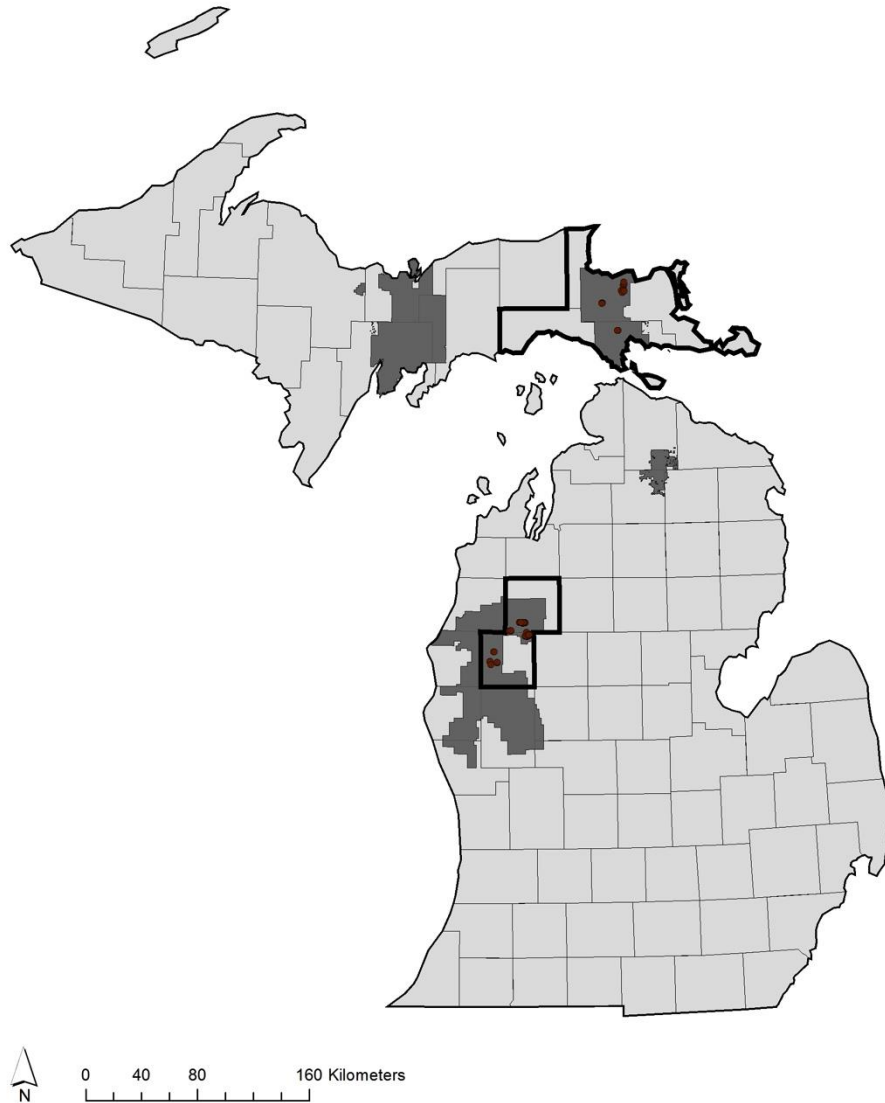


Figure 1. Field-site map of the Manistee National Forest in Lake and Wexford Counties and the Hiawatha National Forest in Chippewa and Mackinac Counties in MI, USA. National Forests are designated by dark grey fill. Den sites are shown as red dots.

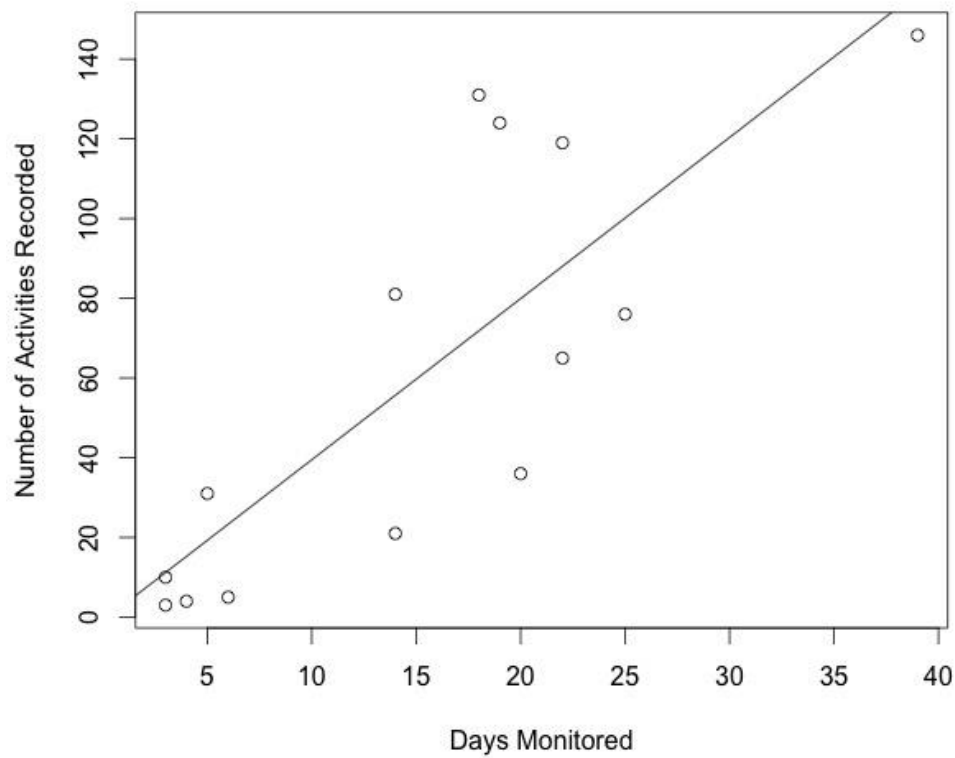


Figure 2. Comparison of the number of days a female American marten was monitored to the number of activities captured on remote-triggered cameras placed at each den site in Michigan during kit-rearing seasons of 2012 to 2014. $R=0.621$, $F=22.3$, $p=0.0005$.



Figure 3. *Martes americana* (American marten).

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