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Detection Probability of the American Marten (Martes americana) in Michigan's Lower Peninsula

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Detection Probability of the American Marten (*Martes americana*) in Michigan's Lower Peninsula

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played an equally important role, providing the equipment, vehicles, and personnel to make this project a reality.

Abstract

To accurately manage for the sustainability of wildlife populations, managers must first determine how to locate individuals of a population with great consistency. Determining the efficiency of detection techniques is a challenge, especially when the study species are scarce or elusive. Such is the case with the American marten (*Martes americana*), a small mustelid found across the Northern United States and Canada. In the lower peninsula of Michigan, marten are considered a species of concern, and the full extent of their range remains unknown. My goal was to test the efficacy of motion-triggered cameras for detecting the presence of American marten in the Manistee National Forest. Marten were live trapped (n=9), fitted with radio collars, and tracked from May 2018 to September 2019 to determine the extent of their home ranges. I then set two, separate, motion-triggered cameras, facing bait sites, within each home range for four weeks to test the probability of detection. Some cameras were set near microsite features (course woody debris, trees with cavities/nests, brush piles), while some cameras were set in randomly generated locations within the home range. Cameras were moved and rebaited after each four-week period and were deployed for a calendar year to test for any differences in detection rates due to seasonality or camera placement. Despite a hypothetical expectation of an approximately 1.0 detection probability, actual probabilities were much lower (0.63), supporting the idea that non-detections should not always be associated with an animal's absence. Additionally, I found marten were more likely to be detected during the winter (Oct-Mar – 0.68, Apr-Sept – 0.56), when cameras were located in the core of the individuals home range (in core – 0.66, outside core – 0.55), and when camera locations were selected based on microsite characteristics rather than randomly placed (selected – 0.69, random – 0.39). This study reveals that camera traps alone are not efficient enough to consistently confirm a marten's presence, even when the cameras are placed in the home range. I recommend high camera densities (4 per 3.27 km^2) and selective camera placement, as well as additional detection techniques such as track and scat surveys for increasing the overall

likelihood of detecting marten presence. This research should be used to strengthen any inferences made using camera trap studies in the future and will ideally provide wildlife managers and biologists with a framework for better detecting American marten in Michigan's lower peninsula.

Table of contents

Title Page………1

Approval Page………………………………………………………………………………………………………2

Acknowledgements…………………………………………………………………………………………………3

Abstract……5

List of Tables……9

List of Figures………………………………………………………………………………………………………10

Chapter 1 – Introduction…………………………………………………………………………………………11

Scope……13

Assumptions…………………………………………………………………………………………………13

Objectives and Hypotheses………………………………………………………………………………14

Significance…………………………………………………………………………………………………14

Study Site……………………………………………………………………………………………………14

Chapter 2 – Detection Probability of the American Marten………………………………………………17

Methodology…………………………………………………………………………………………………17

Results………………………………………………………………………………………………………22

Discussion……………………………………………………………………………………………………25

Conservation Recommendations and Future Direction……………………………………………….33

Chapter 3 – Appendix and Extended Literature Review…………………………………………………….36

Appendix……….36

Extended Literature Review…………………………………………………………………………………39

Tables……….42

Figures……..45

Literature Cited……58

List of Tables

Table 1: Land cover types present within the home range of each marten, separated by individual and by location. Land cover data was analyzed in ArcGIS (Ver. 10.4). Any land cover that composed less than 0.05% was not included in this figure. Developed land cover included areas of high, medium, and low levels of development. Roads comprised the majority of developed areas.

Table 2: American marten home ranges, generated using ArcGIS (Ver. 10.4).

Table 3: Overall detection probability of American marten and comparisons between variables based on Pearson's Chi-square test ($\alpha = 0.05$). All cameras were placed within the 95% fixed kernel home range. Locations in the 50% isopleth were the number of detections from the total number of cameras placed within the 'core' of the marten's home range. Location in the 95% interval are restricted to those in the home range, but not in the core.

Table 4: Detection probability of each marten in the core of their range, and in their home range but outside the 50% core interval. Probabilities were calculated by taking the total number of detections from the total number of cameras. Probabilities from individuals with overlapping ranges were calculated as a range. It was assumed that either all detections were of the target marten, or that none of the detections were of the target marten. Cameras locations consisted of cameras deployed for four weeks.

Table 5: Detection probability based on region in the northern Manistee National Forest. Winter was determined as Oct—March; summer as April—Sep. On three occasions, the four-week period for a camera was set in both seasons (e.g., from Sep – Oct or Mar – Apr). In these instances, detections were assigned to the season in which the marten was first detected (i.e., a camera set in mid-Sep detects a marten on Oct 1, that detection was assigned to winter).

List of Figures

Figure 1. Locations of regions in which marten were trapped and tracked.

Figure 2. The influence of home range size on the detection probability of the American marten.

Figure 3. Camera locations and results within the home range of 225F in the Pine River region.

Figure 4. Camera locations and results within the home range of 722F in the Ward Hills region.

Figure 5. Camera locations and results within the home range of 767M in the Caberfae region.

Figure 6. Camera locations and results within the home ranges of 541F and 061M in the Harrietta region.

Figure 7. Camera locations and results within the home ranges of 100M, 413F, and 057M in the Olga Lake region.

Figure 8. Telemetry locations recorded for 100M, 413F, and 057M in the Olga Lake region. Home range boundaries (50% and 95% interval) using fixed kernel estimations are included.

Figure 9. Telemetry locations recorded for 225F in the Pine River region. Home range boundaries (50% and 95% interval) using fixed kernel estimations are included.

Figure 10. Telemetry locations recorded for 722F in the Ward Hills region. Home range boundaries (50% and 95% interval) using fixed kernel estimations are included.

Figure 11. Telemetry locations recorded for 767M in the Caberfae region. Home range boundaries (50% and 95% interval) using fixed kernel estimations are included.

Figure 12. Telemetry locations recorded for 541F and 061M in the Harrietta region. Home range boundaries (50% and 95% interval) using fixed kernel estimations are included.

Figure 13. Telemetry locations recorded for 181M in the Caberfae region. Home range boundaries (50% and 95% interval) using fixed kernel estimations are included. Mortality was recorded before a minimum of 30 locations were recorded.

Chapter 1 - Introduction

Management for long-term sustainability of wildlife populations requires the ability to consistently detect the presence of individuals within a population. Many survey techniques are used to detect wildlife species. Some are non-invasive, such as motion-triggered cameras, track surveys, scat identification and hair snares, while others may require the direct handling, tracking, or harvest of the focal species (Long et al., 2007, O'Connell et al., 2006; Zielinski & Kucera, 1995). Researchers often assume if a species is present, it will be detected (Smith et al., 2007). However, the density, abundance, and movements of individuals within populations vary spatially and temporally and can be affected by variables such as weather, biological rhythms, and seasonality (O'Connell et al., 2006). Since the probability of detecting a species may change in response to these variables, it is unlikely that actual detection probabilities are ever 1.0 (Mackenzie et al., 2002). When the probability of detection is assumed or overlooked, the results of presence-absence surveys may be subject to significant bias as non-detections lead to underestimations of wildlife populations (Smith et al., 2007; Mackenzie, 2005; Gu & Swihart, 2004). To understand the efficiency of a detection method, it must be implemented and assessed in areas where a species' presence is certain (i.e., within known home ranges).

The American marten (*Martes americana*) is an excellent study species for detection probability studies (Sirén et al., 2016) for several reasons. First, marten have been shown to use many vegetation types (deciduous, coniferous, mixed) and forest stand ages (mid successional to old growth) (Poole et al., 2004). While often associated with mature, old growth forests, their presence has been confirmed in a wide range of habitats as long as shelter and prey are available (Porter, St Clair, & Vries, 2005; Poole et al., 2004). This adaptability could mean detecting their presence will vary regionally, and that populations and abundancies may be hard to estimate without using one or several detection techniques. Second, marten are elusive, often nocturnal, and, for their size, occupy home ranges proportionally larger than expected for terrestrial predators (Buskirk & McDonald, 1989). Locating these animals to estimate densities and population health can therefore be difficult. Third, differences in habitat quality, sex, age, and season are known to alter marten movements (Zielinski et al., 2015; Bull, 2000; Buskirk & Ruggiero, 1994; Buskirk & McDonald, 1989). It is likely that these biotic and abiotic factors affect the likelihood of detecting a marten's presence. Fourth, marten are known to be sensitive to habitat alterations and fragmentation (Smith et al., 2007, Hargis, Bissonette & Turner, 1999). Their presence or absence is often used to determine the health of the forest ecosystem in which they inhabit (Smith et al., 2007), so marten conservation would likely benefit many other species as well. For example, any species that benefits from large tracts of contiguous habitat (large predators, ungulates, birds), any species that regularly utilizes cavities (birds, mammals), or any species that relies upon the presence of downed woody debris (reptiles, amphibians, small mammals, invertebrates, fungus, etc.) would benefit from the conservation of marten habitat. Finally, marten have been shown to respond regularly and positively to bait and camera traps making them an ideal species for population estimations and detection probability studies through the use of motion-triggered cameras (Sirén et al., 2016; Aubry et al., 2012).

In the lower peninsula of Michigan, U.S.A, the American marten (*Martes americana*) was extirpated around the turn of the 20th century due to extensive deforestation and overharvest (Williams, 2007, Ludwig 1986). To re-establish local populations, 85 individuals were reintroduced in 1985 and 1986 (49 in the Pigeon River Country State Forest, 36 in the Manistee National Forest and Pere-Marquette State Forest) (Williams, 2007, Ludwig, 1986). Since then the population has not been monitored thoroughly, the exact numbers and locations of current marten populations remains unclear, and the marten is listed as a species of special concern across the lower peninsula of Michigan. Understanding the extent of marten presence throughout areas deemed to be marten range is important for their conservation and management. Therefore, reliable detection methods are necessary, and the detection probability of these methods must be understood.

Scope

This project took place in the northern half of the Manistee National Forest in Michigan's lower peninsula. The implications of this research, however, are wide-ranging and transferable. I have attempted to quantify and validate the efficacy of motion-triggered cameras as a detection technique for presence-absence surveys for the American marten. While detection probability may vary geographically, the methodology used here will ideally provide a framework for similar studies conducted not only in the state of Michigan, but across the entirety of the American marten's range.

Assumptions

The study design and implementation were based on the following assumptions: 1) marten remain in a well-defined home range year-round (Godbout and Ouellet, 2008, Chapin et al., 1997); 2) marten will encompass their entire home range in 4 weeks or less (Moriarty et al., 2017).

Objectives and hypotheses

The main objective was to determine the probability with which motion-triggered cameras placed inside a known marten home range capture a photo of an individual, thus confirming marten presence at that location. I hypothesized that the detection probability of cameras placed within the 95% fixed kernel home ranges would be less than 1.0, despite the known marten presence. Second, I hypothesized that winter detection rates would be higher than summer detection rates. Third, I hypothesized that cameras placed at randomly generated locations within a home range would not have a different detection probability than locations chosen based on the presence of micro-site features in the home ranges. Finally, I hypothesized that the addition of a second camera facing away from the bait would increase detection probability.

Significance

Wildlife managers cannot reliably assess population abundance and trends without first detecting individuals of that population. However, without knowing the probability of detecting those individuals, managers cannot conclude whether a species is absent or just undetected in an otherwise occupied area; this project will provide them a probabilistic sense as to which is the case. The only way to completely validate the efficacy of a detection technique is to test it in an area of known occupancy. The results of this study will ideally inform local biologists and managers of the detection probability of this animal in the northern lower peninsula, as well as provide information on the most effective methods for camera deployment across the area.

Study Site

The study was conducted in the northern half of the Manistee National Forest in the lower peninsula of Michigan, U.S.A. The National Forest covers a total area of approximately 538,909 hectares, 40% of which is under the management of the US Forest Service (USDA Forest Service, 2011). Our field work was restricted to Wexford County and Lake County, as these were the counties in which previous studies successfully trapped and collared marten (Sanders et al., 2017). This area was fragmented by the presence of highways, private inholdings, housing developments, small towns, and pine plantations. Elevation in the region ranged between approximately 259—333 meters above sea level (USDA Forest Service, 2019). Seasonal temperatures ranged from -11.1 °C to 14.7 °C from October – March, and -0.3 °C to 27.5 °C from April – September (NCEI, 2019). Annual average precipitation was 90.37 cm (NCEI, 2020), with an average of 38.97 cm of precipitation from October – March (NCEI, 2020). Land cover types were variable and contained a mixture of deciduous and coniferous forests. This region is predominantly comprised of mixed forest, but disturbance and fragmentation lead to a mixture of stand ages and successional stages across the landscape. Dominant species include red pine (*Pinus resinosa*), white pine (*Pinus strobus*), jack pine *(Pinus banksiana*), red oak (*Quercus rubra*), white oak (*Quercus alba*), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), black cherry (*Prunus serotina*), American basswood (*Tilia americana*), quaking aspen (*Populus tremuloides*), bigtooth aspen (*Populus grandidentata*), and cottonwood (*Populus deltoides*).

Marten were captured in five different regions around the northern Manistee (Figure 1)(Harrietta, Caberfae, Olga, Ward Hills, and Pine River). These locations were all given names based on towns, lakes, or other features near each site. Despite being in close proximity to each other, land cover types differed from one site to the next (Table 1). The land cover types in the Harrietta and Caberfae regions were comprised predominantly of mixed deciduous forest. Olga was dominated by coniferous forest, mostly red pine, but contained some mature oak as well. The Ward Hills site was a mixed coniferous-deciduous forest. The Pine River region was a semi-open site comprised of scrubby jack pine and oak.

Chapter 2 – Detection Probability of the American Marten

Methodology

Live trapping was conducted by focusing on areas of the study site in which marten had been captured in previous studies (Sanders et al., 2017). Tomahawk live traps (Tomahawk Live Trap Company, Tomahawk, WI, model 103 and 105) were placed along coarse woody debris, at the base of large diameter trees (those that visually ‘stood out’ against the rest of the forest), trees that contained cavities and nests, or near brush piles, as these have been shown to be key microsite features frequently used by marten (Vigeant-Langlois & Desrochers, 2011; Dumyahn, Zollner, & Gilbert, 2007; Powell et al., 2003; Bull & Heater, 2000). Traps were baited with a small cube of pork, approximately 5—8 cm in diameter, that hung from a wire in the back of the trap. A scent lure known as ‘Gusto’ (Minnesota Trap Line, Pennock, MN) was then added to a stick or log near the trap site to attract the marten from long distances. Traps were covered with debris from the forest floor (leaves, sticks, moss) with only the opening visible to conceal as much of the trap as possible, as well as provide insulation and protection from the elements. Traps were checked each morning and were re-baited when necessary (i.e., bait was rotten or removed by a non-target species).

When a marten was captured, the trap was covered with a tarp, to reduce the animal’s stress, before being transported to the nearest road. Marten were briefly anesthetized via isoflurane inhalation (Desmarchelier et al., 2007) to prevent injuries to the marten or ourselves. Once sedated, the sex, weight, and approximate age of the marten was recorded. Age was estimated based on dental wear patterns. A PIT tag (Passive Integrated Transponder, AVID

Identification Systems Inc., Norco, CA) was inserted under the skin between the shoulder blades. A very high frequency (VHF) radio collar (Advanced Telemetry Systems, model M1555) was then placed around their neck. Finally, the marten was placed into a recovery box until it awoke and appeared alert and healthy. Marten were then released back into the area from which they were captured. These procedures complied with the protocols set forth by the Grand Valley State University Institutional Animal Care and Use Committee (protocol 12-05-A) and adhered to the American Society of Mammalogists guidelines for the use of wild mammals (Sikes et al. 2016). Capture and processing of marten was always conducted under the supervision of experienced wildlife biologists from Grand Valley State University or the Little River Band of Ottawa Indians.

Marten were radio tracked throughout the year. Each marten was located a minimum of 30 times, with locations being recorded from May of 2018 to September of 2019 (Table 2). Marten were tracked a minimum of 30 times to ensure accurate home range estimations (Seaman et al., 1999). Marten were never tracked more than once daily to provide as much independence between points as possible. Once a marten was found, the time, GPS location, and resting site data were recorded. Resting site data included a qualitative description of the structure being used (i.e., tree cavity, hollow log, exposed branch, nest, subnivean foray). Telemetry data was put into ArcGIS (version 10.4.1) to calculate home ranges. Home ranges were estimated using a fixed kernel method. Both 50% and 95% isopleths were calculated using Geospatial Modeling Environment (Beyer, 2010) and R 3.2.2 (R Development Core Team, 2015) for each marten with ≥ 30 locations.

Once home ranges were estimated, motion-triggered cameras (Browning Strike Force, Sub Micro Series, Model BTC-5HD-850) were placed in the marten's estimated home range to determine detection probability. Two baited cameras were set within the home range. Cameras were consistently located in areas with abundant course woody debris and large diameter trees. The amount of coarse woody debris and classification of large diameter trees was visually estimated (i.e., there was no measurement used to quantify the amount of coarse woody debris present nor was there a threshold or minimum amount of these features that was required). This methodology was used to simulate a wildlife biologist or manager using visual estimations of features important to marten to determine locations in which to set a camera in an area of unknown occupancy. When placing cameras, I would look for areas where downed woody debris had fallen between two trees. I would attach a camera to one tree, the bait to the other, and place the Gusto either on the coarse woody debris between the trees, or on a stick at the base of the bait tree. If I could not find a location that met these criteria, I would set cameras in areas that contained downed debris within approximately 20 yards. I would clear vegetation, debris or brush that obscured the camera's view of the bait. Camera sites were baited with pork and Gusto. A small red bag of pork was nailed to a tree in front of the camera. The distance between the camera and the bait was approximately 4—6m. Bait was hung approximately 0.5 – 1.5 m off the ground. The height of the bait was largely determined by the elevation and contours of the landscape, the angle of the camera tree, and the angle of the bait tree. These variables were considered to ensure the bait and lure were in the frame of the camera. Gusto was placed on the log or stick in front the camera near the bait. Cameras were never set closer than 100 meters from each other when set in the home range at the same time (i.e., there were never two cameras set during the same 4-week period in the same home range that were closer than 100 meters). This procedure was done to provide independence between points (a marten discovering one camera was theoretically not correlated with their discovery of another). After the 4-week period, cameras were checked and moved to another location in the marten's home range. Cameras were rotated throughout the home range to prevent any bias from learned behavior. A detection was any confirmed photo of a marten in that home range. I compared summer to winter detection rates by classifying any detection from April 1st – September 30th as summer, and any detection from Oct. 1st – March 31st as winter.

From July 2019 to September 2019, ArcGIS was used to randomly select locations within the marten's home range instead of selecting locations based on microsite features. This change in methodology allowed me to determine if there was a difference in detection probability between random and researcher-selected locations within a home range. Two randomly selected locations were chosen; one was baited as before (pork nailed to a tree in front of the camera, Gusto on a stick or log beneath the bait), and the other was baited with salmon oil (Superior Alaskan Salmon Oil – Minnesota Brand, Minnesota Trapline Products, Pennock, MN) and no additional scent lure. Salmon oil (16oz) was poured on to a tree in front of the camera, approximately 1.5 m off the ground and allowed to run down to the base of the tree. A small orange reference scale (about 17—18cm) was spray painted (vertically) on the tree and allowed to dry before the salmon oil was poured. The camera always faced north to prevent lens flare from the sunrise or sunset. On the same tree as the north-facing camera, I placed an additional camera, this time facing south, away from the bait. At approximately 4—6 meters from the south-facing camera, a 1-meter scale was stuck into the ground. The purpose of both the spray painted and wooden scales was to ensure that sightings were of marten, and not of the similar but much larger fisher (*Martes pennanti*). Scales were also deployed to help determine the size of the marten in the photographs and to aid in our identification of the individual. The height of both camera lenses (cm), the composition of the forest (e.g., understory cover, canopy cover, dominant species), the distance to each scale (m), and the presence or absence of downed woody debris were all recorded. Cameras were again left out for 4 weeks, before being checked (pictures, batteries, SD card) and moved to another randomly generated point.

Land cover data was analyzed to determine if detection probabilities were at all correlated to differences in habitat within each region and each individuals' home range. The composition of land cover types was calculated using land cover data in ArcGIS (ver. 10.4.1) (Digital Coast Data, 2020). The amount of each vegetation type present was calculated as a percentage out of the whole home range (95% interval). Percentages were rounded to the nearest tenth of a percent (i.e., any vegetation types that comprised less than 0.05% of the entire home range were not included).

Detection probability data was analyzed using a Pearson's chi-square (χ^2) test using program R (ver. 3.2.2) to evaluate how likely it was that any observed difference in detection arose by chance. All detection data met all the required assumptions for this statistical analysis (McHugh, 2013). A linear regression model was computed in Microsoft Excel (ver. 1902). There were five comparisons made: 1) winter vs. summer detection probabilities, 2) the detection probability of random vs. researcher-selected locations, 3) detection probabilities of different bait and lure combinations, 4) the detection probability of cameras located within the core

(50%) of the home range vs. those located outside of the core but still within the home range (95%), and 5) the correlation between detection probability and home range size. A standard alpha ($\alpha=0.05$) was used to determine significance.

Results

Trapping, telemetry, and home ranges

Trapping was conducted from May 2018 – May 2019, when resources and personnel availability allowed. During this time, I captured and radio collared six marten, giving me a total sample size of nine individuals (three marten were captured and collared prior to the onset of this study). This sample consisted of four females and five males. Three marten were captured in the Olga region, two in the Harrietta region, two in the Caberfae region, one in the Pine River region, and one in the Ward Hills region (Figure 1). At the end of the study, seven marten remained alive; two males died in April or May and July of 2019, respectively. I suspect mammalian predation to be the cause of at least one death, as those remains were found buried under the soil (i.e., likely *Lynx rufus* or *Canis latrans* predation). I was able to collect enough telemetry data from one of the two mortalities; the other happened too soon after he was captured, and I was not able to collect enough telemetry locations to create an accurate home range (Table 2).

Marten were tracked a minimum of 30 times each (except 181M), and no marten was located more than 40 times during this project (Table 2). Most locations were taken during the summer months (April—Sep) as difficult winter conditions made transportation and tracking challenging. Average female home range size (95% interval) was 688.24 ha (6.88km^2); average male home range size (95% interval) was 1400.54 ha (14.01 km²). The core areas within home ranges (50% interval) averaged 247.03 ha (2.47 km²) for females and 520.98 ha (5.21 km²) for males. These home range estimations excluded 181M.

Deciduous forest was found to be the dominant forest type in the home ranges of individuals in the Harrietta, Caberfae, and Ward Hills regions. Coniferous forest was found to be the dominant land cover type in the Olga and Pine River regions (Table 1). In the home ranges of 541F, 061M, and 767M, land cover type comprised mostly of deciduous forest (89.3%, 86.9%, and 79.0%, respectively). In the home ranges of 413F, 100M, and 057M, land cover was comprised mostly of coniferous forest (84.9%, 82.4%, and 85.5% respectively). The home range of 722F was an even mixture of both coniferous and deciduous (46.1% deciduous, 40.2% evergreen, 10.1% mixed forest). The home range of 225F was also a mixture of cover types but contained more coniferous than deciduous (23.7% deciduous, 42.4% coniferous, 14.9% mixed forest). Deciduous and coniferous forests were the dominant land cover types throughout these regions, but there were other land cover types (e.g., wetlands, openings) present in smaller amounts (Table 1).

Detection Probability

Because I used more than one bait and lure combination, I compared the detection probabilities of camera sets with different bait and lure types and found no difference [χ^2 (df = 1, n = 120) = 1.9339, p = 0.164); Table 3]. Therefore, total detection probability within the study was computed by combining all cameras regardless of bait type. The total detection probability within my study was 75/120 (62.5%), meaning that 75 cameras confirmed the presence of a marten out of 120 cameras placed within home ranges from September 2018 to September 2019. Winter detection probabilities were 43/63 (68.25%) across all regions; summer detection probabilities were 32/57 (56.14%). Winter and summer detection did not differ statistically [χ^2 (df = 1, n = 57 summer, n = 63 winter) = 1.874, p = 0.171); Table 3]; however, camera locations chosen based on observed microsite characteristics had higher detection than randomly-selected locations [χ^2 (df = 1, n = 94 chosen, n = 26 random) = 8.183, p = 0.004]. Researcher-selected camera locations that were chosen based on microsite features revealed a detection probability of 65/94 (69.15%), whereas camera locations that were randomly selected had a smaller detection probability of 10/26 (38.46%) (Table 3). Cameras set within the core (50% interval) of a marten's range had a detection probability of 57/87 (65.52%). Cameras set within a home range (95% interval) but not in the core (50% interval) detected a marten 18/33 (54.55%); however, there was no statistical difference in detection between these variables [χ^2 (df = 1, n = 87 in the core, n = 33 in the 95% interval) = 1.229, p = 0.268] (Table 3).

Individual and regional detection probabilities varied as well (Tables 4, 5). In areas where more than one marten's home ranges overlapped, the resulting detection probabilities ranged from the lowest to the highest possible detection probability for each individual (Table 4). For example, since I was unable to identify individual marten, I had to assume that every detection was of the same marten, and that every capture event was of a different marten, giving me a range from the lowest to highest possible probability (ex., 1/28 or 9/28 (061M)). The highest detection probabilities throughout the five regions were found in Ward Hills (14/17, 82.35%) and in Olga (41/52, 78.85%). The lowest detection probabilities across these regions were found in Harrietta (9/28, 32.14%) and Pine River (7/17, 41.18%). More cameras were placed in Olga and Harrietta than Ward, Pine, and Caberfae due to the number of individuals captured and collared in these regions (Table 5).

The linear regression used to analyze the relationship between detection probability and home range size revealed a weak negative correlation between variables (Figure 2). As home range sizes increased, detection probability decreased, but this relationship explained only 34% of the variation in the data (r^2=0.3406).

Finally, the additional backwards-facing camera was found to increase the detection probability on three camera sets (3/26), meaning that there were three instances in which a marten would not have been detected had the additional camera not been deployed. The additional camera was only determined to have increased the detection probability if the camera facing the bait and lure did not capture a picture of a marten, but the additional camera did.

Discussion

Motion-triggered cameras are useful for detecting and monitoring wildlife (Shannon, G., Lewis, J.S., Gerber, B.D., 2014) and are being used with increasing regularity (Burton et. al., 2015). However, cameras do not detect species presence with absolute certainty. My study has shown that if marten detection and occupancy was determined using only camera data, I would have concluded that no marten were present 38% of the time. The overall detection probability of 0.63 was lower than expected, especially considering camera placement within known occupied home ranges. Even in regions with small home range sizes and relatively high marten abundance (i.e., Olga), detection probability was comparatively low (Table 5) relative to other studies. Zielinski et. al. (2015) found detection probabilities varied seasonally from 0.83 to 0.95 in California, and Smith et. al. (2007) found detection rates of 0.952 in regions with high marten density in South Dakota.

Several factors may have affected the detectability of marten in this study area. One of which could have been related to methodology. In previously mentioned studies with higher detection probabilities, detection techniques and methods were more thorough. For example, Smith et. al. (2007) checked and rebaited track-plates every 4 days. Zielinski et. al. (2015) checked track-stations every 2—3 days, and camera sites every 2—8 days. I set cameras out for 4 weeks and left them until the 28-day period was over. I did not rebait sites or check cameras during that 28-day period. Admittedly, there may be differences in detection probabilities due to detection technique (e.g. track-plates, cameras), but ensuring that each site had bait and lure present would have seemingly increased my detection probability. While it was not feasible to check camera sites with this regularity, my methodology could, in part, explain the lower overall detection probability.

Additionally, marten in my study site may have developed a bait aversion. Throughout the study, and previous studies conducted in this region, I used similar scent lures, and often the same bait. Meso-carnivores and mustelids have been shown to exhibit learning behaviors when exposed to a previously negative stimulus (Conover 1990). Therefore, marten may remember their previous encounter with that scent and bait and may not want to approach the bait again. Evidence for this hypothesis was present during the study, as there was an increase (+11.54%) in detection probability when a backwards-facing camera was present. It would appear as though the marten were still interested in the bait, but upon arriving at the source, approached cautiously from behind without approaching the bait or lure in front of the original camera.

A third factor potentially affecting marten detection was the presence of interspecific competition. The bait and lure were frequently stolen or disturbed by other predators. Black bear (*Ursus americanus*), Northern raccoon (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), and even barred owl (*Strix varia*), were all observed removing or disturbing the bait and lure. The negative impact of non-target species on camera studies has been documented previously (Kreplins et al., 2018), and this study was no exception. Additionally, black bear, bobcat, coyote, and opossum were observed rolling in the scent lure, a common behavior in predators known as scent rubbing (Reiger, 1979). Logically, if a bait and lure are removed, or potentially replaced by the scent of a larger predator, a marten detection would be less likely. This is again tied to the methodology, as I did not replace the bait or lure during our 4-week survey period.

A final explanation for low marten detection is that the marten simply did not detect the scent of the lure and bait during the 4-week period. This study did not investigate how marten moved across the landscape, or how they used different areas of their home ranges throughout the year. VHF collars allowed me to approximate their home ranges at a course scale, but they did not allow me to determine how they moved across their habitat at a fine scale. The importance of microsite features in marten habitat selection has been well documented (Vigeant-Langlois & Desrochers, 2011; Dumyahn, Zollner, & Gilbert, 2007; Powell et al., 2003; Bull & Heater, 2000); however, marten may not cover their home range in its entirety during a 4-week period, and there may be certain landscape or habitat features that are used more frequently in this study area. It has been shown previously that regions of a martens' home range are used more frequently than others (Dumyahn, Zollner, & Gilbert, 2007; Gosse, Cox, & Avery, 2005; Payer and Harrison 2003), but those high-use areas likely vary regionally. For example, while Payer and Harrison (2003) concluded that high-use areas contained more late successional forest, Porter, St Clair, & Vries, (2005) and Poole et al., (2004) have revealed that marten are able to use earlier successional forests as well. Therefore, frequently used forest types and microsite features within the martens' home ranges of my study are probably site-specific. Some of our cameras may have been placed in a low-use portion of a home range, consequently resulting in low detection probability. While research in this region has quantified marten use of microsite features during resting periods (Sanders et al., 2017), the movements of marten during active and foraging periods must be determined in future studies.

Detection probabilities were likely influenced by a combination of all four factors mentioned above. In most cases, camera evidence revealed factors influencing detection; however, in some cases it was not possible to tell. For instance, some cameras did not record which species (marten or non-target) removed the bait or took very few pictures during the 4-week period yet were found to be on and working at the end of that survey period. This is not the first camera study to describe this phenomenon (Kreplins et al., 2018). These cameras were included in our overall detection probability; but cameras that were malfunctioning, destroyed, or found with dead batteries were excluded from the overall detection probability. As the goal of the study was to answer a binary question, (detection, yes or no), details regarding the species that removed the bait, and on whether the bait was left at the end of each 4-week period, were often not recorded. However, of the 45 cameras recorded as a 'no', at least 6 cameras took few pictures and did not photograph which species removed the bait, and in at least 6 other locations, the bait was stolen by a non-target species.

Seasonal Detection Probability

Detection probabilities were found to be higher in the winter than during summer, a result that was consistent with similar research conducted in California (Zielinski et al., 2015). This result could be attributed to several factors. First, this result may be due to the fact that marten during the summer have a greater abundance and diversity of food options and may not be as likely to visit a bait site. A marten's diet varies seasonally. Marten during the summer and fall months eat more insects, fish, young birds and mammals, berries, and fruits (Buskirk and Ruggeiro, 1994). As these resources are seasonally limited, the marten's winter diet changes, and is comprised mostly of rodents and lagomorphs (Buskirk and Ruggeiro, 1994). With fewer options during the winter, marten become strictly carnivorous, and perhaps bolder. This combination may have made the marten more likely to approach bait sites.

Another possible explanation for this seasonal trend in marten detection probability was interspecific competition. The presence of other carnivores likely impacted seasonal detection probabilities. For example, two species that were frequently observed disturbing the bait and lure, the black bear and northern raccoon, reduce their activity considerably during the winter (Tøien, Øivind, et al., 2011; Zeveloff, S. I., 2002). With reduced activity from the marten's competitors, the bait and lure were removed or bothered less frequently. Marten were still occasionally detected after the bait was removed, but likely only if some of the scent from the bait or lure remained.

Factors within seasons affected the functionality of cameras, which may have influenced detection probabilities as well. During the winter, the batteries in the cameras seemed to die much quicker than during the summer, resulting in the data from some cameras being discarded as inconclusive and unusable. If the batteries were found dead at the end of a 4-week period, and the camera did not yet detect the presence of a marten, I assumed the camera was not able to take photos throughout the entire survey period. Occasional extremes in snow depth and blizzard conditions reduced the likelihood of cameras conclusively detecting a marten as well. Summer conditions were also challenging. Thick vegetation often obscured the view of the cameras. Vegetation was cleared before the cameras were set, but the actual frame of view was hard to estimate, and vegetation grew back quickly.

It should also be noted that during July and August of 2019, cameras were placed at randomly generated points. These points were occasionally on the edges of the estimated home ranges and could not always be placed near microsite features, which may have had an influence on seasonal detection probability; however, these data were useful in determining detection probability differences in researcher-selected vs. random locations.

Habitat composition and detection probability

Marten in coniferous forest or mixed forest were detected more frequently than those in deciduous regions. Marten in regions such as Ward and Olga, habitats dominated by pine or mixed habitat, had higher overall detection probabilities (82.35%, 78.85%) than those in Harrietta and Caberfae (32.14%, 66.67%), which was dominated by deciduous forest (Table 5). There are two possible explanations for these results. First, average home ranges in deciduous regions were much larger than the average home range size in coniferous or mixed habitat (Table 1,2). In theory, an animal in a smaller home range would be more likely to cover that range more thoroughly, and therefore more likely to detect the bait. The two individuals with the largest home ranges showed the lowest detection probability (061M and 541F) (Table 4). The second explanation is tied more to the overall diversity of the two habitats. The coniferous-dominated region (Olga, Table 1) was comprised almost entirely of regenerating red pine. Plantations such as this are widely known for their lack of diversity in relation to native, undisturbed forest (Hartley, 2002, review of Freedman et. al., 1996 and Friend, 1982). In contrast, the deciduous-dominated study sites (Harrietta and Caberfae, Table 1) contained a diverse assortment of tree species, greater elevation changes, a thick overhead canopy and a diverse understory. A fundamental principal of community ecology is that greater diversity of resources creates a trophic cascade throughout the ecosystem, leading to greater overall species diversity (Whittaker, 1972). More specifically and locally, small mammal capture rates in the Northern lower peninsula have been to be shown higher in areas with greater deciduous tree presence (Haskins et al., 2020). Therefore, it is possible that the marten in deciduous forest had greater resource availability, and therefore were less likely to respond to a baited camera. In red pine stands, however, food options were likely restricted, and the marten may be more willing to approach the bait and lure. Large home range sizes in Harrietta and Caberfae, in combination with presumably higher resource availability, may explain the disparity in detection probabilities between these regions and the Olga and Ward Hills study sites.

The exception here was the individual in the Pine River region (225F). This site contained a low, open, scrubby canopy, and consisted largely of jack pine and oak. Despite this mixed habitat, and a small home range, detection probabilities for this individual were low (Table 4, 5). This may be due in part to abundant small mammal populations and greater habitat diversity in this region compared to those in primarily coniferous regions. Haskins et. al. (2020) found a negative correlation between basal area and small mammal abundancies in the Manistee National Forest, so it is possible that this semi-open habitat had a high diversity of prey available.

Camera set-up and detection probability

My study has further emphasized the importance of camera locations and microsite features in detecting American marten. Cameras set within the core areas of a marten's home range detected a marten with greater regularity than those set in the home range but outside of the core (+10.97%)(Table 2). Despite a weak correlation, this result again suggests that marten value certain regions of their home range as more important than others, a result that has also been shown in Northern Wisconsin (Dumyahn, Zollner, & Gilbert, 2007). I should note, however, that there was no significant difference between these data likely due to small sample sizes and a difference in the sample sizes of cameras inside and outside of the core (in core, n=87, outside core, n=33). Despite these differences, this correlation suggests that the proximity of a camera to the core of the home range and the presence of microsite features played a significant role in determining the likelihood of detecting the martens' presence.

Camera locations that were chosen based on the presence of microsite features showed a significantly higher detection probability (+30.96%) than those set in randomly generated locations throughout the home range (Table 3). This contradicted my hypothesis, as I expected any camera located in the marten’s home range to have approximately the same probability of detection. Randomly generated points were occasionally on the edges of the marten’s home range and were not always located in the presence of microsite features such as downed woody debris, however, and the importance of those features is well known (Vigeant-Langlois & Desrochers, 2011; Dumyahn, Zollner, & Gilbert, 2007; Powell et al., 2003; Bull & Heater, 2000) These cameras also may have been set in areas of low marten use, as marten do not use all portions of their home range equally (Dumyahn, Zollner, & Gilbert, 2007; Gosse, Cox, & Avery 2005; Payer and Harrison, 2003).

Additional Camera and Detection Probability

The additional camera facing directly away from the lure was found to increase the detection probability by a total of 11.54% during two separate 4-week surveys. The additional camera increased the detection probability by detecting marten at three sites that the forward-facing camera did not, therefore increasing the detection probability from 0.385 to 0.5 at bait sites set with a backwards-facing camera. Adding additional cameras to a site has been shown to increase detection probability of several mammals, including marten, in Maine (Evans, Mosby, & Mortelliti, 2019), and these results confirmed this is the case in this region as well.

Conservation Recommendations and Future Direction

It is clear that there are many factors that impact the detection probability of the American marten in this region, but the overall takeaway for future surveys and research being done in this region is that a non-detection should not always be associated with the absence of an American marten. Intense camera monitoring is needed to properly estimate marten abundances as well as marten presence or absence. The research conducted during this study can be used to increase detection rates and inform future camera results as well.

After testing and analyzing the impacts of season and camera placement on marten detections, I recommend a combination of techniques to increase detection probability. I suggest that cameras should be placed in the winter, with one camera facing forward at the bait and one facing backward. Cameras should be checked once a week, if feasible, during the 4-week period to reset the bait, reapply lure, and change the batteries in each camera. Managers should always set cameras in areas that contain the presence of microsite features such as coarse woody debris and large-diameter trees that contain nests or cavities, instead of placing them randomly across a landscape. Cameras should be set in high density, when feasible. Smith et. al. (2007) used suggestions from Otis et al. (1978) regarding trap density (4 or more per home range) and I recommend those guidelines be used in our region with camera traps. Therefore, in our study area, I would recommend that at least 4 motion-triggered cameras be placed per 326.6 ha, as this was the smallest home range recorded (Table 2). Higher saturation of cameras across a landscape will increase the probability of a camera being placed in the core area of an individual home range, which will likely increase detectability. The type of bait and lure can vary, assuming they have been found effective in the marten literature, and managers should choose those that are the most cost-effective. Additionally, I recommend a mixture of baits and lures, especially if the marten was captured, handled, and released. These novel scents and baits may prevent bait-shyness due to a previously negative encounter. This combination of techniques will help managers detect marten more frequently and reliably.

As for marten research in the northern Lower Peninsula, the next logical step is to increase the frequency with which marten locations are recorded. With the VHF collars used in this study, I was unable to determine where marten foraged, when they foraged, how far they traveled, and what habitat types they used outside of the resting site locations. Research has already begun re-capturing and re-collaring the marten in this study area and GPS collars with a high fix rate are being employed. The data collected during this next phase of the marten study will not only provide vital information regarding marten behavior in this region but may also provide information that will fill in some gaps in this current study, including how they move across the landscape and how long it takes each individual to encompass its entire home range. It is not yet known how much of their home range they actually cover during a 4-week period, or how often they venture outside of their calculated home range, and a high fix rate on GPS collars will likely provide answers to those questions. Once future research reveals how marten use different features across their home range, researchers will be able to detect and trap marten with greater frequency. This, in turn, could lead to the discovery of new populations and provide information on the habitat and landscape features managers need to preserve for the long-term sustainability of the American marten in Michigan's Lower Peninsula.

Chapter 3 - Appendix and Extended Literature Review

Appendix

Trapping, telemetry and home ranges

Throughout the duration of this study, my trapping success rates were low due to a combination of factors. As previously mentioned, the population I was studying was reintroduced in the mid 1980's (Williams, 2007, Ludwig, 1986), the study area was highly fragmented due to urbanization and logging, and it is assumed that populations persist in low densities across the region. Therefore, finding suitable habitat in large enough patches was a challenge, and with low population numbers, finding a patch with a marten present was even harder. Additionally, I lost many trap nights due to non-target captures or non-target disturbances at the traps. Traps were often turned over, closed, moved and occasionally smashed from non-target species. Black bear, northern raccoon, Virginia opossum, bobcat, and coyote were the most probable non-target species as they were observed frequently disturbing baited camera sites throughout the study. Trapping success was higher in the winter, and this is likely due to the fact that non-target species were less active.

Radio telemetry data revealed that marten remained in well-defined home ranges throughout the year (Figures 3–13). This finding is consistent with other research claiming that home range sizes do not differ significantly throughout the seasons (Godbout and Ouellet, 2008; Chapin et. al., 1997), but that behavioral differences are attributed more to small scale use of the habitat (Phillips et. al., 1998; Chapin et al., 1997), such as differences in preferred resting sites (Sanders et al., 2017; Spencer, 1987). Because of this result, I combined telemetry data from the summer and winter months into one home range, even though winter locations were recorded less frequently than summer locations. Also, it is important to note that home ranges may not have encompassed the entirety of each marten's actual home range, as I calculated territories based predominantly on resting site locations. To account for this potential error, I used a fixed kernel method of home range estimation that would extend our home range boundaries slightly beyond the actual marten's location. Though it is impossible to determine exactly how far marten may have travelled between rest site recordings, this method allowed me to estimate home ranges with enough accuracy to ensure that cameras were always placed within a known individuals' home range.

Home range sizes vary regionally (Gehring et al., 2019; Smith & Schaefer, 2002; Bull and Heater, 2001; Wynne and Sherburne, 1984), and home ranges in this study were consistent with other research conducted in the northern lower peninsula (Gehring et al., 2019; Watkins, 2012; McFadden, 2007). Home range sizes were also found to correlate with habitat composition. The home ranges of marten that contained predominantly deciduous forest were much larger than those in coniferous or mixed forest. Average home ranges in deciduous forests were 1,845.3 ha (18.45km^2), while average home ranges in mixed or predominantly coniferous forest were 563.84 ha (5.64km^2). However, I cannot say with certainty that the differences in home range size were directly correlated with habitat type or sex due to the behavior of one individual during this study. A young male (061M) was found to occupy an area notably larger than the other marten (Table 2). This individual may have still been establishing a home territory, and marten have been shown to disperse great distances during home range establishment (Bull & Heater, 2001). The exact reason for this behavior, however, remains somewhat unknown as dispersal is an understudied part of marten life history (Broquet et al., 2006). Regardless, the home ranges for males, including the young male were 1,400.6 ha (14.01km^2), while male ranges excluding 061M averaged 673.9 ha (6.74km^2). When 061M is excluded, average male home ranges were smaller than the average females home ranges, 688.2 ha (6.88km^2). This result is not common throughout marten literature but has been observed before when outliers such as this have occurred (Godbout & Ouellet, 2008). Other research from our region (northern lower peninsula) found that males had home ranges that were much larger. For example, McFadden (2007) found that average male home ranges (1,123 ha (11.23km^2)) were larger than female home ranges (770 ha (7.70km^2)) (Watkins, 2012). Only with 061M included were the home ranges consistent with other research from the area. Because of that, I included the entire region in which 061M occupied as part of our home ranges and detection probability study.

Additionally, 061M occupied a region dominated by deciduous forest, which skewed my results there as well. With 061 excluded, the average home range size for marten occupying predominantly deciduous regions dropped from 1,845.3 ha (18.45km^2) to 977.7 ha (9.78km^2). This is still more than 400 ha (4.0km^2) larger than the home ranges of marten in mixed or coniferous regions (Table 1, 2). Unfortunately, with a small sample size, the impacts of outliers such as 061 are magnified. Overall, the purpose of this study was detection probability, and not on differences in home range characteristics due to season, sex, or age. It should be noted, however, that the movements and behavior of this one male could have impacted the overall detection probability of the marten in this study.

Bait and Lure

My results showed that there was no significant difference in detection probability based on bait or lure type, allowing me to lump all camera data together. Because the literature contains many examples of different bait and lure combinations that were found to be effective attractants for the American marten (Sirén et al., 2016; Zielinski et al., 2015; Flynn and Schumacher, 2009; Dumyahn et al., 2007; Poole et al., 2004), I was not surprised that there was no difference in detection probabilities due to bait or lure types.

Extended Literature Review

To accurately model the current and future health of a population and their habitat, researchers must realize that the lack of a species presence does not mean it is truly absent (MacKenzie, 2005). As mentioned previously, there are a great variety of both invasive and non-invasive techniques that biologists use in an attempt to confirm the existence of a species with the greatest possible consistency (Long et al., 2007; O'Connell et al., 2006; Zielinski & Kucera, 1995). The efficacy of a survey method, however, has been known to vary due to species, geographic region, and season. For example, hair snares in Vermont were shown as an effective detection technique for black bear but were completely ineffective at detecting fisher (*Martes pennanti*) and bobcat (Long et al., 2007). A similar study in Michigan's Upper Peninsula, however, found that hair snares were useful to not only detect the presence of bobcat, but also to estimate the number of individuals in that region (Stricker et al., 2012). Additionally, detection probabilities have been shown to vary seasonally, but variations among and between species were not consistent, i.e., there was no season in which detection probabilities were high for all species (O'Connell et al., 2006). These regional, seasonal, and species-specific disparities in detectability emphasize the importance of comprehensive detection probability studies.

Some organisms inherently influence their surroundings more drastically than others, and wildlife surveys should primarily focus on the conservation of those species. Members of the order Carnivora, for example, are believed to have a disproportionally large impact on the processes and function of an ecosystem (Estes et al., 1998; Gompper et al., 2006; Post et al., 1999; Ray et al., 2013; Terborgh et al., 1999), and are often referred to as indicators of the health of a community’s trophic levels (Zielinski & Kucera, 1995). Surveying for carnivore populations can present several challenges, as they are relatively rare and wary (Gompper et al., 2006), often occur in low densities, and occupy large home ranges (Long et al., 2007). Despite these difficulties, biologists should emphasize the protection of members of the carnivore family, as even small predators are believed to play crucial roles in maintaining ecosystem health (Gittleman & Gompper, 2005; Gompper et al., 2006; Jędrzejewska & Jędrzejewski, 1998; Korpimaki & Norrdahl, 1998).

The American marten (*Martes americana*) is a small carnivore in the mustelid family whose survival is ecologically, economically, and culturally important. As they are also a species of concern, marten conservation is a primary focus to wildlife managers and biologist across their range. Marten range from the Atlantic to the Pacific coast of the northern United States and most of Canada (Powell, Buskirk, & Zielinski, 2003). Marten are often associated with mature forests but have been shown capable of adapting to a variety of stand ages (Vigeant-Langlois & Desrochers, 2011, Porter, St Clair, & Vries, 2005, Poole et al., 2004). At a finer scale, marten utilize portions of their home ranges in different ways (Dumyahn, Zollner, & Gilbert, 2007; Gosse, Cox, & Avery, 2005; Payer & Harrison, 2003), and habitat preferences vary regionally. For example, marten in Quebec were found to prefer deciduous or mixed habitat over coniferous during the winter (Potvin, Belanger, & Lowell, 2000), but Mowat (2006) found that marten during the winter in British Columbia preferred coniferous stands instead of deciduous. Marten have been shown to use different portions of their habitat due to seasonal differences as well. In Michigan, Sanders et. al. (2017) found that martens preferred resting sites varied with season, as marten chose cavities more frequently during the winter, and more open branches during the summer. Regional habitat preferences and fine scale site selection is likely driven by climate, as marten have low overall body fat (Buskirk & Harlow, 1989; Cobb, 2002) and relatively inefficient pelage (Buskirk et. al., 1988; Powell, Buskirk, & Zielinski, 2003).

These differences in marten behavior and activity across their geographic range suggest that detection probabilities will vary from one study site to the next. This literature also further emphasizes the importance of testing and validating a detection technique in a known home range in order to validate the results of future wildlife surveys (Zielinski & Kucera, 1995).

Table 1: Land cover types present within the home range of each marten, separated by individual and by location. Land cover data was analyzed in ArcGIS (Ver. 10.4). Any land cover that composed less than 0.05% was not included in this figure. Developed land cover included areas of high, medium, and low levels of development. Roads comprised the majority of developed areas.

		Land Cover Type									
Location	**ID #**	Developed	Deciduous Forest	Evergreen Forest	Mixed Forest	Shrub/ Scrub	Herbaceous	Woody Wetlands	Cultivated Crops/Hay/ Pasture	Emergent Herbaceous Wetlands	Open Water
Harrietta	541F	3.6%	89.3%	4.8%	1.4%	0.6%	0.3%	0.0%	0.0%	0.0%	0.0%
	061M	3.8%	86.9%	4.1%	1.1%	0.9%	2.5%	0.1%	0.6%	0.0%	0.0%
Olga	413F	5.6%	3.8%	84.9%	5.2%	0.2%	0.0%	0.3%	0.0%	0.0%	0.0%
	100M	4.8%	5.8%	82.4%	6.6%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%
	057M	7.2%	3.9%	85.5%	1.8%	0.0%	0.1%	1.1%	0.0%	0.1%	0.3%
Caberfae	767M	4.5%	79.0%	11.7%	3.0%	0.8%	0.1%	1.0%	0.0%	0.0%	0.0%
Pine River	225F	5.1%	23.7%	42.4%	14.9%	10.0%	4.0%	0.0%	0.0%	0.0%	0.0%
Ward Hills	722F	2.8%	46.1%	40.2%	10.1%	0.6%	0.2%	0.0%	0.0%	0.0%	0.0%

Table 2: American marten home ranges, generated using ArcGIS (Ver. 10.4).

Marten ID	Sex	Location	Total Telemetry Points	Summer Points (Apr-Sep)	Winter Points (Oct-Mar)	50% Probability Contour (ha)	95% Probability Contour (ha)
057	M	Olga	30	19	11	172.7	561.3
413	F	Olga	40	33	7	274.5	866.3
100	M	Olga	40	33	7	222.0	607.3
767	M	Caberfae	31	26	5	408.4	853.1
181	M	Caberfae	9*	1**	8	689.5	2044.5
061	M	Harrietta	34	21	13	1280.9	3580.5
541	F	Harrietta	34	22	12	438.1	1102.3
722	F	Ward Hills	39	32	7	103.7	326.6
225	F	Pine River	32	22	10	171.9	457.7

*Marten mortality limited number of points collected. **Only summer point was taken at site of mortality.

Table 3: Overall detection probability of American marten and comparisons between variables based on Pearson's Chi-square test (α = 0.05). All cameras were placed within the 95% fixed kernel home range. Locations in the 50% isopleth were the number of detections from the total number of cameras placed within the 'core' of the marten's home range. Locations in the 95% interval are restricted to those in the home range, but not in the core.

Camera Setup	# of Detections	Expected Detections	# of Cameras	Probability	Chi-square statistic	P-Value
Summer	32	35.62	57	56.14%	1.8736	0.171
Winter	43	39.38	63	68.25%		
Chosen Locations*	65	58.75	94	69.15%	8.1833	0.004
Random Locations**	10	16.25	26	38.46%		
Locations in 50%	57	54.38	87	65.52%	1.2288	0.267
Locations in 95%	18	20.62	33	54.55%		
Pork/Gusto	48	44.38	71	67.61%	1.9339	0.164
Other Bait/Lures	27	30.62	49	55.10%		
Total cameras	75		120	62.50%		

*Researcher-selected sites chosen by the presence of microsite features. **Locations selected at randomly generated points; microsite features used if available. If no microsite features were available, or if random point was placed in an opening, a location was chosen within 30m of the randomly generated point, using whatever features were available.

Table 4: Detection probability of each marten in the core of their range, and in their home range but outside the 50% core interval. Probabilities were calculated by taking the total number of detections from the total number of cameras. Probabilities from individuals with overlapping ranges were calculated as a range. It was assumed that either all detections were of the target marten, or that none of the detections were of the target marten. Cameras locations consisted of cameras deployed for four weeks.

		Detections			**Camera Locations**			
ID #	**Sex**	**In Core**	**Outside Core**	**Total**	**In Core**	**Outside Core**	**Total**	**Probability**
722	F	11	3	14	13	4	17	82.35%
225	F	5	2	7	11	6	17	41.18%
767	M	2	2	4	4	2	6	66.67%
057	M	0-18	0-15	33	19	22	41	0-80.49%
100	M	0-13	0-14	27	15	17	32	0-84.38%
413	F	0-23	18	41	26	25	51	0-80.39%
061	M	1-9	0	9	22	6	28	3.57%-32.14%
541	F	0-6	0-2	8	19	8	27	0-29.63%

Table 5: Detection probability based on region in the northern Manistee National Forest. Winter was determined as Oct—March; summer as April—Sep. On three occasions, the four-week period for a camera was set in both seasons (e.g., from Sep – Oct or Mar – Apr). In these instances, detections were assigned to the season in which the marten was first detected (i.e., a camera set in mid-Sep detects a marten on Oct 1, that detection was assigned to winter).

Region	**# of Marten**	**Winter Detections**	**# of Winter Cameras**	**Summer Detections**	**# of Summer Cameras**	**Total DP**
Olga	3	23	26	18	26	78.85%
Harrietta	2	5	16	4	12	32.14%
Ward	1	7	8	7	9	82.35%
Pine	1	6	10	1	7	41.18%
Caberfae	1	1	1	3	5	66.67%

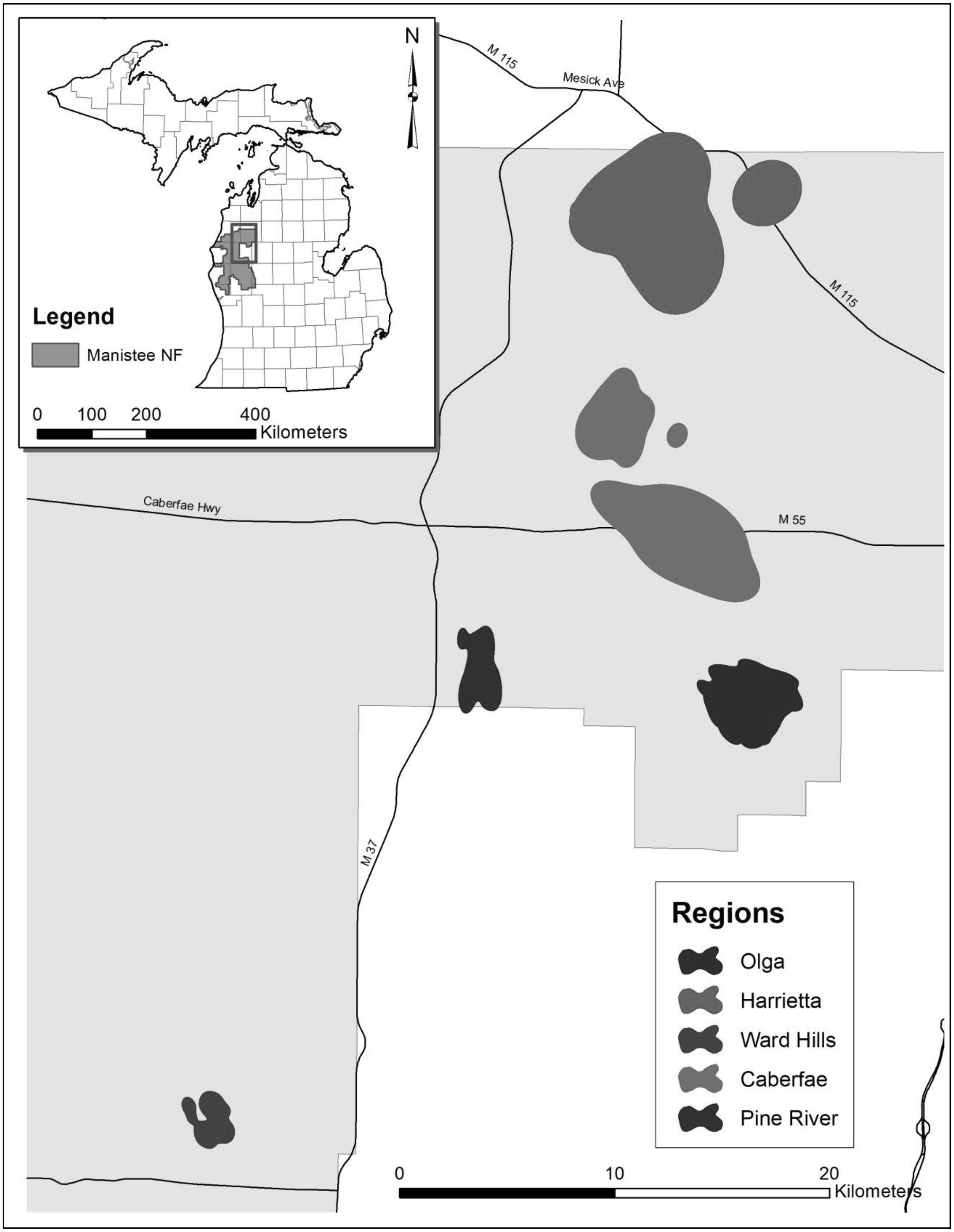

Figure 1. Locations of regions in which marten were trapped and tracked in the Northern Manistee National Forest of Michigan, U.S.A.

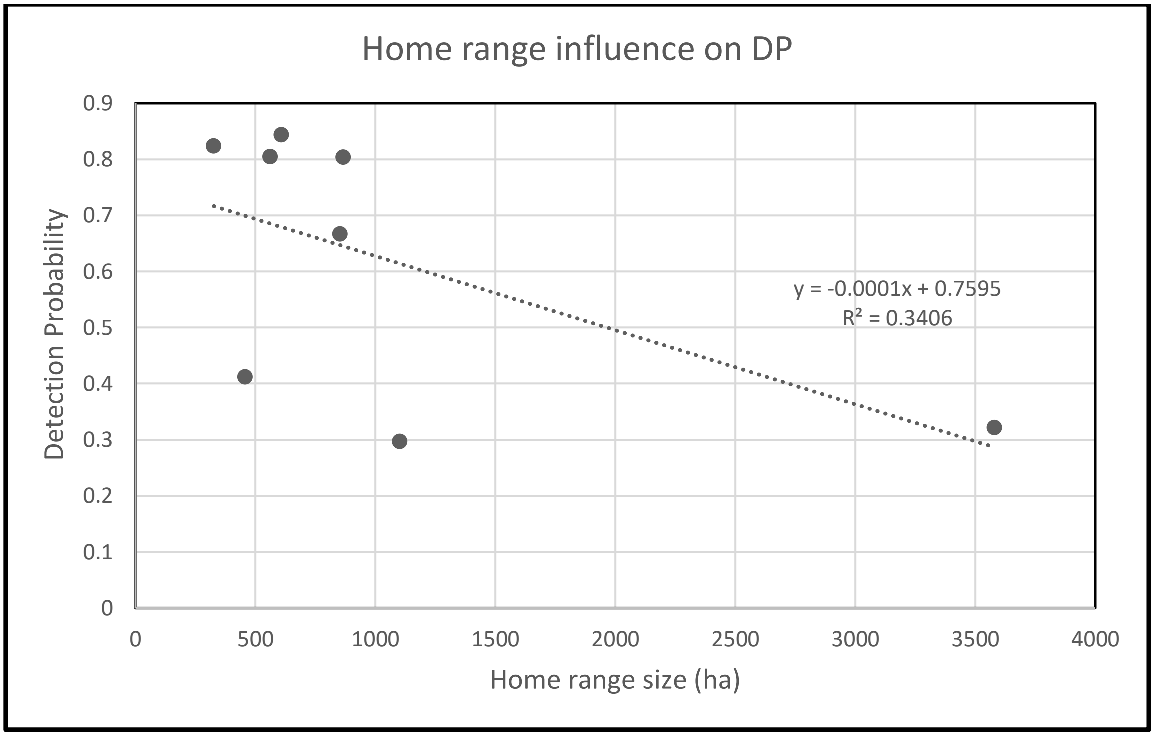

Figure 2. The influence of home range size on the detection probability of the American marten.

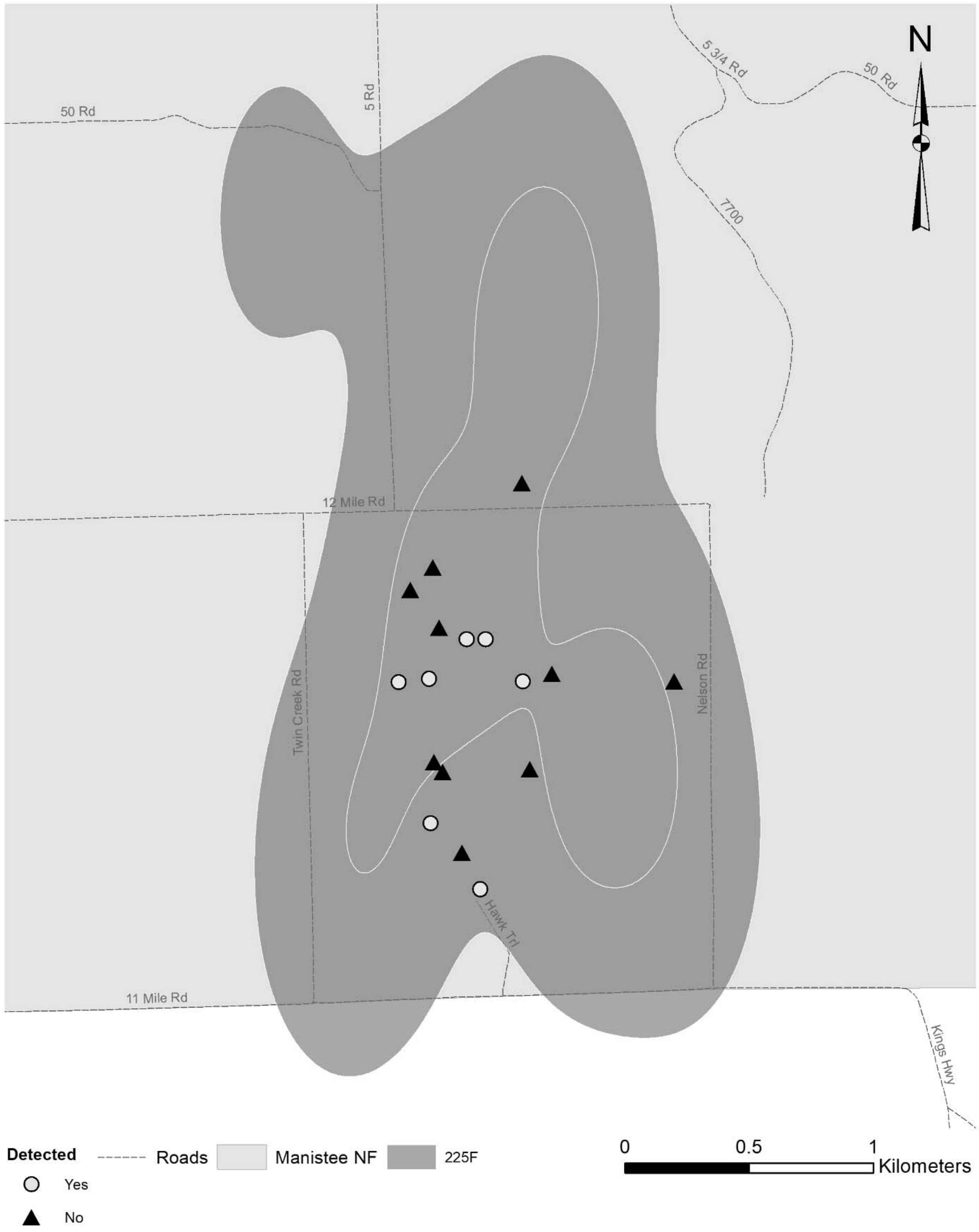

Figure 3. Camera locations and results within the home range of 225F in the Pine River region.

Figure 4. Camera locations and results within the home range of 722F in the Ward Hills region.

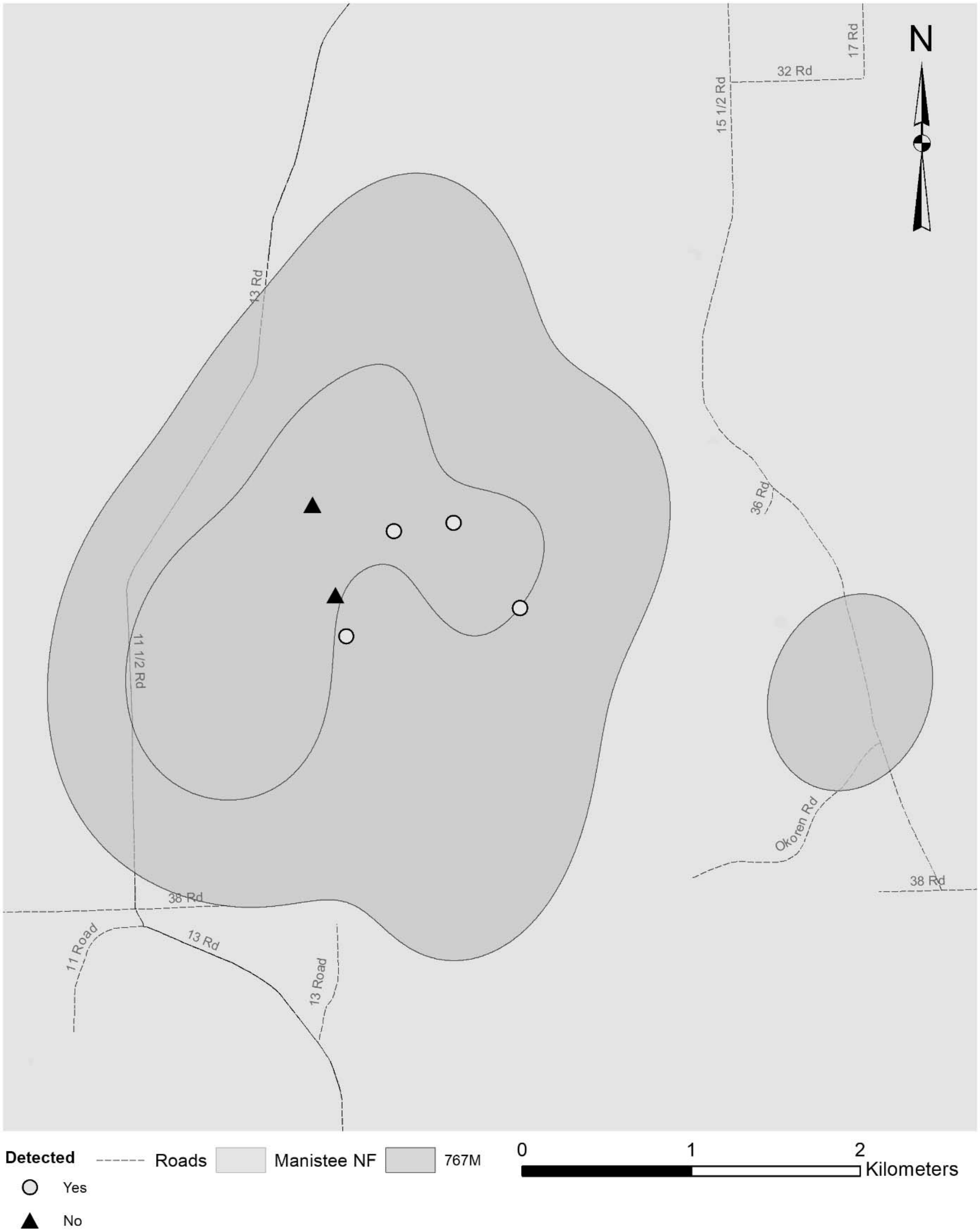

Figure 5. Camera locations and results within the home range of 767M in the Caberfae region.

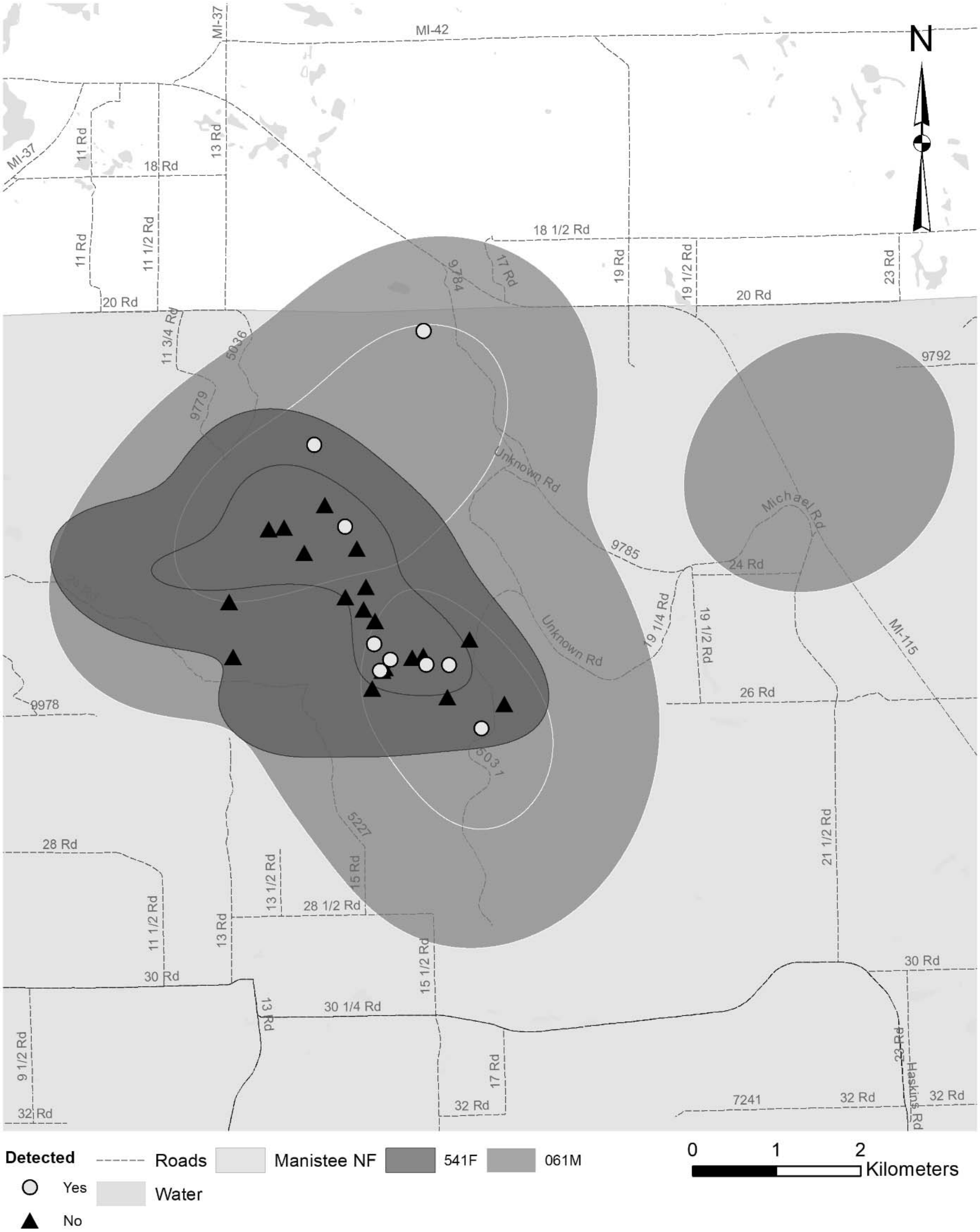

Figure 6. Camera locations and results within the home ranges of 541F and 061M in the Harrietta region.

Figure 7. Camera locations and results within the home ranges of 100M, 413F, and 057M in the Olga Lake region.

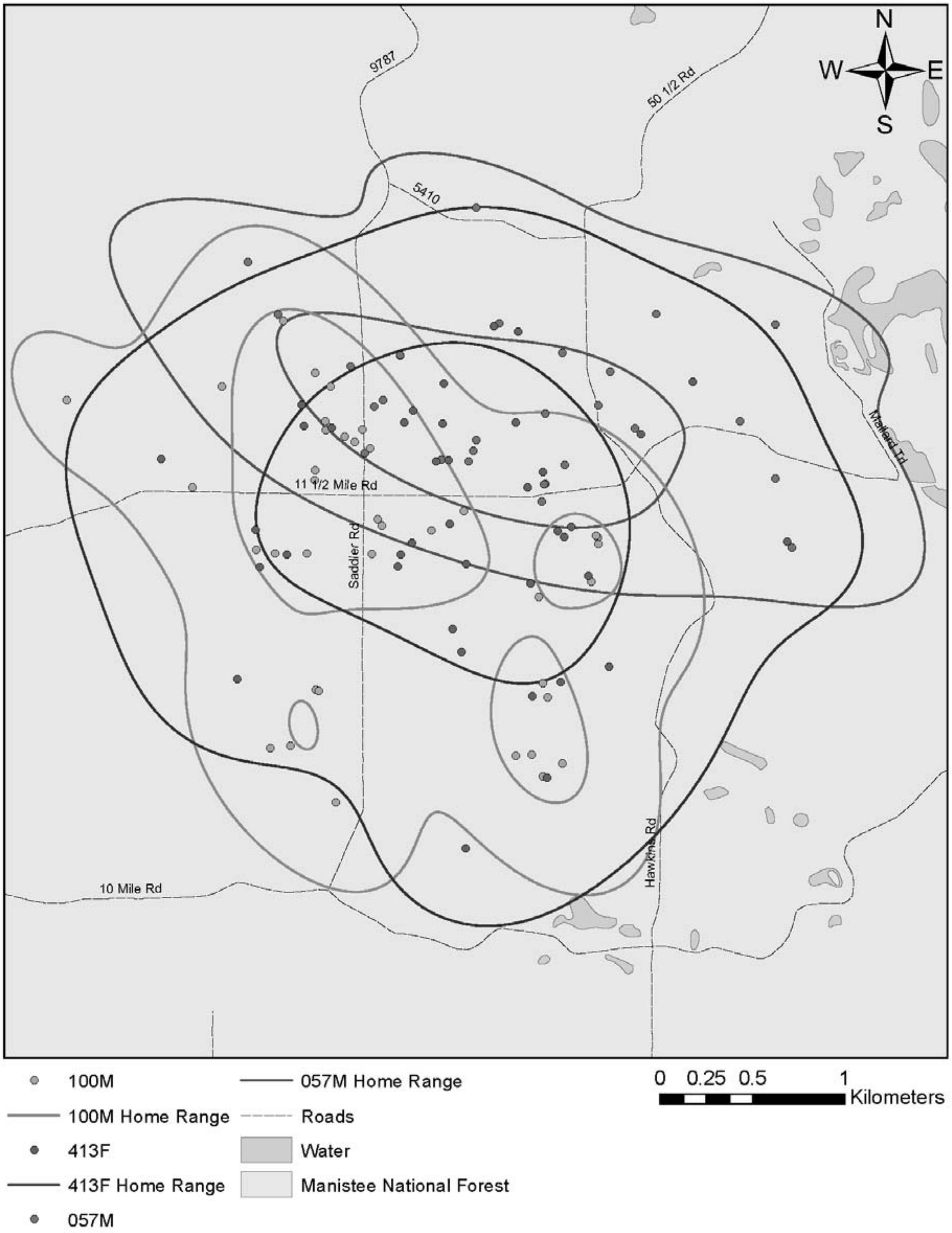

Figure 8. Telemetry locations recorded for 100M, 413F, and 057M in the Olga Lake region. Home range boundaries (50% and 95% interval) using fixed kernel estimations are included.

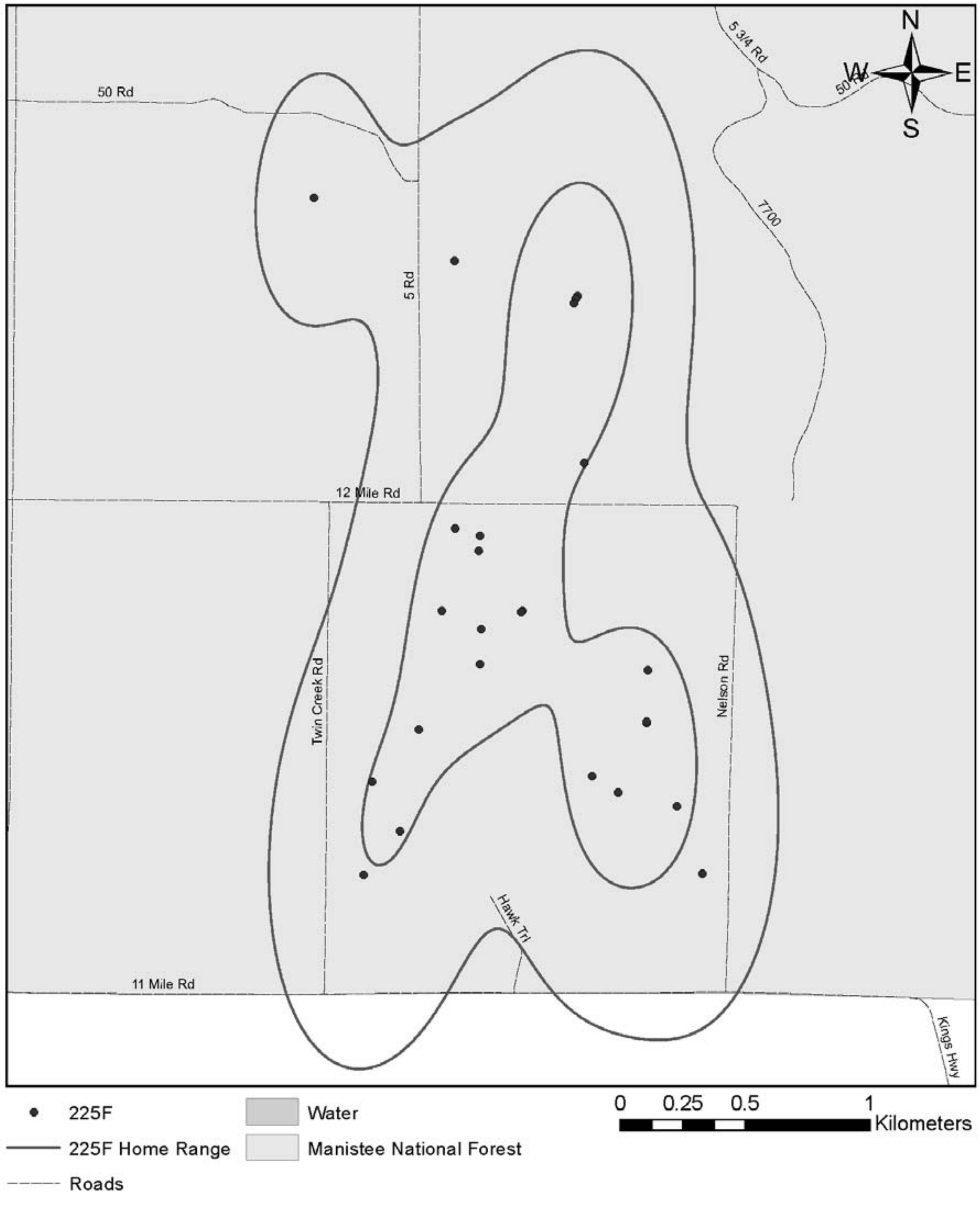

Figure 9. Telemetry locations recorded for 225F in the Pine River region. Home range boundaries (50% and 95% interval) using fixed kernel estimations are included.

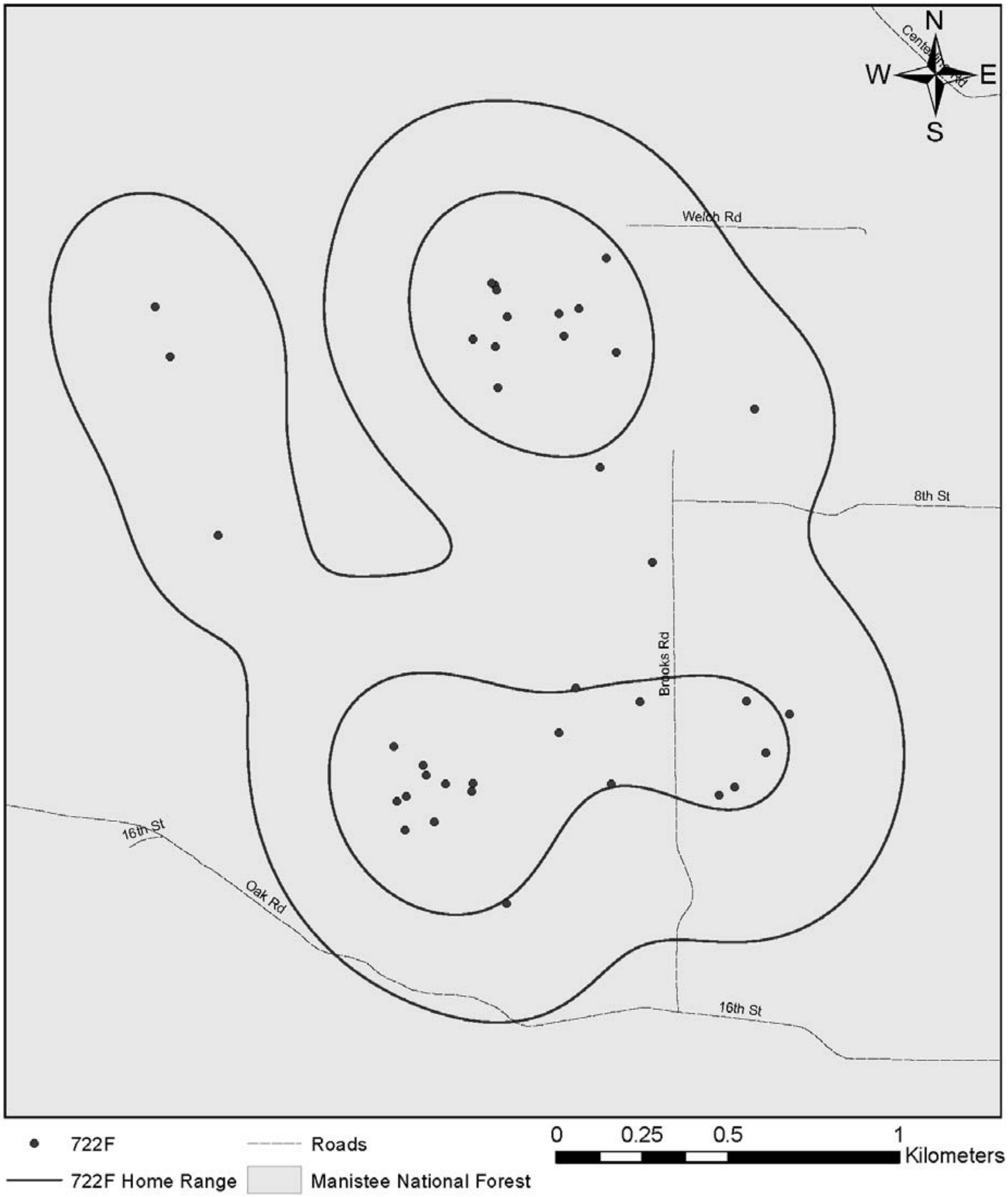

Figure 10. Telemetry locations recorded for 722F in the Ward Hills region. Home range boundaries (50% and 95% interval) using fixed kernel estimations are included.

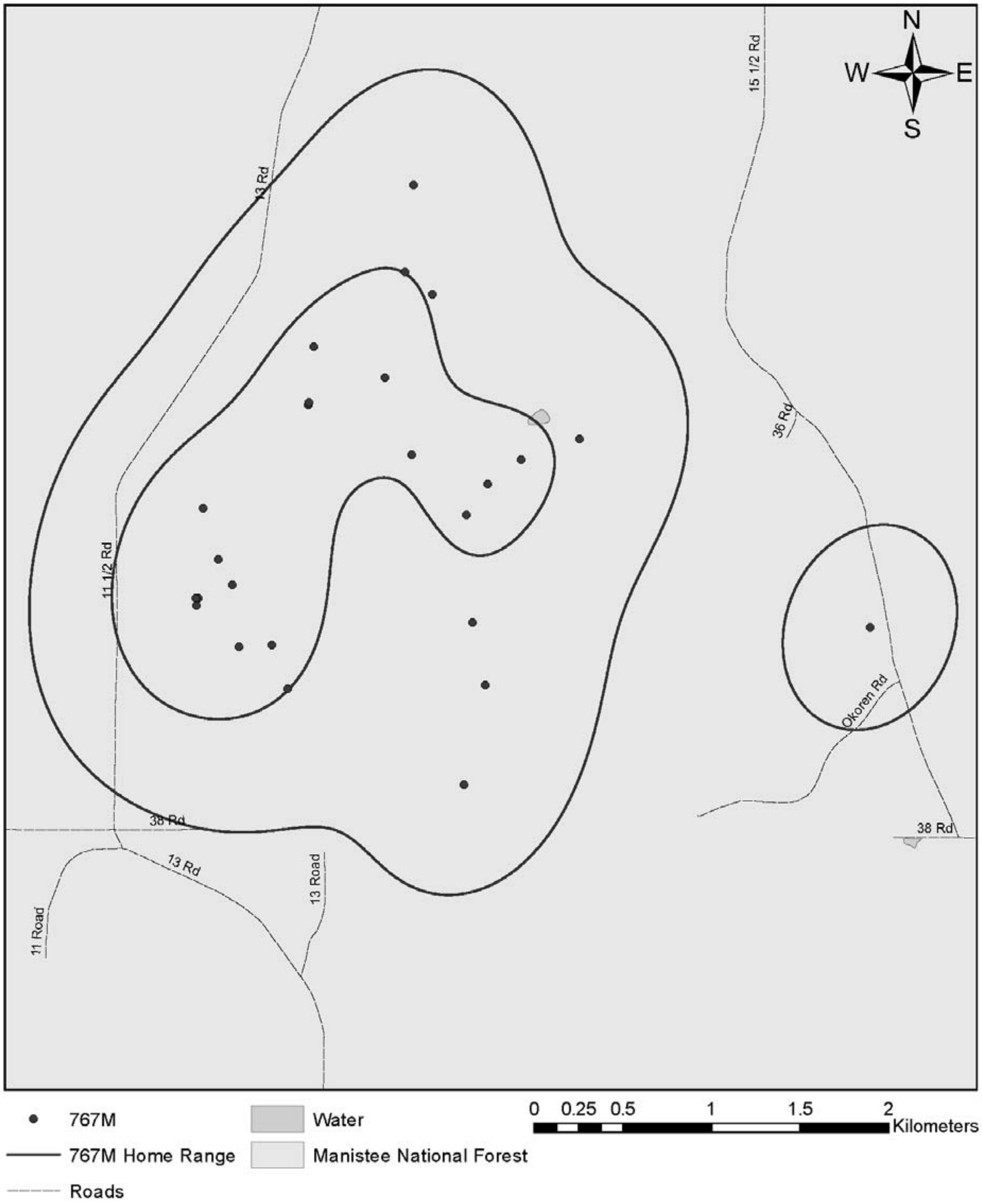

Figure 11. Telemetry locations recorded for 767M in the Caberfae region. Home range boundaries (50% and 95% interval) using fixed kernel estimations are included.

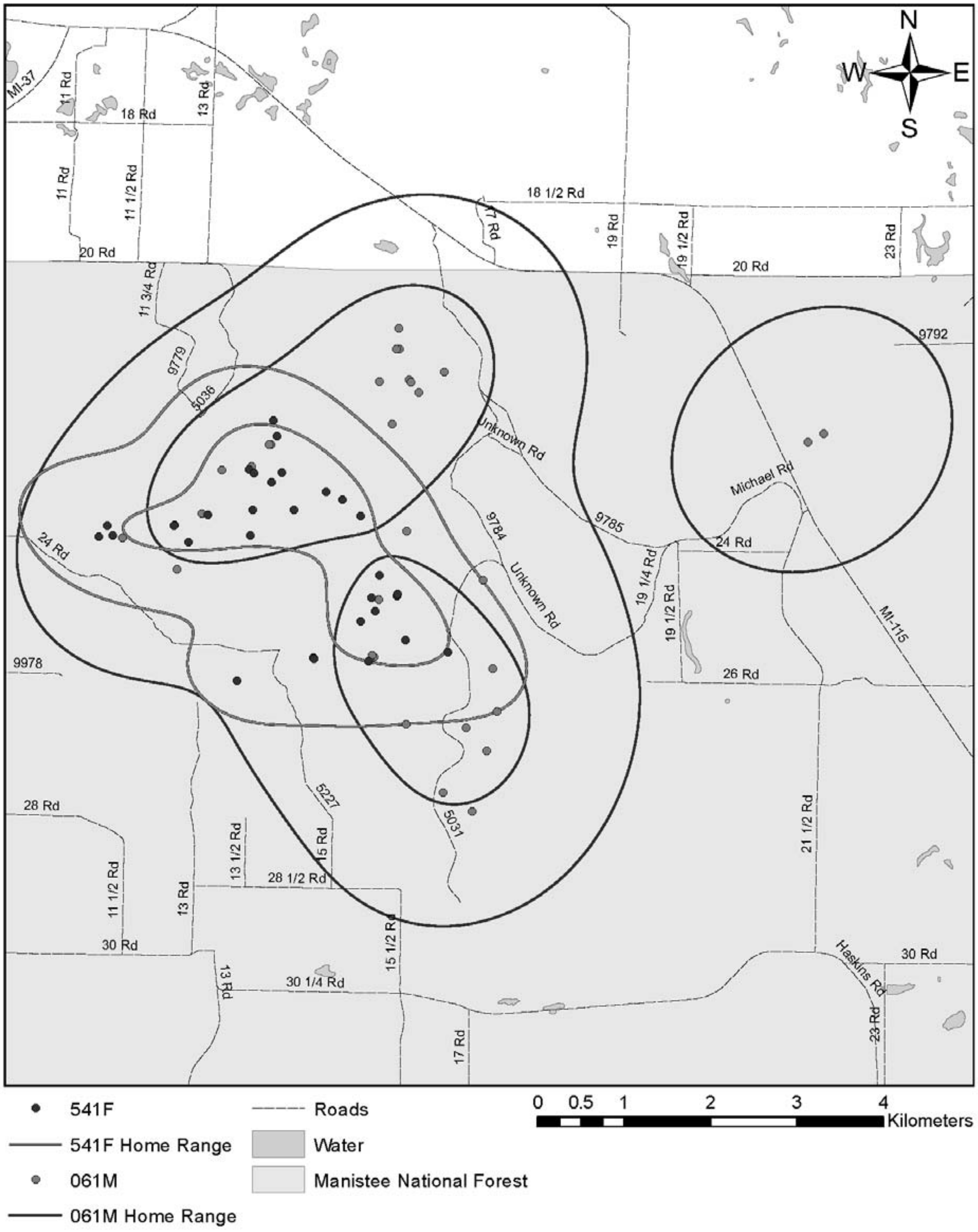

Figure 12. Telemetry locations recorded for 541F and 061M in the Harrietta region. Home range boundaries (50% and 95% interval) using fixed kernel estimations are included.

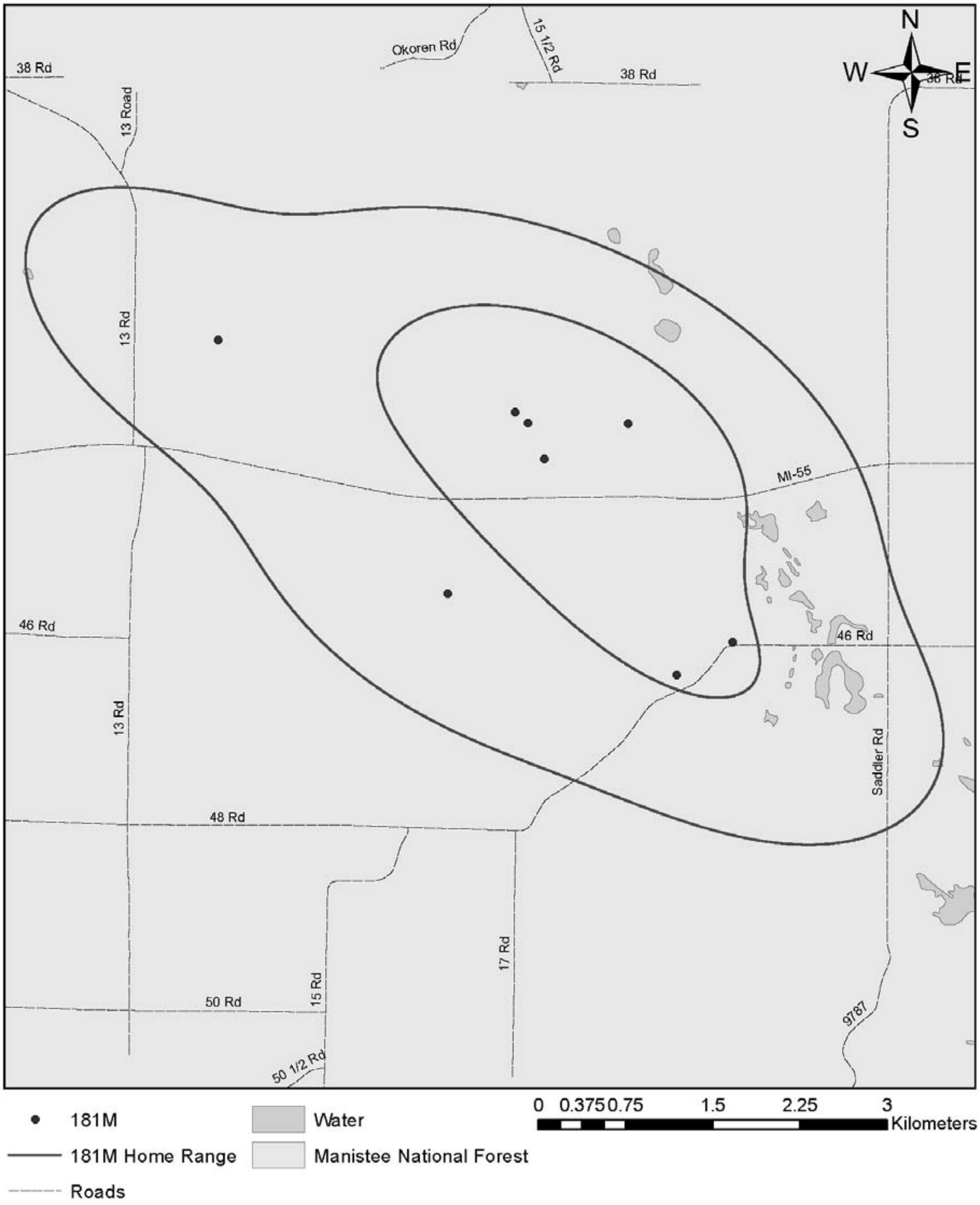

Figure 13. Telemetry locations recorded for 181M in the Caberfae region. Home range boundaries (50% and 95% interval) using fixed kernel estimations are included. Mortality was recorded before a minimum of 30 locations were recorded.

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