American marten occupancy and habitat associations using a camera trap array in the Northern Lower Peninsula, Michigan

2020 Survey Effort

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Cover Photo(s): American marten photographed on remote camera traps during this survey.

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Study area showing mixed upland forest during winter 2020 American marten and fisher camera trap survey on state forest land in the Chandler Hills Management Area (Weber/Mason Pit site).

Abstract

American martens (*Martes americana*) and fishers (*Pekania pennanti*) are small forest carnivores of high ecological and cultural value in Michigan. They are indicators of ecological integrity due to their close association with late-successional forests with structurally complex woody features that support numerous wildlife species. Therefore, ensuring their viability on the landscape demands explicit action by forest management and conservation decision making to sustain and promote these forest conditions where martens occur or are likely to occur. In the Northern Lower Peninsula (NLP) of Michigan, marten reintroduction efforts established two small and geographically isolated populations in the mid-1980s. We used a remote camera trap grid and occupancy modeling to assess the distribution and habitat associations of martens on state forest lands occurring 20–50 km west to northwest of the Pigeon River Country State Forest reintroduction site. Given recent evidence of fishers occurring within our study area, we were also interested in determining the extent of their presence using the same camera trap grid. We deployed 46 camera traps from January–May 2020 (5,147 trap nights) and estimated site occupancy and habitat associations using single-season occupancy models within a model selection framework. We evaluated the influence of dominant land cover classes on marten occupancy probability using LANDFIRE and Michigan Forest Inventory (MiFI) spatial data sources. We detected martens at 31% of survey sites, with 40 total unique (daily) detections across sites. We did not detect fishers during this survey. The abundance of coarse woody debris was a significant ($\alpha = 0.05$) predictor of marten detection probability. Only the proportion of upland deciduous forest (LANDFIRE data source) occurring within each surveyed grid cell was a significant predictor of marten occupancy probability, which suggested a positive association. Other covariates assessed generally supported marten resource selection studies in the NLP but high variance in parameter estimates precluded robust inference. Overall marten occupancy probability derived from the top-supported model was 0.30 (95% CI = 0.14–0.52) for sites at the mean surveyed proportion of upland deciduous forests (65.3%) within grid cells. Our application of camera traps deployed in a grid-based survey design successfully detected martens both within areas known to be occupied by martens and in areas where martens were not previously detected. In a population whose range extent is poorly understood, and suitable habitat remains unoccupied, camera traps were a cost-effective and informative method for building upon what we know about marten distribution in the NLP. Our results may serve as a baseline for monitoring the long-term status of martens and fishers within the NLP, including investigation of colonization-extinction patterns in relation to silvicultural practices or ecological processes on state forest lands, identification of priority conservation areas and wildlife management needs, and accumulation of basic knowledge about marten and fisher ecology in Michigan.

American marten at camera MF112 on state forest land in the Chandler Hills Management Area (Weber/Mason Pit site).

Introduction

Understanding the distribution and status of small carnivore populations is critical to their effective conservation (Schipper et al. 2008). Populations often occur at low densities and are difficult to census at spatial scales meaningful to conservation planning. Small carnivores are of high conservation priority because they are often vulnerable to extinction or extirpation (Marneweck et al. 2021), are regulated by harvest (Hiller et al. 2011), affect ecosystem function (Norrdahl et al. 2002), and are indicators of ecosystem integrity (Proulx 2020). Their populations may be especially vulnerable to extirpation in fragmented landscapes with anthropogenic barriers that limit connectivity among populations (Hargis et al. 1999, Howell et al. 2016).

American martens (*Martes americana*; hereafter martens) are a small forest carnivore generally associated with late-successional upland deciduous or coniferous forests having high canopy closure (> 50%) and complex physical structure near the ground (Buskirk and Powell 1994, Dumyahn et al. 2007). Their presence serves as an indicator of ecological integrity in forested systems (McLaren et al. 1998) and are culturally significant as a clan animal (Wabizhashi Dodem) to the Anishinaabek. They were reintroduced to Michigan's Northern Lower Peninsula (NLP) in the mid-1980s following extirpation due to habitat loss and overexploitation during the late 19th and early 20th century and were protected as a State Threatened species until 1999 (Earle et al. 2001, Williams et al. 2007). Reintroduction efforts took place in two distinct landscapes, the Pigeon River Country State Forest and the Manistee National Forest/Pere-Marquette State Forest, which are separated by about 150 km of land fragmented by agriculture, highways, and urban areas. Harvest is currently banned in the NLP where they are designated as a Regional Forester's Sensitive Species by the National Forest System (USDA Forest Service 1996) and a Featured Species by the Michigan Department of Natural Resources (MDNR; MDNR 2016). Marten populations in the NLP occupy a landscape dominated by upland deciduous forests and as such, their habitat associations have differed considerably from populations in other regions (Buskirk and Powell 1994, Ruggiero et al. 1994). Several studies have begun to improve our understanding of marten distribution, ecology, and habitat use in the NLP (Buchanan 2008, Williams and Scribner 2010, Nichols 2016, Sanders et al. 2017, Gehring et al. 2019). For example, Gehring et al. (2019) estimated that < 25% of the NLP may contain primary marten habitat and was mostly comprised of habitat patches that are smaller (i.e., < 1,000 ha) and isolated. Occupancy and population persistence of these patches may rely on the interconnectedness among suitable patches (Howell et al. 2016) and studies have indicated loss of genetic diversity in the NLP population resulting from a small founding population size and limited natural dispersal due to these isolated habitat conditions (Watkins 2012, Hillman et al. 2017).

Fishers (*Pekania pennanti*) are sympatric with martens throughout much of their geographic range and share many life history traits (Croose et al. 2019, Proulx and Aubry 2020). As such, the conservation issues facing fisher populations mirror those of martens (Proulx 2021). Fishers were also declared extirpated from the NLP due to habitat loss and overexploitation during the late 19th and early 20th century (Williams et al. 2007). Their reliance on mature forests with complex structural components near the ground (e.g., coarse woody debris) made their populations susceptible to the large-scale clearcutting activities prevalent in this region and the last known sighting in all of Michigan was documented in 1936 in Marquette County, Upper Peninsula, Michigan (Powell et al. 2003, Williams et al. 2007). Unlike marten reintroduction efforts, fishers were only reintroduced to the Upper Peninsula (Williams et al. 2007) so no extant population has been formally recognized in the NLP since their presumed extirpation. However, recent evidence of fishers occurring in the NLP has stimulated interest in determining if a viable population has persisted (Rusz 2012, Wilton 2020).

A rare fisher captured on a camera trap in the NLP by LTBB NRD staff in 2018.

The effects of forest fragmentation and conversion on the persistence of marten and fisher populations have been well documented in the scientific literature (Chapin et al. 1998, Koen et al. 2012, Happe et al. 2019, Gurtler 2020). Numerous studies suggest martens and fishers may be sensitive to forest management that degrades or reduces fine-scale habitat features (e.g., coarse woody debris [CWD], snag trees) required for foraging, denning, resting, and escape cover (Proulx 2021). Monfils et al. (2011) found that managed northern hardwood and aspen stands in Michigan had significantly less large diameter and highly decayed CWD than in unmanaged forests. Much of the potential marten and fisher habitat in the NLP, and specifically within the 1855 Little Traverse Bay Bands of Odawa Indians (LTBB) Reservation, occurs on managed state forest land that is subject to varying forest and wildlife management goals. The MDNR designates numerous highly valued wildlife species as Featured Species, where each designated species faces certain habitat problems for which solutions can be addressed through management actions (MDNR 2013). Martens are designated as a Featured Species within 8 of the 33 Forest Resources Division (FRD) Management Areas, mostly concentrated around the marten reintroduction sites. Marten habitat management within these focal Management Areas prioritizes increasing available habitat through management actions that maintain and improve contiguous tracts of mature forest that contain the ecological characteristics necessary to meet marten life history requirements. These requirements also contribute to the habitat needs of fishers and 13 additional Featured Species (MDNR 2013).

In the NLP where marten and fisher harvest data are not available (Frawley 2019), evaluation of population status and conservation priorities relies on other direct or indirect survey methods (Fuller et al. 2016). Early efforts to monitor the NLP marten population used a combination of sightings and sign, bait station track surveys, winter track survey routes, habitat assessments, and live-trapping (Earle et al. 2001). Most current studies in the NLP used live-trapping and radiotelemetry to study various aspects of marten ecology, including den and rest site characteristics (Nichols 2016, Sanders et al. 2017), genetic diversity (Hillman et al. 2017), home range and resource use (Buchanan 2008), and regional habitat suitability (Gehring et al. 2019). Other methods to monitor marten populations in the NLP have included remote camera traps to estimate occupancy probability and detection probability, dietary needs, and denning ecology (Nichols 2016, Root 2020, Little River Band of Ottawa Indians [LRBOI] *unpublished data*[1]). Hair snares and scat detection dogs have also been used to collect genetic samples for determining marten and fisher presence and understanding marten population genetics (Watkins 2012, LTBB *unpublished data*).

Advancements in both field survey technologies and statistical models are improving our ability to monitor rare and elusive animal populations without the need to estimate abundance or density (Kery and Royle 2015, MacKenzie et al. 2018). Non-invasive sampling methods and population parameters based around collection of detection/non-detection data may be more appropriate and feasible for discerning population level information at finer spatial resolutions (e.g., management area, compartment) (Long et al. 2011). Camera traps are an increasingly used method for non-invasively surveying highly mobile and elusive carnivores throughout the world (Steenweg et al. 2016), and their application to monitoring the occurrence of species in an occupancy modeling framework (MacKenzie et al. 2002) may provide a lower cost and efficient tool for monitoring the status of wildlife populations and communities (Fuller et al. 2016, Iannarilli et al. 2021).

Although several studies and monitoring efforts have tracked marten population status and predicted

[1] LRBOI Wildlife Division collaborative research projects with Grand Valley State University.

suitable habitat in the NLP, many areas still lack formal surveys to validate marten occupancy and detecting potential range expansion from source populations remains a critical challenge. Moreover, evidence of fisher populations is supported only by anecdotal and incidental observations. No formal survey has been done to estimate baseline occupancy or habitat associations of either species on state forest lands within the 1855 LTBB Reservation (hereafter Reservation) and adjacent landscape. The LTBB have documented the presence of both martens and fishers within its Reservation on private and public lands (Bill Parsons, LTBB Natural Resources Department [NRD], *unpublished data*). Moreover, a recent camera trap survey of American black bears (*Ursus americanus*) within the Reservation detected several new occurrences of martens and fishers (Wilton 2020). Given the ecological and cultural value of martens and fishers to the region, improving understanding of these populations is important for informing habitat management practices and predicting how associated landscape changes may affect marten and fisher population distribution and viability in the NLP. Our objectives were to: (1) use a grid-based remote camera trap survey to estimate site occupancy of martens and fishers that leverages information gained from previous survey efforts, (2) predict relationships between site occupancy and habitat characteristics, and (3) provide these data and estimates to help inform wildlife and forest management practices for the improvement of marten and fisher population viability on state forest lands in the NLP.

Methods

Study Area

We conducted this survey in the Northern Lower Peninsula (NLP), Michigan within Charlevoix, Cheboygan, and Emmet county, including the 1855 LTBB Reservation. This area occurs within the MDNR Gaylord Forest Management Unit (FMU), including the Emmet Moraines and Chandler Hills FRD Management Areas. The Emmet Moraines survey area is about 50 km and the Chandler Hills survey area is about 20 km from the marten reintroduction sites in the Pigeon River Country State Forest. These areas comprise Gaylord State Forest and State Park lands that are managed for various recreational, silvicultural, and ecological objectives (MDNR 2013). Timber extraction is the primary silvicultural treatment on state forest lands but is spatially variable in intensity. Other conservation and recreation land ownerships include local governments, non-governmental organizations, private, and the University of Michigan Biological Station (UMBS) (Figure 1).

Human population density was about 30 people/km^2 (U.S. Census Bureau 2010) within Emmet County and is concentrated primarily in the cities of Charlevoix, Petoskey, and Harbor Springs, which make up much of the 2% developed land uses in the study area. Housing density decreases sharply away from these city centers, with much of the landscape dominated by upland forest (52% of land cover), lowland forest (15%), agriculture (6%), and open water (15%) land cover (see Figure 1 map inset for area used to summarize land cover types). Upland forests are characterized by northern hardwoods (dominated by *Acer saccharum*, *A. rubrum*, *Fagus grandifolia, Tilia americana*), with intermixed stands of aspen (*Populus* spp), oak (*Quercus* spp), and planted pine (*Pinus* spp). Extensive lowland forests (dominated by *Thuja occidentalis*, *Larix laricina*, *Abies balsamea*, *Picea* spp, *Fraxinus* spp) and non-forested wetlands occur scattered along hydrographic features (e.g., lakes, streams). Elevation reaches a maximum of 398 meters and much of the forested landscape is characterized by moderate to steep sloped glacial moraines.

Sampling Design

We used ArcGIS Pro (ESRI 2020) to establish a 4-km^2 hexagonal random grid over the study area to form the basis of our sampling design. This grid size was used to maximize detection of martens by approximating the minimum home range size of martens in Michigan (Gehring et al. 2019, Roloff et al. 2020) and the Great Lakes Region (Mech and Rogers 1977, Woodford et al. 2013). This grid size simultaneously balances trade-offs between maximizing landscape coverage, assessing fine-scale habitat associations, and detecting other medium- to large-bodied carnivores of interest (e.g., fisher [*Pekania pennanti*], coyote [*Canis latrans*], bobcat [*Lynx rufus*], and black bear [*Ursus americanus]*) (Wilton 2020).

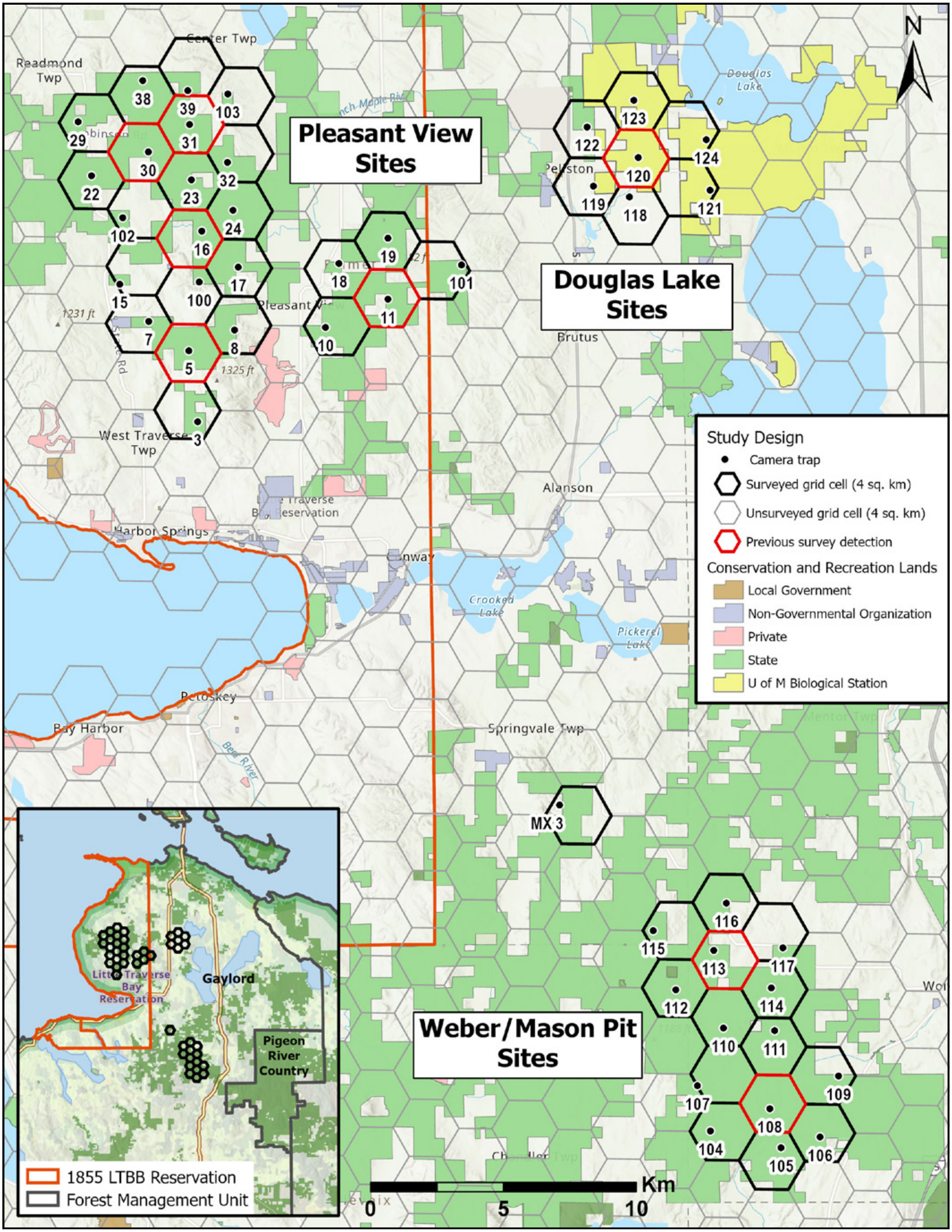

Figure 1. Survey design, including location of camera traps, study area site names, and land ownership. Map inset shows location of grid cells relative to 1855 LTBB Reservation and MDNR Forest Management Units.

To select target grid cells for deploying camera traps, we first selected grid cells that contained at least one previous detection of martens and/or fishers during camera trap and scat detection dog surveys during 2018–2019 (Figure 1). We then placed a camera trap at each of the six adjacent cells to the cell with a previous detection to determine the extent of their occurrence around known locations. Due to land access restrictions and interest in marten occurrence on lands under active management, we focused survey areas to grid cells containing access to public lands (i.e., state forest). We also included lands within the UMBS due to previously detected marten occurrence during LTBB NRD detection dog surveys. This resulted in an array of 46 grid cells totaling 184-km^2 (Figure 1). The survey grid was comprised of three distinct sites, including the Pleasant View, Douglas Lake, and Weber/Mason Pit sites (Figure 1). The Pleasant View and Douglas Lake sites occur within the Emmet Moraines FRD Management Area and the Weber/Mason Pit sites occur within the Chandler Hills FRD Management Area. The center of each randomly derived grid cell or nearest public land location within a forested cover type served as an initial location for selecting camera trap placement, with one camera trap per grid cell.

Field Sampling

We deployed 46 passive infrared camera traps (Browning Spec-Ops Advantage, model BTC-8A, Birmingham, Alabama, USA) programmed to take 2 photos per trigger (Rapidfire mode) with a 1-second delay between consecutive triggers. We used a predator trapping lure (Gusto and Skunk Junk; Minnesota Trapline Products) placed in a biodegradable cup and suspended from a branch about 2 meters above ground in front of each camera to increase the likelihood of attracting a marten or fisher within a camera's detection zone. We deployed cameras from 09–17 January 2020 and retrieved all cameras during 04–06 May 2020 ($\bar{x}$ = 114, range = 109–117 days). We revisited camera sites every 26 days on average (SD = 2, range = 21–29 days, n = 2 visits between deployment and retrieval) to reapply lure, replace memory cards and batteries, and maintain camera operation (Appendix I).

Within a 100-meter radius of the initial random location, we searched until a location having a suitable field of view to allow marten and fisher to be photographed was found. Camera site selection was further refined by aiming the camera's detection zone towards available fine-scale natural features that may facilitate marten and fisher detection, with an emphasis on large coarse woody debris. We avoided placing cameras on human-use roads and trails to minimize theft or vandalism.

Cameras were mounted about 0.5–1.0 meters above ground to a tree and about 3–5 meters from the target detection zone (e.g., CWD feature). We aimed cameras facing North, if possible, to minimize false triggers caused by exposure to the sun's rays. If applicable, we mounted cameras at about a 45-degree angle to linear log features to maximize detection of traveling animals. We trimmed vegetation obstructing the camera's detection zone and vegetation that may falsely trigger the camera.

We ranked the abundance of CWD at a camera trap site using 3 general categorgies (low, medium, high). We measured the maximum distance a camera was able to detect a passing animal (Detection Distance) by setting the camera to Motion Test mode and walking back-and-forth in front of the camera at increasing distance until the camera was no longer triggered (Appendix I, Appendix II). This metric serves as an index of horizontal vegetation density or topography that may obstruct a camera's view and detection probability. We described basic dominant species composition of the canopy and sub-canopy, as well as general characteristics of the immediate habitat surrounding a camera site to validate against GIS-based land cover layers.

We triggered cameras upon arrival and before leaving each site by holding an informational whiteboard with date, time, camera ID, visit #, and observer initials. This provided a confirmation of a camera's operational status and a basic digital backup of a site's datasheet. (Appendix II).

Image Processing

We downloaded images from memory cards after each camera check and organized images into folders distinguished by camera site (e.g., "MF1") and subfolders by camera visit number (e.g., "visit1"). This folder structure was designed to facilitate data extraction using the package *camtrapR* (Niedballa et al. 2016) in program R (www.r-project.org), which reads images according to this specified structure and renames each image file with its respective site ID, visit number, date taken, time taken, and image sequence number (e.g., MF10__visit1__2020-01-27__23-38-35(1).JPG).

We used Adobe Lightroom Classic CC software (hereafter Lightroom; Adobe, San Jose, CA, USA) to classify species and manage image organization. Lightroom utilizes a hierarchical keyword structure (e.g., Species > [black bear, fisher, marten etc.]) that we used to add species classifications back into the EXIF metadata of each image. These keyword tags form the foundation of converting a collection of images into a data set for statistical analysis. This process is critical for efficient database management and quality control as each image classification is permanently associated with the physical image. To facilitate queries of the image database for users without access to Lightroom, a species' common name can be searched using a computer's File Explorer (Windows) search bar. For example, typing 'marten' will filter and display images tagged with this species ID (this can be done at any level of the database's folder structure). We can also provide subsets of the image database for any species or species group of interest upon request.

In addition to marten and fisher, we assigned species-level tags for other carnivores of interest and grouped all other species into the classification "other". All mammalian prey species of marten or fisher (i.e., squirrels [*Glaucomus* spp., *Sciurus* spp., *Tamias striatus*, *Tamiasciurus hudsonicus*], rabbits and hares [*Sylvilagus floridanus, Lepus americanus*], and small rodents [*Peromyscus* spp., *Microtus* spp., *Napaeozapus insignis*]) were grouped into a "prey" classification. Images of animals unable to be classified were labeled "unknown". We then used *camtrapR* to extract species classifications along with the date and time for each image to generate a spatiotemporal database of animal detections. We note that no fishers were detected during this survey and further sections will refer only to detections of marten.

Occupancy Analysis

We defined a positive marten detection at a camera site as at least 1 image of marten collected per day. For each camera site, we used *camtrapR* to generate a daily detection history, where a "1" indicates a positive marten detection and a "0" represents a non-detection event for a given day. For example, a detection history of "01011" illustrates a detection history where a marten was not detected on the first day, detected on the second day, not detected on the third day, and detected on the last 2 days.

Due to the sparse positive detections typical of carnivore surveys and associated limitations of zero-inflated datasets, we collapsed the raw 119-day daily occasions into 24, 5-day occasions. This period was the shortest occasion length that permitted convergence of occupancy models.

We used single-species, single-season occupancy modeling (MacKenzie et al. 2002) in a likelihood-based model selection framework (Akaike Information Criterion (AIC; Arnold 2010) to test and rank the relative support among hypotheses about factors affecting marten occupancy probability from our detection-nondetection camera trap data.

We used a two-step approach to first determine the most parsimonious model explaining detection probability, and then included these detection covariates in all combinations of our occupancy models (Erb et al. 2012). All covariates were first standardized by subtracting the mean and dividing by the standard deviation of each covariate. During the first step, we included all possible occupancy covariates as a constant while investigating each combination of detection covariates. In the second step, the resulting most supported detection model was held constant while all combinations of occupancy covariates were investigated. We then used the final most supported model describing detection probability and occupancy probability to predict and describe marten occupancy throughout the study area.

For the first step, we modeled the abundance of CWD that occurred at a site (factor with 3 levels: low, medium, high), and by survey period (Time). We hypothesized that marten detection probability would increase with increasing abundance of CWD at a camera site, and that detection probability would decrease over the study duration. The covariate Time was investigated by dividing the total survey length into 6 equal length intervals to test for changes in marten detection over each camera's deployment period. Low overall sample size precluded assessment of more complex models.

We considered models to have competing support if they were within 2.00 ΔAIC of the most supported model and assessed proportional support for each model using AIC weights (w_i; Burnham and Anderson 1998). We examined the significance of each covariate in the top model by determining if the 95% confidence interval (CI) of the beta coefficients overlapped zero (significance = non-overlapping CI). All analyses were performed using the package *unmarked* (Fiske and Chandler 2011) in RStudio (v. 1.2.5033; R Core Team 2019).

Since we were interested in ecological drivers of marten occupancy as well as relationships between marten occupancy and stand-scale factors described by the Michigan Forest Inventory (MiFI) land cover GIS layer for state forest lands, we developed and tested 2 separate sets of occupancy models (see LANDFIRE and MiFI occupancy model sections below). We used the LANDFIRE model set to infer marten occupancy probability across the study area due to greater data consistency and spatial data coverage and used results derived from the MiFI model set to describe general differences in marten occupancy probability as they relate to stand-scale differences among sites.

LANDFIRE occupancy models

We developed an a priori set of models to investigate landscape covariates hypothesized to influence (either positively or negatively) marten occupancy probability within surveyed grid cells. For each covariate, we used ArcGIS Pro to extract values at a 4-km^2 spatial scale as this represents the minimum expected home range size of marten in this region (Gehring et al. 2019, Roloff et al. 2020). We calculated the proportion of lowland forest (LF), upland deciduous forest (UDF), upland conifer forest (UCF), managed tree plantations (MTP), and total forest cover (ForCov) within each camera's 4-km^2 grid cell. We included these cover types because these are the most dominant natural land cover classes in the study area and may be important drivers of marten resource selection (Roloff et al. 2020). The proportion of total forest cover within a grid cell may positively influence marten occupancy because of their dependence on forested cover types (Hargis et al. 1999).

Specifically, we hypothesized that marten occupancy probability would increase with increasing proportion of LF, UDF, and UCF but decrease with increasing proportion of MTP. We used LANDFIRE's Existing Vegetation Type (EVT) classification layer (30-m^2 resolution) to extract all land cover covariates (Rollins 2009) within each grid cell and reclassified 25 focal EVT group names into 5 ecological classes, including 'upland deciduous forest', 'upland conifer forest', 'mixed forest', 'lowland forest', 'agriculture', and all other classes (Appendix III).

MI Forest Inventory occupancy models

We applied the same covariate extraction protocol described above to independently assess the influence of spatial variation in land cover types as described within the MiFI land cover classification layer (MDNR 2009). The MiFI system collects a variety of data on stand-scale (e.g., one to several hundred-acre polygons) attributes, including hierarchical land cover classifications and silvicultural measurements (e.g., stem basal area, dominant age, canopy cover). We used the broadest land cover classification (Cover Type) to generate 4 covariates hypothesized to influence marten occupancy probability. We reclassified upland deciduous forest cover types (*n* = 5) into a single classification group (UDF_MiFI) to reduce the complexity of occupancy models. We also tested if the proportion of aspen dominated cover types (ASPN_MiFI) or the proportion of planted pine cover types (PLPI_MiFI) influenced marten occupancy probability. We used the MiFI "Size Density" variable as an index of stands that may have more characteristics of mature forests (e.g., larger/older trees, more snags and CWD). The Size Density variable is an integer (1–9) that combines a stand's overall size class (sapling, pole, log) and overall canopy closure (25–50%, 50–75%, 75–100%), where greater values indicate both a larger size class and greater canopy closure (MDNR 2009). We calculated the proportion of stands within each 4-km^2 grid cell having a Size Density value of 9 (SD9) (i.e., stands designated as Log size class *and* 75–100% Canopy Closure).

Finally, we used camera trap data to calculate a relative abundance index (RAI; Conroy 1996) for all combined prey species (prey_RAI) using the equation RAI = (D/TN)*100, where D is the number of independent daily detections and TN is the total number of trap nights per camera trap (Allen et al. 2017). This served as an index of prey abundance at each camera trap site and we hypothesized that sites with greater prey RAI would be positively associated with greater marten occupancy probability.

Results

Field Sampling

We deployed 46 camera traps for a total survey effort of 5,147 trap nights. Average camera deployment period was 114 days (range = 109–117 days). Three cameras were not operational from their deployment date to their first check date ($\bar{x}$ = 23 days, range = 22–25 days) and one camera was not operational from 17 April to 05 May (19 days) due to the memory card filling up from false trigger events (Figure 2).

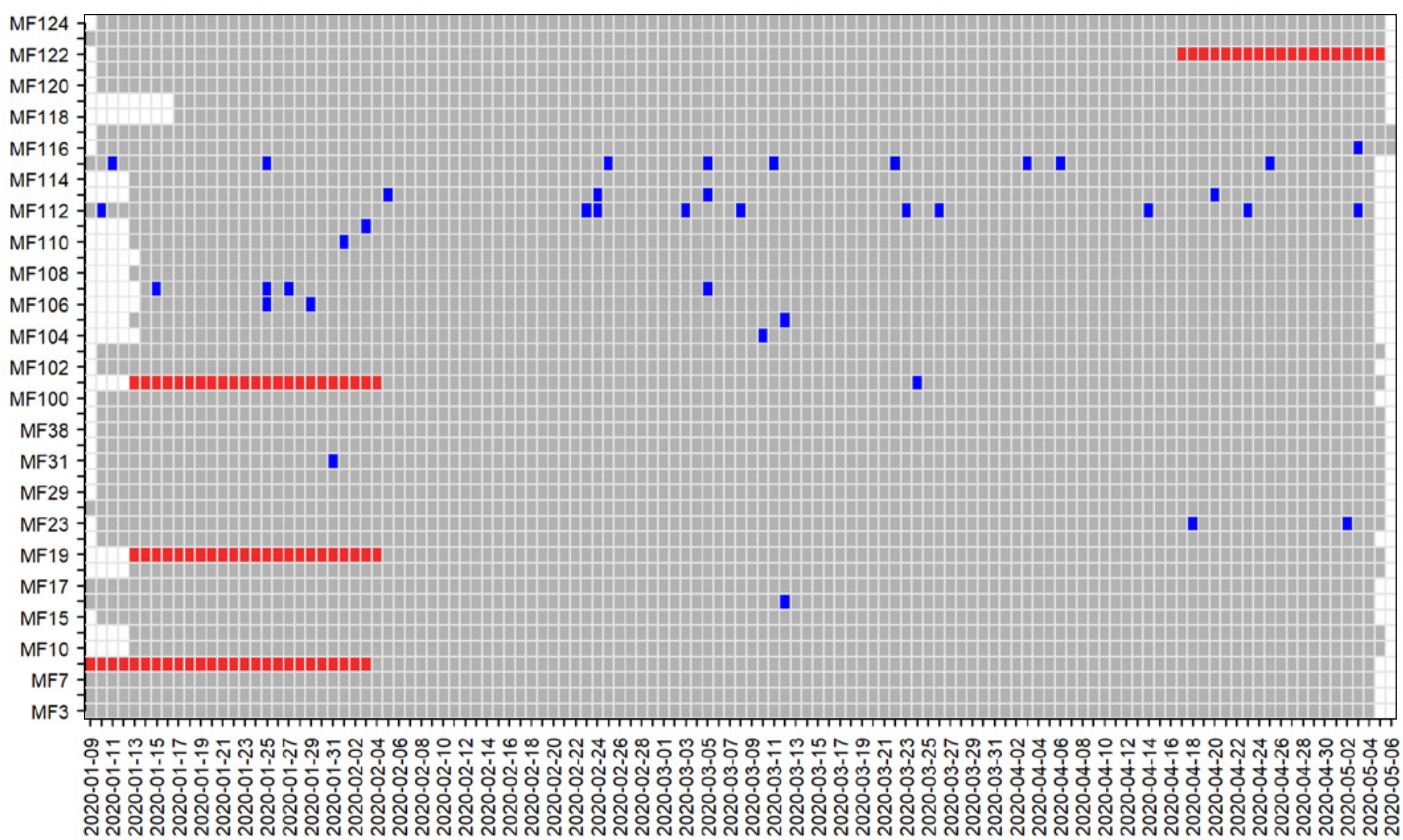

Figure 2. Camera trap site operation matrix displaying days when cameras were deployed and operative (gray squares), deployed but inoperative (red squares), not deployed (white squares), and days when a marten was detected (blue squares) at a camera trap site during 09 January– 06 May 2020.

Image Processing

Camera traps collected 197,618 images, comprising 98,809 unique triggers (i.e., total number of animal detections, non-animal detections, and false triggers). We classified 57,710 images of animals to species or group level. False triggers and white-board photos comprised 139,900 images (71%). We identified 23 unique mammal species, including 11 native members of the Order Carnivora across 7 Families. In addition to marten, we detected American badger (*Taxus taxidea*), American mink (*Neovison vison*), black bear (*Ursus americanus*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), and red fox (*Vulpes vulpes*) at camera traps. We grouped detections of the Genus *Mustela* (i.e., *Mustela erminea, M. frenata*) into a single classification group (*Mustela* spp). We also grouped common raccoon (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), striped skunk (*Mephitis mephitis*), woodchuck (*Marmota monax*), common porcupine (*Erethizon dorsatum*), white-tailed deer (*Odocoileus virginianus*), elk (*Cervus elaphus*) and all avian species into the classification “other”. Fishers were not detected at camera traps (Appendix IV).

Marten triggered cameras 209 times at 15 unique camera sites, though we dropped site MX3 from subsequent occupancy analyses due to missing data (i.e., analyses use data from 45 camera sites with 14 sites having at least 1 marten detection) (Appendix V). Subsequent summary statistics also reflect this omission. We detected marten at 31% (i.e., naïve occupancy) of survey sites. At sites having marten detections, the number of daily detections averaged 2.9 (SD = 3.2, range = 1 – 10), with 40 total daily detections across sites (Figure 3, Figure 4). Detections were most frequent across cameras between 0100 hours and 0300 hours, with smaller activity peaks around 0600 and 2000 hours (Figure 5).

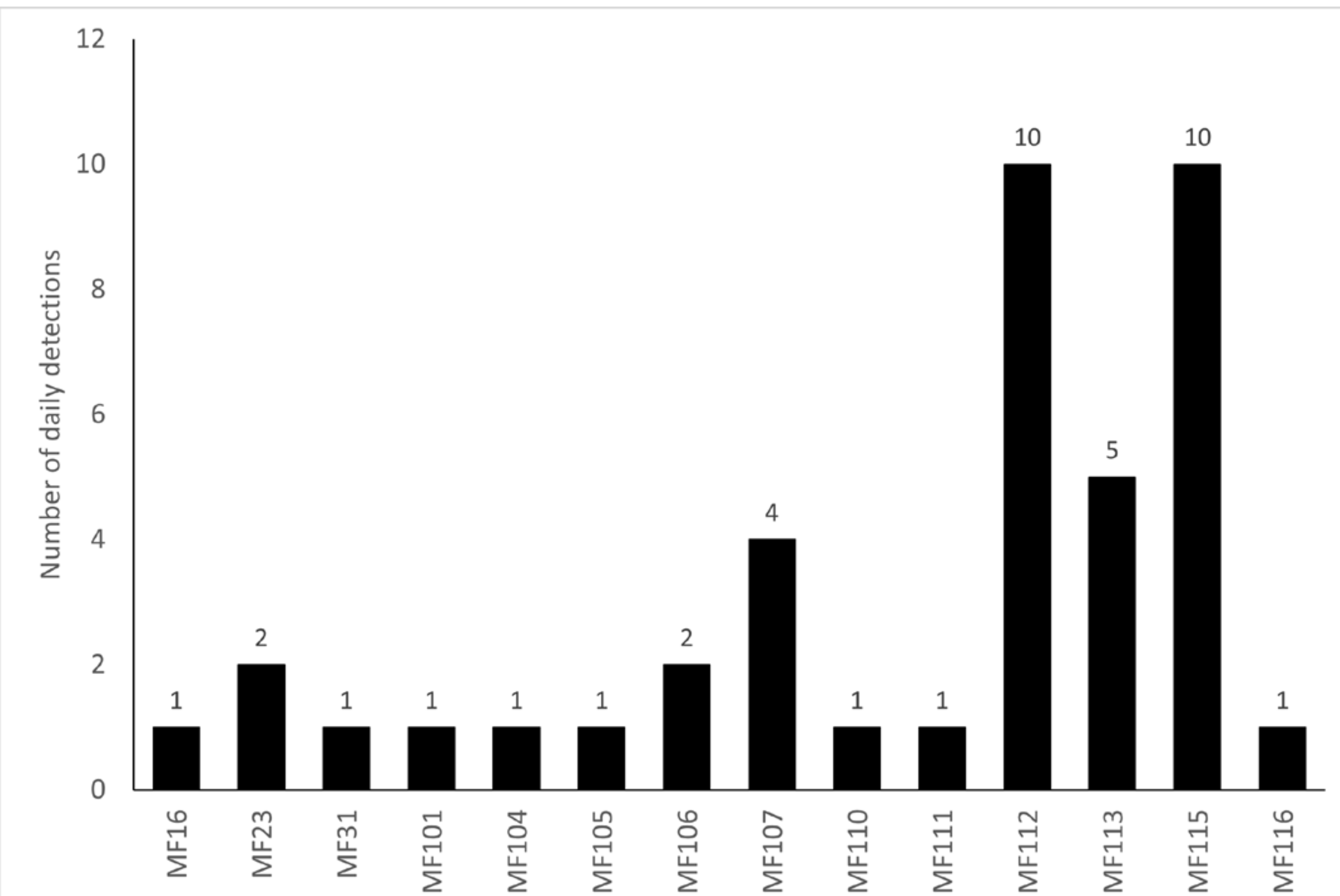

Figure 3. Number of daily marten detections at camera trap sites having at least one marten detection during 09 January – 06 May 2020.

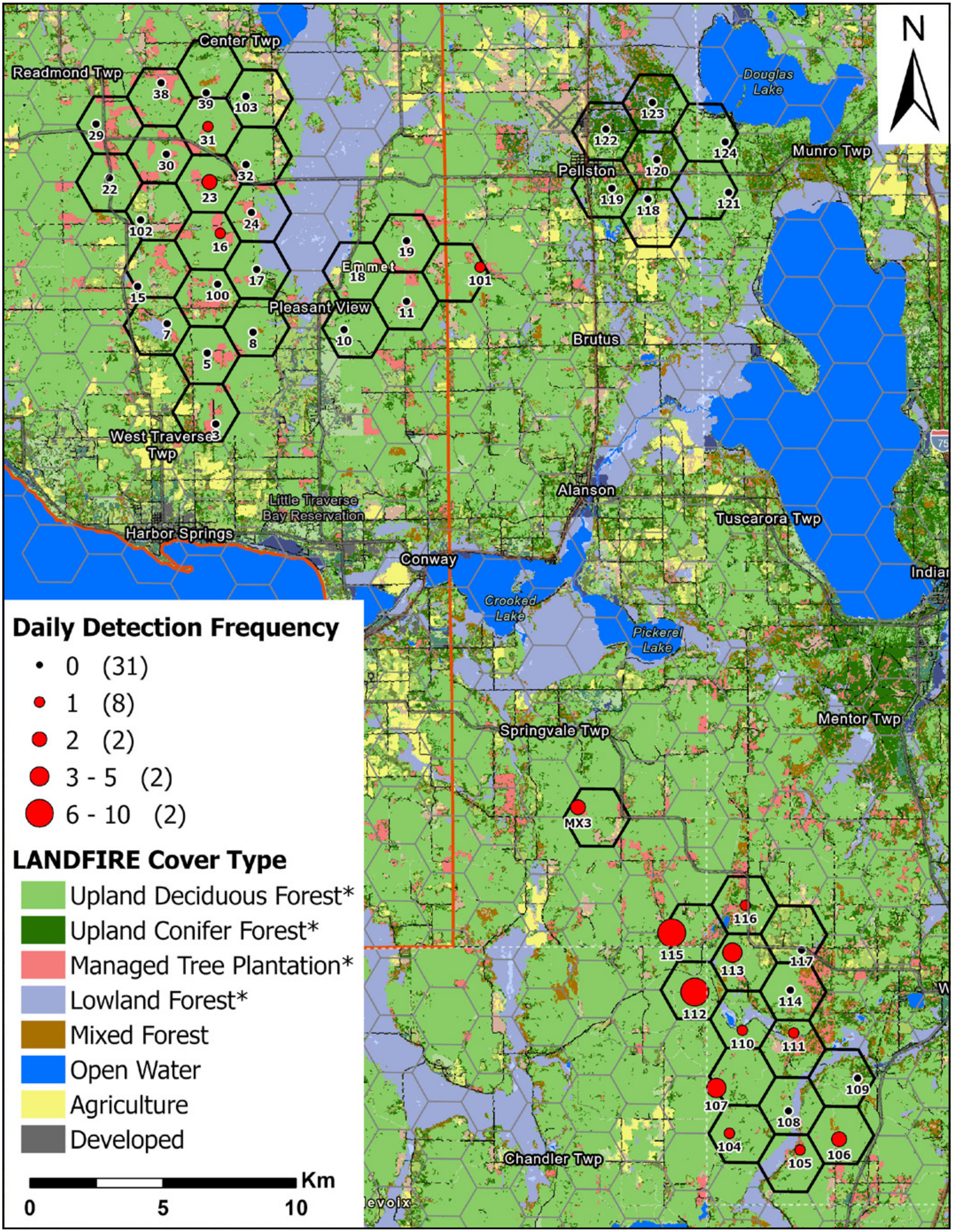

Figure 4. Marten daily detection frequency in relation to LANDFIRE land cover covariates. Cover types with asterisks were included as model covariates.

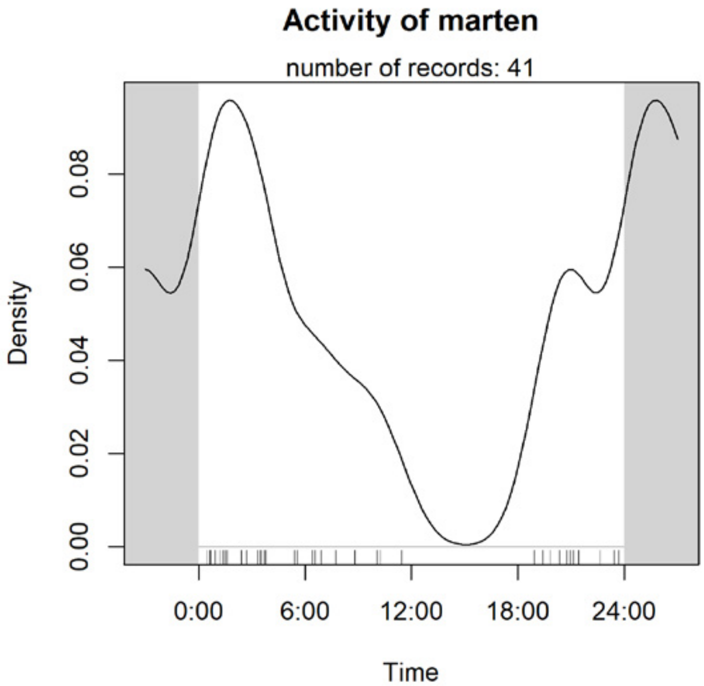

Figure 5. Diel activity pattern of marten during 09 January– 06 May 2020 and a marten detected at site MF115 during peak activity (0100 - 0300 hrs).

Occupancy Analysis

The top-supported model describing marten detection probability included 'CWD' and was supported 10 times as much (w_i = 0.80) as the second ranked model (w_i = 0.08). Model selection results were similar between LANDFIRE and MiFI model sets, so we used the CWD covariate to describe detection probability under both occupancy model sets. Marten detection probability was significantly (α = 0.05) lower at sites with low levels of CWD compared to sites with high levels of CWD. Detection probability between sites with medium levels of CWD were not significantly different than sites with high levels of CWD (Figure 6).

LANDFIRE models

LANDFIRE covariates used to evaluate occupancy probability were similar among grid cells (Figure 4). Most grid cells were dominated (≥ 50% of cover class) by upland deciduous forest (n = 37 sites). No other cover type classification comprised ≥ 50% of a surveyed cell. Overall, mean percent cover type among grid cells was 65.3% (SD = 19.5) for upland deciduous forest , 8.1% (SD = 9.8) for upland conifer forest, 5.1% (SD = 7.9) for lowland forest, and 6.9% (SD = 6.3) for managed tree plantation. Total forest cover among grid cells averaged 91.3% (SD = 9.8) (Table 1). At the specific location of a camera trap, 83% of camera locations were deployed in upland deciduous forest, 4% in upland conifer forest, 2% in lowland forest, 7% in tree plantations, and 4% in mixed forest.

The top-supported occupancy model included only the proportion of upland deciduous forest occurring within each camera site's 4-km^2 grid cell and was included as a covariate in all models with competing support (Table 2). This model suggested greater marten occupancy probability in grid cells having proportionally greater upland deciduous forest cover (β = 1.34, SE = 0.58, p-value = 0.02). Covariates included in competing models also suggested

Table 1. Mean proportion of LANDFIRE land cover covariates occurring within each survey grid cell.

Site Covariate	Mean	SD	Min	Max
Upland deciduous forest (%)	65.3	19.5	14.7	93.5
Tree plantation (%)	6.9	6.3	0	23.6
Lowland forest (%)	5.1	7.9	0	32.8
Upland conifer forest (%)	8.1	9.8	1	48.9
Forest cover (%)	91.3	9.8	52.9	99.8

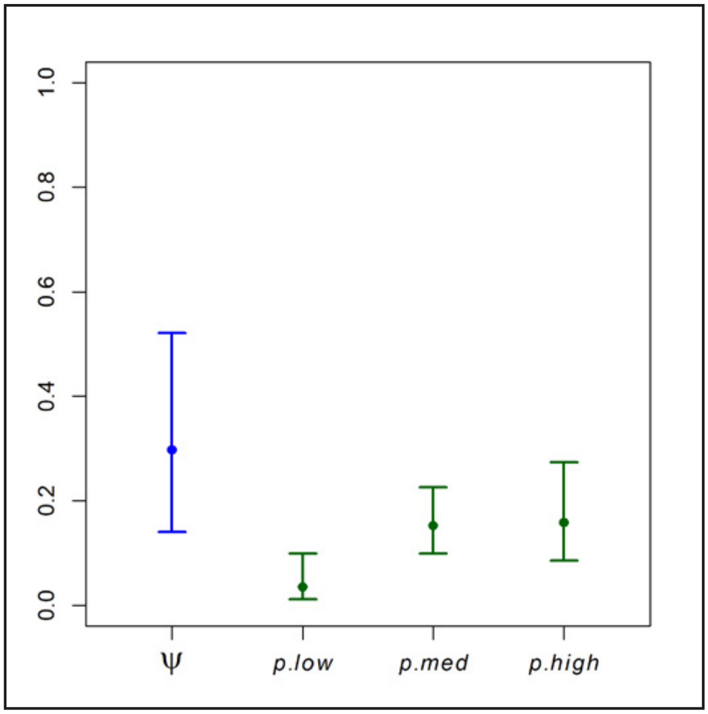

Figure 6. Marten occupancy and detection probability derived from the top-supported LANDFIRE model. Detection probability displayed for each CWD category.

greater marten occupancy probability in grid cells having proportionally greater lowland forest (β = 0.31, SE = 0.49, p-value = 0.53), upland coniferous forest (β = 0.16, SE = 1.08, p-value = 0.88), total forest cover (β = 0.15, SE = 0.78, p-value = 0.85), and lesser marten occupancy probability in grid cells having proportionally greater managed tree plantation (β = -0.46, SE = 0.49, p-value = 0.35). Only upland deciduous forest was considered a significant (α = 0.05) predictor of marten occupancy probability (Figure 7a, Figure 8).

Overall marten occupancy probability derived from the top-supported model was 0.30 (95% CI = 0.14–0.52) for sites at the mean surveyed proportion of upland deciduous forests within grid cells (65.3%; Figure 6). Occupancy probability was 0.01 (SE = 0.02) for sites at the minimum surveyed proportion of upland deciduous forest within grid cells (14.7%) and was 0.75 (SE = 0.16) for sites at the maximum surveyed proportion of upland deciduous forest within grid cells (93.5%; Figure 9). Detection probability at low, medium, and high levels of CWD was 0.04 (95% CI = 0.01–0.10), 0.15 (95% CI = 0.10–0.23), and 0.16 (95% CI = 0.09–0.27), respectively (Figure 6).

MI Forest Inventory models

MiFI covariates used to evaluate occupancy probability were similar among grid cells (Figures 10a, 10b), though 6 Douglas Lake sites did not occur in grid cells containing state forest land (Figure 1) and were omitted from occupancy analysis. Most grid cells were dominated (≥ 50% of cover class) by upland deciduous forest cover types (n = 35 sites). One grid cell (camera MF117) was dominated by planted pine forest (54%), though only 13% of this grid cell was comprised of state forest land. One grid cell (camera MF122) was dominated by upland conifer forest (78%), though only 20% of this grid cell was comprised of state forest land. No other cover type classification comprised ≥ 50% of a surveyed cell. Overall, mean percent cover type among grid cells was 79.1% (SD = 19.7) for upland deciduous forest, 11.8% (SD = 11.7) for planted pine forest, and 15.5% (SD = 11.5) for aspen forest. Grid cells varied in the proportion of stands with a Size Density class of 9 ($\bar{x}$ = 48.2%, SD = 22.2) (Table 3). Similarly, relative abundance of prey (prey RAI) varied among camera trap sites ($\bar{x}$ = 41.6

Table 2. LANDFIRE model selection results ranked in order of decreasing AIC support (ΔAIC < 2.00). Number of model parameters (K), Akaike's Information Criterion (AIC), the difference in AIC between the top-supported model and the i^{th} ranked model (ΔAIC), model weight (w_i), and cumulative model weight (cuml. w_i) are presented for each candidate model. Only models with ΔAIC ≤ 3.0 are displayed (32 total models).

Formula	K	AIC	ΔAIC	w_i	cuml. w_i
Ψ(Upland Deciduous Forest)	5	264.87	0.00	0.17	0.17
Ψ(Upland Deciduous Forest + Managed Tree Plantation)	6	265.91	1.03	0.10	0.27
Ψ(Upland Deciduous Forest + Lowland Forest)	6	266.49	1.62	0.08	0.34
Ψ(Upland Deciduous Forest + Forest Cover)	6	266.83	1.96	0.06	0.41
Ψ(Upland Deciduous Forest + Upland Conifer Forest)	6	266.85	1.98	0.06	0.47
Ψ(Upland Deciduous Forest + Managed Tree Plantation + Forest Cover)	7	267.63	2.76	0.04	0.51
Ψ(Upland Deciduous Forest + Managed Tree Plantation + Lowland Forest)	7	267.81	2.93	0.04	0.55
Ψ(Upl. Deciduous Forest + Managed Tree Plantation + Upl. Conifer Forest)	7	267.90	3.02	0.04	0.59

detections/100 trap nights, SD = 21.2). We note that not all grid cells were entirely comprised of state forest land ($\bar{x}$ = 65%, SD = 28, range 8–100%), and that this variability may affect occupancy parameter estimates within MiFI model sets. For camera traps within state forest, 82% of camera locations were deployed in Northern Hardwood, 10% in Red Pine, 3% in Aspen, 3% in Cedar (lowland), and 3% in White Pine (natural) MiFI Cover Type classification (See Appendix VI for MiFI variables associated with sites).

Table 3. Mean proportion of MiFI stand covariates occurring within each survey grid cell.

Site Covariate	Mean	SD	Min	Max
Upland deciduous forest (%)	76.1	19.7	0.0	100.0
Planted Pine (%)	11.8	11.7	0.0	54.1
Aspen Types (%)	15.5	11.5	0.0	41.7
Size Density 9 (%)	48.2	22.2	4.7	100.0

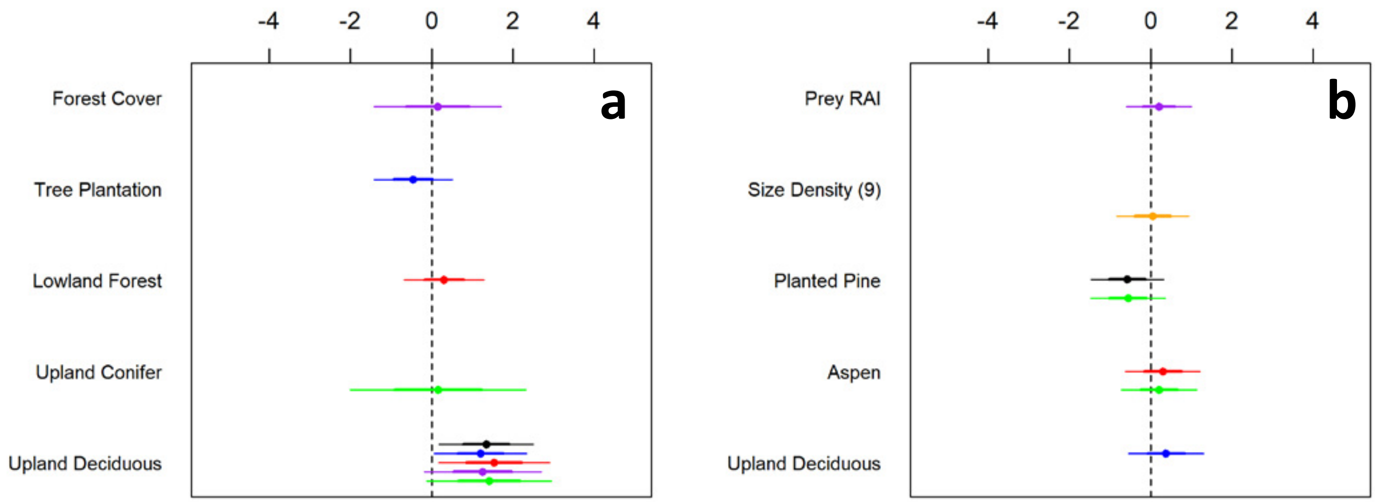

Figure 7. LANDFIRE (panel **a**) and MiFI (panel **b**) scaled ($\bar{x}$ = 0, SD = 1) beta (β) coefficients from all competing models (ΔAIC ≤ 2.00; Table 2 & 4) and their 95% confidence intervals, where overlapping zero suggests non-significance (i.e., poor explanatory power; α = 0.05). Colors correspond to covariates appearing in the same model together (e.g., in panel **a**, green points/lines display results from the LANDFIRE model Ψ(UCF + UDF)). Model rank is displayed in order of top to bottom (i.e., black>blue>red>purple>green>yellow). Values greater or lesser than zero indicate a positive or negative relationship with marten occupancy probability, respectively.

Table 4. MiFI model selection results ranked in order of decreasing AIC support (ΔAIC < 2.00). Number of model parameters (K), Akaike's Information Criterion (AIC), the difference in AIC between the top-supported model and the i^{th} ranked model (ΔAIC), model weight (w_i), and cumulative model weight (cuml. w_i) are presented for each candidate model. Only models with ΔAIC ≤ 3.0 are displayed (32 total models).

Formula	K	AIC	ΔAIC	w_i	cuml. w_i
NULL	4	266.15	0.00	0.13	0.13
Ψ(Planted Pine)	5	266.19	0.04	0.12	0.25
Ψ(Upland Deciduous forest)	5	267.44	1.29	0.07	0.32
Ψ(Aspen)	5	267.70	1.55	0.06	0.38
Ψ(prey RAI)	5	267.90	1.74	0.05	0.43
Ψ(Aspen + Planted Pine)	6	267.99	1.84	0.05	0.48
Ψ(Size Density 9)	5	268.14	1.99	0.05	0.53
Ψ(Upland Deciduous Forest + Planted Pine)	6	268.16	2.01	0.05	0.58
Ψ(Planted Pine + prey RAI)	6	268.17	2.02	0.05	0.62
Ψ(Planted Pine + Size Density 9)	6	268.17	2.02	0.05	0.67

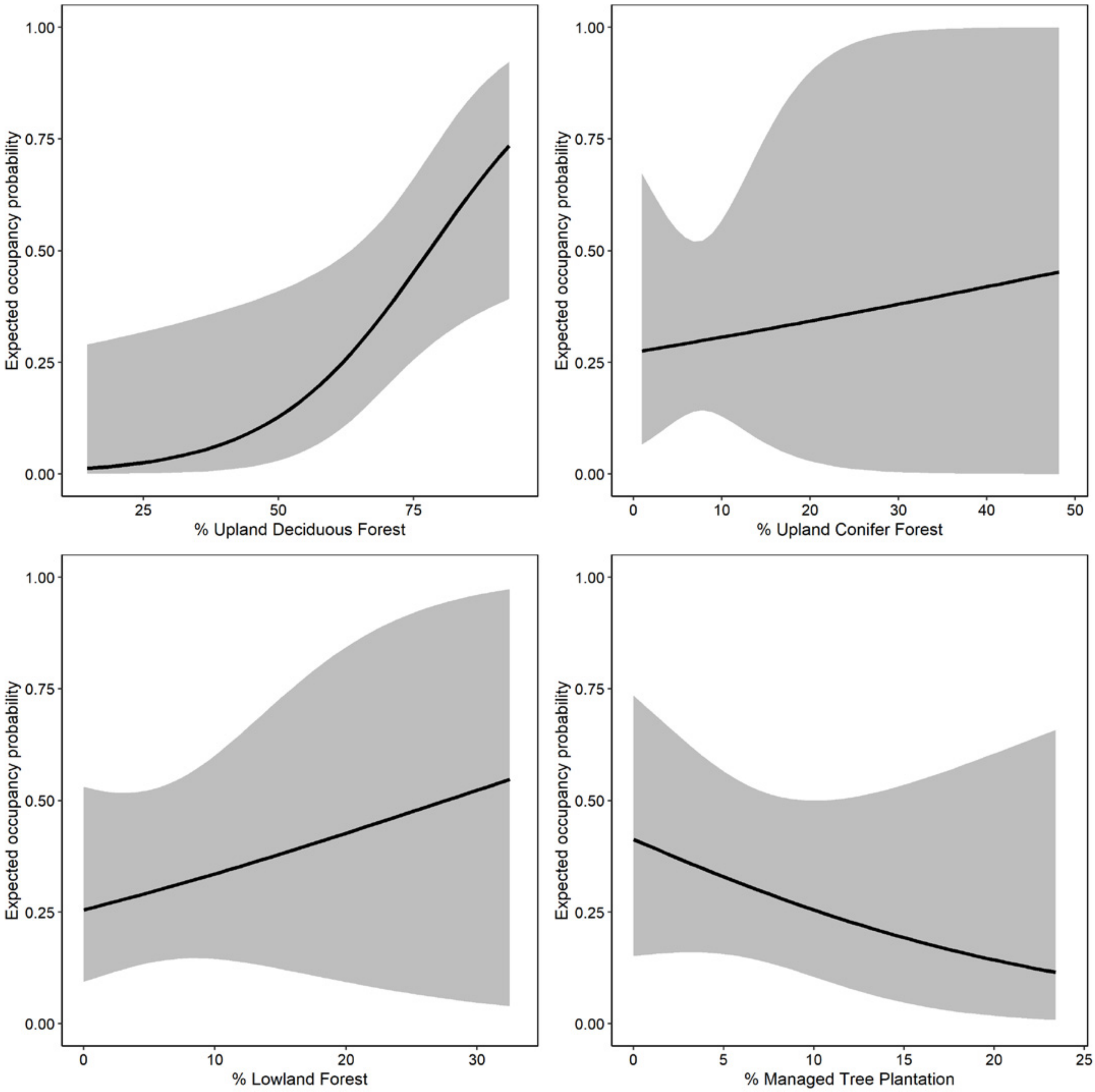

Figure 8. Change in predicted marten occupancy probability as a function of supported LANDFIRE site covariates, including the percent of upland deciduous forest, upland conifer forest, lowland forest, and managed tree plantation occuring within surveyed grid cells. Gray bands represent 95% confidence intervals.

The top-supported occupancy model included the proportion of planted pine stands, although the null model (no covariates) was equally supported (i.e., ΔAIC = 0.04, Table 4). This model suggested lesser marten occupancy probability in grid cells having proportionally greater planted pine cover (β = -0.57, SE = 0.45, p-value = 0.20). Covariates included in competing models also suggested greater marten occupancy probability in grid cells having proportionally greater upland deciduous forest (β = 0.38, SE = 0.46, p-value = 0.41), aspen forest (β = 0.30, SE = 0.46, p-value = 0.52), prey abundance (β = 0.20, SE = 0.40, p-value = 0.61), and size density class (β = 0.05, SE = 0.45, p-value = 0.91). No MiFI cover type covariates were considered significant (α = 0.05) predictors of marten occupancy probability (Figure 7b).

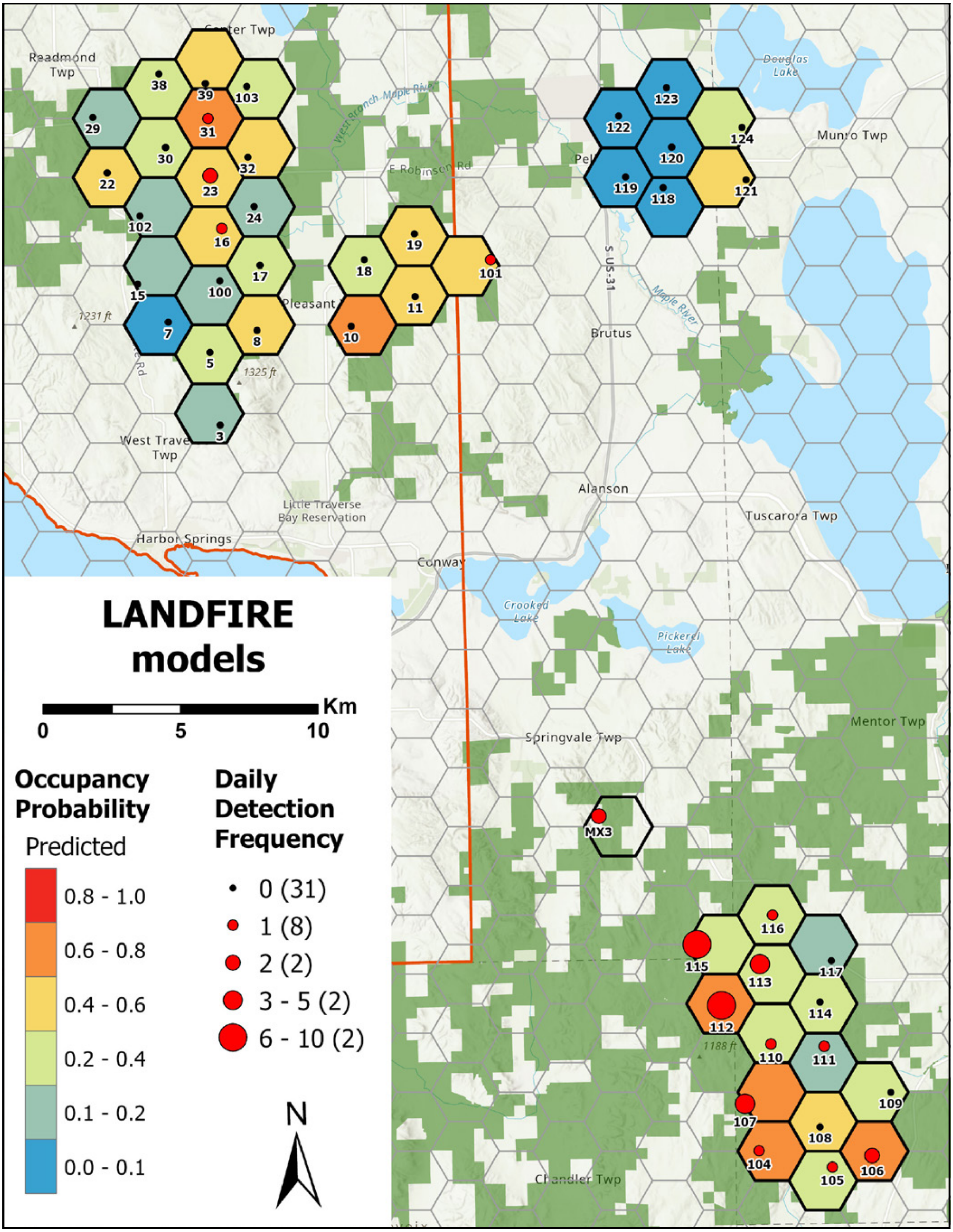

Figure 9. Predicted marten occupancy probability as a function of occupancy covariates included in the top-supported model (i.e., upland deciduous forest). Marten daily detection frequency is included for reference to raw camera trap data.

Discussion

Our application of camera traps deployed in a grid-based survey design successfully detected martens both within areas known to be occupied by martens and in areas where martens were not previously detected. However, we failed to detect either species on camera traps (sites 5, 11, 30, 108, 120) within grid cells where martens and/or fishers were detected during previous survey efforts (e.g., scat detection dog surveys). Martens may have been present but not detected by the camera traps or were truly not occupying these grid cells during our survey period. Although these sites failed to detect marten, they varied greatly in occupancy probability predicted from the top supported LANDFIRE model, reflecting the associated land cover differences among grid cells.

For example, sites 5, 11, and 30 in the Pleasant View region and site 108 in the Weber/Mason Pit region were dominated by upland deciduous forest and had predicted occupancy probability range from 0.2 (SE = 0.2) to 0.6 (SE = 0.2) (Figure 9). Conversely, site 120 in the Douglas Lake region was dominated by upland conifer forest and managed tree plantation and had a very low predicted marten occupancy probability of 0.06 (SE = 0.08). This difference in predicted occupancy is driven by these differences in land cover type, where the upland deciduous forests dominating the Pleasant View and Weber/Mason Pit sites were predicted to contain more suitable marten habitat than the Douglas Lake site dominated by upland conifer forest and managed tree plantation. However, other studies in the NLP found that marten selected for upland conifer and mixed forests within core home ranges, whereas upland deciduous forests were avoided (McFadden 2007, Buchanan 2008). These studies estimated marten habitat selection within core home range areas (i.e., ~2 km^2) using radiotelemetry, whereas we assessed the influence of land cover composition more broadly (i.e., 4 km^2). Therefore, our analysis more likely approximates habitat associations at the entire home range area, which corroborates marten resource use at similar scales found by other studies where martens occupy upland deciduous dominated landscapes (McFadden 2007, Gehring, et al. 2019, Roloff et al. 2020). This variability highlights the importance of evaluating habitat associations at different spatial scales before inferring ecological relationships or recommending conservation actions (Wevers et al. 2021).

Although LANDFIRE land cover classifications provided some support for expected marten habitat associations in this region (Gehring et al. 2019), uncertainty among land cover relationships to marten occupancy probability precluded prediction of habitat associations to non-surveyed portions of the study area (e.g., Wilton 2020). Increasing the surveyed area and/or changing the scale of land cover covariates may improve occupancy model results and enable more meaningful inference throughout the study area (Wilton 2020, Wevers et al. 2021). MiFI variables also were poor overall predictors of marten occupancy probability. Variation in MiFI spatial coverage within grid cells and among stand-level data accuracy may have limited the reliability of this data source for quantifying marten habitat

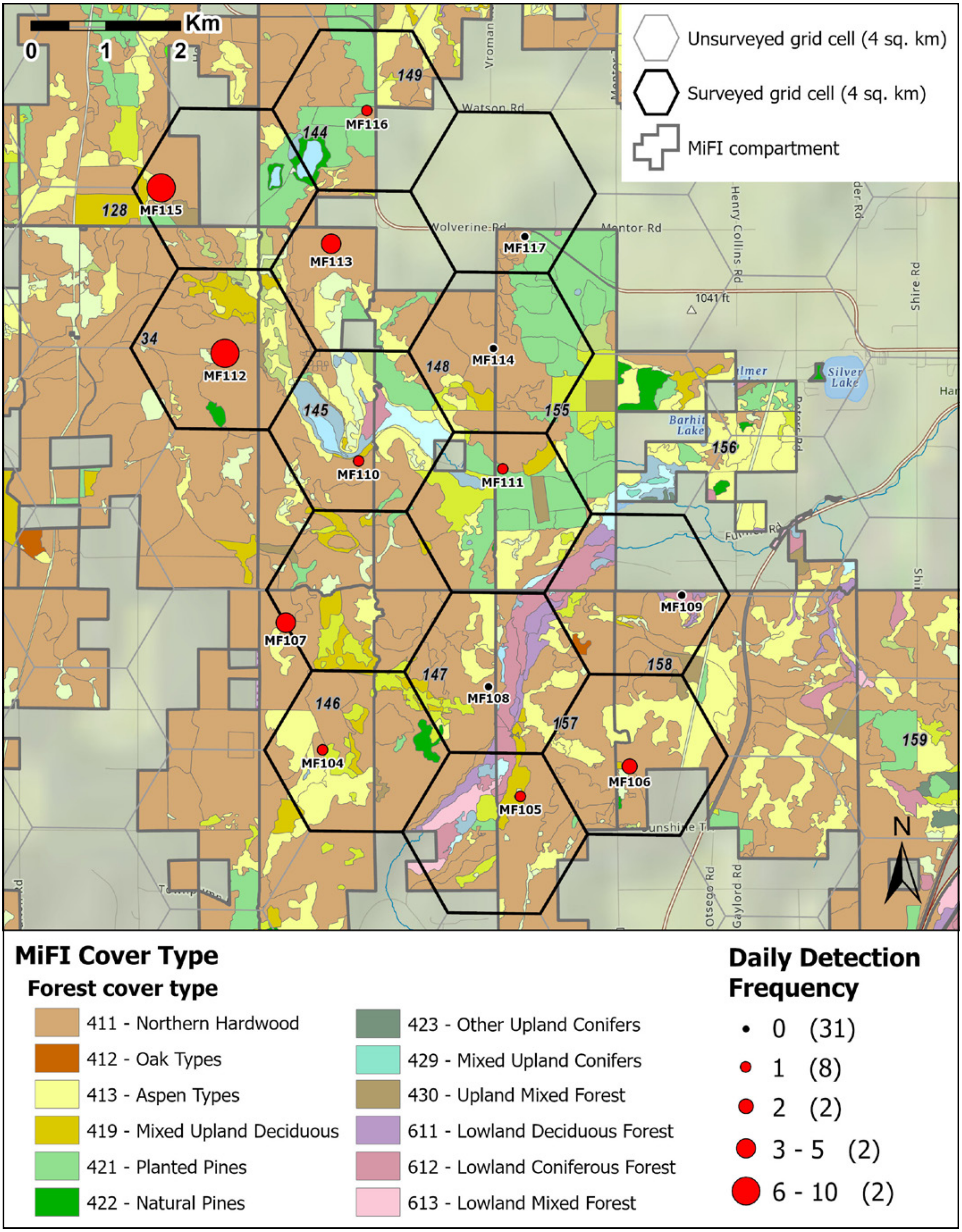

Figure 10a. Number of daily marten detections in the Weber/Mason Pit region (Chandler Hills) during January–May 2020 in relation to MiFI stand cover type classification and state forest compartment boundaries.

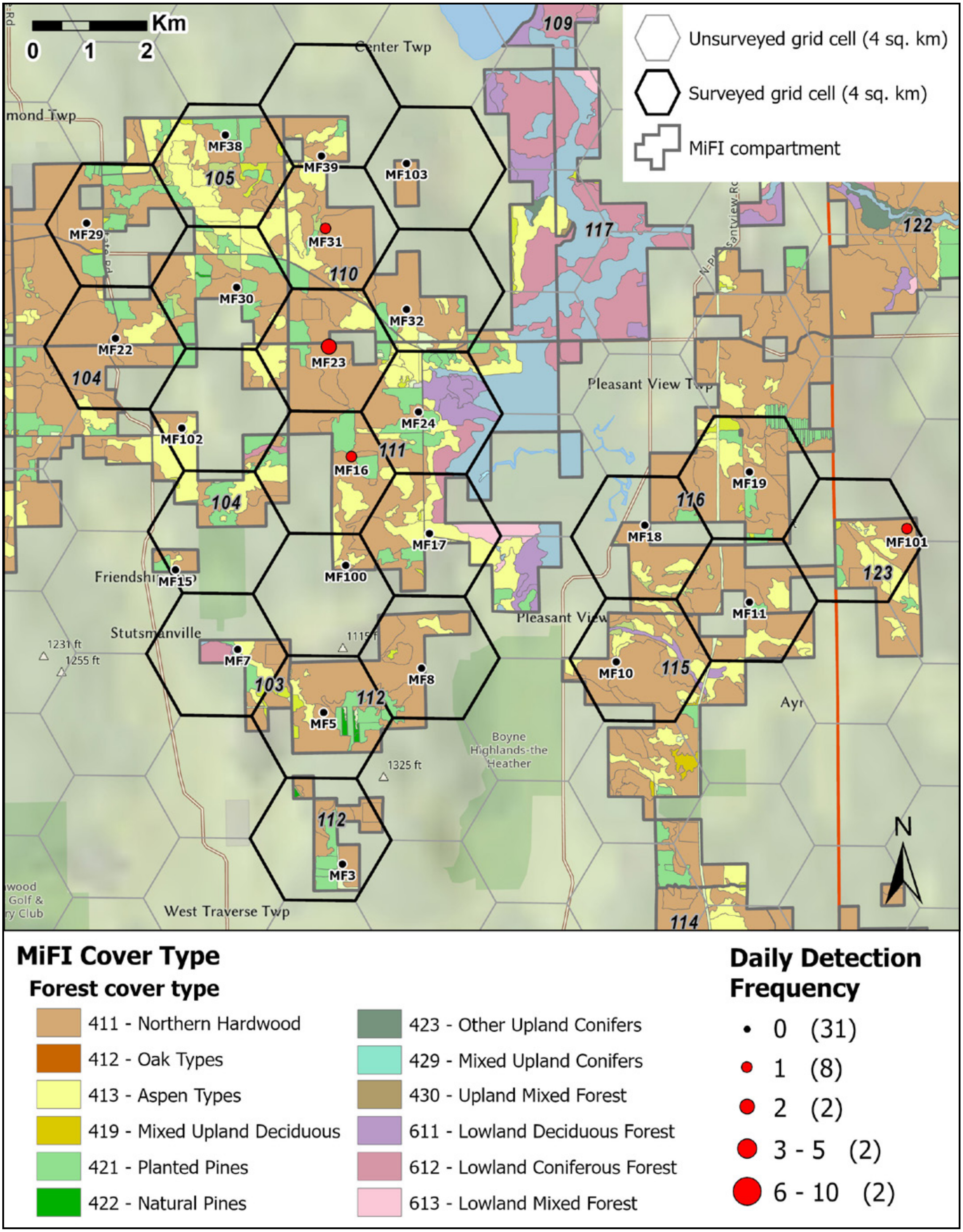

Figure 10b. Number of daily marten detections in the Pleasant View region (Emmet Moraines) during January–May 2020 in relation to MiFI stand cover type classification and state forest compartment boundaries.

use. Evaluating MiFI stand variables to predict drivers of marten occupancy was important because these inventory data are directly used to implement forest management practices relevant to marten ecology (e.g., timber extraction).

Composite photo of a marten next to one of its prey species, a red squirrel, at camera site MF112.

Several ecological and statistical factors may have precluded robust inference of marten occupancy from LANDFIRE and MiFI data sources. Marten habitat selection may be more driven by fine-scale habitat features (e.g., horizontal and vertical structure; Buskirk and Powell 1994) than by coarse-scale land cover classifications (Silet 2017). We attempted to incorporate fine-scale habitat characteristics into our model sets, both as predictors of detection probability (i.e., CWD) and occupancy probability (i.e., SD9). Although our measure of CWD abundance at camera trap sites was subjective and may have varied greatly among observers, it was positively and significantly associated with marten detection probability. This supports the general understanding that CWD is an important characteristic of marten habitat and that this variable deserves a more detailed and objective assessment in future survey efforts.

We also assessed if the MiFI Size Density variable (SD9) may serve as an index for stands having more fine-scale natural features associated with suitable marten habitat. This variable was included in supported models (ΔAIC = 1.9) but was not a significant predictor of marten occupancy. Although upland forests with larger trees and greater overall canopy cover indicative of the SD9 class are often associated with fine-scale features critical to marten life history requirements (Payer and Harrison 2003, Fuller and Harrison 2005, Nichols 2016), variation in this relationship among stands having a SD9 classification likely minimized its effectiveness at predicting marten occupancy across the landscape. Another explanation may be that much of the suitable marten habitat within our study area is unoccupied by martens, such that unoccupied grid cells with a high proportion of SD9 Size Density stands are minimizing any genuine positive association with marten habitat use.

A similar pattern may explain the lack of relationship between marten occupancy and the relative abundance of prey at camera trap sites. Sites with high prey abundance but low marten occupancy does not infer poor quality habitat in and of itself, but either that marten have not yet colonized these patches or that other site-level factors not measured are driving occupancy patterns. The method to estimate prey relative abundance from camera traps may also have confounded the true relationship between marten and their prey abundance. For example, instances where a small number of individual prey animals are frequently detected at a site will result in a relative abundance similar to sites with high actual abundance. Therefore, this approach may poorly reflect prey abundance at a scale meaningful to marten occupancy. Explicitly incorporating prey abundance or co-occurrence within the occupancy modeling framework may improve estimation of the relationship between marten resource use and their prey abundance (Sweitzer et al. 2016, Kafley et al. 2019).

Conclusions & Management Recommendations

Interpretation of habitat use metrics in landscapes sparsely or patchily occupied by animal populations must be done with caution (Greene and Stamps 2001). Land covers or regions with low occupancy probability may not necessarily infer unsuitable habitat, rather that colonization of all suitable land cover types has not yet occurred. By explicitly accounting for detection probability and variation in land cover composition, occupancy modeling allows for predictions to be made about marten habitat suitability where martens were not detected. However, these predictions may not be reliable for minor land cover types occurring over a small proportion of the landscape. For example, upland conifer forest only comprised an average of 8% of surveyed grid cells and much of this area can be attributed to the Douglas Lake sites where no martens were detected.

Although our analysis suggested low marten occupancy probability in this region, its potential for suitable marten habitat should not be discredited (Buchanan 2008, Gehring et al. 2019).

Camera traps used within an occupancy modeling framework were an effective tool to understand broad occurrence and distribution patterns of this rare and elusive small carnivore. In a non-harvested population whose range is poorly understood, camera traps are a cost-effective and informative method for improving what we know about marten distribution in the NLP (Fuller et al. 2016). Their ability to continuously collect data for long time periods make them ideal tools for detecting rare species occurring at low densities. However, robust statistical relationships between marten occupancy probability and MiFI land cover variables were of limited utility within this study design. We suggest general relationships derived from this survey are most useful for identifying specific MiFI stands or groups of adjacent stands that are known, or likely, to be seasonally occupied by marten to inform where intensive silviculture (e.g., clearcutting) should be avoided or adapted on state forest lands (see Figures 10a-b and Appendix VI). MiFI stand data may also be informative for assessing relationships between marten occupancy and stand treatment history (e.g., timber harvest history).

Although limited in ecological complexity, this knowledge provides an essential foundation to further study this low and patchily distributed marten population. Moving beyond this foundation may be accomplished with several approaches. First, increasing the spatial distribution of camera traps under the same sampling design throughout the study area will help provide a more complete understanding of the spatial extent of occupied marten habitat. We also recommend assessing land cover associations at different spatial scales (e.g., 2 km^2) to assess the relationship more thoroughly between scale and marten habitat associations. Second, once a satisfactory distributional extent is attained, decisions about methods to further improve our understanding of more fine-scale marten ecology and conservation needs can be efficiently assessed. For example, increasing the density of camera traps in known marten areas (e.g., specific state forest compartments) may provide more specific information about which stands marten are using or using with greater frequency (Root 2020). If even finer scale information on marten resource selection is desired, live-trapping and deploying GPS tracking collars can provide high resolution and high frequency data on seasonal resource use (Doster et al. 2015, Roloff et al. 2020), den site selection (Nichols 2016, Sander et al. 2017), spatial ecology (Gehring et al. 2019), and genetic health (Hillman et al. 2017). These fine-scale monitoring methods should also be combined with fine-scale and detailed assessments of the habitat features (e.g., horizontal and vertical woody structure) within stands that may be more directly affecting marten habitat use than coarse-scale land cover features assessed in this survey (Monfils et al. 2011, Silet 2017, Roloff et al. 2020).

Results of this study also may serve as a baseline for monitoring the long-term status of these species within the NLP. These applications include investigation of colonization-extinction patterns in relation to silvicultural practices or ecological processes on state forest lands, identification of priority conservation areas and wildlife management needs, and accumulation of basic knowledge about marten and fisher ecology in Michigan. Our general survey design paired with occupancy models performed over multiple years may also be used to determine a minimum occupancy threshold for consideration of a marten harvest season (Fuller et al. 2016). Although occupancy estimates may not accurately reflect population density, spatial patterns in occupancy may serve as a useful index of spatial patterns in density (Clare et al. 2015). This study also may provide useful information for developing related studies of martens and fishers. For example, our camera trap survey results could provide a foundation for developing scat-detection dog surveys (Thompson et al. 2012, Moriarty et al. 2018) or specialized camera trap surveys to identify

unique pelage markings if estimates of marten population density are desired (Drummey 2021). Independent estimates of density may also be useful for validating occupancy estimates as a useful metric for informing management decisions (Fuller et al. 2016).

Martens are designated Featured Species within the Chandler Hills Management Area (Weber Lake/Mason Pit sites), but not within the Emmet Moraines Management Area (Pleasant View and Douglas Lake sites). Our survey highlights the Emmet Moraines as being at least partially occupied by martens with moderate to high predicted occupancy probability throughout much of the state forest lands. Although suitable habitat for martens is recognized within the Emmet Moraines (MDNR 2013), elevating martens to a Featured Species will help ensure forest management activities maintain and improve existing suitable habitat. Specifically, forest management should prioritize conservation and restoration of mature forested tracts encompassing forested corridors that connect suitable habitat to source populations (e.g., Emmet Moraines to Chandler Hills). Additional management activities in northern hardwood stands that retain large diameter (> 38 cm diameter at breast-height) trees, potential cavity trees, and increase coarse woody debris (standing and down) abundance should also be prioritized (Monfils et al. 2011, MDNR 2013, Buskirk and Powell 1994, Nichols 2016).

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Appendix I. Raw camera trap site data from field data sheets.

Site	Set.By	Setup Date	Vist.1	Visit.2	Retrieval Date	Problem1 From	Problem1 To	Detection Distance	CWD
MF3	SM	1/9/2020	2/3/2020	3/2/2020	5/4/2020			45	LOW
MF5	SM	1/9/2020	2/3/2020	3/2/2020	5/4/2020			20	LOW
MF7	SM	1/9/2020	2/3/2020	3/2/2020	5/4/2020			12	LOW
MF8	SM	1/9/2020	2/3/2020	3/2/2020	5/4/2020	1/9/2020	2/3/2020	10	MED
MF10	SM	1/13/2020	2/4/2020	3/3/2020	5/5/2020			8	HIGH
MF11	SM	1/13/2020	2/4/2020	3/3/2020	5/5/2020			12	LOW
MF15	KH	1/10/2020	2/3/2020	3/2/2020	5/4/2020			NA	LOW
MF16	KH	1/9/2020	2/3/2020	3/2/2020	5/4/2020			NA	MED
MF17	KH	1/9/2020	2/3/2020	3/2/2020	5/4/2020			NA	LOW
MF18	SM	1/13/2020	2/4/2020	3/3/2020	5/5/2020			40	LOW
MF19	KH	1/13/2020	2/4/2020	3/3/2020	5/5/2020	1/13/2020	2/4/2020	NA	MED
MF22	KH	1/10/2020	2/5/2020	3/3/2020	5/4/2020			NA	HIGH
MF23	SM	1/10/2020	2/3/2020	3/2/2020	5/5/2020			10	HIGH
MF24	KH	1/9/2020	2/3/2020	3/2/2020	5/5/2020			NA	MED
MF29	KH	1/10/2020	2/5/2020	3/3/2020	5/5/2020			NA	HIGH
MF30	KH	1/10/2020	2/3/2020	3/2/2020	5/5/2020			NA	LOW
MF31	SM	1/10/2020	2/5/2020	3/3/2020	5/5/2020			30	MED
MF32	SM	1/10/2020	2/5/2020	3/3/2020	5/5/2020			25	MED
MF38	SM	1/10/2020	2/5/2020	3/3/2020	5/5/2020			15	LOW
MF39	SM	1/10/2020	2/5/2020	3/3/2020	5/5/2020			15	LOW
MF100	SM	1/10/2020	2/3/2020	3/2/2020	5/4/2020			15	MED
MF101	KH	1/13/2020	2/4/2020	3/3/2020	5/5/2020	1/13/2020	2/4/2020	NA	LOW
MF102	KH	1/10/2020	2/3/2020	3/2/2020	5/4/2020			NA	HIGH
MF103	SM	1/10/2020	2/5/2020	3/3/2020	5/5/2020			30	LOW
MF104	MF,BP	1/14/2020	2/6/2020	3/2/2020	5/4/2020			12	LOW
MF105	MF,BP	1/13/2020	2/5/2020	3/2/2020	5/4/2020			12	LOW
MF106	MF,BP	1/14/2020	2/6/2020	3/2/2020	5/4/2020			25	LOW
MF107	MF,BP	1/14/2020	2/6/2020	3/2/2020	5/4/2020			10	MED
MF108	MF,BP	1/13/2020	2/5/2020	3/2/2020	5/4/2020			12	LOW
MF109	MF,BP	1/14/2020	2/5/2020	3/2/2020	5/4/2020			12	MED
MF110	MF,BP	1/13/2020	2/5/2020	3/2/2020	5/4/2020			25	MED
MF111	MF,BP	1/13/2020	2/5/2020	3/2/2020	5/4/2020			15	HIGH
MF112	MF,CW	1/9/2020	2/5/2020	3/2/2020	5/4/2020			27	HIGH
MF113	MF,BP	1/13/2020	2/5/2020	3/2/2020	5/4/2020			18	MED
MF114	MF,BP	1/13/2020	2/5/2020	3/2/2020	5/4/2020			12	HIGH
MF115	MF,CW	1/9/2020	2/6/2020	3/2/2020	5/4/2020			NA	MED
MF116	MF	1/10/2020	2/3/2020	3/3/2020	5/6/2020			18	MED
MF117	MF	1/10/2020	2/3/2020	3/3/2020	5/6/2020			44	MED
MF118	BP	1/17/2020	2/7/2020	3/4/2020	5/5/2020			14	HIGH

Site	Set.By	Setup Date	Vist.1	Visit.2	Retrieval Date	Problem1 From	Problem1 To	Detection Distance	CWD
MF119	BP	1/17/2020	2/7/2020	3/4/2020	5/5/2020			12	LOW
MF120	BP	1/10/2020	2/7/2020	3/4/2020	5/5/2020			12	HIGH
MF121	BP	1/10/2020	2/7/2020	3/4/2020	5/5/2020			12	LOW
MF122	BP	1/10/2020	2/4/2020	3/3/2020	5/5/2020	4/17/2020	5/5/2020	10	NONE
MF123	BP	1/9/2020	2/4/2020	3/3/2020	5/5/2020			10	MED
MF124	BP	1/10/2020	2/4/2020	3/3/2020	5/5/2020			12	HIGH

Appendix II. Camera deployment and checking protocol and field data sheet.

MARTEN-FISHER PROJECT - CAMERA SETTING PROTOCOL

Camera Deployment

- Within about a **100-meter** radius of the planned GPS point search around the GPS point until you find a location having a suitable field of view to allow martens and fishers to be photographed.
    a. Avoid placing cameras on human-use roads and trails to minimize theft/vandalism. Also try to avoid having the camera face roads/trails if possible.
    b. If the planned camera location is inaccessible, try to find an accessible location within the same or similar habitat within the grid cell, if possible.
    c. **Also try to maintain at least a 1.3-mile distance between adjacent cameras, but just do the best you can.** This is the center-to-center distance between adjacent grid cells.

Camera Site Details

- Set cameras facing available coarse woody debris (CWD) features that may facilitate detection. Marten often use these features for hunting and traveling during winter; large diameter logs may be better features if available and multiple stacked logs even better.
    a. Place cameras about **2–3 ft** (**about knee-waist height**) above ground to a sturdy tree and about **10 ft** from the target detection zone (e.g., log). But you can adapt this to the situation as needed (e.g., it is better to make sure you are getting a good and clear angle on the coarse woody debris feature than it is to stick to these numbers).
    b. If possible, set the camera on a tree at about a **45-degree angle to the log feature** (see below photos for examples). This maximizes the time a traveling animal is within the camera's detection zone. With this set up, cameras can often be placed closer (~5 ft) from the log.
    c. Record the feature you chose to place the camera at (***Set Type***). This should be some kind of coarse woody debris feature (log(s), root mound/tip-up, tree snags), but if you cannot find adequate CWD, describe the type of set you used.
    d. Set cameras facing **North**, if possible, and record the bearing (***Camera Bearing***).
    e. If necessary, angle cameras **slightly downward** toward the target using a small stick placed between the camera and tree. This can be helpful when trying to exclude unnecessary canopy elements from the frame (see below photo examples).

Neither of these camera setups follow my 45-degree angle suggestion but were very successful at detecting marten. The complex structure (e.g., stacked logs and root masses) of the coarse woody debris in these sets was likely very attractive to marten and helped encourage them to explore the features and increase their detection probability. Note also that most of the frame is focused towards the ground, excluding much of the canopy; this maximizes the use of the sensor's full detection zone for marten/fisher.

Aiming the camera down the length of a log maximizes the likelihood an animal traveling along the log will trigger the camera's sensor.

If you find a nice log feature but cannot aim the camera down the log, make sure the camera is set far enough away to capture as much of the log as possible while still being close enough to have a marten trigger the sensor (probably about 10–15 feet depending on size of log). Both of these sets were obviously successful, but the set on the left will detect an animal over a much greater length of the target feature than the set on the right.

f. **Double check your camera angle and framing by checking the view on the camera's LCD screen**.
g. **Clear vegetation obstructing the camera's detection zone and vegetation that may falsely trigger the camera.** Check the edges of the frame as well for branches that may trigger the sensor

This set was otherwise perfect except for this nuisance beech branch at the edge of the frame that kept triggering the sensor every time the wind blew. Most of the time this branch was not even within the frame.

h. Set the camera to **Motion Test** mode and walk back-and-forth in front of the camera at increasing distances from the camera. Record the approximate distance (***Detection Dist***) between you and the camera when the red light stops flashing (i.e., stops detecting you).
i. Circle the most appropriate **Habitat Type** for the location of the camera trap.

ACTIVATE THE CAMERA

1) Turn the camera on.
2) **Name the camera "CAMERA ##" with the site's ID number.**
3) **Double check cameras are on <u>2-shot Rapidfire</u> with <u>1-sec delay</u> between triggers.**
4) **Double check the Date and Time stamp are correct before activating the camera.**
5) Double check the camera is set to "Trail cam".
6) Navigate back to the main screen.
7) Check the angle of the camera (you can take a picture by pressing the center "E" button).

The first picture

- Once the camera is set and activated, trigger the camera by holding the whiteboard with **DATE**, **TIME**, **CAMERA ID#**, **SD ID#**, **VISIT #,** and your **INITIALS.**

<u>Camera checking protocol</u>

1) When you arrive at the camera, trigger the camera by holding the whiteboard with **DATE**, **TIME**, **CAMERA ID#**, **SD ID#**, **INITIALS,** and **VISIT #.** This step confirms to me that the camera was operational during the entire period.
2) Record the SD ID # on the datasheet, make sure it is clearly written on the SD card you are removing from the camera, and record the number of pictures taken on the datasheet.
3) Reapply lure at the site.
4) Once the camera has been loaded with the new SD card, retake the whiteboard photo with new SD ID # and Visit #. This signifies the start of the next session and is a good way to make sure the camera is operational before leaving.

Example of whiteboard photo taken at first deployment, camera maintenance checks, and camera retrieval. This shows that the camera was functional at the beginning and end of a deployment period and provides enough data to correct any date/time stamp or site naming errors.

LTBB ODAWA CAMERA TRAP DATASHEET 2019

CAMERA DEPLOYMENT		
Observer Initials:		
Camera ID:		***SD ID:
Planned UTMs:	**E:**	**N:**
Actual UTMs:	**E:**	**N:**
Waypoint ID:		

HABITAT	
Horizontal cover density: shrub/tree	None / Low / Med / High
Coarse Woody Debris:	None / Low / Med / High
Other natural/human features: *E.g., timber harvest, power line cut, topography, windthrow, wet soils, etc.	

CAMERA SITE DETAILS	*E.g., game trail, ORV trail, stream, river, pond
Set Type:	Trail / Water / Log / Other:
Set Type Details*:	
Mount:	Tree / Other:
Camera Bearing:	
Detection Dist (ft):	

DOMINANT VEGETATION
Canopy:
Sub-canopy:

Visit	**Initials**	**Date**	**Time (military)**	****** SD ID**	**Cam Status**	**# of images**	**Battery life**	**Lure type**	**Notes** (malfunctions, vandalism, cam moved by animals, animal sign, weather, other observations) *more space on back of page

Appendix III. Reclassification of LANDFIRE's existing vegetation classification used to estimate the percentage of each cover type class per 4-km^2 grid cell.

Group Name - Reclassified	Group Name - Original	Physiognomy
Agriculture	Agricultual-Aquaculture	Agricultural
Agriculture	Agricultural-Bush fruit and berries	Agricultural
Agriculture	Agricultural-Close Grown Crop	Agricultural
Agriculture	Agricultural-Fallow/Idle Cropland	Agricultural
Agriculture	Agricultural-Orchard	Agricultural
Agriculture	Agricultural-Pasture and Hayland	Agricultural
Agriculture	Agricultural-Row Crop	Agricultural
Agriculture	Agricultural-Row Crop-Close Grown Crop	Agricultural
Agriculture	Agricultural-Vineyard	Agricultural
Agriculture	Agricultural-Wheat	Agricultural
Developed	Developed-High Intensity	Developed-High Intensity
Developed	Developed-Low Intensity	Developed-Low Intensity
Developed	Developed-Medium Intensity	Developed-Medium Intensity
Developed	Quarries-Strip Mines-Gravel Pits-etc.	Quarries…
Developed-Lowland Forests	Developed-Wetland Mixed Forest	Developed
Developed-Mixed Forest	Developed-Upland Mixed Forest	Developed
Developed-Nonforested Lowland	Developed-Wetland Herbaceous	Developed
Developed-Nonforested Lowland	Developed-Wetland Shrubland	Developed
Developed-Nonforested Upland	Developed-Upland Herbaceous	Developed
Developed-Nonforested Upland	Developed-Upland Shrubland	Developed
Developed-Roads	Developed-Roads	Developed-Roads
Developed-Upland Deciduous Forest	Developed-Upland Deciduous Forest	Developed
Developed-Upland Evergreen Forest	Developed-Upland Evergreen Forest	Developed
Lowland Forest	Atlantic Swamp Forests	Riparian
Lowland Forest	Eastern Floodplain Forests	Riparian
Lowland Forest	Eastern Small Stream Riparian Forests	Riparian
Lowland Forest	Peatland Forests	Riparian
Managed Tree Plantation	Managed Tree Plantation	Conifer
Mixed Forest	Pine-Hemlock-Hardwood Forest	Conifer
Mixed Forest	Pine-Hemlock-Hardwood Forest	Conifer-Hardwood

Appendix III. continued...

Group Name - Reclassified	Group Name - Original	Physiognomy
Mixed Forest	Pine-Hemlock-Hardwood Forest	Hardwood
Mixed Forest	Spruce-Fir-Hardwood Forest	Conifer
Mixed Forest	Transitional Forest Vegetation	Conifer
Nonforested Wetland	Inland Marshes and Prairies	Riparian
Nonforested Wetland	Introduced Herbaceous Wetland Vegetation	Riparian
Nonforested Wetland	Wet Meadow	Riparian
Open Water	Open Water	Open Water
Other Forested	Hardwood Flatwoods	Hardwood
Other Forested	Ruderal Forest	Conifer-Hardwood
Other Nonforested	Atlantic Dunes and Grasslands	Grassland
Other Nonforested	Great Lakes Alvar	Shrubland
Other Nonforested	Introduced Perennial Grassland and Forbland	Exotic Herbaceous
Other Nonforested	Introduced Upland Vegetation-Shrub	Exotic Tree-Shrub
Other Nonforested	Sparse Vegetation	Sparsely Vegetated
Other Nonforested	Tallgrass Prairie	Grassland
Other Nonforested	Transitional Herbacous Vegetation	Grassland
Other Nonforested	Transitional Shrub Vegetation	Shrubland
Upland Conifer Forest	Jack Pine Forest	Conifer
Upland Conifer Forest	Jack Pine Forest	Conifer-Hardwood
Upland Conifer Forest	Jack Pine Forest	Hardwood
Upland Conifer Forest	Red Pine-White Pine Forest and Woodland	Conifer
Upland Conifer Forest	Red Pine-White Pine Forest and Woodland	Conifer-Hardwood
Upland Conifer Forest	Red Pine-White Pine Forest and Woodland	Hardwood
Upland Deciduous Forest	Aspen-Birch Forest	Hardwood
Upland Deciduous Forest	Beech-Maple-Basswood Forest	Hardwood
Upland Deciduous Forest	Black Oak Woodland and Savanna	Hardwood
Upland Deciduous Forest	Bur Oak Woodland and Savanna	Hardwood
Upland Deciduous Forest	White Oak-Red Oak-Hickory Forest	Hardwood
Upland Deciduous Forest	Yellow Birch-Sugar Maple Forest	Hardwood

Appendix IV [Table 1]. A subset of carnivore species and non-target animals identified in camera trap images. Unique Events refers to the number of images taken of a given species that occurred at least 30 minutes apart (note that occupancy detections were based on daily detections and may differ from values here). Number of sites refers to the number of unique camera sites where a species was detected.

Common Name	Order	Family	Species Name	Unique Events	Number of Sites
American Badger	Carnivora	Mustelidae	*Taxidea taxus*	4	3
American Black Bear	Carnivora	Ursidae	*Ursus americanus*	5	2
American Marten	Carnivora	Mustelidae	*Martes americana*	41	14
American Mink	Carnivora	Mustelidae	*Neovison vison*	1	1
Bobcat	Carnivora	Felidae	*Lynx rufus*	3	3
Coyote	Carnivora	Canidae	*Canis latrans*	117	31
Weasels	Carnivora	Mustelidae	*Mustela frenata, erminea*	57	26
Red Fox	Carnivora	Canidae	*Vulpes vulpes*	64	23
Other[a]	NA	NA	NA	1173	44
Prey[b]	NA	NA	NA	5197	45

[a]Other: common raccoon, Virginia opossum, striped skunk, woodchuck, common porcupine, white-tailed deer, and all avian species.

[b]Prey: squirrels [*Glaucomus* spp., *Sciurus* spp., *Tamias striatus*, *Tamiasciurus hudsonicus*], rabbits and hares [*Sylvilagus floridanus, Lepus americanus*], and small rodents [*Peromyscus* spp., *Microtus* spp., *Napaeozapus insignis*]).

Appendix IV [Table 2]. Species-level and group-level classifications for carnivores and their associated frequency of detections aggregated at 30-minute intervals at each camera trap station.

Site	**Common Name**	**Order**	**Family**	Species Name	**Unique Events**
MF10	American Badger	Carnivora	Mustelidae	*Taxidea taxus*	2
MF31	American Badger	Carnivora	Mustelidae	*Taxidea taxus*	1
MF112	American Badger	Carnivora	Mustelidae	*Taxidea taxus*	1
MF22	American Black Bear	Carnivora	Ursidae	*Ursus americanus*	3
MF114	American Black Bear	Carnivora	Ursidae	*Ursus americanus*	2
MF16	American Marten	Carnivora	Mustelidae	*Martes americana*	1
MF23	American Marten	Carnivora	Mustelidae	*Martes americana*	2
MF31	American Marten	Carnivora	Mustelidae	*Martes americana*	1
MF101	American Marten	Carnivora	Mustelidae	*Martes americana*	1
MF104	American Marten	Carnivora	Mustelidae	*Martes americana*	1
MF105	American Marten	Carnivora	Mustelidae	*Martes americana*	1
MF106	American Marten	Carnivora	Mustelidae	*Martes americana*	2
MF107	American Marten	Carnivora	Mustelidae	*Martes americana*	4
MF110	American Marten	Carnivora	Mustelidae	*Martes americana*	1
MF111	American Marten	Carnivora	Mustelidae	*Martes americana*	1
MF112	American Marten	Carnivora	Mustelidae	*Martes americana*	10
MF113	American Marten	Carnivora	Mustelidae	*Martes americana*	5
MF115	American Marten	Carnivora	Mustelidae	*Martes americana*	10
MF116	American Marten	Carnivora	Mustelidae	*Martes americana*	1
MF17	American Mink	Carnivora	Mustelidae	*Neovison vison*	1
MF117	Bobcat	Carnivora	Felidae	*Lynx rufus*	1
MF120	Bobcat	Carnivora	Felidae	*Lynx rufus*	1
MF123	Bobcat	Carnivora	Felidae	*Lynx rufus*	1
MF3	Coyote	Carnivora	Canidae	*Canis latrans*	9
MF11	Coyote	Carnivora	Canidae	*Canis latrans*	1
MF16	Coyote	Carnivora	Canidae	*Canis latrans*	1
MF17	Coyote	Carnivora	Canidae	*Canis latrans*	8
MF18	Coyote	Carnivora	Canidae	*Canis latrans*	1
MF19	Coyote	Carnivora	Canidae	*Canis latrans*	1
MF22	Coyote	Carnivora	Canidae	*Canis latrans*	2
MF23	Coyote	Carnivora	Canidae	*Canis latrans*	1
MF24	Coyote	Carnivora	Canidae	*Canis latrans*	4
MF29	Coyote	Carnivora	Canidae	*Canis latrans*	2
MF39	Coyote	Carnivora	Canidae	*Canis latrans*	2
MF102	Coyote	Carnivora	Canidae	*Canis latrans*	2
MF104	Coyote	Carnivora	Canidae	*Canis latrans*	5
MF105	Coyote	Carnivora	Canidae	*Canis latrans*	5
MF106	Coyote	Carnivora	Canidae	*Canis latrans*	2
MF107	Coyote	Carnivora	Canidae	*Canis latrans*	6

Appendix IV [Table 2]. Continued...

Site	Common Name	Order	Family	Species Name	Unique Events
MF108	Coyote	Carnivora	Canidae	*Canis latrans*	1
MF109	Coyote	Carnivora	Canidae	*Canis latrans*	3
MF110	Coyote	Carnivora	Canidae	*Canis latrans*	4
MF111	Coyote	Carnivora	Canidae	*Canis latrans*	1
MF112	Coyote	Carnivora	Canidae	*Canis latrans*	10
MF113	Coyote	Carnivora	Canidae	*Canis latrans*	3
MF114	Coyote	Carnivora	Canidae	*Canis latrans*	4
MF115	Coyote	Carnivora	Canidae	*Canis latrans*	3
MF116	Coyote	Carnivora	Canidae	*Canis latrans*	2
MF117	Coyote	Carnivora	Canidae	*Canis latrans*	3
MF118	Coyote	Carnivora	Canidae	*Canis latrans*	14
MF119	Coyote	Carnivora	Canidae	*Canis latrans*	9
MF120	Coyote	Carnivora	Canidae	*Canis latrans*	1
MF122	Coyote	Carnivora	Canidae	*Canis latrans*	2
MF123	Coyote	Carnivora	Canidae	*Canis latrans*	5
MF3	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	2
MF8	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	2
MF15	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	3
MF18	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	1
MF22	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	8
MF30	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	1
MF31	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	1
MF32	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	2
MF38	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	2
MF39	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	5
MF102	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	4
MF104	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	1
MF105	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	1
MF106	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	3
MF107	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	3
MF108	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	1
MF112	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	4
MF113	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	10
MF114	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	5
MF115	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	1
MF117	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	1
MF121	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	2
MF124	Red Fox	Carnivora	Canidae	*Vulpes vulpes*	1

Appendix IV [Table 2]. Continued...

Site	Common Name	Order	Family	Species Name	Unique Events
MF5	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	2
MF8	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	4
MF10	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	5
MF11	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	1
MF17	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	1
MF18	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	1
MF19	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	2
MF22	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	3
MF23	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	5
MF24	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	5
MF30	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	1
MF31	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	4
MF39	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	1
MF100	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	1
MF103	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	1
MF104	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	1
MF105	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	1
MF106	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	1
MF109	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	2
MF110	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	1
MF111	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	4
MF112	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	3
MF114	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	2
MF120	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	3
MF123	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	1
MF124	Weasel spp	Carnivora	Mustelidae	*Mustela* spp	1

Appendix V. Marten detection history where each survey occasion (e.g., o1) represents a 5-day period for each camera trap site in which a marten was either detected [1] or not detected [0] during January-May 2020.

Site No.	o1	o2	o3	o4	o5	o6	o7	o8	o9	o10	o11	o12	o13	o14	o15	o16	o17	o18	o19	o20	o21	o22	o23
MF 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 8	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 10	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 11	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 15	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 16	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
MF 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 18	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 19	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 22	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 23	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
MF 24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 29	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 30	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 31	NA	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 32	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 38	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 39	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 100	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 101	NA	NA	NA	NA	NA	NA	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
MF 102	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 103	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 104	NA	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
MF 105	NA	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
MF 106	NA	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 107	NA	1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
MF 108	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 109	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 110	NA	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 111	NA	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 112	1	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	0	0	0	1	0	1	0
MF 113	NA	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0
MF 114	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 115	1	0	0	1	0	0	0	0	0	1	0	1	1	0	1	1	1	1	0	0	0	1	0
MF 116	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 117	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 118	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 119	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 120	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 121	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 122	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NA	NA	NA	NA
MF 123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MF 124	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix VI. MiFI stand data associated with camera trap site locations and marten detections.

Site	Marten Detec-tions	FCS_KEY	Stand	Planted Natural	Over-all Size	Age (yrs)	Basal Area	Cover Code	Size Density	CoverType	Acres
MF3	0	52112024	24	Natural	Log	97	81-110	M	9	Northern Hardwood	65
MF5	0	52112040	40	Natural	Log	92	81-110	M	9	Northern Hardwood	149
MF7	0	52103004	4	Planted	Pole	63	111-140	R	6	Red Pine	41
MF8	0	52112002	2	Natural	Pole	92	51-80	M	6	Northern Hardwood	487
MF10	0	52115043	43	Natural	Log	94	51-80	M	9	Northern Hardwood	246
MF11	0	52116039	39	Planted	Log	64	111-140	R	9	Red Pine	16
MF15	0	52104052	52	Natural	Log	106	111-140	M	9	Northern Hardwood	38
MF16	1	52111047	47	Natural	Pole	92	81-110	M	6	Northern Hardwood	427
MF17	0	52111065	65	Natural	Pole	37	51-80	A	6	Aspen	44
MF18	0	52116050	50	Natural	Pole	93	81-110	M	6	Northern Hardwood	332
MF19	0	52116044	44	Natural	Log	93	111-140	M	9	Northern Hardwood	118
MF22	0	52105078	78	Natural	Pole	81	81-110	M	6	Northern Hardwood	182
MF23	2	52111003	3	Natural	Log	80	51-80	M	9	Northern Hardwood	128
MF24	0	52111008	8	Natural	Pole	80	51-80	M	6	Northern Hardwood	251
MF29	0	52105001	1	Natural	Log	101	81-110	M	9	Northern Hardwood	306
MF30	0	52105067	67	Natural	Pole	61	18264	M	4	Northern Hardwood	60
MF31	1	52110019	19	Natural	Log	97	51-80	M	9	Northern Hardwood	277
MF32	0	52110029	29	Natural	Log	97	81-110	M	9	Northern Hardwood	187
MF38	0	52105032	32	Natural	Log	102	51-80	M	9	Northern Hardwood	104
MF39	0	52110006	6	Natural	Log	97	51-80	M	9	Northern Hardwood	43

Site	Marten Detec-tions	FCS_KEY	Stand	Planted Natural	Over-all Size	Age (yrs)	Basal Area	Cover Code	Size Density	CoverType	Acres
MF100	0	52111047	47	Natural	Pole	92	81-110	M	6	Northern Hardwood	427
MF101	1	52123014	14	Natural	Log	86	81-110	M	9	Northern Hardwood	172
MF102	0	52104029	29	Natural	Log	99	81-110	M	9	Northern Hardwood	55
MF103	0	52110013	13	Natural	Log	97	81-110	M	9	Northern Hardwood	81
MF104	1	52146040	40	Natural	Log	72	111-140	M	9	Northern Hardwood	12
MF105	1	52157032	32	Natural	Pole	81	81-110	M	6	Northern Hardwood	659
MF106	2	52158019	19	Natural	Log	83	81-110	M	9	Northern Hardwood	118
MF107	4	52146021	21	Natural	Log	81	111-140	M	9	Northern Hardwood	256
MF108	0	52147018	18	Natural	Log	83	111-140	M	9	Northern Hardwood	481
MF109	0	52158004	4	Natural	Log	88	81-110	C	9	Cedar	17
MF110	1	52145072	72	Natural	Log	99	81-110	M	9	Northern Hardwood	105
MF111	1	52155024	24	Planted	Log	87	111-140	R	9	Red Pine	81
MF112	10	52034029	29	Natural	Log	97	81-110	M	9	Northern Hardwood	174
MF113	5	52145007	7	Natural	Log	130	81-110	M	9	Northern Hardwood	211
MF114	0	52148004	4	Natural	Pole	89	81-110	M	6	Northern Hardwood	159
MF115	10	52128061	61	Natural	Log	82	81-110	M	9	Northern Hardwood	156
MF116	1	52144023	23	Planted	Log	92	111-140	R	9	Red Pine	38
MF117	0	52155006	6	Natural	Pole	90	81-110	M	6	Northern Hardwood	187
MF118	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
MF119	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
MF120	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

Site	Marten Detec-tions	FCS_KEY	Stand	Planted Natural	Over-all Size	Age (yrs)	Basal Area	Cover Code	Size Density	CoverType	Acres
MF121	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
MF122	0	52131016	16	Natural	Log	44	51-80	W	8	White Pine	96
MF123	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
MF124	0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
MX3	2	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A