

# **Role of predators, winter weather, and habitat on white-tailed deer fawn survival in the Upper Peninsula of Michigan**

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**Abstract** We captured 110 (41 male, 69 female) individual white-tailed deer (*Odocoileus virginianus*), including 48 adults, 9 yearlings, and 53 fawns. We radio-collared 33 female deer of which 33 received vaginal implant transmitters (VIT). We detected pregnancy using ultrasound in 97% of adult ( $n = 31$ ) and 33% of yearling ( $n = 2$ ) females. We captured and radio-collared 51 neonate fawns (26 male, 23 female, 2 unknown sex). Thirteen of 17 (76%) VIT searches resulted in the location of 18 live fawns. We obtained 22,730 adult female deer GPS locations, and monitored fawn survival using VHF telemetry. We located 18 radio-collared adult female white-tailed deer mortalities, 24 mortalities of radio-collared fawns born during 2019, and 15 mortalities of fawns born during 2018. To estimate deer abundance, we placed 52 remote infrared cameras throughout the study area at baited sites. We placed 52 remote infrared cameras at non-baited sites along trails throughout the study area to evaluate the effectiveness of a non-baited deer camera abundance estimate. We immobilized 8 adult black bears (*Ursus americanus*: 4 male, 4 female) in their dens and observed 3 cubs (2 male, 2 female) from 1 females and 6 yearlings (3 male, 3 female) from 3 females. From May to July we captured and immobilized 5 black bears (*Ursus americanus*; 3 male, 2 female), 1 bobcat (*Lynx rufus*; 1 male), 3 coyote (*Canis latrans*; 2 male, 1 female), and 12 wolves (*C. spp.*; 4 male, 8 female) and fitted them with GPS collars. We collected 316 hair samples and 118,459 images from bobcat hair snares and remote cameras, respectively. We collected 489 hair samples and 2,406 images from black bear hair snares and remote cameras at hair snare sites, respectively. During our howl survey we recorded an average coyote response rate of 16.25% and wolf response rate of 0.1% through 6 of 8 total sessions. We investigated 659 carnivore cluster sites to identify prey remains. We conducted a ruffed grouse (*Bonasa umbellus*) drumming survey to estimate grouse abundance and had a 50.6% average detection rate across sessions. We completed snowshoe hare (*Lepus americanus*) pellet counts at 455 random locations stratified across 6 landcovers to estimate hare densities. We used an aerial survey to estimate beaver (*Castor canadensis*) abundance and detected 14 active lodges with a cache present. We hosted volunteers from several organizations and personnel from 1 television crew, provided 13 presentations and 2 workshops, and maintained our Facebook page and website.

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## Summary

- From 14 January to 1 March we captured 110 (41 male, 69 female) individual white-tailed deer (*Odocoileus virginianus*) using clover traps, including 48 adults, 9 yearlings, and 53 fawns.
- We fitted 33 female deer with a GPS collar and a vaginal implant transmitter.
- We detected pregnancy using ultrasound in 97% of adult ( $n = 36$ ) and 33% of yearling ( $n = 6$ ) females.
- We captured and radio-collared 51 neonate fawns (26 male, 23 female, 2 unknown sex).
- Thirteen of 17 (76%) vaginal implant transmitter searches resulted in the location of 18 live fawns.
- We immobilized 8 adult black bears (*Ursus americanus*: 4 male, 4 female) in their dens and observed 3 cubs (2 male, 2 female) from 1 females and 6 yearlings (3 male, 3 female) from 3 females.
- We used cage traps to capture and fit 1 bobcat (*Lynx rufus*; 1 female) with a GPS collar.
- We captured and immobilized 5 black bears (3 male, 2 female) using barrel traps and Aldrich foot snares. We fitted each bear with a GPS collar.
- We used foothold traps to capture 1 bobcat (*Lynx rufus*; 1 male), 3 coyotes (*Canis latrans*; 2 male, 1 female), and 12 wolves (*C. spp.*; 4 male, 8 female) fitting each with a GPS collar.
- We obtained 22,730 radiolocations of adult female deer.
- We observed 18 mortalities of radio-collared adult female deer. We attributed these to 10 wolf predations, 2 starvations, 1 vehicle collision, 1 legal hunter harvest, 1 unknown predation, and 3 unknown causes. We censored 4 adult female deer from the sample because they died within 14 days of capture.
- We observed 24 mortalities of fawns born during 2019. We attributed these to 3 bear predations, 8 coyote predations, 4 wolf predations, 3 unidentified predations, 3 vehicle collisions, 1 weak fawn syndrome mortality, and 2 unknown causes. Additionally, we censored 5 fawns from the sample after their radio-collars appeared to have failed or fallen off.
- We observed 15 mortalities of fawns born during 2018. We attributed these to 1 bobcat predation, 6 wolf predations, 1 coyote predation, 1 vehicle collision, 3 unidentified predations, and 3 unknown causes.
- We placed 52 remote infrared cameras at baited sites throughout the study area to estimate deer abundance and obtained 23,666 images.

- We placed 52 remote infrared cameras at non-baited sites along trails throughout the study area as a trial method to estimate deer abundance. This survey is ongoing as of 5 September 2019.
- We deployed hair snares and remote cameras at 52 sites throughout the study area to estimate bobcat abundance. We obtained 316 hair samples and 118,459 images.
- We deployed hair snares and remote infrared cameras at 49 sites throughout the study area to estimate black bear abundance and obtained 489 hair samples and 2,406 images.
- We obtained a coyote response rate of 16.25% and wolf response rate of 0.1% to broadcasted recordings of coyote group-yip-howls during 6 of 8 sessions of coyote howl survey.
- We conducted 5 ruffed grouse (*Bonasa umbellus*) drumming survey sessions to estimate grouse abundance. Probability of detection was 50.6% resulting in an estimated density of 2.86 grouse/km<sup>2</sup>.
- We completed snowshoe hare (*Lepus americanus*) pellet count surveys at 455 random locations stratified within 6 different land cover types to estimate hare densities with respect to available land cover. Across land cover types estimated hare density was 3.83 hares/km<sup>2</sup>.
- We conducted a beaver (*Castor canadensis*) cache survey to estimate beaver abundance. We flew 235 km of river and lakeshore and detected 14 active beaver lodges with caches.
- We conducted investigations at 659 carnivore cluster sites to identify prey.
- We hosted individuals from Michigan Department of Natural Resources (MDNR), Keweenaw Bay Indian Community Natural Resources Department (KBNRD), Michigan State University, Michigan Out-of-Doors during black bear den checks and white-tailed deer trapping.
- We updated our Facebook page (<https://www.facebook.com/campfirewildlife/>) and project website (<https://campfirewildlife.com/projects/predator-prey/>) to provide the public with project results.
- We hosted undergraduate students from Purdue University for demonstrations and presentations of detection dogs, field techniques and study results.
- We hosted educators from Michigan Department of Natural Resources' Academy of Natural Resources-North for demonstrations and presentations of detection dogs, field techniques and study results.
- We gave presentations to 13 groups or organizations (including school groups) about project activities and findings.

## Introduction

Management of wildlife is based on an understanding, and in some cases, manipulation of factors that limit wildlife populations. Wildlife managers sometimes manipulate the effect of a limiting factor to allow a wildlife population to increase or decrease. White-tailed deer (*Odocoileus virginianus*) are an important wildlife species in North America providing many ecological, social, and economic values. Most generally, factors that can limit deer numbers include food supply, winter cover, disease, predation, weather, and hunter harvest. Deer numbers change with changes in these limiting factors.

White-tailed deer provide food, sport, income, and viewing opportunities to millions of Americans throughout the United States and are among the most visible and ecologically-important wildlife species in North America. They occur throughout Michigan at various densities, based on geographical region and habitat type. Michigan spans about 600 km from north to south. The importance of factors that limit deer populations vary along this latitudinal gradient. For example, winter severity and winter food availability have less impact on deer numbers in Lower Michigan than in Upper Michigan.

Quantifying the relative role of factors potentially limiting white-tailed deer recruitment and how the importance of these factors varies across this latitudinal gradient is critical for understanding deer demography and ensuring effective management strategies. Considerable research has demonstrated the effects of winter severity on white-tailed deer condition and survival (Ozoga and Gysel 1972, Moen 1976, DelGiudice et al. 2002). In addition, the importance of food supply and cover, particularly during winter, has been documented (Moen 1976, Taillon et al. 2006). Finally, the role of predation on white-tailed deer survival has received considerable attention (e.g., Ballard et al. 2001). However, few studies have simultaneously addressed the roles of limiting factors on white-tailed deer.

The overall goal of this project is to assess baseline reproductive parameters and the magnitude of cause-specific mortality and survival of white-tailed deer fawns, particularly mortality due to predation, in relation to other possible limiting mortality agents along a latitudinal gradient in Michigan. We will simultaneously assess effects of predation and winter severity and indirectly evaluate the influence of habitat conditions on fawn recruitment. Considering results from Lower Michigan (Pusateri Burroughs et al. 2006, Hiller 2007) as the southern extent of this gradient, we propose three additional study sites from south to north across Upper Michigan. Because of logistical and financial constraints, we propose to conduct work sequentially across these study areas. The following objectives are specific to the Upper Michigan study area but applicable to other study areas with varying predator suites.

## Objectives

1. Estimate survival and cause-specific mortality of white-tailed deer fawns and does.
2. Estimate proportion of fawn mortality attributable to black bear (*Ursus americanus*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), and wolf (*C. spp.*).
3. Estimate number and age of fawns killed by a bear, coyote, bobcat, or wolf during summer.
4. Provide updated information on white-tailed deer pregnancy and fecundity rates.
5. Estimate annual and seasonal resource use (e.g., habitat) and home range of white-tailed deer.
6. Estimate if familiarity of an area to each predator species affects the likelihood of fawn predation.

7. Assess if estimated composite bear, coyote, bobcat, and wolf use of an area influences fawn predation rates.
8. Describe association between fawn birth site habitat characteristics and black bear, coyote, bobcat, or wolf habitat use.
9. Estimate seasonal resource use (e.g., habitat, prey) and home range size of black bear, coyote, bobcat and wolf.

### **Study Area**

The third phase of this study spans about 1,550 km<sup>2</sup> (598 mi<sup>2</sup>) within Deer Management Unit 031 in Baraga, Houghton, and Ontonagon counties (Figure 1). The general study area boundaries follow US Highways 41/141 on the east, State Highway M-38 on the north, US Highway 45/ State Highway M-26 on the west, and State Highway M-28 on the south. Dominant land covers are deciduous (35%), evergreen (23%), and mixed forests (21%). Road density is 0.62 km/km<sup>2</sup> with greater densities around several small towns on the study area boundary. The core study area, where we conducted most capture efforts and population surveys, encompasses National Forest Rd 16 and is almost exclusively within the Ottawa National Forest. The final study area will comprise a minimum convex polygon that includes the composite locations of all telemetered animals. We selected this study area because it occurs within the high-snowfall range, receiving >250 cm of snowfall annually (about 70 cm more snowfall annually than the Phase 2 study area near Crystal Falls, Figures 1–2).

### **Accomplishments**

#### Deer Trapping

From 14 January to 1 March 2019 we captured white-tailed deer in Clover traps (Figure 2) to place radio-collars on pregnant females. We captured 110 unique deer (69 female, 41 male), with an additional 109 recaptures. Individuals captured included 36 adult and 6 yearling females, 15 adult or yearling males, 27 female fawns, and 26 male fawns. The fawn:adult female ratio for winter captures was 1.48:1. For comparison, the fawn:adult female ratio was 1:1 for winter 2012–2013 captures, 0.27:1 for winter 2013–2014 captures, 0.48:1 for winter 2014–2015 captures, 1.39:1 for winter 2016–2017 captures, and 1.59:1 for winter 2017–2018.

We immobilized 39 females and fitted 33 with GPS collars (model vertex survey 1D, Vectronic Aerospace, Berlin, Germany) set to record location information at 13-hour intervals. We monitored temperature, respiration, and heart rate as soon as practical after immobilization and at about 10-minute intervals thereafter until we administered a reversal drug. We estimated and recorded deer morphometric data and mid-rump fat depths (Table 1) when practical. We detected pregnancy with ultrasound in 97% of adult females and 33% of yearling females. We collected body condition scores (BCS) by palpation of fat deposits (scale = 1 [moribund]–5 [obese]) by two independent observers and attached ear tags (females = blue, males = yellow) to each deer.

We fitted 33 pregnant females with a vaginal implant transmitter (VIT; model 3930, Advanced Telemetry Systems Inc., Isanti, MN). Five immobilized females (1 adult, 4 yearling) were not pregnant and did not receive a VIT. We assisted the project “Quantifying Upper Peninsula Deer Movements and Abundance: Preparing for CWD Management”, by capturing and attaching expandable GPS collars (model LifeCycle 330, Lotek Wireless Inc., Newmarket, Ontario, Canada) to 12 adult males, 4 male fawns, and 1 female fawn.

### Fawn Capture

Beginning mid-May we captured, radio-collared, and obtained radio-locations for white-tailed deer fawns. We captured 51 neonate fawns (26 male, 23 female, 2 unknown sex) and fitted them with expandable radio-collars (model 4210, Advanced Telemetry Systems, Inc., Isanti, MN) during May–July. We attached individually numbered plastic ear tags to fawns and collected morphometric data when practical (Table 2) along with blood, hair, and determined sex. We also recorded bed site and surrounding habitat, flush distance, presence of dam, additional deer sighted, and handling time.

Twenty-three adult female deer fitted with vaginal implant transmitters (VITs) during Jan–Mar 2019 survived through 1 June 2019. Estimated parturition dates of VIT tagged does ranged from 31 May to 25 June. Three VITs failed or were expelled before parturition with no evidence of a birth site, so we did not conduct a fawn search. An additional two VITs were expelled in open areas during sunny periods such that we did not detect parturition until >2 days later. We conducted fawn searches at these sites but fawns were likely no longer in the area. One VIT was not yet expelled as of 4 Sep. We successfully detected parturition and conducted searches at the birth site in the effort to find fawns of 17 implanted pregnant adult females. Thirteen of 17 (76%) VIT searches resulted in the location of  $\geq 1$  live or dead fawn (18 live fawns and 0 stillbirths). An additional 5 parturition events were identified through GPS movements of deer without VITs, at which 3 live fawns were located. We opportunistically captured 30 fawns within the study area.

### Deer Telemetry

We recorded 22,750 locations of GPS-collared adult female deer from 6 September 2018 to 5 September 2019. We monitored VHF fawn collars for survival status using ground-based telemetry daily from capture to 31 July, at 48-hour intervals from 1 August to 1 September. For fawns located in areas too remote to monitor signals from truck, aerial telemetry was used to monitor survival status as often as possible, generally 2-3 times per week.

### Deer Mortality

From 6 September 2018 to 5 September 2019, we observed 18 mortalities of radio-collared adult female deer. We attributed these to 10 wolf predations, 2 starvations, 1 vehicle collision, 1 legal hunter harvest, 1 unknown predation, and 3 unknown causes. We censored 4 adult female deer from the sample because they died within 14 days of capture.

We observed 24 mortalities of fawns born during 2019. We attributed these to 3 bear predations, 8 coyote predations, 4 wolf predations, 3 unidentified predations, 3 vehicle collisions, 1 weak fawn syndrome mortality, and 2 unknown causes. Additionally, we censored 5 fawns from the sample after their radio-collars appeared to have failed or fallen off.

We observed 15 mortalities of fawns born during 2018. We attributed these to 1 bobcat predation, 6 wolf predations, 1 coyote predation, 1 vehicle collision, 3 unidentified predations, and 3 unknown causes.

### Deer Camera Surveys

We pre-baited 52 sites (Figure 3) with 7.5 L of whole kernel corn beginning 12 August and re-baited sites at 3-day intervals. The 10-day survey period started at pre-baited sites beginning 22 August and ended 3 September. From camera images, we will estimate deer density for the 298 km<sup>2</sup> sampling area following Duquette et al. (2014).

A non-baited camera survey of 52 sites was conducted during July–September 2018 (Figure 3). Non-baited sites were separated by  $>1.2$  km to ensure independence, and  $\geq 500$  m from the nearest baited site to reduce effects of deer movements from baited survey sites. We will compare non-baited results with baited survey results and assess the suitability of a non-baited approach to estimate deer abundance.

#### Black Bear Den Checks

During 28 January–1 February we immobilized 2 adult black bears (2 male). From 28 February–12 March we immobilized 6 adult (2 male, 4 female) and 4 yearling (2 male, 2 female) black bears. Two yearling (1 male, 1 female) black bears were observed in the den without immobilization. We weighed, recorded morphometric measurements, and drew blood from each immobilized bear. We replaced batteries on GPS collars. Three collars were removed and not replaced due the bear moving outside of the study area. We programmed the GPS collars to obtain a location every 35 h until 1 May and then every 15 min thereafter until we remove the collar. We handled 3 cubs (3 male, 1 female) from 1 adult female (Table 3).

#### Bobcat Capture

We set cage traps ( $n = 3$ ) to capture bobcats at previously baited bobcat hair snare during 14 January–22 February. We captured 1 adult female and 1 kitten; we released the kitten without immobilization. Once immobilized, we weighed (9.5 kg), sexed, and collected morphometric measurements from the adult bobcat. We also attached a GPS collar that we programmed to record 35 h locations until 1 May and then every 15 min until 31 August.

#### Coyote Cable Neck Restraints

We baited 2 locations with vehicle-killed deer carcasses to attract coyotes for capture. Due to cold temperatures and deep snow levels, we did not set cable neck restraints.

#### Spring/Summer Carnivore Capture

During 13 May–15 June, we captured 12 wolves (4 male, 8 female), 3 coyotes (1 female, 2 male), and 1 bobcat (male) using foothold traps. Five black bears (2 female, 3 male) were captured in barrel traps or modified Aldrich foot snares. We immobilized captured individuals and recorded gender, weight, and affixed uniquely numbered ear tags (Table 4). We recorded morphometric measurements and collected blood and hair from each immobilized carnivore. We estimated body condition scores for each carnivore and estimated body condition of black bears using bioelectrical impedance analysis. We removed a vestigial premolar for age estimation in black bears. We fitted all captured carnivores with Lotek 7000SU or LiteTrack (Lotek Engineering, Newmarket, ON, Canada) global positioning system (GPS) radiocollars.

We programmed all GPS radiocollars to obtain a location every 15 minutes from 1 May–31 September and then every 35 hours thereafter.

#### Carnivore Monitoring

We recovered one GPS radio-collar during May 2019 after a black bear removed the collar. Ten black bears (5 male, 5 female) radio-collared and/or ear-tagged during phase 3 (2016–2018) were legally harvested during the 2018 Michigan black bear hunting season and their collars recovered. Additionally, one ear-tagged female black bear captured in the Phase II study area was legally harvested during the 2018 hunting season.



### Bobcat Hair Snares

We began baiting 52 bobcat hair snare sites (Figure 4) on 8 December 2019. After a two-week pre-bait period, we set 4 hair snares at each site beginning 5 January 2019. We also deployed a trail camera at each site, directed at the bait, to obtain images of animals visiting the site. We visited each bait site every 7 days for 6 weeks to collect hair samples, reset snares, perform trail camera maintenance, and add bait as necessary. Due to extreme winter conditions, the survey was limited to 6 weeks as opposed to 8 weeks as in previous seasons.

We collected 316 hair samples of target and non-target species and will send samples to the MDNR Wildlife Disease Laboratory in Lansing for DNA extraction. We also obtained 118,459 camera images. Data entry and analysis is ongoing.

### Black Bear Abundance Estimation: Hair Snares

During 20 May–23 July 2017 we conducted a hair snare survey to estimate black bear abundance. Hair snares ( $n = 49$ ; Figure 5) erected during 2016, consisted of a single strand of 4-pronged barbed wire placed around three or four trees to create an enclosure about 50 cm above ground. We baited snares by placing 0.5 L of fish oil on a pile of dead wood in the center of each enclosure and spraying anise oil on each of the trees 2 m above ground. We also placed a remote trail camera at each site to document site visitation and obtained 2,406 images. We checked snares, added lure, and collected hair samples every ten days, for a total of six checks. We collected 489 hair samples. We sent these hair samples to the MDNR Wildlife Disease Laboratory for DNA extraction and subsequent individual identification.

### Coyote Howl Surveys

We completed 8 howl survey sessions at 40 sites (Figure 6) from 13 July to 24 September 2018. Survey sessions are on a 10 day rotation with all sites completed in 4 days, weather permitting. Overall, we obtained coyote and wolf response rates of 16.3% and 0.1%, respectively. We have completed 6 of 8 howl survey sessions which began on 13 July 2019.

We elicited vocalizations using a FoxPro game caller (FoxPro Inc., Lewistown, PA) using a group-yip howl to elicit coyote vocal response. At each survey site we recorded moon phase, cloud cover, wind speed, species responding, response time and direction, number of individuals responding, type of response (e.g., bark-howl, lone howl), and recordings of responses. We will estimate coyote abundance using an occupancy modeling approach (Petroelje et al. 2014).

### Wolf Track Surveys

The Michigan Department of Natural Resource (DNR) conducted wolf track surveys during 2–20 February to identify the number of wolf packs and minimum number of individuals within each pack. Track surveys were informed by locations of 4 GPS-collared individuals. Michigan DNR personnel identified a minimum of 48 individuals in 9 packs whose territories include the study area: Baraga Plains (minimum 4 individuals), Frost Junction (minimum 6 individuals), Sidnaw-Kenton (minimum 8 individuals), Trout Creek (minimum 5 individuals), Prickett Dam (minimum 5 individuals), Gardner Road (minimum 7 individuals), Rousseau (minimum 5 individuals), Six-mile Creek (minimum 4 individuals), Sturgeon Gorge (minimum 3 individuals).

### Carnivore Cluster Investigation

We used clusters of carnivore locations obtained from GPS radio-collars to identify potential kill sites and estimate the number of prey species killed. From 15 May to 31 August 2019, we investigated 659 GPS cluster locations identified using ArcGIS and the statistical program R (R Development Core Team, Vienna, Austria). We defined a cluster as > 4 locations within 50 m of each other within a 24-hour period. Of the 659 clusters investigated this year, 231 were black bear (mean clusters/black bear = 38.5), 15 bobcat (mean clusters/bobcat = 15.0), 100 coyote (mean clusters/coyote = 33.3), and 313 wolf (mean clusters/wolf = 26.1).

Preliminary results from cluster investigations include black bears foraging on chokecherries (*Prunus virginiana*), raspberries (*Rubus ideaus*), blueberries (*Vaccinium* spp.), fawns, and colonial insects (e.g., ants). We identified ruffed grouse (*Bonasa umbellus*), porcupine (*Erithizon dorsatum*), muskrat (*Ondatra zibethicus*), beaver (*Castor canadensis*), and fawn predations at bobcat clusters sites. We identified predations of snowshoe hare (*Lepus americanus*), frog (*Rana* spp.), ruffed grouse, and fawn and adult deer at coyote clusters. We identified predations of beaver, and fawn and adult deer at wolf clusters.

### Ruffed Grouse Drumming Survey

We conducted ruffed grouse (*Bonasa umbellus*) drumming surveys during 5–10 May 2019. We conducted surveys from one half hour before sunrise to 5 hours after sunrise. Each survey contained 5 routes with 10–15 sites in each route for a total of 64 sites (Figure 7). Observers listened for 5 minutes at each site for drumming grouse and recorded number and bearing of each. We used site occupancy to estimate male grouse density. Probability of detection was 50.6% resulting in an estimated density of 2.86 grouse/km<sup>2</sup>.

### Snowshoe Hare Pellet Counts

We conducted snowshoe hare (*Lepus americanus*) pellet counts during 5–14 May. We counted number of hare pellets within a 1 m<sup>2</sup> rectangle at 455 random locations (Figure 8). We separated pellet counts into 6 main land cover types (aspen [*Populus tremuloides*]), deciduous (excluding aspen), coniferous, mixed forest, woody wetland, and open herbaceous). We related hare pellet densities to hare abundance using a linear regression developed by McCann et al. (2008). Overall estimated hare density was 3.83 hare/km<sup>2</sup>.

### Aerial Beaver Cache Survey

We flew 235 km of river and lakeshore on 14 November 2018 at an altitude of 550–650 m to identify active beaver caches. We detected 14 lodges with an active cache and 10 caches with no sign of a lodge (Figure 9). Inclement weather precluded surveying the entire study area.

### Public Outreach

During black bear den checks and white-tailed deer trapping we hosted individuals from Michigan Department of Natural Resources (MDNR), Keweenaw Bay Indian Community Natural Resources Department (KBNRD), Michigan State University, Michigan Out-of-Doors, and other interested members of the public. We participated in one television show who obtained images and video footage of project staff performing various field duties and will provide this media to Safari Club International Foundation to promote the project.

We gave presentations at the MDNR District 1 Conservation Officers Meeting and Partners for Watershed Restoration (PWR). We reported select project results at a national conference.

We hosted 25 undergraduate students from Purdue University on 31 May for demonstrations of detection dogs, carnivore immobilizations, fawn capture, vegetation surveys, and deer telemetry. We gave presentations to 11 classes at local public schools, reaching 263 students. We hosted 21 educators from the Michigan DNR Academy of Natural Resources-North for demonstrations of detection dogs, carnivore capture, and telemetry.

We updated our project website (<https://campfirewildlife.com/projects/predator-prey/>) and Facebook page (<https://www.facebook.com/campfirewildlife/>) with project results.

*Peer-reviewed publications:*

Croose, E., F. Bled, N.L. Fowler, D.E. Beyer, and J.L. Belant. 2019. American marten and fisher do not segregate in space and time during winter in a mixed-forest system. *Ecology and Evolution* 9:4906-4916.

Fowler, N.L., D.E. Beyer, Jr., and J.L. Belant. 2019. Non-linear relationships between human activities and wolf livestock depredations. *Biological Conservation* 236:385-392.

Gantchoff, M.G., D.E. Beyer, Jr., and J.L. Belant. 2019. Reproductive class influences risk tolerance during denning and spring for American black bears. *Ecosphere* 10:e02705.

Kautz, T.M. 2018. Factors influencing white-tailed deer mortality risk within a multi-predator system in Michigan, USA. M.S. Thesis, Mississippi State University, Mississippi State, MS, USA.

Kautz, T.M., J.L. Belant, D.E. Beyer, Jr., B.K. Strickland, T. R. Petroelje, and R. Sollmann. 2019. Predator densities and white-tailed deer fawn survival in a four-predator system. *Journal of Wildlife Management* 83:1261-1270.

Norton, D.C., J.L. Belant, D.E. Beyer, Jr., and J.G. Bruggink. 2018. Female American black bears do not alter space use or movements to reduce infanticide risk. *Plos One*. 13:0203651.

Scharf, A.K., J.L. Belant, D.E. Beyer, Jr., M. Wikelski, and K. Safi. 2018. Habitat suitability cannot capture the essence of animal-defined corridors. *Movement Ecology* 6.

Svoboda, N.J., J.L. Belant, D.E. Beyer, Jr., J.F. Duquette, and P.E. Lederle. 2019. Carnivore space use shifts in response to seasonal resource availability. *Ecosphere* 10:e02817.

*Presentations to scientific and professional groups:*

Kautz, T., J. Belant, D. Beyer Jr., B. Strickland, J. Duquette, T. Petroelje. Influence of biological and environmental conditions on winter mortality risk of a northern ungulate: Evidence for a late-winter survival bottleneck. The Wildlife Society National Conference, Cleveland, OH, USA, 8 October 2018.

Kautz, T., T. Petroelje, A. Lutto, J. Magee, N. Fowler, J. Belant, and D. Beyer. Michigan Predator-Prey Study 2009-2019: Summary and update of deer survival in a 4-predator system. Safari Club International Foundation Conservation Committee strategic planning meeting. Escanaba, MI, USA, 23 July 2019.

Petroelje, T., J. Belant, D. Beyer Jr., T. Kautz. Interference competition with coyotes and wolves during variable prey availability. The Wildlife Society National Conference, Cleveland, OH, USA, 11 October 2018.

*Presentations to hunting groups, service organizations, and schools:*

Kautz, T. M., A.L. Lutto, N. Fowler, J. Magee, J.L. Belant, D.E. Beyer, Jr. 23 July 2019. Role of predators, winter weather, and habitat on white-tailed deer fawn survival in Michigan. Partners for Watershed Restoration (PWR) Meeting, Porcupine Mountains, MI. 25 attendees.

Lutto, A.L., J. Magee, N. Fowler, T. Kautz, J.L. Belant, D.E. Beyer, Jr. 31 May 2019. Role of predators, winter weather, and habitat on white-tailed deer fawn survival in Michigan's Upper Peninsula. Purdue Wildlife Ecology Field Class. Silver Mountain Field Station, Pelkie, MI. 26 attendees.

Lutto, A.L, N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 13 May 2019. Michigan Predator-Prey Project. West Iron County Schools Agriculture Biology Class, Iron River, MI. 10 attendees.

Lutto, A.L, N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 13 May 2019. Michigan Predator-Prey Project. West Iron County Schools Fifth Grade, Iron River, MI. 25 attendees.

Lutto, A.L, N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 13 May 2019. Michigan Predator-Prey Project. West Iron County Schools First and Second, Iron River, MI. 33 attendees.

Lutto, A.L, N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 13 May 2019. Michigan Predator-Prey Project. West Iron County Schools Kindergartens, Iron River, MI. 20 attendees.

Lutto, A.L, N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 10 May 2019. Michigan Predator-Prey Project. West Iron County Schools Sixth and Seventh Grades, Iron River, MI. 36 attendees.

Lutto, A.L, N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 10 May 2019. Michigan Predator-Prey Project. West Iron County Schools Third and Fourth Grades, Iron River, MI. 35 attendees.

Lutto, A.L, N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 10 May 2019. Michigan Predator-Prey Project. West Iron County Schools First Grade, Iron River, MI. 15 attendees.

Lutto, A.L, N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 10 May 2019. Michigan Predator-Prey Project. West Iron County Schools Second Grades, Iron River, MI. 23 attendees.

Lutto, A.L, N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 10 May 2019. Michigan Predator-Prey Project. West Iron County Schools First Grade, Iron River, MI. 20 attendees.

Lutto, A.L., N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 10 May 2019. Michigan Predator-Prey Project. West Iron County Schools First Grade, Iron River, MI. 20 attendees.

Kautz, T., J. Belant, D. Beyer Jr., B. Strickland, J. Duquette, T. Petroelje. Influence of biological and environmental conditions on winter mortality risk of a northern ungulate: Evidence for a late-winter survival bottleneck. The Wildlife Society National Conference, Cleveland, OH, USA, 8 October 2018.

Petroelje, T., J. Belant, D. Beyer Jr., T. Kautz. Interference competition with coyotes and wolves during variable prey availability. The Wildlife Society National Conference, Cleveland, OH, USA, 11 October 2018.

Kautz, T. M., Fowler, A.L. Lutto, Z. Farley, J.L. Belant, D.E. Beyer, Jr. 5 October 2018. Role of predators, winter weather, and habitat on white-tailed deer fawn survival in Michigan. MDNR Law Enforcement Division District 1 Meeting, Marquette, MI. 15 attendees.

#### *Seminars and Workshops:*

Lutto, A.L., N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 8 Aug 2019. Field techniques for Michigan Predator-Prey Project. Michigan Department of Natural Resources' Academy of Natural Resources, Silver Mountain Field Station, Pelkie, MI. 22 attendees.

Lutto, A.L., J. Magee, N. Fowler, T.M. Kautz, J.L. Belant, D.E. Beyer, Jr. 31 May 2019. Field techniques for wildlife capture and predation investigation. Purdue Wildlife Ecology Field Class. Silver Mountain Field Station, Pelkie, MI. 26 attendees.

#### *Outdoor shows:*

Michigan Out-of-Doors – Episode #1911

[https://www.youtube.com/watch?time\\_continue=670&v=mu5oBuW10Tw](https://www.youtube.com/watch?time_continue=670&v=mu5oBuW10Tw)

#### Field Assistants

During January–March 2018 and May–August 2018 we recruited 7 and 8 seasonal assistants, respectively. We recruited 2 assistants for September–October 2019.

#### **Work to be completed (September–December 2018)**

##### White-tailed Deer Monitoring

We will use radio and aerial telemetry to locate collared does and fawns weekly, investigating mortalities as soon as practical after detecting a mortality signal to determine cause of death.

##### Carnivore Monitoring and GPS Radio-collar Recovery

We will continue to monitor collared carnivores twice monthly until drop-off mechanisms detach for coyotes and wolves. We will recover the dropped radio-collars and download location and activity data. We will clear recovered collars of data, clean them, and store or send them back to the manufacturer for refurbishment. We will monitor black bears until dens are located in late November.

### Black Bear Den Checks

We will locate and mark black bear dens in late-October before heavy snow fall and conduct black bear den checks beginning in mid-February to remove GPS collars from all black bears.

### Aerial Beaver Cache Survey

Starting around 15 October, after leaf-off, we will conduct an annual aerial beaver cache survey. We will fly along rivers, streams, lakes, and other hydrology to locate and mark active beaver caches as an index to beaver abundance.

### Equipment Organization, Inventory, and Storage

We will inventory, organize, repair, and move all remaining project equipment to State University of New York and Michigan Department of Natural Resources field offices.

### Public Outreach

We will continue to update our project website (<https://campfirewildlife.com/projects/predator-prey/>) and Facebook page (<https://www.facebook.com/campfirewildlife/>) with project results.

### **Acknowledgements**

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Victoria Frailey

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**Table 1.** Mean ( $\bar{x}$ ) and standard deviation (SD) of adult ( $n = 33$ ) and yearling ( $n = 6$ ) female white-tailed deer morphometrics and body condition estimates, Upper Peninsula of Michigan, USA, January–March 2019.

Metric	Age Class			
	Adults		Yearlings	
	$\bar{x}$	SD	$\bar{x}$	SD
Body weight (kg)	65.2	6.6	52.6	4.1
BCS <sup>1</sup>	2.61	0.79	2.38	0.68
MIDF <sup>2</sup> (cm)	0.45	0.48	0.24	0.24

<sup>1</sup> Body condition score (BCS) derived from palpation following Cook et al. (2010).

<sup>2</sup> Middle rump fat (MIDF) estimate measured at mid-point between ilium and ischial tuberosity on right hip (Cook et al. 2007).

**Table 2.** Mean ( $\bar{x}$ ) and standard deviation (SD) of characteristics for 49 captured female ( $n = 24$ ) and male ( $n = 25$ ) neonate fawn white-tailed deer, Upper Peninsula of Michigan, USA, 30 May–5 July 2019.

Estimate	Sex			
	Female		Male	
	$\bar{x}$	SD	$\bar{x}$	SD
Age at capture	3.6	4.4	2.5	2.8
Birth date	10-June	8.4	7-June	6.8
Birth Mass (kg) <sup>1</sup>	3.8	1.0	3.4	0.9

<sup>1</sup> Birth masses of fawns with unknown parturition dates estimated by assuming an average daily mass gain of 0.2 kg since birth (Carstensen et al. 2009, Verme and Ullrey 1984).

**Table 3.** Data for black bears handled during den checks, Upper Peninsula of Michigan, USA, 28 January–12 March 2019.

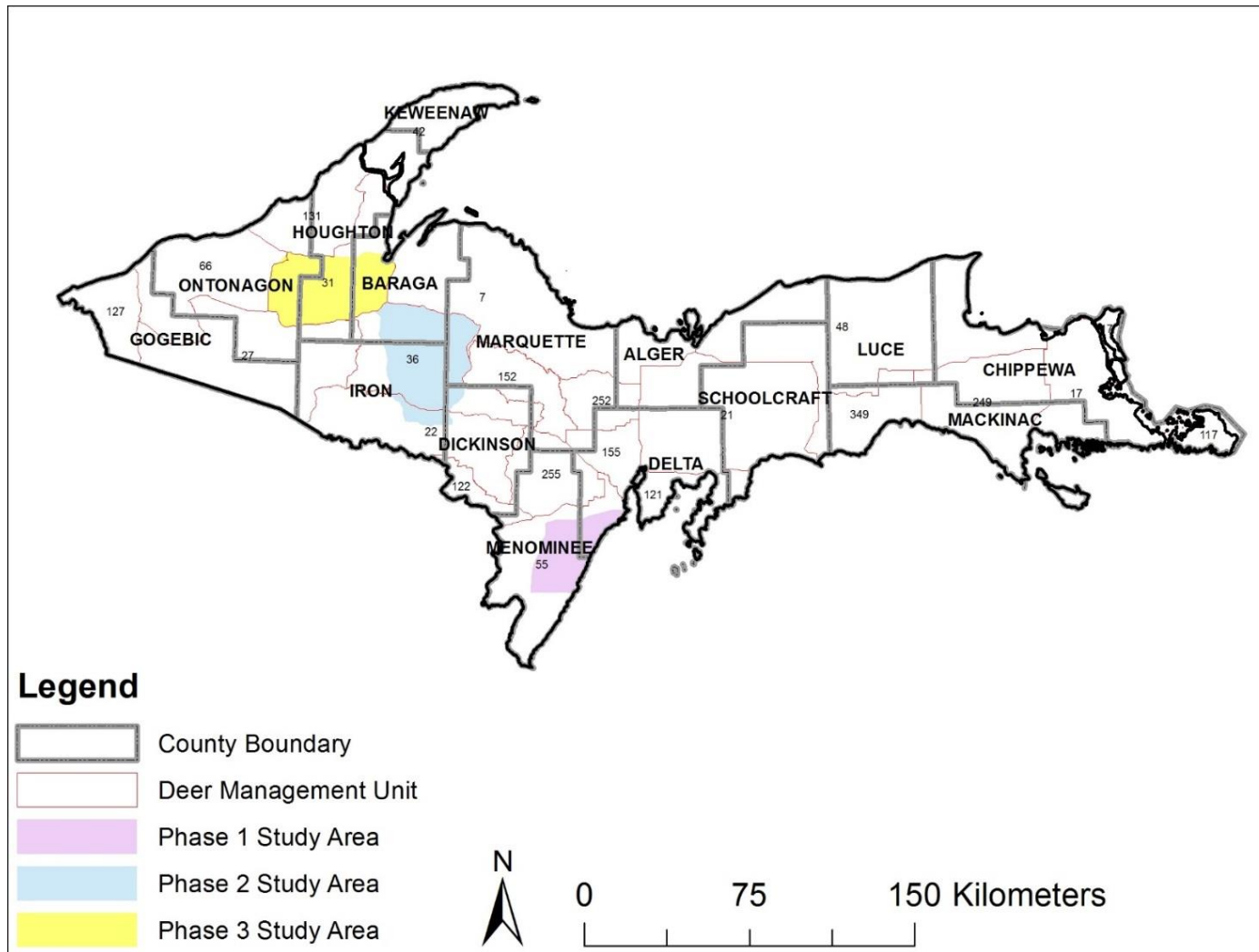
ID	Den check date	Age	Sex	Body weight (kg)	Right ear tag	Left ear tag
BB358	28-Jan-19	Adult	M	67.7	619	617
BB359	1-Feb-19	Adult	M	47.5	638	637
BB335	28-Feb-19	Adult	F	78.5	429	428
BB349	28-Feb-19	Yearling of BB335	M	NA <sup>2</sup>	NA <sup>3</sup>	NA <sup>3</sup>
BB350	28-Feb-19	Yearling of BB335	F	NA <sup>2</sup>	NA <sup>3</sup>	NA <sup>3</sup>
BB339	2-Mar-19	Adult	F	59.9	438	439
Yearling 1	2-Mar-19	Yearling of BB339	M	18.2	630	628
Yearling 2	2-Mar-19	Yearling of BB339	F	18.5	632	626
BB303	3-Mar-19	Adult	M	NA <sup>1</sup>	663	601
BB338	8-Mar-19	Adult	M	144.8	445	444
BB351	11-Mar-19	Adult	F	73.5	441	621
BB361	11-Mar-19	Cub of BB351	M	2.2	NA	NA
BB362	11-Mar-19	Cub of BB351	F	2.2	NA	NA
BB343	11-Mar-19	Cub of BB351	M	2.3	NA	NA
BB355	12-Mar-19	Adult	F	63.8	440	368
BB364	12-Mar-19	Yearling of BB355	F	24.7	694	NA
BB365	12-Mar-19	Yearling of BB355	M	22.1	699	698

<sup>1</sup>Unable to weigh bear due to den location.

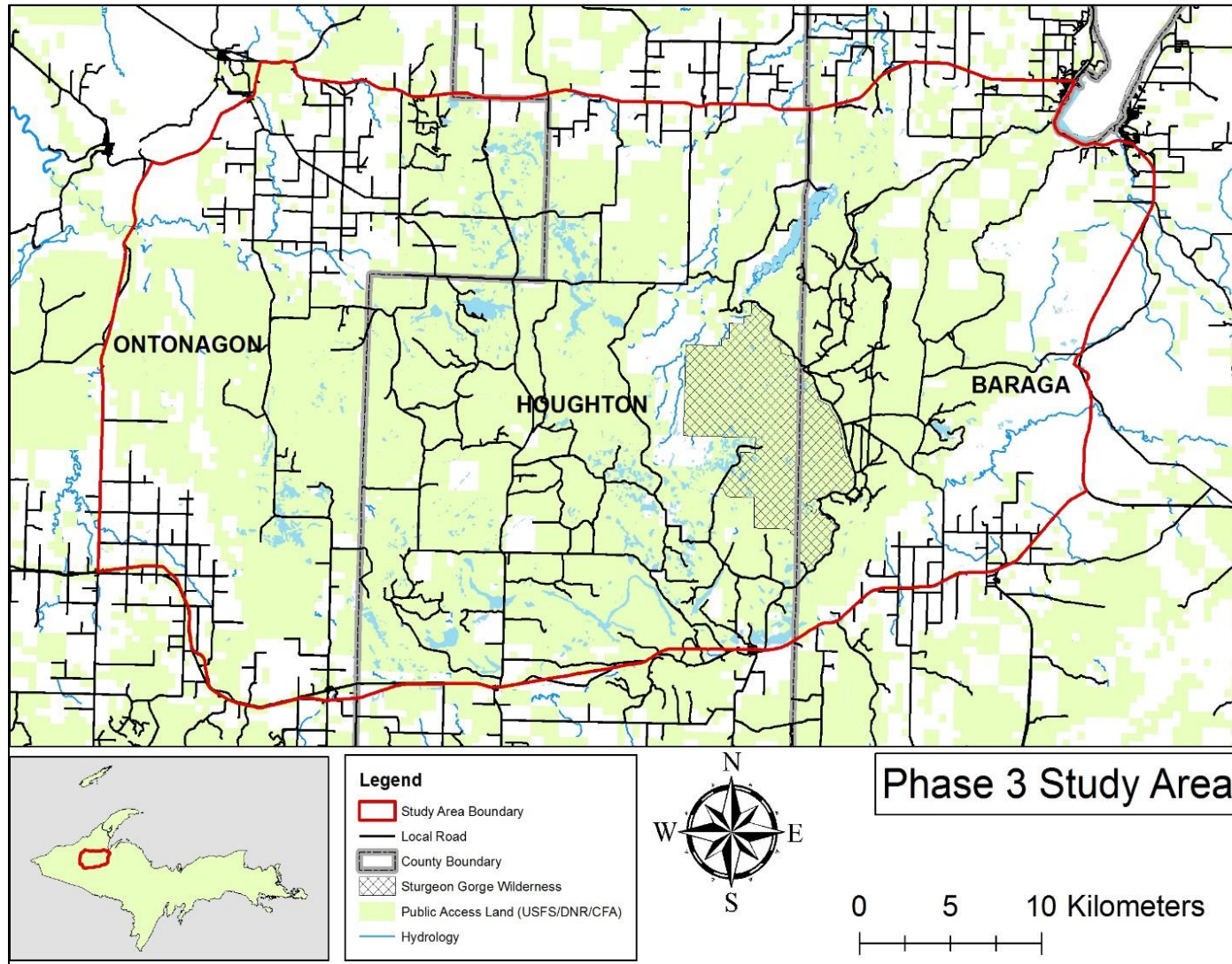
<sup>2,3</sup>Yearlings were not immobilized.

**Table 4.** Carnivore capture data, Upper Peninsula of Michigan, USA, 15 May–13 July 2019.

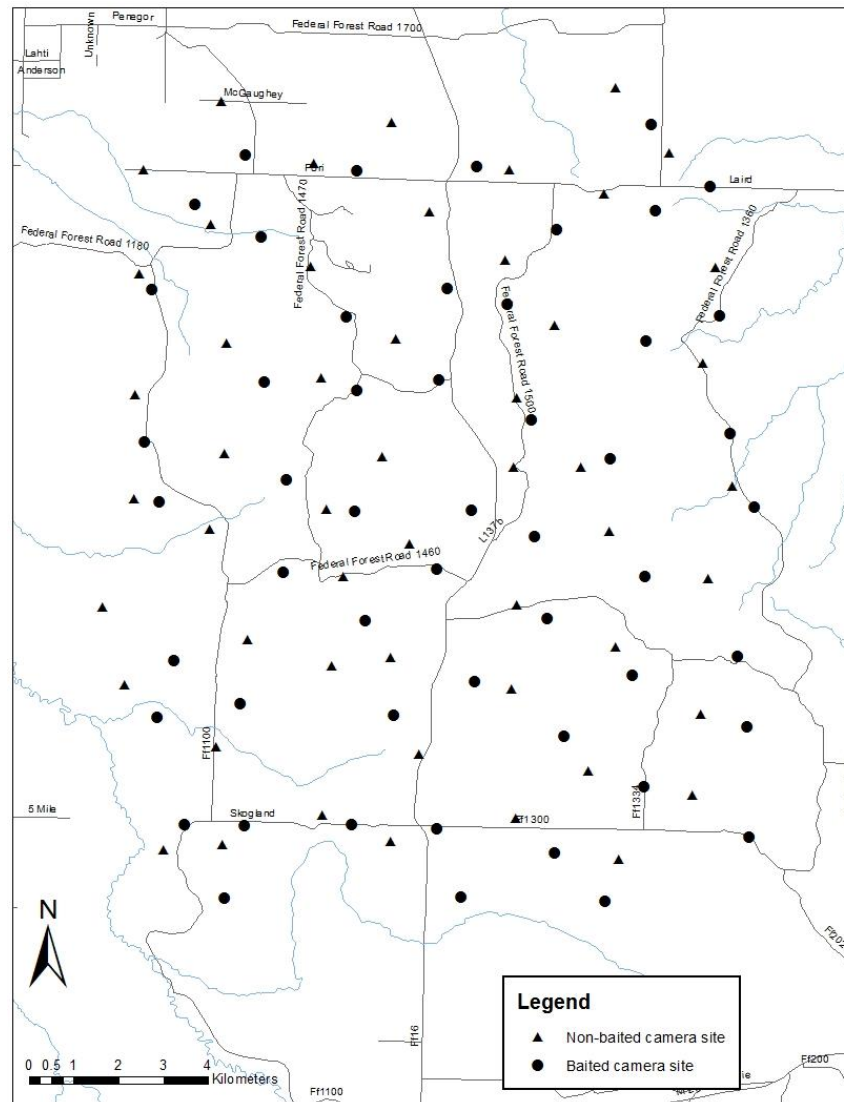
<b>SPECIES</b>	<b>DATE</b>	<b>ID #</b>	<b>SEX</b>	<b>WEIGHT (kg)</b>
Wolf	15-May-2019	WO317	Female	36.1
Wolf	17-May-2019	WO318	Male	35.5
Wolf	17-May-2019	WO319	Male	34.7
Black bear	23-May-2019	BB366	Female	54.2
Coyote	23-May-2019	CO304	Female	10.7
Wolf	23-May-2019	WO320	Female	32.5
Wolf	23-May-2019	WO321	Male	28.5
Wolf	24-May-2019	WO322	Male	37.2
Wolf	24-May-2019	WO323	Female	26.4
Wolf	24-May-2019	WO324	Female	30.9
Wolf	25-May-2019	WO325	Female	29.7
Coyote	27-May-2019	CO305	Male	13.9
Black bear	28-May-2019	BB367	Male	65.3
Wolf	30-May-2019	WO326	Female	27.1
Coyote	4-Jun-2019	CO306	Male	12.8
Wolf	7-Jun-2019	WO327	Female	25.2
Wolf	7-Jun-2019	WO300 (Recap)	Female	Did not weigh
Black bear	8-Jun-2019	BB368	Male	58.5
Bobcat	9-Jun-2019	BC304	Male	9.5
Black bear	13-Jun-2019	BB369	Male	Did not weigh
Black bear	13-Jun-2019	BB370	Female	46.1



**Figure 1.** Location of phase 1, 2 and 3 study areas and Michigan Department of Natural Resources Deer Management Units, Upper Peninsula of Michigan, 2008–2019.

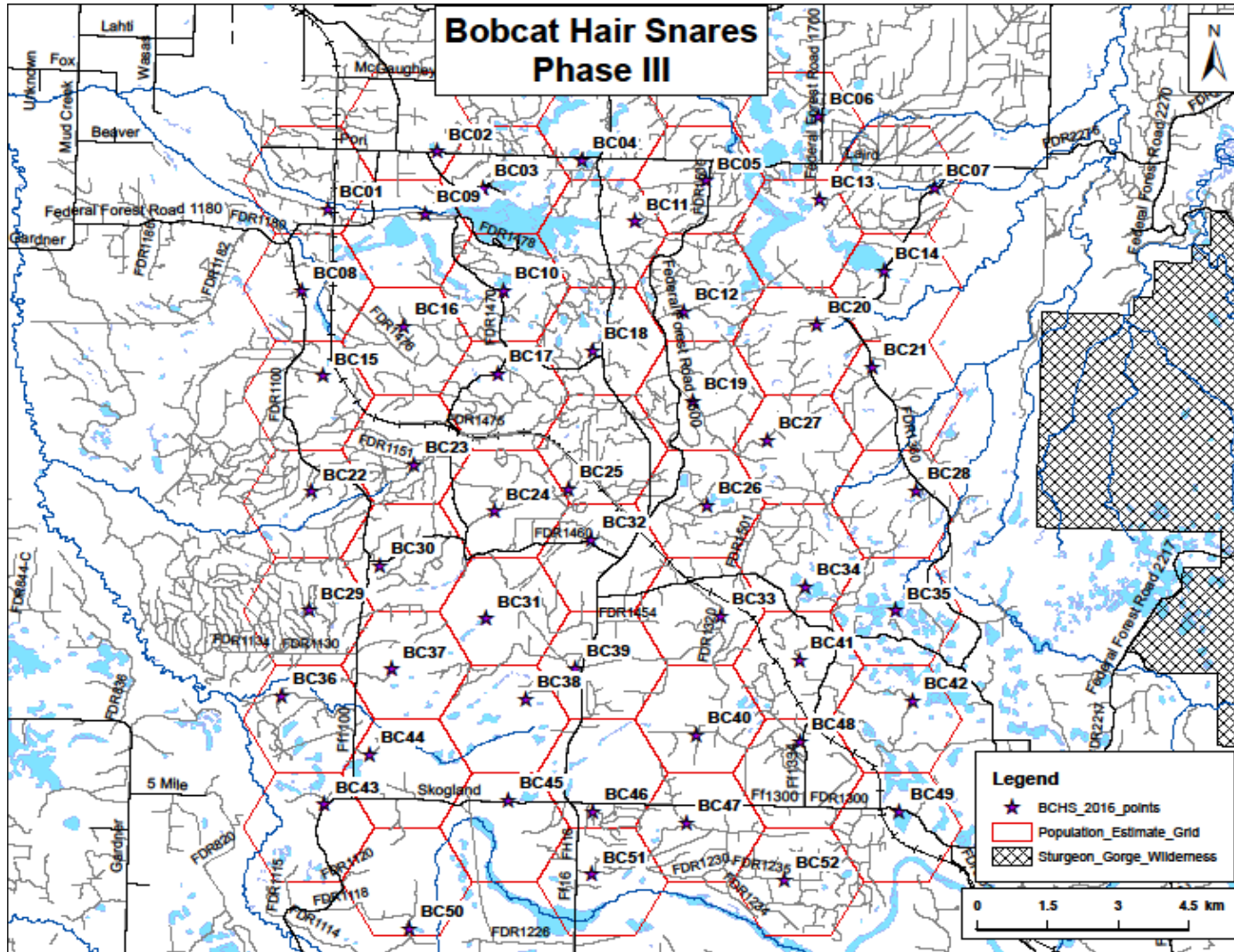


**Figure 2.** Location of phase 3 study area and counties, Upper Peninsula of Michigan, USA.

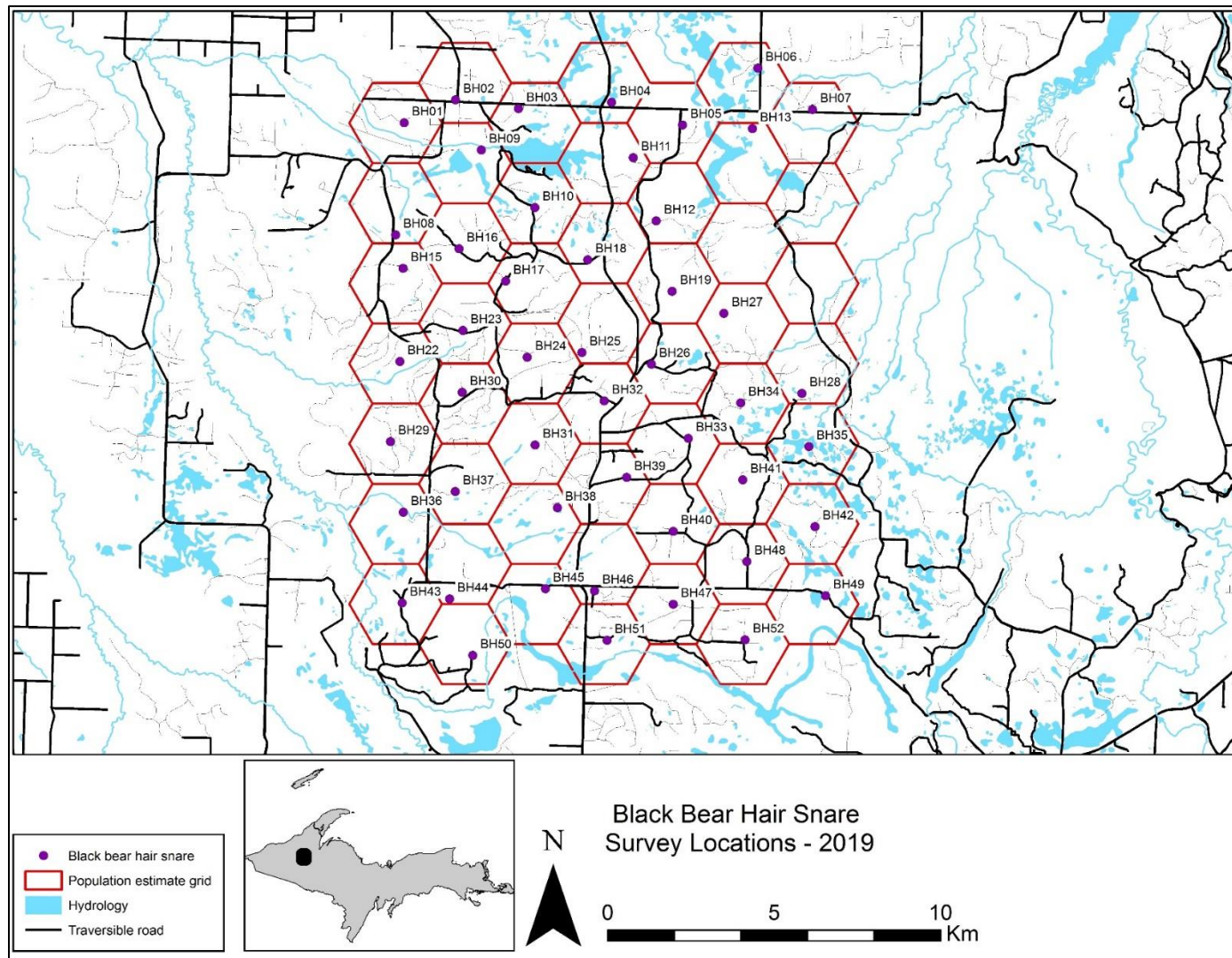


**Figure 3.** Locations of 52 baited and 52 non-baited remote camera sites to estimate deer abundance, Upper Peninsula of Michigan, USA, 2019.

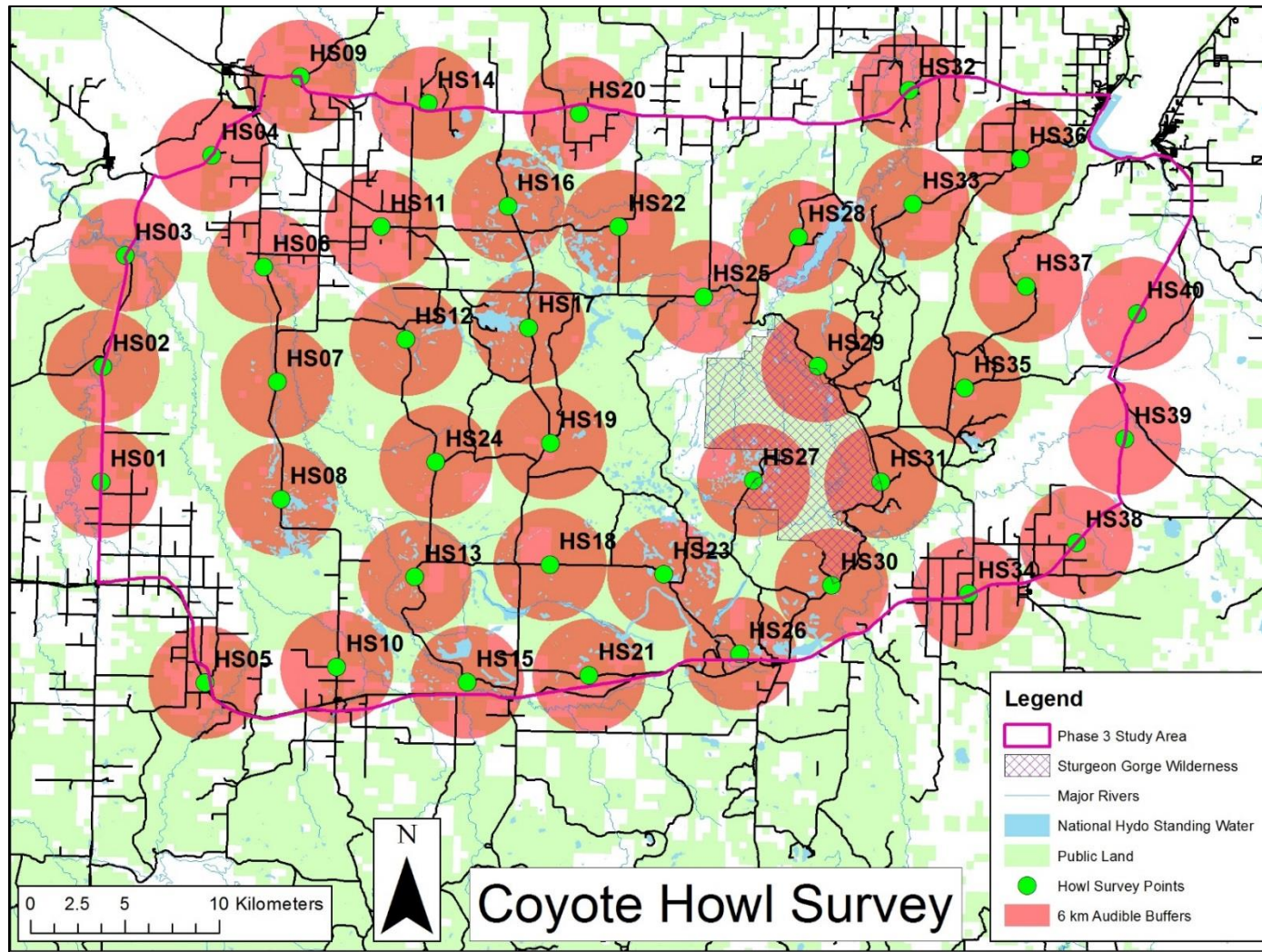




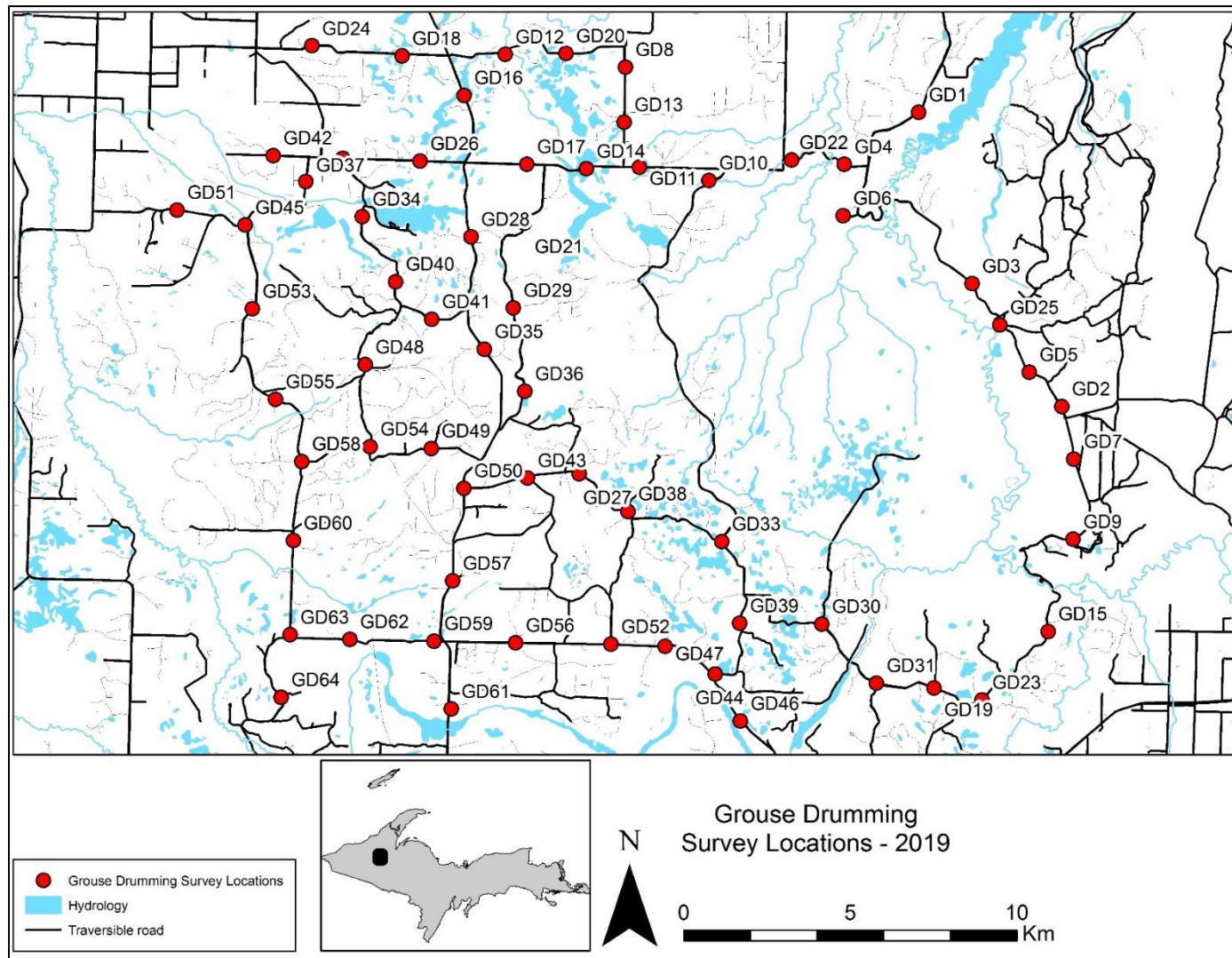
**Figure 4.** Locations of 52 bobcat hair snare sites to estimate bobcat abundance, Upper Peninsula of Michigan, USA, 2019.



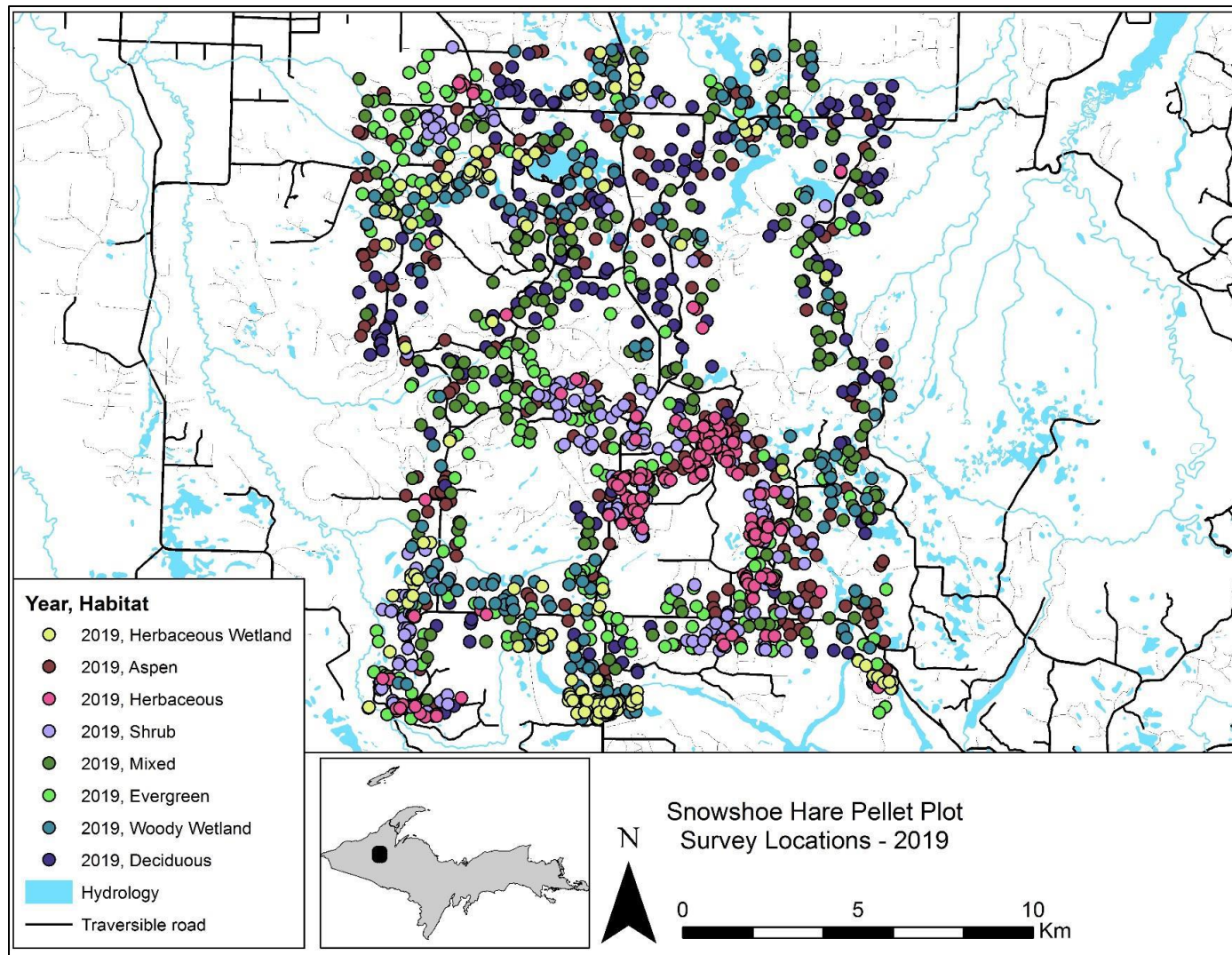
**Figure 5.** Locations of 49 black bear hair snare sites to estimate black bear abundance, Upper Peninsula of Michigan, USA, 2019.



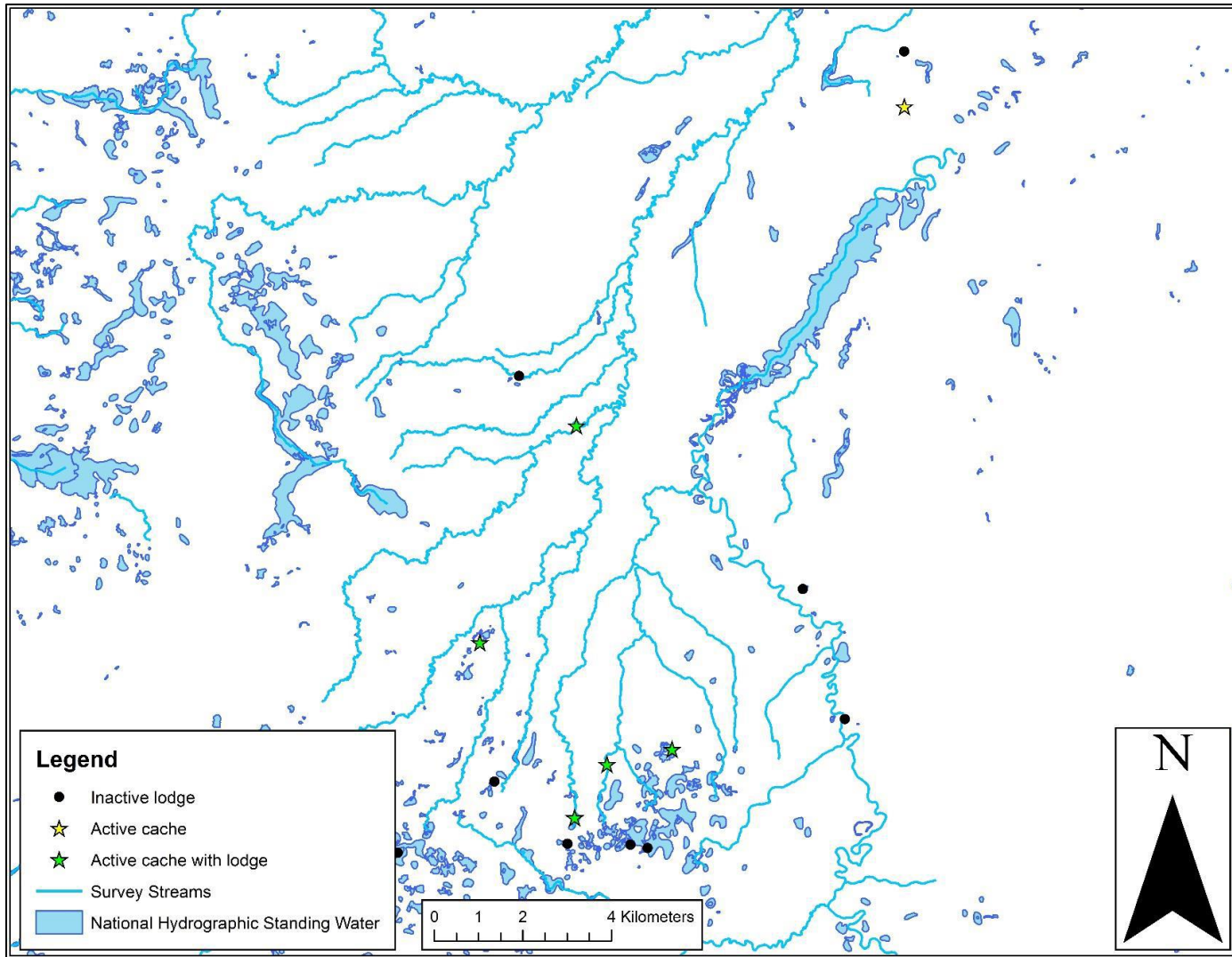
**Figure 6.** Locations of 40 howl survey sites to estimate coyote abundance, Upper Peninsula of Michigan, 2019.



**Figure 7.** Locations of 64 grouse drumming survey sites with 550 m audible buffer to estimate abundance, Upper Peninsula of Michigan, USA, 2019.



**Figure 7.** Locations of pellet plot locations to estimate snowshoe hare abundance, Upper Peninsula of Michigan, USA, 2019.



**Figure 9.** Locations of beaver caches and lodges detected aerially during 6–8 November, Upper Peninsula of Michigan, USA, 2018.