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 191 (74 male, 117 female) individual white-tailed deer (*Odocoileus virginianus*), including 74 adults, 20 yearlings, and 97 fawns. We radio-collared 59 female deer of which 51 received vaginal implant transmitters (VIT). We detected pregnancy using ultrasound in 98% of adult (n = 57) and 50% of yearling (n = 12) females. We captured and radio-collared 48 neonate fawns (22 male, 26 female). Twenty-three of 30 (77%) VIT searches resulted in the location of 24 live and 5 stillborn fawns. We obtained 20,372 adult female deer GPS locations, and monitored fawn survival using VHF telemetry. We located 27 radio-collared adult female white-tailed deer mortalities, 24 mortalities of radio-collared fawns born during 2018, and 12 mortalities of fawns born during 2017. 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 14 adult black bears (*Ursus americanus*: 8 male, 4 female) in their dens and observed 5 cubs (3 male, 2 female) from 2 females and 2 yearlings (both male) from 1 female. From May to July we captured and immobilized 13 black bears (*Ursus americanus;* 6 male, 7 female), 1 coyote (*Canis latrans*; 1 male), and 9 wolves (*C*. spp.; 4 male, 5 female) and fitted them with GPS or VHF collars. We collected 568 hair samples and >166,900 images from bobcat hair snares and remote cameras, respectively. We collected 588 hair samples and 3,827 images from black bear hair snares and remote cameras, respectively. During howl surveys we recorded an average coyote response rate of 14.2% and wolf response rate of 0.4% through 6 of 8 total sessions. We investigated 531 carnivore cluster sites to identify prey remains. We conducted a ruffed grouse (*Bonasa umbellus*) drumming survey to estimate grouse abundance and had a 41.0% average detection rate across sessions. We completed snowshoe hare (*Lepus americanus*) pellet counts at 637 random locations stratified across 6 different landcovers to estimate hare densities. We used an aerial survey to estimate beaver (*Castor canadensis*) abundance and detected 50 inactive lodges, 57 active lodges with a cache present, and 13 caches with no sign of a lodge. We hosted volunteers from several organizations, personnel from 10 news organizations, provided 25 presentations and 3 workshops, and maintained our Facebook page and website.

Summary

- We captured 191 (74 male, 117 female) individual white-tailed deer (*Odocoileus virginianus*), including 74 adults, 20 yearlings, and 97 fawns.

- We fitted 59 female deer with a GPS collar and 51 with a vaginal implant transmitter.

- We detected pregnancy using ultrasound in 98% of adult (*n* = 57) and 50% of yearling (*n* = 12) females.

- We captured and radio-collared 48 neonate fawns (22 male, 26 female).

- Twenty-three of 30 (77%) vaginal implant transmitter searches resulted in the location of 24 live and 5 stillborn fawns.

- We immobilized 14 adult black bears (*Ursus americanus*: 8 adult male, 4 adult female, 2 yearling male) in their dens and observed 5 cubs (3 male, 2 female) from 2 females and 2 yearlings (both male) from 1 female.

- We set 13 cage traps to capture bobcats (*Lynx rufus*).

- We captured and immobilized 13 *Ursus americanus* (6 male, 7 female) using barrel traps and Aldrich foot snares. We fitted all bears with a GPS collar.

- We used foothold traps to capture 1 coyote (*Canis latrans*; 1 male) and 9 wolves (*C*. spp.; 4 male, 5 female), fitting each with a GPS collar.

- We obtained 20,372 radiolocations of adult female deer.

- We observed 27 mortalities of radio-collared adult female deer. We attributed these to 14 wolf predations, 7 starvations, 1 coyote predation, 1 black bear predation, and 4 unknown causes. We censored two adult female deer from the sample because they died within 14 days of capture.

- We observed 24 mortalities of fawns born during May–June, 2018. We attributed these to 7 bear predations, 3 coyote predations, 1 wolf predation, 5 unidentified predations, 3 vehicle collisions, and 5 weak fawn syndrome mortalities. Additionally, we censored 3 fawns from the sample after their radio-collars appeared to have fallen off.

- We observed 12 mortalities of fawns born during May–June, 2017. We attributed these to 6 starvations, 3 bobcat predations, 1 wolf predation, 1 coyote predation, and 1 vehicle collision.

- We placed 52 remote infrared cameras at baited sites throughout the study area to estimate deer abundance and obtained 33,961 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 15 September 2018.

- We deployed hair snares and remote cameras at 52 sites throughout the study area to estimate bobcat abundance. We obtained 568 hair samples and > 166,900 images.

- We deployed hair snares and remote infrared cameras at 52 sites throughout the study area to estimate black bear abundance and obtained 588 hair samples and 3,827 images.

- We obtained a *coyote* response rate of 14.2% and wolf response rate of 0.4% 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. On average, grouse response rate was 41.0% across sessions.

- We completed snowshoe hare (*Lepus americanus*) pellet count surveys at 637 random locations stratified across 6 land covers to estimate hare densities.

- We conducted a beaver (*Castor canadensis*) cache survey to estimate beaver abundance within the study area. We flew 578 km of river and lakeshore and detected 57 active beaver caches.

- We conducted investigations at 531 carnivore cluster sites to identify prey.

- We hosted individuals from Michigan Department of Natural Resources, Michigan State University, Michigan Technological University, Purdue University, and members of the Safari Club International Michigan Involvement Committee during black bear den checks. We hosted production crews of Discovering Michigan, ABC 10 News, WJMN-TV3 News, WLUC-TV6 News, Daily Mining Gazette, The Mining Journal, The L'Anse Sentinel, and Into the Outdoors Education Network who took photos and video footage of project staff performing field duties featured the project in television, news, and print specials.

- We updated our Facebook page (https://www.facebook.com/campfirewildlife/) to provide the public with project results.

- We hosted students from Purdue University and Michigan Technological 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 25 different groups or organizations (including school groups) about ongoing project activities and findings.

- We were assisted by 7 technicians during January–March 2018, 8 technicians May–August 2018, and 3 technicians during September–December 2018.

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^2 (598 mi^2) 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^2 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

<u>Deer Trapping</u>

From 7 January 2017 to 23 March 2017 we captured white-tailed deer in Clover traps (Figure 2) to place radio-collars on pregnant females. We captured 191 unique deer (74 males, 117 females), with an additional 130 recaptures. Individuals captured included 61 adult females, 13 adult males, 12 yearling females, 8 yearling males, 44 female fawns, and 53 male fawns. The fawn:adult female ratio for winter captures in 2014–2015 was 1.59:1. 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, and 1.39:1 for winter 2016-2017 captures. 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 also assessed pregnancy of yearling and adult females using ultrasonography.

We immobilized 59 female deer and fitted 57 with radio-collars (model vertex survey 1D, Vectronic Aerospace, Berlin, Germany). We fitted 51 pregnant females with a vaginal implant transmitter (VIT; model 3930, Advanced Telemetry Systems Inc., Isanti, MN). 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 morphometrics and mid-rump fat depths (Table 1) when practical.

We detected pregnancy with ultrasound in 98% of adult females (n = 57), and 50% of yearling females (n = 12).

Fawn Capture

Beginning mid-May we captured, radio-collared, and obtained radio-locations for white-tailed deer fawns. We captured 48 live neonate fawns (22 male, 26 female) and fitted them with expandable radio-collars (model 4210, Advanced Telemetry Systems, Inc., Isanti, MN) during May–June. We attached 2 individually numbered plastic ear tags to fawns and attempted to collect fawn morphometrics (Table 2), blood, hair, and identify sex. We also recorded bed site and surrounding habitat, flush distance, presence of dam, additional deer sighted, and handling time.

Thirty-four adult female deer fitted with vaginal implant transmitters (VITs) during Jan–Mar 2018 survived through June 2018. Estimated parturition dates of VIT tagged does ranged from 31 May to 25 June. Three VITs were expelled early with no evidence of a fawn birth and 1 VIT was expelled in an open area precluding signal transmission of estimated parturition and subsequent fawn search. We conducted fawn searches of 30 implanted pregnant adult females. Twenty-three of 30 (77%) VIT searches resulted in the location of ≥1 fawn (24 live fawns and 5 stillbirths). We characterized vegetation and horizontal cover at birth sites. We captured 24 fawns during opportunistic encounters.

Deer Telemetry

We recorded 20,372 locations of GPS-collared adult female deer from 16 September 2017 to 15 September 2018. 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, and twice per week from 1 September to 15 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 16 September 2017 to 15 September 2018, we recorded 27 adult female mortalities. We attributed these to 14 wolf predations, 7 starvations, 1 coyote predation, 1 black bear predation, and 4 unknown causes. We censored two adult female deer mortalities from the study sample because they occurred within 14 days of capture.

We recorded 24 mortalities of neonate fawns born in May–July 2018. We attributed these to 7 bear predations, 3 coyote predations, 1 wolf predation, 5 unidentified predations, 3 vehicle collisions, and 5 weak fawn syndrome mortalities. Additionally, we censored 3 fawns from the study sample after their radio-collars appeared to have fallen off. Excluding censors, 2017 fawn apparent survival from birth to 15 September was 47%.

Deer Camera Survey

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 on and ended by 3 September. We obtained 33,961 images including 15,807 images of deer (13,510 adult females, 1,063 adult males, 862 fawns, and 372 unidentified deer). From camera images, we will estimate deer density for the 298 km^2 sampling area following Duquette et al. (2014).

We completed a preliminary estimate of deer density from the 2016 and 2017 baited deer camera surveys. Estimated total deer densities were 1.7 deer/km^2 (95% C.I. = 1.2–2.7) and 3.2 deer/km^2 (95% C.I. = 2.2–4.5) for August 2016 and 2017, respectively.

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 ≥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 16–19 December 2017 we immobilized 4 adult black bears (4 male). From 17 February to 2 March we immobilized 8 adult (3 male, 5 female) and 2 yearling (both male) black bears. We weighed, recorded morphometric measurements, and drew blood from each immobilized bear. We replaced VHF radio-collars with new VHF radio-collars or GPS collars. One collar was 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 minute thereafter until we remove the collar. We handled 5 cubs (3 male, 2 female) from 2 adult females; mean litter size was 2.5 (Table 3).

Bobcat Capture

We set cage traps (*n* = 13) to capture bobcats at previously baited bobcat hair snare sites or locations of observed bobcat sign during 6 Mar–9 July 2018. No bobcats were captured.

Coyote Cable Neck Restraints

We baited 6 locations with vehicle-killed deer carcasses to attract coyotes for capture. Due to warm temperatures and limited snow, we did not set cable neck restraints.

Spring/Summer Carnivore Capture

During 10 May–12 July, we captured 13 black bears (6 male, 7 female), 1 coyote (1 male, and 9 wolves (4 male, 5 female) using barrel traps, Aldrich foot snares, and foothold traps. 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 coyotes and wolves with Lotek 7000SU or Litetrack global positioning system (GPS) radio-collars (Lotek Engineering, Newmarket, ON, Canada). One bear received a Lotek 7000SU GPS radio-collars, 4 bears received a Lotek 7000MU GPS collar and 8 received a vertex survey 1D collar (Vectronic Aerospace, Berlin, Germany).

We programmed all 7000SU GPS radio-collars for bear, coyote and wolves to obtain a location every 35 hours until 1 May, every 15 minutes from 1 May to 31 September and every 35 hours from 1 October until the scheduled collar drop-off date. We programmed 7000MU GPS radio-collars fitted on black bear, to obtain a location every 35 hours until 1 May and then every 15 minutes until we replaced their collars in their dens. All 7000SU GPS radio-collars included a drop-off mechanism to release collars 25–35 weeks after deployment. We fit all radio-collars on black bears with a leather breakaway device.

Carnivore Monitoring

We recovered four GPS or VHF radio-collars during May–July 2018 after black bears removed their collars. Seven black bears (1 female, 6 male), radio-collared and/or ear-tagged during Phase III (May–July 2016; May–July 2017), and five ear-tagged black bears (4 female, 1 male), previously captured in the Phase I and II study areas, were harvested during the 2017 Michigan and Wisconsin black bear hunting seasons.

From 2 October 2017 to 15 January 2018, we located 12 black bears 12 times to confirm den sites. We located 4 bear dens during 5–10 December and during 16–19 December 2017 we immobilized 4 adult male black bears. We located 8 remaining bear dens (4 male, 4 female) during 1–15 January 2018 and during 17 February–2 March 2018 we immobilized 8 adult (3 male, 5 female) and 2 yearling (2 male) black bears.

Bobcat Hair Snares

We began baiting 52 bobcat hair snare sites (Figure 4) on 9 December 2017. After a two-week pre-bait period, we set 4 hair snares at each site beginning 5 January 2018. We also deployed a trail camera at each site, directed at the bait, to obtain images of all animals visiting the site.

We visited each bait site every 7 days to collect hair samples, reset snares, perform trail camera maintenance, and add bait as necessary. The eight-week survey was completed and we removed snares during 2–8 March 2018.

We collected 568 hair samples (of both target and non-target species) which we sent to the MDNR Wildlife Disease Laboratory for DNA extraction and subsequent individual identification. We obtained >166,900 camera images.

Black Bear Abundance Estimation: Hair Snares

During 27 May–21 July 2017 we conducted a hair snare survey to estimate black bear abundance. Hair snares (*n* = 52; 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 checked snares, added lure, and collected hair samples every ten days, for a total of five checks. We collected 588 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 2017. Survey sessions are on a 10 day rotation with all sites completed in 4 days, weather permitting. Through the end of the survey we obtained coyote and wolf response rates of 13.9% and 1.4%, respectively. We have completed 6 of 8 howl survey sessions which began on 13 July 2017. Currently, coyote and wolf response rates are 14.2% and 0.4% respectively.

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 49 individuals in 9 packs whose territories include the study area: Baraga Plains (minimum 5 individuals), Frost Junction (minimum 7 individuals), Sidnaw-Kenton (minimum 8 individuals), Trout Creek (minimum 6 individuals), Prickett Dam (minimum 5 individuals), Gardner Road (minimum 7 individuals), Rousseau (minimum 4 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 22 May to 31 August 2018, we investigated 531 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 531 clusters investigated this year, 134 were black bear (mean clusters/black bear = 19.1), 39 bobcat (mean clusters/bobcat = 39.0), 86 coyote (mean clusters/coyote = 86.0), and 272 wolf (mean clusters/wolf =34.0).

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 drumming surveys during 3–7 May 2018. We conducted surveys from one half hour before sunrise to 5 hours after sunrise. Each survey contained 3 routes with 20–25 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 41.0% resulting in an estimated density of 2.86 grouse/km^2.

Snowshoe Hare Pellet Counts

We conducted snowshoe hare pellet counts during 2–15 May. We counted number of hare pellets within a 1 m^2 rectangle at 637 random locations stratified across 6 land covers 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 linear regression (McCann et al. 2008). Estimated hare density was 29.29 hare/km^2.

Aerial Beaver Cache Survey

We flew 578 km of river and lakeshore on 6–8 November 2017 at an altitude of 200–250 m to identify active beaver caches. We detected 50 inactive lodges, 57 active lodges with a cache, and 13 caches with no sign of a lodge (equates to one active cache for every 8.2 km surveyed; Figure 8).

Public Outreach

During black bear den checks and white-tailed deer trapping we hosted individuals from Michigan Department of Natural Resources (MDNR), Michigan State University, Michigan Technological University, 906 Outdoors (Discovering), Safari Club International Michigan Involvement Committee, ABC 10 News, WJMN-TV3 News, WLUC-TV6 News, Daily Mining Gazette, The Mining Journal, The L'Anse Sentinel, Into the Outdoors Education Network and other interested members of the public. We participated in two television shows and will provide this media to Safari Club International Foundation to promote the project.

We attended several local sportsman's coalition meetings to discuss the project and improve awareness of project goals and activities. We hosted 23 and 19 undergraduate students from Purdue University (8 June) and Michigan Technological University (1 August) for demonstrations of detection dogs, carnivore immobilizations, fawn capture, vegetation surveys, and deer telemetry. We gave presentations to 17 classes at local public schools, reaching 378 students. We hosted 23 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:

Duquette, J.F., J.L. Belant, C.M. Wilton, N. Fowler, B.W. Waller, D.E. Beyer, Jr., N.J. Svoboda, S.L. Simek, J. Beringer. 2017. Black bear functional resource selection relative to intraspecific competition and human risk. Canadian Journal of Zoology 95:203–212.

Friedrich, A. U., J. Kakuturu, P. J. Schnorr, D. E. Beyer Jr, J. A. Palesty, E. W. Dickson, G. Basadonna, and M. A. Cahan. 2017. Comparative coagulation studies in hibernating and summer-active black bears (*Ursus americanus*). Thrombosis Research 158:16.

Presentations to hunting groups, service organizations, and schools:

Fowler, N., T. Kautz, A.L. Lutto, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 30 Aug 2018. Role of predators, winter weather, and habitat on white-tailed deer fawn survival in Michigan's Upper Peninsula. Lake Linden-Hubbell Sports Association. Rice Lake, MI. 20 attendees.

Kautz, T., N. Fowler, A.L. Lutto, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 15 Aug 2018. Role of predators, winter weather, and habitat on white-tailed deer fawn survival in Michigan's Upper Peninsula. Michigan Department of Natural Resources Marquette Office, Marquette, MI. 12 attendees.

Lutto, A.L, N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 14 Aug 2018. Role of predators, winter weather, and habitat on white-tailed deer fawn survival in Michigan's Upper Peninsula. Land O' Lakes Fish and Game Club, Land O Lakes, WI. 28 attendees.

Lutto, A.L, N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 6 Aug 2018. Role of predators, winter weather, and habitat on white-tailed deer fawn survival in Michigan's Upper Peninsula. Michigan Department of Natural Resources' Academy of Natural Resources-North, Alberta, MI. 23 attendees.

Lutto, A.L, N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 1 Aug 2018. Role of predators, winter weather, and habitat on white-tailed deer fawn survival in Michigan's Upper Peninsula. Michigan Technological University Forestry and Wildlife Field Class, Silver Mountain, MI. 19 attendees.

Kautz, T., N. Fowler, A.L. Lutto, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 19 July 2018. Role of predators, winter weather, and habitat on white-tailed deer fawn survival in Michigan's Upper Peninsula. Ottawa National Forest Visitor Center, Watersmeet, MI. 43 attendees.

Lutto, A.L, Z. Farley, N. Fowler, T. Kautz, , J.L. Belant, and D.E. Beyer, Jr. 8 June 2018. 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, MI. 23 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 14 May 2018. Michigan Predator-Prey Project. Forest Park School Second Grade, Crystal Falls, MI. 17 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 14 May 2018. Michigan Predator-Prey Project. Forest Park School Third Grade, Crystal Falls, MI. 16 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 14 May 2018. Michigan Predator-Prey Project. Forest Park School Fourth and Fifth Grades, Crystal Falls, MI. 31 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 11 May 2018. Michigan Predator-Prey Project. Forest Park School Biology Class, Crystal Falls, MI. 15 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 11 May 2018. Michigan Predator-Prey Project. Forest Park School Environmental Science Class, Crystal Falls, MI. 18 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 11 May 2018. Michigan Predator-Prey Project. Forest Park School First Grades, Crystal Falls, MI. 37 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 11 May 2018. Michigan Predator-Prey Project. Forest Park School Sixth Grade, Crystal Falls, MI. 15 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 11 May 2018. Michigan Predator-Prey Project. Forest Park School Kindergarten Grade, Crystal Falls, MI. 26 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 7 May 2018. Michigan Predator-Prey Project. West Iron County Schools Third Grades, Iron River, MI. 37 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 7 May 2018. Michigan Predator-Prey Project. West Iron County Schools Second Grades, Iron River, MI. 25 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 4 May 2018. Michigan Predator-Prey Project. West Iron County Schools Seventh and Eighth Grade, Iron River, MI. 19 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 4 May 2018. Michigan Predator-Prey Project. West Iron County Schools First Grade, Iron River, MI. 29 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 4 May 2018. Michigan Predator-Prey Project. West Iron County Schools Biology Class, Iron River, MI. 15 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 4 May 2018. Michigan Predator-Prey Project. West Iron County Schools Sixth and Fourth Grades, Iron River, MI. 37 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 4 May 2018. Michigan Predator-Prey Project. West Iron County Schools Kindergarten Grade, Iron River, MI. 22 attendees.

Lutto, A.L, N. Fowler, T. Kautz, Z. Farley, J.L. Belant, and D.E. Beyer, Jr. 4 May 2018. Michigan Predator-Prey Project. West Iron County Schools First Grade, Iron River, MI. 19 attendees.

Lutto, A.L., T. Kautz, N. Fowler, Z. Farley, J.L. Belant, D.E. Beyer Jr. 8 March 2017. Michigan Predator-Prey Project. TriO Pre-College Programs Finlandia University. Hancock, MI. 16 Attendees.

Kautz, T. M., Fowler, A.L. Lutto, Z. Farley, J.L. Belant, D.E. Beyer, Jr. 5 October 2017. 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, A.L. Lutto, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 6 Aug 2018. Field techniques for Michigan Predator-Prey Project. Michigan Department of Natural Resources' Academy of Natural Resources, Silver Mountain Field Station, Pelkie, MI. 23 attendees.

Lutto, A.L., N. Fowler, T. Kautz, J. Magee, J.L. Belant, and D.E. Beyer, Jr. 1 Aug 2017. Field techniques for wildlife capture and predation investigation. Michigan Technological University Field Class, Silver Mountain Field Station, Pelkie, MI. 19 attendees.

Lutto, A.L., Z. Farley, N. Fowler, T.M. Kautz, J.L. Belant, D.E. Beyer, Jr. 8 June 2018. Field techniques for wildlife capture and predation investigation. Purdue Wildlife Ecology Field Class. Silver Mountain Field Station, Pelkie, MI. 23 attendees.

News Broadcast:

ABC 10 News – Bear den checks with the DNR
News segment
WJMN-TV3 News segment
WLUC-TV6 News segment

Print Media:
Daily Mining Gazette – Researchers lowered in bear dens in predator-prey study
Newspaper article
Dave Schneider, freelance outdoor writer
The Mining Journal
The L'anse Sentinel
Richard P. Smith, freelance outdoor writer

Outdoor shows:
906 Outdoors Discovering
Television segment
Into the Outdoors Education Network

Field Assistants

During January–March 2018 and May–August 2018 we recruited 7 and 8 seasonal technicians, respectively. We recruited 3 technicians for September–December 2018. One technician from the summer will continue to work through the fall.

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-November before heavy snow fall and conduct black bear den checks beginning in mid-December to change GPS collar batteries on collared male black bear.

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 store all summer field equipment and repair and store all project ATVs. We will prepare deer and bobcat traps for winter trapping, as well as bobcat hair snares.

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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Nathan Svoboda, Graduate Student (Phase 1), Mississippi State University
Cody Norton, Graduate Student (Phase 2), Northern Michigan University
Tyler Petroelje, Graduate Student (Phase 1 & 2), Mississippi State University

Phase 3 – Project Technicians:

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Ben Murley	Ryan Harris	Chris Kailing
Kathryn Sliwa	Forrest Rosenbower	Jackie Tauberman
Clara Shattuck	Elaine Gallenberg	Chris Varner
Adam Fahnestock	Abigail Thiemkey	Jesse Ritter
Rebekah Lumkes	Victoria Frailey	

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906 Outdoors
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Neil Harri (Air 1), MDNR
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Table 1. Mean ($\bar{x}$) and standard deviation (SD) of adult (n = 57) and yearling (n = 12) female white-tailed deer morphometrics and body condition estimates, Upper Peninsula of Michigan, USA, January–March 2018.

	Age Class			
	Adults		Yearlings	
Metric	$\bar{x}$	SD	$\bar{x}$	SD
Body weight (kg)	65.0	6.4	54.2	5.5
BCS[1]	2.36	0.71	2.7	0.61
MIDF[2] (cm)	0.34	0.35	0.27	0.2

[1] Body condition score (BCS) derived from palpation following Cook et al. (2010).

[2] 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 morphometrics for 48 captured female (n = 26) and male (n = 22) neonate fawn white-tailed deer, Upper Peninsula of Michigan, USA, 1–24 June 2018.

	Sex			
	Female		**Male**	
Estimate	$\bar{x}$	SD	$\bar{x}$	SD
Body weight (kg)	3.5	1.0	3.8	1.8
Body Length (cm)	55.8	6.7	56.6	8.7
Chest Girth (cm)	33.7	3.3	35.4	9.5
Hind Foot (cm)	25.2	2.0	24.9	2.7
Shoulder Height (cm)	47.2	6.1	48.5	5.7
Birth Mass (kg)[1]	2.8	0.9	2.8	1.2

[1] 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, 16 Dec 2017-2 March 2018.

ID	Den check date	Age	Sex	Body weight (kg)	Right ear tag	Left ear tag
BB337	16-Dec-17	Adult	M	48.3	446	447
BB341	17-Dec-17	Adult	M	64.8	433	461
BB316	18-Dec-17	Adult	M	93.9	474	475
BB342	19-Dec-17	Adult	M	82.5	366	427
BB300	17-Feb-18	Adult	M	93.7	270	340
BB310	18-Feb-18	Adult	M	103.0	392	442
BB303	19-Feb-18	Adult	M	NA	372	NA
BB302	20-Feb-18	Adult	F	67.3	328	329
Yearling 1	20-Feb-18	Yearling of BB302	M	17.7	622	623
Yearling 2	20-Feb-18	Yearling of BB302	M	18.3	624	625
BB343	21-Feb-18	Adult	F	57.4	454	455
BB346	21-Feb-18	Cub of BB343	M	1.8	NA	NA
BB347	21-Feb-18	Cub of BB343	F	1.7	NA	NA
BB348	21-Feb-18	Cub of BB343	M	1.5	NA	NA
BB339	21-Feb-18	Adult	F	66.7	438	439
BB335	23-Feb-18	Adult	F	99.6	429	428
BB349	23-Feb-18	Cub of BB335	M	2.3	NA	NA
BB350	23-Feb-18	Cub of BB335	F	1.9	NA	NA
BB345	2-Mar-18	Adult	M	80.4	459	460

Table 4. Carnivore capture data, Upper Peninsula of Michigan, USA, 15 May–12 July 2018.

Species	ID	Capture date	Sex	Body weight (kg)	Right ear tag	Left ear tag
Wolf	WO308	15-May-18	F	32.0	1247	1248
Wolf	WO309	23-May-18	M	35.3	1209	1205
Wolf	WO310	24-May-18	F	24.3	1399	1400
Wolf	WO311	27-May-18	F	31.3	1395	1243
Wolf	WO312	02-Jun-18	F	30.5	1378	1376
Wolf	WO313	03-Jun-18	M	33.8	1398	1382
Wolf	WO314	10-Jun-18	F	30.0	1397	1396
Wolf	WO315	17-Jun-18	M	37.7	1240	1242
Wolf	WO316	22-Jun-18	M	32.7	1277	1276
Coyote	CO302	14-Jun-18	M	16.0	609	610
Black Bear	BB351	19-Jun-18	F	59.5	441	621
Black Bear	BB352	21-Jun-18	F	42.4	607	370
Black Bear	BB353	25-Jun-18	M	54.2	620	606
Black Bear	BB303	26-Jun-18	M	107.7	372	601
Black Bear	BB354	26-Jun-18	F	38.4	605	602
Black Bear	BB355	27-Jun-18	F	61.4	440	368
Black Bear	BB356	27-Jun-18	M	42.9	603	469
Black Bear	BB357	28-Jun-18	F	30.5	604	614
Black Bear	BB302	05-Jul-18	F	67.0	328	329
Black Bear	BB358	06-Jul-18	M	51.4	619	617
Black Bear	BB338	06-Jul-18	M	106.3	445	444
Black Bear	BB359	11-Jul-18	M	49.4	638	637
Black Bear	BB360	11-Jul-18	F	64.8	633	635

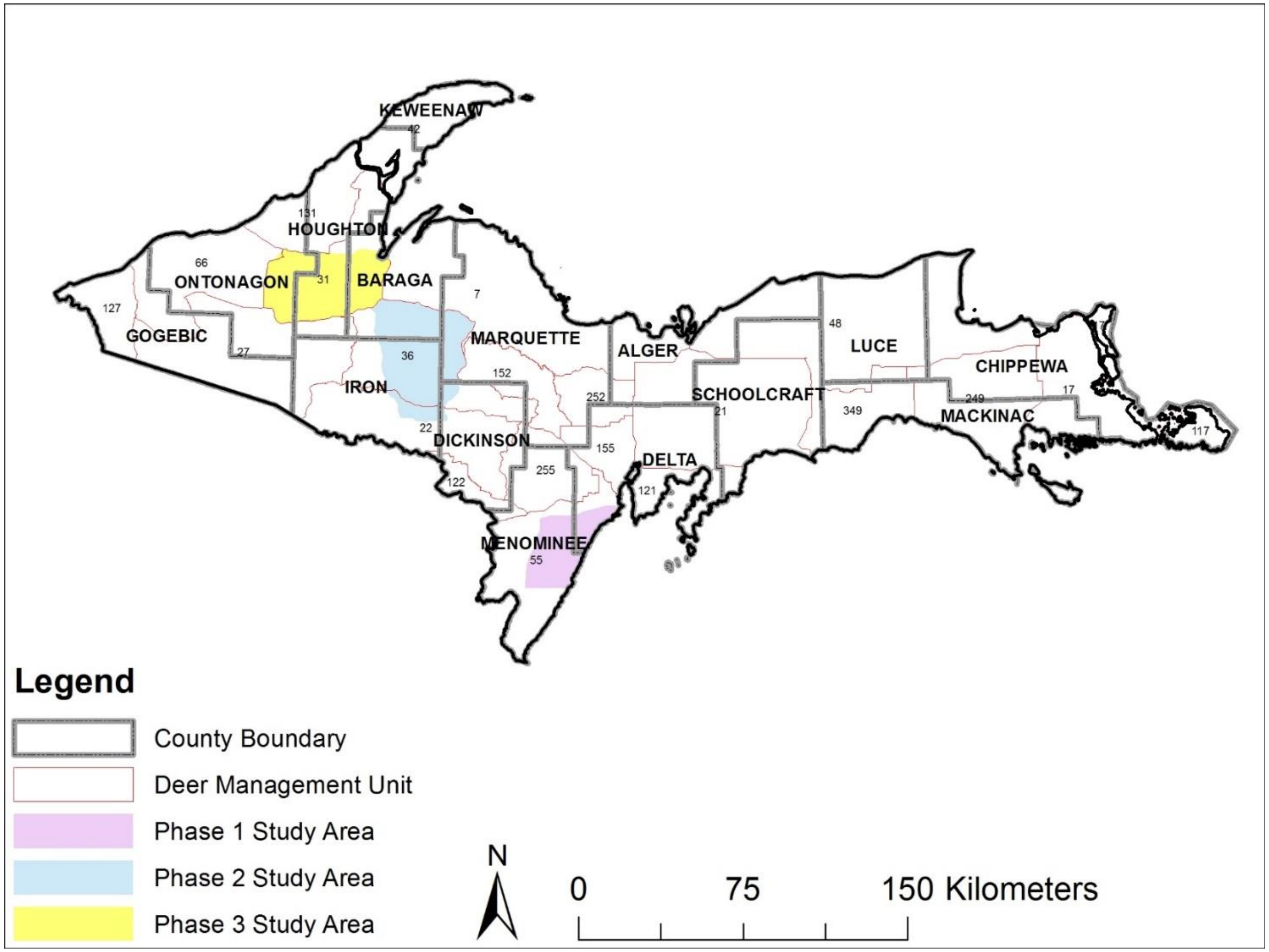

Figure 1. Location of phase 1, 2 and 3 study areas and Michigan Department of Natural Resources Deer Management Units, Upper Peninsula of Michigan, 2008–2017.

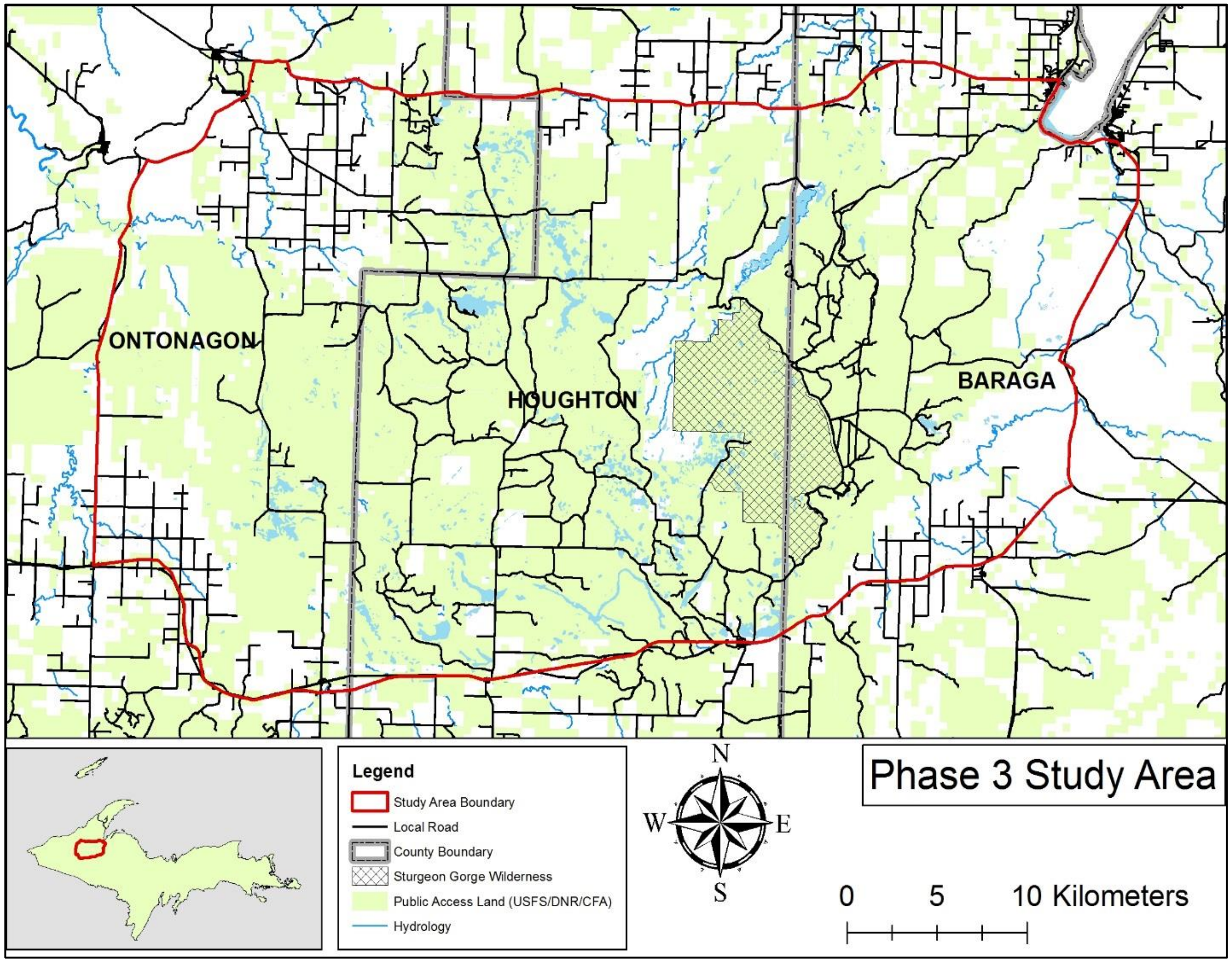

Figure 2. Location of phase 3 study area and counties, Upper Peninsula of Michigan, USA.

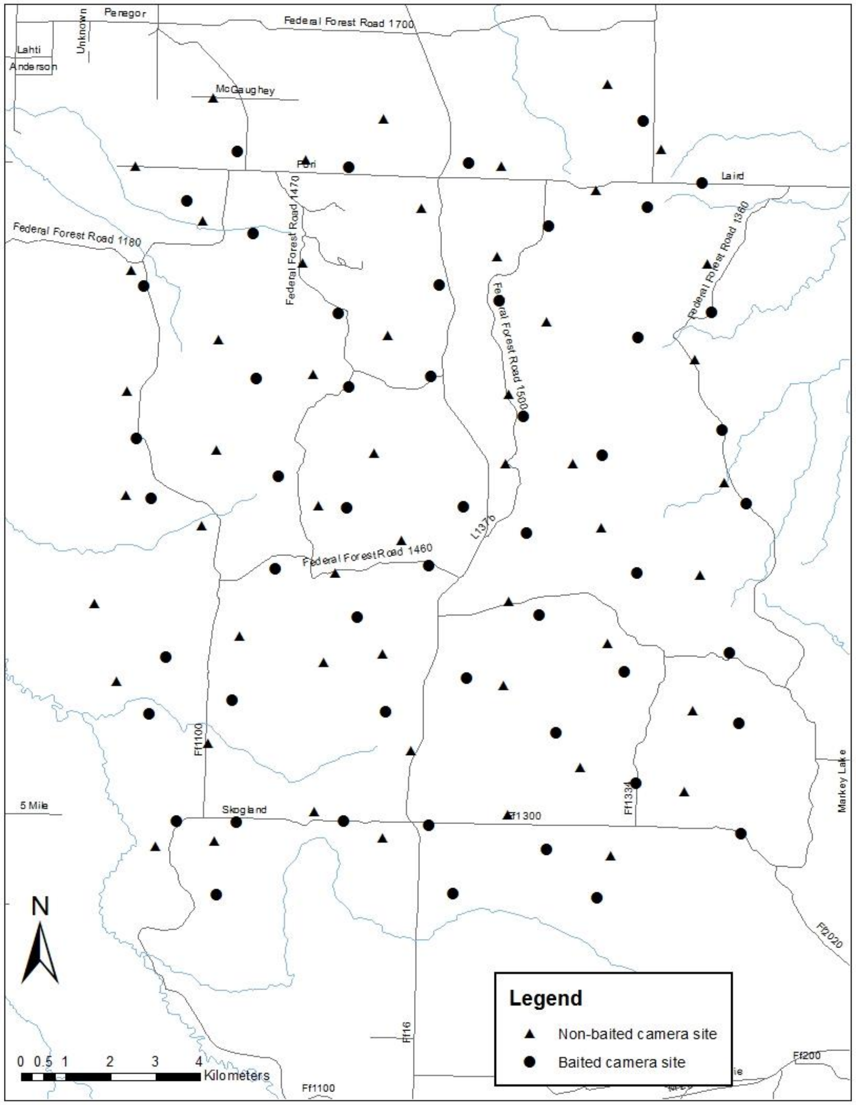

Figure 3. Locations of 52 baited and 52 non-baited remote camera sites to estimate deer abundance, Upper Peninsula of Michigan, USA, 2018.

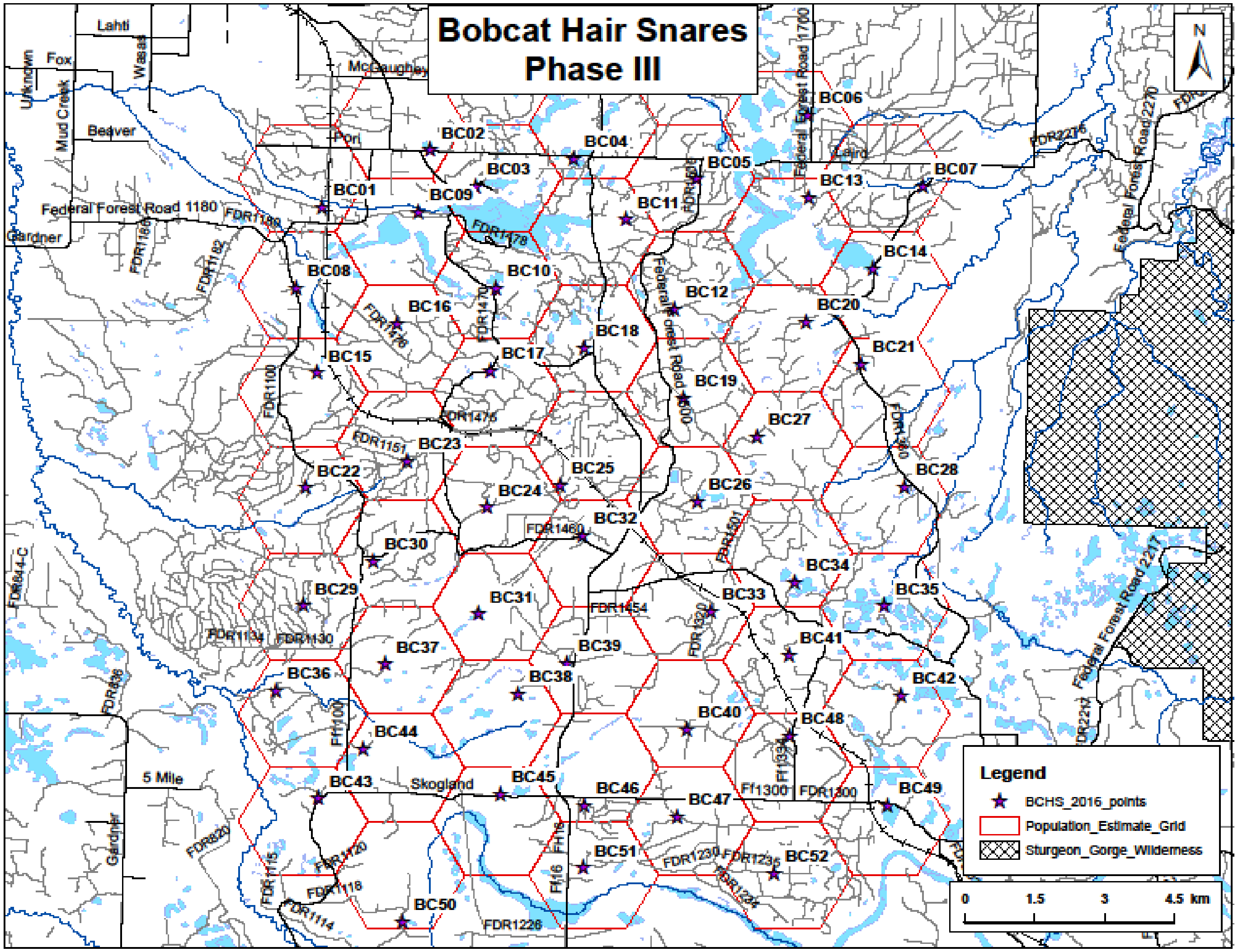

Figure 4. Locations of 52 bobcat hair snare sites to estimate bobcat abundance, Upper Peninsula of Michigan, USA, 2018

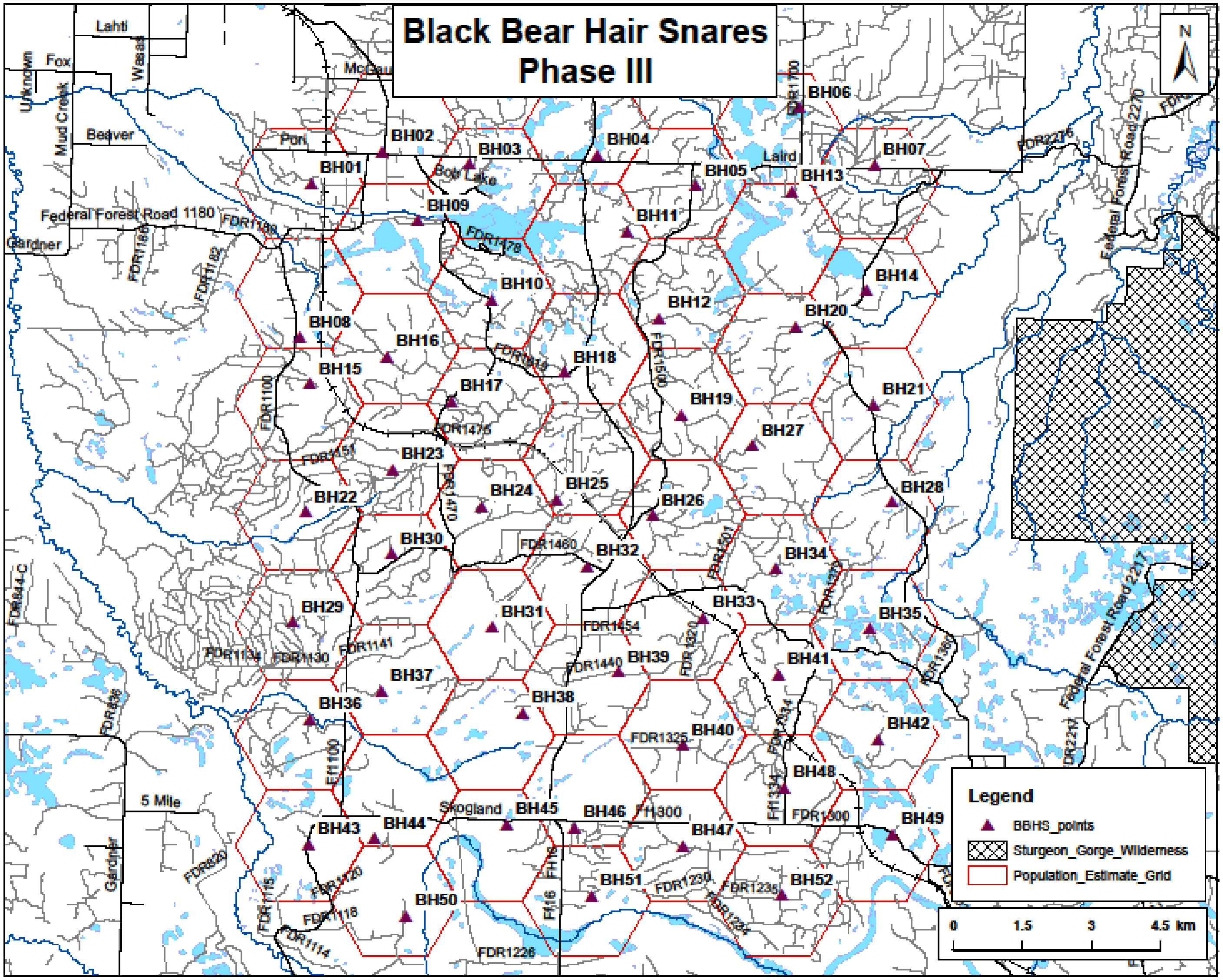

Figure 5. Locations of 52 black bear hair snare sites to estimate black bear abundance, Upper Peninsula of Michigan, USA, 2018.

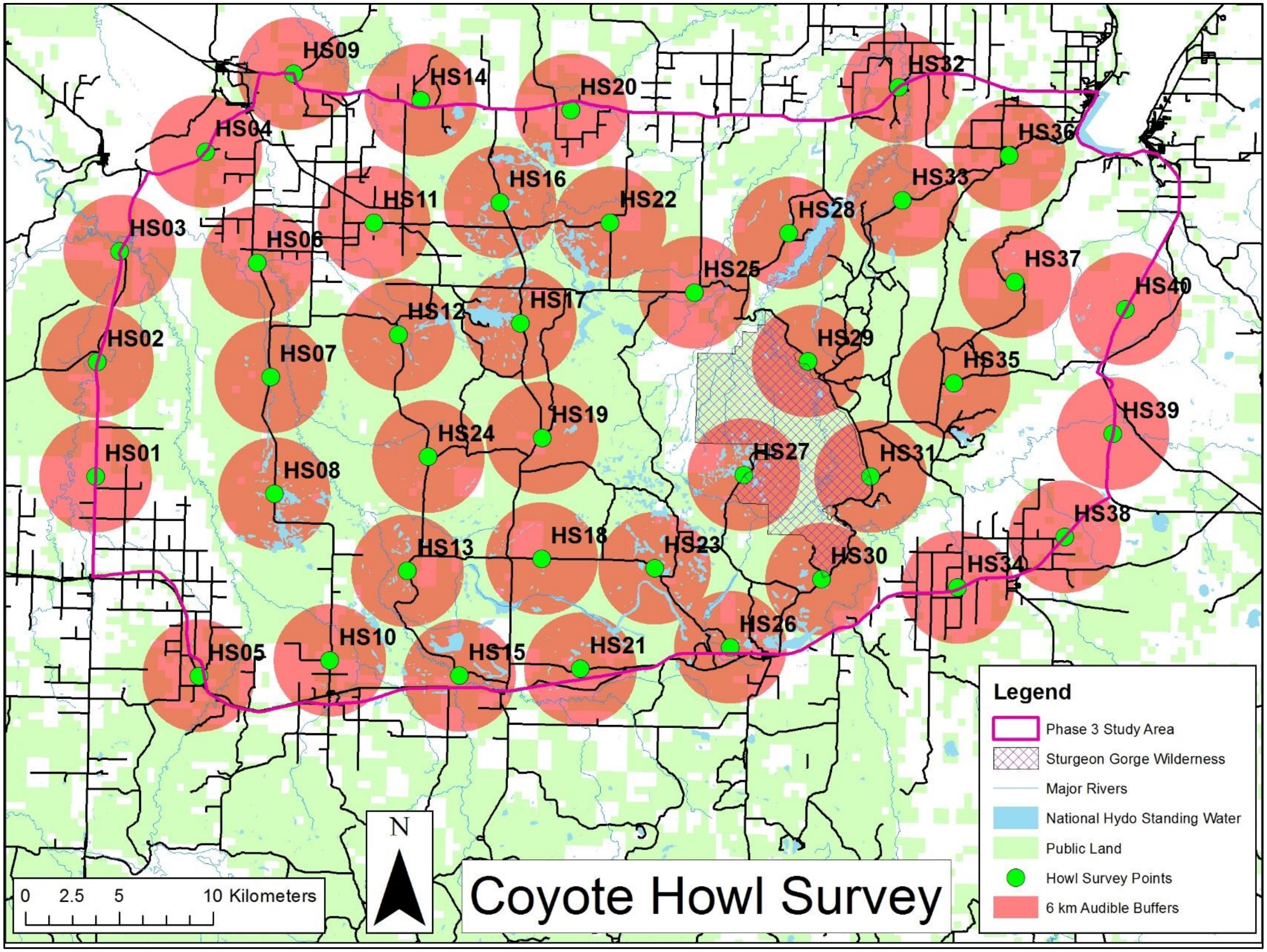

Figure 6. Locations of 40 howl survey sites to estimate coyote abundance, Upper Peninsula of Michigan, 2018.

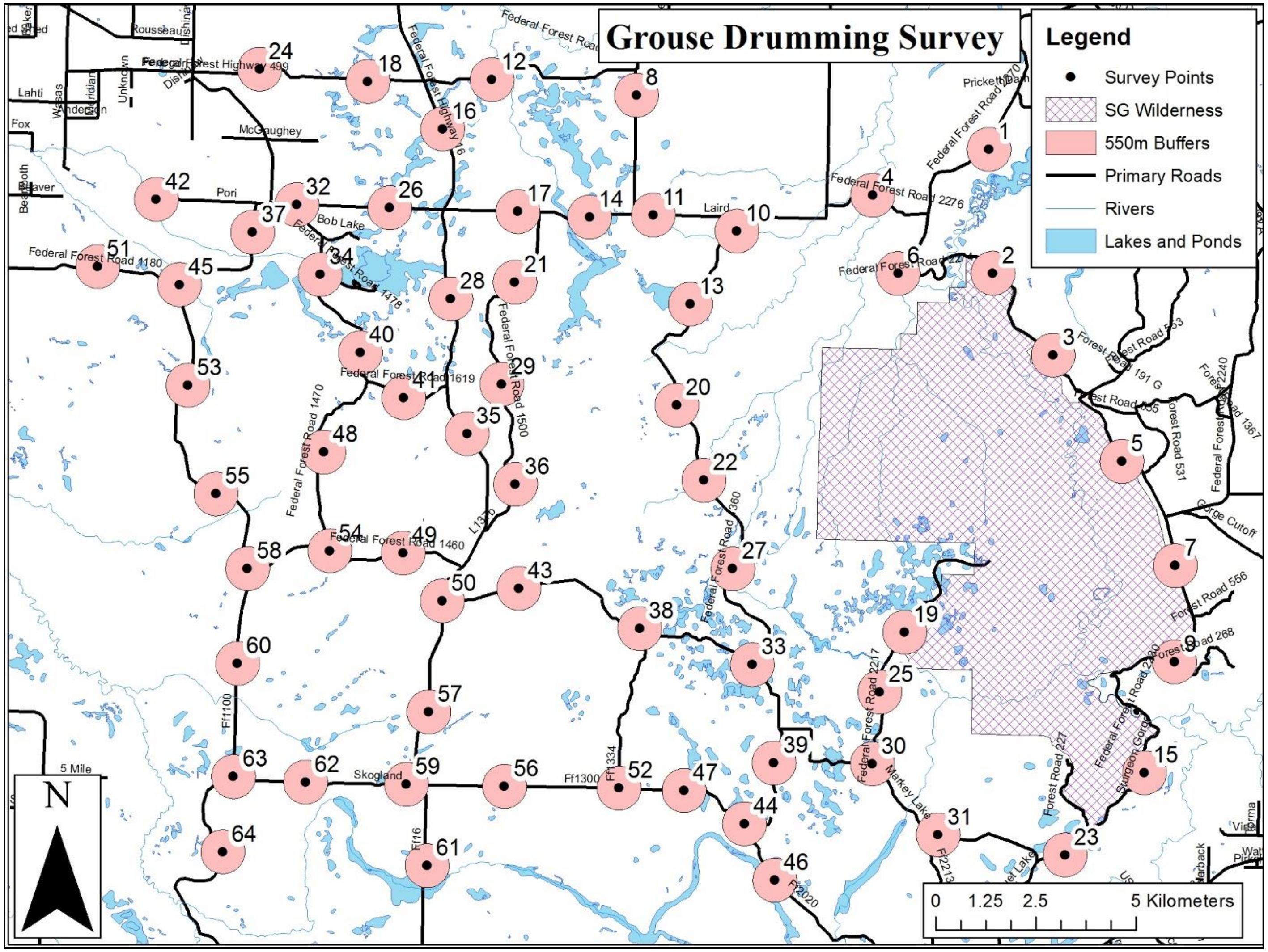

Figure 7. Locations of 64 grouse drumming survey sites with 550 m audible buffer along 3 routes to estimate abundance, Upper Peninsula of Michigan, USA, 2018.

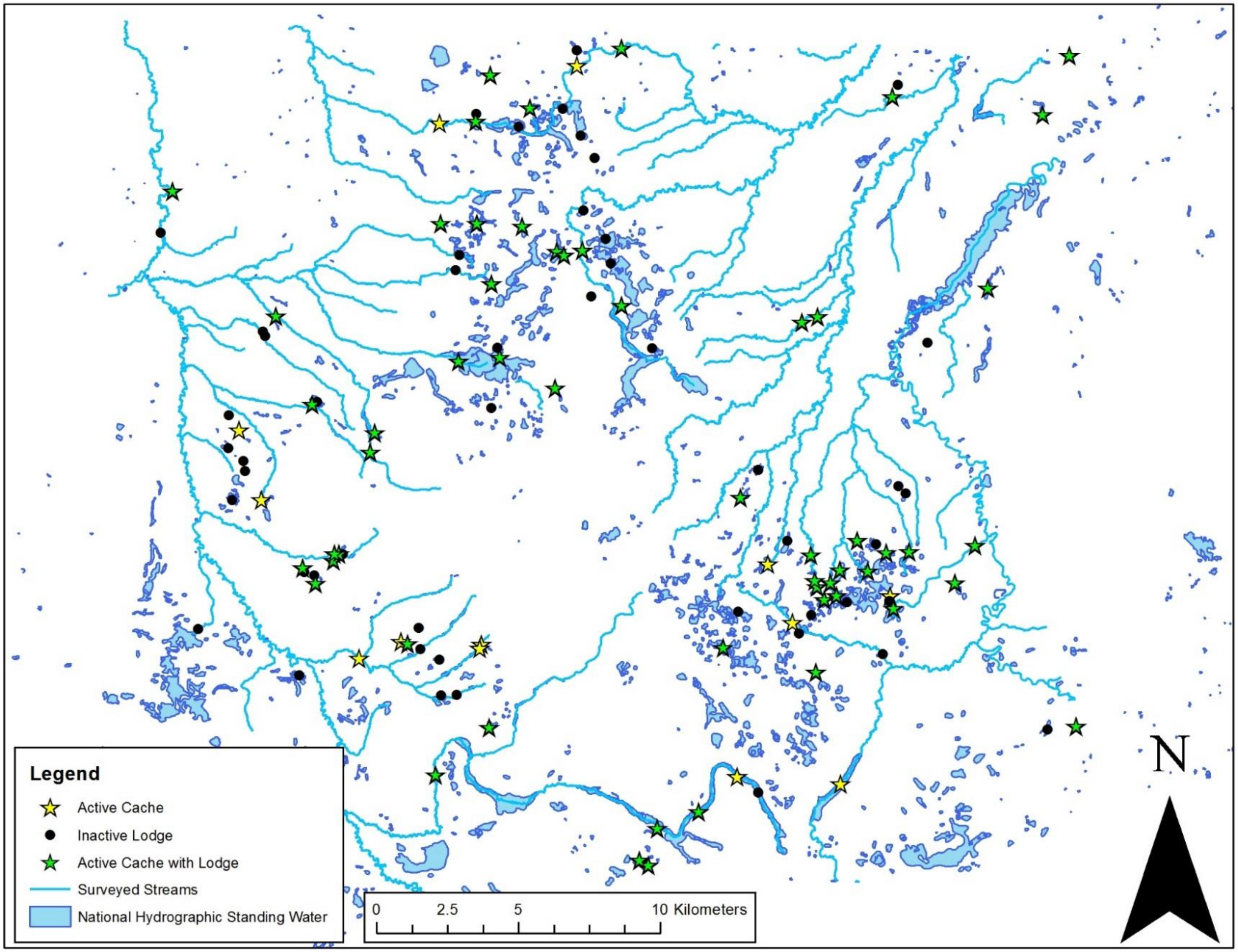

Figure 8. Locations of beaver caches and lodges detected aerially during 06-08 November, Upper Peninsula of Michigan, USA, 2017.