Abstract  We captured and radiocollared 48 neonate white-tailed deer (*Odocoileus virginianus*) 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. Sixteen adult female and 12 neonate fawn mortalities occurred this quarter. We collected 8,131 adult female GPS and radiolocations and radio-monitored fawns for daily survival. We captured 7 wolves (*Canis lupus*; 2 male, 5 female) with foothold traps. We conducted investigations at 130 carnivore cluster sites to identify carnivore prey sources. We conducted 5 ruffed grouse (*Bonasa umbellus*) drumming surveys to estimate abundance. We completed snowshoe hare (*Lepus americanus*) pellet surveys at 637 random locations stratified within 6 land covers to estimate hare density. We deployed hair snares at 52 sites to estimate black bear abundance. We gave 17 presentations, conducted a trapping demonstration for undergraduates, and hosted 22 undergraduate students to provide a field techniques seminar on the study. We updated the project website and project Facebook page with information and results obtained this quarter. We hired 8 technicians to assist with ongoing field activities.
Summary

- We observed 16 dead radio-collared adult female white-tailed deer (*Odocoileus virginianus*) which were attributed to 1 myopathy, 5 starvations, 7 wolf predations, 1 black bear predation and 2 unknown causes.

- We captured and radio-collared 48 neonate fawns, including 22 males and 26 females.

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

- We obtained 8,131 adult female deer GPS radiolocations and monitored VITs and fawn collars daily via VHF telemetry.

- We observed 12 radio-collared neonate fawn mortalities attributed to 3 from weak fawn syndrome, 2 coyote predations, 1 bear predation, 1 wolf predation, 3 unidentified predations, and 2 non-predation natural causes (pending lab necropsy).

- We captured 7 wolves (2 male, 5 female) and 1 coyote (male). Each were fitted each with a GPS collar.

- We conducted investigations at 130 carnivore cluster sites to identify carnivore prey sources.

- We conducted 5 ruffed grouse (*Bonasa umbellus*) drumming surveys to estimate grouse abundance. Probability of detection was 41.0% resulting in an estimated density of 2.86 grouse/km$^2$.

- We completed snowshoe hare (*Lepus americanus*) pellet count surveys at 637 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 29.29 hare/km$^2$.

- We deployed hair snares at 52 sites throughout the study area to estimate black bear abundance.

- We hosted 22 undergraduate students from Purdue University to demonstrate detection dog work, carnivore capture and immobilization, radio-telemetry, and fawn capture.

- We gave 17 presentations to local school classes.

- We updated our Facebook page ([www.Facebook.com/MIPredPrey](http://www.Facebook.com/MIPredPrey)) to provide the public with project results.
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.

Our overall goal 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 Upper 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 have now completed field work within a low snow depth study site and are currently collecting data within a second study site with moderate snow depth. The following objectives are specific to the Upper Michigan study areas but are also 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 (*Canis* 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 km² (598 mi²) 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 at 0.62 km/km² 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**

**Fawn Capture**

Beginning in June, we captured and radio-collared white-tailed deer fawns. Forty-eight neonate fawns were captured and fitted with expandable radio-collars (model 4210, Advanced Telemetry Systems, Inc., Isanti, MN) during 01 Jun – 24 June, consisting of 22 males and 26 females. We attached 2 individually numbered plastic ear tags to fawns and attempted to collect fawn morphometrics (Table 1), blood, hair, vitals, and identify sex. We also recorded bed site and surrounding habitat, presence of dam, additional deer sighted, and handling time as available. An additional 6 stillborn fawns were found at collared doe parturition sites. Parturition of collared does began on 31 May and all does had given birth by 25 June.

Thirty-four adult female deer fitted with vaginal implant transmitters (VITs) during Jan-Mar 2018 survived through 15 Jun 2018. Four VITs were expelled prior to parturition with no evidence of a birth site nearby, so we could not conduct a fawn search. All adult females expelled their VIT by 25 June. We conducted searches in the effort to find fawns of 30 implanted pregnant adult females. Twenty-three of 30 (77%) VIT searches resulted in the location of ≥1 live or dead fawn (24 live fawns and 5 stillbirths). An additional 3 parturition events were identified through GPS movements of deer collared during 2017, at which 2 live and 1 stillborn fawns were located. Twenty-two fawns were captured through opportunistic encounters within the study area.
Deer Mortality

We recorded 16 adult female mortalities during 15 Mar – 30 Jun 2018. Seven mortalities were attributed to wolf predation. Five mortalities were attributed to starvation. One mortality was attributed to black bear predation. One mortality was attributed to capture myopathy. We were unable to diagnose cause of mortality for two adult females in the field.

We recorded 6 juvenile deer mortalities on individuals born during 2017, including 3 bobcat predations, 1 coyote predation, 1 unidentified predation, and 3 starvations. Two juvenile deer slipped their collars and were censored from survival analyses.

We recorded 12 neonatal deer mortalities of fawns born during 2018, including three from probable weak fawn syndrome, two from unidentified non-predation natural causes, two coyote predations, 1 wolf predation, 1 bear predation, and 3 predations in which the predator species could not be identified based on field evidence. Additionally, 2 neonatal fawns slipped their collars and were censored from survival analyses.

All mortality causes are preliminary until results from carcass DNA swabs and lab necropsies are obtained.

Deer Telemetry

We obtained 8,131 GPS locations of radiocollared adult females between 15 March and 30 June 2018. Beginning 15 May, we conducted daily truck-based telemetry and tri-weekly aerial telemetry to monitor VIT status of does and survival of VHF collared fawns.

Carnivore Capture

During 10 May–15 June, we captured 7 wolves (2 male, 5 female) and 1 coyote (male) using foothold traps. We immobilized captured individuals and recorded gender, weight, and affixed uniquely numbered ear tags (Table 2). 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 wolves 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 until the scheduled collar drop-off date. We fitted all GPS radiocollars with a drop-off mechanism to release collars 25–35 weeks after deployment.

Carnivore Cluster Investigation

During 22 May–15 June, we used clusters of carnivore locations obtained from GPS radiocollars to identify potential kill sites and estimate the number and species of prey killed. Currently, we have investigated 130 GPS location clusters identified using ArcGIS and the statistical software program R (R Development Core Team, Vienna, Austria). We defined a cluster spatially as ≥5 locations within 50 m of each other within a 24-hour period. Of the 130 clusters, 67 were black bear, 32 bobcat and 31 wolf. Analysis of cluster data is ongoing.

Ruffed Grouse Drumming Survey

We conducted ruffed grouse (*Bonasa umbellus*) drumming surveys during 03 May – 07 May. We conducted surveys from one half hour before sunrise to 5 hours after sunrise. Each survey contained 3 routes with 20–25 sites per route for a total of 64 sites (Figure 4). Observers listened for 5
minutes at each site for drumming grouse and recorded number and bearing of each drumming grouse. 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 ($Lepus$ $americanus$) pellet counts during 02 May – 15 May. We counted number of hare pellets within a 1 m$^2$ rectangle at 644 random sites (Figure 5). 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). Across land cover types estimated hare density was 29.29 hare/km$^2$.

Black Bear Abundance Estimation
On 15 May we began the pre-bait period for a hair snare survey to estimate black bear abundance. Hair snares ($n = 52$; Figure 6) consist 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 or raspberry oil on close proximity trees. We also placed a remote trail camera at each site to document site visitation. Project personnel check snares, add lure, and collect hair samples every ten days. We will check each snare five times; the survey will continue through 11 July. We will send hair samples to the MDNR lab for DNA extraction and subsequent individual identification. We have 174 samples collected after 2 of 5 checks.

Public Outreach
We hosted 28 undergraduate students from Purdue University on 2 June for demonstrations of detection dogs, carnivore immobilizations, fawn capture, vegetation surveys, and deer telemetry. We presented at Michigan Department of Natural Resources Wildlife Through Forest Forum and Calumet-Keweenaw Sportsmen’s Club to inform members of the public about ongoing research in the area. We also gave presentations to 27 classes at local public schools, reaching 549 students. We updated our Facebook page (www.Facebook.com/MIpredprey) to provide the public with project results.

Presentations:


Seminars and Workshops:

Technician Selection and Hiring
We hired 8 seasonal technicians to assist with field work from 1 May through 31 August 2017. Additionally, we contracted work with Find It Detection Dogs for the use of 3 conservation detection dogs and 2 handlers to aid in the search for predation events at carnivore cluster sites.

Work to be completed (16 June 2017 – 30 September 2017)
Carnivore Monitoring
We will continue monitoring carnivores twice weekly via aerial telemetry. We will download location data from carnivore GPS collars through 31 August for predation site investigation.

Predation Site Investigation
We will continue investigations of carnivore predation site locations (clusters) through 31 August to assess their role in predation on white-tailed deer.

Deer Telemetry
Collared adult female deer will transmit location and survival status at 13-hr intervals via satellite. Through post-parturition we will continue to observe radio-collared deer daily to monitor the remaining VIT tag expulsion and capture fawns. We will investigate mortalities as soon as practical (generally <24 hours) after detecting a mortality signal to determine cause of death.

Black Bear Abundance Estimation
We will check each hair snare for a total of five checks; the survey will continue through 11 July. We will continue to send hair samples to the MDNR lab for DNA extraction and subsequent individual identification.

Fawn Capture and Radio-collaring
We will continue capture fawns opportunistically and using VIT signals, then fit each fawn with an expandable VHF collars. At each capture, we will collect blood and morphometric indicators of health. We will check mortality status of radio-collared fawns daily through 90 days post-parturition.

Carnivore Trapping and Radio-collaring
We will continue trapping black bear, bobcat, coyote, and wolves until July 8. We will use #3 Victor soft-catch (Oneida Victor Inc., Cleveland, Ohio) foothold traps for bobcat and coyote; MB 750 (Minnesota Trapline Products Inc., Pennock, Minnesota) foothold traps to capture wolves; and barrel traps and foot-snares to capture black bear. We will fit captured carnivores with a GPS collar, affix ear tags, record morphometric measurements, determine sex and body condition, and evaluate for injury. We will collect blood, hair, and extract a vestigial premolar from black bear.
Coyote Abundance Estimation

On 12 July we will begin conducting howl surveys at 40 sites to estimate coyote abundance. We will conduct surveys every ten days and will continue through approximately 4 October for a total of eight surveys. We will estimate coyote abundance using an occupancy modeling approach (Royle and Nichols 2003).

Deer Abundance Estimation

We will begin pre-baiting 52 sites with 7.5 L of whole kernel corn on 12 August, and will re-bait each site at 3-day intervals. Beginning 22 August we will place remote infrared cameras at each site. We will continue re-baiting each site every three days during the ten day survey. On 1 September we will start retrieving cameras. From camera images, we will estimate deer abundance/density for the sampling area using an occupancy modeling approach (Duquette et al. 2014).

In order to estimate deer abundance using a non-baited survey, we will place remote infrared cameras at 52 sites along secondary roads and trails within the study area from 15 July – 28 September. Non-baited camera sites will be placed a minimum of 500 m from the nearest baited camera site in order to avoid changes in deer movement associated with baited camera sites. Results from the non-baited survey will be analyzed using an occupancy modeling approach and compared with results from the baited survey.

Public Outreach

We will continue to update our project Facebook page (http://www.facebook.com/MIpredprey) and website (http://fwrc.msstate.edu/carnivore/predatorprey/) with project results.

Acknowledgements

We thank the following for their support:
Michigan Department of Natural Resources (MDNR)
Safari Club International Foundation
Safari Club International, Michigan Involvement Committee
Plum Creek Timber Company
Ottawa Sportsmen’s Club
Ontonagon Valley Sportsmen’s Club
Mississippi State University; College of Forest Resources; Department of Wildlife, Fisheries, and Aquaculture; and Forest and Wildlife Research Center
Jared Duquette, Graduate Student (Phase 1), Mississippi State University
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:

Emma Rosenfield
Sofia Ziemienski
Brendan Popp
Courtney Dotterweich
Emily Monfort
Morgan Oberly
Sara Harrington
Emma Doden
Jessica Beach
Braiden Quinlan
Steve Gurney
Kristina Kennedy
Megan Petersohn
DJ Steakley
Clara Shattuck
Adam Fahnestock
Rebekah Lumkes
Sarah Trujillo
Abigail Thiemkey
Forrest Rosenbower
Elaine Gallenberg
Mark Jackson       Ben Murley       Victoria Frailey
Brandon Bernhardt  Kathryn Sliwa  Devon Hains
Gregory Robertson  Ryan Harris    Chris Kailing

Visiting Researcher from the United Kingdom:
Lizzie Crosse

Chuck and Jim Sartori
Rick Westphal – Westphal Productions
Michigan Out-of-Doors
906 Outdoors
Greg Davidson and Find It Detection Dogs
Mike Cushway
Mike and Karen Williams
Pat Sommers – Sommers Sausage Shop
Rich Alt – Superior Meat Processing
Dr. Dean Beyer, Jr., Co-Principle Investigator, MDNR
Erin Largent, MDNR
Jeff Lukowski, MDNR
Gordy Zuehlke (Air 3), MDNR
Neil Harri (Air 1), MDNR
Dr. Dan O’Brien, MDNR
Melinda Cosgrove, MDNR
Tom Cooley, MDNR
Dr. Dwayne Etter, MDNR
Dr. Pat Lederle, MDNR
Brian Roell, MDNR
Monica Joseph, MDNR
Bob Doepker, MDNR
Jason Peterson, MDNR
Jason Neimi, MDNR
Mark Mylchrest, MDNR
Caitlin Ott-Conn, MDNR
Brad Johnson, MDNR
John Depue, MDNR
Corey Highway, MDNR
Dennis Gast, MDNR
Brian Bogacyk, USFS
Pam Nankervis, USFS

Literature Cited


Table 1. 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.

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Female $\bar{x}$ ± SD</th>
<th>Male $\bar{x}$ ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight (kg)</td>
<td>3.5 ± 1.0</td>
<td>3.8 ± 1.8</td>
</tr>
<tr>
<td>Body Length (cm)</td>
<td>55.8 ± 6.7</td>
<td>56.6 ± 8.7</td>
</tr>
<tr>
<td>Chest Girth (cm)</td>
<td>33.7 ± 3.3</td>
<td>35.4 ± 9.5</td>
</tr>
<tr>
<td>Hind Foot (cm)</td>
<td>25.2 ± 2.0</td>
<td>24.9 ± 2.7</td>
</tr>
<tr>
<td>Shoulder Height (cm)</td>
<td>47.2 ± 6.1</td>
<td>48.5 ± 5.7</td>
</tr>
<tr>
<td>Birth Mass (kg)$^{1}$</td>
<td>2.8 ± 0.9</td>
<td>2.8 ± 1.2</td>
</tr>
</tbody>
</table>

$^{1}$ 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 2. Carnivore capture data, Upper Peninsula of Michigan, USA, 16 May – 15 June 2018.

<table>
<thead>
<tr>
<th>Species</th>
<th>ID</th>
<th>Capture Date</th>
<th>Body weight (kg)</th>
<th>Sex</th>
<th>Right ear tag</th>
<th>Left ear tag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolf</td>
<td>WO308</td>
<td>16-MAY-18</td>
<td>32.0</td>
<td>F</td>
<td>1247</td>
<td>1248</td>
</tr>
<tr>
<td>Wolf</td>
<td>WO309</td>
<td>23-MAY-18</td>
<td>35.3</td>
<td>M</td>
<td>1209</td>
<td>1205</td>
</tr>
<tr>
<td>Wolf</td>
<td>WO310</td>
<td>24-MAY-18</td>
<td>24.3</td>
<td>F</td>
<td>1399</td>
<td>1400</td>
</tr>
<tr>
<td>Wolf</td>
<td>WO311</td>
<td>27-MAY-18</td>
<td>31.3</td>
<td>F</td>
<td>1395</td>
<td>1243</td>
</tr>
<tr>
<td>Wolf</td>
<td>WO312</td>
<td>02-JUN-18</td>
<td>30.5</td>
<td>F</td>
<td>1378</td>
<td>1376</td>
</tr>
<tr>
<td>Wolf</td>
<td>WO313</td>
<td>03-JUN-18</td>
<td>33.8</td>
<td>M</td>
<td>1398</td>
<td>1382</td>
</tr>
<tr>
<td>Wolf</td>
<td>WO314</td>
<td>10-JUN-18</td>
<td>30.0</td>
<td>F</td>
<td>1397</td>
<td>1396</td>
</tr>
<tr>
<td>Coyote</td>
<td>CO302</td>
<td>14-JUN-18</td>
<td>16.0</td>
<td>M</td>
<td>610</td>
<td>609</td>
</tr>
</tbody>
</table>
Figure 1. Location of phases 1-3 study areas and Michigan Department of Natural Resources Deer Management Units, Upper Peninsula of Michigan.
Figure 2. Location of phase 3 study area and counties, Upper Peninsula of Michigan, USA.
Figure 5. Locations of pellet plot locations to estimate snowshoe hare abundance, Upper Peninsula of Michigan, USA, 2018.
Figure 4. Locations of 64 grouse drumming survey sites with 550 m audible buffer, Upper Peninsula of Michigan, USA, 2017
Figure 6. Locations of 52 black bear hair snare sites to estimate black bear abundance, Upper Peninsula of Michigan, USA, 2016.