Michigan Predator-Prey Project
Phase 1 Preliminary Results and Management Recommendations

Study Background

White-tailed deer are important ecologically, socially, and economically throughout their geographic range, and in Michigan generate 1 billion dollars in economic revenue annually. In Michigan's western Upper Peninsula, white-tailed deer populations declined precipitously during the mid-1990s and now persist at lower levels. Many factors could have contributed to failed growth of the population since that time, including disease, harvest, food availability, habitat attributes, weather, and predation. After reviewing scientific literature and available unpublished data, including long-term monitoring data from the Michigan Department of Natural Resources, we deduced that predation in concert with severe winter weather and habitat conditions were likely dominant factors contributing to lack of growth in this population. For example, the deer population decline occurred following two consecutive severe winters. Following this decline, available forage from timber harvest declined and populations of potential predator species increased. Therefore, our overall goal is to understand the interrelationships of predation, habitat conditions, and winter severity on white-tailed deer population dynamics by evaluating direct cause-specific mortality on fawns and their dams. Further, we aim to assess the indirect effects these factors have on deer space use, behavior, and nutritional condition. From this improved understanding, we provide preliminary recommendations on specific management actions for predator and prey populations and their habitat to help the agency achieve their long-term management goals for white-tailed deer in the Upper Peninsula of Michigan.

This study is designed to determine the effects of winter weather, habitat, and predation on white-tailed deer fawn survival across the environmental gradient in the Upper Peninsula. We identified three study areas based broadly on winter snowfall to capture the variation in winter severity, vegetation characteristics, and the carnivore community (both abundance and species composition) experienced by white-tailed deer that in turn would affect fawn survival. Further, other factors (e.g., alternate prey) that vary across this snowfall gradient, can have important effects on predation rates of deer. We conducted field work in the low snowfall zone (< 50 inches annually) from 2009-2011 in a study area in Delta and Menominee counties. We are currently working in a study area in Iron county, which falls in the mid snowfall zone (50-100 inches), and expect to complete fieldwork in June 2016. Work in the high snowfall zone (≥ 100 inches), in a study area including parts of Houghton and Ontonagon counties, will begin in the spring of 2016, pending funding.

This study is unique for several reasons. First, we are investigating deer, predators, habitat and weather simultaneously. Second, the study design captures the range in variability in these relationships across the Upper Peninsula. Third, we are estimating the abundance of the deer and predators on the study areas in order to better extrapolate the results to the population level.

For white-tailed deer, we are interested in estimating the annual and seasonal survival and cause-specific mortality of fawns, emphasizing the proportion of fawn mortality that is attributed to different predators. This work relies on capturing an adequate sample of deer that are fitted with radio-collars and monitored to determine their movements and survival. To untangle the importance of predators, winter weather, and habitat we are also collecting information on doe and fawn condition by taking morphological measurements, body weights, measurements of body fat, and looking at blood parameters. We are characterizing the habitat at fawn birth sites, fawn capture sites, and predation sites, as well as random sites throughout the study area. We established a weather station in each study area to collect those data. For predators, we are estimating the relative kill rates (of fawns) for black bears, wolves, coyotes, and bobcats. To do this we fit predators with GPS collars programmed to collect locations every 15 minutes. We download location data from the air then view these data to look for locations where the predators have spent about 2 hours of time within a 24-hour period. We then search these locations to determine what the animal was doing at that location—was it a resting site or a kill site. To estimate the population sizes of deer, bear, wolves, coyotes, and bobcats on the study area, we are using a variety of techniques, some of which we developed as part of the project.

Important Findings

White-tailed Deer Pregnancy Rates

- Female pregnancy rates were high (99% adults, *n* = 88; 80% yearlings, *n* = 10; 0% fawns, *n* = 3). Yearling pregnancy rates are often lower than adults in northern deer populations because some yearlings haven't reached the body size and condition necessary for reproduction.
- High pregnancy rates suggest relatively mild winters during 2009-2011 which allowed most adult females to remain in satisfactory physical condition to survive and reproduce. The high pregnancy rates also indicate the buck-to-doe ratio is adequate to breed most adult does. High pregnancy rates estimated from road kills during the 1990s and current pregnancy rates suggest reproductive potential has not regulated growth of this population.
- Does were pregnant up to 15.6 years old and reproductive senescence was not observed.
- Peak parturition was during the first three days of June each year (2009-2011) and most fawns were born within a week of the peak. Given the range in length of gestation (190-210 days), these data confirm previous work showing that most adult does are bred in November with the peak of breeding activity in mid-November.

Adult Female White-tailed Deer Survival

- Annual survival was 0.55-0.78 during 2009-2011 with greater survival of prime-aged females (2.5-6.5 years) (0.83-0.92) than old-aged females (> 6.5 years) (0.42-0.75).
- Body condition indices were directly linked to female survival. A 2.2 lb increase in winter body mass increased survival 3.8%. A 1 mg/dl increase in serum urea nitrogen decreased survival 3.4%. Higher serum urea nitrogen levels indicates depleted fat reserves and directly indicates deer are using muscle for energy.
- Increasing winter severity reduced body condition of adult females, resulting in lower fawn body mass at parturition and decreased fawn survival.
- Greater energetic demands on females (e.g., females with two fawns) in the year preceding a severe winter resulted in lower survival of the adult female the following year.
- Adult female mortality was greatest during winter (44% of total deaths), followed by spring-summer (37%), and fall (19%).
- Predation was the leading cause of mortality, 3.5 times more hazardous than human-caused mortality sources. Only one adult female died from malnutrition during the 3 years of study.

- Overall, coyotes were the leading cause of adult female mortality, followed by wolves. Good physical condition of some adult deer killed by coyotes throughout most of the year suggests partial additive mortality. Poor physical condition of adult deer killed by wolves suggests these mortalities were at least partially compensatory.
- The amount of horizontal cover provided by trees, shrubs, herbaceous vegetation and downed woody debris influenced the likelihood of predation of adult females. As the amount of horizontal cover increased, the chance of predation was less.

Fawn Survival

- Annual survival was 0.35-0.59 during 2009-2011; most mortality occurred within 12 weeks of parturition, mortality rates after 12 weeks was similar across years.
- Fawns born to dams in poorer condition had lower body mass and were more vulnerable to predation.
- Winter severity influenced fawn survival indirectly through maternal energetic effects. For example, a 2.2 lb decrease in birth body mass increased likelihood of mortality 11.0%. Adult females also selected areas with greater forage and lower predation risk (from wolves), which in turn increased predation risk of fawns (especially by coyotes; see interactions section below). These factors in combination explained 71% of the variation in fawn survival.
- Predation was the greatest source of mortality (75%); 77% of predations occurred before 31 August.
- While predation was the leading cause of fawn mortality, the condition of the mother and the amount of hiding cover influenced the vulnerability of fawns. Fawn mortality was higher following severe winters because of the poorer condition of the adult females and the delayed spring green up that reduced hiding cover. Availability of hiding cover from predators positively influenced survival of fawns, explaining 16% of observed variation.
- Coyotes were the greatest predator of fawns, followed by bobcats.
- The hazard of predation was more than 3 times greater than the hazard of human-caused mortality sources (e.g., hunting, vehicle collisions) and more than 2 times greater than all other mortality sources.
- Annual variation in fawn survival was most responsible for variation in growth of this deer population.
- Survival of male and female fawns was similar.
- As fawn sex ratios and survival were similar between males and females, the observed 1:3 adult male to adult female ratio is likely a consequence of adult mortality patterns, particularly hunter harvest.

Deer Population

- We estimated a pre-hunt sex ratio of 1 adult male to every 3 adult females using two different methods. This adult sex ratio estimate is in agreement with sex ratios typically reported by hunters who participate in the DNR's U.P. Deer Camp Survey during firearm season in this deer management unit.
- From this study, adult males comprised 16–19% of the herd, adult females comprised 58-67%, and fawns comprised 14-25%.
- Our pre-hunt deer density estimates, derived from a camera survey (deer per sq. mile: 19, 22, and 17 for 2009-2011, respectively) are consistent with C. Albright's perception of deer density in the Green Bay Lake Plain.

Predators and Predation

- Mean fawn age for coyote predations was 24 days, wolf predations was 42 days, bobcat predations was 31 days, black bear predations was 40 days, and unknown predations was 85 days.
- Coyotes were the main predator of adult females and fawns, with some predations likely compensatory. Comparative high predations were the result of high coyote abundance and adult females selecting areas to avoid wolves which also contained high food availability. Coyotes also occupied these areas because they were also avoiding wolves. This strategy that benefitted adult females through increased forage and reduced predation risk actually increased predation risk of fawns.
- Coyotes did not select for areas of high fawn use. Fawn predations by coyotes were opportunistic and the high number of fawn predations was a consequence of high coyote abundance and high spatial overlap.
- Adult and fawn white-tailed deer provided 66-88% of the energetic requirements for coyotes May 26 through June 30 (when fawns hide from predators) and 35-39% from July 1-August 31 (when fawns flee from predators).
- Coyotes avoided areas of high wolf use.
- Bobcats killed fawns at a greater rate than other predators but the population-level effect was small due to low bobcat abundance. Bobcats selected areas of high probability fawn use throughout spring and summer. Though hiding cover improved fawn survival overall, it may have facilitated the ambush hunting strategy of bobcats. Low availability of alternate prey (e.g., snowshoe hares) may have exacerbated bobcat predation rates.
- Wolves were not important predators of fawns, though most predations occurred during July 1-August 31 (when fawns flee from predators). Wolves did not select areas of high probability fawn use. Wolves were subsidized by livestock carcass dumps, a more efficient food source particularly during pup-rearing. However, estimates of wolf predation may be biased low because some predation events could not be assigned to species.
- Black bears were not important predators of fawns, selecting for areas with alternate foods (e.g., berries, ants, crops) due to presumed greater foraging efficiency. That black bears did not shift space use to areas containing fawns when they were vulnerable (through June 30 when fawns hide from predators) suggests the few predations observed were opportunistic.

Estimated wildlife densities (individuals/mi^2)

Species/age/sex	2009	2010	2011
Adult deer females (fall)	12.51	12.43	10.08
Deer fawns (fall)	2.54	5.31	3.32
Adult deer males (fall)	3.47	4.01	3.24
Total deer (fall)	18.52	21.75	16.64
Coyotes (summer-fall)	-	0.83	0.96
Black bears (summer)	0.36	0.39	0.49
Bobcats (winter)	-	0.08	~0.08
Wolves (winter)	-	0.03	0.03

Winter Weather

- Winter weather influenced fawn survival through maternal energetic effects and available vegetation for hiding and food.
- Most adult females had adequate body condition to survive and reproduce, but more severe winters reduced body condition, which resulted in smaller fawns and poorer fawn survival.
- Though good overall, adult female survival depended on winter severity and the nutritional demands of fawns. Greater female nutritional demands (e.g., 2 fawns vs. 1 fawn) during the spring-summer preceding increasingly severe winters will result in reduced adult female survival.
- Our winter severity index incorporating snow depth, wind speed, precipitation, and daily minimum temperature did not correlate strongly with variation in deer physiological condition.
- The cascading effects of winter weather on maternal nutritional effects was demonstrated by low deer survival following high winter severity in 2009, and high deer survival following low winter severity in 2010. However, there appeared to be a threshold of winter severity which increased the fawn mortality hazard nearly 7-fold between 2011 and 2009.

Habitat

- Adult females selected mixed forest types with high horizontal cover as parturition sites.
- Fawns were more likely to be located near roads, water, pastures, hayfields and maintained forest openings and avoided areas near land cover edges through June 30 (when fawns hide from predators). Relative to deciduous forest, fawns used mixed forest and avoided all other land cover types (e.g., coniferous, wetland, grassland, croplands).
- From July 1-August 31 (when fawns flee from predators), fawns used areas near roads, water, and edges. Fawns used croplands more than other land cover types and did not demonstrate avoidance for any land cover compared to deciduous forest.
- Horizontal hiding cover explained 16% of the variation in fawn survival. Fawn survival was higher in years with more hiding cover.
- Predation sites were more likely to be near cropland and with less horizontal (hiding) cover and canopy cover, suggesting fawns using more open habitats had greater mortality risk.
- Although horizontal cover was influential to fawn parturition and predation sites, multiple predator species (with differing hunting strategies) in the study area may have reduced the ability of females to hide fawns, even in adequate cover.

Important interactions

- Our results suggest that population growth in the low snowfall zone study area has not rebounded due to poor fawn survival. The results demonstrate that multiple environmental (e.g., winter severity, hiding cover, predation risk) and biological factors (e.g., doe condition, fawn birth weight) can interact to affect survival of fawns. We observed these relationships at the scale of a deer's home range and for the entire study area. Important interactions to be aware of include:
    - Adult does selected areas to avoid wolves and obtain abundant food. Coyotes used these same areas to also avoid wolves. This resulted in increased predation of fawns by coyotes but increased the survival of the does. Although adult females increased predation risk of fawns to coyotes, attaining adequate forage and avoiding wolves would improve their lifetime reproductive success. Observed mean age (6.8 years) and lack of reproductive senescence would allow females to produce multiple litters of fawns, increasing the chance that some fawns would survive to adulthood.

- Although coyotes were the most abundant predator species in the study area and greatest predator of fawns, dams placing fawns in poor hiding cover likely exacerbated the impact.
- Variation in winter weather affects the nutritional and physical state of pregnant females. Following severe winters, females gave birth to fawns with smaller body mass, and those fawns subsequently exhibited reduced survival. Decreased birth body mass of fawns may have made them more susceptible to predation. For example, the number of predations from the 4 primary predators decreased 43% from 2009 to 2010 when birth body mass increased, but then increased 83% from 2010 to 2011 when birth body mass decreased.
- Similarly, more severe winter conditions can delay vegetation growth in spring. Delays in spring 'green-up' can reduce fawn hiding cover, potentially increasing their vulnerability to predation during the first few weeks of life.

Management Recommendations

Deer Management

- That total deer relative abundance varied among years and was not directly linked to winter severity is a reminder to biologists that we cannot monitor only winter weather to estimate deer population trends.
- Wildlife managers should make fawns a priority cohort for monitoring because deer population growth was most sensitive to annual fawn survival and recruitment, (see monitoring section below).
- Managers should consider deer reproductive rates and weather conditions from previous years in addition to the current year when developing harvest or other management goals because a time-lag pattern in doe survival was observed (e.g., survival influenced by circumstances at least 1 year prior).
- Wildlife managers should consider yearly variation and lag effects in energetic demands caused by weather, forage availability, and gestation when forecasting potential influences on deer survival and reproductive success as part of the regulation setting process.
- Wildlife managers should also consider how temporal patterns in winter weather and vegetation growth could influence potential predation rates when developing harvest recommendations.
- Within the context of regional planning, especially in areas where deer are a featured species, biologists should consider creating greater early successional stage forests, particularly in areas where food is poor and predation risk is greater (e.g., non-wetland late-successional forests, high wolf use areas). Creating a better distribution of young forest could allow deer to reduce overlap with coyotes and provide fawns better hiding cover, potentially decreasing overall predation rates.
- An improved distribution of young forests would also enhance year-round forage for adult females which could help mediate the effects of winter severity on their nutritional condition; an important factor influencing survival of both adult females and fawns.
- While coyote density possibly resulted in some additive mortality for fawns, reducing coyote density across large spatial scales would likely not be a feasible management strategy to increase fawn survival in the long-term. Coyote and bobcat predation of deer, particularly fawns, could potentially be reduced through habitat management that provides deer greater

spatially dispersed forage and hiding cover, particularly during spring. Although creating more suitable deer habitat in interior forests could introduce greater wolf predation risk, wolf predations of adult females were mainly compensatory based on body condition.

Deer Monitoring

- For monitoring deer populations, we suggest occupancy models and radio telemetry are superior to other indices (e.g., pellet counts, SAK reconstructions) as abundance (with confidence intervals) can be directly estimated. Importantly, these two techniques showed similar trends in annual deer population growth and survival. If biologists desire population trends and demographic parameters of deer (e.g., fawn recruitment), occupancy models using detection/non-detection data collected from remote cameras may be preferred over radio telemetry because marking deer is not required, reducing labor and costs.
- To collect data for occupancy models, we recommend conducting 10-day surveys (including 4 day pre-baiting) during late August using arrays of at least 60 cameras. To estimate absolute density, estimates of deer space use during the survey period are required (important if applying this technique to other areas).
- Biologists could potentially implement the camera survey technique cooperatively with sportsperson groups enhancing those partnerships.
- Although fawn mortality over winter was relatively consistent among the 3 years of study in the low snowfall zone, there may be important variability in the other snowfall zones. To index potential fawn recruitment across the landscape, wildlife managers could conduct fawn: total deer counts when deer leave wintering complexes and are most visible.
- Additional work needs to be done to develop a winter severity index that better reflects finer-scale variation in weather across years.
- A series of camera surveys and spring fawn: total deer counts conducted annually that reflect variation in winter severity and habitat conditions, coupled with a refined winter severity index, should provide biologists information on deer recruitment, abundance, and population trends.

Hunter Outreach

- The number of fawns surviving to one-year of age was the most important factor influencing deer population growth in this area. Although predation was the leading cause of deer mortality, the effects of winter severity on nutritional condition of adult does was the most important factor influencing fawn survival. Adult does stressed by winter weather gave birth to smaller fawns that were more susceptible to predation.
- Winter weather was the fundamental factor ultimately influencing deer population growth, even in the low snowfall zone. Habitat and predation were more proximate (i.e., immediate) factors, with habitat conditions and predation rates indirectly influenced by winter weather.
- Population-level effects of predation on white-tailed deer are related to not only the kill rates of individual predator species but also the abundance of predator species. That is, a predator species exhibiting high kill rates but low abundance (e.g., bobcat) will often have a lesser effect on deer populations than a predator species exhibiting low kill rates but high abundance (e.g., coyote).
- White-tailed deer are not the only prey of predators in the Upper Peninsula. Availability of alternate prey (e.g., livestock carcasses for wolves, snowshoe hare for coyotes and bobcats, vegetation for black bears) will influence predation rates on white-tailed deer.

- Some hunters are concerned that the buck-to-doe ratio is so skewed that some females are not bred. This study documented high pregnancy rates of adult and yearling deer indicating that the proportion of bucks in the population is not reducing pregnancy rates.
- Some hunters believe that adult does without fawns are barren and harvesting them is beneficial to the herd. Similar to a study in Minnesota, we did not observe reproductive senescence despite the older age structure of adult does.
- Some hunters are concerned about the potential impacts of antlerless harvest in this area. Though multiple factors can influence deer age structure, the age structure of adult females suggests there is little effect of antlerless license quotas in this deer management unit.
- Develop outreach to inform the public of the concepts of biological and habitat carrying-capacity to promote a greater understanding of what constitutes a 'healthy' deer herd in DMU 55. While hunters harvest mature males in this area, most appear to come from the small agricultural areas with higher-quality food. Outreach could link enhancing herd health to forest management that increases deer nutritional condition and provides hiding vegetation.
- Biologists regularly hear concerns over deer herbivory effects on forest regeneration. Based on scientific literature, current deer densities appear too low to have caused observed browse lines in the study area. We suggest that browse lines were established before the population decline in the mid-1990s.