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Melissa M. Turner
*North Carolina State University at Raleigh*, mmturner@ncsu.edu

Aimee P. Rockhill
*North Carolina State University at Raleigh*

Christopher S. Deperno
*North Carolina State University at Raleigh*

Jonathan A. Jenks
*South Dakota State University*, jonathan.jenks@sdstate.edu

Robert W. Klaver
*USGS EROS*

*See next page for additional authors*

## Authors

Melissa M. Turner, Aimee P. Rockhill, Christopher S. Deperno, Jonathan A. Jenks, Robert W. Klaver, Angela R. Jarding, Troy W. Grovenburg, and Kenneth H. Pollock

*Research Article*

# Evaluating the Effect of Predators on White-Tailed Deer: Movement and Diet of Coyotes

**MELISSA M. TURNER,**[1] *Fisheries and Wildlife Sciences Program, North Carolina State University, Raleigh, NC 27695, USA*

**AIMEE P. ROCKHILL,** *Fisheries and Wildlife Sciences Program, North Carolina State University, Raleigh, NC 27695, USA*

**CHRISTOPHER S. DEPERNO,** *Fisheries and Wildlife Sciences Program, North Carolina State University, Raleigh, NC 27695, USA*

**JONATHAN A. JENKS,** *Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, SD 57007, USA*

**ROBERT W. KLAVER,** *USGS Earth Resources Observation and Science Center, Sioux Falls, SD 57198, USA*

**ANGELA R. JARDING,** *Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, SD 57007, USA*

**TROY W. GROVENBURG,** *Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, SD 57007, USA*

**KENNETH H. POLLOCK,** *Department of Zoology, North Carolina State University, Raleigh, NC 27695, USA*

**ABSTRACT** Coyotes (*Canis latrans*) may affect adult and neonate white-tailed deer (*Odocoileus virginianus*) survival and have been implicated as a contributor to the decline of deer populations. Additionally, coyote diet composition is influenced by prey availability, season, and region. Because coyote movement and diet vary by region, local data are important to understand coyote population dynamics and their impact on prey species. In southeast Minnesota, we investigated the effect of coyotes on white-tailed deer populations by documenting movement rates, distances moved, and habitats searched by coyotes during fawning and non-fawning periods. Additionally, we determined survival, cause-specific mortality, and seasonal diet composition of coyotes. From 2001 to 2003, we captured and radiocollared 30 coyotes. Per-hour rate of movement averaged 0.87 km and was greater ($P = 0.046$) during the fawning (1.07 km) than the non-fawning period (0.80 km); areas searched were similar ($P = 0.175$) between seasons. Coyote habitat use differed during both seasons; habitats were not used in proportion to their availability ($P < 0.001$). Croplands were used more ($P < 0.001$) than their proportional availability during both seasons. Use of grasslands was greater during the fawning period ($P = 0.030$), whereas use of cropland was greater in the nonfawning period ($P < 0.001$). We collected 66 fecal samples during the nonfawning period; coyote diets were primarily composed of *Microtus* spp. (65.2%), and consumption of deer was 9.1%. During the study, 19 coyotes died; annual survival rate range was 0.33–0.41, which was low compared with other studies. Consumption of deer was low and coyotes searched open areas (i.e., cropland) more than fawning areas with dense cover. These factors in addition to high coyote mortality suggested that coyote predation was not likely limiting white-tailed deer populations in southeast Minnesota. © 2011 The Wildlife Society.

**KEY WORDS** *Canis latrans*, coyotes, habitat selection, Minnesota, *Odocoileus virginianus*, white-tailed deer.

Coyotes (*Canis latrans*) can affect adult and neonate white-tailed deer survival (*Odocoileus virginianus*; Kie et al. 1979, Stout 1982, Ballard et al. 1999, Whittaker and Lindzey 1999, Patterson and Messier 2000) and have been implicated as a major contributor to the decline of deer in eastern Canada, Maine, and South Dakota (Lavigne 1992, Patterson 1994, Crête and Lemieux 1996, Benzon 1998, DePerno et al. 2000) and likely in the southeastern United States (Kilgo et al. 2010). Coyote diet composition is influenced by prey availability (Springer 1982, MacCracken and Hansen 1987), season, and region (Andrews and Boggess 1978, Andelt 1985, Andelt et al.

1987, Cypher et al. 1994, Morey et al. 2007). For example, in Alberta, Canada, Lingle (2000) detected deer remains in 55% of scats in December and January and 15% in June and July. In Oklahoma, Litvaitis and Shaw (1980) noted that deer represented similar portions of coyote diets for spring, summer, and winter (27%, 22%, and 23%, respectively) but only 8% in fall. However, in southeast Idaho and southwest Minnesota, coyote consumption of deer was low (Andrews and Boggess 1978, MacCracken and Uresk 1984, MacCracken and Hansen 1987, Brinkman 2003) and primarily composed of carrion or neonates (Berg and Chesness 1978, Bekoff and Wells 1986, Paquet 1992, Brinkman 2003, Schrecengost et al. 2008).

Coyote home range size, movement, and habitat selection suggest a high level of plasticity and seasonal and spatial variability (Andelt and Andelt 1981, Laundré and Keller 1981, Shivik et al. 1997). Home range use (i.e., movement)

varies seasonally with the greatest movement in winter months (Andelt and Gipson 1979, Laundré and Keller 1984, Roy and Dorrance 1985, Gosselink et al. 2003). Further, seasonal fluctuations in coyote home range size and movements may be a function of changes in food availability (Springer 1982, Reichel 1991, Gosselink et al. 2003); however, other studies correlate the fluctuations with life cycle events such as breeding (Berg and Chesness 1978, Andelt and Gipson 1979, Shivik et al. 1997). It is possible that regional variation in home range size and movement between studies is an artifact of different tracking methodologies (Laundré and Keller 1984, Holzman et al. 1992a).

Because coyote movement, home ranges (Andelt and Andelt 1981, Laundré and Keller 1981, Shivik et al. 1997), and diet (Andrews and Boggess 1978, Andelt 1985, Andelt et al. 1987, Cypher et al. 1994, Morey et al. 2007) vary by region and season, local data are important to understand coyote population dynamics and their impact on prey species (Schrecengost et al. 2008). Research has been conducted on coyotes in farmland habitats in Vermont (Person and Hirth 1991), Nebraska (Andelt and Andelt 1981), and Illinois (Van Deelan and Gosselink 2006). In Minnesota, research has focused on forested regions (Berg 1977, Preece 1978, Haroldson 1981, Mech et al. 1985, Smith 1985); however, empirical data on the impact of coyotes on white-tailed deer are lacking in southeast Minnesota, which is dominated by agriculture. High plasticity in coyote life history characteristics, particularly movement and diet, warrant examination of coyotes and their interactions with white-tailed deer in southeast Minnesota. Additionally, there are concerns from the public and wildlife managers that coyotes were affecting the local deer population. White-tailed deer and, to some extent, coyotes are economically important in Minnesota. Statewide in 2002, 633,862 deer licenses were sold, and Minnesota hunters harvested 220,050 deer (M. H. Dexter, Minnesota Department of Natural Resources, unpublished report). In 2002–2003, an estimated 12,000 coyote hunters removed 1.2 animals/hunter, and 1,000 trappers harvested 4 animals/trapper (M. H. Dexter, unpublished report). As part of a study examining survival rates and cause-specific mortality of white-tailed deer in southeast Minnesota (DePerno et al. 2003), we investigated the local impact of coyotes on white-tailed deer populations. Our primary objectives were to determine movement rates, distances, and habitats searched by coyotes during the fawning and nonfawning periods in an effort to isolate effects of the fawning season on coyote movement and potential predation of neonates. Also, because coyote population dynamics are important to an analysis of impacts on deer, secondary objectives included determining survival, causes of mortality, and seasonal diet composition of coyotes.

## STUDY AREA

The study area encompassed 359 km$^2$ in Wabasha and Goodhue counties in southeast Minnesota (44 °30′N to −44 °36′N and −092 °33′W to −092 °21′W; Fig. 1). Landscape transitioned from forest to agricultural land, and topography consisted of rugged river bluffs, rolling uplands with deep, stream-cut valleys, and wooded hillsides (Minnesota Department of Natural Resources 1979). Land composition was dominated by agriculture (54%), grassland (26%), and upland forest (14%). Common agricultural uses included row crops, primarily corn, soybeans, alfalfa, and pasture. Red oak (*Quercus rubra*) and white oak (*Q. alba*) were among the most common tree species in forested areas (Porter 1978). Other common species included elm (*Ulmus* spp.) and basswood (*Tilia americana*) with thick undergrowth of prickly ash (*Zanthoxylum americanum*) and gooseberry (*Ribes* spp.). Mean annual temperature in Rochester, Minnesota was 6.3 °C with July being the warmest (26.7 °C) and January the coldest month (−11.2 °C).
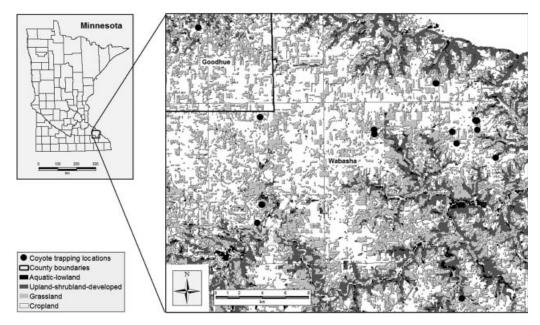


**Figure 1.** Coyote capture locations in Goodhue and Wabasha counties, Minnesota, 2001–2003.

Average annual precipitation was 80 cm and snowfall was 135 cm (Midwest Regional Climate Center 2002).

## METHODS

During October 2001 through May 2003, we captured coyotes using Duke No. 1.75 unpadded coil-spring foothold traps (Duke Company, West Point, MS). We restrained trapped animals with a noose pole, measured neck, chest, and crown to rump length, aged by tooth wear (juvenile or adult), and fitted each with a radiocollar (Advanced Telemetry Systems, Isanti, MN). All traps met the Best Management Practice specifications established by the International Association of Fish and Wildlife Agencies (2003). Animal handling methods we used in this project-followed guidelines approved by the American Society of Mammalogists (Gannon et al. 2007) and were approved by the Institutional Animal Care and Use Committee at South Dakota State University (Approval number 02–A043).

We randomly selected coyotes for radiotracking and located animals at 30-min intervals during randomly selected 6-hr periods during the night, following the sequential method modified from Laundré and Keller (1984). Hence, we located individual coyotes a maximum of 12 times over a 6-hr tracking session. Tracking sessions occurred between sunset and sunrise, when coyote activity typically peaked (Andelt et al. 1979, Smith et al. 1981, Woodruff and Keller 1982). We conducted tracking sessions 5 times/week during the white-tailed deer fawning period (15 May–1 Jul) and 1–2 times/week during the nonfawning period (2 Jul–14 May). We selected seasonal dates based on parturition of deer observed in other studies (Ozoga et al. 1982, Brinkman et al. 2004, Carstensen Powell and DelGiudice 2005, Swanson et al. 2008). We obtained 3–5 directional bearings from established telemetry stations using a vehicle mounted null-peak antenna system (Brinkman et al. 2002) connected to an electronic compass (C100 Compass Engine, KVH Industries Inc., Middletown, RI). We estimated coyote locations using Locate II (Nams 2001) and plotted locations on United States Geological Survey 3-m digital orthophoto quadrangles using ArcMap 9.2.

To evaluate coyote movements, we plotted locations in ArcMap and calculated total distance by summing the distance between sequential points (e.g., 1–2, 2–3, 3–4). To standardize distance measurements, we calculated movement rate by dividing total distance by the number of sequential points collected (linear distance per half-hour). We created a 100% minimum convex polygon (MCP) that encompassed all points during each tracking session using Hawth's Tool (Beyer 2004) in ArcMap. We overlaid polygons onto Gap Analysis Program (GAP) vector land cover obtained from the Minnesota Department of Natural Resources Data Deli (2009). We compared search areas and rates (linear distance per hour) across time periods (fawning and nonfawning) using PROC GLM in SAS 8.2 (SAS Institute, Cary, NC). Because our sampling design resulted in some animals being tracked more than once within a season, we averaged data within a season by animal. Additionally, our sampling design resulted in some animals being tracked in both seasons and some only in one season; thus, we conducted paired and unpaired t-tests, respectively, which we weighted by the number of tracking sessions per animal and per season (we pooled P-values from the paired and unpaired analyses [Steel et al. 1997]). We compared habitat composition used in each time period to habitat composition available in the study area using Chi-square goodness-of-fit tests (Thomas and Taylor 1990, Manly et al. 2002). We classified habitats as aquatic (aquatic, barren, and marsh), cropland, developed, grassland, lowland (lowland-deciduous; silver maple [*Acer saccharinum*]), shrubland (lowland shrubland, upland shrubland), and upland (maple [*Acer* spp.]-basswood, oak [*Quercus* spp.], pine [*Pinus* spp.], pine-deciduous, eastern red cedar [*Juniperus virginiana*]-deciduous, upland cedar, upland deciduous). We used Program R (Version 2.9.1 http://cran.r-project.org, accessed 25 Apr 2009) and the adehabitat package (Calenge 2006) to calculate habitat selection ratios using Design II (Manly et al. 2002). Habitat selection for Design II analysis was indicated if the selection ratio ($\hat{w}$) differed significantly from 1. For instance, selection for a habitat category was indicated if the confidence interval for $w_i$ did not contain the value 1 and the lower limit was >1. A habitat category was avoided if the confidence interval for $w_i$ did not contain the value 1 and the upper limit was <1. Use in proportion to availability was indicated if the confidence interval for $w_i$ contained the value 1 (Manly et al. 2002). We compared habitat use by percentage of MCP across time periods (fawning and nonfawning) using PROC GLM in SAS employing paired and unpaired t-tests and weighting by the number of tracking sessions per animal and per season; we pooled P-values from the paired and unpaired analyses (Steel et al. 1997).

We collected coyote fecal samples along 6 fecal line transects walked 1 time/week (Knowlton 1984, Cavallini 1994, Kost 1997). We systematically placed 0.8 to 1.6-km-long transects throughout the study area, with transects ≥4.8 km apart (Gerads 2000). We dried, weighed, separated, and identified the contents of samples (Johnson and Hansen 1979). We analyzed percent fresh weight of prey using PROGRAM Scat 1.5 (Kelly and Garton 1993).

We attempted to determine the timing of radiocollared coyote mortality to the nearest day. When possible, we determined cause of death from field necropsy and evidence at the mortality site (White et al. 1987). Radiocollared coyotes were legal game all year, and we asked hunters and trappers to return collars, report the day and location of kill, and return the skull for age determination. We categorized mortality as predator hunter, trapper, vehicle collision, firearms deer hunter, and unknown. We calculated annual and study-wide survival rates using the Kaplan–Meier procedure (Kaplan and Meier 1958) modified for a staggered entry design (Pollock et al. 1989). We calculated survival rates by sex, year, and season and compared them using Program CONTRAST (Hines and Sauer 1989). We used a Bonferroni correction factor to maintain the experiment-wide error rate when we performed multiple Chi-square tests (Hopkins and Gross 1970, Neter and Wasserman 1974, Neu et al. 1974). We set alpha at $P \leq 0.05$ for all tests.

## RESULTS

From 2001 to 2003, we captured and radiocollared 30 coyotes. During 2001, we captured and radiocollared 8 (5 M, 3 F) coyotes; however, 1 day after capture, 1 female lost the collar. In 2002, we captured and radiocollared 13 (3 M, 10 F) coyotes. In 2003, we captured and radiocollared 9 (4 M, 5 F) coyotes; however, 8 days after capture a female lost the collar. Catch rates were 22.7 trap-nights/coyote (22 traps set for 1 night = 22 trap nights), and average handling time was 4.6 min/coyote ($n = 28$). No trap-related injuries occurred.

We conducted 88 nocturnal tracking sessions over 3 years for the 18 live animals we were able to relocate after collaring; the remaining collared animals lost collars ($n = 2$), died ($n = 7$), or disappeared ($n = 3$) before we tracked them. Per-hour rate of movement averaged 0.87 km (range 0.12 km–3.58 km) and was greater (paired $F_{9,8} = 4.58$; unpaired $F_{1,7} = 1.10$; pooled $P = 0.041$) during the fawning (1.07 km, range 0.31–3.58 km) than the nonfawning (0.80 km, range 0.12–2.23 km) period. Overall, MCPs we derived from search areas averaged 1.1 km$^2$ (range = 0.01–7.33 km$^2$) and were similar (paired $F_{9,8} = 1.87$; unpaired $F_{1,7} = 1.86$; pooled $P = 0.175$) for nonfawning and fawning periods. MCP perimeters averaged 4.36 km (range = 0.55–12.50 km) and did not differ (paired $F_{9,8} = 1.73$; unpaired $F_{1,7} = 1.77$; pooled $P = 0.202$) by season.

Coyotes did not select all habitats similarly during the nonfawning season ($\chi^2_{L1} = 14,262,444$, df = 390, $P < 0.001$). Croplands were used more during the nonfawning season than their proportional availability ($\hat{w} = 1.22$, SE = 0.04). Other land cover types (e.g., aquatic, developed,

lowland, shrubland, and upland) were used less than their availability (Tables 1 and 2). Likewise, coyotes did not use habitat similarly during the fawning season ($\chi^2_{L1} = 7,356,343$, df = 126, $P < 0.001$). Based on confidence interval overlap, cropland was used more during the fawning season than available ($\hat{w} = 1.26$, SE = 0.08), grasslands were used in proportion to their availability ($\hat{w} = 1.08$, SE = 0.11), and remaining habitats (e.g., aquatic, developed, lowland, shrubland, and upland) were used less than available (Tables 1 and 2).

Overall use of grassland was 25.3% in the nonfawning period and 31.1% in the fawning period (paired $F_{9,8} = 7.35$; unpaired $F_{1,7} = 0.93$; pooled $P = 0.030$) and differed between seasons. Overall use of cropland was 68.2% in the nonfawning period and 58.1% in the fawning period (paired $F_{9,8} = 21.56$; unpaired $F_{1,8} = 0.10$; pooled $P < 0.001$) and differed between seasons. Use of other habitats was similar between time periods (Table 1).

We collected 66 scats throughout the nonfawning period (2 Jul–14 May). Because of prohibitively dense vegetative growth, we were unable to collect scat during the fawning period, preventing comparison between seasons. Frequency of occurrence data indicated that voles (*Microtus* spp.) were the most common prey item in coyote diets in the nonfawning period (65.2%; Table 3). White-tailed deer occurred in 9.1% of coyote fecal samples during the nonfawning period.

Over the 20-month study, 19 coyotes died. Causes of mortality included hunters ($n = 9$, 47.4%), trappers ($n = 5$, 26.3%), vehicle collisions ($n = 4$, 21.1%), and unknown ($n = 1$, 5.3%). During 2002 and 2003, annual survival rate

**Table 1.** Habitat composition (%) of the study area and habitats searched (%) by coyotes during the fawning (15 May–1 Jul) and nonfawning periods (2 Jul–14 May) in southeast Minnesota, 2001–2003.

| Habitat | Habitat composition (%) | Fawning period ($n = 22$) | Nonfawning period ($n = 66$) | P |
|---|---|---|---|---|
| Cropland | 53.51 | 58.09 | 68.16 | <0.001 |
| Developed | 1.81 | 0.47 | 0.51 | 0.587 |
| Grassland | 25.69 | 31.12 | 25.34 | 0.030 |
| Lowland deciduous | 2.35 | 0.73 | 0.49 | 0.928 |
| Nonforest | 1.99 | 0.44 | 0.04 | 0.769 |
| Shrubland | 0.74 | 1.79 | 0.22 | 0.421 |
| Upland | 13.92 | 7.37 | 5.23 | 0.078 |

**Table 2.** Estimated selection rations, standard errors, and confidence intervals of selection for coyotes ($n = 18$) separated into nonfawning (2 Jul–14 May) and fawning (15 May–1 Jul) periods in southeastern Minnesota, 2001–2003, using design II (Manly et al. 2002) with known proportions of available resource units.

| | Nonfawning period | | | | Fawning period | | | |
|---|---|---|---|---|---|---|---|---|
| | | | CI | | | | CI | |
| Habitat | Selection index ($\hat{w}$) | SE | Lower | Upper | Selection index ($\hat{w}$) | SE | Lower | Upper |
| Aquatic | 0.02[c] | 0.01 | 0.000[a] | 0.038 | 0.03[c] | 0.02 | 0.000[a] | 0.084 |
| Cropland | 1.22[b] | 0.04 | 1.106 | 1.330 | 1.26[b] | 0.08 | 1.050 | 1.471 |
| Developed | 0.28[c] | 0.08 | 0.073 | 0.493 | 0.20[c] | 0.05 | 0.071 | 0.335 |
| Grassland | 1.16 | 0.07 | 0.981 | 1.349 | 1.08 | 0.11 | 0.782 | 1.372 |
| Lowland | 0.18[c] | 0.04 | 0.063 | 0.292 | 0.36[c] | 0.20 | 0.000[a] | 0.900 |
| Shrubland | 0.28[c] | 0.07 | 0.096 | 0.475 | 0.36[c] | 0.17 | 0.000[a] | 0.825 |
| Upland | 0.27[c] | 0.07 | 0.081 | 0.453 | 0.24[c] | 0.10 | 0.000[a] | 0.497 |

[a] We truncated the lower confidence interval to zero.
[b] Indicates that the selection coefficient $\hat{w}$ is significantly different from 1 and the habitat is used more than expected from the availability of this habitat.
[c] Indicates that the selection coefficient $\hat{w}$ is significantly different from 1 and the habitat is used less than expected from the availability of this habitat.

**Table 3.** Frequency of prey occurrence in coyote scats ($n = 66$) collected during the nonfawning period (2 July–14 May) in southeast Minnesota, 2001–2003.

| Species | Occurrence (%) |
|---|---|
| Vole | 65.2 |
| Vegetation | 53.0 |
| Insect | 45.5 |
| Cattle | 33.3 |
| Unknown | 24.2 |
| Rabbit | 21.2 |
| Bird | 16.7 |
| Mice | 10.6 |
| Shrew | 9.1 |
| White-tailed deer | 9.1 |
| Thirteen-lined ground squirrel | 7.6 |
| Raccoon | 3.0 |
| Squirrel | 3.0 |
| Fruit | 1.5 |
| Horse | 1.5 |
| Coyote | 1.5 |

was $0.41 \pm 0.17$ and $0.33 \pm 0.18$, respectively. Throughout the study, overall survival rate was $0.085 \pm 0.06$.

## DISCUSSION

Search areas were similar between the nonfawning and fawning periods, and rate of movement was greater during the fawning period. Other studies have shown movement, home range, and overall activity of coyotes to be highly variable by season (Andelt and Gipson 1979, Andelt 1985, Shivik et al. 1997, Gosselink et al. 2003). In Illinois, Gosselink et al. (2003) attributed seasonal differences in home range size to changes in food resources. Whereas our results documented greater rate of movement in the fawning season, others have observed expansion of home range and movement in winter (Andelt and Gipson 1979, Gosselink et al. 2003). In farmland Minnesota, it is possible food resource changes drive seasonal fluctuations in rate of movement, a standardized measure of linear distance traveled, even when search area remains constant. Dense growth in riparian corridors within agricultural areas provided greater cover for prey, necessitating increased travel to feed. Further, the birth of pups likely necessitated increased activity and movement rates, the timing of which corresponded to the fawning period in our study (Shivik et al. 1997). Nevertheless, our inability to analyze movement during the fawning season by sex might mask a difference in movement due to care of offspring.

Contrary to our study, Andelt (1985) did not document a difference in movements such as home range and paired straight-line movements by season, although their timeline did not correspond precisely to the timeline we described. However, the coyote population studied by Andelt (1985) appeared stable, with lower mortality (32%) than coyotes in our study (59–67%), and had continuous occupation of nearly all available habitats. Therefore, the coyote population in southeast Minnesota, which had higher mortality due in large part to human influences, was characterized by more plastic home ranges and movements.

We did not have appropriate data to calculate home ranges, but we must acknowledge the apparent contradiction of having equivalent search areas across both seasons and non-equivalent rates of movement. One possible explanation is the type of movement made by coyotes. Many animals exhibited a clear tendency to cross back over their paths multiple times, searching a small area intensively and generating a high rate measurement with a small MCP. These movements likely indicated a highly productive area for searching, a shift in habitat type, or some other structural change in the landscape such as a barrier to movement (With 1994, Phillips et al. 2004). Also, fine-scale movements that deviate from straight lines may be a response to habitat heterogeneity, suggesting a higher level of search intensity (With 1994, Bascompte and Vila 1997, Nams and Bourgeois 2004).

Cropland and grassland were the primary habitats searched by coyotes during both nonfawning and fawning periods in southeast Minnesota (Table 1). Although not conducted in an agricultural region, Holzman et al. (1992a) calculated that coyotes selected for open areas and forest at lower proportions. Our results are contrary to those of Roy and Dorrance (1985), who noted that coyotes in an agricultural region selected for forest over open areas. Also, Andelt and Andelt (1981) determined that forested areas were selected over agricultural fields among coyotes, but pasture was the second most-selected habitat. In our study, forested areas of all types were selected at lower-than-available proportions. Coyotes are less efficient predators in forested landscapes compared with more open areas (Gese et al. 1996, Richer et al. 2002, Rohm et al. 2007). Large patches of forested habitat likely provide neonate deer with cover and concealment, are more difficult for predators to search completely, may be searched less often, and prevent chased neonates from having to leave adequate cover, decreasing risk of predation (Andren and Angelstam 1988, Brown and Litvaitis 1995, Phillips et al. 2003, Rohm et al. 2007).

Open areas (i.e., grasslands and croplands) were the primary habitats used by coyotes in our study, but we detected a seasonal shift in habitat use. Croplands comprised a greater percentage of MCPs during the nonfawning period, whereas grasslands comprised a greater percentage of MCPs during the fawning period. Other studies have documented seasonal shifts in habitat selection (Andelt and Andelt 1981, Person and Hirth 1991, Gosselink et al. 2003), but time periods varied, making direct comparisons difficult. For example, our long nonfawning period, which encompassed summer, fall, and winter, could mask specific seasonal changes detected in other studies (Smith et al. 1981, Laundré and Keller 1984). Moreover, spring and early summer were encompassed within the white-tailed deer fawning period (15 May–1 Jul), which includes part of the period when Person and Hirth (1991) documented that coyotes in farmlands selected forest. Although time frames in other studies of coyote movement varied, the seasonal variation in habitat use we observed is supported by previous work (Andelt and Andelt 1981, Person and Hirth 1991, Gosselink et al. 2003) and is likely related, at least in part, to food availability (Springer 1982, Reichel 1991, Gosselink et al. 2003).

Deer were a minor component of coyote diets in our region during the nonfawning season, comprising 9.1% of scats by frequency. Although coyotes have been documented killing deer (Bowen 1981, Paquet 1992, Lingle 2000), opportunistic scavenging is more common (Berg and Chesness 1978, Bekoff and Wells 1986, Paquet 1992). Additionally, packs were associated with hunting larger prey, whereas solitary or paired coyotes hunted small mammals (Bowen 1981). We did not observe coyotes in groups and believe coyotes in our study area were solitary, which might be a result of the low survival rate in this region. Further, because deer in southeast Minnesota have high survival with only 5% of mortality due to canid predation (DePerno et al. 2003), we suspect killing of adult deer was rare.

The fawning season in our study coincided with a period of particularly dense vegetative growth in forested areas. A related study involving vaginal implant transmitters on white-tailed deer determined that neonates were born in dense forested areas, and we believe neonates were concealed in these areas when most vulnerable (C. S. DePerno, North Carolina State University, unpublished data). We believe dense vegetative growth would have hindered coyote movement, limiting access to white-tailed deer neonates. Although many studies have documented neonate consumption by coyotes, several have demonstrated a lag time between births and the appearance of remains in coyote scats (Bartush 1978, Litvaitis and Shaw 1980, Stout 1982), so it is possible neonates appear later in the diets of coyotes in southeast Minnesota, an effect our lengthy nonfawning season may not have detected. However, coyotes were not traveling in areas used by deer for parturition, which in concert with low neonate mortality in the region supports our conclusion that coyotes were not negatively impacting the white-tailed deer population in farmland Minnesota (C. S. DePerno, unpublished data).

We believe that coyotes spent more time in croplands and grasslands not because they were avoiding the dense forests, but they were hunting for voles along transition areas between forests and agricultural areas. Similarly, Theberge and Wedeles (1989) documented coyotes primarily using edges between forested and open habitats. Although coyote diets are highly variable, numerous studies have documented consistent consumption of small mammals throughout the year (Bekoff and Wells 1986, Reichel 1991, Cypher et al. 1994), which could explain the consistency we observed in habitat use and reliance on voles as a food source. Additionally, Bowen (1981) observed that consumption of small mammals (i.e., voles) peaked in May, which falls partly within the fawning period of our study. Croplands are not the preferred habitat for voles; they are often located in pasture and will use planted fields if cover is sufficient (Getz 1985, Basquill and Bondrup-Nielsen 1999). Nevertheless, coyote selection of agricultural areas could be explained if voles were the most available and easiest obtained food during the fawning season (Reichel 1991).

Annual survival rates of coyotes in southeast Minnesota (0.33–0.41) were low compared with numerous other studies (0.38–0.87; Roy and Dorrance 1985, Harrison 1986, Gese et al. 1989, Holzman et al. 1992b, Grinder and Krausman 2001). Vehicle collisions, predator hunters, and trapping accounted for 89% of the coyote mortalities in southeast Minnesota, which is high compared to human caused factors reported in other studies (22–93%; Tzilkowski 1980, Harrison 1986, Holzman et al. 1992b, Van Deelan and Gosselink 2006).

We hypothesize that during the fawning season, coyote use of croplands and grasslands when neonates were concentrated in forest indicated that coyotes had limited opportunities to locate and kill neonates. In addition, our nonfawning season diet analysis and low coyote survival suggested coyotes had minimal impact on white-tailed deer populations in southeast Minnesota.

## MANAGEMENT IMPLICATIONS

Our study showed large patches of forested habitats likely provided neonate white-tailed deer with concealment from coyote predation. In areas where coyotes may be negatively impacting white-tailed deer populations, habitat management efforts that promote understory cover in forested areas may be necessary to provide obscured fawning sites. Further, in areas with dense forest cover, our study indicated that coyotes will focus search efforts along croplands and grasslands that support small mammals. In farmland Minnesota, coyote diets during the nonfawning season were primarily composed of voles. It is likely food availability and habitat composition were driving seasonal fluctuations in movement by coyotes; however, further study is necessary. Additionally, we speculate coyotes in southeast Minnesota are unlikely to significantly affect deer populations and the local hunting economy; however, we acknowledge the need for additional research on coyote diets during the fawning season to provide direct evidence of the impacts of coyotes on white-tailed deer neonates in southeast Minnesota.

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