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Notes and Discussion

Survival Estimates of White-tailed Deer Fawns at Fort Rucker, Alabama

Abstract.—Decreases in white-tailed deer (*Odocoileus virginianus*) fawn recruitment have been noted at several locations across the Southeast. Understanding the reason for these decreases is important for management of deer populations. We monitored fawns from birth until 6 mo to examine age and cause specific mortality rates, at Fort Rucker, Alabama. During 2009–2010, 14 fawns were captured immediately after birth and monitored, with three surviving until 6 mo of age. Six of 7 predation events were attributed to coyotes (*Canis latrans*), and we determined coyote density in the study area during 2010, using DNA isolated from 44 coyote scats, to be 0.40 coyotes/km^2. This study, like other recent studies in the Southeast, has found low fawn recruitment seems to be driven by coyote predation.

Introduction

Within the last 40 y, coyotes (*Canis latrans*) have expanded their range east into areas previously occupied by larger extirpated predators (Hill *et al.*, 1987). Since the recent increase in the coyote population, fawn recruitment in some deer populations in the Southeast is thought to have decreased. Evidence of this has been documented in a recent study in westcentral South Carolina (Kilgo *et al.*, 2010) in which fawn mortality was estimated at 77%, with 90% of mortalities attributed to probable or definitive predation (Kilgo *et al.*, 2012). Of all mortalities, 80% were confirmed or probable coyote predation (Kilgo *et al.*, 2012). The effect of predation on fawn recruitment can also be seen in studies that have examined predator control programs. The removal of predators (*e.g.*, coyotes and bobcats) from study areas in southwest Georgia (Howze *et al.*, 2009) and northeast Alabama (VanGilder *et al.*, 2009) have led to substantial increases in fawn recruitment.

To provide a baseline for the effects of coyote density on white-tailed deer survival in the Southeast we estimated juvenile survival of white-tailed deer, as well as coyote density at Fort Rucker, Alabama, where recent increases in coyote numbers and decreases in white-tailed deer density have been noted.

Methods

study area

This study was conducted at Fort Rucker, Alabama, a 183-km^2 military facility that conducts helicopter training for the U.S. Army (31.3437°N, 85.7080°W). The southeastern portion of the facility comprised the study area, approximately 31.6 km^2. The vegetation on the area was mostly of forested land that was comprised of primarily pine (*Pinus spp.*) and mixed pine-hardwood forests. Dominant tree species included loblolly (*P. taeda*), shortleaf pine (*P. enchinata*), longleaf pine (*P. palustris*), slash pine (*P. elliottii*), southern red oak (*Quercus falcate*), water oak (*Q. nigra*), laurel oak (*Q. laurifolia*), sweetgum (*Liquidambar styraciflua*), yellow-poplar (*Liriodendron tulipifera*), and sassafras (*Sassafras albidum*; Mount and Diamond, 1992). Throughout the study period an approximate area of 12.5 km^2 underwent prescribed burning, and in the 5 y prior to the study an approximate area of 2.4 km^2 underwent thinning or clear cutting.

Both firearm and archery hunting were allowed on the majority of Fort Rucker. In recent years, 2002–2011, Fort Rucker hunters had reported a total harvest of 50 to 120 deer for the entire installation. The majority of Fort Rucker had a 2.4 m chain linked fence with barbed wire at the top; however, there were breaks over streams and for natural boundaries. This fence limited, but did not prohibit, movement of individuals to and from the population.

A camera study on Fort Rucker following the methods of Demarais *et al.* (2000) conducted in the study area in Feb. 2005 estimated deer density to be 11 deer/km^2 and fawn recruitment to be 0.28 fawns per doe. Unfortunately, this was the most recent estimate of deer density within the study area and may not be representative of the population at the time of the study. The estimate may also be unreliable due to the use of bait and general inconsistency of methods to estimate deer density (Langdon, 2001; Roberts *et al.*, 2006; McCoy *et al.*, 2011; Collier *et al.*, *in press*). Populations without coyotes in the Southeast have reported fawn recruitment estimates as great as 0.80 (Kilgo *et al.*, 2010). Five years of data collection had shown that pregnancy rates at Fort Rucker were above 90% (C.W. Cook personal communication), suggesting that depressed recruitment rates were not a function of low rates of pregnancy. Additionally, low recruitment was not believed to be due to changes in cover, habitat type, or yearly climate, as body weights and herd health checks had indicated that the population was in excellent physical condition. Established predator populations on the study area include bobcat and coyote as well as red and gray fox.

DOE CAPTURE AND HANDLING

From Feb. to Jul. of 2009–2010, we trapped does using cannon nets over areas baited with corn (Hawkins *et al.*, 1968): trap sites were baited for at least a month before capture started (Ditchkoff *et al.*, 2001). After capture, does were sedated using a combination of 125 mg of telazol to 100 mg of xylazine (1 ml/45.36 kg) injected intramuscularly. To reverse sedation, an intramuscular injection of tolazine (yohimbine hydrochloride; 3 ml/45.36 kg) was given after data collection and vaginal transmitter insertion (Saalfeld and Ditchkoff, 2007). While the deer were sedated, we inserted vaginal implant transmitters (VITs; M3960B, Advanced Telemetry Systems, Insanti, MN) approximately 20 cm into the vaginal canal with the silicone wings pressed against the cervix (Carstensen *et al.*, 2003; Saalfeld and Ditchkoff, 2007). These VITs were capable of sensing a temperature drop from the body temperature of the doe to 30 C, and would change the pulse frequency signal emitted when expelled from the doe during parturition. We monitored does approximately once a week from initial capture until more intense monitoring began in middle Jul., approximately 2 wk before the peak of birth in Alabama (Lueth, 1955, 1967).

VIT MONITORING

Vaginal transmitters were monitored three times a day beginning in middle Jul. After the first birth of the season, we monitored transmitters every 6 h. Monitoring continued until all vaginal transmitters were expelled or the doe was identified as nonpregnant. We determined if a doe was nonpregnant by examining photographs, taken by remote cameras over baited sites, for visible signs of pregnancy. Fawns were not approached until at least 2 h after the VIT indicated expulsion. A precise event timer in the vaginal transmitter allowed for time of birth to be calculated to within 30 min. We followed the methods of Roberts (2007) and Kilgo *et al.* (2012) to locate fawns that moved from the birth site. A thermal imaging camera (Raytheon Palm IR 250D, Waltham, MA) was used to aid in conducting all searches.

FAWN CAPTURE AND MONITORING

We captured fawns by hand and used nonscented latex gloves to reduce scent transfer (White *et al.*, 1972; Powell *et al.*, 2005; Saalfeld and Ditchkoff, 2007). Fawns were sexed and fitted with expandable collars (M4200, Advanced Telemetry Systems, Insanti, MN) that were designed to fall off at approximately 6 mo of age. Handling was completed in an efficient manner to reduce stress and handling times were normally less than 10 min per fawn.

Fawns were located at least once every day for the first 2 mo and then located once a week until they reached 6 mo of age or the expandable collar fell off. When we received a mortality signal, the fawn was immediately located and cause of death determined. Cause of death due to predation was determined by assessing remains at the site for puncture wounds and evidence of predators such as hair, scat, or tracks (O'Gara, 1978). All other causes of death were determined during necropsy by the State of Alabama Department of Agriculture, Thompson Bishop Sparks Diagnostic Lab, Auburn, Alabama. All procedures involving the use of live animals were approved by the Auburn University IACUC (PRN# 2008-1474).

COYOTE DENSITY

Coyote density was estimated for summer 2010 by identifying individual coyotes within the study area using DNA extracted from scat. We collected scat samples opportunistically on roads throughout the area from Jun. to Sep. 2010 during doe and fawn monitoring. Since does were located throughout the study area and checked multiple times a day after middle Jul., most roads were checked at least once a day for coyote scat during the sampling period. Samples were taken along the side of the fecal sample and 0.4 mL of feces was placed into vials containing 1.5 mL DETs buffer (Stenglein *et al.*, 2010). Genetic analyses were conducted by the Laboratory for Conservation and Ecological Genetics, University of Idaho using techniques described by Stenglein *et al.* (2010).

DATA ANALYSIS

All analysis was conducted in Program R version 2.10.1 (The R Foundation for Statistical Computing, 2009). Age specific survival rate of fawns was estimated until 180 d using a Kaplan-Meier survival curve without staggered entry and any individuals with an unknown fate were right censored (Hosmer *et al.*, 2008). To compare hazards of covariates, including sex, year, age, and age^2, we used a Cox proportional hazards model (Hosmer *et al.*, 2008). In this model, entries were staggered based on date of birth (*i.e.*, Jul. 27) to allow the effects of age to be tested. Cause specific mortality of fawns was analyzed using competing risks analysis; three types of mortality were used in this analysis: abandonment, bobcat predation, and coyote predation (Heisey and Patterson, 2006).

To estimate coyote density we iterated a rarefaction curve, an accumulation of unique individuals or genotype with the asymptote representing the estimated population size [$y = (a \times x) / (b + x)$, where x was the number of amplified samples, y was the cumulative number of unique genotypes, a was the asymptote, and b the rate of decline in the slope], 1000 times to determine the number of coyotes in the study area (Kohn *et al.*, 1999). The median, rather than the mean (Frantz and Roper, 2006), number of coyotes, as determined by the rarefaction curves, was used to determine coyote density on the study area.

RESULTS

We captured 15 does and recaptured one doe in year two of the study, resulting in 16 deployed VITs during 273 trap sessions over two field seasons: nine VITs were deployed in 2009 and seven in 2010. The 16 deployed VITs resulted in 11 birth events: six in 2009 and five in 2010. Twelve live fawns (four in 2009 and eight in 2010) and two stillborn fawns in 2009 were found at or near VIT birth sites. In 2009, one VIT was expelled prematurely; although a fawn was found within 24 hours of birth near the doe. One additional fawn was found in 2009 during searches using a window mounted thermal imager as described by Ditchkoff *et al.* (2005). Capture efforts resulted in a total of 14 fawns for survival analysis.

Overall probability of fawn survival to 6 mo of age was determined to be 0.26 (CI = 0.10–0.68) with 3 of 14 fawns surviving and 2 fawns right censored due to unknown fate. All mortalities occurred between 3 and 40 d of age, but no patterns of mortality were apparent within this period (Fig. 1). No covariates were found to be predictors of mortality, based on a full model including age ($P = 0.74$, $\beta = 0.97$, CI = 0.82–1.15), age^2 ($P = 0.88$, $\beta = 1.00$, CI = 0.99–1.00), sex ($P = 0.61$, $\beta = 0.57$, CI = 0.07–4.80), and year ($P = 0.76$, $\beta = 1.57$, CI = 0.085–29.08).

Three types of mortality were identified: abandonment ($n = 2$), bobcat predation ($n = 1$), and coyote predation ($n = 6$). Vehicle collisions were not a cause of mortality for any individual within the study; however, other fawns without radio collars were noted to have died from vehicle collisions within the study area. Competing risks analysis determined that the probability of mortality by 180 d of age due to abandonment, bobcat predation, and coyote predation was 0.15 (CI = 0–0.33), 0.13 (CI = 0–0.33), and 0.65 (CI = 0.14–0.86), respectively. Since fawns were monitored daily during the time frame when all mortalities occurred, we are confident that scavenging events were not misdiagnosed as predation.

Forty-four of 57 coyote scat samples sent for analysis were used to determine coyote density within the study area. The 13 samples which were not used in analysis were due to lack of amplification ($n = 6$), incorrect species ($n = 2$), or inability to determine individual ($n = 5$). Ten individuals were identified from these samples and 1000 rarefaction curves of bootstrapped sampling taken with replacement resulted in a median number of 12.78 (CL = 10.21–18.48) coyotes in the area. Coyote density was determined to be 0.40 (CL = 0.32–0.58) coyotes/km^2 for the study area. Of the 10 individuals identified, six had replicate samples. The greatest number of replicates for one individual was 11. Four individuals were first found in Jun. and 2 new individuals were found in each of the remaining months of sampling.

DISCUSSION

Fawn survival to 180 d in our study was 0.26; however, confidence intervals were large for survival rate estimates due to low sample size. We were unable to determine if any variables in our models affected

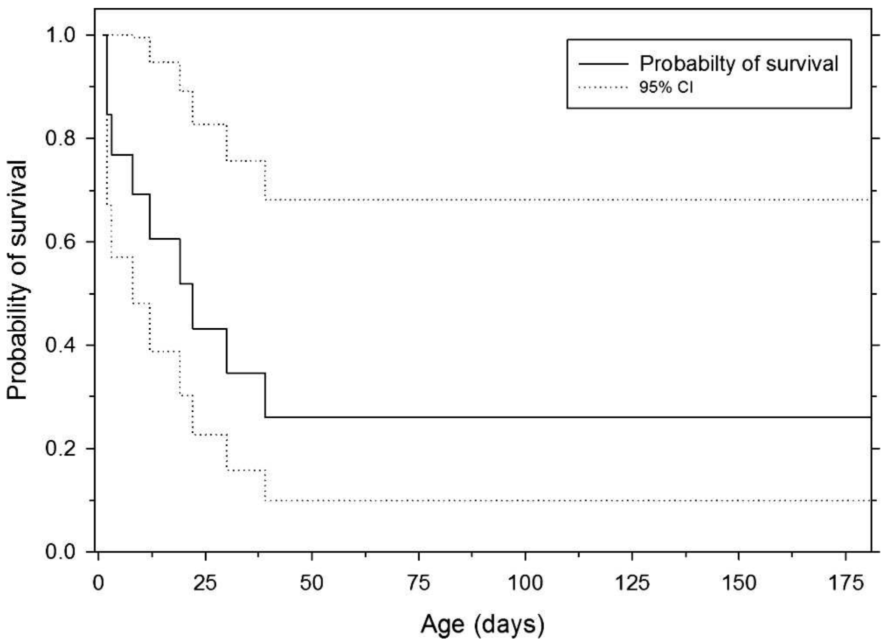

FIG. 1.—Survival of white-tailed deer fawns from birth to 180 days of age at Fort Rucker, AL during 2009 and 2010

survival, but whether this was due to a true lack of effect or a product of low sample size is unknown. It is important to note that we do not believe the abandonment incident (the two abandoned individuals were siblings) was handling related based on research done by Powell *et al.* (2005). Also, the dam of the abandoned individuals was the recaptured doe, and she successfully raised a fawn to 180 d during the first year of the study. We believe if handling was the cause of her abandonment she would have abandoned her fawns in both years. Assuming our estimated rates of survival were representative of the population at Fort Rucker, fawn survival was less than historic averages for white-tailed deer (54%, Linnell *et al.*, 1995) and consistent with more recent studies of fawn survival in the Southeast (33.3%, Saalfeld and Ditchkoff, 2007; 23%, Kilgo *et al.*, 2012). The fawn survival estimate from this study was also consistent with recruitment estimates (0.28 fawns per doe, C.E. Mayo, pers. comm.) at Fort Rucker.

Our data suggest that low recruitment at Fort Rucker was the result of high rates of predation on fawns, which has been documented in other recent studies in the Southeast (Saalfeld and Ditchkoff, 2007; Howze *et al.*, 2009; VanGilder *et al.*, 2009; Kilgo *et al.*, 2012). Coyotes were the leading cause of fawn mortality in our study and probability of mortality due to coyotes was estimated to be 0.649. Again, large confidence intervals due to low sample size were an issue; however our data is congruent with recent studies in the Southeast. Coyotes potentially caused up to 63% of mortalities in white-tailed deer fawns in an Alabama population (Saalfeld and Ditchkoff, 2007) and 80% of mortalities in a South Carolina population (Kilgo *et al.*, 2012).

We determined coyote density on Fort Rucker to be 0.40 coyotes/km^2, which is near the suggested average density of coyotes throughout their range (Knowlton, 1972). Density estimates for coyotes are expected to vary based on habitat and prey availability and this is seen from studies conducted in the native range of the coyote as well as areas to the west (0.26 coyotes/km^2, Steigers and Flinders, 1980; 0.8–1.0, Andelt, 1982; 0.29, Gese *et al.*, 1989; 0.71, Hein and Andelt, 1995; 0.8–0.9, Kamler and Gipson, 2000). These density estimates may also vary due to differences in methods for determining density. In western Tennessee, coyote density was reported to be 0.35 coyotes/km^2 (Babb and Kennedy, 1989). The equation for rarefaction curves for population abundance generated by Kohn *et al.* (1999) has been shown to frequently overestimate populations (Frantz and Roper, 2006). We feel the small difference between the median value, 12.78, and the known number of individuals based on DNA, 10, makes an overestimate of the population unlikely.

Fort Rucker is not the only location that has observed low fawn recruitment and low deer densities in the Southeast. Two other studies have recently reported low recruitment with below average deer densities (4–8 deer/km^2, Johns and Kilgo, 2005; 3.8–5.8, Howze *et al.*, 2009). A third study has also reported low recruitment of fawns following heavy doe harvest and attributed the low recruitment to predation (VanGilder *et al.*, 2009). Unfortunately, recent data on population growth, fawn survival, and recruitment have not been reported for other Southeastern deer populations with average or above average densities, thus preventing comparisons with these reported studies. Presenting both estimates of fawn survival and coyote density creates a baseline for comparison with future studies and could help to elucidate our understanding of the interactions between these two species.

Our study and others indicate that low fawn recruitment may be an issue on some properties in the Southeast. Property managers, particularly in areas with low deer density or heavy antlerless harvest, need to monitor recruitment in their population and be aware of the potential impact of coyote predation. Healthy deer populations are attainable in areas with low recruitment rates as has been reported previously (*see* Ditchkoff *et al.*, 1997). Populations where success has been achieved are closely monitored and antlerless harvest rates are adjusted annually based upon current data. Finally, an examination of predator-prey theory could shed light on this changing dynamic in the Southeast and potentially provide insight into management approaches that may prove most effective in maintaining healthy harvestable populations of white-tailed deer.

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