Coyote and Bobcat Predation on White-tailed Deer Fawns in a Longleaf Pine Ecosystem in Southwestern Georgia

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Abstract: Managing white-tailed deer (*Odocoileus virginianus)* populations requires an understanding of fawn survival and cause-specific mortality. In the Southeast, coyotes (*Canis latrans*) and bobcats (*Lynx rufus*) can be major sources of fawn mortality and may limit some white-tailed deer populations. We captured and radio-collared 47 fawns at the Joseph W. Jones Ecological Research Center in southwestern Georgia during 2007, 2008, 2011, and 2012 to quantify cause-specific mortality and survival. Fawn survival to 20 weeks of age (i.e., opening day of firearms season) was 29.0%. Coyote predation accounted for 52.4% of all fawn mortalities and 68.7% of predation-caused mortalities, while bobcat predation accounted for only 9.5% of all mortalities and 12.5 % of all predation. During 2007 and 2008, we quantified and then compared the percentage of coyote and bobcat scats that contained deer remains during the fawning season. Deer remains occurred more frequently in coyote scats (40% of 167) than in bobcat scats (16% of 71). Collectively, these results suggest predation has profound effects on fawn survival in our system. Similar to other studies, our results suggest that in areas where bobcats and coyotes are sympatric, white-tailed deer are not a major component of bobcat diets. Finally, our study provides further evidence that coyote predation can be a substantial source of fawn mortality that may influence population dynamics of white-tailed deer in the southeastern United States. We suggest managers monitor fawn recruitment and adapt antlerless harvest accordingly.

Key words: bobcat, coyote, fawn, survival, white-tailed deer

Managing white-tailed deer (*Odocoileus virginianus*) requires an understanding of fawn survival and sources of mortality (Pusateri Burroughs et al. 2006). Survival of newborn fawns is affected by their health at birth, disease prevalence, food availability, availability of escape cover, condition of the dam, predator abundance, and other unforeseen factors (Jackson et al. 1972). Numerous investigators have documented losses of deer fawns to predation (Vreeland et al. 2004, Lomas and Bender 2007, Kilgo et al. 2012), which is typically the main source of mortality (Ballard 2011). Recent studies have suggested that coyote (*Canis latrans*) predation on fawns may be limiting growth of certain deer populations in the eastern United States (Kilgo et al. 2010), especially when white-tailed deer populations are not limited nutritionally (Ballard et al. 2001). Yet predicting the specific effects of predation on fawn recruitment as a basis for management action can be challenging. Robinson et al. (2014) suggested that state agencies may compensate for high levels of predation through manipulation of antlerless harvest. However, an understanding of fawn recruitment is needed to accurately adjust for this added source of mortality.

Several studies have examined white-tailed deer fawn mortality, but did not specifically report bobcat (*Lynx rufus*) predation. Pusateri Burroughs et al. (2006) found mortality rates as low as 23% in Michigan, with little evidence of predation. In north-central South Dakota, Grovenburg et al. (2012) reported a mortality rate of 28%, with predation accounting for 52% of mortalities; of those fawns killed by predators, 83% were killed by coyotes. In Alabama, Saalfeld and Ditchkoff (2007) reported a 67% fawn mortality rate, with coyote predation causing 42% of deaths.

Other studies have separately identified bobcat and coyote predation as sources of fawn mortality. In Alabama, Jackson and Ditchkoff (2013) reported a 74% mortality rate, with predation by coyotes accounting for 66% of identified mortalities vs. 11% for bobcats. On a South Carolina study site where predators were removed by trapping, McCoy et al. (2013) reported a 32% fawn mortality rate with coyote predation accounting for 48% of confirmed predation events, compared to 24% for bobcats. On another South Carolina study site where predator removal did not occur, Kilgo et al. (2012) reported a 77% fawn mortality rate with coyote preda-

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tion accounting for 37%–80% of mortalities and bobcat predation for only 7%–9%. Thus, several studies have documented that when coyotes are present, they usually represent the leading source of fawn mortality by predators.

Minimal data exist on white-tailed deer fawn mortality in the Lower Coastal Plain of Georgia. Therefore, we worked in a managed longleaf pine ecosystem in southwestern Georgia to determine cause-specific mortality of radio-collared fawns during 2007–08 and 2011–12, and measured and compared the proportion of bobcat and coyote scat containing deer remains during the fawning season in 2007–08. Our objective was to quantify the relative contribution of bobcat and coyote predation on white-tailed deer fawn mortality as a basis for understanding the effects of cause-specific mortality on fawn recruitment.

Study Area

Our study was conducted on Ichauway, the outdoor research facility at the Joseph W. Jones Ecological Research Center (Jones Center) located in Baker County, Georgia. This 11,735-ha research facility was one of the largest privately-held tracts of longleaf pine (*Pinus palustris*) forest in the United States. White-tailed deer management objectives were to maintain relatively low densities to maximize individual nutritional condition while maintaining a balanced sex-ratio and diverse age structure through selective harvest (J. W. Jones Ecological Research Center 2012). Spotlight and track-count surveys were conducted annually to obtain estimates of white-tailed deer abundance across the property. The estimated deer density at the Jones Center during 2007–2012 varied between 4.6–8.8 deer/km^2 (Joseph W. Jones Ecological Research Center 2012).

The climate was characterized by mild, wet, short winters and hot summers, with temperatures ranging on average from 11 C during winter to 27 C during summer (Boring 2001). The average annual rainfall was 132 cm. The site was dominated by longleaf pine overstory and associated isolated limesink and cypress-gum (*Taxodium ascendens-Nyssa biflora*) wetlands. The dominant understory species were wiregrass (*Aristida beyrichiana*) and old field grasses (e.g., *Andropogon* spp.) on areas where the soil has been disturbed. The Flint River forms 21 km of the eastern property boundary and 24 km of the Ichawaynochaway Creek flows through the middle of the property. Forest management at the Jones Center included prescribed fire on an approximate two-year return interval, hardwood removal from the longleaf pine uplands, and longleaf pine restoration. Management practices were implemented on approximately half of the property for northern bobwhite (*Colinus virginianus*). These practices included supplemental feeding, food plot maintenance, and removal of mesopredators (e.g., bobcat,

coyote, raccoon [*Procyon lotor*], opossum [*Didelphis virginiana*]*,* and gray fox [*Urocyon cinereoargenteus*]). Wildlife food plots were planted in brown top millet (*Urochloa ramose*), cowpea (*Vigna* spp.), corn (*Zea mays*), grain sorghum (*Sorghum bicolor*), Egyptian wheat (*Sorghum* spp.), and winter wheat (*Triticum aestivum*), (Joseph W. Jones Ecological Research Center 2012).

Methods

During May through August of 2007, 2008, 2011, and 2012, we used a thermal imaging camera (Raytheon Commercial Infrared, Dallas, Texas) or thermal infrared camera (FLIR Systems, Inc. Wilsonville, Oregon) to scan woodlands adjacent to primary and secondary roads at night to view bedded fawns. After locating a fawn, we attempted to capture the fawn with a long-handled landing net while the camera operator directed the other person(s) to the animal's location via handheld radio. We also opportunistically captured fawns by responding to reports of fawn sightings by Center employees.

During 2012, we also located and captured fawns at, or near doe parturition sites with the aid of vaginal implant transmitters (VIT). Between January and April 2012, we captured adult does using chemical immobilization, assuming they had been bred during the previous rut. We immobilized does with a mixture of xylazine hydrochloride (Rompun, 2.2 mg/kg body weight) and Telazol (4.4 mg/kg body weight; Kreeger et al. 2002) delivered via a CO_2-powered dart gun (JMspecial; Dan-inject, Inc., Borkop, Denmark). Once immobilized, we moved does into the sternal position, applied ophthalmic ointment to each eye and a blindfold, then monitored heart rate, body temperature, and respiration. With the doe restrained, we fitted them with a prototype temperature- and photo-activated VIT (Advanced Telemetry Systems, Isanti, Minnesota; Cherry et al. 2013) and a mortality-sensing VHF radio transmitter with GPS capabilities (G2110D; Advanced Telemetry Systems, Isanti, Minnesota). We reversed the xylazine with tolazoline (1.4 mg/kg body weight; Kreeger et al. 2002) ≥90 minutes post-injection and continued to monitor the deer until recovery.

We monitored VIT transmissions using a hand-held 3-element yagi antenna portable receiver (TRX-2000S; Wildlife Materials, Murphysboro, Illinois) weekly following doe capture and then twice daily beginning in May to identify parturition sites and to facilitate rapid fawn capture (Cartensen et al. 2003, Cartensen-Powell 2005). In the event of a VIT transmission signaling a parturition event had taken place, we initiated a systematic search between the expelled VIT to the VHF signal of the doe using a thermal imaging camera.

When capturing fawns, we wore surgical gloves while handling them to reduce scent transfer (Kilgo et al. 2012). We estimated age

of opportunistically captured fawns (days) using hoof growth measurement and umbilicus condition (Brinkman et al. 2004) as well as body condition and behavior. Captured fawns were sexed, aged, weighed, and fitted with elastic, breakaway collars with a VHF transmitter (M4210; Advanced Telemetry Systems, Isanti, Minnesota) with a motion-sensitive mortality switch on a four-hour delay and then released at the capture location (Kilgo et al. 2012). We acknowledge that opportunistically captured fawns were a few days older than those captured using a VIT and, thus, may underrepresent the level of mortality that could have occurred during the first three-four days post-partum. We handled all deer under the University of Georgia's Animal Use Proposal A2011 03-009-R2.

The greatest probability of mortality occurs during the first few weeks of a fawn's life (Cook et al. 1971, Kilgo et al. 2012). Therefore, we intensified monitoring efforts during that time period to ensure accurate estimation of time-of-death and to facilitate identification of mortality sources. From capture until approximately six weeks of age, we monitored fawn survival ≥2 times per day. After six weeks of age, we monitored fawns ≥5 times per week. We ceased monitoring fawns during October of each year when we considered them to be recruited into the fall population. During 2012, to satisfy a separate research objective, we also visually observed fawns from approximately 10 m during their first two weeks of life. We examined whether changes in the 2012 protocol affected fawn survival during data analyses.

We identified cause-specific mortality using field methods based on identification of signs of trauma, external hemorrhaging, scattering of remains, caching behavior, and presence of scat or tracks near the mortality site (White 1973, Garner et al 1976, Epstein et al. 1983, Kilgo et al. 2012). We classified all predation mortalities as caused by "coyote," "bobcat," or "unknown predator." Mortalities not classified as predation events were classified as "other," which included deaths attributed to emaciation or unknown causes. Due to the intensity of our monitoring efforts, we believe we were able to identify all mortalities soon after they occurred and therefore there was little possibility that our determination of cause of death was based upon scavenging rather than predation. Our fawn-monitoring protocols were similar to those used by Kilgo et al. (2012), who confirmed all probable coyote predation in fawns based on collected field evidence using DNA identification.

We also collected bobcat and coyote scat opportunistically from roads and firebreaks across the study site during the fawning season (June–August) of 2007 and 2008 (Howze 2009). We only collected fresh scat for analysis (Godbois et al. 2003), and identified it as bobcat or coyote based on a combination of size, shape, odor, and tracks around the scat (Danner and Dodd 1982, Bowyer et al. 1983). We discarded scat of questionable origin. We placed individual scats in labeled paper bags and froze them to prevent further decomposition before processing.

Samples were placed in a drying oven for 72 hours at 60 C before processing to kill bacteria or parasites (Baker et al. 2001, Godbois et al. 2003). Each scat was separated and contents were examined macroscopically. Deer remains were identified based on size, color, and texture of hair (Blanton 1988), as well as the presence of bones, hooves, and teeth.

We estimated fawn survival from capture until recruitment into the fall population (i.e., the opening day of firearms hunting season: 20 October 2007, 18 October 2008, 15 October 2011, and 22 October 2012) using the Kaplan-Meier method modified for staggered entry (Pollock et al. 1989) and right-censored fawns that experienced premature transmitter failure (Jackson and Ditchkoff 2013). We believe our study met the assumptions for Kaplan-Meier survival analysis. Our fawn captures occurred randomly across the study site; therefore, survival events likely were independent. Although we included both members of twin sets when the opportunity arose during capture, Bishop et al. (2008) determined that treating sibling neonates as independent sample units resulted in limited overdispersion and therefore was reasonable. Also, censoring of neonates was independent of the fate of those neonates (Kilgo et al. 2012). To determine if we could pool survival estimates obtained during different years, we compared years with the least and greatest survival estimates using a χ^2 test (Pollack et al. 1989) in SAS 9.3 (SAS Institute Inc., Cary, North Carolina). To determine if the occurrence of deer remains in scat differed between coyotes and bobcats during the fawning season, we conducted a Fisher's exact test of independence using SAS (SAS 2003).

Results

In total, we captured and radio-collared 47 fawns during the study. Five fawns were captured using VITs from three implanted females during 2012, and all were captured either at, or within a close distance (≤200 yards) to, the identified parturition site and were located through systematic daytime searches. There was minimal variation in average age at capture of neonates among years (Table 1) although neonates were on average younger in 2012 due to five fawns being captured using VITs. Even though the opportunistically captured fawns were older than those captured using VITs, the average age at fawn capture was 3–4 days (Table 1). During both 2007 and 2011, two fawns (four fawns total) were right censored because they prematurely shed their radio-collars. Most (66.7%) of the fawn mortalities occurred within the first two weeks of life, and all but two mortalities occurred during the first 30 days of life. Further, 82% of coyote predations, and all bobcat predations and unknown predations occurred during the first 30 days of life.

Table 1. Number of fawns captured, average estimated age at time of capture, and estimated fawn survival until hunting season for white-tailed deer fawns at the Joseph W. Jones Ecological Research Center (Ichauway), Baker County, Georgia, during 2007–2008 and 2011–2012.

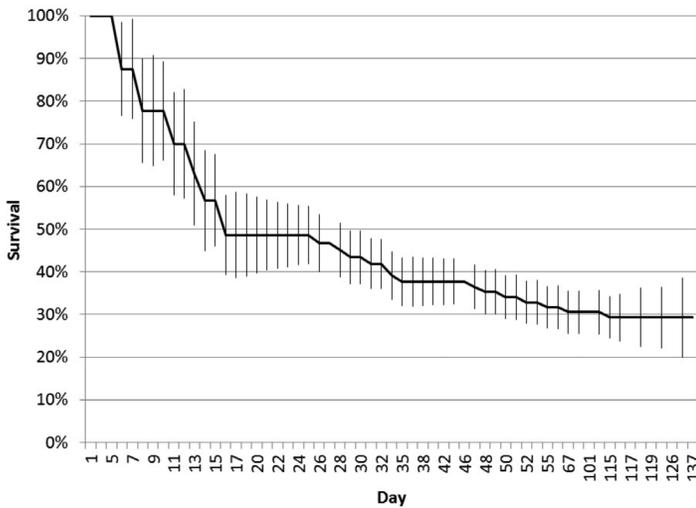| Year	n	Age (days)		Survival (%)	
		Mean	SE	Mean	SE
2007	8	4.4	0.50	0.267	0.13
2008	13	4.2	0.60	0.222	0.07
2011	13	4.5	0.60	0.675	0.14
2012	13	3.1	0.70	0.205	0.08

Figure 1. Survivorship curve of radio-collared white-tailed deer fawns from capture until October (the beginning of the firearm deer hunting season season) at the Joseph W. Jones Ecological Research Center (Ichauway), Baker County, Georgia. Data are pooled for years 2007, 2008, 2011, and 2012). Vertical bars represent standard errors.

Kaplan-Meier survivorship did not vary ($\chi^2 = 2.32$, $P = 0.128$) between year for the greatest (2011) and least (2012) survival estimates, which is likely due to the high variability of our estimate in 2011 (Table 1). Our pooled survival estimate was 29.0% ± 9.3% ($\bar{x} \pm SE$; Figure 1). Of 21 fawns that died (i.e., 71% mortality), coyotes were responsible for 52.4% (11), bobcats for 9.5% (2), unknown predator for 14.3% (3), starvation for 4.8% (1), and unknown causes for 19.0% (4). Predation accounted for 76.2% of all fawn mortalities with coyotes being responsible for 68.7% of those predation events, compared to 12.5% for bobcats. We could not determine the cause of 18.8% of fawn predations due to lack of definitive evidence at mortality sites; however, we did find tooth marks and/or blood on the radio-collar, which indicated they likely were predation-based mortalities.

We collected 167 coyote and 71 bobcat scats during June–August 2007 and 2008. Deer remains occurred more frequently in coyote scat (39.5%; n = 66) than in bobcat scat (15.6%; n = 11) during both years (Fisher's exact $P = 0.0015$ for 2007 and $P = 0.0423$ for 2008).

Discussion

Our results suggest predation can be a major driver of recruitment in deer populations in well-managed forest systems. Yet, the fawn survival rates we observed are below the mean reported in 14 different studies of white-tailed deer fawn mortality published from 1971–2004 (Saalfeld and Ditchkoff 2007) plus two more recent studies included in the mean estimate (Kilgo et al. 2012, McCoy et al. 2013). Our study site provided abundant hiding cover for fawns through management for open canopy forests and prescribed fire, as well as alternative food resources for predators through supplemental feeding and forest management. This suggests that in spite of forest management practices on our site providing abundant alternative food items and concealment cover, fawns are readily consumed by coyotes and to a lesser extent by bobcats.

Our results support the findings of other studies suggesting that white-tailed deer fawns are most vulnerable to predation during their first few weeks of life (Whittaker and Lindzey 1999, Pusateri Burroughs et al. 2006, Kilgo et al. 2012). Also consistent with previous studies, our results suggest that once fawns survive their first few weeks of life, predation mortality is low and survival until recruitment into the fall population is moderately high (Pusateri Burroughs et al. 2006).

Several studies indicate that predator community diversity greatly influences the specific causes of fawn mortality (Ballard 2011). In the Southeast, in cases where coyotes are not present, several authors have reported high levels of fawn predation by bobcats — Epstein et al. (1983) reported 29% mortality from bobcat predation, Boulay (1992) reported ≥60% mortality from bobcats, and Roberts (2007) reported 57%–82% mortality from bobcats. Conversely, in areas of the Southeast where bobcats are apparently not present, coyotes have been reported to be the primary cause of fawn mortality — Saalfeld and Ditchkoff (2007) found that coyotes accounted for 42% of fawn mortality. Similar to what we observed on our study site, in areas of the southeastern United States where bobcats and coyotes occur sympatrically, coyotes appear to be the primary cause of fawn mortality — Kilgo et al. (2012) found that coyotes accounted for 37%–80% of all fawn mortalities, compared to 8.5% for bobcats. Studies of bobcat food habits in the Southeast also confirm this conclusion —in areas where bobcats and coyotes are sympatric, white-tailed deer are not a major component of bobcat diets (Godbois et al. 2003, Thornton et al. 2004, VanGilder 2008). Given that we observed fawn remains more frequently in coyote scat than in bobcat scat, our results affirm these findings as well.

During capture, four fawns showed signs of red imported fire ant (*Solenopsis* spp.) bites. Of those fawns, two died shortly thereafter of unknown causes. Although the role of fire ants in the deaths of these two fawns is uncertain, it has been hypothesized that fire

ants may affect white-tailed deer recruitment (Allen et al. 1997). Additionally, irritation from fire ant stings may cause neonatal fawns to increase their movements, which could make them more susceptible to predation during the most critical period in their lives (Mueller and Forbes 2001).

Coyotes are an opportunistic species. In the southeastern United States their primary food items include soft mast, insects, and small mammals; when available, fawns can be a major food item in their diets (Thornton et al. 2004, Schrecengost et al. 2008, Howze 2009, Ballard 2011). In South Carolina, Schrecengost et al. (2008) found white-tailed deer fawns occurred in 15% to 38% of coyote scats collected on a study site in the South Carolina Upper Coastal Plain region during May–June of two years, despite a low deer density on the site. In a study on two areas in the Georgia Piedmont region, Kelly (2012) found that 26.7% and 61.5% of coyote scats collected during the fawning season contained fawn remains, and that a high abundance of small mammals did not buffer coyote predation on fawns. Blanton and Hill (1989) found that in areas with a high deer density, fawns were a staple in coyote diets; whereas, in areas with a low deer density, fawns were less abundant in their diets. These results suggest that coyotes exploit seasonal food items as they become available, and may selectively prey on fawns rather than other less energetically beneficial prey items (Blanton and Hill 1989, Schrecengost et al. 2008).

Management Implications

The impact of coyotes on deer populations in the Southeast may depend on deer population density (Kilgo et al. 2012). Even in areas where predation is responsible for 100% of fawn mortalities, the population-level effect will be negligible if mortalities account for an insignificant proportion of the total number of fawns produced (Ballard 2011). When predators are limiting white-tailed deer populations, reducing harvest of females may be necessary to offset losses (Kilgo et al. 2012, Robinson et al. 2014). The Georgia Department of Natural Resources Wildlife Resources Division (GA DNR-WRD) has already reduced the opportunities for antlerless harvest in many regions of Georgia to counteract decreased fawn recruitment due to high levels of coyote predation (C. H. Killmaster, GA DNR-WRD, personal communication).

Acknowledgments

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