Mortality Patterns of Female White-tailed Deer in Southwest Florida

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Abstract: Eleven of 66 radio-collared white-tailed deer (*Odocoileus virginianus*) in southwest Florida were killed by bobcats (*Felis rufus*) and 4 by Florida panthers (*Felis concolor coryi*). Average doe home range size was 194 ha, and 2 bucks ranged from 454–1,560 ha. There were no differences (P = 0.336) in doe survival rates among seasons. The average annual survival rate for does was 0.813 (95% CI- 0.68, 0.94) and 64% of the annual mortality was attributable to predation. Average neonate mortality rate was 37.8% ± 16.1 and appeared to increase with surface water levels. Human hunting activities had little impact on the number of radio-collared does, and the population was stable with a net reproductive rate (R_0) of 0.96.

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White-tailed deer are an important prey item for the endangered Florida panther (*Felis concolor coryi*) (Maehr et al. 1990), and variation in prey density appears to affect panther productivity and home range size (Maehr et al. 1989). Knowledge of the causes and rates of deer mortality is needed to manage deer within occupied panther range. We studied the highest density deer herd on public lands in occupied panther range (Schortemeyer et al. 1989) to characterize mortality patterns of female white-tailed deer.

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Methods

Bear Island is the northernmost unit of the Big Cypress National Preserve (BCNP) and lies northeast of the intersection of State Road 84 (I–75) and State Road 29. The BCNP is a wildlife management area where bucks with antlers >12.7 cm are legal game. The climate is sub-tropical savannah with a hot, humid rainy season (May through Sep) and a mild dry season (Oct through Apr) (Duever et al. 1986). Average annual rainfall and temperature are 136.0 cm and 23° C, respectively. Major plant communities are herbaceous freshwater marshes, pinelands, mixed-species swamps, and hardwood hammocks (Davis 1943).

We netted deer from a Bell Jet Ranger helicopter with a handheld netgun (Barrett et al. 1982) during early morning and late afternoon hours. Deer were hog-tied and blind-folded for taking measurements and attachment of a radio-collar or ear tag. We also darted deer at night from an airboat using a combination of ketamine hydrochloride and Rompun®. We attempted to capture young fawns (<2 months of age) at night by spot-lighting for mother-fawn pairs or by making daytime searches near radio-instrumented does. Older fawns were captured from helicopters with the netgun. We captured deer from September 1986 through February 1990.

Does were fitted with mortality-sensing radio-collars (Telonics, Inc., Mesa, Ariz.) and released within 20–30 minutes; however, the few animals that were drugged required several hours to recover from anesthesia. Yearling bucks were eartagged only. Fawns were fitted with expanding or breakaway collars (Telonics, Inc., Mesa, Ariz.). Animals were eartagged and length, mass, and girth recorded.

We located each deer 1 time per week from a Cessna 172 and monitored the transmitters 3 additional times per week for mortality signals. We obtained some locations by ground triangulation. We monitored collared deer from September 1986 through January 1993. When a mortality signal was detected, we located the carcass within hours and searched for signs of predators or other causes of death. If the carcass was fresh, it was subjected to a full necropsy to determine the condition of the animal prior to death and to verify the mortality agent. We used tooth wear and replacement (Severinghaus 1949) to determine age-at-death.

Habitat type, associations with other deer, and presence of fawns or yearlings were noted when possible. We defined the activity center of a home range as the average east-west and north-south Universal Transverse Mercator coordinates. Home ranges were calculated as 95% convex polygons using HOMERANGE (Samuel 1985) and mean home range size was obtained using animals monitored for at least 1 year.

Habitat availability was provided by the FDOT Geographic Information System (GIS). Differences between habitat use and availability were determined through Chi-square analysis. When significant differences occurred, we examined the influence of each habitat with Bonferroni comparisons of their individual Chi-square values (Johnson and Wichern 1982). Individual Chi-square values were considered significant when $P <$ a/number of categories.

We divided the year into 3 seasons, hunting (1 Sept–31 Dec), spring (1 Jan–30 Apr), and summer (1 May–31 Aug). Hunting season was defined by the period in which antlered deer could be harvested legally. The remainder of the year was divided equally between spring and summer with the summer interval beginning at the onset of the rainy season (Duever et al. 1986). We used chi-square analyses to examine variation in seasonal habitat use.

We used observations of does with and without fawns as a measure of fawning success. These observations were then used to estimate neonatal fawn mortality by calculating predicted fawn production based upon known pregnancy rates (93.1% pregnant) and fetal counts (1.2 fetuses/doe) for Bear Island does (McCown 1991).

We calculated survival rates for deer by the formula:

$$S_i = [(X_i - Y_i) / X_i]^n$$

where S_i is the interval survival rate, X_i is the number of radio-transmitter days, Y_i is the number of animals dying during the interval, and n is the length of the interval in days (Trent and Rongstad 1974, Heisey and Fuller 1985). We used this procedure to estimate 6-month to 1 year of age fawn survivorship.

We collected bobcat scats throughout Bear Island. Scats were washed in a sieve and air-dried. Contents were identified macroscopically by examining bones, teeth, or claws and by comparing hair to known samples.

We constructed a life table following Caughley (1977) using ages at death of radio-instrumented does. Because fawn mortality rates are higher than for adults, back-tallying would underestimate the initial size of the fawn age class (f_0). We estimated f_0 by adding expected fawn losses, generated from our estimates of fawn mortality (neonate and older fawns), to the yearling age class (f_i). To calculate survivorship (1_x), we divided f_x by f_0. We incorporated fecundity data (m_x) from collected does (McCown 1991) to calculate the net reproductive rate ($R_0 = S l_x m_x$). We assumed that m_x remained constant across all ages and that yearling does did not produce fawns.

Results and Discussion

We captured 66 deer and radio-instrumented 57 of these animals. Four deer were captured in 7 airboat nights (1 deer/10.5 hours), but 1 died from capture stress and another died from a dart-inflicted broken femur resulting in a 50% mortality rate using this method. We captured 60 deer by helicopter/netgunning (1 deer/1.3 hours) with only 1 mortality possibly related to the capture method. This animal was found killed by a black bear (*Ursus americana*) 3 days post-capture. Although a necropsy confirmed a bear killed the deer, we could not rule out that the capture increased the deer's vulnerability to predation. We did not count as captured one doe, which died from an attempt to collect blood by a cardiac puncture; this method was discontinued. Two fawns were hand-captured during daytime searches of radio-instrumented does. Helicopter-netgunning was the better capture method for adult white-tailed deer in our study area. The capture rate was 8-fold greater than darting from airboats and mortality was nearly eliminated.

Home Range and Habitat Use Characteristics

We obtained 4,423 locations of radio-collared deer. Ground triangulation provided 3.5% of these locations ($N = 154$). We spotted 24% of the target deer in a subset of 1,107 aerial locations.

Adult doe home ranges varied from 28–214 ha and were not influenced by number of radio locations ($R^2 = 0.03$, $P = 0.336$). Average home range size was 194 ha and within the range reported for adult does in upland habitats in Florida: 85 ha (Marchinton and Jeter 1967), 270 ha (Bridges 1968), 331 ha (Labisky et al. 1991), and 342 ha (Smith 1970). Home ranges for the 2 adult bucks were 472 and 1,049 ha.

Adult doe activity centers shifted between hunting and non-hunting seasons ($Z = 5.5$, $P < 0.01$). However, 95% of these shifts were less than 600 m ($x = 300$ m) and did not result in separate, disjunct use areas. Radio-instrumented deer did not vacate the BCNP during hunting season. The shift of activity centers was probably the result of significant changes between summer and fall habitat use ($c^2 = 193.4$, df = 6, $P < 0.0001$). Two upland habitat types, hardwood hammocks and pine flatwoods, were used more ($c^2 = 43.3$ and 18.8, respectively; df = 6, $P < 0.007$) and freshwater marshes less ($c^2 = 98.0$) than expected in fall when compared to summer habitat use. Fruits of live oaks (*Quercus virginianus*), laurel oaks (*Q. laurifolia*), gallberry (*Ilex glabra*), and saw palmetto (*Serenoa repens*) are utilized by white-tailed deer (Halls 1977) primarily during fall. In addition, hardwood hammocks and pine flatwoods have more structural diversity than open marshes so their utility as hiding cover may be greater. Other studies have shown that deer will move to areas of denser hiding cover at the onset of hunting season activities (Pilcher and Wampler 1981, Kufeld et al. 1988). Because we detected no home range abandonment, deer home ranges appeared to provide adequate refugia.

Summer and spring habitat use differed significantly ($c^2 = 96.2$, df = 6, $P < 0.0001$); thicket swamps were used more and freshwater marshes less in spring ($c^2 = 18.1$ and 47.3, respectively; df = 6, $P < 0.007$). This pattern was reversed in summer. Differences between spring and fall habitat use were significant ($c^2 = 26.4$, df = 6, $P = 0.0002$); however, the differences could not be attributed to changes in use of a particular habitat.

Fawning Success and Fawn Mortality

Ten of 17 radio-instrumented does were observed with single fawns during spring 1991 for a 58.8% fawning success rate. Of these 17 does, 15.8 should have been pregnant and produced 19.0 fetuses. Neonatal fawn mortality was 47.0% for spring 1991. This neonatal fawn mortality rate was comparable to that of 1988 (55.2%) and much higher than 1989 (28.4%) and 1990 (20.4%). Average annual neonate fawn mortality rate was 37.8% ± 16.1 SE.

Fluctuations in neonate fawn mortality may have been related to surface water levels. Peak fawn drop is 28 February (McCown 1991) and coincides with the driest time of the year. During the springs of 1989 and 1990, freshwater marshes had no surface water except in artificial wells. In contrast, these same areas were inundated during the springs of 1988 and 1991. Low water conditions may have allowed does to avoid concentrating on limited higher ground for parturition and fawn cover, thus reducing predation.

We captured 13 fawns-of-the-year and affixed them with radio-collars. Two fawns were captured as neonates. Of the 13 fawns that were at least 6 months old, 1 was preyed upon by a bobcat before reaching 1 year of age. Fawn survivorship was 0.9 for the 6-month to 1-year age interval.

Adult Mortality and Survival

Twenty-eight marked deer (23 does) died between September 1986 and June 1992. Bobcats preyed upon 11 does and were the most important source of mortality in this study. Florida panthers killed 4 radio-collared deer and 1 was killed by an alligator (*Alligator mississippiensis*). Humans shot 4 deer legally, including 3 ear-tagged bucks and a doe harvested outside the management area during the antlerless season. Two does were killed illegally during the general gun season of 1988. Four does died of natural, non-predator causes, including a broken leg, a broken jaw, a pneumonia-like infectious agent, and complications associated with parturition (D. Forrester, pers. commun.). Two deer died of unknown causes.

Bobcats and panthers selected prey from all age classes. Predator-killed does, however, were younger (x = 3.7 years) than does that died of other causes (x = 5.3 years) ($Z = 3.4$, $P < 0.01$). Seven of 8 does that died during the fawning season were killed by bobcats ($N = 5$) and panthers ($N = 2$). Four of the 7 were 3 year olds and predation was the only mortality source for this age group. Does appeared to be more vulnerable to predation during the fawning season (63.4% of all predation occurred during spring).

Two adult does killed by bobcats were recovered within 24 hours of death and were necropsied. One doe (4.5 years of age) was in good physical condition with moderate levels of tail, heart, kidney, and pericardial fat, and was pregnant. The second doe (2.5 years of age) was in poor condition with little fat, and was not pregnant. There were no indications that either animal's health was compromised before predation occurred.

Does (all ages combined) had an average annual survival rate of 0.813 (95% CI = 0.68, 0.94). There was no differences in survival rates among the 3 seasons (summer, hunting, and spring) nor within or between years. When mortality was partitioned among bobcats and other causes, bobcat predation occurred at an average annual rate of 0.0856 (SE = 0.042) and was responsible for 45.9% of annual

Table 1. Frequency and percent occurrence of prey items in bobcat scats ($N = 87$), Bear Island Unit, Big Cypress National Preserve, Collier County, Florida, September 1986–February 1990, compared to panther food habits reported by Maehr et al. (1990).

Prey	Frequency		% occurence	
	Bobcat	Panther	Bobcat	Panther
Rodent (primarily *Sigmodon hispidus*)	59	4	67.8	1
Rabbit (*Sylvilagus* spp.)	48	12	55.2	4
Bird	20	1	23.0	t[a]
White-tailed deer	4	77	5.5	28
Raccoon (*Procyon lotor*)	10	33	11.5	12
Turtle	1		1.1	
Wild hog (*Sus scrofa*)		116		42
Armadillo (*Dasypus novemcinctus*)		22		8
Unknown	2	5	2.3	1
Other		8		4

[a] < 0.5%.

mortality. Predation by Florida panthers and bobcats accounted for 64.0% of the annual mortality rate.

Bobcat and Panther Food Habits

Our analysis of 87 scats was similar to a statewide analysis (Maehr and Brady 1986) and demonstrated that deer were not an important component of bobcat diets (Table 1). Rodents (primarily *Sigmodon hispidus*) and rabbits (*Sylvilagus* spp.) were their principal foods. All 4 occurrences of white-tailed deer were in the spring fawning season, supporting our suggestion of increased deer vulnerability during this period. In contrast, 28% of panther scats contained evidence of deer consumption and deer were the second most important food in terms of biomass consumed (Maehr et al. 1990).

A comparison of the relative importance of deer in panther and bobcat diets might suggest that panther predation on our radio-instrumented deer would be higher than bobcat predation. However, the total area used by our marked herd was only 187 km^2. This area could accommodate a single adult female panther but only provide one-third of an adult male panther's home range, assuming non-overlapping home ranges of 193 km^2 and 519 km^2, respectively (Maehr et al. 1991). This same area could support 32 adult female and 16 adult male bobcats (mean home range sizes of 5.8 km^2 and 11.6 km^2 respectively, Foster 1992). Inasmuch as bobcat density could be 30 times greater than panther density, the fact that bobcats killed more deer than panthers was not contradictory to the relative occurrence of deer in these 2 predators' diets. In other words, many bobcats killing deer infrequently would result in more mortality than few panthers killing deer regularly.

Table 2. Life and fecundity table for female white-tailed deer, Bear Island Unit, Big Cypress National Preserve, Collier County, Florida.

x[a]	f_x[b]	l_x[c]	d_x[d]	q_x[e]	P_x[f]	B_x[g]	m_x[h]	$l_x m_x$[i]
0	35	1.0	0.43	0.43	0.57			
1	20	0.57	0.03	0.05	0.95			
2	19	0.54	0.05	0.09	0.91	17.7	0.5586	0.302
3	17	0.49	0.23	0.47	0.53	15.8	0.5586	0.274
4	9	0.26	0.06	0.23	0.77	8.4	0.5586	0.145
5	7	0.20	0.06	0.30	0.70	6.5	0.5586	0.112
6	5	0.14	0.05	0.36	0.64	4.7	0.5586	0.078
7	3	0.09	0.09	1.0	0	2.8	0.5586	0.050
8	0	0						
					$x = 0.75$			R_o[j] $= 0.96$

[a] x = age class.
[b] f_x = N of does.
[c] l_x = survivorship = f_x/f_o.
[d] d_x = mortality = $l_x - l_{x+1}$.
[e] q_x = mortality rate = d_x/l_x.
[f] P_x = survival rate = $1 - q_x$.
[g] B_x = expected number of pregnant does = $f_x \times 0.931$ (pregnancy rate).
[h] m_x = N of female births per female = $(B_x \times 0.5 \times 1.2) / f_x$. where 0.5 = sex ratio and 1.2 = litter size.
[i] $l_x m_x$ = N of female births per surviving adult female.
[j] R_o = net reproductive rate = $\sum l_x m_x$.

Life Table Analyses for Adult Does

We generated a life table from ages-at-death for 20 does >1 year of age (Table 2). Our estimate of f_0 (initial cohort size) was calculated at 35 newborn fawns. This life table represented a hypothetical population of $N = 115$ does.

Life table averages of doe age and their survival probability were compared to our estimates calculated from field data. The average age of collected does was 2.7 years (McCown 1991), which was in close agreement with the life table estimate of 2.9 years. We calculated an average annual survival rate of 81% for radio-instrumented does, regardless of age class. The life table estimate was 75%.

The net reproductive rate (R_0) is the number of female offspring that a female is expected to produce in her lifetime. When R_0 is much less than 1.0, a population should decline because females are not replacing themselves; conversely, if R_0 is much more than 1.0, a population should increase. Because our estimate was close to 1.0, females were replacing themselves and the population was probably stable. The mean generation time of 3.6 years indicated that females produce replacements before reaching 4 years of age.

Management Implications

Hunting season activities had little impact on the Bear Island deer herd either in number of illegal kills or in deer movements. Home ranges remained stable throughout the year and any shifts in home range activity centers were probably the result of changes in habitat use due to changing environmental conditions.

The Bear Island deer herd was stable with females replacing themselves before their death and was at equilibrium with losses caused by predation and hunting. Fawn mortality seemed to fluctuate with spring surface water conditions so several successive springs of high surface water may lead to a short-term decrease in herd size. However, with the increase in fawn survivorship during drier springs, these short-term losses can be recovered and thus should not have long-term impacts on the population.

Our data do not support contentions that hunting in Bear Island has adverse impacts upon female white-tailed deer. The deer herd provides a stable prey base for panthers and bobcats and is not prone to wide fluctuations in survival patterns. If an increase in deer abundance is desired, more intensive land management would be necessary to increase the nutrient base. This could involve a burning program designed to enhance wildlife forage (McCown et al. 1991, Schortemeyer et al. 1991) and maintaining previously disturbed sites in higher quality forage or mast species.

Literature Cited

Barrett, M. W., J. W. Nolan, and L. D. Roy. 1982. Evaluation of a hand-held net-gun to capture large animals. Wildl. Soc. Bul. 10:108–114.

Bridges, R. J. 1968. Individual white-tailed deer movement and related behavior during the winter and spring in northwestern Florida. M.S. Thesis, Univ. Ga., Athens. 86pp.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, Ltd. London. 232pp.

Davis, J. H. 1943. The natural features of southern Florida. Fla. Geol. Surv. Geol. Bul. 25. 311pp.

Duever, M. J., J. E. Carlson, J. F. Meeder, L. C. Duever, L. H. Gunderson, L. A. Riopelle, T. R. Alexander, R. L. Myers, and D. P. Spangler. 1986. The Big Cypress National Preserve. Res. Rep. No. 8. Natl. Audubon Soc. New York, N.Y. 444pp.

Foster, M. L. 1992. Effectiveness of wildlife crossings in reducing animal/auto collisions on Interstate 75, Big Cypress Swamp, Florida. M.S. Thesis, Univ. Fla., Gainesville. 103pp.

Halls, L. K. 1977. Southern fruit-producing woody plants used by wildlife. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. So-16. 235pp.

Heisey, D. M. and T. K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. J. Wildl. Manage. 49:668–674.

Kufeld, R. C., D. C. Bowden, and D. L. Schrupp. 1988. Influence of hunting on movements of female mule deer. J. Range Sci. 41:70–77.

Johnson, R. A. and D. W. Wichern. 1982. Applied multivariate statistical analysis. Prentice-Hall, Englewood Cliffs, N.J. 594pp.

Labisky, R. F., D. E. Fritzen, and J. C. Kilgo. 1991. Population ecology and management of white-tailed deer in the Osceola National Forest, Florida. Final Rep. to Fla. Game and Fresh Water Fish Comm. Dep. Wildl. and Range Sci., Univ. Fla., Gainesville. 87pp.

Maehr, D. S., R. C. Belden, E. D. Land, and L. Wilkins. 1990. Food habits of panthers in southwest Florida. J. Wildl. Manage. 54:420–423.

———, and J. R. Brady. 1986. Food habits of bobcats in Florida. J. Mammal. 67:133–138.

———, E. D. Land, and J. C. Roof. 1991. Social ecology of Florida panthers. Nat. Geogr. Res. and Explor. 7:414–431.

———, ———, ———, and J. W. McCown. 1989. Early maternal behavior in the Florida panther (*Felis concolor coryi*). Am. Midl. Nat. 122:34–43.

Marchinton, R. L. and L. K. Jeter. 1967. Telemetric study of deer movement-ecology in the Southeast. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 20:189–206.

McCown, J. W. 1991. Big Cypress deer/panther relationships: deer herd health and reproduction. Final perf. rep. Fla. Game and Fresh Water Fish Comm. Tallahassee, Fla. 66pp.

———, M. E. Roelke, D. J. Forrester, C. T. Moore, and J. C. Roboski. 1991. Physiological evaluation of 2 white-tailed deer herds in southern Florida. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 45:81–90.

Pilcher, B. K. and G. E. Wampler, 1981. Hunting season movements of white-tailed deer on Fort Sill Military Reservation, Oklahoma. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 35:142–148.

Samuel, M. D., D. J. Pierce, E. O. Garton, L. J. Nelson, K. R. Dixon. 1985. Users manual for program HOMERANGE. Univ. Idaho, Moscow. 70pp.

Schortemeyer, J. L., E. D. Land, P. D. Manor, J. W. McCown, and J. B. McGrady. 1989. Big Cypress National Preserve deer and hog annual report, 1988–1989. Fla. Game and Fresh Water Fish Comm. Tallahassee, Fla. 88pp.

———, D. S. Maehr, J. W. McCown, E. D. Land, and P. D. Manor. 1991. Prey management for the Florida panther: a unique role for wildlife managers. Trans. N. Am. Wildl. Nat. Resour. Conf. 56:512–526.

Severinghaus, C. A. 1949. Tooth development and wear as criteria of age in white-tailed deer. J. Wildl. Manage. 13:195–216.

Smith, F. H., Jr. 1970. Daily and seasonal variation in movements of white-tailed deer on Eglin Air Force Base, Florida. M.S. Thesis, Univ. Ga., Athens. 99pp.

Trent, T. T. and O. J. Rongstad. 1974. Home range and survival of cottontail rabbits in southwestern Wisconsin. J. Wildl. Manage. 38:459–472.