Survival and Cause-specific Mortality of Raccoons on a Northern Bobwhite Management Area

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Abstract: We estimated survival and cause-specific mortality of 59 raccoons *(Procyon lotor)* on a wildlife area in Mississippi which was in the early stages of an intensive land management program to enhance northern bobwhite *(Colinus virginianus)* habitat quality and populations. Average annual survival of radio-collared raccoons was 0.81 for males (N=47) and 0.79 for females (N=12) from March 1997 to February 1999. We detected no effect of sex, season, year, or age ($P \geq 0.05$) on survival. Causes of mortality (N=14) included vehicle collision (N=5), unknown (N=4), harvest (N=2), predation (N=1), parasites (N=1), and weather-related (N=1). Potential factors controlling raccoon populations on these areas may only include harvests and periodic epizootic outbreaks. The effects of habitat management used to enhance bobwhite populations on raccoons and other nest predators, including varying spatial-temporal distributions of edge and disturbance, are not well known. Although based on preliminary data, observed survival rates of raccoons warrant the examination of harvest and long-term mortality patterns of raccoons on areas managed for bobwhite.

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Northern bobwhite have declined through much of their North American range (Sauer et al. 1997, Brennan 1991), including the Southeast. This decline has accelerated the acquisition of land for intensive management of this species (Taylor and Burger 1997). Such management practices in agricultural landscapes include establishment of woody corridors in large fields of grasses and crops coupled with the creation of early successional habitats by disking, burning, and seeding (Stoddard 1931, Rosene 1969, Burger et al. 1990). The factors affecting bobwhite populations and the mechanisms by which bobwhite populations respond to management are still poorly understood (Brennan 1991, Brennan 1993, Church et al. 1993, Robel 1993, Stauffer 1993). Hurst et al. (1996) identified predation as a primary cause of reproductive failure of bobwhite, reducing population growth. Furthermore, they recognized a need to understand predators and predator community structure to assist in management of bobwhite populations. A lack of information regarding raccoon population dynamics on areas managed intensively for bobwhite warranted a study of raccoon survival and cause-specific mortality rates. We studied radio-collared raccoons at the Black Prairie Wildlife Management Area (BPWMA) in east-central Mississippi to examine survival and cause-specific mortality rates of raccoons on an area in early stages of intensive land management for bobwhite.

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Methods

We studied raccoons on BPWMA in Lowndes County, Mississippi, in the Black Prairie physiographic region from March 1997 to February 1999. Specific soil series on the study site included Sumter silty clay loam, Vaiden silty clay, and Demopolis-Binnsville complex (U.S. Dep. Agric. 1979). The mean annual precipitation was 150 cm and mean annual temperature was 17 C (Owenby and Ezell 1992).

Historically, BPWMA was farmed intensively and used for cattle production. During our study, BPWMA included approximately 2,024 ha with primary habitat features of pasture and hayfields (28%), row crop fields (25%), conservation reserve program fields (CRP) (24%), woody cover (20%), ponds and lakes (1%), old fields (1%), and road row and yard (1%). The management on the area included burning and herbicide application to aid in the removal of exotic grass species and addition of woody corridors to increase the juxtaposition of cover in large crop fields.

Legal raccoon harvest on BPWMA occurred each year from 1 October until 28 February of the following year. Harvest was allowed on Friday and Saturday nights from 1997 to 1999. This harvest was more restrictive than the statewide harvest, which allowed harvest any day during the same period.

Raccoon Trapping and Processing

We captured raccoons with 81.3 × 25.4 × 30.5 cm livetraps from mid December to early March each year. Traps were placed throughout the entire study area at sites that contained habitat features thought to attract raccoons such as areas with water. We baited traps with commercial cat food or sardines and checked them each morning.

We immobilized captured raccoons with an intramuscular injection of ketamine hydrochloride (Bigler and Hoff 1974) at a rate of 8–10 mg/kg of body weight. We recorded sex, age (adult or juvenile estimated by tooth wear [Grau et al. 1970], and reproductive characteristics [Sanderson and Nalbandov 1973]), weight, linear measurements, and general condition of each raccoon. Raccoons were marked with a passive integrated transponder (pit tag) (Avid Microchip Identification Systems, Folsom, La.), injected subcutaneously between the scapulars. We fitted a subsample of raccoons with 130-g radio transmitters (Advanced Telemetry Systems Inc., Isanti, Minn.). Transmitters were equipped with a 12-hour mortality switch. After processing, raccoons were held overnight and released at their capture site the following morning.

Telemetry Techniques

We monitored each raccoon daily to detect the occurrence of a mortality signal. If a mortality signal was detected, we approached the raccoon to verify status. If the raccoon was dead, we examined the raccoon and the site for evidence of the cause of death. All carcasses were taken to the Mississippi State University, College of Veterinary Medicine, for necropsy. We classified mortality agents as 1) natural, including predation and disease, 2) human-related, such as harvest and vehicle collisions, or as 3) unknown.

Statistical Analysis

We used the non-parametric Kaplan-Meier Product limit survival estimator [PROC LIFETEST; SAS (Pollock et al. 1989)] to estimate age and sex-specific survival rates. We estimated annual survival from 1 March 1997 to 28 February 1999. Seasonal periods were: 1) winter (Dec–Feb), 2) spring (Mar–May), 3) summer (Jun–Aug), and 4) fall (Sep–Nov). Seasons were based on the biological events of raccoons.

We assumed that survival times were independent for each raccoon, and that trapping, handling, and radio-marking did not influence survival. Survival distributions were left-truncated because of staggered entry and we assumed survival distributions of animals introduced into the study later had similar survival distributions as those marked previously. We allowed radio-collared raccoons 2 weeks to acclimate to transmitters before including them in analysis. Raccoons were censored on the last day that we achieved radio contact (Vangilder and Sheriff 1990). If we recaptured these individuals and replaced radios, they were re-entered into the model as independent observations 1 day following capture. Radio-collared raccoons captured prior to radio failure were censored the day of capture, but re-entered into the model 1 day after capture (Chamberlain et al. 1999). We stratified survival by age, sex, seasons, and years and compared survival rates with log-rank tests (Mantel-Haenszel test). The detection of no differences among sex and age classes warranted the estimate of an overall pooled survival.

We estimated cause-specific mortality using the Heisey-Fuller approach in program MICROMORT (Heisey and Fuller 1985*a*). This test assumes a constant daily survival rate and that each day a raccoon is monitored as an independent event. Cause-specific mortality was defined as the probability of a raccoon dying within a given interval from 1 mortality agent in the presence of other competing mortality agents (Chamberlain et al. 1999). We used likelihood ratio tests to test for the effects of year, season and sex on mortality rates. The full model contained the 2 years, 4 seasons, and 2 sexes, but not age due to a small sample size of juveniles (N=9). We collapsed effects of interest and constructed reduced models. We then compared survival between reduced and full models using the absolute value of the difference between the 2 × log-likelihood for each model (Heisey and Fuller 1985*b*). Degrees of freedom used in the model comparisons were the difference between those from the full and reduced models. We pooled causes of mortality into large categories, natural, human-related, and unknown, to increase the power of the tests given the small sample of mortalities.

Results

We radio-marked 59 raccoons (12 females and 47 males; 9 juveniles and 50 adults) with a sample size of 22,313 radio days from March 1997 to February 1999. Thirteen raccoons (5 females and 8 males) were monitored during both years. During the study 14 radio-marked raccoons died.

Survival Analysis

We detected no differences in annual survival rates between years (χ^2_1=1.29, P=0.26), sexes (χ^2_1=0.001, P=0.99), or ages (χ^2_1=0.39, P=0.53), Similarly, we detected no difference in survival rates of male and female raccoons among years (χ^2_3=2.26, P=0.52) (Table 1). The overall pooled estimate of annual survival rate was 0.80 (SE=0.06). The pooled annual survival rate for males was 0.81 (SE=0.06) and for females was 0.79 (SE=0.11). The survival rate for Year 1 was 0.73 (SE=0.10) and Year 2 was 0.84 (SE=0.07). The annual survival rate for juveniles was 0.75 (SE=0.16) and for adults was 0.81 (SE=0.06).

Raccoon survival rates did not differ significantly between seasons (χ^2_3=1.60, P=0.66), sexes (χ^2_1=0.09, P=0.76), or ages (χ^2_1=1.61, P=0.20). Similarly, we detected no difference in the survival rate of male and female raccoons among seasons (χ^2_7=3.94, P=0.79) (Table 2). The overall pooled estimate of seasonal survival was 0.93 (SE=0.02). The pooled seasonal survival rate for males was 0.94 (SE=0.02) and for females was 0.93 (SE=0.03). The survival rate for both sexes was 0.90 (SE=0.03) in spring, 0.95 (SE=0.02) in summer, 0.95 (SE=0.03) in fall, and 0.94 (SE =0.03) in winter. The seasonal survival rates was 0.87 (SE=0.07) for juveniles and 0.94 (SE=0.02) for adults.

Table 1. Annual survival rate estimates and standard errors (SE) of male and female raccoons on Black Prairie Wildlife Management Area, Mississippi, 1997–1999.

	Males			Females		
Year[a]	Survival rate	N	SE	Survival rate	N	SE
Year 1	0.71	22	0.12	0.86	10	0.13
Year 2	0.88	35	0.07	0.75	11	0.15

a. Year 1=1 Mar 1997 to 28 Feb 1998; Year 2=1 Mar 1998 to 28 Feb 1999.

Table 2. Estimated survival rates and standard errors (SE) of male and female raccoons by season on Black Prairie Wildlife Management Area, Mississippi, 1997–1999.

	Males			Females		
Season	Survival rate	*N*	SE	Survival rate	*N*	SE
Spring	0.91	65	0.04	0.90	23	0.07
Summer	0.97	59	0.02	0.91	22	0.06
Fall	0.97	33	0.03	0.92	12	0.08
Winter	0.92	48	0.05	1.00	17	0.00

Cause-specific Mortality

We determined that 3 raccoon deaths were natural (21%), 7 were human-related (50%), and 4 were from unknown causes (29%). Three females died of natural causes, 1 each to predation, parasites, and exposure to weather. Four males and 1 female were hit by vehicles, 2 males were harvested, and 3 males and 1 female died from unknown causes. We compared the full model (year*sex*season) to a reduced model (sex*season) with years collapsed; we detected no differences in mortality between years (χ^2_{24}=18.3, P=0.79). Similarly, when we collapsed sexes and compared them to the reduced model (sex*season) we did not detect a difference between sexes (χ^2_{12}=10.50, P=0.57). We detected a difference in seasons (χ^2_{18}=30.8, P=0.03) when seasons were collapsed and compared to the reduced model (sex*season) (Table 3).

Discussion

Our survival rates of 0.81 for male and 0.79 for female raccoons at BPWMA were greater than most estimates previously reported in the Southeast (Nottingham 1985, Glass 1991, Chamberlain et al. 1999), and other regions of the United States (Clark et al. 1989, Robel et al. 1990, Hasbrouck et al. 1992, Nixon et al. 1992). We believe high survival of raccoons on our study area reflects low harvest rates. Annual survival of raccoons in Iowa was 0.53 (Hasbrouck et al. 1992) and was 0.64 and 0.42 for males and females, respectively, in Mississippi (Chamberlain et al. 1999). Both of

Table 3. Seasonal cause-specific mortality of female and male raccoons on Black Prairie Wildlife Management Area, Mississippi, 1997–1999.

	Natural		Human-related		Unknown		
Season[a]	Female	Male	Female	Male	Female	Male	Total
Spring	0	0	0	4	1	2	7
Summer	2	0	1	0	0	1	4
Fall	1	0	0	0	0	0	1
Winter	0	0	0	2	0	0	2
Total	3	0	1	6	1	3	14

a. Spring = March–May, summer = June–August, fall = September –November, winter = December–February.

these studies reported substantial harvests of raccoons on their study areas. Gehrt and Fritzell (1999) reported annual survival estimates (0.84) similar to ours from a nonharvested raccoon population in south Texas. Thirty-four raccoons were harvested over 3 years on BPWMA, of which 2 were radio-marked. Low harvest of raccoons at BPWMA may be a consequence of the belief that optimal raccoon hunting areas are forested, such as bottomland hardwoods. Low fur prices may also influence harvest participation (Lovell et al. 1998).

Although based on a small sample, natural mortality agents did not seem to cause substantial raccoon mortality on BPWMA during our study. In Minnesota, Mech et al. (1968) determined that a raccoon population with light harvest had 57% of mortalities attributed to natural causes. Similarly, on a refuge without harvest in South Texas, Gehrt and Fritzell (1999) reported 61% of mortalities were from natural causes. Differences in rates of natural mortality reported among regions of the United States may be caused by climatic differences (Gehrt and Fritzell 1999), which influence resource availability and winter survival. It is important to note that the density of the raccoon population on BPWMA, which can influence natural mortality factors, was not measured due to the short duration of the study. The 3 raccoons that died of natural causes on BPWMA were females. Female raccoons experience increased resource demands during parturition/young rearing (Urban 1970, Fritzell 1978, Gehrt and Fritzell 1997), which may predispose them to disease and parasites that can cause mortality. The greatest cause of mortality on BPWMA was vehicle collisions, mostly males in the spring, which may be due to their increased movements during the breeding season (Tabatabai 1988).

The effect of bobwhite management, such as the addition of edges and disturbance, on resource acquisition and survival of raccoons and other predators is poorly understood. Agricultural areas that have crop rotation during fall and winter and man-made water sources are productive areas for raccoons (Pedlar 1994, Pedlar et al. 1997, Dijak and Thompson 2000). Landscape alterations can positively influence populations of nest predators, which ultimately increase nest depredation rates (Greenwood et al. 1995).

Privately-owned properties managed for bobwhite often institute aggressive predator management programs to reduce the density of mammalian nest predators prior to the breeding season. Removal of nest predators increases nest success, fall density and recruitment for various ground nesting birds (Cote and Sutherland 1997), but this has not been rigorously examined for bobwhite. If harvest alters raccoon survival and hence local population levels, and if raccoon density influences bobwhite productivity, one might expect different levels of bobwhite population response on a public area with light harvest, relative to a privately-owned area under similar management intensity but with more intensive raccoon harvest.

Management Recommendations

Natural mortality agents and other human-related mortality agents did not compensate for low harvest levels on BPWMA. Potential factors limiting raccoons on this area may only include harvest and periodic epizootic outbreaks, such as canine distemper. Raccoon harvest regulations on this bobwhite management area should be liberal to allow maximal raccoon mortality. Continued raccoon research on this management area will reveal if mortality patterns of raccoons change over time.

Future research should address the habitat use of generalist mammals relative to a landscape under intensive bobwhite or other wildlife management activities. Long term survival and cause-specific mortality research on raccoons, including the estimation of the density of raccoon populations, is needed to examine density dependent mortality. Ultimately, the impact of raccoon population levels and the effect of raccoon harvest on the recruitment of bobwhite populations needs to be examined.

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