SURVIVAL, CAUSE-SPECIFIC MORTALITY, AND TELEMETRY EFFECTS ON NORTHERN BOBWHITES

By

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INTRODUCTION

Knowledge of survival rates and mortality sources is useful in understanding the population dynamics of northern bobwhites. Historically, the annual survival rate of bobwhites was thought to be about 20% based on interpretation of age ratios determined from harvest data (Guthery 1997). The 20% figure best fits mid-latitude populations, with survival rates being <20% in northern-latitude populations and >20% in southern-latitude populations (Guthery 2002:47).

Previous work on cause-specific mortality for bobwhites indicates that sources of mortality vary among populations (Table 1). Susceptibility to predators changes with season (Robel 1965, Burger et al. 1995, Taylor et al. 2000), age class (Robel 1965), and sex (Burger et al. 1995). In Mississippi, survival differed between sexes with females having a higher survival rate than males during the breeding season (Taylor et al. 2000). In Missouri, males had a greater avian mortality rate (0.27 spring–fall) than females (0.20 spring–fall; Burger et al. 1995). Higher male mortality from avian predators in the spring was attributed to increased exposure through calling from whistling posts (Burger et al. 1995). The general trend places heaviest avian mortality in the fall and winter seasons and heaviest mammalian mortality in the spring and summer (Curtis et al. 1988, Burger et al. 1995, DeMaso et al. 1998).

Radio telemetry has become a common tool in wildlife research (White and Garrot 1990:xi). In the last 20 years radio transmitters have become smaller and more technologically advanced. This allows researchers to attach transmitters to smaller animals and receive information that is more reliable. Telemetry data have commonly been used for estimating survival (Robel 1965, Liu et al. 2000) and cause-specific mortality (Burger et al. 1995, Taylor et al. 2000).

The main assumption of telemetry studies is that the radio-collared sample reflects an unbiased picture of the dynamics of the population without influence from the radio transmitter (White and Garrot 1990:27), and that a radio-collared individual behaves, survives, and experiences conditions identical to a nonradio-collared individual.

Survival rates reported in some previous telemetry studies were too low to permit population persistence, thus drawing into question the assumption that radioed bobwhites present an unbiased representation of population dynamics. According to Guthery (1997), a population of bobwhites would need to produce 18 juveniles/surviving adult to persist at an annual survival rate of 0.053 as reported by Burger et al. (1995). Production of 18 juveniles/adult is impossible for a population to reach, given normal survival of adults (Guthery et al. 2000).

The possible bias in telemetry estimates of bobwhite survival raises 2 issues in the conduct of telemetry research. First, survival rates estimated from telemetry should be checked against survival rates estimated independent of telemetry data. The second issue is the application of the correct censor period for radioed bobwhites. When a radio collar is attached to a bobwhite there is a period of time required to recover from capture and handling and adjust to the radio (Urban and Klimstra 1972). This period of adjustment is known as the censor period. Gilmer et al. (1974) inferred that there was a lower survival rate for radio-collared birds during the period of adjustment to radio transmitter attachment due to increased susceptibility to predation. At the end of the censor period, researchers assumed that the radio does not adversely affect the behavior of the radioed individual. A 7-day censor period has become the most commonly used period (Curtis et

Table 1. Variation in reported annual survival (%) and cause-specific mortality (%) of northern bobwhites as determined with radiotelemetry methodology.

				Cause-specific mortality			
Source	County and state	Years	Annual survival	Mammal-ian	Avian	Harvest	Other
Curtis et al. 1988	Leon , FL; Hoke and Cumberland , NC	1985–1988	6.1	35.6	64.4	0.0	0.0
Mueller et al. 1988[a]	Leon, FL	1986		29.0	71.0	0.0	0.0
Burger et al. 1995	Macon and Knox, MO	1989–1992	5.3	27.4	30.5	29.3	12.7
Liu et al. 2000[b]	Trinity, TX	1990–1992		9.1	57.6	0.0	33.3
Taylor et al. 2000[b]	Oktibbeha, MS	1993–1996		41.7	21.4	0.0	36.9

[a] Time span for study was 45 days.

[b] Time span for studies was breeding season only.

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al.1988, Pollock et al. 1989, Robinette and Doerr 1993, Suchy and Munchel 1993, Burger et al. 1995, Townsend et al. 1999) but this period is based on tradition, not on critical analysis. Other censor periods reported include 0 days (Mueller et al. 1993), 10 days (Puckett et al. 1995), and 14 days (Mueller et al. 1988, DeVos and Mueller 1993).

My primary objective was to obtain descriptive data on seasonal and annual survival and cause-specific mortality rates of bobwhites in the Texas Panhandle. Secondary objectives were to (1) compare survival rates of radioed bobwhites with survival estimates from line transect density estimates and (2) estimate the optimal censor period under conditions prevailing during the study. The secondary objectives were established because of possible bias in survival rates estimated with radio-collared bobwhites.

STUDY AREA

The study was conducted on the Mesa Vista Ranch (11,332 ha) in the Texas Panhandle during September 2000–May 2002. The area is in the Rolling Plains vegetation region (Hatch and Pluhar 1993:2). The study area was 32 km north of Pampa, Texas, along the Canadian River in Roberts County. Research was concentrated on Tallahone Pasture (802 ha). This pasture was chosen because it contained a representative sample of habitat types found throughout the ranch.

Roberts County is in a cool temperate climate zone (Wyrik 1979:71). Generally mild winters are characterized by frequent abrupt temperature changes (Wyrik 1979:2). Roberts County receives on average 53 cm of precipitation (Wyrik 1979:2).

There are 7 soil types on the study site ranging from fine sand to clay. Likes loamy sand was found on upland areas with 1–8 % slope (Wyrik 1979:20).

Likes–Tascosa association can be found on hills. Lincoln fine sand was found in frequently flooded areas. Obaro Quinlan was a loam occurring on rolling ridges and hills. Spur clay loam occurs on occasionally flooded areas. Sweetwater silty clay loam occurs in wet bottomland. Tivoli fine sand was found on upland areas.

I defined 9 habitat types inside the study pasture. These included riparian, grass bottomland, grass bottomland with salt cedar (*Tamarix ramosissima*), upland grass, sand sagebrush (*Artemisia filifolia*), mixed shrub, other wooded area, hilltop, and other cover types. Cottonwood trees (*Populus deltoides*) along dry creek beds characterized riparian habitat. Grass bottomland habitats were characterized by water-tolerant species in lowland areas where the water table was near the surface. Grass bottomland with salt cedar was the same as grass bottomland with the addition of salt cedar. Western wheatgrass (*Elytrigia smithii*) and other upland grasses characterized upland grass habitat. The presence of sand sagebrush characterized sand sagebrush habitat. Mixed shrub habitat contained a mixture of sand sagebrush, sand plum (*Prunus augustifolia)*, and skunkbush (*Rhus aromatica*). Other wooded areas were any areas with tree coverage other than riparian habitat, composed primarily of hackberry (*Celtis laevigata*). Hilltop habitat was located on sparsely vegetated hilltops. The vegetation there was made up of various short grasses, forbs, and mosses. The class, other cover types, contained any habitat not included in the other habitat types. These included water holes, construction areas, roads, and structures.

METHODS

Bobwhites were trapped using funnel traps baited with a mixture of corn, wheat, and milo (Stoddard 1931:442). Trap sites were prebaited a week prior to a trap being set.

Traps were checked twice daily, at midday and at dusk. When bobwhites were caught they were sexed, weighed, aged, and fitted with leg bands. A portion of the bobwhites captured were fitted with 5–6-g, bib-style radio transmitters (American Wildlife Enterprises, Monticello, Florida, USA) to monitor survival, cause-specific mortality, and censor period. During the first year, trapping concentrated on females with the goal of obtaining a ratio of 80% female to 20% male radio-collared bobwhites in an attempt to have a large sample of females leading into the breeding season. The second year, any bobwhite of adequate size (>170 g) was radio-collared to obtain a larger sample of radio-collared bobwhites.

I monitored survival using radio telemetry. Bobwhites were monitored by triangulation at least twice a week throughout the year. When mortality was detected the radio transmitter was located and cause of mortality estimated. Cause of mortality was determined from evidence obtained at and around the site where the radio transmitter was found (Curtis et al. 1988), including bobwhite remains, location, tracks, and marks on the transmitter and antenna.

Bobwhite density estimates were obtained using the line transect method (Ratti et al. 1983, Guthery 1988, Buckland et al. 1993). Eight transects running north–south were laid out across the pasture to provide representative coverage of the entire pasture. Transects ranged in length from 0.84 km to 2.9 km, for a total length of 16 km. Start and end points were fixed using a GPS II plus (Garmin, Olathe, Kansas, USA.) hand-held unit. Transects were walked in mid-March and mid-October of each year. Transect counts were conducted by having an observer walk a transect recording the coveys encountered, distance from the transect line to the point of flush at a right angle to the transect line, and habitat type where the covey flushed. Each of the 8 transects were walked by each observer during a 2–5-day period. Transects were conducted during 2 counting periods each day; in the morning starting shortly after sunrise continuing until 2 transects had been walked by the observer, and about 3 hours before sunset and again continuing until 2 transects were walked by the observer. Data were then used to calculate an effective strip width and density in birds per hectare (Ratti et al. 1983, Buckland et al. 1993:105).

DATA ANALYSIS

Survival

Survival was calculated using the Kaplan-Meier staggered entry method (Pollock et al. 1989). Data used for calculation were pooled over sex and age classes. If contact was lost with a bobwhite and it was not located in 2 weeks, it was right censored and not counted as a death. If the bobwhite was later found it was added back to the sample in the proper category. Multiple survival rates were calculated using different censor periods (0, 7, 14, and 21 days). Survival was estimated seasonally for the fall–spring (Sep–May), spring (Apr–May), and fall (Oct–Mar). Comparisons were made among seasons and years by assessing overlap in confidence intervals. Additionally, annual (Sep–Aug) and breeding season (Apr–Sep) survival rates were calculated for 2000–2001.

Justification for pooling sex-age classes for estimation of survival rates was assessed with bootstrap simulation (Mooney and Duval 1993, Davidson and Hinkley 1997) of elapsed time (days) from capture to death for individuals in each class. I considered elapsed time from capture to death an index of survival rate, and I used bootstrapping because of small samples. One thousand samples of size n_i, where n_i is the number of sample individuals in sex-age class *i*, were drawn to compute bootstrap means for a sex-age class based on 2000–2001 and 2001–2002 data. Differences in survival were determined using 95% CLs based on the distribution of bootstrap means.

Cause-Specific Mortality

Cause-specific mortality was calculated using the MICROMORT computer program (Heisey and Fuller 1985). To increase numbers for calculation purposes, causes of mortality were classified into 4 classes. The classes were mammal, avian, hunter, and other (all mortality not included in the previous classes). Cause-specific mortality was calculated seasonally for the fall–spring (Sep–May), spring (Apr–May), and fall (Oct–Mar). Comparisons were made among seasons and years by assessing overlap in the 95% CLs.

G-tests were conducted to determine if sources of mortality were independent of time since capture. The test was done with 3 cutpoints because the results of the test may depend on arbitrary classifications. The cutpoints (days) used were (A) ≤ 20, 21–40, and >40; (B) ≤ 14, 15–21, and >21; (C) ≤ 7, 8–21, and >21.

Radio-Collared vs. Nonradio-Collared

Survival rates for nonradio-collared bobwhites were calculated from density estimates obtained from line transect method (Ratti et al. 1983, Guthery 1988, Buckland et al. 1993). Survival was calculated using the formula $S = D_S/D_F$ where D_S is the spring density estimate and D_F is the fall density estimate (Ratti et al. 1983). Variance was calculated following procedures in Ratti et al. (1983). These rates were compared to survival estimates from telemetry data for the period between fall and spring line-transect counts. Ninety-five percent CLs were used to evaluate differences in survival between radio-collared and nonradio-collared populations.

Censor Period

To estimate the correct censor period I developed survival curves for bobwhites radio tagged between 1 September and 7 January 2000–2001 ($n = 62$) and the same time period 2001–2002 ($n = 46$). Regardless of capture date, bobwhites were moved to a common starting point (day 0). Then the number of bobwhites surviving was plotted as a function of elapsed time for 100 days. Survival curves were smoothed using a 3-point moving average (Kendall and Ord 1990:28). The derivative of the smoothed survival curve was determined numerically (Anonymous 2002). The optimal censor period occurred when the instantaneous rate of increase stabilized.

RESULTS

Survival

Survival estimates for the first year (2000–2001) were based on 99 radio-collared bobwhites (15 ad F, 44 juv F, 8 ad M, and 32 juv M). The second season (2001–2002) estimates were based on 90 radio-collared bobwhites (24 ad F, 22 juv F, 16 ad M, and 28 juv M).

Estimated survival rates differed over censor period, season, and year (Table 2). The highest estimate for survival in 2000–2001 was from a censor period of 14 days. Fall–spring (Sep–May) survival of 2000–2001 (0.07) was lower than 2001–2002 (0.30). Survival in 2000–2001 was much lower (0.13) than 2001-2002 (0.44). Spring survival was higher as well in 2001–2002 (0.83) than in 2000–2001 (0.62). Additionally, a yearly (1 Sep–31 Aug) and spring–summer (1 Apr–31 Sep) were calculated for 2000-2001.

Confidence limits for days survived from capture to death overlapped

Table 2. Seasonal and annual survival rates (95% CL) of northern bobwhites estimated from radio telemetry data collected from 1 September 2000 to 31 May 2002 using different censor periods, Mesa Vista Ranch, Roberts County, Texas.

Period[a] Censor period (days)	2000–2001	2001–2002
1 Oct–31 Mar		
0	0.01 (0.00–0.02)	0.44 (0.35–0.52)
7	0.13 (0.08–0.18)	0.44 (0.36–0.54)
14	0.20 (0.13–0.27)	0.36 (0.28–0.43)
21	0.12 (0.07–0.17)	0.34 (0.25–0.42)
1 Apr–31 May		
0	0.52 (0.32–0.72)	0.81 (0.71–0.92)
7	0.62 (0.46–0.78)	0.81 (0.71–0.92)
14	0.61 (0.45–0.77)	0.81 (0.70–0.91)
21	0.60 (0.44–0.76)	0.77 (0.65–0.89)
1 Sep–31 May		
0	0.06 (0.03–0.09)	0.30 (0.22–0.37)
7	0.07 (0.04–0.10)	0.30 (0.23–0.38)
14	0.08 (0.05–0.11)	0.23 (0.17–0.29)
21	0.02 (0.01–0.03)	0.26 (0.18–0.33)
1 Apr–31 Sep		
0	0.13 (0.00–0.30)	
7	0.32 (0.13–0.51)	

14	0.38 (0.21–0.55)
21	0.31 (0.18–0.44)
1 Sep–31 Aug	
0	0.03 (0.01–0.05)
7	0.04 (0.02–0.06)
14	0.05 (0.02–0.07)
21	0.00 (0.00–0.00)

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[a] 1 Oct–31 Mar = fall, 1 Apr–31 May = spring, 1 Sep–31 May = fall–spring, 1 Apr–31 Sep = spring–summer, 1 Sep–31 Aug = annual.

considerably between sex and age classes (Table 3). The exception was in 2001–2002. Bootstrapping indicated that days survived differed ($P \sim 0.01$): adult females had greater survival (220.0) than juvenile males (117.8).

Cause-Specific Mortality

Mortality rates did not differ between season or year (Table 4). The mortality rate from other sources for the annual rate in 2000–2001 was higher than expected. Hunter related mortality contributed only a small portion to the total mortality of bobwhites in each year.

The *G*-test results showed that in the majority (75%) of tests sources of mortality were independent of time since capture (Table 5). Tests that showed significance were with a 7-day cutpoint. When tests indicated a lack of independence, frequencies of mammal deaths were roughly double avian deaths in the first 3 weeks and then became roughly equal after 3 weeks (Appendix 2).

Radio-Collared vs. Nonradio-Collared

Telemetry and transect data were analyzed to check for a difference in estimated survival rates between radio-collared and nonradio-collared bobwhites. Confidence intervals from line transect survival estimates overlapped those obtained from telemetry (Table 6). Point estimates of survival for both methods were similar as well.

Censor Period

Survival curves showed different properties between years (Fig. 1). The probability of survival for 100 days in 2000–2001 was 0.42 ± 0.097 SE compared with 0.63 ± 0.103 SE in 2001–2002. The absolute rate of increase decreased (meaning survival increased) for a period of about 45 days in 2000–2001; this is the first

Table 3. Bootstrapping means for days of survival and 95% CL from capture to death for sex-age classes of northern bobwhites on Mesa Vista Ranch, Roberts County, Texas, during 9 September–7 January 2000–2001, 13 September–7 January 2001–2002, and pooled (9 Sep 2000–7 Jan 2002).

Year	Sex	Age	$\bar{x}$	SE	LCL	UCL
2000–2001	F	Ad	73.90	25.54	13.49	134.26
	F	Juv	79.30	12.56	53.45	105.17
	M	Ad	85.70	66.39	0.00	371.34
	M	Juv	121.00	24.55	68.67	173.33
2001–2002	F	Ad	220.00	17.56	174.86	265.14
	F	Juv	159.50	25.64	104.47	214.46
	M	Ad	187.70	26.02	129.76	245.69
	M	Juv	117.80	24.48	64.89	170.68
Pooled	F		115.70	12.02	91.60	139.80
	M		134.30	14.54	104.90	163.60

Table 4. Cause-specific mortality rates (95% CLs) of northern bobwhites calculated from radio telemetry data collected between 6 September 2000 and 31 May 2002, Mesa Vista Ranch, Roberts County, Texas.

Period[a] Source	2000–2001	2001–2002
1 Oct–31 Mar		
Avian	0.42 (0.26–0.58)	0.19 (0.07–0.31)
Mammal	0.30 (0.15–0.45)	0.22 (0.10–0.35)
Hunter	0.06 (0.00–0.13)	0.02 (0.00–0.05)
Other	0.06 (0.00–0.18)	0.09 (0.00–0.20)
1 Apr–31 May		
Avian	0.13 (0.01–0.25)	0.02 (0.00–0.05)
Mammal	0.22 (0.08–0.36)	0.07 (0.00–0.14)
Other	0.03 (0.00–0.08)	0.09 (0.02–0.17)
1 Sep–31 May		
Avian	0.30 (0.04–0.56)	0.32 (0.14–0.52)
Mammal	0.22 (0.02–0.42)	0.22 (0.10–0.34)
Hunter	0.04 (0.00–0.10)	0.02 (0.00–0.04)
Other	0.37 (0.00–0.87)	0.12 (0.02–0.21)

[a] 1 Oct–31 Mar = fall, 1 Apr–31 May = spring, 1 Sep–31 May = fall–spring.

Table 5. *G*-test for independence of cause of mortality from time since capture for northern bobwhites radio collared between 6 September 2000 and 7 January 2002, Mesa Vista Ranch, Roberts County, Texas.

Time period Time class	*G*	*P*
6 Sep 2000–7 Jan 2001		
A[a]	7.28	>0.100
B[b]	6.34	>0.100
C[c]	9.36	>0.050
6 Sep 2000–7 Jun 2001		
A	4.60	>0.250
B	8.74	>0.050
C	13.56	>0.005
13 Sep 2001–7 Jan 2002		
A	5.36	>0.250
B	3.20	>0.500
C	9.48	>0.025
6 Sep 2000–7 Jan 2002		
A	6.38	>0.100
B	10.30	>0.025
C	14.86	>0.005

[a] A cutpoints of ≤20 days, 21–40 days, and >40 days.

[b] B cutpoints of ≤14 days, 15–21 days, and >21 days.

[c] C cutpoints of ≤7 days, 8–21 days, and >21 days.

Table 6. Comparison of survival estimates of northern bobwhites and 95% CLs from line transect method and radio telemetry, Mesa Vista Ranch, Roberts County, Texas, 2000–2002.

	Line transect			Telemetry		
Period	Survival	LCL	UCL	Survival	LCL	UCL
18 Oct 2000–18 Mar 2001	0.11	0.02	0.20	0.23	0.15	0.30
15 Oct 2001–15 Mar 2002	0.64	0.22	1.00	0.55	0.45	0.65

approximation of censor period for this sample. Adjustment from capture and handling manifested as a trend rather than a threshold, based on the derivative of the survival curve. If adjustment is a trend then each individual bobwhite in the population may require a different amount of time to adjust to the attachment of radio transmitters. This period of adjustment took place over a span of about 25 days (from day 20 to day 45, Fig. 1B). In 2001–2002, the optimal censor period was 0 days.

DISCUSSION

Survival

Pooling of the sex and age classes within years for survival calculation does not produce bias in the estimate of population performance if classes survive at the same rate such as they did in 2000–2001 (Table 3). If classes did not survive at the same rate, such as in 2001–2002, the pooling can still be justified. Such pooling can present an unbiased picture of population behavior if the classes in the sample are represented in proportion to their occurrence in the population. This was approximated by attaching radio collars to every bobwhite of adequate size regardless of sex and age. In the absence of some sort of trapping response the corresponding proportions of each sex and age class should have radio collars as in the population.

The winter of 2000–2001 (3 weeks of snow cover) was more severe than the winter of 2001–2002 (0 weeks of snow cover) based on weather records maintained on the study area. The total energy expenditure per individual bobwhite during the third week in September through the second week in March was estimated at 7,802 kcal in 2000–2001 versus 7,440 kcals in 2001–2002 (Case and Robel 1974). The difference in winter severity might explain the difference in survival rate between years (Table 2).

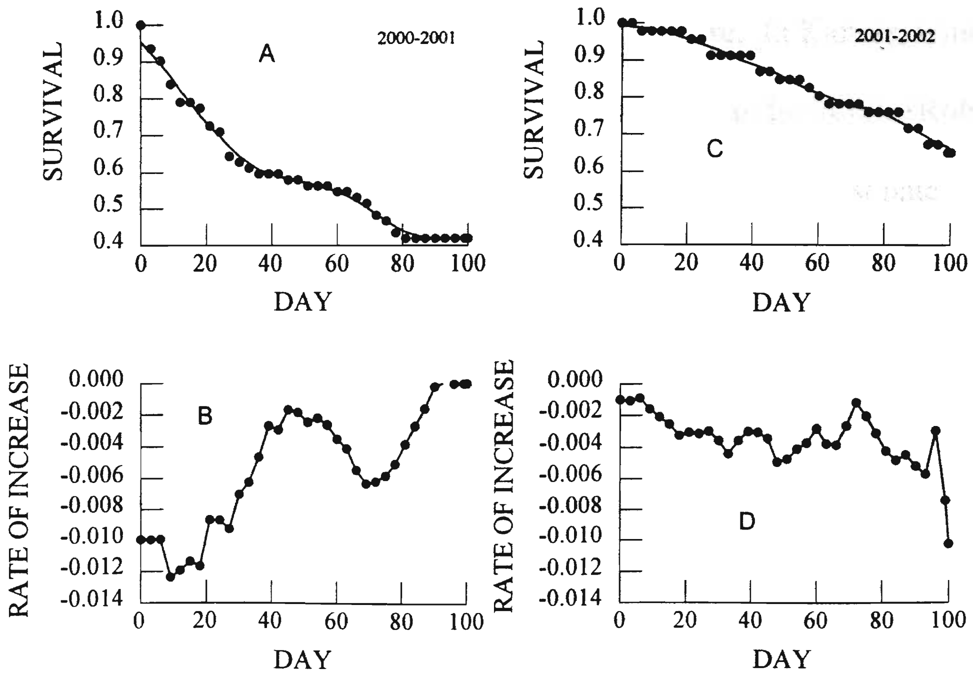

Fig. 1. Survival curves (A, C) and derivatives (B, D) for northern bobwhites radioed for the periods 6 September 2000–7 January 2001 and 13 September 2001–7 January 2002, Mesa Vista Ranch, Roberts County, Texas.

Survival rate did not vary over year and season in this study, and was not consistent with other reported survival rates in the literature. In Kansas, winter survival was found to be lower for juveniles (0.27 of ad survival) than for adults (Robel 1965). Survival of bobwhites with broods (0.78) during the first 21 days post hatch was less than those without broods (0.90; Burger et al. 1995). This was attributed to the high cost of parental care (Burger et al. 1995).

Comparison of long-term survival estimates for stable populations at equal latitudes can further illuminate direction of population trends. Long-term annual survival estimates for hunted populations should decrease with increasing latitude (Guthery 2000:116). Long-term survival for north Texas should be close to 20% per year (Guthery 2000:116). The 2-year data for the Mesa Vista Ranch suggested an average annual survival rate of 11.8%. This average is based on 4% survival in 2000–2001 (Table 2, 7-day censor period). The annual survival rate for 2001–2002 was estimated at 19.6%. This estimate was obtained by using data for the period 1 September–31 May (Table 2, 7-day censor period). I assumed constant daily survival for the period, estimated the daily survival rate (0.9956), and raised this rate to the power 365 to obtain an estimate of the annual survival rate.

Cause-Specific Mortality

The results of this study varied somewhat with findings reported in the literature. Mortality from different causes has been reported to vary over season (Robel 1965, Curtis et al. 1988, Burger et al. 1995, DeMaso et al. 1998). Previous studies have described a pattern of cause-specific mortality with avian mortality being highest in the fall and winter and mammalian mortality being highest in the spring and summer (Curtis et al.

1988, Burger et al. 1995, DeMaso et al. 1998). This study did not show any difference in mortality rates between season or year with the exception of hunting losses, which only occurred in the fall.

Cause-specific mortality rates reported for radio-collared bobwhites could be biased due to visibility of the radio transmitter (Mueller et al. 1988, Burger et al. 1991). The transmitter was preened under feathers and made of similar colors to bobwhite plumage with the antenna running on top of the back. The antennae or odd feather patterns produced from the transmitter could possibly be visible to predators. This would be most relevant to avian predators, which hunt from above by sight.

Calculated cause-specific mortality rates are dependent on observations in the field. For mortality rates to be accurate, cause of death must be correctly identified. Most deaths were not known with certainty, except for those deaths directly observed. Possible future research should ascertain the accuracy of these observations.

Several anomalies presented themselves from the data. First, the high rate of mortality from other causes during the first year was a result of high mortality from this category at the beginning of the study when the radio-collared population numbers were lower. Second, mortality from hunting occurred only in the fall (Nov–Feb) due to hunting season in Texas.

Radio-Collared vs. Nonradio-Collared

Researchers who have compared survival rates of telemetered versus wild birds have reported contradicting results. This contradiction lacks intensive research for bobwhites (Corteville et al. 2000). Mueller et al. (1988) found that short-term mortality was virtually the same between radio-marked and nonradio-marked bobwhites. By flushing the covey containing the radio-collared bobwhite and counting the number of bobwhites flushed, a count of nonradio-collared bobwhites was obtained (Mueller et al. 1988). Mortality rates between radio-collared bobwhites (0.27) and nonradio-radio collared bobwhites (0.24) were similar for the first 45 days post capture. Osborne et al. (1997) studied pen-reared bobwhites with 2 different types of harnesses, and found that survival was less for bobwhites with bib-style harnesses than those without or with backpack harnesses. They expressed that this fact could bias results of survival and nesting studies, and recommended less stressful alternatives (whistle counts) when possible. At the Packsaddle Wildlife Management Area in western Oklahoma, Parry et al. (1997) found that radio-marked bobwhites (0.30 chance of harvest) were less likely to be harvested than were bobwhites with only a leg band (0.39 chance of harvest). They suggested that radio-tagged bobwhites became accustomed to people being close and did not flush as quickly as bobwhites with leg bands only.

The lack of difference between survival estimates from radio telemetry and line transect method (Table 6) could indicate that estimates reflected the population dynamics on the study site. Alternatively, the lack of difference could be a factor of the method of sampling. Line transect and radio telemetry survival estimates produce a large variance. For differences to be detected the estimates would need to be at extremes (survival equal 1.00 or 0.001).

A source of bias in telemetry estimates could arise from capture and handling. Time spent in traps by bobwhites could increase injuries, harassment by predators, and possibly death (Mueller et al. 1988). Procedures used during the project were developed to reduce time spent in the trap and handling time. Frequent removal of bobwhites from traps served to reduce self-inflicted trap-related injuries (trampling, head scalping, and wing scraping).

The main assumption needed for line transect sampling is that every individual bobwhite directly on the line walked by the observer is seen. If this assumption fails, the density estimate will be biased. This should not normally be a problem in that it is unlikely that an observer would literally walk over a healthy bobwhite.

Movement of coveys unseen by the observer could lead to an underestimate of density (Guthery 1988). Movement would manifest as higher frequencies of flushes in middle belts (distances) parallel to the transect line. Guthery (1988) concluded that this was rare based on research conducted in south Texas, and movement behavior did not seem apparent in my density estimates.

Censor Period

Analysis of survival curves provided at best a crude approximation of censor-period effects on estimates of survival. The survival curves and derivatives (Fig. 1) were subject to time-confounding. Accordingly, they were unbiased only if daily survival was constant from the date of first capture through the time required for the last bird captured to survive for 100 days. Seasonal effects on survival rates were evident in my analysis (Table 2), as well as in previous studies (Curtis et al 1988, Burger et al. 1995). Bobwhites captured earlier in the sample would have had winter months (Nov, Dec) within 100-day survival, whereas the birds captured later would have had spring months (Feb, Mar). The expectation would be for birds captured just prior to the winter months to experience lower survival than later-captured birds.

The results were ambiguous relative to the question of optimal censor period because a period ≥45 days appeared optimal in 2000–2001, whereas a 0-day censor period appeared optimal in 2001–2002. Undoubtedly, a larger dataset for analysis of censor-period effects is necessary to better understand censor effects on estimates of survival.

Nonetheless, these preliminary results provided some insights into the question of censor-period effects. First, although the sample was limited and time-confounded, no support was obtained for the widely used 7-day censor period. Second, the possibility exists that the optimal censor period depends on such matters as season and weather, so that general application of some fixed value may be inappropriate. Third, when recovery effects from capture and adjustment to transmitters occur, the effect may manifest as a trend rather than a threshold (Fig. 1B; days 20–45). If the effect is a trend, the appropriate censor period depends on properties of individual bobwhites, which change from area to area and time to time. Possible individual heterogeneity in censor periods provides further lack of support for general application of any fixed censor period because the average optimal censor period for any population will depend on the probability distribution of censor periods of individuals within the population.

The fixed censor period seems illogical for the reasons mentioned above. However, until the question of censor period has been addressed with a larger sample, biologists probably should continue to apply censor periods because in empirical cases a censor period is meritorious (Fig. 1B). However, the length of censor period to apply remains problematic. Generally, in modeling, when one makes an assumption the sensitivity of results to the assumption must be tested. With radio-telemetry data, the sensitivity of estimates of seasonal or annual survival to the censor period can be estimated by calculating the survival rate of interest under different censor periods (say periods of 0, 7, 14, and 21 days). If the estimates are similar, the censor period might be irrelevant. If the estimates differ, the highest estimated survival rate may provide the best approximation of survival in the population under study.

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Appendix 1. Monthly cause-specific mortality of northern bobwhites determined from telemetry data collected on the Mesa Vista Ranch, Roberts County, Texas, from 1 September 2000 to 31 May 2002.

			Mortality source					
Year	Period	n^a	Bird	Mammal	Hunt	Other	Censored	Survived
2000	1 Sep–1 Oct	6	0	0	0	1	0	5
	2 Oct–29 Oct	26	1	2	0	1	0	22
	30 Oct–26 Nov	28	4	0	0	0	0	24
	27 Nov–24 Dec	28	4	2	2	0	0	20
2001	25 Dec–21 Jan	31	3	6	0	0	1	22
	22 Jan–18 Feb	28	1	1	0	0	0	26
	19 Feb–18 Mar	31	4	2	1	0	0	24
	19 Mar–15 Apr	34	4	2	0	0	0	28
	16 Apr–13 May	39	1	6	0	0	3	29
	14 May–10 Jun	29	2	3	0	1	0	21
	11 Jun–8 Jul	21	1	1	0	0	1	19
	9 Jul–5 Aug	19	1	1	0	1	1	16
	6 Aug–2 Sep	16	1	1	0	0	1	13
	3 Sep–30 Sep	21	2	0	0	0	1	18
	1 Oct–28 Oct	40	1	1	0	1	2	35
	29 Oct–25 Nov	48	3	2	0	0	1	42
	26 Nov–23 Dec	43	1	3	0	1	1	37
2002	24 Dec–Jan 20	39	2	2	1	0	0	34

21 Jan–17 Feb	57	2	2	0	2	0	51
18 Feb–17 Mar	55	0	1	0	0	0	54
18 Mar–14 Apr	54	0	1	0	1	0	52
15 Apr–12 May	53	1	2	0	3	0	47
13 May–31 May	47	0	2	0	1	0	44

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[a] Birds did not have to be at risk for the entire month.

Appendix 2. Frequency tables for cause of mortality for northern bobwhites used in calculation of *G* statistics, Mesa Vista Ranch Roberts County, Texas, 1 September 2000–7 January 2002.

Date		Cause of mortality			
Time class[a]	Period (days)	Bird	Mammal	Other	Total
1 Sep 2000–7 Jan 2001					
A	0–20	3	9	1	13
	21–40	6	1	1	8
	>40	11	12	3	26
B	0–14	3	6	1	10
	15–21	0	3	0	3
	>21	17	13	4	34
C	0–7	3	4	0	7
	8–21	0	5	1	6
	>21	17	13	4	34
1 Sep 2000–7 Jun 2001					
A	0–20	4	12	2	15
	21–40	7	6	2	15
	>40	21	17	5	43
B	0–14	4	9	1	14
	15–21	0	4	1	5
	>21	28	22	7	57
C	0–7	4	7	0	11

	8–21	0	6	2	8
	>21	28	22	7	57
13 Sep 2001–7 Jan 2002					
A	0–20	0	2	0	2
	21–40	1	2	0	3
	>40	5	6	5	16
B	0–14	0	1	0	1
	15–21	0	1	0	1
	>21	6	8	5	19
C	0–7	0	1	0	1
	8–21	0	1	0	1
	>21	6	8	5	19
1 Sep 2000–7 Jan 2002					
A	0–20	4	14	2	20
	21–40	8	8	2	18
	>40	26	23	10	59
B	0–14	4	10	1	15
	15–21	0	5	1	6
	>21	34	30	12	76
C	0–7	4	8	0	12
	8–21	0	7	1	8
	>21	34	30	13	77

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[a] Refers to period classes given in the next column

VITA 2

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