Effects of Pen-raised Northern Bobwhite Introductions on Wild Bobwhites in South Texas

Ashton R. Hutchins, *Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX 78363*

Fidel Hernández, *Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX 78363*

Abstract: Although restocking wild populations with pen-raised bobwhites *(Colinus virginianus)* is considered ineffective, it has become popular and acceptable among sportsmen to supplement hunting opportunities. Nonetheless, their impact on wild bobwhite populations remains unknown. The objectives of this study were to compare bobwhite survival, core area of use, and relative predator abundance between treatment (release of pen-raised bobwhites) and control areas. We monitored 136 wild bobwhites via radiotelemetry from September to February 2000–01 and 2001–02 on 2 areas (1 release and 1 control site) in Brooks County, Texas. We released 800 pen-raised bobwhites on the treatment site from November to December 2000 and 1,920 pen-raised bobwhites during the same time period in 2001. We documented greater survival of wild bobwhites in the control site (38%; $N = 39$ bobwhites) compared to the treatment site (14%; $N = 41$ bobwhites) only during 2001 ($P = 0.02$). Core area of use was greater on the treatment site (16.01 ± 1.23 ha; $N = 9$ coveys) compared to control site (10.39 ± 1.09 ha; $N = 11$ coveys) only during 2000 ($P = 0.003$). There was no difference in relative abundance of raptor or mammalian predators between control and treatment sites for either year ($P > 0.05$). The release of pen-raised bobwhites might negatively impact of wild bobwhites by increasing the amount of space used by wild bobwhites.

Key words: Colinus virginianus, bobwhite, pen-raised bobwhite, predators

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Supplementing northern bobwhite (*Colinus virginianus;* hereafter bobwhites) populations via pen-raised bobwhites is a controversial aspect of bobwhite management. Although the stocking of pen-raised bobwhites to increase or restore wild-bobwhite populations is considered ineffective (Baumgartner 1944, Pough 1948, Roseberry et al.1987, De Vos and Speake 1995), this practice still is used for field dog trials and is popular and acceptable among sportsmen to supplement their hunting. However, the impact of this practice on wild bobwhite populations remains unknown (Brennan 1991).

Potential impacts range from disease and parasite transmission to changes in habitat use, social structure, genetic fitness, and survival rates of wild bobwhites (Brennan 1991). Much research has been conducted on the survival of pen-raised bobwhites (Baumgartner 1944, Buechner 1950, Perez et al. 2002). However, there is relatively little published information regarding the effects of pen-raised bobwhite releases on wild bobwhite populations (Brennan 1991, DeVos and Speake 1995, Sisson et al. 2000). Although it can be argued that pen-raised bobwhites pose minimal threat to wild populations because of their low survival, the continued presence of pen-raised bobwhites over a prolonged period of time resulting from multiple releases might impact wild bobwhite populations. Thus a need existed to document the potential impacts that pen-raised bobwhite releases might have on wild bobwhites.

The objectives of our study were to compare bobwhite survival, core area of use, and relative predator abundance between treatment (pen-raised bobwhite releases) and control areas (no releases).

Methods

Study Area

We conducted our study area on a private ranch in Brooks County, Texas, located within the Rio Grande Plains ecoregion of Texas (Gould 1975). Topography within the Rio Grande Plains is level to rolling, and the land is dissected by creeks and rivers flowing into the Rio Grande River and Gulf of Mexico. The elevation range is from sea level to 330 m. The Rio Grande Plains is characterized by rangeland, open prairies with a growth of mesquite *(Prosopis glandulosa)*, huisache *(Acacia smallii)*, granjeno *(A. berlandieri)*, and Texas pricklypear cactus *(Optuntia lindheimeri)*. Average annual rainfall is 35 to 66 cm and soils range from clays to sandy loams (Correll and Johnston 1979). Although large acreages of cultivated land exist within the Rio Grande Plains, predominant land use is livestock production (i.e. rangeland). Land holdings are predominately large cattle ranges (>20,000 ha) with abundant wildlife (Correll and Johnston 1979).

Experimental Design

This study involved a control (no releases of pen-raised bobwhites) and a treatment (release of pen-raised bobwhites) and 2 experimental units (i.e., pastures). We could not randomly assign treatments to experimental units because of landowner restrictions on areas authorized for release. However, we attempted to minimize potential bias resulting from this limitation by selecting similar experimental units. Thus we believe our study remains valid. Experimental units were separated by >8 km.

We defined three treatment periods (i.e., pre-release, release, and post-release) respective to the time of release of pen-raised bobwhites. The pre-release period extended from 1 September–31 October, the release period from 1 November–31 December, and post-release from 1 January–28 February. We conducted this study during 2000–01 and 2001–02.

Radiotelemetry

Wild Northern Bobwhites.—We trapped wild bobwhites using standard funnel traps baited with milo (*Sorghum* sp.) (Stoddard 1931:442–445) and night netting (Labisky 1968). We weighed, sexed, aged, and banded all captured bobwhites. We fitted any bobwhite weighing >150g with a 6-g, neck-loop radiotransmitter (American Wildlife Enterprises, Tallahassee, Florida). During the first field season (September–February 2000–2001), we radiomarked 2–3 bobwhites per covey and monitored

8–11 coveys per experimental unit. We monitored bobwhites twice per week for the duration of the study. We located bobwhites by homing and obtained Global Positioning System (GPS) coordinates using a hand-held unit with an accuracy of ±15 m (Garmin Global Positioning Systems, *e*trex model, Olathe, Kansas). We calculated a core area of use for radiomarked coveys using 95% fixed kernel estimator (Worton 1989) with the least squares cross validation smoothing parameter using the Animal Movement Extension (Hooge and Eichenlaub 1997) in ArcView (version 3.1; 1998 ESRI, Redlands, California). We use the term "core area of use" instead of home range size because we only were able to obtain 15–25 coordinates per covey and therefore did not feel comfortable referring to this area as "home range."

Pen-raised Northern Bobwhites.—Beginning in late October and lasting through late December (i.e., eight-week treatment period), we released one pen-raised covey (i.e., 10–12 bobwhites) every seven days into the core area of use of each wild covey located in the treatment site. We purchased pen-raised bobwhites from a commercial breeder, who banded all pen-raised bobwhites prior to delivery. We received weekly shipments of pen-raised bobwhites to avoid the need for long-term containment of pen-raised bobwhites at our study area. During the first field season, we also radiomarked one pen-raised bobwhite per pen-raised covey to obtain baseline information on movements and survival. Every pen-raised covey released did not have a radiomarked pen-raised bobwhite. Rather, for each release date, we randomly selected a subset of coveys from all pen-raised coveys to be released and radiomarked one member of their respective covey. We followed the same protocol to radiomark pen-raised bobwhites as was previously described for wild bobwhites, except that we used a modified neck-loop attachment (Wildlife Materials, Carbondale, Illinois) to facilitate reuse of transmitters.

During the second field season, we increased the number of pen-raised bobwhites comprising a covey to 24–27. We implemented this modification because we wanted to adequately mimic the practice of most wildlife enterprises (i.e., releasing many [>1,000] pen-raised bobwhites). We did not radiomark any pen-raised bobwhites during the second field season because we documented that pen-raised bobwhites remained within the core area of use of wild coveys, thereby producing our desired treatment effect.

In both field seasons, we kept pen-raised bobwhites overnight in their original transport boxes and released them immediately the next morning to minimize mortality at release. We released pen-raised bobwhites in the shade and protection of a brush motte and allowed them to leave the transport boxes on their own. We did not provide any food or water at release sites because this practice might attract predators or influence the movements of wild and pen-raised bobwhites.

Predator Relative Abundance

Avian Predators.—We determined relative abundance of avian predators (diurnal raptors) using roadside surveys following the general protocol of Fuller and Mosher (1987). We selected a 10-km road transect in each experimental unit and conducted raptor surveys during morning hours (0800–1000) unless weather conditions provided for low visibility (e.g., dense fog), in which case we conducted transects in the early afternoon hours as soon as weather permitted. Raptor surveys were conducted from a vehicle traveling at approximately 8–16 km/hour and involved three persons (i.e., driver and one or two outside observers). The survey did not involve predetermined stops but rather the vehicle traveled continuously until a raptor was observed, at which point the vehicle stopped for raptor identification. We used binoculars (10x50 mm) to assist with the identification of raptors and recorded the number of avian predators observed by species. During the first field season, we conducted raptor surveys once per day for three consecutive days each month. However, during the second field season, we modified our survey methodology and conducted raptor surveys once per week to provide a more continuous monitoring of raptor abundance through time.

Mammalian Predators.—We attempted to determine relative abundance of mammalian predators during the first season using spotlight counts following the protocol of Henke and Bryant (1999). However, we discontinued spotlight counts after three months because of low or no predator count data. Thus, no mammalian predator data was collected for the first year and we determined relative abundance of mammalian predators during the second field season using scent stations (Morrison et al. 1981, Conner et al. 1983).

We established scent stations in a grid pattern (500 x 1000 m) for each experimental unit to obtain uniform coverage. Each experimental unit contained four scent-station lines with each line containing 3–6 scent stations. Lines were separated by 1,000 m and scent stations within lines were separated by 500 m. We established 18 and 20 scent stations in the control and treatment site, respectively.

We conducted scent stations once per week from September through February 2001–2002. A scent station consisted of a 1-m diameter circular area cleared of debris and vegetation according to the design of Linhart and Knowlton (1975). Each week, the soil in the scent station area was resifted and leveled, and a scent capsule with a fish oil attractant was placed in the middle. After preparing scent stations in the late afternoon (1400–1830 hrs), we checked scent stations the next morning (0730–1200 hrs) and recorded the number of scent stations visited by mammalian predators. We categorized tracks as canid, felid, raccoon, opossum, skunk, or other (e.g. feral hog [*Sus scrofa*]). For each site, we calculated a visitation rates for each week. We defined visitation rate as the number of scent stations visited by target predators divided by the total number of operable scent stations for that week (Stapper et al. 1989).

Statistical Analysis

We calculated survival curves for wild bobwhites for pre-release (1 September–31 October), release (1 November–31 December), and post-release (1 January–28 February) periods using the staggered entry design as described by Pollock et al. (1989). We calculated survival with the Kaplan-Meier survival estimator (Kaplan and Meier 1958) using the program STAGKAM (Kulowiec 1989). We then used log-rank chi-square tests to compare survival curves following the protocol of Burger et al. (1995).

We used randomization tests (Edgington 1995) to compare core area of use of wild coveys between treatments. The absolute difference between $\bar{x}_{control}$ and $\bar{x}_{release}$ was the test statistic, and its distribution was estimated by 1,000 random permutations of the sequence of inter-treatment differences. The $|\bar{x}_{control(random)} - \bar{x}_{release(random)}|$ was calculated for each of the possible permutations. The proportion of values of $|\bar{x}_{control(random)} - \bar{x}_{release(random)}|$ that exceeded the observed value gave the *P* value (Edgington 1995).

We used Randomized Intervention Analysis (RIA; Carpenter et al. 1989) to compare relative predator abundance between treatments across periods (i.e., pre-, during-, and post-release) for both raptor and mammalian predators. RIA is suited for unreplicated experiments where experimental and control sites were observed before and after a manipulation (Carpenter et al. 1989). We used RIA for our predator data because we had predator data before, during, and after releases of pen-raised bobwhites. We will briefly describe the RIA analysis because although this approach has been used in ecosystem experiments for about 40 years (Hulbert 1984, Likens 1985, Schindler 1987), it might not be familiar within the wildlife profession.

Randomized Intervention Analysis begins with a series of parallel observations of experimental and control sites, paired in time, spanning periods before and after a manipulation (Carpenter et al. 1989:1143–1144). A time series of inter-site differences then is calculated, and from these are calculated mean values for premanipulation and postmanipulation differences, $\bar{x}_{Diff(pre)}$ and $\bar{x}_{Diff(post)}$, respectively. The absolute difference between $\bar{x}_{Diff(pre)}$ and $\bar{x}_{Diff(pre)}$ is the test statistic, and its distribution is estimated by random permutations of the sequence of inter-site differences. The null hypothesis states that all possible permutations of the data have an equal probability of being observed. The $|\bar{x}_{Diff(pre)} - \bar{x}_{Diff(post)}|$ is calculated for each of the possible permutations. The proportion of values of $|\bar{x}_{Diff(pre)} - \bar{x}_{Diff(post)}|$ that exceeds the observed value is the approximate *P* value, which indicates the probability of a test statistic as or more extreme than that observed, under the null hypothesis. Thus, for our study, we compared the paired difference in relative predator abundance between treatments from the pre-release to release periods, and from the release to post-release periods.

We analyzed our data using SAS (1999). We analyzed each year separately because the modifications we implemented in our methodology during the second year prevented pooling. We report all our results as $\bar{x} \pm$ SE and consider results significant at $\alpha = 0.05$.

Results

Survival and Core Area of Use

We monitored 11 and 10 wild coveys in the control and treatment site, respectively, during 2000–2001. We released 800 pen-raised bobwhites in the treatment site during the release period, of which 58 were radiomarked. During 2001–2002, we monitored 15 and 13 wild coveys in the control and treatment site, respectively. We released 1,920 pen-raised bobwhites in the treatment site during the release period.

We documented no difference in the survival distributions of wild bobwhites between the control and treatment site during any of the treatment periods in

Table 1. Comparison of Kaplan-Meier survival distributions ($\hat{S}$) between wild northern bobwhites in a control and treatment (pen-raised bobwhite releases) site during pre-release (1 September–31 October), release (1 November–31 December), and post-release (1 January–28 February), Brooks County, Texas, 2000–01 and 2001–02.

Year	Control			Treatment				
Period	*N*	$\hat{S}$	S.E.	*N*	$\hat{S}$	S.E.	Chi-square	*P*-value
2000–01								
Pre-release	25	0.79	0.08	28	0.83	0.07	0.14	0.71
Release	22	0.77	0.09	24	0.78	0.09	0.00	0.99
Post-release	17	0.51	0.14	18	0.28	0.10	1.05	0.31
Sep–Feb	26	0.31	0.10	30	0.18	0.07	0.13	0.72
2001–02								
Pre-release	35	0.84	0.07	38	0.83	0.06	0.00	0.98
Release	29	0.82	0.07	35	0.58	0.08	3.85	0.05
Post-release	23	0.55	0.11	20	0.25	0.10	4.86	0.03
Sep–Feb	39	0.38	0.14	41	0.14	0.06	5.33	0.02

2000–2001 (Table 1). However, wild-bobwhite survival was greater in the control site during the release and post-release periods compared to the treatment site in 2001–2002 (Table 1).

Pen-raised bobwhites experienced a 0.00% survival rate from 1 November 2000 through 28 February 2001. Only 15 (1.8%) of the 800 pen-raised bobwhites released during 2000–2001 were harvested (period = 18–94 days after liberation). Eight birds were harvested 26–50 days after release, with four and three harvested 0–25 days and 76–94 days, respectively. Twenty-five (1.3%) of the 1,920 pen-raised bobwhites released during 2001–2002 were harvested (period = 1–70 days after liberation). Eleven birds were harvested 26–50 days after release, with seven each harvested 0–25 days and 51–70 days.

We documented larger core areas of use of wild bobwhite coveys in the treatment site (16.01 ± 1.23 ha; $N = 9$ coveys) compared to the control site (10.39 ± 1.09 ha; $N = 11$ coveys) during 2000–2001 ($P = 0.003$). We documented no difference in core area of use between the control site (14.56 ± 0.99 ha, $N = 10$ coveys) and treatment site (21.16 ± 3.60 ha; $N = 8$ coveys) during 2001–2002 ($P = 0.055$).

Relative Abundance of Predators

Avian Surveys.—We documented no difference in mean raptor abundance between treatments comparing the pre-release to release periods for either year (Table 2). We also documented no difference in mean raptor abundance between treatments comparing the release to post-release periods (Table 2).

Mammalian Surveys.—We documented no difference in mean visitation rates between treatments comparing the pre-release to release periods in 2001–2002 (Table 3). We also documented no difference in mean visitation rates between treatments comparing the release to post-release periods (Table 3).

Table 2. Comparison of avian predators counted along 10-km road transects in a control and treatment (pen-raised bobwhite release) site between treatment periods, Brooks County, Texas. Surveys were conducted in the morning between 0800–1130 for three consecutive days per month during September–February 2000–2001 and one time per week during September–February 2001–2002.

	Control			Treatment				
Year Period[a]	*N*[b]	$\bar{x}$(*N*/km)	SE	*N*	$\bar{x}$(*N*/km)	SE	*T*-value[c]	*P*-value
2000–01								
Pre-release	6	0.37	0.11	6	0.46	0.16		
							2.25	0.07
Release	6	0.41	0.16	6	0.62	0.20		
							1.82	0.14
Post-release	5	0.60	0.20	5	0.77	0.25		
2001–02								
Pre-release	6	0.54	0.29	6	0.44	0.33		
							0.67	0.53
Release	6	0.82	0.38	6	0.92	0.47		
							1.96	0.10
Post-release	7	0.57	0.28	7	0.86	0.19		

a. Pre-release corresponds to Sep–Oct and indicates time period prior to pen-raised bobwhite releases; release corresponds to Nov–Dec and indicates time period of releases; post-release corresponds to Jan–Feb and indicates time period after releases.

b. Sample size refers to number of surveys conducted during a particular period.

c. Test statistic corresponds to Randomized Intervention Analysis conducted between periods.

Table 3. Comparison of mean visitation rates (%) of mammalian predators between control and treatment (pen-raised bobwhite releases) sites across treatment periods, Brooks County, Texas. Scent stations were conducted once per week during September to February 2001–02.

	Control			Treatment				
Period[a]	*N*[b]	$\bar{x}$	SE	*N*	$\bar{x}$	SE	*T*-value[c]	*P*-value
Pre-release	90	0.37	0.18	100	0.18	0.18		
							–0.49	0.65
Release	108	0.45	0.26	120	0.43	0.14		
							0.81	0.45
Post-release	126	0.41	0.16	140	0.44	0.17		

a. Pre-release corresponds to Sep–Oct and indicates time period prior to pen-raised bobwhite releases; release corresponds to Nov–Dec and indicates time period of releases; post-release corresponds to Jan–Feb and indicates time period after releases.

b. Sample size refers to number of operable scent stations conducted during a particular period.

c. Test statistic corresponds to Randomized Intervention Analysis conducted between periods.

Discussion

We documented significantly lower survival of wild bobwhites on the treatment site only in 2001–2002. However, terminal survival rates (1 September–28 February) were about 50% lower on the treatment site relative to the control site for both years. From a statistical perspective, our results are similar to DeVos and Speake (1995). From a trend perspective, they more closely reflect those of Sisson et al. (2000).

Similar to our study, DeVos and Speake (1995) reported no difference in survival of wild bobwhites (22 weeks post-release of pen-raised bobwhites) between control sites (0.41) and wild bobwhites on release-area sites (0.36). Their survival rates for control sites were consistently greater than release sites, but not statistically different. It is possible that our relatively low sample sizes (≈30 radiomarked bobwhites) might have resulted in low statistical power and low precision, a possibility also considered by DeVos and Speake (1995:269) in their study. Pollock et al. (1989) documented that precision of survival estimates is poor unless the number of animals radiomarked at a particular time is >20. They suggested that in order to obtain good precision, a minimum of 40–50 animals would need to be radiomarked at all times.

In contrast to DeVos and Speake (1995), Sisson et al. (2000) documented that fall-spring survival (November–April) of wild bobwhites on a release area (0.18) was lower than that of wild bobwhites on a control area (0.43) over three years. Their trend of lower terminal survival rates on the treatment site compared to the control (about 50% lower) is similar to ours. However, it is important to note that in the study of Sisson et al. (2000), pen-raised bobwhites were not released into their treatment area per se. Rather, their treatment represented an influx of pen-raised bobwhites from an adjoining property where pen-raised bobwhites were released. Because they did not quantify the number of pen-raised bobwhites in their treatment area, it is difficult to evaluate their results.

We documented significantly larger core areas of use for wild coveys in treatment sites only in year 1 of the study. However, in both years, core area of use was about 70% larger for wild coveys in the treatment site compared the control site. We hypothesize this increase in core area of use for wild coveys in the treatment site possibly resulted from a negative social interaction between the wild and pen-raised coveys. Although some (<10%) of the radiomarked pen-raised bobwhites were found intermixed with wild, non-radiomarked bobwhites, we never observed any intermixing between our radiomarked wild coveys and pen-raised coveys. On the contrary, wild radiomarked coveys often shifted their area of use away from the release sites of pen-raised coveys. DeVos and Speake (1995) questioned the existence of an interaction between wild and pen-raised bobwhites. They stated that pen-raised bobwhites did not appear to displace wild bobwhites from their established covey ranges, based on their observation that wild and pen-raised coveys intermixed. Of 15 wild coveys radiomarked in their study, only four (27%) were not mixed. However, the study of DeVos and Speake (1995) involved fewer bobwhites (200 in one site and 600 in a second site) than our study and represented a single release in time for each treatment area. It is difficult to interpret the effect of these releases from a social interaction perspective because DeVos and Speake (1995) did not provide data concerning home range size of wild bobwhites on their control and treatment sites.

We did not detect any significant differences in relative predator abundance during the study. However, the data indicate a general trend for increased predator abundance following the release of pen-raised bobwhites. For example, raptor abundance exhibited a 35% increase from pre-release to release period in the treatment site during year 1 and a 109% increase during year 2, compared to the control site which exhibited an 11% and 52% increase, respectively. Visitation rates for mammals also increased 139% from pre-release to release periods in the treatment site, whereas the control site only exhibited a 22% increase. This trend for increased relative predator abundance might represent a numerical, density-dependence response of predators to increased prey numbers, resulting from pen-raised covey releases. Newton (1993) stated that avian predators, by virtue of their mobility, can rapidly accumulate in areas where prey densities increase. We often observed raptors perching in nearby trees during our releases of pen-raised bobwhites, especially during the latter releases. Sisson et al. (2000) also observed that raptors were drawn to their area subjected to an influx of pen-raised bobwhites but provided no empirical data. Our trend of increased relative predator abundance in the treatment sites might represent a biological difference and not a statistical difference. However, we acknowledge this statement is difficult to confirm because indices of relative abundance might not necessarily reflect actual predator densities.

Management Implications

Our research indicates that releasing pen-raised bobwhites exerts negative impacts on wild bobwhite survival and core area of use. Based on Guthery (1997), seasonal survival (September–February) for a stable bobwhite population would range from about 0.43 to 0.53. Compared to our survival estimates, bobwhite populations in the control site would be relatively stable or slightly declining (0.31 and 0.38 seasonal survival), whereas populations in the treatment site would be drastically declining (0.14 and 0.18 seasonal survival). Given a general trend for 50% lower survival rates of wild bobwhites on release areas, it is conceivable for an area subjected to fall releases to have 50% fewer bobwhites beginning the breeding season than one without releases. We hypothesize that lower bobwhite survival results from a numerical, density-dependence response of predators to increased prey density following releases. Further, given limited intermixing of wild and pen-raised coveys in our study, we speculate that negative social interactions possibly accounts for the larger core areas of use of wild bobwhites in release areas.

Because the use of pen-raised bobwhites for recreational purposes is common and widespread, we propose the following general guidelines to help minimize any potential negative impacts on wild bobwhite populations:

— conduct releases on small areas (e.g., 50–100 ha) that possess an inherent low potential as suitable habitat for wild bobwhites (i.e., inherent low density of wild bobwhites);

— designate these areas as release sites and only conduct the practice within such areas; and

— scale the number of pen-raised bobwhites to be released to the hunting pressure for the day of hunting to help ensure a high return of pen-raised bobwhites.

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Literature Cited

Baumgartner, F. M. 1944. Dispersal and survival of game farm bobwhite quail in northcentral Oklahoma. Journal of Wildlife Management 8:112–118.

Buechner, B. K. 1950. An evaluation of restocking with pen-reared bobwhite. Journal of Wildlife Management 14:363–377.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:554–555.

Burger, L. W., Jr., T. V. Dailey, E. W. Kurzejeski, and M. R. Ryan. 1995. Seasonal and annual survival and cause-specific mortality of northern bobwhite in Missouri. Journal of Wildlife Management 59:401–410.

Carpenter, S. R., T. M. Frost, D. Heisey, and T. K. Kratz. 1989. Randomized intervention analysis and the interpretation of whole-ecosystem experiments. Ecology 70:1142–1152.

Conner, M. C., R. F. Labisky, and D. R. Progulske. 1983. Scent-station indices as measures of population abundance for bobcats, raccoons, gray foxes, and opossums. Wildlife Society Bulletin 11:146–152.

Correll, D. S. and M. C. Johnston. 1979. Manual of the vascular plants of Texas. University of Texas at Dallas, Richardson.

DeVos, T. and D. W. Speake. 1995. Effects of releasing pen-raised northern bobwhites on survival rates of wild populations of northern bobwhites. Wildlife Society Bulletin 23:267–273.

Edgington, E. S. 1995. Randomization tests. Marcel Dekkler, Inc. New York.

Fuller, M. R. and J. A. Mosher. 1987. Raptor survey techniques. Pages 37–66 *in* B.A. Giron Pendleton, B.A. Millsap, K.W. Cline, and D.M. Bird, editors. Raptor management techniques manual. National Wildlife Federation. Washington D.C.

Gould, F. W. 1975. Texas plants: a checklist and ecolgical summary. Texas Agricultrual Experimental Station Bulletin, 1183.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61: 291–301.

Henke, S. E. and F. C. Bryant. 1999. Effects of coyote removal on the faunal community in western Texas. Journal of Wildlife Management 63:1066–1081.

Hooge, P. N. and B. Eichenlaub. 1997. Animal Movement Extension to ArcView, Version 1.1. Alaska Biological Science Center, U.S. Geological Survey, Anchorage.

Hulbert, S. H. 1984. Psuedoreplication and the design of ecological field experiments. Ecological Monographs 54:187–211.

Kaplan, F. L. and P. Meier. 1958. Non-parametric estimation from incomplete observations. Journal of American Statistics Association 53:457–481.

Kulowiec, T. 1989. SAS program for conducting log-rank tests of survival distributions from two trials analyzed using the Kaplan-Meier estimator program, STAGKAM. Montana Department of Conservation, Columbia.

Labisky, R. F. 1968. Nightlighting: its use in capturing pheasants, prairie chickens, bobwhites, and cottontails. Illinois National History Survey Biology Notes 62.

Likens, G. E. 1985. An experimental approach for the study of ecosystems. Journal of Ecology 73:381–396.

Linhart, S. B. and F. F. Knowlton. 1975. Determining the relative abundance of coyote by scent station lines. Wildlife Society Bulletin 3:119–124.

Morrison, D. W., R. M. Edmunds, G. Linscombe, and J. W. Goertx. 1981. Evaluation of specific scent station variables in northcentral Louisiana. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 35:281–291.

Newton, I. 1993. Predation and limitation of bird numbers. Pages 143–198 in D. M. Power, editor. Current Ornithology. Plenum Press, New York, New York.

Perez, R. M., D. E. Wilson, and K. D. Gruen. 2002. Survival and flight characteristics of captive-reared and wild northern bobwhite in southern Texas. Proceedings of the National Quail Symposium 5:81–85.

Pollock, K. H., S. R. Winterstein, C. M. Bunick, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry approach. Journal of Wildlife Management 53:7–14.

Pough, R. H. 1948. The arguments against the annual stocking of already inhabited coverts with artificially reared game birds. Transactions of the North American Wildlife Conference 13:228–235.

Roseberry, J. L., D. L. Ellsworth, and W. D. Klimstra. 1987. Comparative post-release behavior and survival of wild, semi-wild, and game farm bobwhites. Wildlife Society Bulletin 15:449–455.

SAS 1999. SAS user's guide: statistics. Cary, North Carolina.

Schindler, D. W. 1987. Detecting ecosystem response to anthropogenic stress. Canadian Journal of Fisheries and Aquatic Sciences 44(supplement):6–25.

Sisson, D. C., D. W. Speake, and H. L. Stribling. 2000. Survival of northern bobwhites on areas with and without liberated bobwhites. Proceedings of the Fourth National Quail Symposium 4:92–94.

Stapper, R. J., Rakestraw, D. B. Fegre, and N. J. Silvy. 1989. A comparison of scent-station surveys and track counts for monitoring furbearers. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 43:452–459.

Stoddard, H. L. 1931. The bobwhite quail—its habits, preservation and increase. Charles Scribners and Sons, New York, New York.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70(1):164–168.