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FINAL REPORT

UPLAND GAME INVESTIGATIONS

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STUDY JOB 5 - QUAIL MORTALITY STUDY

JULY 1, 1991 - JUNE 30, 1997

FINAL REPORT

State of Oklahoma

Grant Number W-82-R
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Grant Title: Upland Game Investigations

Grant Period: July 1, 1991 -- June 30, 1997

Project Title: Quail Mortality Study

Project Objective: To identify causes and rates of quail mortality and to investigate relationships between quail mortality, predator abundance, and supplemental feed.

Abstract: We investigated survival and cause-specific mortality of 1,115 radiomarked northern bobwhites (*Colinus virginianus*) and the effect of supplemental feeding on these population parameters. Reproductive parameters for bobwhites were also estimated. Research was conducted from 1 October 1991 through 1 October 1996 on the Packsaddle Wildlife Management Area (WMA) in western Oklahoma. Thirty-two feeders filled with sorghum were located near the center of every 8.1 ha on the 283.3 ha treatment area. The control treatment was 283.3 ha and contained no quail feeders. Mean monthly survival rates were similar for most months, however, monthly survival rates did differ during February ($Z = -1.66$, $P = 0.0485$). Annual survival on the control area was 17.9% and 21.0% on the feeder area. Annual survival pooled over areas was 19.8%. Avian predation (36.9% control, 44.1% feeder) was the highest cause of mortality on both treatments, followed by mammalian predation (28.3% control, 22.9% feeder), and hunting (14.1% control, 15.5% feeder). Most cause-specific mortality was similar between treatments area during the 5 year study period. However, avian predation was higher ($Z = -2.22$, $P = 0.0132$) on the feeder area. Mean bobwhite density was similar ($t = -1.07$, $P = 0.2919$) between the feeder (0.44 birds\acre) and control (0.31 birds\acre) areas. Density differed ($F = 2.67$, $P = 0.0299$) among years and between seasons ($F = 20.60$, $P = 0.0001$). Mean covey size was similar ($t = 0.19$, $P = 0.8525$) between the feeder (10.2 birds\covey) and control (10.5 birds\covey) areas. Mean covey size was similar ($F = 1.30$, $P = 0.2798$) among years, but differed ($F = 40.56$, $P = 0.0001$) between seasons. Mammalian mean monthly visitation rates were similar ($P \geq 0.2660$) between areas. Mean monthly visitation rates were not correlated ($P \geq 0.2505$) with estimated crude mean monthly bobwhite mortality caused by mammals. Incidental sighting of accipiter hawks was higher ($P = 0.0387$) on the feeder area. Sightings of buteos and northern harriers (*Circus cyaneus*) were similar ($P \geq 0.2730$) between areas. Mean monthly sightings of all avian predators pooled and northern harriers were strongly

correlated (r = 0.74, P = 0.0001) to avian cause-specific mortality of bobwhites. During the 1992 through 1996 nesting seasons we monitored 211 bobwhite nests. The average clutch size was 14.2 eggs (SE = 0.3). We have also documented polygamous behavior during the breeding season. Of the birds alive on April 1 each year (223 females and 289 males) 37.7% of females and 9.3% of males successfully hatched >1 nest. Nesting females that survived the nesting period incubated an average of 1.5 nests and surviving males incubated just over 1 nest. Of the females that were successful on their initial nesting attempt, 24.3% attempted second nests. Female first nests represented 56.6%, female renests 13.3%, female double-clutch attempts 6.2%, and male-incubated nests 23.9% of all nests located. Chicks hatched in only about half of the nests, the remainder of the nests were destroyed by predators (mainly snakes). The average brood-rearing period was 39 days (SE = 4.1 days). The estimate of chick survival pooled over years and sex of the parent from hatching to 39 days was 37%, most dying within the first 3 weeks. Male bobwhites raise 5 to 35 percent of the broods. Adult bobwhites will adopt and/or abandon chicks within broods as nearly 17% of the broods eventually had more chicks than were hatched from the nest.

Northern bobwhites are hunted in over 30 states. In Oklahoma, about 85,000 quail hunters harvest about 2.0 million bobwhites annually (LaPierre 1997). However, Oklahoma, like many states in the southeast, has not been immune from the steady decline in bobwhite populations since the early 1970's (Brennan 1991, Church et al. 1993). Suspected reasons for the decreasing and fluctuating bobwhite populations in the southeastern United States and Oklahoma include habitat changes, changes in agricultural practices, weather, disease, predation, and overharvest (Mueller 1989, Brennan 1991).

Supplemental feeding is commonly used in Oklahoma and throughout the bobwhite's range in an attempt to augment bobwhite populations (Frye 1954, Guthery 1986:48, Peoples 1992). Few studies have examined the effect of supplemental feeding on wild bobwhite populations (Frye 1954, Peoples 1992) and provide conflicting results. Frye (1954) reported an increase in bobwhite numbers from supplemental feeding in south Florida. In Kansas, Robel et al. (1979) found bobwhites had lower weights, lower fat content, and increased mortality when supplemental feed was not available during winter. Supplemental feeding may increase survival during stressful periods (i.e., severe winter weather and drouth) and increase productivity if applied properly (Guthery 1986:48). Bobwhites have not benefitted from supplemental feeding programs in Oklahoma (Peoples 1992).

Survival of bobwhites has been estimated by differences between fall and spring population surveys (Dimmick et al. 1982, Roseberrry and Klimstra 1984), covey counts (Kabat and Thompson 1963), age-ratio information (Marsden and Baskett 1958, Roseberry

and Klimstra 1984), and radio telemetry (Curtis et al. 1988, Burger et al. 1995*a*). Radio telemetry allows direct determination of survival and mortality of individuals, thereby permitting estimation of survival functions and associated variances (Pollock et al. 1989*b,c*). Survival estimated using radio telemetry assumes that the behavior and survival of radiomarked individuals is similar to that of unmarked individuals. Survival rates of northern bobwhites on supplementally fed and control areas are lacking in the literature.

Estimates of cause-specific mortality have been reported for few bobwhite populations (Burger et al. 1995*a*). Adult bobwhite sex ratios are skewed toward males (Roseberry and Klimstra 1984:136). There are competing hypotheses regarding sources and timing of differential mortality that cause sex-ratio bias. Stoddard (1931:94) suggested that females have lower winter survival; Pollock et al. (1989*a*), Shupe et al. (1990), and Roseberry and Klimstra (1992) reported higher female harvest rate; and Leopold (1933), Buss et al. (1947), and Bennitt (1951) suggest that females experience higher mortality during incubation. Mortality of northern bobwhites on supplementally fed and control areas are absent in the literature.

Bobwhite management has operated under the assumption that more food results in better habitat; this is why many bobwhite management programs use supplemental feeding, food plots, strip discing to promote annual forbs, and prescribed burning. If food is the limiting factor then practices aimed at increasing food should also increase bobwhite density. Guthery (1997) analyzed data collected by Frye 1954, Keeler 1959, Doerr 1988, and Kane 1988. His analysis showed that the mean autumn density on control sites was similar to that on fed sites. Guthery (1997) concluded that food suplementation is a neutral management practice.

Avian and mammalian predators can influence bobwhite populations. Avian and possibly mammalian predators can sometimes prey on bobwhites at feeders; especially if adequate cover is not available (Guthery 1986:53-56). Wildlife managers and landowners alike, have often "managed" for bobwhite quail by supplemental feeding. Whatever benefits supplemental feed may provide to bobwhites, the concentration of predators, disease and other factors may make the process unproductive. Relative indices of avian and mammalian predators could give an indication of increased predator abundance on supplementally fed areas. The abundance of predators is assumed to impact bobwhite mortality; although, it is not understood, how densities of predators and prey relate to predation (Leopold 1933:230-242). However, indices of predator abundance should be correlated with cause-specific estimates of bobwhite mortality.

Relationships among population structure, reproductive strategies, and population growth are very poorly understood for

most avian species (Breitwisch 1989), including northern bobwhite, despite decades of investigation (Curtis et al. 1993, DeVos and Mueller 1993, Suchy and Munkel 1993). Bobwhites lay large clutches, renest multiple times, and male bobwhites share the responsibility of incubating the nest, and caring for the brood with the hen (Roseberry and Klimstra 1984:79, Curtis et al. 1993, DeVos and Mueller 1993, Suchy and Munkel 1993, Burger et al. 1995*b*, DeMaso et al. 1997). Managing bobwhite depends on understanding the reproductive mechanisms that enable recovery from high annual mortality and catastrophic events that can reduce populations (Roseberry 1962, Stanford 1972*a*, Roseberry and Klimstra 1984, Suchy et al. 1991). Bobwhites also exhibit a reproductive system that responds to population density, weather, resource availability, and physiological condition (Burger et al. 1995*b*).

Although bobwhite nesting habits and success have been investigated (Stoddard 1931, Klimstra 1950, Simpson 1972, Dimmick 1974, Klimstra and Roseberry 1975), these studies relied on procedures that could not determine the relative contribution of different reproductive strategies and reproductive success. Furthermore, they provided limited information about bobwhite reproductive success for individual birds in the spring population.

Bobwhite can renest following failed initial attempts (Stoddard 1931, Klimstra and Roseberry 1975, Curtis et al. 1993, Suchy and Munkel 1993, Burger et al. 1995*b*, DeMaso et al. 1997). Some authors have assumed that nests initiated after 1 June are renests (Stanford 1972a, Klimstra and Roseberry 1975, Suchy and Munkel 1993) or double clutches (Stanford 1972*b*). Renesting is poorly documented for bobwhite (Roseberry and Klimstra 1984), and the probability of renesting and relative contribution to production is unknown. The occurrence of double clutches in bobwhite populations is widespread, but infrequent, and therefore difficult to detect (Sermons and Speake 1987, Curtis et al. 1993, DeVos and Mueller 1993, Suchy and Munkel 1993, Burger et al. 1995b, DeMaso et al. 1997).

Males incubate 13-27% of bobwhite nests (Stoddard 1931, Klimstra and Roseberry 1975, Curtis et al. 1993, Suchy and Munkel 1993, Burger et al. 1995*b*, DeMaso et al. 1997). Male incubation could result from death of, or nest abandonment by, females (Klimstra and Roseberry 1975, Suchy and Munkel 1993), but evidence identifying mechanisms resulting in male incubation and its consequences for the population are lacking.

Our objectives were to: (1) estimate bobwhite survival and investigate its relationship to suplemental feeding,(2) estimate causes and rates of bobwhite mortality and investigate its relationship to supplemental feeding, (3) investigate the relationship between predator abundance and bobwhite mortality.

STUDY AREA

Research was conducted on the Packsaddle WMA in southern Ellis County, Oklahoma (Fig. 1). Cole et al.(1966) described the soils, ecological, and climatic conditions in the county. DeMaso et al. (1997) provided details on the Packsaddle WMA study area.

METHODS

Study Treatments

The study area consisted of 2, 283.3 ha areas that were separated by a 242.8 ha buffer area. The treatment area had a feeder located near the center of every 8.1 ha and the control area contained no supplemental feeders. Thirty-two, 55 gallon, gravity-flow feeders were set on wooden pallets and filled with sorghum. Feeders were fenced to exclude livestock.

Trapping

We trapped bobwhites in baited funnel traps (Stoddard 1931:442, Wilbur 1967) during the entire study period (1 October 1991 to 1 October 1996). Additional birds were caught throughout the study period by netting roosting coveys (Labisky 1968). Bobwhites were classified by age and sex (Rosene 1969:44-54). Captured bobwhites were fitted with a leg band and a radio transmitter weighing <7 g. Radio transmitters were only placed on bobwhites ≥6 weeks old. Necklace-style transmitters were similar to those described by Shields et al. (1982). However, some transmitters had an adjustable neck loop, an adjustable body loop, a mortality sensor, and a ≤26-cm antenna (Holohil Systems Ltd., Carp, Ont.; Wildl. Materials Inc., Carbondale, Ill.).

We located birds ≥6 days/week using hand-held 3-element yagi antennas. Occasionally, aircraft were used to locate widely dispersed individuals. Radiomarked bobwhites were approached on foot until radio signal strength indicated the observer was about 20 m from the adult, and the bird was then circled to determine an exact location. When a mortality signal was detected, transmitters were immediately located and the proximate cause of mortality was determined from evidence at the recovery site and condition of the transmitter (Dumke and Pils 1973). When we recovered an entire bird and the cause of mortality could not be identified, they were necropsied at the Oklahoma Animal Disease Diagnostic Laboratory at Oklahoma State University, Stillwater.

Survival Rates

We calculated mean daily survival rates by month for the entire study period. We used the Kaplan-Meier method (Kaplan and Meier 1958) to estimate mean daily survival rates by month, generalized to the staggered entry case (Pollock et al. 1989*b*,*c*). We assummed birds were randomly sampled, survival times for individuals were independent, left-censored individuals (Stagger entered) had survival distributions similar to previously marked individuals, and causes for censoring (i.e., radio failure) were independent of the birds fate. Birds had to survive ≥7 days after radiomarking to ensure survival probabilites were not biased by trapping or handling (Pollock et al. 1989*b*,*c*; White and Garrott 1990).

We right-censored birds because of transmitter failure or loss or they survived beyond the period of interest. We excluded birds that died or were censored ≤7 days of marking (Kurzejeski et al. 1987; Pollock et al. 1989*b*,*c*). Birds that survived the entire month were reintroduced as a new independent observation at the beginning of the next month. We also, reintroduced birds that had been censored and were recaptured and radiomarked again as new independent observations.

We used the log-rank test extended to the staggered entry case to compare monthly survival distribution between treatments (Pollock et al. 1989*b*).

Rates and Causes of Mortality

We estimated crude cause-specific mortlity rates as the percentage of the total population of radiomarked individuals, who had the same cause of mortality. Cause-specific mortality categories included avian predation, mammalian predation, hunting, capture, missing, adverse weather, and unknown. Birds that survived ≥7 days post-capture, but died when they were recaptured were considered capture mortalities. Hunting mortalities were determined from hunters checking out at the Packsaddle WMA headquarters after controlled hunts. Hunting occured on Tuesdays and Saturdays with ≤60 hunters participating either day, from 1 December to 15 February.

We used a *Z*-test to compare cause-specific mortality between treatments and treatments by month.

Bobwhite Density

Bobwhite density was estimated using line transect methodology (Burnham et al. 1980). Each treatment had 2 sites with 4 transects 800 m long, 300 m apart, and oriented north-south. Transects were ridden on horseback repeatedly during the first and last 3 hours of daylight (Guthery 1988) until cumulative length ridden was 32

km/site per year. Transects are ridden in October to give a reproductive (pre-hunt) density and in March to give an over-winter (post-hunt) density. Each time a covey flushed, the number of birds and right-angle distance from the transect to the point where the covey flushed were recorded. Covey centers were determined at the point of first sighting for coveys that did not flush. Line-transect data were analyzed according to Guthery (1988) using the computer program CKBOB (F. S. Guthery, Caeser Kleberg Wildlife Research Institute, Texas A&I Univ., pers. commun.). The Fourier series detection model was used because it satisfies criteria of model and pooling robustness, efficiency, and shape (Burnham et al. 1980).

Relative Predator Abundance (Mammalian Scent Stations and Incidental Raptor Sightings)

To determine relative abundance of mammalian predators, we conducted monthly scent station surveys from December 1991 through September 1996. We created 9, 3-m diameter, circles throughout the control area and 11 circles throughout the feeder area. Every month, all vegetation removed from each site. The site was then raked and about 3-5 cm of agricultural lime was placed evenly on the circle to provide an optimum tracking surface. An FAS scent disk (Pocatello Supply Depot, Pocatello, ID 83201) was placed in the center of the circle. This occurred approximately one-half hour before sunset. At approximately one-half hour after sunrise each site was checked for tracks and the scent disk was removed.

We calculated percent visitation rates of the mammalian predators by the following formula:

# of tracks observed/# of operable station nights.

Percent visitation rates were transformed using an arc-sin transformation. We tested for differences, using a general linear model, between the feeder and control areas and mammalian predator abundance.

To determine relative avian predator abundance, we conducted daily incidental sightings of potential avian bobwhite predators from December 1991 through September 1996. We report three different groups of raptors: 1)accipiter, 2)buteo, and 3)harrier. We censored owls because most owl activity did not coincide with our observation period, leading to a low number of observations. Falcons were also censored due to very few number of sightings. The incidental sighting data consisted of date, time observation period began, time observation period ended, species observed, time of observation, and an X and Y UTM coordinate to determine if the observation occurred on the supplementally fed or control area. We assumed equal observation periods on both areas.

To determine differences in raptor sightings between areas we used a general linear model. We used Pearson correlations (r) to test for correlations between mean monthly avian predator sightings and mean monthly avian crude bobwhite mortality. Pearson correlations were also used to test between arc-sin visitation rates and mammalian bobwhite quail mortality.

Reproduction

We studied bobwhite reproductive activity by monitoring radiotagged adults during the 1992-1996 breeding seasons. Radiomarked adult bobwhite were monitored throughout the year, but data for this report were collected during spring and summer (April-October). Radiomarked bobwhites were located ≥1 per day until the reproductive season approached.

Nest locations were detected by daily, identical, consecutive locations of radiomarked birds. Attempts to visually locate nests were made during morning and evening feeding periods, while the adults were away from the nest. Only when telemetry demonstrated the bird was away from the nest, was the nesting area approached. Care was taken not to disturb the bird, nest, and vegetation in the nesting area while searching for nests. Once a radiomarked bird's nest was found, we counted the eggs in the nest, flagged each nest >8 m in at least three locations (due to seasonal grazing of livestock, we had to periodically re-flag nest sites), estimated initial date of incubation (with detailed notes of radiomarked bird's daily activities), and estimated date of hatching. As the hatching date approached, the bird was located >2 times/day to confirm hatch date. If a nest was determined to be depredated, destroyed, abandoned, or otherwise unsuccessful, a thorough investigation of the nest site was conducted. Evidence such as tracks, egg shell remains, evidence of snake trails, and nest disturbance characteristics was obtained in an attempt to determine the cause of the nest failure. After the radiomarked bird and brood vacated the nest site, nests were examined to determine hatching success.

A destroyed nest was any nest in which >1 egg was destroyed and to which the adult did not return to incubate the remainder of the clutch. Abandoned nests were those for which all eggs remained intact, but a surviving adult did not complete incubation. Successful nests were those for which >1 egg hatched. A destroyed nest were those for which a radiomarked bird was killed by a predator or the radiomarked bird was killed during incubation of that nest and no subsequent adult bird incubated the nest at any time.

We estimated nesting rate, bird success, renesting rate, and double-clutching rate for each sex on the basis of a spring population of birds radiomarked prior to and surviving after 1 April (Stanford 1972*a*, Burger et al. 1995*b*). We were able to

detect nesting activity shortly after the "spring break-up" when females and males were closely associated in a similar area during mid-afternoon hours. However, we gave each bird a grace period before attempting to locate their nesting sites. We determined the onset of incubation when the nesting bird held in an area for (>2 days). Nesting rate was the percentage of birds in the spring population that attempted to incubate ≥1 nest. Bird success was the percentage of birds in the spring population that successfully hatched ≥1 nest. We lost contact with 12 of 235 females and 6 of 295 males during the breeding season due to radio failure, loss, or movement that we were unable to find by airplane. We excluded these birds from estimates of nesting rate and bird success. Radiomarked birds that moved off of the study area and were found several miles away were included in our estimates. We defined renesting as birds failing on an initial incubation attempt and subsequently incubating a second nest. We defined double-clutching rate as the percentage of birds successful on an initial nesting attempt that incubated ≥1 subsequent nest. We also included triple attempts by females in our estimates, but did not have any triple-clutch successes.

Methods for estimating bobwhite chick survival are provided by DeMaso et al. 1997.

Since our study was not replicated in different areas, we will stress descriptive statistics. All statistical tests were considered significant at the $P < 0.05$ level.

RESULTS

We radiomarked 1,115 bobwhites that survived ≥7 days; 579 birds on the control area and 536 on the feeder treatment. Three hundred and nine birds were radiomarked, but survived ≤7 days. We right-censored 214 (19.2%) observations because radio failure or battery expiration (55) and birds that slipped their radiotransmitters (159).

Survival Rates

Mean monthly daily survival rates (n = 5 years/month) were higher on the feeder area during February, March, May, October, November, and December (Table 1, Fig. 2). During February mean monthly daily survival rates differed ($Z = -1.66$, $P = 0.0485$) between the feeder area and the control area (Table 1). However, the P-value was just barely significant. Average annual survival of bobwhites on the control area was 17.9% and 21.0% on the feeder area. Annual survival pooled over areas was 19.8%.

Rates and Causes of Mortality

Pooled over years, avian predation mortalities accounted for 36.9% (n = 176) of total mortalities on the control area, mammalian

predation 28.3% (n = 135), hunting 14.1% (n = 67), capture 10.1% (n = 48), missing (birds we lost contact with) 5.2% (n = 25), unknown 3.3% (n = 16), and adverse weather 2.1% (n = 10)(Table 2). On the feeder area, avian predation mortalities 44.1% (n = 191) of the total mortalities, mammalian predation 22.9% (n = 99), hunting 15.5% (n = 67), missing 6.9% (n = 30), unknown 5.3% (n = 23), capture 4.6% (n = 20), and adverse weather 0.7% (n = 3) (Table 3) when pooled over years. Rates and causes of mortality pooled over years and areas are reported in Table 4.

Overall, cause-specific mortality was similar between areas during the 5 year study period (Table 5). However, avian predation was higher (Z = -2.22, P = 0.0132) on the feeder area (Table 5). Total mortalities on the control area were lowest during April and highest in December (Table 6). On the feeder area, total mortalities were lowest in February and highest during January (Table 6). Total mortalities differed ($P \leq 0.0158$) during January, February, April, and December between areas (Table 6).

Bobwhite Density

Mean bobwhite density was similar (t = -1.07, P = 0.2919) between the supplementally fed (0.44 birds\acre) and control (0.31 birds\acre)areas (Table 7). Density differed (F = 2.67, P = 0.0299) among years and between seasons (F = 20.60, P = 0.0001). Mean covey size was similar (t = 0.19, P = 0.8525) between the supplementally fed (10.2 birds\covey) and control (10.5 birds\covey) areas (Table 7). Mean covey size was similar (F = 1.30, P = 0.2798) among years, but differed (F = 40.56, P = 0.0001) between seasons.

Relative Predator Abundance (Mammalian Scent Stations and Incidental Raptor Sightings)

Overall, the sightings of accipiter hawks [mostly Cooper's hawks (*Accipiter cooperii*) and sharp-shinned hawks (*A. Striatus*)] on the feeder area (n = 168) were higher (F = 4.40, P = 0.0387) than the control area (n = 115). Buteo [mostly red-tailed hawks (*Buteo jamaicensis*)] sightings were similar (F = 0.31, P = 0.5799) between areas (feeder = 452, control = 478), and northern harrier (*Circus cyaneus*) sightings were similar (F = 1.22, P = 0.2730), but had a tendency to be higher on the feeder area (n = 286) than on the control area (n = 230)(Table 8).

Average monthly visitation rates were similar between areas for bobcat (*Lynx rufus*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), swift fox (*Vulpes velox*), and striped skunk (*Mephitis mephitis*)(Table 9).

When the areas were pooled there was no correlation between mean monthly avian bobwhite mortality and mean monthly sightings of accipiters (r = 0.16356, P = 0.4451), and buteos (r = 0.15113, P = 0.4809). However, avian bobwhite mortality was strongly correlated (r = 0.73469, P = 0.0001) with northern harrier sightings, and with pooled mean monthly avian sightings (r = 0.66317, P = 0.0004)(Table 10). There were no correlations between the mean monthly visitation rates of bobcats (r = -0.18668, P = 0.3824), gray foxes (r = -0.15717, P = 0.4633), raccoons (r = -0.24403, P = 0.2505), and swift foxes (r = -0.03619, P = 0.8667), and mean monthly mammalian crude bobwhite mortality. Coyote mean monthly visitation rates were negatively correlated (r = -0.56991, P = 0.0036) with mean monthly mammalian crude bobwhite mortality.

Reproduction

We used 223 female and 289 male radiomarked bobwhites to estimate reproductive effort and success. Of these, 120 females and 46 males incubated 211 nests. Of the nests monitored, our earliest nest incubation date was 17 April and the latest being 17 September. Our earliest hatch date was 26 May and latest hatch date being 1 October. However, unmarked adults were observed with chicks that hatched earlier than 17 April and as late as 1 November.

Six females incubated 3 nests in one breeding season (Table 1). Seventeen of 61 (27.9%) females that were successful on their initial nest attempted to incubate a second clutch. We had 3 instances where a male took over incubation after females were killed by mammals. The males were successful 2 of 3 (66.7%) attempts.

Of bobwhites that were alive on 1 April (n = 223 F, n = 289 M), 37.7% of females and 9.3% of males successfully hatched >1 nest (Table 11). Seventy percent of females (n = 73) and 14.4% of males (n = 111) surviving until 1 October successfully hatched >1 nest. Nesting females that survived the nesting period incubated a mean of 1.5 nests (SE = 0.08), and males incubated 1.04 nests (SE = 0.04)(Table 12). The number and percentage of incubated nests (n = 218) and successful nests (n = 113) resulting from female first attempts was 59.6% (n = 130), female renesting after initial nest failure 11.5% (n = 25), female second clutches 8.3% (n = 18), and male incubation 21.1% (n = 46). Of successful nests, female first nests represented 56.6%, female renests 13.3%, female double-clutch attempts 6.2%, and male-incubated nests 23.9% of all nests located (Table 13). Mean clutch size for female-incubated first nests was 14.2 (SE = 0.3), female-incubated second attempts 12.1 (SE = 0.5), female-incubated third attempts 11.5 (SE = 0.7), and for male-incubated nests the mean clutch size was 12.9 (SE = 0.4)(Table 14). Of those birds that failed on an initial nesting attempt, 54.1% of

females (n = 37) and 1 of 46 males incubated >1 renest. Of those females that were successful on their initial nesting attempt, 27.9% attempted second nests and 14.8% females had success on a double-clutch. Nest survival rate of female-incubated first nest was 42.6% (SE = 0.4), female-incubated renests 63.7% (SE = 0.6), male-incubated nests 50.7% (SE = 0.7), and all nests 44.6% (SE = 0.6)(Table 15).

Fate of radiomarked bobwhite nests was 53.4% successful and 46.6% unsuccessful (Table 16). Abandonment represented 7.2%, nest depredation 85.6%, adult mortality 6.2%, and other was 1.0%. Nest depredation consisted of snake [mostly bullsnakes (*Pituophis melanoleucus*) and prairie rat snakes (*Elaphe spp.*)] 41.2%, mammalian (raccoon and striped skunk) 27.8%, unknown 11.3%, cattle 2.1%, capture 2.1%, and radio collar (radio collar caused the death of the incubating bird) 1.0%. Adult mortality consisted of mammals (coyotes, bobcats, gray foxes) and raptors (buteos, accipiters, and northern harriers). Of these, mammalian mortality was 1.0% and avian mortality was 5.2%.

Results of estimating survival of bobwhite chicks are provided in DeMaso et al. 1997.

DISCUSSION

Survival Rates

The annual survival rate of our sample (19.8%) was similar to that reported in studies using age-ratio and count data (18.0%, Marsden and Baskett 1958; 15.4%, Kabat and Thompson 1963:36; 18.8% based on age-ratios, 18.2% based on the product of fall-spring and spring-fall survival rates, Roseberry and Klimstra 1984:89). Our estimate was higher than that reported by other radio telemetry studies of bobwhite survival. Burger et al. (1995a) estimated annual survival of bobwhites in northern Missouri to be 5.3%. Curtis et al. (1988) estimated annual survival to be 6.1% for bobwhites in North Carolina. Curtis et al. (1988) reported a higher survival (25.7%) for a unhunted, radiomarked sample in Florida. Pollock et al. (1989a) estimated bobwhite annual survival (16.7%) in Florida using band recovery models.

Differences between our estimates and those reported in the literature may be because of differences in techniques, locations and/or time, and climate. The effect of radio transmitters on bobwhite survival needs further investigation.

We were unable to find any other studies that researched the effect of quail feeders on survival. Our data suggest that supplemental feeding has little or no effect on the survival of northern bobwhites in western Oklahoma.

Rates and Causes of Mortality

Predation was the primary cause of bobwhite mortality on the study area. The overall rates and causes of mortality were similar to the results of other studies in Illinois (Roseberry and Klimstra 1984), southern Alabama(Sermons 1987), North Carolina (Curtis et al. 1988), northern Florida (Mueller et al. 1988), and northern Missouri (Burger et al. 1995a). Our observations of high avian predation during the fall and increased mammalian predation during the spring are consistent with Curtis et al. (1988) and Burger et al. (1995a). Our data suggest that cause-specific mortality was similar between feeder and control areas, except for avian predation which was higher on the feeder area. We feel that quail feeders tended to concentrate quail around feeders, thus increasing predation when food was limiting during the 5 year study period. This observation is consistent with what has been speculated by other biologists (Guthery 1986:54-56). We could not find any other estimates of cause-specific bobwhite mortality on supplementally fed areas in the literature.

We did not find any mortalities caused by disease. Our data do not support the hypothesis (Guthery 1986:54) that quail feeders may augment the transmission of avian diseases (through digestion of diseased birds feces, while feeding) by concentrating bobwhites around quail feeders.

Bobwhite Density

We found no difference in bobwhite density between the control and feeder areas. Our results are consistent with researchers in south Texas (Doerr 1988, Kane 1988) and in Alabama (Keeler 1959). However, Frye (1954) reported an increase in bobwhite numbers from using automatic quail feeders. We agree with Guthery (1997) that food supplementation is a neutral management practice.

Relative Predator Abundance (Mammalian Scent Stations and Incidental Raptor Sightings)

The number of the accipiter and harrier sightings, by month, varies according to time of year (Fig. 3). Our data show that northern harrier sightings and overall raptor sightings correlate strongly with the bobwhite avian mortality (Fig. 4, Fig. 5, Fig. 6). When these raptors are at their highest density, any element that may concentrate them in one area could have causal mortality effects on prey populations. Although it may seem that predator control could be an easy solution Leopold (1933:252) points out that predator prey relationships are complex and some predators prey on other predators which could result as a benefit to the game. The control of some predators on bobwhites may not have much of an effect on bobwhite populations. On the feeder area accipiter hawks were significantly higher in abundance and avian

bobwhite mortality correlated with these sightings (Table 10). The northern harrier sightings had a tendency to be higher on the feeder area, but was not significant, and avian bobwhite mortality strongly correlated with northern harrier sightings (Fig 7). Buteo sightings did not correlate with quail avian mortality, nor were they different between fed and control areas (Table 8). From our observations, it appears that concentration of bobwhite predators (mainly avian) on the feeder area occurs mainly during the fall, winter, and early spring (Fig. 4, Fig. 6). We feel during the summer period supplemental feed would not be beneficial due to a high number of insects and other food reserves.

The percent visitation rates of all the mammals reported did not differ between areas and only coyotes had correlations with bobwhite mammalian mortality; however, it was negative. At this time we have no explanation for this observation. It appears percent visitation rates have no effect on bobwhite mammalian mortality (Fig 8).

Since raptor sightings correlate with quail avian mortality, and supplemental feeders may have a tendency to concentrate avian predators, we would not recommend supplementally feeding bobwhites. We feel efforts should be concentrated more on sound bobwhite quail management, such as, habitat manipulation to provide proper food and cover. Provided the food supply is varied and ample and the habitat has escape cover then mortality of bobwhites should be minimal (Leopold 1933:240-244).

Reproduction

Although bobwhites experience low individual nest success, the "majority" of pairs are eventually successful through renesting (Stoddard 1931:24-25). In western Oklahoma, we observed 54% of females alive 1 April incubated ≥1 nest but only 38% hatched ≥1 nest. Suchy and Munkel (1993) reported that 62% of females alive on 1 April incubated a nest and similarly reported 39% successfully hatched a nest. Burger et al. (1995*b*) reported 66% incubation and 40% hatching of females alive 15 April. Our study showed that females (73%) surviving until 1 October incubated ≥1 nest and 70% hatched ≥1 nest. Burger et al. (1995*b*) reported much higher survival (95%) in Missouri, but a similar hatching rate of 74%. Success rates in Iowa (76%; Suchy and Munkel 1993) and Florida (72%; DeVos and Mueller 1993) were more comparable to our study.

Like Burger et al.(1995*b*), we also had one female that incubated three nests during the same nesting season. She incubated her first and third nest attempts with both being successful while a male incubated her second nest attempt but was unsuccessful. Suchy and Munkel (1993) reported in Iowa that on one occasion they observed both a male and female sharing incubation of the same clutch. We had similar findings during one of the nesting

periods where we observed both male and female bobwhites sharing incubation simultaneously on two different occasions. In 1994, we observed a radiomarked female that left a radiomarked male on her first clutch of eggs, moved off of the study area a distance of >8 miles with another radiomarked male and left him to incubate her second nest attempt before succumbing to predation a week later. If radiomarked birds exhibit lower survival than unmarked birds, our estimates of nesting rate and success rate, and those of Curtis et al. (1993), Suchy and Munkel (1993), and Burger et al. (1995*b*), could be possibly biased.

Renesting effort.--The extent and frequency of renesting is poorly understood and has not been well documented. Stoddard (1931:224-225), Dimmick (1974), Klimstra and Roseberry (1975:33), Suchy and Munkel (1993), and Burger et al. (1995*b*) have assumed that females will attempt ≥1 renest. We observed that of those birds that failed on an initial nesting attempt, 34% of females and 2% of males incubated ≥1 renest. Burger et al. (1995*b*) reported that 58% of females and 9% of males incubated ≥1 renest of those birds that failed on an initial nesting attempt. Roseberry and Klimstra (1984:83) suggest that bobwhites high annual rate of female nesting success, in relation to average nest success (34%), would require that females initiate 2-3 nests/season. The findings of Burger et al. (1995*b*) are consistent with this hypothesis. In northern Missouri they reported females had a mean nest rate of 1.8 and males 1.0 nests that survived the nesting season. Our findings are similar Burger et al. (1995*b*) where an average of 1.5 nests/female and 1 nest/male survived the nesting season. Some nests probably went undetected due to depredation during the laying period, so our estimates of reproductive success are conservative.

Double clutching.--We found 28% of all females that hatched their initial nest attempted to lay a second clutch. Burger et al. (1995*b*) reported in northern Missouri, that 26% of the females attempted to lay a second clutch after a successful initial attempt. Roseberry and Klimstra (1984:83) speculated that although double clutching might occur in wild populations, it was not necessary to replace populations under normal conditions. Sermons and Speake (1987) reported that 4 of 16 radiomarked females with broods renested after the 7-35-day-old broods disappeared. Suchy and Munkel (1993) observed 33% of all females that hatched nests before 3 July attempted a second clutch. Curtis et al. (1993) reported that 4 radiomarked females renested after abandoning their first broods. They observed an additional female that incubated a second nest after her first brood was adopted by a radiomarked male. We also observed brood adoption and abandonment. DeMaso et al. (1997) reported that 17% of all adult birds that hatched nests were found to have a net gain of chicks over the entire brood-rearing period. The majority (25.4%) of this net gain of chicks was between 20 to 39 days old. It was not uncommon for us to observe >14 day old chicks unaccompanied by an adult bird. Burger et al. (1995*b*) reported unmarked 7-28-day-old broods that were not

accompanied by an adult. Suchy and Munkel (1993) reported similar survival between radiomarked chicks in abandoned broods and those accompanied by adults. We agree with Stanford (1972b) and Burger et al. (1995*b*) that second clutches are a regular component of bobwhite reproduction and annual variation in the rate of second clutches could substantially affect production.

Male incubation.--We believe male incubation of 21% of all nests, and 24% of successful nests was very important to total reproductive effort and production of nesting bobwhites. Burger et al. (1995*b*) reported 28% of all nests and 29% of successful nests were incubated by males. The importance of male incubation should not be overlooked. We feel males have an important role in reproduction and nesting effort during critical periods of population fluctuations. It has always been assumed that males incubated only after the death of a female (Stoddard 1931:31). Suchy and Munkel (1993) along with Burger et al. (1995*b*) believe that in most cases the female is free to continue breeding while a male incubates the clutch. We tend to agree with this assumption based on the percentage of males that incubate nests and the percentage of females that attempt second clutches and or renest attempts. If a male is left to incubate, the female is afforded a second or even third chance of nesting. We have observed such behavior from female bobwhites in western Oklahoma. If the sex ratio is biased toward males this will lead to more breeding chances not only for females but for males as well. Since we observed 21% male incubation of all nests, this would leave a significant number of females to attempt a double/triple clutch during the breeding season. Burger et al. (1995*b*) states that although incubation and brood rearing reduce survival, males that would otherwise be unmated because of the skewed sex ratio could play a role in production by assuming parental care. Incubating or brood rearing males may also benefit if they are responsible for fertilizing some or all of the eggs laid in subsequent nests of the female who abandoned the clutch.

Reproductive strategies.--Of the nesting attemptsmonitored, females incubated 60% and males incubated 21% of all nests. Female-incubated renests represented 12% and female-second clutch attempts represented 8% of all nests. Female-incubated first nests contained an average of 14.2 eggs, male-incubated nests had a mean of 12.9 eggs, female-incubated second attempts had a mean of 12.1 eggs, and female-incubated third attempts contained an average of 11.5 eggs. Renests, second clutches, third clutches, and male-incubated nests provide a reproductive strategy that bobwhites can employ based on the fate of the first nest. If a female is successful on her first attempt she has the option of raising the brood, abandoning the brood, or leaving them to an adoptive parent (male or female). This allows the opportunity to start a second nest which may also be left to a male to incubate enabling her to attempt a third clutch. Burger et al. (1995*b*) suggests studies that observe only female reproductive activity underestimate

reproductive effort and production by ≤33%. Late season first attempts may also be underestimating the number of clutches a female has actually attempted. These late season nests may actually be renests, second attempts, or even third attempts. This may possibly underestimate reproductive effort and production by the end of the nesting season.

A discussion pertaining to bobwhite chick survival is provided by DeMaso et al. 1997.

Management Implications

Although bobwhite populations have declined in Oklahoma, our research suggests that food availability is not the cause of the decline. Supplemental feeding of bobwhites in western Oklahoma did not increase survival or the number of birds on the feeder area. Avian predation of bobwhites was higher on the feeder area.

Bobwhite managers should focus management activities on habitat manipulation. Management activities such as prescribed burning, strip discing, and cattle grazing can be used to augment the late fall and winter supply of bobwhite food. Also, these techniques can increase the amount of insects available to bobwhites during the spring and summer. These activities should take place in close proximity (≤100 m)to woody (escape) cover to minimize predation.

The decline of the bobwhite throughout its range is a complex problem. Many factors may be responsible for suppressing bobwhite numbers, however, it is unlikely that any one individual factor is cause for the decline. Further research is needed to understand these factors, their mechanisms, and dynamics that are responsible for bobwhite population fluctuations.

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Table 1. Mean monthly daily survival rate estimates (s) for northern bobwhites on control and feeder areas by month on Packsaddle WMA, Ellis County, Oklahoma, 1991-96.

	Treatment					
	Control		Feeder			
Month	(s)	SE	(s)	SE	Z	P[a]
January	0.76	0.036	0.74	0.038	0.38	0.6480
February	0.78	0.035	0.86	0.033	-1.66	0.0485
March	0.88	0.030	0.91	0.022	-0.81	0.2090
April	0.94	0.021	0.90	0.022	1.32	0.9066
May	0.87	0.028	0.92	0.021	-1.43	0.0764
June	0.91	0.026	0.90	0.024	0.28	0.6103
July	0.89	0.027	0.88	0.026	0.27	0.6064
August	0.92	0.020	0.91	0.023	0.33	0.6293
September	0.96	0.015	0.92	0.022	1.50	0.9332
October	0.91	0.021	0.93	0.020	-0.69	0.2451
November	0.86	0.025	0.90	0.020	-1.25	0.1057
December	0.75	0.035	0.79	0.029	-0.88	0.1894

[a]P-value for 1-tailed Z-test, H_o: Survival rates on the control treatment are greater than or equal to survival rates on the feeder treatment.

Table 2. Number (n) and percentage (%) of crude cause-specific mortalities of radiomarked northern bobwhites on the control treatment, pooled over years, by month on Packsaddle WMA, Ellis County, Oklahoma, 1991-96.

	Cause-Specific Mortality															
	Capture		Hunting		Mammal		Missing		Avian		Unknown		Weather		Total	
Month	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
January	9	16.7	12	22.1	9	16.7	1	1.9	22	40.7	1	1.9	0	0.0	54	100.0
February	4	8.0	7	14.0	9	18.0	1	2.0	20	40.0	1	2.0	8	16.0	50	100.0
March	1	3.1	0	0.0	10	31.2	0	0.0	18	56.3	2	6.3	1	3.1	32	100.0
April	3	15.0	0	0.0	5	25.0	3	15.0	8	40.0	1	5.0	0	0.0	20	100.0
May	6	20.0	0	0.0	13	43.3	0	0.0	9	30.0	2	6.7	0	0.0	30	100.0
June	2	9.1	0	0.0	10	45.4	1	4.6	9	40.9	0	0.0	0	0.0	22	100.0
July	3	10.7	0	0.0	11	39.3	2	7.1	12	42.9	0	0.0	0	0.0	28	100.0
August	6	21.4	0	0.0	12	42.9	0	0.0	9	32.1	1	3.6	0	0.0	28	100.0
September	1	4.4	0	0.0	7	30.4	7	30.4	7	30.4	1	4.4	0	0.0	23	100.0
October	2	5.1	0	0.0	13	33.3	7	18.0	16	41.0	1	2.6	0	0.0	39	100.0
November	7	14.3	1	2.0	20	40.8	2	4.1	15	30.7	3	6.1	1	2.0	49	100.0
December	4	3.9	47	46.1	16	15.7	1	1.0	31	30.4	3	2.9	0	0.0	102	100.0
Total	48	10.1	67	14.1	135	28.3	25	5.2	176	36.9	16	3.3	10	2.1	477	100.0

Table 3. Number (n) and percentage (%) of crude cause-specific mortalities of radiomarked northern bobwhites on the feeder treatment, pooled over years, by month on Packsaddle WMA, Ellis County, Oklahoma, 1991-96.

	Cause-Specific Mortality															
	Capture		Hunting		Mammal		Missing		Avian		Unknown		Weather		Total	
Month	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
January	1	1.4	29	41.4	6	8.6	3	4.3	28	40.0	3	4.3	0	0.0	70	100.0
February	0	0.0	2	10.0	2	10.0	0	0.0	14	70.0	1	5.0	1	5.0	20	100.0
March	3	11.1	0	0.0	3	11.1	0	0.0	19	70.4	2	7.4	0	0.0	27	100.0
April	5	15.6	0	0.0	6	18.8	2	6.2	18	56.3	1	3.1	0	0.0	32	100.0
May	1	3.9	0	0.0	10	38.3	1	3.9	13	50.0	1	3.9	0	0.0	26	100.0
June	5	20.8	0	0.0	11	45.8	1	4.2	4	16.7	3	12.5	0	0.0	24	100.0
July	2	5.4	0	0.0	18	48.7	2	5.4	13	35.1	2	5.4	0	0.0	37	100.0
August	1	3.7	0	0.0	7	25.9	1	3.7	16	59.3	2	7.4	0	0.0	27	100.0
September	1	3.9	0	0.0	5	19.2	6	23.0	13	50.0	1	3.9	0	0.0	26	100.0
October	0	0.0	0	0.0	12	30.8	7	17.9	15	38.5	5	12.8	0	0.0	39	100.0
November	1	2.4	5	12.2	7	17.2	6	14.6	21	51.2	0	0.0	1	2.4	41	100.0
December	0	0.0	31	48.4	12	18.7	1	1.6	17	26.6	2	3.1	1	1.6	64	100.0
Total	20	4.6	67	15.5	99	22.9	30	6.9	191	44.1	23	5.3	3	0.7	433	100.0

Table 4. Number (n) and percentage (%) of crude cause-specific mortalities of radiomarked northern bobwhites pooled over treatments and years, by month on Packsaddle WMA, Ellis County, Oklahoma, 1991-96.

	Cause-Specific Mortality															
	Capture		Hunting		Mammal		Missing		Avian		Unknown		Weather		Total	
Month	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
January	10	8.1	41	33.1	15	12.1	4	3.2	50	40.3	4	3.2	0	0.0	124	100.0
February	4	5.7	9	12.9	11	15.7	1	1.3	34	48.6	2	2.9	9	12.9	70	100.0
March	4	6.8	0	0.0	13	22.0	0	0.0	37	62.7	4	6.8	1	1.7	59	100.0
April	8	15.4	0	0.0	11	21.2	5	9.6	26	50.0	2	3.8	0	0.0	52	100.0
May	7	12.5	0	0.0	23	41.1	1	1.8	22	39.3	3	5.3	0	0.0	56	100.0
June	7	15.2	0	0.0	21	45.7	2	4.3	13	28.3	3	6.5	0	0.0	46	100.0
July	5	7.7	0	0.0	29	44.6	4	6.1	25	38.5	2	3.1	0	0.0	65	100.0
August	7	12.7	0	0.0	19	34.6	1	1.7	25	45.5	3	5.5	0	0.0	55	100.0
September	2	4.1	0	0.0	12	24.5	13	26.5	20	40.8	2	4.1	0	0.0	49	100.0
October	2	2.6	0	0.0	25	32.1	14	17.9	31	39.7	6	7.7	0	0.0	78	100.0
November	8	8.9	6	6.7	27	30.0	8	8.9	36	40.0	3	3.3	2	2.2	90	100.0
December	4	2.4	78	47.0	28	16.9	2	1.2	48	28.9	5	3.0	1	0.6	166	100.0
Total	68	7.5	134	14.7	234	25.7	55	6.0	367	40.3	39	4.3	13	1.4	910	100.0

Table 5. Number (n) and percentage (%) of crude cause-specific mortalities of radiomarked northern bobwhites pooled over months and years, by cause and treatment, on Packsaddle WMA, Ellis County, Oklahoma, 1991-96.

	Treatment					
	Control		Feeder			
Cause	n	%	n	%	Z	P
Capture	48	10.1	20	4.6	3.16	0.9992
Hunting	67	14.1	67	15.5	-0.60	0.2743
Mammal	135	28.3	99	22.9	1.86	0.9686
Missing	25	5.2	30	6.9	-1.08	0.1401
Avian	176	36.9	191	44.1	-2.22	0.0132
Unknown	16	3.3	23	5.3	-1.49	0.0681
Weather	10	2.1	3	0.7	1.77	0.9616
Total	477	100.0	433	100.0		

Table 6. Number (n) and percentage (%) of total crude monthly mortalities of radiomarked northern bobwhites, by month and treatment, pooled over years on Packsaddle WMA, Ellis County, Oklahoma, 1991-96.

	Treatment					
	Control		Feeder			
Month	n	%	n	%	Z	P
January	54	11.3	70	16.2	-2.15	0.0158
February	50	10.4	20	4.6	3.56	0.0002
March	32	6.7	27	6.2	0.31	0.3783
April	20	4.2	32	7.4	-2.08	0.0188
May	30	6.3	26	6.0	0.19	0.4247
June	22	4.6	24	5.5	-0.62	0.2676
July	28	5.9	37	8.6	-1.58	0.0571
August	28	5.9	27	6.2	-0.19	0.4247
September	23	4.8	26	6.0	-0.80	0.2119
October	39	8.2	39	9.0	-0.43	0.3336
November	49	10.3	41	9.5	0.40	0.3446
December	102	21.4	64	14.8	2.58	0.0049
Total	477	100.0	433	100.0		

Table 7. Estimates of northern bobwhite covey size and density (D = no./acre), by year, season, and treatment, Packsaddle WMA, Ellis County, Oklahoma, 1991-97.

Year Season Treatment	n[a]	Covey size X	SE	D	SE	CV
1991						
Fall						
Control-north	14	15.1	1.66	1.19	0.53	45.8
Control-south	11	15.9	2.08	0.75	0.44	58.7
Control-pooled	25	15.5	1.28	0.97	0.35	36.2
Feeder-north	11	13.8	2.88	1.30	0.59	45.0
Feeder-south	11	14.3	2.17	0.67	0.40	59.1
Feeder-pooled	22	14.1	1.76	0.99	0.35	35.4
Pooled	47	14.8	1.06	0.99	0.25	25.2
1992						
Spring						
Control-north	3	9.3	2.19	0.15	0.15	100.0
Control-south	4	10.5	1.85	0.17	0.12	71.8
Control-pooled	7	10.0	1.31	0.16	0.11	71.3
Feeder-north	3	12.3	0.88	0.06	0.06	100.0
Feeder-south	6	8.5	2.50	0.27	0.15	56.1
Feeder-pooled	9	9.8	1.75	0.19	0.09	47.5
Pooled	16	9.9	1.11	0.16	0.06	36.9
Fall						
Control-north	8	15.6	0.60	0.74	0.30	41.0
Control-south	5	21.4	1.03	0.11	0.11	100.0
Control-pooled	13	17.9	0.96	0.37	0.13	35.7
Feeder-north	9	16.7	1.11	0.79	0.46	58.0
Feeder-south	7	14.1	0.67	0.44	0.31	70.8
Feeder-pooled	16	15.6	0.75	0.61	0.27	44.9
Pooled	29	16.6	0.62	0.41	0.10	23.2
1993						
Spring						
Control-north	2	7.0	0.00	0.07	0.05	70.7
Control-south	2	14.5	1.50	0.08	0.08	100.0
Control-pooled	4	10.8	2.25	0.08	0.05	60.2
Feeder-north	2	5.5	0.50	0.09	0.09	100.0
Feeder-south	0	0.0	0.00	0.00	0.00	0.0
Feeder-pooled	2	5.5	0.50	0.04	0.04	100.0
Pooled	6	9.0	1.81	0.06	0.03	48.2
Fall						
Control-north	5	13.4	3.75	0.32	0.20	62.1
Control-south	9	8.0	1.75	0.50	0.27	53.5
Control-pooled	14	9.9	1.81	0.39	0.19	47.6
Feeder-north	12	14.8	0.52	0.77	0.25	31.8
Feeder-south	4	13.0	1.29	0.20	0.12	58.3
Feeder-pooled	16	14.3	0.52	0.49	0.14	28.0
Pooled	30	12.3	0.96	0.41	0.10	25.4
1994						
Spring						
Control-north	4	13.0	1.23	0.20	0.12	58.3
Control-south	0	0.0	0.00	0.00	0.00	0.0
Control-pooled	4	13.0	1.23	0.10	0.06	58.3
Feeder-north	1	8.0	[b]	[b]	[b]	[b]
Feeder-south	5	4.8	2.22	0.11	0.08	69.0
Feeder-pooled	6	5.3	1.89	0.08	0.05	58.7
Pooled	10	8.4	1.72	0.08	0.03	42.3

Table 7. Continued.

Year Season Treatment	n[a]	Covey size X	SE	D	SE	CV
Fall						
Control-north	4	17.0	1.87	0.36	0.18	50.9
Control-south	9	14.0	0.65	0.88	0.31	35.6
Control-pooled	13	14.9	0.79	0.64	0.20	30.6
Feeder-north	5	15.6	1.89	0.49	0.25	51.1
Feeder-south	5	9.0	2.98	0.42	0.27	63.8
Feeder-pooled	10	12.3	2.00	0.39	0.15	38.5
Pooled	23	13.8	0.99	0.51	0.12	24.0
1995						
Spring						
Control-north	2	4.0	1.00	0.02	0.02	100.0
Control-south	0	0.0	0.00	0.00	0.00	0.0
Control-pooled	2	4.0	1.00	0.01	0.01	100.0
Feeder-north	3	4.3	2.40	0.14	0.11	80.9
Feeder-south	0	0.0	0.00	0.00	0.00	0.0
Feeder-pooled	3	4.3	2.40	0.07	0.06	80.9
Pooled	5	4.2	1.36	0.03	0.03	74.3
Fall						
Control-north	3	12.3	5.24	0.19	0.19	100.0
Control-south	3	20.0	0.58	0.31	0.18	57.8
Control-pooled	6	16.2	2.92	0.21	0.10	47.5
Feeder-north	4	13.5	0.87	0.42	0.30	70.9
Feeder-south	2	11.5	2.50	0.18	0.18	100.0
Feeder-pooled	6	12.8	0.95	0.30	0.18	58.1
Pooled	12	14.5	1.55	0.23	0.12	50.8
1996						
Spring						
Control-north	0	0.0	0.00	0.00	0.00	0.0
Control-south	0	0.0	0.00	0.00	0.00	0.0
Control-pooled	0	0.0	0.00	0.00	0.00	0.0
Feeder-north	2	14.0	1.00	0.07	0.07	100.0
Feeder-south	1	10.0	0.00	0.00	0.00	0.0
Feeder-pooled	3	12.7	1.50	0.06	0.05	71.2
Pooled	3	12.7	1.50	0.03	0.02	71.2
Fall						
Control-north	5	9.6	2.25	0.38	0.19	49.4
Control-south	2	16.5	1.50	0.52	0.37	71.0
Control-pooled	7	11.6	2.03	0.36	0.19	52.3
Feeder-north	8	17.6	1.35	1.93	0.74	38.5
Feeder-south	3	13.7	6.74	0.43	0.34	78.9
Feeder-pooled	11	16.6	2.13	1.17	0.42	35.5
Pooled	18	14.6	1.50	0.74	0.22	29.4
1997						
Spring						
Control-north	5	6.8	1.50	0.46	0.28	60.5
Control-south	2	9.0	5.00	0.14	0.11	80.9
Control-pooled	7	7.4	1.56	0.29	0.13	42.5
Feeder-north	4	2.5	0.50	0.23	0.12	52.9
Feeder-south	7	7.9	1.70	0.62	0.27	42.8
Feeder-pooled	11	5.9	1.34	0.40	0.18	45.8
Pooled	18	6.3	0.98	0.32	0.09	28.0

[a]Number of right-angle distance measurements.
[b]No estimate possible, because of only 1 right-angle measurement.

Table 8. Number of raptor sightings (n) by group, and mean number of sightings ($\bar{x}$) per month, on feeder and control treatments pooled over years, and by treatment pooled over months and years, on Packsaddle WMA, Ellis County, Oklahoma, 1991-96.

Month	Treatment					
	Feeder		Control			
Group	n	$\bar{x}$	n	$\bar{x}$	F	P
January						
Accipiter	20	4.0	17	3.4	0.14	0.7225
Buteo	40	8.0	55	11.0	3.00	0.1215
Harrier	61	12.2	41	8.2	0.60	0.4593
February						
Accipiter	18	3.6	7	1.4	3.97	0.0815
Buteo	27	5.4	38	7.6	1.17	0.3100
Harrier	64	12.8	44	8.8	0.52	0.4914
March						
Accipiter	10	2.0	3	0.6	3.50	0.0983
Buteo	26	5.2	30	6.0	0.07	0.7969
Harrier	41	8.2	24	4.8	1.25	0.2968
April						
Accipiter	15	3.0	7	1.4	0.74	0.4147
Buteo	25	5.0	31	6.2	0.26	0.6239
Harrier	15	3.0	7	1.4	0.96	0.3553
May						
Accipiter	16	3.2	6	1.2	1.09	0.3276
Buteo	33	6.8	19	3.8	2.59	0.1465
Harrier	4	0.8	0	0.0	1.00	0.3466
June						
Accipiter	7	1.4	9	1.8	0.11	0.7440
Buteo	33	6.6	22	4.4	0.50	0.5004
Harrier	0	0.0	0	0.0		

Table 8. Continued.

Month	Treatment					
	Feeder		Control			
Group	n	$\bar{x}$	n	$\bar{x}$	F	P
July						
Accipiter	6	1.2	5	1.0	0.03	0.8619
Buteo	52	10.4	25	5.0	1.59	0.2431
Harrier	1	0.2	0	0.0	1.00	0.3466
August						
Accipiter	12	2.4	5	1.0	0.03	0.8619
Buteo	33	6.6	22	4.4	0.50	0.5004
Harrier	1	0.2	2	0.4	0.20	0.6667
September						
Accipiter	16	3.2	18	3.6	0.04	0.8465
Buteo	68	13.6	50	10.0	0.38	0.5539
Harrier	9	1.8	3	0.6	0.90	0.3706
October						
Accipiter	11	2.8	18	4.5	1.32	0.2936
Buteo	41	10.3	60	15.0	0.74	0.4232
Harrier	11	2.8	12	3.0	0.05	0.8291
November						
Accipiter	18	4.5	9	2.3	1.61	0.2516
Buteo	39	9.8	50	12.5	0.71	0.4316
Harrier	44	11.0	45	11.3	0.00	0.9568
December						
Accipiter	19	3.8	11	2.2	1.73	0.2249
Buteo	34	6.8	46	9.2	0.58	0.4692
Harrier	35	7.0	52	10.4	1.28	0.2914
Pooled						
Accipiter	168	2.9	115	2.0	4.40	0.0387
Buteo	452	7.8	478	8.2	0.31	0.5799
Harrier	286	4.9	230	4.0	1.22	0.2730

Table 9. Mean monthly visitation rates of mammals to scent stations on Packsaddle WMA, Ellis County, Oklahoma, 1991-96.

Mammal	Visitation rate		F	P
	Control	Feeder		
Bobcat	0.7%	0.8%	0.07	0.7974
Coyote	7.2%	8.7%	1.26	0.2660
Gray Fox	3.7%	4.6%	0.92	0.3403
Raccoon	2.3%	3.3%	0.24	0.6289
Striped skunk	6.3%	7.4%	0.05	0.8306
Swift fox	3.2%	3.1%	0.33	0.5690

Table 10. Correlation coefficents (*r*) between cause-specific bobwhite crude mortality and indices of relative avian and mammalian predator abundance, by treatment, pooled over years, on Packsaddle WMA, Ellis County, Oklahoma, 1991-96.

	Treatment					
	Feeder		Control		Areas Pooled	
Predator	*r*	*P*	*r*	*P*	r	P
Accipiter	0.62	0.0323	0.15	0.6320	0.16356	0.4451
Buteo	-0.05	0.8896	0.29	0.3683	0.15113	0.4809
Harrier	0.66	0.0184	0.81	0.0013	0.73469	0.0001
Avian Pooled	0.65	0.0218	0.64	0.0239	0.54910	0.0055
Bobcat	-0.05	0.8642	-0.38	0.2266	-0.18668	0.3824
Coyote	-0.46	0.1277	-0.72	0.0078	-0.56991	0.0036
Gray Fox	-0.24	0.4420	-0.05	0.8769	-0.15717	0.4633
Raccoon	-0.17	0.5895	-0.26	0.4201	-0.24403	0.2505
Swift Fox	0.49	0.1030	-0.51	0.0904	-0.03619	0.8667
Striped Skunk	0.26	0.4116	0.29	0.3644	0.21638	0.3098
Mammal Pooled	-0.17	0.5870	-0.42	0.1706	-0.33587	0.1086

Table 11. Reproductive effort and success of radiomarked male and female northern bobwhite on Packsaddle WMA, Ellis County, Oklahoma, 1992-96.

Year	Sex	n	Nesting Rate		Success Rate		Renest[a] Rate		Renest Success		Double-clutch[b] Rate		Double-clutch[c] Success	
			n	%	n	%	n	%	n	%	n	%	n	%
1992	F	58	32	55.2	23	39.7	4		2		7		4[d]	
	M	69	3	4.3	2	2.9	0		0		0		0	
		127	35	27.6	25	19.7	4	26.7	2	13.3	7	41.2	4	6.6
1993	F	42	21	50.0	15	35.7	4		3		1		1	
	M	64	10	15.6	6	9.4	0		0		0		0	
		106	31	29.2	21	19.8	4	40.0	3	30.0	1	9.1	1	9.1
1994	F	49	29	59.2	18	36.7	4		2		1		1	
	M	58	9	15.5	4	6.9	0		0		0		0	
		107	38	35.5	22	20.6	4	28.6	2	14.3	1	6.7	1	6.7
1995	F	31	16	51.6	8	25.8	2		1		2		0	
	M	43	4	9.3	3	7.0	0		0		0		0	
		74	20	27.0	11	14.9	2	22.2	1	11.1	2	28.6	0	0.0
1996	F	43	22	51.2	20	46.5	6		4		6		3	
	M	55	20	36.4	12	21.8	1		0		0		0	
		98	42	42.9	32	32.7	7	70.0	4	40.0	6	50.0	3	25.0
92-96	F	223	120	53.8	84	37.7	20	34.5	12	20.7	17	27.4	9	14.5
	M	289	46	15.9	27	9.3	1	1.7	0	0.0	0	0.0	0	0.0
Total		512	166	32.4	111	21.7	21	36.2	12	20.7	17	27.4	9	14.5

[a] No. And % of those birds that failed on their initial nesting attempt and subsequently renested.

[b] No. And % of those F that successfully hatched their first clutch and subsequently renested.

[c] No. And % of those F that successfully hatched their first clutch and subsequently hatched a second.

[d] Pooled F with three attempts and had a double-clutch success with her first and third attempts.

Table 12. Number of birds that nested (%), number that successfully nested (%), and mean number of nests incubated per nesting bird for radiomarked male and female northern bobwhites that survived until 1 October, on Packsaddle WMA, Ellis County, Oklahoma, 1992-96.

	Sex											
	F						M					
Year	n	Nesting rate	Number of nests	Success rate	x̄ nests/ nesting rate	SE	n	Nesting rate	Number of nests	Success rate	x̄ nests/ nesting rate	SE
1992	16	13	22	13	1.7	0.21	26	2	2	1	1.0	0.00
1993	16	10	13	11	1.3	0.15	21	6	6	5	1.0	0.00
1994	17	11	14	10	1.3	0.14	26	5	5	2	1.0	0.00
1995	12	9	13	8	1.4	0.18	25	4	4	3	1.0	0.00
1996	12	10	18	9	1.8	0.20	13	8	9	5	1.1	0.13
Total	73	53(72.6)	80	51(69.9)	1.5	0.08	111	25(22.5)	26	16(14.4)	1.04	0.04

Table 13. Number and percentage (%) of incubated nests (n = 218) and successful nests (n = 113) of radiomarked northern bobwhites resulting from female first attempts, female renesting after initial nest failure, female second clutches, and male incubation, on Packsaddle WMA, Ellis County, Oklahoma, 1992-96.

	Nest type			
Nest Type Year	F-incubated first nest	F-incubated renest	Second clutch renest	M-incubated nest
Incubated nests				
1992	35 (68.6)	6 (11.8)	7 (13.7)	3 (5.9)
1993	21 (58.3)	5 (13.9)	1 (2.8)	10 (27.8)
1994	30 (68.2)	4 (9.1)	1 (2.3)	9 (20.5)
1995	19 (70.4)	2 (7.4)	2 (7.4)	4 (14.8)
1996	25 (41.7)	8 (13.3)	7 (11.7)	20 (33.3)
Total	130 (59.6)	25 (11.5)	18 (8.3)	46 (21.1)
Successful nests				
1992	18 (72.0)	2 (8.0)	3 (12.0)	2 (8.0)
1993	10 (50.0)	4 (20.0)	0 (0.0)	6 (30.0)
1994	16 (70.0)	2 (8.7)	1 (4.3)	4 (17.4)
1995	8 (66.7)	1 (8.3)	0 (0.0)	3 (25.0)
1996	12 (36.4)	6 (18.2)	3 (9.1)	12 (36.4)
Total	64 (56.6)	15 (13.3)	7 (6.2)	27 (23.9)

Table 14. Mean clutch size for female-incubated first nests, female-incubated renests, and male incubated nests of radiomarked northern bobwhites, on Packsaddle WMA, Ellis County, Oklahoma, 1992-96.

	Nest type											
	F-incubated first atts.			F-incubated second atts.			F-incubated third atts.			M-incubated nests		
Year	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
1992	28	14.5	0.5	8	12.1	0.8	2	11.5	0.5	3	13.7	1.5
1993	15	14.9	0.7	5	13.8	1.9	1	10.0	0.0	9	14.1	0.9
1994	23	14.7	0.7	5	12.6	1.2	0			9	13.0	1.0
1995	17	12.7	1.0	3	10.0	1.5	0			4	12.3	0.9
1996	22	14.1	0.4	14	11.7	0.7	1	13.0	0.0	18	12.2	0.5
Total	105	14.2	0.3	35	12.1	0.5	4	11.5	0.7	43	12.9	0.4

Table 15. Estimated nest survival rate (S) of female-incubated first nests, female-incubated renests, and male-incubated nests of radiotagged bobwhites, on Packsaddle WMA, Ellis County, Oklahoma, 1992-96.

	Nest Type											
	F-incubated first nests			F-incubated renests			M-incubated nests			All nests		
Year	n	S	SE	n	S	SE	n	S	SE	n	S	SE
1992	35	48.8	0.7	6	24.8	2.9	3	65.6	1.8	44	50.2	0.7
1993	21	32.7	1.4	5	68.4	1.6	10	51.8	1.4	36	39.0	1.0
1994	30	45.4	0.9	4	19.3	4.7	9	37.9	1.8	43	43.6	0.8
1995	18	37.3	1.3	2	42.0	3.6	4	61.6	2.0	24	40.6	1.1
1996	25	41.4	1.0	8	28.8	3.6	20	52.2	1.0	53	46.0	0.7
Total	129	42.6	0.4	25	63.7	0.6	46	50.7	0.7	200	44.6	0.6

Table 16. Fate of nests of radiomarked northern bobwhite, on Packsaddle WMA, Ellis County, Oklahoma, 1992-96.

	Year											
	1992		1993		1994		1995		1996		Total	
Fate	n	%	n	%	n	%	n	%	n	%	n	%
Successful	25	52.1	21	58.3	22	51.2	11	45.8	32	56.1	111	53.4
Unsuccessful	23	47.9	15	41.7	21	48.8	13	54.2	25	43.9	97	46.6
Abandoned	1	4.3	1	6.7	2	9.5	1	7.7	2	8.0	7	7.2
Nest Depredation	21	91.3	13	86.7	17	80.9	12	92.3	20	80.0	83	85.6
Snake	9		8		11		4		8		40	41.2
Mammalian	9		2		2		6		8		27	27.8
Unknown	2		2		4		1		2		11	11.3
Cattle	1		0		0		0		1		2	2.1
Collar	0		0		0		0		1		1	1.0
Capture	0		1		0		1		0		2	2.1
Adult Mortality	1	4.4	1	6.6	1	4.8	0	0.0	3	12.0	6	6.2
Mammalian	1		0		0		0		0		1	1.0
Raptor	0		1		1		0		3		5	5.2
Other	0	0.0	0	0.0	1	4.8	0	0.0	0	0.0	1	1.0
Total	48	100.0	36	100.0	43	100.0	24	100.0	57	100.0	208	100.0

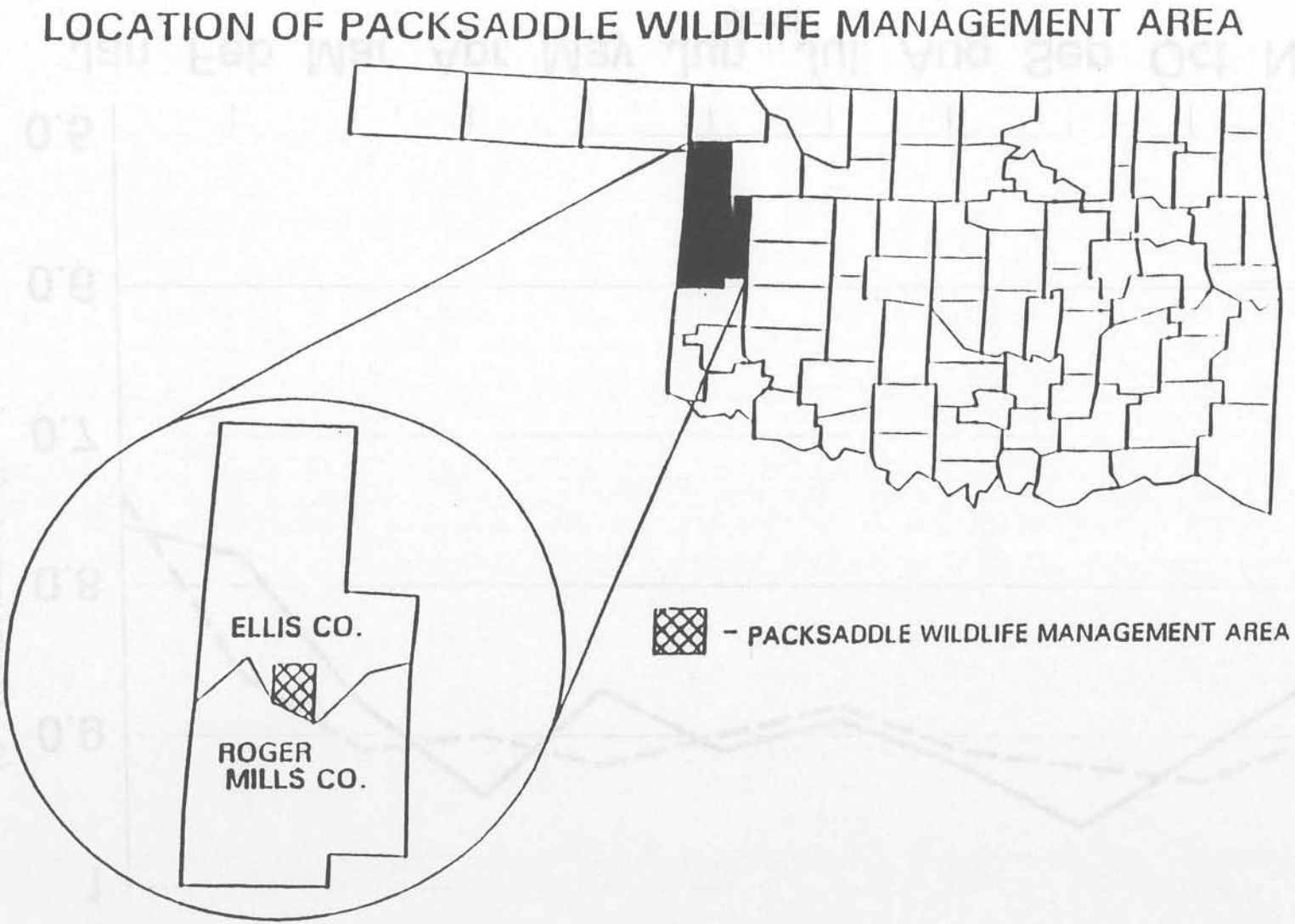

Fig. 1. Location of Packsaddle WMA, Ellis County, Oklahoma.

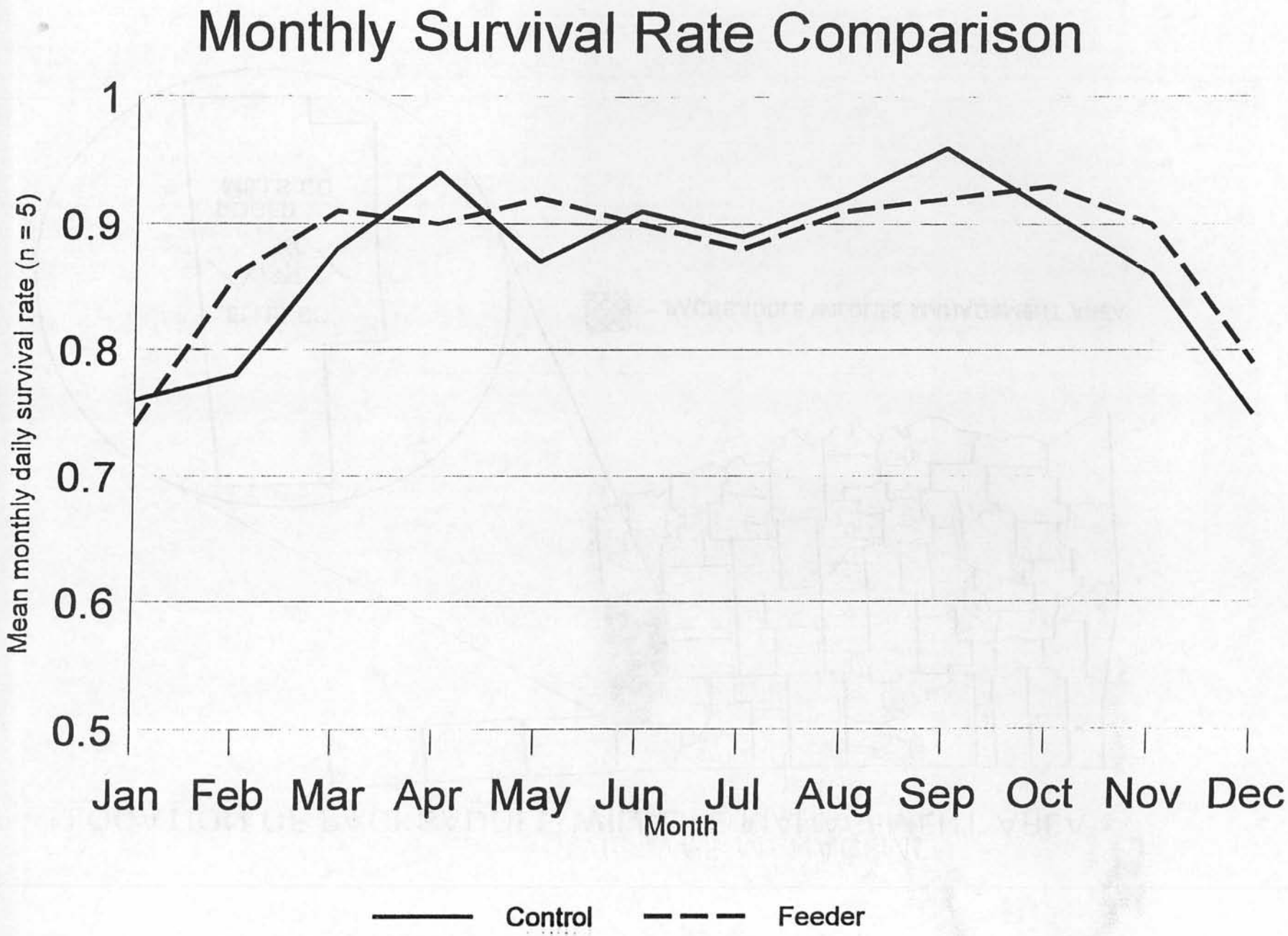

Figure 2. Trends in mean monthly-daily-survival-rate of radiomarked northern bobwhite

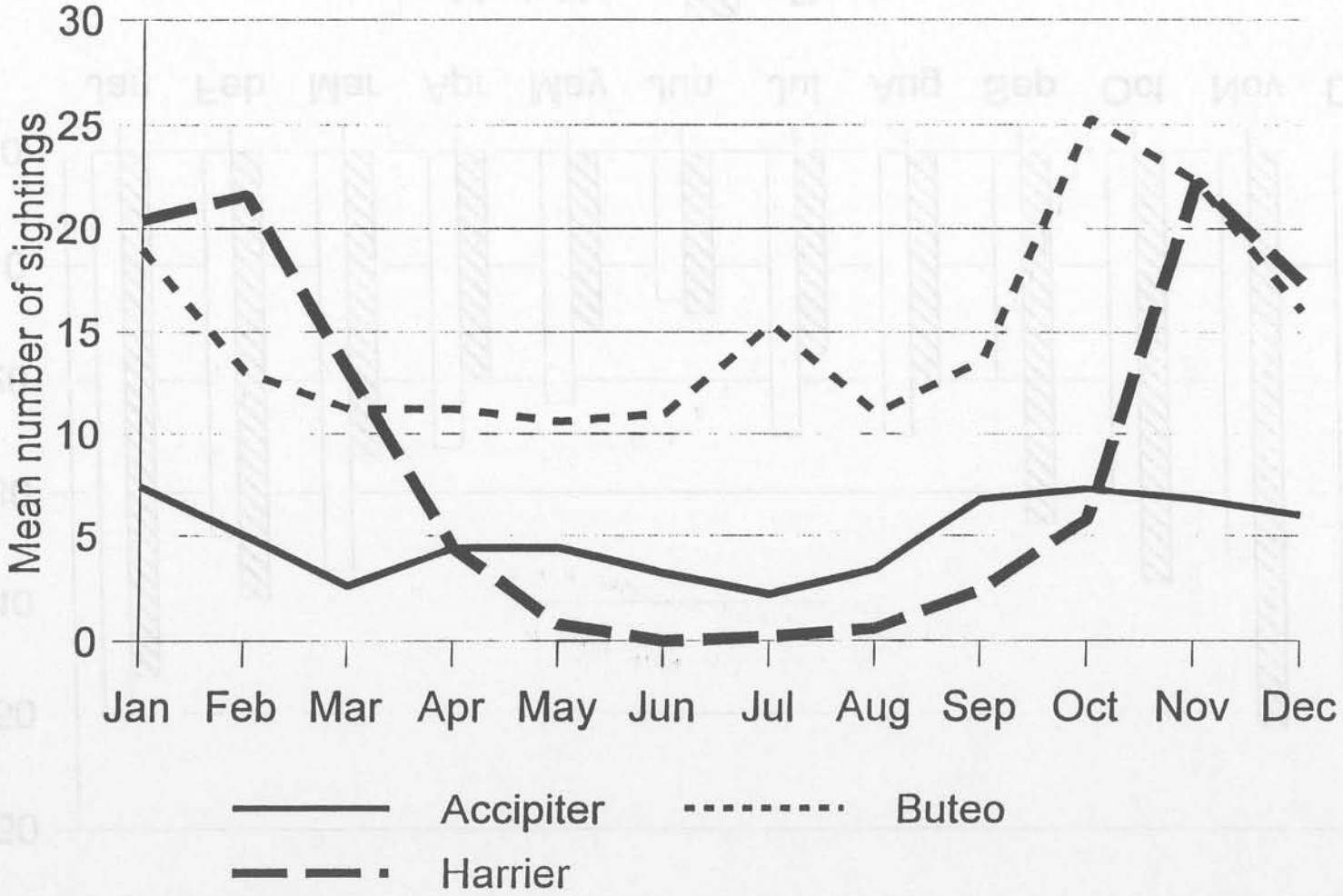

Fig. 3. Mean monthly sightings of raptors by month, areas and years pooled, from 1991-96 at Packsaddle WMA, Ellis County, Oklahoma.

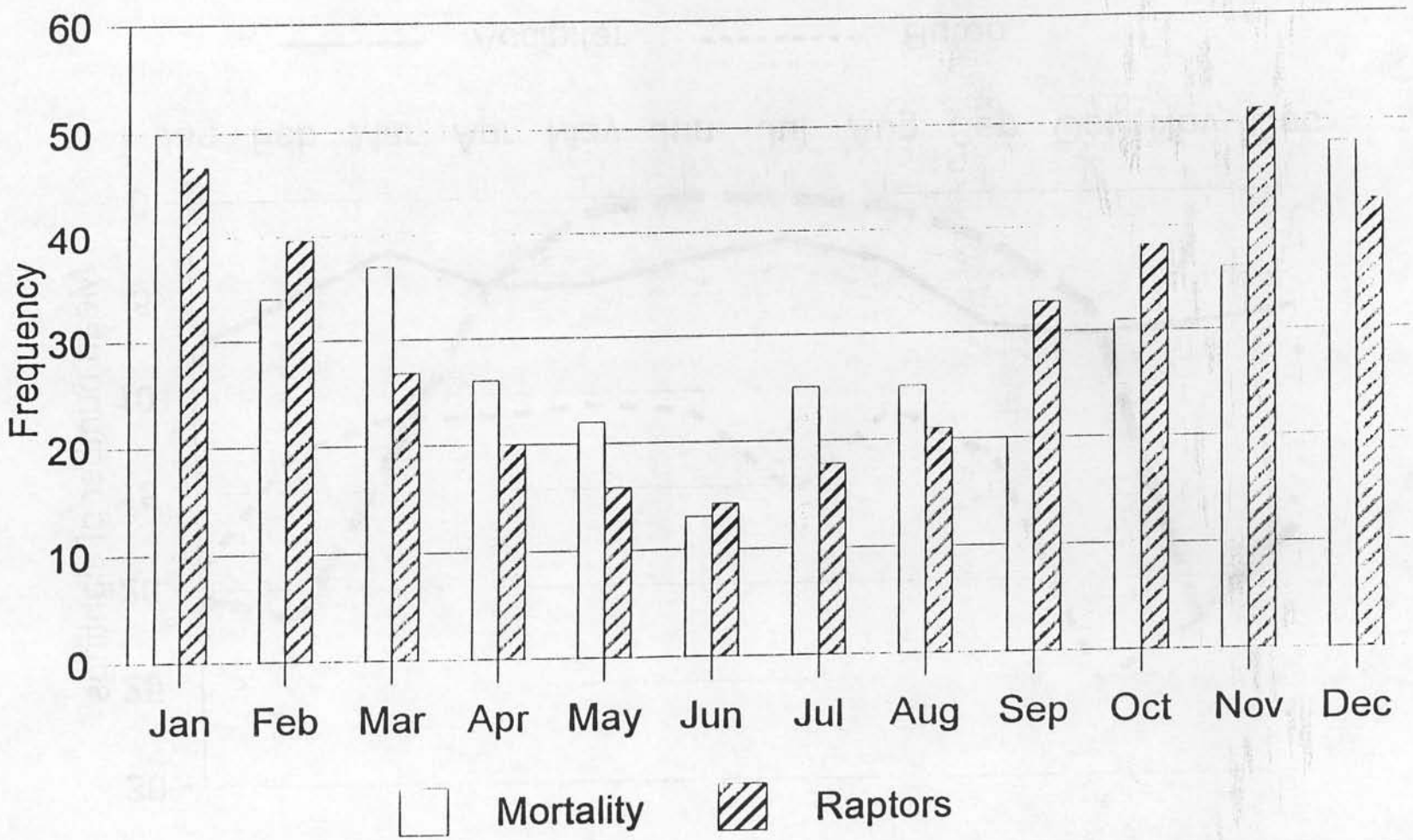

Fig. 4. Mean pooled monthly sightings of raptors and crude bobwhite mortality, by month, areas and years pooled, at Packsaddle WMA, Ellis County, Oklahoma, 1991-96.

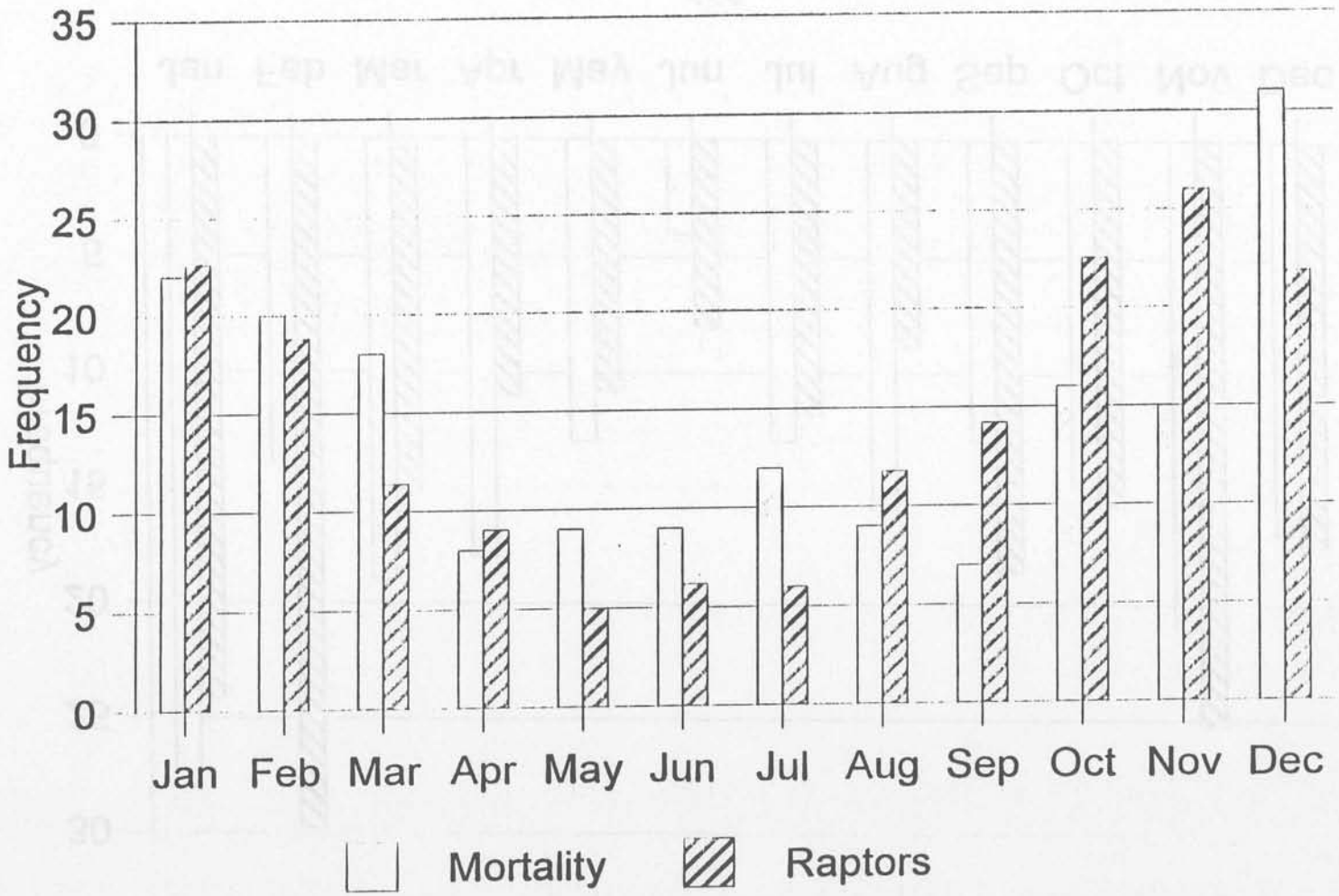

Fig. 5. Mean pooled monthly sightings of raptors and crude bobwhite mortality, by month, on control area, years pooled, at packsaddle WMA, Ellis County, Oklahoma, 1991-96.

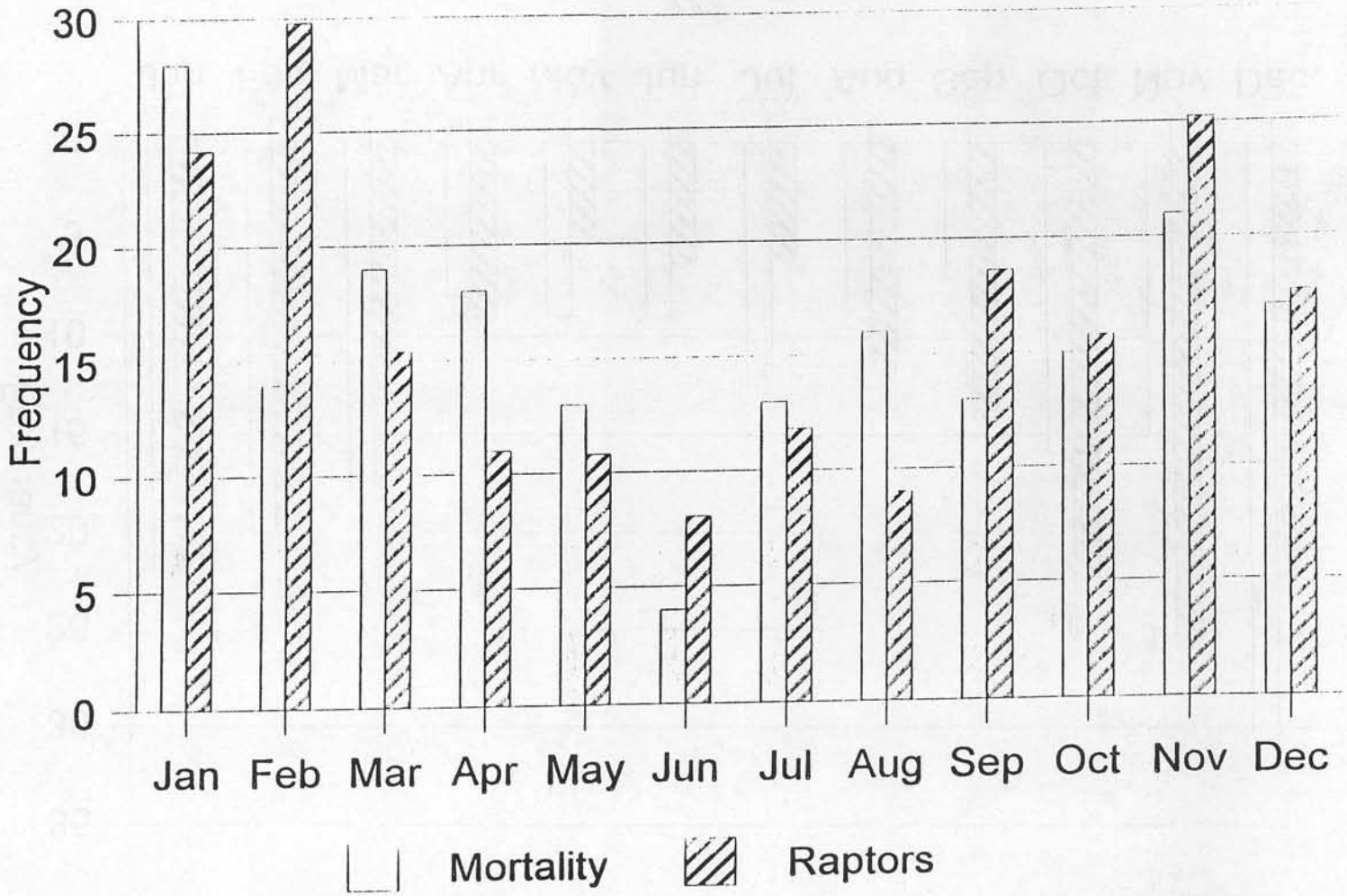

Fig. 6. Mean pooled monthly sightings of raptors and crude bobwhite avian mortality, by month, on feeder area, years pooled, at Packsaddle WMA, Ellis County, Oklahoma, 1991-96.

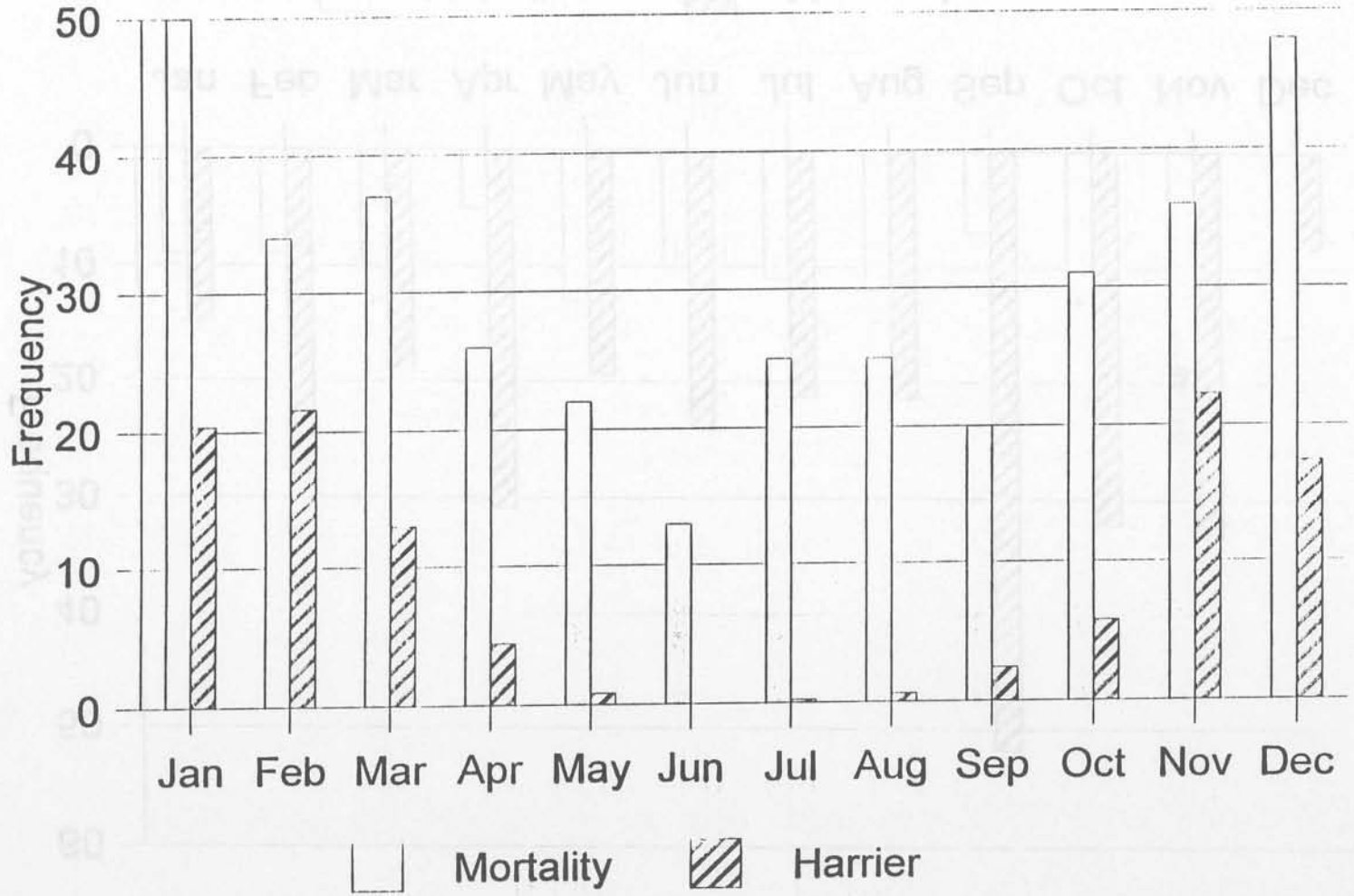

Fig. 7. Mean pooled monthly sightings of harriers and crude bobwhite avian mortality, by month, on control area, years pooled, at Packsaddle WMA, Ellis County, Oklahoma, 1991-96.

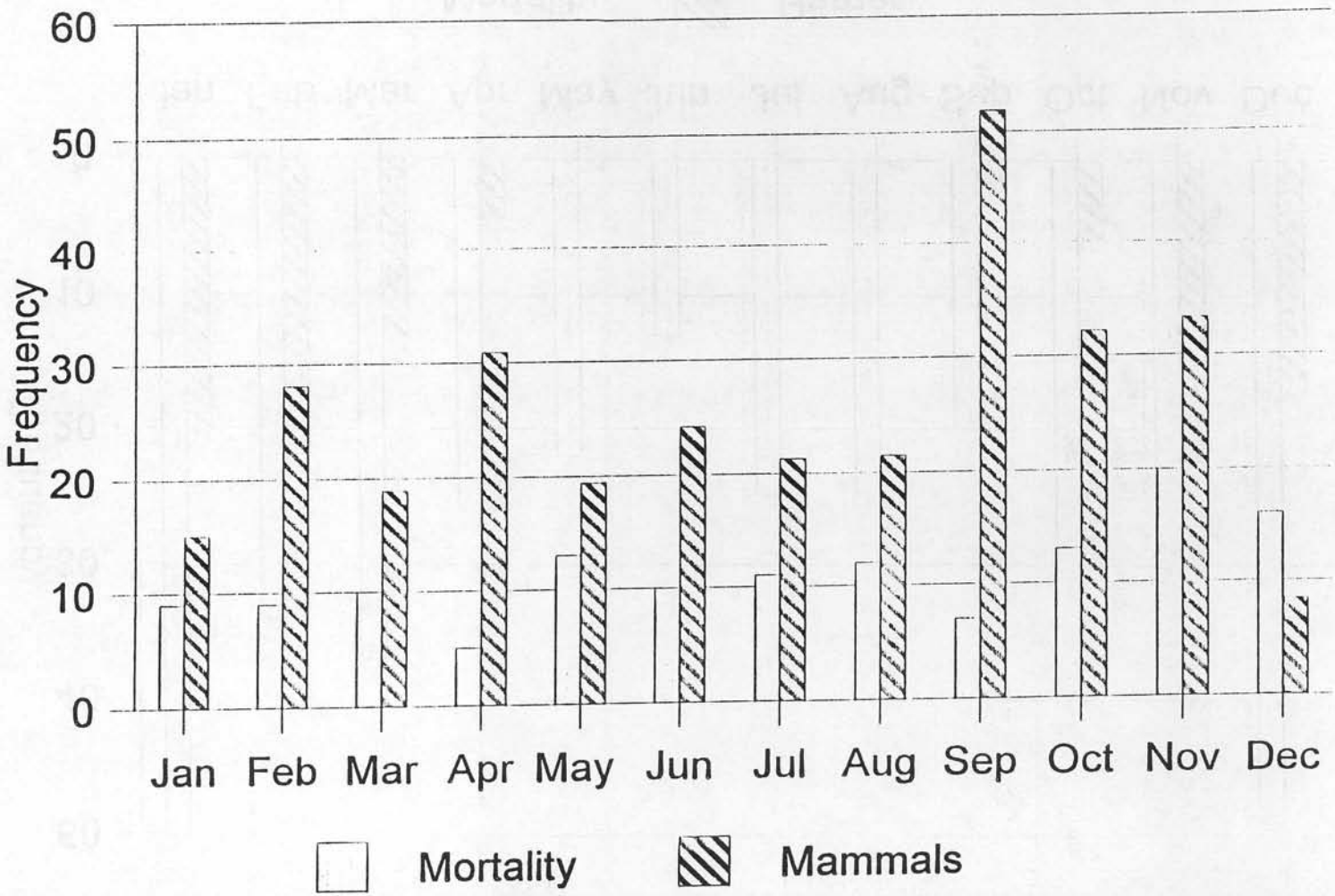

Fig. 8. Mean pooled monthly percent visitation rates of mammals and crude bobwhite mammalian mortality, by month, areas and years pooled, at Packsaeddle WMA, Ellis County, Oklahoma, 1991-96.

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