National Quail Symposium Proceedings

Volume 6 | Article 6

2009

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Morning covey-call surveys have been mentioned extensively as a practical and efficient way to estimate abundance of northern bobwhite (*Colinus virginianus*) with minimal effort. However, many of the protocol specifics such as radius of audibility and probability of a covey calling were not based on empirical data. Other limitations also existed such as variation in observers' detection capacity and calling behavior of coveys. These shortcomings limit the reliability of this survey technique. The objectives of our study were to 1) obtain an empirical estimate of radius of audibility, 2) document observer variability in estimating number of coveys heard, and 3) document calling behavior of bobwhite coveys. We found no difference in radius of audibility for areas with low-brush density (6%; 956 ± 72m; mean ± SE; *n* = 4 observers) and high-brush density (30%; 931 ± 66 m). We calculated an overall radius of audibility of 900 m (254 ha) pooled across sites. We documented considerable observer variability (CV 18-49%; *n* = 12 observers) in detecting coveys. Regarding calling behavior, we observed that 67% ± 9.0 (*n* = 30 coveys) of coveys emitted the covey-call during 2004 whereas 88% ± 7.8 (*n* = 17 coveys) of coveys emitted the covey-call during 2005. Of the coveys that called, 70% ± 10.2 in 2004 and 93% ± 6.4 in 2005 involved >1 bird calling/covey. Our findings allow for a refinement of the morning covey-call survey. We recommend obtaining site-specific radius of audibility and using a core number of observers that remain consistent from year to year.

Citation: Rusk JP, Scott JL, Hernández F, Bryant FC. 2009. Refining the morning covey-call survey to estimate northern bobwhite abundance. Pages 38 - 45 in Cederbaum SB, Faircloth BC, Terhune TM, Thompson JJ, Carroll JP, eds. Gamebird 2006: Quail VI and Perdix XII. 31 May - 4 June 2006. Warnell School of Forestry and Natural Resources, Athens, GA, USA.

Key words: morning covey call, northern bobwhite, radius of audibility, survey

Introduction

Northern bobwhites (*Colinus virginianus*; hereafter, bobwhite) are highly social animals whose communication repertoire consists of a wide variety of calls (Stoddard 1931, Stokes 1967). Calls can be classified into general categories based on purpose: reproduction, group movement, and predator avoidance (Collias 1960). The most frequently heard calls regard reproduction and group-movement. Reproduction calls include the familiar *bob-white* and caterwauling calls (Stoddard 1931, Stokes 1967). These calls are issued primarily by males during the breeding season to attract mates or communicate with other males (Stoddard 1931, Stokes 1967). The most commonly heard group-movement call is the covey-call (a *koi-lee* or *hoy*) and is used for reuniting scattered coveys (Stokes 1967). Covey-calls can be heard during daylight hours after flushing a covey and during early-morning hours when coveys leave their night roost at the onset of sunrise (Stokes 1967). Guthery (1986) speculated that bobwhites issued the call at dawn to reunite coveys that had been scattered during the night. From a management perspective, the *bob-white* and *koi-lee* calls have been particularly helpful because they have allowed for estimation of bobwhite abundance (Stoddard 1931, Bennitt 1951, Guthery 1986, DeMaso et al. 1992, Seiler et al. 2002, Wellendorf et al. 2004).

The use of the covey-call as a potential method to index bobwhites was first proposed by Stoddard (1931). He proposed that counting morning covey calls could be used as an alternative method of estimating covey abundance when dogs were not available. The method was subsequently referred to by Roseberry (1982) as a way to index relative abundance but noted that the method was not sufficient

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to provide a measure of absolute abundance. The first reference identifying the use of morning covey calls as a method to estimate density appears to be Davis (1979). He noted that if the mean covey size was obtained, morning covey calls could be used to estimate absolute density by assuming a survey area of 200 ha. Since the Davis (1979) publication, several studies have attempted to validate or refine the morning covey-call survey as a way to estimate bobwhite abundance (DeMaso et al. 1992, Seiler et al. 2002, Wellendorf et al. 2004).

The general protocol of the morning covey-call survey involves establishing listening posts within the area to be surveyed and counting the number of coveys heard calling at these posts during dawn (Guthery 1986). Observers typically arrive at listening posts about 45 minutes prior to sunrise (DeMaso et al. 1992), and once coveys begin calling, observers mark the approximate location and distance of each call (Guthery 1986). Surveys are conducted for about 10-20 minutes beyond the timing of the last call (Guthery 1986, Seiler et al. 2002). Abundance is obtained by converting the index (coveys heard/point) to density (bobwhites/area) using an estimate of radius of audibility and mean covey size. Mean covey size can be readily obtained from field flushes of coveys; however, the radius of audibility is unknown. Estimates have ranged from 400 m (Roseberry 1982) to 15 km (DeMaso 1991).

Morning covey-call surveys have been used extensively to provide an estimate of bobwhite abundance (Roseberry 1982, Guthery 1986, DeMaso et al. 1992, Seiler et al. 2002, Wellendorf et al. 2004). This technique is practical and efficient for estimating densities on large areas with little effort. Guthery (1986) recommended 1 listening post per 800 ha and estimated minimal associated cost ($10-$15/listening post/day). However, because specifics of the technique have not been quantified (e.g., radius of audibility), application of the technique has been limited. Given the extensive and practical use of the technique, the objective of our study was to refine the underlying protocol of the covey-call survey. Specifically, our objectives were to 1) obtain an empirical estimate of the radius of audibility, 2) document observer variability in estimating number of coveys heard, and 3) document calling behavior (i.e., probability of calling and number of individuals/covey calling) of bobwhite coveys.

Study Area

Our study was conducted on 2 study areas in southern Texas: the Encino (Brooks County) and Santa Gertrudis (Kleberg County) Divisions of King Ranch, Inc. The Encino division was located within the Rio Grande Plains ecoregion (Gould 1975) of Texas. This ecoregion is characterized by level to rolling land that is dissected by streams flowing into the Rio Grande or the Gulf of Mexico (Scifres 1980). The average annual rainfall in this area is 40-76 cm with the greatest amount in May and June and the least in January and February (Correll and Johnston 1979). On the Encino division, we used 3 pastures (North Viboras, Loba, and Cuates) for our study. A woody cover gradient existed from north to south with the northernmost pasture, North Viboras, consisting of the greatest brush coverage ($\approx 30\%$) and the southernmost pasture, Cuates, having the least ($\approx 5\%$). Vegetation common to all 3 pastures consisted predominately of honey mesquite (*Prosopis glandulosa*), live oak (*Quercus virginiana*), granjeno (*Celtis pallida*), pricklypear cactus (*Optuntia lindheimeri*) and huisache (*Acacia smallii*). Common grasses consisted of little bluestem (*Schizachyrium scoparium*), paspalum (*Paspalum* spp.), Kleberg bluestem (*Dichanthium annulatum*), King Ranch bluestem (*Bothriochloa ischaemum*), buffelgrass (*Pennisetum ciliare*), red lovegrass (*Eragrostis secundiflora*), gulf cordgrass (*Spartina spartinum*), and sandbur (*Cencchrus incertus*). Predominant forbs included croton (*Croton* spp.), dayflower (*Commelina erecta*), partridge pea (*Chamaecrista fasciculate*), and sunflower (*Helianthus annuus*). Predominant soil types were Falfurrias, Sarita, Sauz, Loba, Quiteria, and Padrones fine sands (United States Department of Agriculture 1993).

The Santa Gertrudis division was located in the Gulf Coast Prairies and Marshes ecoregion (Gould

1975). The topography of this ecoregion is generally level with poorly drained soils (Scifres 1980). The average annual rainfall in this area is 76-127 cm with the greatest amount in May and June and the least in January and February (Correll and Johnston 1979). Brush species present in Santa Gertrudis Division were honey mesquite, live oak, lotebush (*Ziziphus obtusifolia*), blackbrush acacia (*Acacia rigidula*), Texas persimmon (*Diospyros texana*), brasil (*Condalia hookeri*), colima (*Zanthoxylum fagara*), granjeno, and huisache. Predominant grass species included silver bluestem (*Bothriochloa laguroides*), knotroot bristlegrass (*Setaria geniculata*), plains bristlegrass (*Setaria leucopila*), Kleberg bluestem, buffelgrass, and Texas cottontop (*Digitaria patens*).

Methods

Radius of Audibility

Recording of Covey-Call - In order to conduct audibility trials, we first obtained digital recordings of bobwhite coveys under natural field conditions during March 2005. We used radio-marked bobwhites from an ongoing, long-term study (South Texas Quail Research Project) to monitor covey behavior and calling. For the recording, we randomly selected 3 radio-marked bobwhites from the sample (n = 60) and located bobwhites to within 20 m 45 minutes before sunrise. When the covey-call was emitted, we recorded the call using a Sennheiser microphone (Sennheiser Electronic Corporation, Old Lyme, Connecticut) connected to a digital audio tape (DAT) recorder (Sony Corporation of America, New York, New York) and power source (Rolls PB223 Dual Phantom Power Adapter, Rolls Corporation, Murray, Utah).

We also estimated loudness (decibels) of the covey-call from captive birds. We estimated loudness of the call using a digital sound level meter (Extech 407735, Extech Instruments, Waltham, Massachusetts). We obtained estimates of the loudness of the covey-call from captive bobwhites on 3 separate occasions in order to obtain sound readings nearest the source as possible. We recorded the maximum decibel reading observed and the distance to the calling bobwhite.

Delineation of Trial Plots - We attempted to conduct audibility trials under vegetal conditions which potentially captured the minimum and maximum distance over which a covey-call could be detected. Because brush density can influence the distance sound travels, we selected listening posts (i.e., study plots) representing low-brush density (6%) and high-brush density (30%). In order to select these areas we conducted an unsupervised classification of a 1-m resolution color aerial photograph using ERDAS IMAGINE 7.0 (Leica Geosystems, Heerbrugg, Switzerland). We used woody cover, herbaceous cover, bare ground, water, and shadow as our classes. We then visually selected a point that was centered in an open area with little woody cover (low-brush density) and one that was centered in dense brush (high-brush density). The point selected was where the observers would listen for calls. Vegetation directly between the observer and the sound source has a greater effect on the distance a call is heard than the surrounding vegetation (L. Hewett, Physics Department, Texas A&M University-Kingsville, personal communication); therefore, we clipped strips from the classified image that were 40 m wide and 1300 m long radiating out in the 4 cardinal directions from these points (Figure 1). These strips corresponded to the corridor that sound would travel to reach the observers. We then calculated canopy coverage of woody plants within these 4, 40 x 1,300-m strips. The low-brush density study plot contained 6% brush canopy coverage, and the high-brush density study plot contained 30% brush canopy coverage.

Audibility Trials - We conducted audibility trials using a randomized complete block design where brush-density types (n = 2) were the experimental units and observers were the blocks (n = 4). We conducted audibility trials during November, 2005 on days with little to no breeze. Audibility trials involved 4 trained observers and 4 recording-playback assistants, which remained consistent throughout our experiment. We began each trial approximately 2 hours before sunrise to mimic

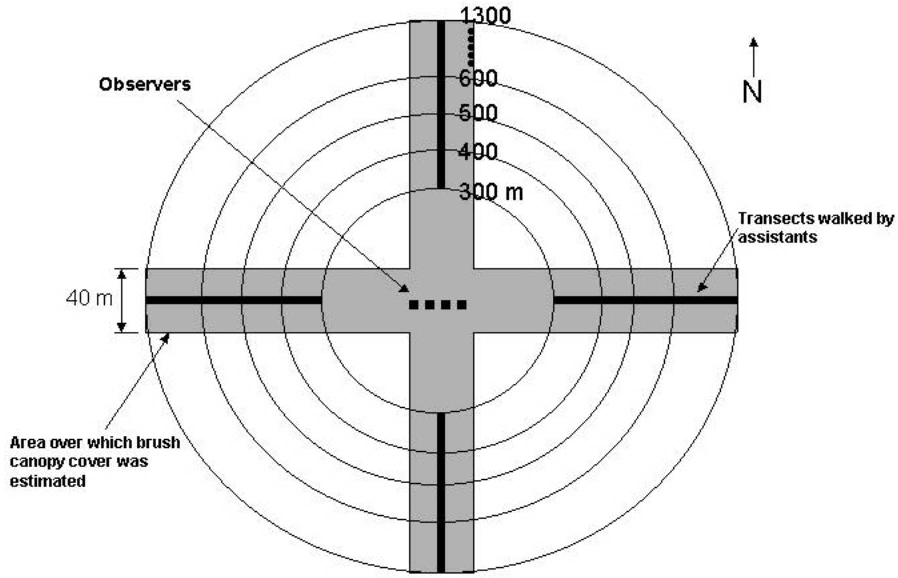

Figure 1: Schematic of experimental layout to test radius of audibility. Observers were positioned in center, oriented north, and spaced 10 m apart. Assistants played calls in the 4 cardinal directions at 100 m intervals from 300 m up to 1300 m.

conditions under which covey-call surveys are normally conducted but to complete the trial before wild birds initiated their calling. Observers were aligned along an east-west transect, oriented northward, and separated 10 m apart in order to isolate observers and prevent intra-observer influence (Figure 1). Recording-playback assistants then moved away from observers in each of the 4 cardinal directions and played the recording of the covey-call every 100 m. Recordings were played using 4 CD radio cassette recorders (model CFD-S350, Sony Corporation of America, New York, New York), one for each assistant. Recordings were broadcasted at about 100 db, the decibel-reading characteristic of covey-calls that was determined earlier during our recording sessions. Play-back assistants positioned CD players such that speakers were about 15 cm off the ground, the approximate height of a bobwhite. Assistants communicated using two-way radios (Motorola TalkAbout T5500, Motorola Incorporated, Schaumburg, Illinois) to avoid playing the recording at the same time. Assistants recorded the number of times the recording was played and the time of playing. Observers were instructed to record the time they heard a covey-call, the direction of the call, and the number of calls. Observers and assistants had time-synchronized watches.

We compared data (e.g., number of times recordings played, recording time) between observers and assistants. From this comparison, we determined the maximum distance over which the recording was detected for each observer in each direction. Mean radius of audibility was simply the maximum detection distances averaged across the 4 directions for each observer. We compared radii of audibility between brush density types with ANOVA using a randomized, complete block model.

Observer Variability

We measured observer variability using a completely randomized design. Our experiment involved 3 listening posts (experimental repetitions) and 12 observers (experimental units) that were randomly assigned to a listening post. Prior to experiment, observers were trained on morning covey-call methodology and listened to a covey-call recording to further refine their ability to detect and identify

Table 1: Radius of audibility (m) of the morning covey-call played at 100 db at low (6%) and high (30%) brush densities in Kleberg County Texas, November 2005.

		Transect Direction					
Brush Coverage	Observer	N	S	E	W	Mean	SE
Low-brush density							
	1	500	1100	1000	400	750	175.59
	2	800	1300	1200	1000	1075	110.87
	3	800	1000	1200	900	975	85.39
	4	1000	1300	1200	600	1025	154.78
	Pooled					956	71.72
High-brush density							
	1	1200	900	1100	800	1000	91.29
	2	1100	900	800	700	875	85.39
	3	1000	1300	1200	800	1075	110.87
	4	700	900	800	700	775	47.87
	Pooled					931	66.44

the call. For observer-variability experiments, observers arrived at posts 45 minutes before sunrise and listened for covey calling. Observers recorded time of first and last call, number of calling coveys, and approximate location of each covey. Weather conditions (temperature, humidity, and wind speed) also were recorded during each experiment. We calculated mean number of coveys detected, range, and percent coefficient of variation (CV) for each experiment.

Calling Behavior

We documented probability of coveys calling and number of individuals per covey calling during October-December, 2004-2005. To do this, we located radio-marked coveys about 45 minutes before sunrise and homed within 20 m of the covey. At the onset of calling, we recorded whether or not the covey called, the number of birds that called within the covey, and the number of calling events. A calling event was defined as a series of covey-calls separated by >1 minute (Wellendorf et al. 2004). We calculated 95% confidence intervals for probability of coveys calling using ($p \pm Z$ 0.025 SE[p]) where p is the proportion of coveys calling and SE(p) is the square root of [$p(1-p)/n$].

Results

We determined 100 db to be the appropriate sound level to play the recording. This was based on our most reliable sound meter reading obtained within 10 cm of a captive bird. The mean radius of audibility was similar between the low-brush (956 $\pm$ 72 m; mean $\pm$ SE) and high-brush density area (931 $\pm$ 66 m; P = 0.75; Table 1). Pooled over areas, mean radius of audibility was 944 $\pm$ 46 m. Because we played covey-call recordings only at 100-m intervals, we estimated an overall radius of audibility of 900 m to more accurately reflect the precision at which our estimates were measured. Using 900 m as the radius of audibility, we calculated that counts surveyed an area of 254 ha.

We measured considerable variation between observers while conducting the morning covey-call survey. Percent coefficient of variation ranged from 18% to 49% (Table 2). Regarding calling behavior, 67% $\pm$ 9.0 (n = 30 coveys) of coveys emitted the covey call during 2004. Of the 20 coveys that

Table 2: Observer variability in number of coveys detected during morning covey-call surveys for northern bobwhite in Brooks and Kleberg Counties, November 2005.

	Observer					
Experiment Repitition[a]	1	2	3	4	Mean	CV
1	14	9	8	8	9.75	29%
2	6	2	3	3	3.5	49%
3	9	6	9	9	8.25	18%

[a] Each repetition consisted of different observers

called, 14 (70% $\pm$ 10.2) involved more than 1 bird calling within the covey (Table 3). In addition, we documented an average of 2.6 $\pm$ 0.32 calling events/covey/morning. Calling events per covey were 1 calling event ($n = 5$ coveys), 2 (n = 6 coveys), 3 (n = 4 coveys), 4 (n = 3 coveys), 5 (n = 1 covey), and 6 (n = 1 covey). During the same time period in 2005, we documented 88% $\pm$ 7.8 (n = 17) of coveys emitting the covey-call. Of the 15 coveys that called, 14 (93% $\pm$ 6.4) involved more than 1 bird calling within the covey (Table 3). In addition, we documented an average of 3.2 $\pm$ 0.22 calling events/covey/morning. Calling events per covey were 1 calling event (n = 1 coveys), 2 (n = 1 coveys), 3 (n = 7 coveys), and 4 (n = 6 coveys).

Discussion

Our empirical estimate of radius of audibility (900 m) for vegetal conditions of South Texas was higher than any estimate used in prior research. Other studies have used radii of audibility consisting of 400 m (Roseberry 1982), 700 m (DeMaso et al. 1992), and 800 m (Guthery 1986). Other than DeMaso et al. (1992), who estimated radius of audibility based on physical laws of sound travel, these prior estimates represented arbitrary values. Although our estimate of radius of audibility was obtained using experimentation, we do not suggest that our estimate be used as the exact value. Factors such as wind, topography, and background noise affects the distance over which a sound travels. We documented that density of woody plants did not influence radii of audibility in our study. However, our study was conducted on level terrain with low growing brush (10-15 m). This relatively low height of woody plants permitted sound to travel just above the brush layer (L. Hewett, Physics Department, Texas A&M University-Kingsville, personal communication). In landscapes with taller vegetation, woody plants may impede the travel of sound and therefore impact radius of audibility. We recommend that the appropriate radius of audibility be determined specifically for each study area. Determining the appropriate radius of audibility is important because it determines survey area and therefore estimated density. The various radii assumed by prior research corresponded to survey areas which differed drastically: 50 ha (Roseberry 1982), 154 ha (DeMaso et al. 1992), and 200 ha (Guthery 1986). Naturally, this large impact of radius of audibility on survey area would affect the accuracy of this survey method. Point transects (Buckland et al. 2001) may be used as an alternative to fixed-radius estimators such as the morning-covey call method; however, accurate distance measurements to the calls (or placement into a correct distance interval) are required which may not be possible given variability in call pitch and loudness from the same

Table 3: Number of individuals emitting covey-call within a covey during morning covey-call surveys, Brooks County, Texas, October-December, 2004-2005.

			No. birds calling					
Year	Observation	n	1	2	3	4	5	Total birds calling
2004	Coveys Calling	20	6	12	2	0	0	36
2005	Coveys Calling	17	1	3	5	5	3	57

covey (see below).

We also obtained an empirical estimate of the loudness of the covey-call. Our estimate (100 db) corresponded to that of DeMaso (1991, 101 db), which was calculated based on the Calder (1990) equation. By assuming sound dissipated over a hemisphere and using the threshold of human hearing (10^{-12} watts/m^2), DeMaso (1991) calculated a radius of audibility of 15 km, which he realized was unrealistic. Alternatively, he speculated the loudness of the covey-call fell between 60 and 70 db thereby suggesting a radius of 700 m. Because we observed decibel readings of 100 db, Calder's equation predicting 101 db for a covey-call may not be unrealistic but rather that the assumptions of DeMaso (1991) (dissipation of sound over a hemisphere and threshold value of human hearing) are incorrect or unrealistic.

Prior research identified 2 primary limitations of the morning covey-call survey: observer variability and calling behavior. Both of these factors influence the number of coveys detected and therefore density. We documented that observers varied considerably in their estimate of coveys heard at a point. DeMaso et al. (1992) also reported observer variability as a limitation of the survey method. In their study, morning covey calls could not be used as an index to abundance for 1 of 3 observers. Wellendorf et al. (2004) suggested that differences among the ability of observers to count covey-calls should be considered and that observers should be trained to lessen the observer effects (Kepler and Scott 1981).

Calling behavior of bobwhites also complicates application of the survey. DeMaso et al. (1992) noted that morning covey-call surveys assumed that probability of calling was constant over space and time. Our and prior research indicate violation of this assumption. We documented probability of calling varied between years (20% difference). Seiler et al. (2002) reported that calling rates differed by 6% between years and fluctuated considerably (50-100%) within a year. Wellendorf et al. (2004) also documented substantial within year variation (48-87%) with a mean calling rate of 58%. In addition, we documented that more than one bird in a covey called. This finding is important because having multiple bobwhites emit the covey call could bias number of coveys detected if observers confused them as separate coveys. We documented an instance in which a covey with multiple calling individuals sounded as different coveys because individual birds were calling at different pitch levels and loudness (F. Herndez, Caesar Kleberg Wildlife Research Institute, personal observation). Naturally, such additional variation would further bias morning covey-call surveys.

Management Implications

Although the morning covey-call survey may be used to obtain crude estimates of abundance, people employing the technique need to be fully aware of its limitations. Refinements to the survey method include using a 900-m radius of audibility (at least as an initial value) and correcting for probability of coveys calling (Wellendorf et al. 2004). Because the probability of calling varies annually, this variable should be estimated each year counts are conducted. In addition, observers should be kept constant from year to year as much as possible to reduce observer variability.

Acknowledgements

We thank the Caesar Kleberg Wildlife Research Institute, The Richard M. Kleberg Jr. Center for Quail Research, and Texas A&M University-Kingsville for providing financial and logistical support. We thank J. A. Arredondo and K. B. Crain for assistance with data collection as research technicians for the South Texas Quail Research Project. We also thank R. L. Bingham for statistical and experimental design consultation, E. J. Redeker for his G.I.S. assistance, and L. D. Hewett for his consultation on sound travel. This research was financially supported by the George and Mary Josephine Hamman Foundation, Amy Shelton McNutt Charitable Trust, William A. and Madeline Welder Smith Foundation, Bob and Vivian Smith Foundation, Robert J. Kleberg Jr. and Helen C. Kleberg Foundation, Texas State Council of Quail Unlimited, the South Texas, Houston, and East Texas Chapters of Quail Unlimited, Quail Associates, and private contributions. We thank King Ranch Inc., in particular M. Barktoskewitz, for providing access to the study area, San Tomas Hunting Camp for in-kind support. We thank L. A. Brennan and D. G. Hewitt for providing helpful comments on an earlier version of this manuscript. Data for this research were provided by the South Texas Quail Research Project.

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