A PRACTICAL AND EFFICIENT HELICOPTER SURVEY TECHNIQUE TO ESTIMATE BOBWHITE ABUNDANCE ON TEXAS RANGELANDS

Stephen J. DeMaso, Matthew J. Schnupp, Eric J. Redeker, Fidel Hernández,
Leonard A. Brennan, Joseph P. Sands, Trent W. Teinert, Alan M. Fedynich,
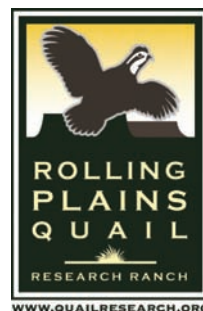Fred C. Bryant, Robert M. Perez, and Dale Rollins

Wildlife Technical Publication No. 2
of the
Caesar Kleberg Wildlife Research Institute
Texas A&M University-Kingsville

2010

A PRACTICAL AND EFFICIENT HELICOPTER SURVEY TECHNIQUE TO ESTIMATE BOBWHITE ABUNDANCE ON TEXAS RANGELANDS

Stephen J. DeMaso, Matthew J. Schnupp*, Eric J. Redeker, Fidel Hernández, Leonard A. Brennan,
Joseph P. Sands, Trent W. Teinert, Alan M. Fedynich, and Fred C. Bryant
Caesar Kleberg Wildlife Research Institute
Texas A&M University-Kingsville
700 University Blvd., MSC 218
Kingsville, Texas 78363

Robert M. Perez
Texas Parks and Wildlife Department
P.O. Box 1081
LaVernia, Texas 78121

Dale Rollins
Texas AgriLife Research
7887 US Highway 87 North
San Angelo, Texas 76901

ABSTRACT

An estimate of abundance is important for knowing whether a quail population is increasing, stable, or declining in a particular area; whether a given management practice is creating more quail; or what quail hunting pressure is appropriate on a property. Counting quail is difficult for several reasons: (1) quail habitat is a mix of grass, weeds, and brush, which provides ample hiding places, (2) quail are usually not distributed evenly across a piece of property, and (3) quail tend to be found in different places during different times of the day. We developed a simple and easy-to-use helicopter survey technique for estimating bobwhite abundance. However, this technique is only reliable if bobwhites are located in coveys during the time of the survey and survey protocols are followed. Otherwise, density estimates may be unreliable. We recommend surveys be conducted with a four-seat R-44 helicopter and 3 observers: a front-seat observer to detect coveys directly in front of the helicopter and 2 rear-seat observers to detect coveys on the left and right sides of the helicopter. Surveys should be flown at a velocity of approximately 23 miles/hr and an approximate altitude of 23–33 feet. Abundance should be estimated using the equation Bobwhite Density = 0.468(Coveys Seen / Mile) – 0.002 or using the nomogram provided in this publication. This relationship is reliable (i.e., the number of coveys seen per mile explains more than 90% of the variation in bobwhite density). We provide 2 practical examples of how this technique could be used to provide information for (1) evaluating the effect of brush management and (2) managing quail hunting pressure. For those wanting more information about our methods, we provide an appendix that explains the theory behind distance sampling and the relationship between bobwhite density and coveys seen per mile of helicopter survey effort. The technique was developed in South Texas and the Rolling Plains and, therefore, is generally applicable only to these regions.

INTRODUCTION AND BACKGROUND

Anyone with an interest in bobwhite hunting or bobwhite management is interested in knowing "How many bobwhites do I have on my place?" While this is a relatively simple question, it turns out that it is usually a difficult one to answer.

There are a number of reasons why it is difficult to count quail. First, they are extremely difficult to see. They like to hide in dense grass and weeds and often prefer to run rather than fly. Second, quail are not distributed evenly across a pasture or given piece of property. Third, they tend to be found in different places during different times of the day. After sunrise, they leave their roosts (which are typically located in open, grassy areas) to feed. When their crops are full, they move to dense, brushy loafing cover (e.g., shrubs) where they will spend most of the day. Toward the end of the day, they typically have another foraging bout before gathering where they will roost for the night. These daily movements alone make counting quail a challenge.

Over the years, bobwhite hunters and managers have typically relied on "indirect counts," e.g., morning covey call counts (DeMaso et al. 1992), whistle counts, or roadside counts (Rollins et al. 2005). Indices of abundance, such as the number of calling males heard per unit of time, or the number of coveys heard calling at sunrise,

---

Figure 1. Range of habitat conditions where northern bobwhite density data were collected to develop the relationship between density and coveys seen per mile with North Texas high brush canopy coverage (A) and low brush canopy coverage (B) and South Texas high brush canopy coverage (C) and low brush canopy coverage (D). Our survey technique provides reliable estimates only on pastures and management units with similar amounts of brush canopy cover or less.

are good ways to assess trends in bobwhite abundance over time, or in response to various management actions. However, these methods do not provide an actual "count" of how many bobwhites are present in a particular area (i.e., density).

Having an actual count or estimate of bobwhite density is beneficial for several reasons. It allows a manager to compare population trends over time, and it also provides information on how many quail are available for harvest, thereby allowing managers to regulate hunting pressure more effectively.

During the past several years, we have been conducting research on the use of helicopters as a platform for observers to count bobwhites. Our technique requires observers to collect 2 basic pieces of information: (1) the number of miles flown during a survey and (2) the number of bobwhite coveys seen during each survey. These 2 pieces of information are then combined to

estimate the density of bobwhites present within a pasture or tract of land.

The purpose of this technical publication is to provide bobwhite managers, biologists, and hunters with a simple and easy-to-use tool that will allow them to obtain a reliable estimate of how many bobwhites are present in a particular pasture or management unit (Figure 1). We caution that the use of this technique is only reliable if bobwhites are located in coveys during the time of the survey (Schnupp 2009). In addition, if the survey protocol is not followed, the density estimates obtained could be unreliable.

The following sections of this publication describe how to collect and analyze survey information. For those interested in how this technique was developed, we provide an appendix with information about the theory and calculations behind "distance sampling," the statistical method upon which this technique is based.

CONDUCTING SURVEYS

What type of helicopter?

Our surveys were conducted using a four-seat R-44 helicopter. However, a similar type helicopter with room for 3 observers and the pilot should work for this type of survey.

How many observers?

Surveys require 3 observers: a front-seat observer to detect bobwhite coveys directly in front of the helicopter and 2 rear-seat observers to detect coveys on the left and right sides of the helicopter (Figures 2 and 3). Each observer should understand that most of the coveys will flush less than 50 yards from the helicopter. The observers in the rear seat should scan forward to the shoulder of the person in the front seat and scan backwards until they see the rear rotor (Figure 2). They should scan back and forth to the reference points until the transect has been completed.

Care should be taken in surveying back to the rear rotor because a majority of the coveys flush after the helicopter passes over them. The pilot's primary responsibilities are to keep the aircraft on the transect line and maintain a safe flying environment.

When to conduct surveys?

Our fall surveys were conducted during mid-to-late October. This time of the year may be appropriate for areas in North Texas, but surveys should be conducted during early December in South Texas. By this time, most birds, even during years where a late hatch occurs, should be observable during surveys. Additionally, density estimates are closer to the actual start of hunting. Generally, quail hunters start hunting later in South Texas when it is cooler and quail hunting conditions for dogs are more favorable.

Spring surveys are typically conducted during March after the hunting season closes. This can also be a good time of the year to count quail, especially if a fall or early winter (as recommended for South Texas) survey is conducted. Comparing fall-winter and spring season surveys can give a manager an estimate of overwinter mortality, and following a spring survey with a fall-winter survey can give a manger an estimate of production or summer population increase (recruitment).

Morning surveys should be conducted from one hour after sunrise for about 3 hours, and evening surveys should be conducted for about 3 hours before one-half

© Matthew Schnupp

Figure 2. Side view of pilot and observer positions during bobwhite helicopter surveys and the area surveyed by each observer.

hour before sunset. Clear, cool days with minimal winds are ideal for counting. However, counts should be suspended if wind speeds exceed 15 miles/hr, if the ambient temperature exceeds 80° F, if the ground is wet, or it is raining.

What data should be collected?

Two kinds of data are needed from the survey. First, you need to know the number of miles that were flown during the survey. Most helicopter pilots have an onboard GPS unit that can be used to record the miles flown. If not, you can use a recreational GPS unit. Second, you need a count of the number of coveys seen during the survey (Figure 4). Covey data can be recorded on a piece of paper during a survey. This information will then be used to estimate bobwhite density. If you intend to collect data so you can compare the fall bobwhite population of

© Matthew Schnupp

Figure 3. Front view of pilot and observer positions during bobwhite helicopter surveys and the area surveyed by each observer.
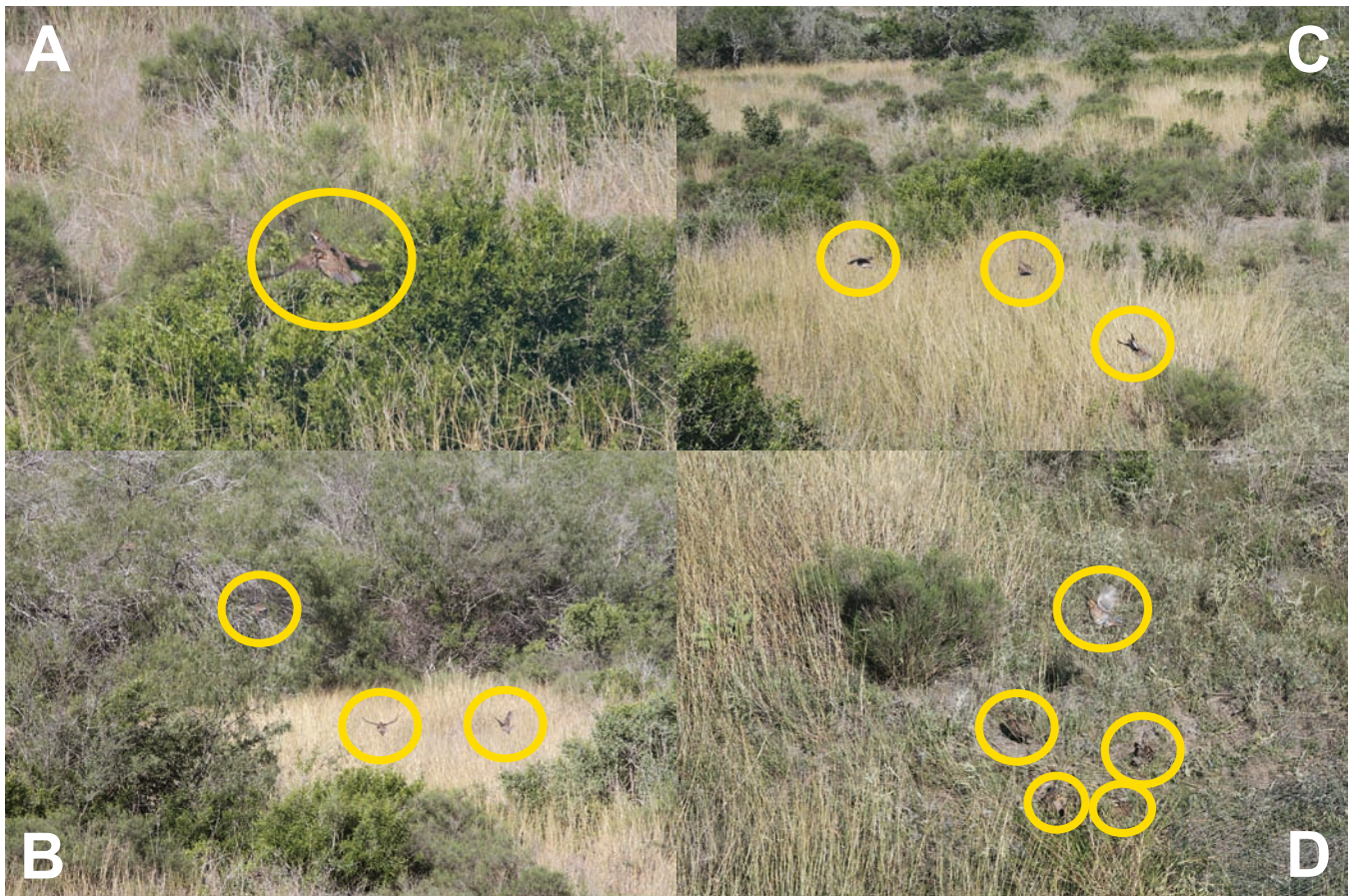
© Timothy Fulbright

Figure 4. Several examples of northern bobwhite response to a R-44 helicopter: (A) single bobwhite flushing from the helicopter path; (B) bobwhites flushing from the helicopter path; (C) bobwhites flushing from the helicopter path; and (D) one bobwhite flushing, but several bobwhites remaining on the ground.

one year to the fall bobwhite population of the next year, make sure that you fly the same GPS track line each year, so the surveys are comparable.

How high and how fast should surveys be flown?

Surveys should be flown at an approximate velocity of 23 miles/hr at an approximate altitude of 23–33 feet.

Can I count deer and quail at the same time?

No, at least not if you seek to obtain reliable density estimates for bobwhites. Typical "deer counts" are flown at twice the speed and twice the altitude of the counts upon which quail estimates are based. Quail counts conducted during deer counts will invariably be lower than using our technique.

How many miles should be flown?

The relationship that we present later in this publication was based on an intensive sampling scheme. We surveyed 100% of the pastures. This sampling effort ranged from 5–26 miles per 1,000 acres, and depended on the season and whether the study pasture was in North Texas or South Texas.

We understand that most landowners or managers will not fly a survey with 100% coverage. We recommend a survey effort of 5–10 miles per 1,000 acres. However, if you fly less than this amount, such as flying 50% of the pasture or 2.5 miles per 1,000 acres, you can multiply your population estimate by 2 to get an estimate of the number of bobwhites for the entire 1,000 acres.

If you don't fly a 100% coverage survey, you will need to ensure that your transects include all types of habitat found in the pasture, and then base your density estimate on the different proportions of habitat. This accounts for the fact that various habitat types have different bobwhite densities. For example, you have a 1,000-acre pasture that is 500 acres of Bermudagrass and 500 acres of native rangeland. You estimate that the density

of bobwhites on the Bermudagrass is 0.07 birds/acre (15 acres/bird) and the native rangeland bobwhite density is 0.8 birds/acre (1.25 acres/bird). The bobwhite density on the 1,000-acre pasture is (0.07 birds/acre x 500 acres) + (0.8 birds/acre x 500 acres) = 435 bobwhites.

How many surveys do I need to conduct?

We recommend that there should be 3 surveys conducted for each area being surveyed over 2–3 days. Most helicopter pilots will not want to dedicate a large amount of time to survey small areas (less than 5,000 acres). The average number of coveys seen per mile should be used to estimate bobwhite density.

What do the data mean?

Suppose you completed a survey where you flew 17 total miles and observed 21 coveys. First, you want to know how many coveys you observed per mile, so

coveys seen per mile = 21 coveys ÷ 17 miles = 1.24.

We can now calculate bobwhite density by using the equation:

Bobwhite Density = 0.468(Coveys Seen / Mile) – 0.002, and simply substitute 1.24 for Coveys Seen / Mile.

Bobwhite Density = 0.468(1.24) – 0.002
Bobwhite Density = 0.580 – 0.002
Bobwhite Density = 0.578, or 0.58 birds/acre

We could also use the nomogram (Figure 5) to approximate bobwhite density. By simply following the x-axis over to 1.24 and then following that line up to the diagonal line, we see that bobwhite density for this survey is about 0.58 birds/acre.
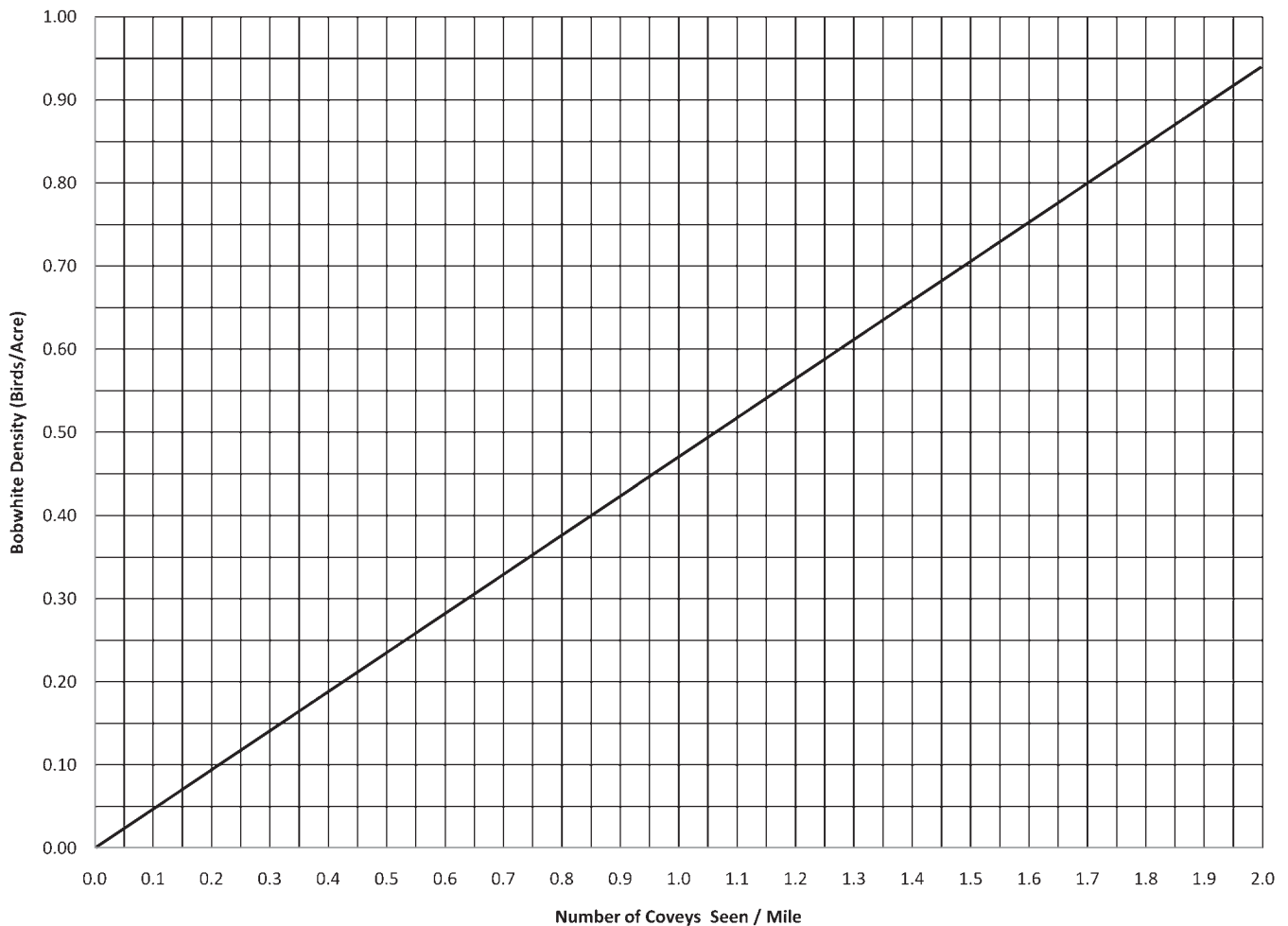

Figure 5. Nomogram of the relationship between the number of northern bobwhite coveys seen per mile and bobwhite density (birds/acre).

It is important to note that the relationship between the number of coveys seen per mile and bobwhite density was developed from covey observations where average covey size was about 8–9 bobwhites. If average covey size during your surveys is considerably below or above 8–9 bobwhites, the relationship becomes less accurate. You will over estimate density if your average covey size is below this range and under estimate density if it is above this range.

Economic comparison of methods

Walked line-transects traditionally have been the method of choice for estimating bobwhite abundance, particularly for research purposes (Figure 6). They are considered an effective method to estimate bobwhite density on rangelands (Guthery 1988, Kuvlesky et al. 1989). This method is time-consuming but feasible when populations are relatively high. However, when populations are moderate-to-low, the effectiveness of walked line-transects diminishes because encounter rates of coveys are very low (Kuvlesky et al. 1989, Rusk et al. 2007). During population lows, researchers have to increase survey effort considerably to obtain the 60–70 detections recommended to estimate density. Alternatively, they have to estimate density based on a low number of encounters. Neither option is attractive.

Helicopter surveys are more expensive per survey hour (about $550/hr), but they are able to survey more area in less time. Ultimately, however, helicopter surveys require less time or effort. For example, data collected

Figure 6. Walking line transects is an effective method for estimating bobwhite abundance. However, the method involves considerable effort and becomes impractical when bobwhite populations are low or the area to be surveyed is large.

from helicopter surveys conducted during October 2007 on 3 ecoregions of Texas (Rio Grande Plains, Coastal Prairies and Marshes, and Rolling Plains) indicate that helicopter surveys require an average of 98% less effort of time than walked transects when populations are moderate (e.g., 0.3–0.6 birds/acre). In the Rio Grande Plains, the helicopter surveys produced a covey every 0.7 mile, whereas walked line-transects produced a covey every 2.2 miles.

Further analysis of the data indicates that the estimated number of miles needed to obtain the necessary number of detections is about 4 times greater for walked line-transects when compared to helicopter surveys. For example, our pooled data indicate that the average number of hours needed to obtain 70 covey detections is about 233 hours using walked line-transects, whereas only 6 hours would be needed for helicopter transects. A cost analysis based on a crew of 3 working for 6 hours a day and paid minimum wage (2010; $7.25/hr) shows that the average cost per encounter is about $45 for helicopter surveys compared to about $30 for walked line-transects.

The cost of helicopter surveys is reasonable, and oftentimes comparable to walked line-transects, especially if populations are low. In addition, helicopter surveys can be conducted in a timely manner and are less of a burden on the manager. The use of helicopter transects can be a cost-effective alternative for estimating bobwhite densities during population lows or highs.

SOME PRACTICAL EXAMPLES
Evaluating the impact of brush management on bobwhite abundance

A 3,000-acre pasture on a ranch has too much brush to be ideal bobwhite habitat. The canopy coverage in this pasture is greater than 70%. You know from reading the wildlife literature that 10–30% brush canopy cover is recommended for bobwhites. Using the survey methodology described above, you have been conducting helicopter surveys for bobwhites every fall for the last 5 years. You fly about 15 miles over this pasture and, on average, observe about 0.85 coveys/mile. Based on the nomogram (Figure 5), you estimate a bobwhite density of 0.40 bobwhites/acre.

You have been leasing the pasture to some friends for quail hunting, but they are concerned that the brush is becoming too thick, making it too hard to hunt. They offer to split the costs of conducting some mechanical

brush removal to lower the brush canopy coverage back down to about 25%. You get a contractor to thin out the brush on the pasture, leaving mottes of brush about 50 feet in diameter approximately every 50–60 yards. After the contractor is finished, your friends rake the debris into piles for burning. Next they aerate the areas between the brush mottes. The following year after these treatments were performed the pasture receives near normal rainfall. The first December after the brush removal, another helicopter survey was flown, and 61 coveys were observed. Survey results yielded an average of 1.4 coveys/mile or 0.65 bobwhites/acre.

In a similar way, you could assess the effect of other management strategies, e.g., supplemental feeding, especially if the particular practice were conducted on a portion of the property and the remainder of the property was left as a "control."

Managing hunting pressure

Elaborating further on the brush example above, consider that a density of 0.40 bobwhites/acre means that there will be about 1,200 bobwhites available for hunting on the 3,000-acre pasture (Figure 7). In Texas, where there are fixed liberal quail hunting regulations that allow a hunter to bag 15 birds/day over a 120-day season, it would be easy to overharvest quail on a pasture such as the one mentioned above.

To be on the safe side, a bobwhite harvest rate of 10–15% means that a manager could "prescribe" a harvest of 120–180 birds on the 3,000-acre pasture.

With yearly surveys, harvest can be increased or decreased based on the standing crop of bobwhites available at the beginning of each hunting season. For example, if in year 2, bobwhite density in the 3,000-acre pasture increased to 0.75 birds/acre (2,250 birds), harvest during that year could be between 225 (10% harvest) and 338 (15% harvest) bobwhites. A key point here is that if only the first year harvest prescription of 120–180 birds were used, the manager would have overlooked a significant opportunity to harvest an additional 100–150 bobwhites from that pasture.

© Jason Hardin

Figure 7. Bobwhite density is a crucial part of estimating the amount of hunting pressure that a pasture or management unit can sustain.

management practice is creating more quail; and for managing quail hunting pressure. We provide bobwhite managers with a simple tool that will allow them to obtain a reliable estimate of how many bobwhites are present in a particular pasture or management unit. This simple technique requires observers to collect only 2 basic pieces of information: (1) the number of miles flown during a pasture or management unit survey and (2) the number of bobwhite coveys seen during each survey. These 2 pieces of information are then used to estimate the density of bobwhites (number of bobwhites per acre of pasture).

We emphasize that the technique is reliable only if (1) bobwhites are in coveys at the time of the survey, (2) average covey size is about 8–9 bobwhites/covey, and (3) survey protocol is followed. The technique was developed in South Texas and the Rolling Plains and, therefore, it is only generally applicable to these regions. Applying the technique outside the conditions in which it was developed is not valid or recommended.

SUMMARY

A key factor in quail management is knowing the abundance of quail on your property. Abundance is important for knowing whether quail are increasing, stable, or declining in a particular area; whether a given

APPENDIX

The theory behind distance sampling

Distance sampling or line-transect sampling has been used to estimate quail density (Brennan and Block 1986, Guthery 1988, DeMaso et al. 1992, Rusk et al. 2007, Schnupp 2009). Reliable estimates of bobwhite density require about 60–80 covey encounters using distance sampling (Buckland et al. 2001). Meeting this recommended number of encounters can require considerable time and effort walking when populations are low (Kuvlesky et al. 1989). We have refined a survey technique that is much easier than distance sampling and is more practical from a management standpoint. First, we give some conceptual background information before we describe the details of this new technique.

Suppose there are 100 golf balls placed randomly on a golf course fairway. If you were asked to walk down the center of the fairway on a marked line transect and locate the golf balls, you might feel confident in finding all 100 balls. However, what if the groundskeeper was laid off, the grass became tall, and you were asked to find the same 100 golf balls in grass that was now a foot tall. Would you still feel as confident in finding all 100 balls? —Probably not. You would have a good chance of finding balls directly under your feet, but your odds of finding balls farther away would be less. Distance sampling accounts for the decrease in detection that occurs with increasing distance between the object and the observer.

To correct for varying detectability, distance sampling requires measurement of right-angle distances between detected objects (coveys in our case) and the transect. This information can then be used to determine the distance over which one effectively finds coveys and estimates the number of coveys missed, therefore yielding an estimate of total coveys in an area (observed + missed). The calculations involve some calculus, but fortunately free software exists that does the calculations for you. The next paragraph gives a more mathematically based explanation of distance sampling.

In distance sampling, straight lines are traversed, and when a bobwhite or covey of bobwhites is observed, the number and right-angle distance from the transect to the point of flush are recorded (Guthery 1988). Distance sampling is based on a detection curve, $g(x)$, which describes the probability of detecting coveys or individual bobwhites, depending on their right-angle distance from the transect line (Burnham et al. 1980). The detection curve is developed from the frequency distribution of these right-angle distances. It is scaled so the area under the curve sums to 1.0; the scaled curve, $f(x)$, is a probability density function. The estimate of $f(\text{o})$ is particularly important because $1/f(\text{o})$ is the right-angle distance which the number of groups missed equals the number seen beyond that distance (Guthery 1988). Therefore, the density of coveys (G) can be estimated (Buckland et al. 2001) as

$$G = n(f(\text{o}))/2L$$

where n = the number of coveys flushed and L = the cumulative length of all transects. The density of bobwhites (D) is estimated as $D = G(c)$ where c is the average covey size (Guthery 1988).

Seven assumptions must be met for distance sampling to provide unbiased estimates of density (Burnham et al. 1980, Guthery 1988). They are as follows:

1. All bobwhites on the transect are detected (i.e., $g(\text{o})$ = 1) or the probability of detection is known. If bobwhites on or near the transect are not seen and counted, bobwhite density is underestimated. However, if you know you are seeing less than 100% of the bobwhites on the transect and know the probability of detection (e.g., 92% of the bobwhites on the transect were detected), the computer program can account for this decreased detectability.

2. Bobwhites are observed at their original location. If bobwhites move away from the transect in response to the observer coming down the transect and are not seen and counted, bobwhite density is underestimated.

3. Right-angle distances are measured accurately. If observers become lazy and don't measure distances accurately, especially near the transect line (e.g., "that covey was close to the transect, I'll just put 0 for the distance on the data sheet"), then "heaping" on distances of zero could result in an over estimate of density.

4. Observations of bobwhites flushing are independent events. For example, if you flushed a covey and that covey flushed another covey, you should only count the first covey that you observed. Also, if you flushed a covey and flushed a second covey while you were measuring the distance to the first covey, you should only count the first covey you observed. Only

Table 1. Average, low, and high estimates of bobwhite density (birds/acre) and number of acres per bird using helicopter-based distance sampling, by region and season, Brooks and Fisher counties, Texas, fall 2007 to spring 2009.

Region	Season	Average (birds/acre)	Average (acres/bird)	Low (birds/acre)	Low (acres/bird)	High (birds/acre)	High (acres/bird)
North Texas							
	Fall	0.44	2.3	0.15	6.7	0.80	1.3
	Spring	0.21	4.8	0.13	7.7	0.29	3.5
South Texas							
	Fall	0.40	2.5	0.09	11.1	0.83	1.2
	Spring	0.27	3.7	0.07	14.3	0.34	2.9

bobwhites observed while you are on the transect can be counted, otherwise, bobwhite density may be overestimated.

5. Coveys are not counted more than once during a survey period. If the same covey is counted more than once, bobwhite density will be overestimated.
6. The probability of sighting a covey is independent of covey size. This simply means that small coveys have the same chance of being detected as large coveys.
7. The creation of transect lines does not influence the distribution of bobwhites. This is not a problem with helicopter-based distance sampling. However, if transects are being walked, caution should be taken when setting up the transects not to modify the habitat in a way that bobwhites are attracted to or away from the transect.

The relationship between bobwhite density and coveys seen per mile

As part of a larger study, we estimated bobwhite density using helicopter-based distance sampling (Rusk et al. 2007, Schnupp 2009). Study sites for this project were located on the Encino Division of the King Ranch, Inc. in Brooks County, south of Falfurrias, Texas, and on the Rolling Plains Quail Research Ranch and one private ranch in Fisher County near Roby, Texas. Bobwhite densities were estimated in October (i.e., fall) and the following March (i.e., spring) from fall 2007 to spring 2009. During each season, bobwhite density was estimated on 5 or 6 total pastures (South Texas and North Texas together). Pasture sizes ranged from 962 to 4,851 acres.

Estimated bobwhite density varied from 0.07 birds/ acre (1 bird/14.3 acres) in the spring to 0.83 birds/acre (1 bird/1.2 acres) in the fall on our study areas (Table 1).

Helicopter-based distance sampling is complex, and can be very time and labor intensive when bobwhite populations are low to get the required observations needed for reliable density estimates. Therefore, we wondered if there was a better way to determine bobwhite density—a method that could be applied by landowners and managers as part of a bobwhite management program for a given property.

Simple linear regression attempts to model the relationship between 2 variables by fitting a linear equation to observed data. One variable is considered to be an explanatory variable (x), and the other is considered to be a dependent variable (y). For example, a researcher might want to relate the weights of individuals to their heights using a linear regression model. We used simple linear regression to determine the relationship between the number of coveys seen per mile and bobwhite density. We conducted this analysis for both ecoregions by season. Our analysis showed a positive relationship between coveys seen per mile and bobwhite density ($r^2 \geq 0.74$; $P \leq 0.03$). Because the estimated slopes of the regression lines did not differ among ecoregions and/ or seasons, we combined all the data together to get an overall relationship (Figure 8) where

Bobwhite Density = 0.468(Coveys Seen / Mile) – 0.002.

The number of coveys seen per mile explains 90.4% of the variation in northern bobwhite density, and the slope of the regression line is different from zero ($P = $ <0.0001). Also, a good index should have a zero-intercept because if no coveys are present, none should be seen (DeMaso et al. 1992). The intercept for our model was equal to zero ($P = 0.9424$).
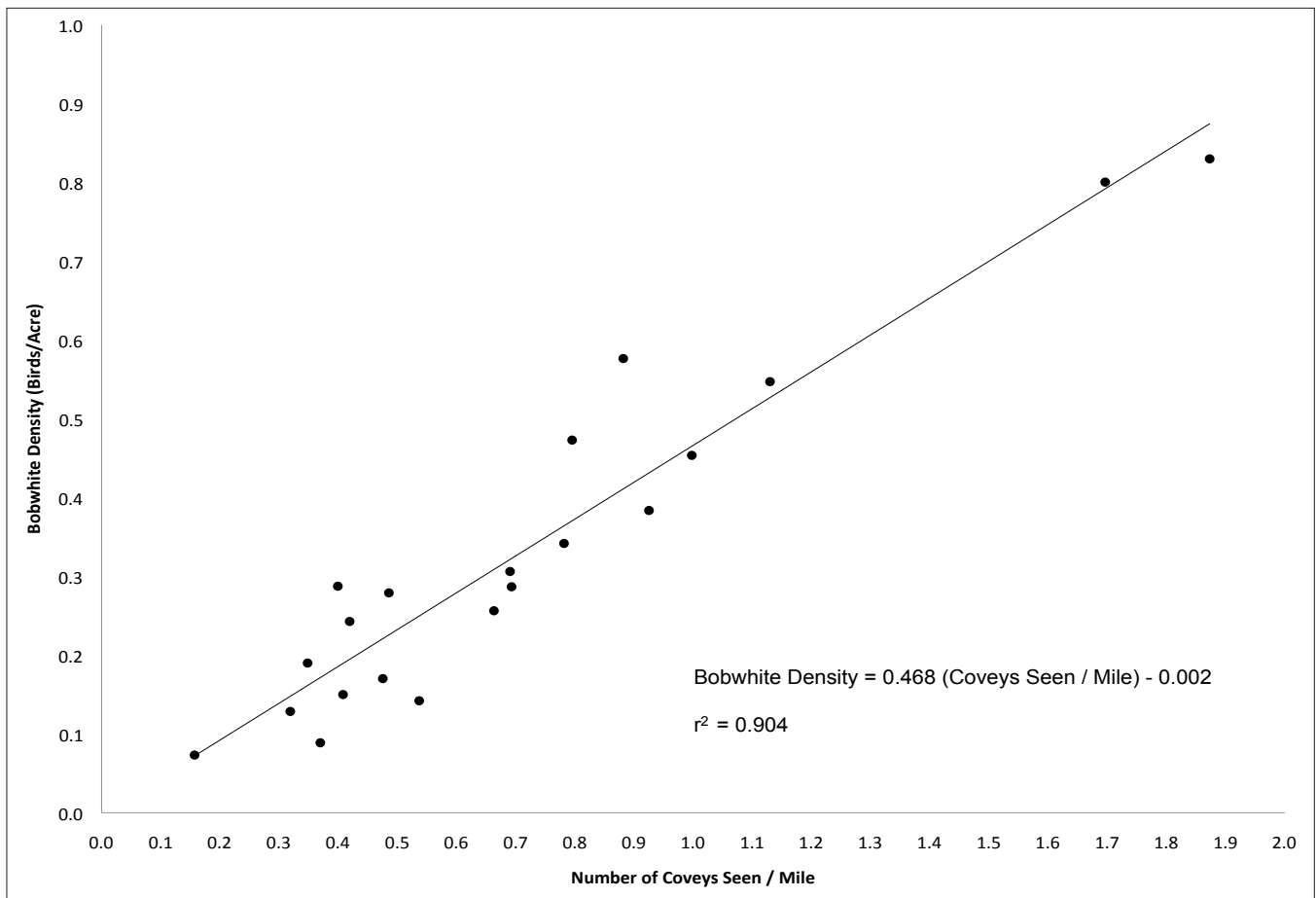
Figure 8. The relationship between the number of northern bobwhite coveys seen per mile and bobwhite density (birds/acre), fall 2008 to spring 2009, Brooks and Fisher counties, Texas, USA (Schnupp 2009).

LITERATURE CITED

Brennan, L. A., and W. M. Block. 1986. Line transect estimates of mountain quail density. Journal of Wildlife Management 50:373–377.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling estimating abundance of biological populations. Oxford University Press, New York, NY.

Burnham, K. P., D. R. Anderson, and J. L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildlife Monograph 72.

DeMaso, S. J., F. S. Guthery, G. S. Spears, and S. M. Rice. 1992. Morning covey calls as an index of northern bobwhite density. Wildlife Society Bulletin 20:94–101.

Guthery, F. S. 1988. Line transect sampling of bobwhite density on rangeland: evaluation and recommendations. Wildlife Society Bulletin 16:193–203.

Kuvlesky, W. P., Jr., B. H. Koerth, and N. J. Silvy. 1989. Problems of estimating northern bobwhite populations at low density. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 43:260–267.

Rollins, D., J. Brooks, R. N. Wilkins, and R. D. Ransom, Jr. 2005. Counting quail. Bulletin B-6173. Texas AgriLife Extension Service. College Station, TX.

Rusk, J. P., F. Hernández, J. A. Arredondo, F. Hernández, F. C. Bryant, D. G. Hewitt, E. J. Redeker, L. A. Brennan, and R. L. Bingham. 2007. An evaluation of survey methods for estimating northern bobwhite abundance in southern Texas. Journal of Wildlife Management 71:1336–1343.

Schnupp, M. J. 2009. Testing an electronic system to estimate density using helicopter-based distance sampling. M.S. Thesis, Texas A&M University-Kingsville, Kingsville, TX.

Bobwhite Helicopter Survey Data Sheet (EXAMPLE)

Date: October 28, 2008

Time: 8:30 am

No. of Miles Flown: 17 Miles

No. of Coveys Seen: 21 Coveys

No. of Coveys Seen per Mile = No. of Coveys Seen / No. of Miles Flown = 21/17 = 1.24

Bobwhite Density = 0.468(No. of Coveys Seen per Mile) - 0.002

$$= 0.468(1.24) - 0.002$$

$$= 0.580 - 0.002$$

$$= 0.58 \text{ bobwhites per acre}$$

Bobwhite Helicopter Survey Data Sheet

Date: _____

Time: _____

No. of Miles Flown: _____

No. of Coveys Seen: _____

No. of Coveys Seen per Mile = No. of Coveys Seen / No. of Miles Flown = __ / __ = _____

Bobwhite Density = 0.468(No. of Coveys Seen per Mile) - 0.002

= 0.468(____) - 0.002

= _____

= _____ bobwhites per acre

Caesar Kleberg Wildlife Research Institute
Texas A&M University-Kingsville
700 University Boulevard, MSC 218
Kingsville, Texas 78363-8202

(361) 593-3922

http://www.ckwri.tamuk.edu