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Sampling of Bobwhite Populations

Estimating Sample Sizes for Distance Sampling of Autumn Northern Bobwhite Calling Coveys

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Point transect sampling of calling coveys has been advocated for estimating autumn abundance of northern bobwhite (*Colinus virginianus*; hereafter bobwhite). We conducted power analysis, over a range of expected bobwhite calling covey densities to determine levels of sampling required to obtain density estimates for calling coveys over a wide range of precision. We used distance/detection information for autumn bobwhite coveys from 701 observer-mornings on 39 farms in the Upper Coastal Plain of Georgia to construct a global detection function (Uniform with cosine adjustment) using Program DISTANCE. We used simulation models to determine the expected coefficient of variation (CV) on density in relation to number of points sampled. We generated 1,000 sets of random samples in increments of 10 at sample sizes of 10-1,000. At each sample size we generated the respective number of observations from a Poisson distribution with λ = 0.5-3.0 and computed the density and associated statistics using the global detection function. We report the mean CV on covey density at each sample size. As expected, the CV on density decreased with increasing sample size and expected number of detections per point. Assuming sufficient observations to estimate the detection function, a CV on density $<$15% could be achieved with 50 points at densities with a mean detection of 1 covey/point or 20 points with a mean detection of 2 coveys/point. A mean CV $<$10% required 100 points at 1 covey/point and 30 points at 2 coveys/point. These simulations demonstrate that distance-based autumn covey surveys can provide density estimates for calling coveys with reasonable precision given sufficient effort.

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Key words: call counts, *Colinus virginianus*, density, distance sampling, Georgia, northern bobwhite, sample size, simulation

Introduction

Precise estimation of northern bobwhite (*Colinus virginianus*; hereafter bobwhite) population size is necessary to understand population dynamics, set population-based hunting regulations, and evaluate effectiveness of habitat management (Schwartz 1974, Stauffer 1993). Development of precise and unbiased techniques to estimate bobwhite population density, however, has constituted an enigma for biologists. Several approaches have been used to index (Bennett and Hendrickson 1938, Kozicky et al. 1956, DeMaso et al. 1992) or estimate (Dimmick et al. 1982, Guthery et al. 1988, Guthery and Shupe 1989, Janvrin et al. 1991) density of bobwhite populations. Point transect sampling of autumn bobwhite populations using covey calling activity has recently been advocated as a means to estimate bobwhite density (Seiler et al. 2002, Wellendorf et al. 2004, Wellendorf and Palmer 2005).

DeMaso et al. (1992) used autumn calling activity to index bobwhite density but reported poor correspondence between covey calling activity and density estimated via line-transect sampling (Guthery 1988). They attributed this lack of correspondence to variation in calling activity, proportion of coveys calling, and observer ability to differentiate coveys in high density areas. Recent studies (Seiler et al. 2002, Wellendorf et al. 2004) have established empirical relationships among calling activity, weather, and density; thereby addressing most concerns of DeMaso et al. (1992). When adjusted for calling rate, Wellendorf and Palmer (2005) reported similar

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covey density estimates of autumn bobwhite populations between point transect sampling and those estimated via quadrant surveys.

Point transect sampling of autumn bobwhites based on covey calling activity is less labor intensive than flush count (Guthery 1988, Janvrin et al. 1991) or mark-recapture (Dimmick et al. 1982, Guthery and Shupe 1989) techniques. However, point transect sampling of bobwhites is subject to several biologically-based constraints. Peak calling activity of coveys occurs during a relatively narrow window of time (2-3 weeks) during autumn and calling occurs most reliably only during a brief period (20 min) before sunrise (Seiler et al. 2002, Wellendorf et al. 2002, 2004); limiting data collection to 1 point/observer/morning. Given these constraints, sampling of multiple points at multiple sites within the brief window of peak calling activity becomes problematic. *A priori* power analysis to determine appropriate levels of sampling required to obtain density estimates with desired levels of precision will facilitate efficient use of resources. Furthermore, researchers and managers will be able to better evaluate the tradeoffs between sampling intensity and statistical power to detect treatment effects when developing sampling protocols to meet research or management objectives while minimizing superfluous sampling effort (Steidl et al. 1997). Our objectives were to use simulation models based on field data measurements of observer-covey distances to estimate sample sizes required to meet desired levels of precision on covey density using point-transect distance sampling of autumn bobwhites.

Study Area

Our study was conducted on 39 privately owned farms enrolled in the Georgia Department of Natural Resource's Bobwhite Quail Initiative (BQI) in the Upper Coastal Plain physiographic region of Georgia. The BQI consisted of 3 focus regions (East, Central, and Southwest) where state-sponsored cost-share incentives were offered for bobwhite habitat development (e.g., prescribed burning, field borders, and conservation tillage). Major land uses were intensive row crop (cotton, peanut, soybean, corn, and winter cereal) agriculture and timber production. However, agricultural intensity varied among the 3 regions, with mean cropland area of 31%, 19%, and 12% for the Southwest, East, and Central regions, respectively (http://www.georgiastats.uga.edu/, February 2003). Mean row crop field size of farms sampled in this study was approximately 23 ha. Forested areas were plantations of loblolly (*Pinus taeda*) and slash (*Pinus elliotti*) pine, with occasional stands of longleaf pine (*Pinus palustris*). Forested land comprised approximately 63% of the Central Region, 62% of the East Region, and 46% of the Southwest Region (http://www.georgiastats.uga.edu/, February 2003). For a complete study area description see Hamrick (2002).

Methods

Field Data Collection

Because distance sampling of autumn bobwhite populations is a new technique, few data sets of sufficient breadth to capture variability in landscape context and bobwhite density (i.e., not site-specific studies) and depth (i.e., number of detections) exist from which observer-covey distances could be used to generate a detection function. In lieu of this data, we generated *post hoc* observer-covey distances from quadrant surveys conducted as part of the population monitoring program of BQI.

Quadrant Approach

The quadrant survey entailed placing one observer at the midpoint along each side of a 25 ha (500 m x 500 m) sampling cell (Wellendorf and Palmer 2005, ; Figure 1). Observers listened for the assemble, or "koi-lee," call (Stoddard 1931) given by bobwhite coveys and recorded the time, azimuth, duration, estimated distance to the covey, and number of covey calls per calling event for coveys within and outside of the quadrant. Surveys ended at sunrise if no calls were detected and were not conducted during periods of sustained rainfall. Upon completion of the survey, observers compared measurements to determine the number and estimated location of coveys. For each covey that was detected by >1 observer, the intersection of azimuths to the covey was used to plot the estimated covey location. Each covey location estimate was plotted on a final field map.

To minimize observer bias, all observers were trained by listening to recorded covey-calls and by spending several mornings in the field listening to calling coveys pointed out by experienced observers before conducting covey-call surveys (Kepler and Scott 1981, Smith 1984, Scott et al. 1981, Seiler et al. 2005). We assumed that observers were able to determine the direction from which a calling covey was heard with reasonable accuracy. Seiler et al. (2005) estimated a mean measurement error of 75 m between known covey caller locations and paired azimuth-derived locations in rolling terrain. Other assumptions of distance sampling that we believed we met were that coveys were detected at their initial location and that all coveys calling at survey points were detected (Buckland et al. 2001). Whereas inter-observer variation in detection probability may substantially affect resulting density estimates (Diefenbach et al. 2003), we assumed no inter-observer variation in observer ability to detect calling coveys. This additional assumption was necessary because we did not have sufficient data to test differences in observer-specific detection functions. We believe this to be a reasonable assumption given that Wellendorf and Palmer (2005) reported observer-specific detection rates to be within 10-15% of the overall mean detection rate among trained individuals conducting autumn calling covey counts in Florida.

Observer-covey Distances

Multiple detections of the same covey permitted estimation of distances from observers to calling coveys. Distances from observers to covey locations were calculated by the intersection of azimuths for >1 observers that detected a particular calling covey. Most covey locations were estimated via the intersection of azimuths from 2 observers. If greater than 2 observers detected the same covey, we used the geometric center of the error polygon created from the intersection of all observer azimuths. Distance from the observer to the predicted covey location was estimated using standard trigonometric relationships between observer locations along the quadrant and reported azimuths to calling coveys (Figure 1).

Our intent was only to use the quadrant data to generate observer-covey distances for developing a detection function for use with simulated covey observation data; therefore, the experimental design (i.e., replication, repetitions, treatment, etc.), and subsequent density estimates, used in the BQI monitoring program were irrelevant and are not addressed. All distances were computed to the nearest 5-m increment. Wellendorf and Palmer (2005) reported that well trained observers could reasonably classify calling coveys into distance categories of 0-100 m, 101-250 m, 251-500 m, and >500 m. Therefore, to simulate probable point-transect distance sampling data, we grouped observer-covey distances into these respective distance categories. Right truncation was set to 700 m, an assumed mean maximum audible range of detection DeMaso et al. (1992).

Detection Function

Prior to analyses, we visually inspected the data by plotting observations by distance category to determine potential detection functions that would best fit observed data patterns. The uniform base function with cosine or hermite polynomial adjustment terms and the hazard rate base function with either cosine or simple polynomial adjustment terms were selected as likely base function-adjustment term combinations that would best model the data. We used Program DISTANCE (Thomas et al. 1998) to fit models and subsequently identify a detection function to estimate the detection probability ($h_{(o)}$), the value of the probability density function $f_{(x)}$ evaluated at 0. Base functions and series expansion terms, increasing in complexity (# of estimable parameters), were sequentially evaluated by comparing Akaike's Information Criterion (AIC) values

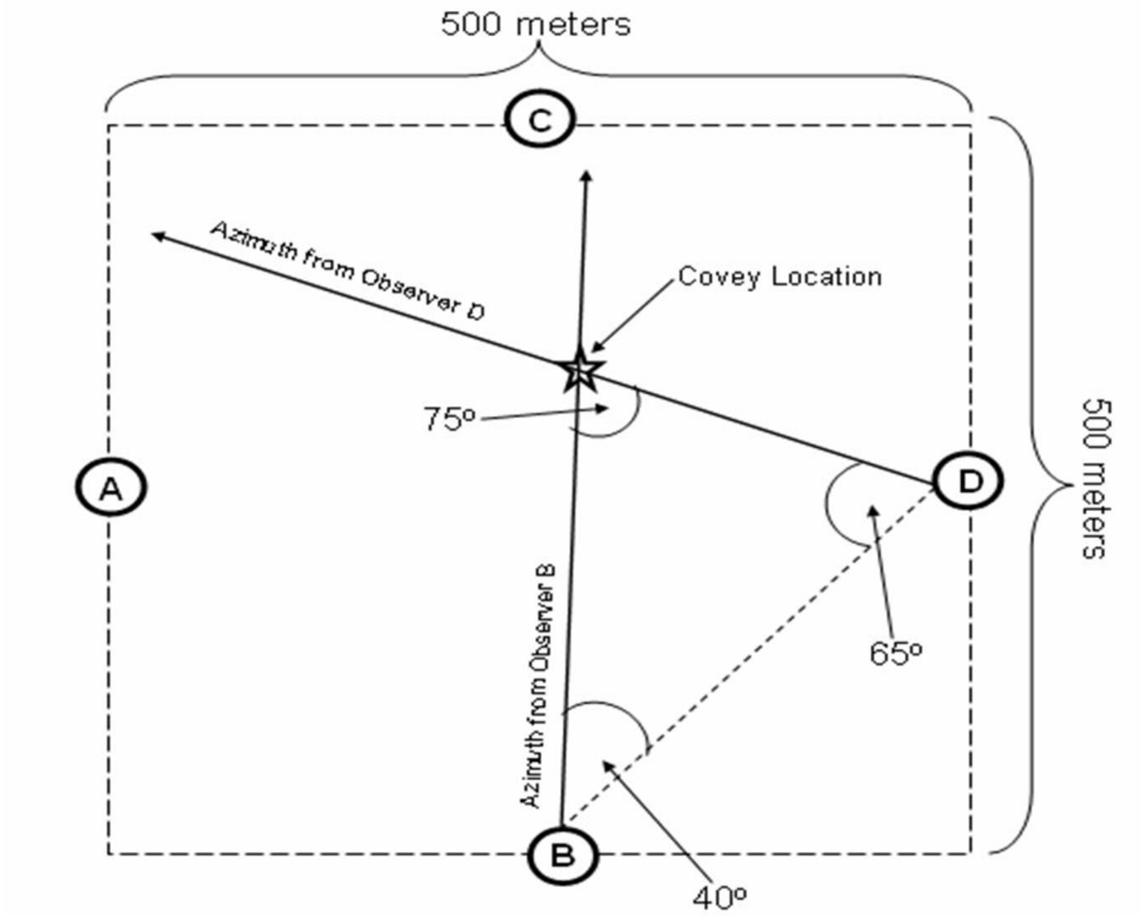

Figure 1: Depiction of how observer-azimuths to calling northern bobwhite coveys (taken during multiple-, independent-observer covey-call-count surveys) were utilized to calculate estimated observer-covey distances.

among competing models (Anderson et al. 2000, Buckland et al. 2001, Burnham and Anderson 2002). When a more complex model failed to adequately fit the data relative to the number of parameters within the model (greater AIC), the previous model was selected as the best approximating model (Buckland et al. 2001).

Simulations

To determine the expected effect of sample size (number of sampling points) on precision of density estimates (i.e., coefficient of variation; CV), we generated 1,000 sets of covey detections from a Poisson distribution in increments of 10 at each sample size from 10-100, in increments of 100 for sample sizes of 100-500, and at 1,000. Because bobwhite densities vary substantially across their range, we repeated this process for Poisson distribution means of 0.5, 1.0, 2.0, and 3.0 detections (i.e., calling coveys)/point. Using the detection probability ($h_{(o)}$) and standard error estimated from the best approximating detection function, we then computed the covey density and CV as described in Buckland et al. (2001) for each of the 1,000 samples at each sample size/mean covey detection combination. All simulations were conducted using programming statements in SAS statistical software (SAS Institute, Inc. 2002). We *a priori* set a CV of 15% as an acceptable

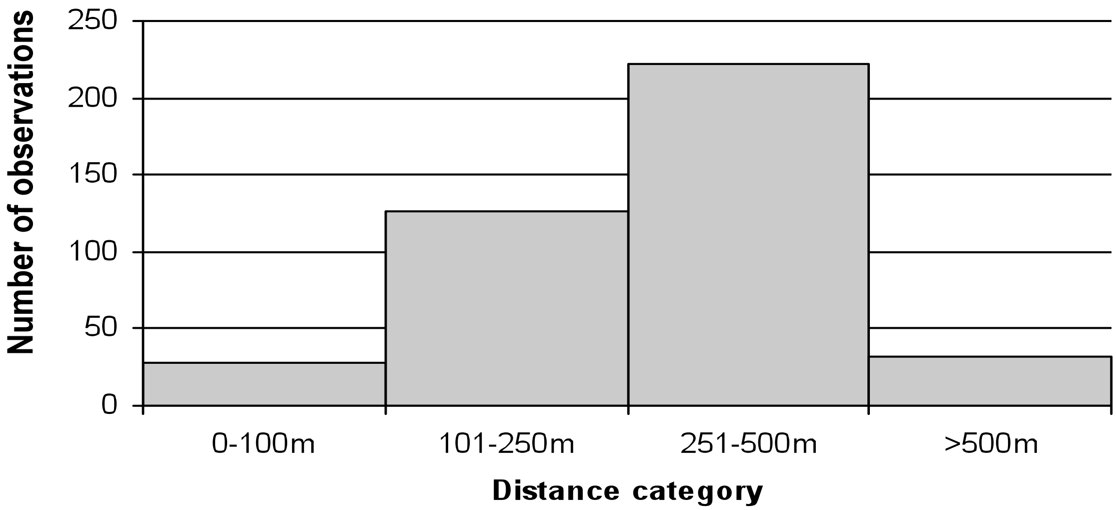

Figure 2: Observer-covey distances of calling northern bobwhite coveys computed via triangulation of azimuths to calling coveys taken by pairs of independent observers positioned 350 m and 500 m apart during quadrant sampling. Distances were then categorized into 0−100m, 101−250m, 251−500m, and 500m+ distance categories, Georgia, 1999−2000.

level of precision.

Results

We computed 408 observer-covey distances from 701 observer mornings for use in estimating a detection function and subsequent detection probability (Figure 2). The uniform base function with a cosine adjustment term (order 1) was selected as the best detection function model (AIC = 883.06) and fit the data well ($\chi 2^2$ = 1.7034, P = 0.42669). Effective detection radius was 381.72 m (SE = 4.977). Detection probability accounted for 10.9% of the variation of density whereas the encounter rate accounted for the balance of this variation.

As expected, the CV on density decreased with increasing sample size and expected number of detections per point (Figure 3). A CV $<$15% could be achieved with 50 points at densities with a mean 1 covey detected/point or 20 points with a mean detection of 2 coveys/point. A mean CV $<$10% required 100 points at 1 covey/point and 30 points at 3 coveys/point. Our simulations suggest that with a sample of 40 points a CV of 16.1% could be expected and with 50 points a CV of 14.5%. Population variability stabilized at a CV of approximately 4%.

Discussion

The availability of observer-covey distance data in agricultural landscapes of the southeastern United States is scant; we were only able to generate *ad hoc* observer-covey distances from previous research. Therefore, we acknowledge several potential biases in this analysis. First, we assumed that observers could reliably detect the direction of, and accurately measure an azimuth to, a calling covey. We further assumed and that these azimuths were recorded without error. From our experiences, and from those of others (Seiler et al. 2002, Wellendorf et al. 2004, Seiler et al. 2005), we do not consider this source of error extremely problematic and assume directional error, and subsequently estimated distance error, to be random. Obviously, as the distance from the observer increases, location error of the covey will increase. This error would affect the detection function, detection probability, and resulting standard error of the detection probability. Random errors in distance measurement, however, are tolerable if they are not too large, and sample size

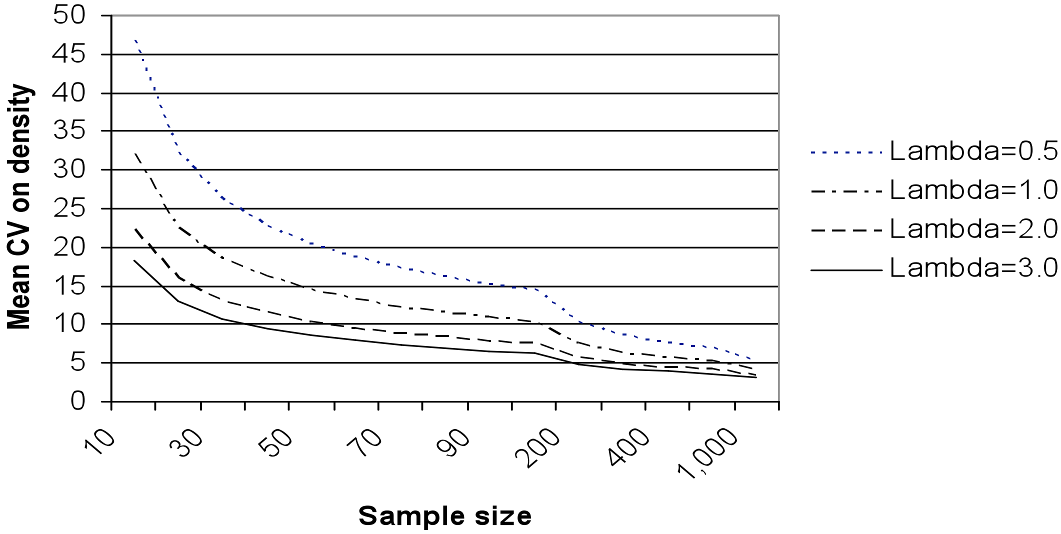

Figure 3: Mean coefficient of variation (CV) of density estimates generated from 1,000 samples (with replacement) for number of points sampled using estimated covey-observer distances from Bobwhite Quail Initiative sites in Georgia, 1999−2000.

is large (Buckland et al. 2001). Minor variations in the detection probability and standard error had little effect on the mean CV on density (M. Smith, unpublished data, Mississippi State University).

Landscape context, hence the structure and composition of land cover within the landscape, may substantially influence detection probability (Bibby et al. 1992, Buckland et al. 2001). The detection function (uniform with cosine adjustment) used in our study was constructed from covey observations obtained in agricultural landscapes within the Upper Coastal Plain physiographic region and may not be applicable to other physiographic regions or landscapes. Cropland varied from 12-31% in landscapes in which counts were conducted. Within forested landscapes under intense bobwhite management in north Florida, Wellendorf and Palmer (2005) reported use of a uniform base function with a simple polynomial adjustment, but model fit was marginal. Although the amount of forested area differed among our sites, we did not have sufficient data to test differences in detection function among the three areas. Given that all of the sites were relatively open agricultural lands, we suspect only minor, if any, differences in detection probability among sites. Similar to other distance-based techniques (Guthery et al. 1988), sampling in areas of low bobwhite densities will be problematic (Kuvlesky et al. 1989). First, sufficient numbers (approximately 70-100; Buckland et al. 2001) of detections may not be obtained to in order to estimate detection functions and secondly, variance will be exceedingly high such that confidence intervals on density will be rendered uninformative.

Management Implications

In October 2004, the Farm Services Agency of the U.S. Department of Agriculture (USDA) announced the availability of a field border practice (CP33-Habitat Buffers for Upland Birds) within the Continuous Conservation Reserve Program. Whereas CP33 is a USDA farm bill conservation practice, state wildlife agencies were delegated the responsibility of developing and implementing a statewide monitoring program that will 1) provide statistically valid estimates of bobwhite density (or some other appropriate measure) on fields enrolled in CP33 at state, regional, and national levels, and 2) provide a measure of the relative effect size of the CP33 practice at state, regional and national levels. The Research Committee of the Southeast Quail Study Group developed a national protocol (Burger et al. 2006) that states could use to meet these objectives. This national monitoring protocol outlined a suggested multi-stage sampling framework and infield protocol to ensure consistency in data collection among states and to facilitate statistically valid measures of the effectiveness of CP33. Point transect sampling was selected as the primary technique for monitoring breeding season bobwhites and songbirds and fall covey densities. Fourteen states adopted this protocol.

Given the statewide availability of the CP33 practice and the relatively limited resources of most state wildlife agencies to conduct monitoring, it was paramount to *a priori* determine an appropriate level of sampling (number of points surveyed) that would provide reasonable (CV $\leq$15%) estimates of bobwhite density while minimizing superfluous sampling effort. We used the approach outlined in this paper to estimate adequate sampling intensity at state, regional (BCR), and national levels. This simulation suggested that at a sample of 40 points a CV of 16.39 could be expected and at 50 points a CV of 14.69. From this simulation we concluded that 40 fields/state would produce estimates sufficiently precise to meet the language in FSA Notice CRP-479 *at the state level* and will produce CVs on regional and national data in the 5-6% range. If fields enrolled in CP-33 were paired with un-enrolled control fields in the vicinity of each contract we could estimate the effect size of the CP-33 practice (number of quail/ac added to the landscape as a result of CP-33) and extrapolate that to the national enrollment to produce a defensible estimate of the national effect of CP33 on bobwhite and select songbirds. The National CP33 Monitoring Protocol recommended that sampling intensity should vary in relation to the number of acres enrolled in the state (i.e., proportional stratified sampling). Under this scheme states would monitor from 40- 141 fields.

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