EVALUATION OF NORTHERN BOBWHITE (*Colinus virginianus*) POPULATION MONITORING METHODS AND POPULATION TRENDS IN AGRICULTURAL SYSTEMS IN THE UPPER COASTAL PLAIN OF GEORGIA

by

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(Under the direction of Dr. John P. Carroll)

ABSTRACT

Declining northern bobwhite *Colinus virginianus* (bobwhite) populations in Georgia led to the development of the Bobwhite Quail Initiative (BQI), a state-funded pilot project aimed at increasing bobwhite habitat in agricultural systems. Bobwhite populations were monitored at BQI managed (treatment) and non-managed (control) sites using autumn covey-call-count indices, 1999-2001. Call-count observer detection rates, utility of several call-count methods, and bobwhite population response to BQI management were evaluated. Capture-recapture models suggested that observer detection rates of calling coveys did not differ among years or sites. Regression analyses suggested that single-observer point counts provided a more efficient means of estimating covey density compared to multi-observer call-count methods. Several different analyses suggested that mean covey numbers increased at treatment sites and declined at control sites. Call-count indices appear to be adequate estimators of autumn population trends when observer detection rates are quantified. Monitoring results suggest that BQI habitat management is positively affecting bobwhite populations.

INDEX WORDS: Agricultural habitats, Bobwhite Quail Initiative, *Colinus virginianus*, Covey-call-counts, Detection rates, Georgia, Habitat management, Indices, Northern bobwhite, Population monitoring

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

The northern bobwhite (*Colinus virginianus*) (hereafter, bobwhite) and many other early successional wildlife species have experienced steady population declines in the southeastern United States since the mid-1900's (Brennan 1999, Sauer et al. 2001). Loss of early successional habitat is the major cause of these population declines. Changes in land use, most notably changes in agricultural and forestry practices, have led to the loss of these once abundant, early successional habitats (Burger 2001). Before World War II, agriculture in the Southeast produced an ideal environment for bobwhite (Brennan 1991). A combination of fallow fields, weedy crop fields, an abundance of edge habitat, "rough" areas (e.g. brushy thickets), and burned woodlots provided excellent year-round bobwhite habitat. However, intensive modern agriculture provides a much less suitable environment for bobwhite. Intensive control of weeds and insects, expansion of crop fields, high-density pine forest management, elimination of rough areas, increased cultivation of marginal acreage, and fire suppression has reduced the quality and availability of bobwhite habitat (Brennan 1991, Burger 2002).

In addition to the obvious concern for a declining species, bobwhite have been a traditionally important gamebird species in Georgia (and the rest of the Southeast) both culturally and economically. Declining bobwhite populations may also adversely impact portions of localized, especially rural, economies due to decreased hunting opportunities.

Burger et al. (1999) estimated that bobwhite hunting in Georgia alone had an economic impact of greater than $42-million in 1991. Thus, the decline of this gamebird is of great concern to many different resource users and managers.

Given these circumstances, the Georgia Department of Natural Resources, Wildlife Resources Division, and the Georgia General Assembly worked together to develop the Bobwhite Quail Initiative (BQI). BQI is a state-funded pilot project (initiated in 1999) aimed at increasing early successional habitat by providing monetary incentives to qualifying cooperators who agree to practice habitat management in privately owned row crop agriculture fields. To be eligible for monetary incentives, cooperators must first obtain a minimum score based on a proposed level of bobwhite habitat quality to be provided. Cooperators must also maintain minimum eligibility requirements throughout the contract period (three years) in order to receive monetary rewards. Technical assistance for bobwhite management is also provided to persons in the BQI focus areas who do not qualify for or are not interested in the incentives portion of the program.

The factors that appear to be most limiting to bobwhite population productivity on farmland are lack of adequate nesting and brood-rearing habitat (Puckett et al. 1995, Puckett et al. 2000). Carroll et al. (1990) concluded that lack of nesting habitat, and most likely brood-rearing habitat, were similarly limiting factors for gray partridge (*Perdix perdix*) (an ecological equivalent of bobwhite) populations in North Dakota agricultural systems. To increase the quality of nesting and brood-rearing habitats, BQI habitat management includes:

1.) establishing $\geq$10 meter, permanently vegetated[a], linear field borders around crop field perimeters;

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[a] Linear habitats are to remain permanently vegetated with the exception of periodic late-fall or winter soil disturbance such as prescribed fire or shallow discing (harrowing).

2.) establishing ≥10 meter, permanently vegetated, linear weedrows (herbaceous vegetation) or hedgerows (combination of scattered shrub and herbaceous vegetation) through crop field interiors;

3.) restoring existing, woody hedgerows and/or fencerows to suitable bobwhite habitat;

4.) practicing conservation tillage (planting spring crops within residues left from a winter cover- or cash-crop);

5.) fallowing patches of land adjacent to enrolled crop fields; and

6.) thinning and/or prescribed burning of pine stands adjacent to enrolled crop fields.

Review of Habitat Management Practices

In row crop agriculture systems, linear habitat management is an effective way to increase available bobwhite habitat while minimizing the amount of crop acreage taken out of production. Though such habitats are seldom optimal, they provide much improved habitat conditions for bobwhite in intensively cropped farmland. Linear habitat management combined with fallow patch and woodland management further enhances farmland habitat. The following review focuses on research pertaining to management activities and species similar to those on my study areas. The majority of such research has been conducted in Europe, but similar management strategies are beginning to be applied in the United States.

Linear Habitats.--Use of linear habitats by bobwhite and similar gamebirds has been reasonably well documented, and linear habitat management is a common bobwhite management practice. Managers [e.g. Stoddard (1931), Rosene (1969), Exum et al. (1982)] have advocated leaving field borders (vegetated strips of suitable cover along field margins) to improve bobwhite habitat in crop fields. Stinnett and Klebenow (1986) reported that California quail (*Callipepla californica*) on agricultural lands in Nevada used vegetated field borders extensively throughout the year. In Iowa (McCrow 1980), Wisconsin (Church 1983), and North Dakota (Carroll and Crawford 1991), various linear habitats associated with agricultural systems were apparently important gray partridge habitats.

In North Carolina, row crop agricultural sites with vegetated filter strips established along drainage ditches provided preferred bobwhite cover resources and possibly more productive nesting and brood-rearing habitat compared to sites with no filter strips (Puckett et al. 1995, Puckett et al. 2000). Smith (2001) reported bobwhite use of linear strip-cover for nesting and brood-rearing in Mississippi.

Other species that require similar habitats as bobwhite have also been reported to benefit from linear habitat management. In Great Britain, several studies have found that ring-necked pheasant (*Phasianus colchicus*) and gray partridge brood survival and size were increased in agricultural systems where herbicide and pesticide treatments were excluded or selectively used along field edges (Rands 1985, 1986*b*, Sotherton and Robertson 1990, Sotherton 1991). In Iowa, ring-necked pheasants exhibited greater nest site preference and nesting success in strip-cover associated with crop fields (Basore et al. 1986). Rands (1986*a*, 1987) concluded that greater amounts of nesting cover in field edges available for breeding gray and red-legged partridges (*Alectoris rufa*) in Great Britain resulted in greater population productivity. Warner and Joselyn (1986) reported a positive response by nesting ring-necked pheasants in Illinois to roadsides managed by grass plantings and delayed mowing. Similarly, in North Dakota farmland, linear strips of unmowed vegetation along roadsides apparently provided critical nesting habitat for gray partridge (Carroll and Crawford 1991). Boatman and Brockless (1998) reported increased nesting and brood-rearing success of ring-necked pheasant and gray and red-legged partridges after implementation of linear, herbaceous cover through interiors and along edges of agricultural fields in Great Britain. In Switzerland, gray partridge and common quail (*Coturnix coturnix*) populations increased after the establishment of herbaceous linear cover and fallow land in agricultural landscapes (Jenny et al. 1998).

Conservation Tillage.--Basore et al. (1986) found that no-till corn and soybean fields in Iowa were used by a greater diversity of bird species and had greater densities of nesting birds (though their study focused only on no-till methods that left a maximum amount of surface residue). However, Best (1986) expressed concern that no-till fields may be ecological traps (Gates and Gysel 1978) for some nesting bird species, and this topic may warrant more research. Minser and Dimmick (1988) believed that implementing no-till methods in a Tennessee study area increased available bobwhite nesting cover. However, nest success was not drastically different in conventional and no-till fields for the small sample of nests that were found.

Warburton and Klimstra (1984) found a greater summer abundance of birds and invertebrates in Illinois no-till fields compared to conventionally tilled fields. Castrale (1985) also reported greater summer and winter bird abundance associated with some no-till fields in Indiana. In Iowa, Basore et al. (1987) found no difference in arthropod abundance between conventionally tilled and several no-till crop plantings during the ring-necked pheasant brood-rearing period. They concluded that crop type and pesticide use influenced arthropod abundance to a greater extent than the method of tillage. Recently, Cederbaum (2002) conducted research evaluating insect and bird abundance in conservation tillage fields in the Upper Coastal Plain of Georgia. This research found that for all species of birds during migration, wintering, and breeding seasons, densities were greater in conservation tillage and strip-till (clover cover crop) fields compared to conventionally tilled fields. Strip-till fields appeared to have the greatest bird densities during all seasons except winter, when conservation tillage fields appeared to have greater bird densities. Cederbaum (2002) also found that overall and beneficial (predators of crop pests) arthropod biomass and density were greater in strip-till fields throughout summer.

Fallow Patches.--Management of early successional fallow patches for bobwhite habitat is a common practice. Numerous researchers have documented the use of these habitats by bobwhite (e.g. Stoddard 1931, Rosene 1969, Exum et al. 1982, Yates et al. 1995). Parnell et al. (2002) found fallow areas to be important habitats for bobwhite in a mixed agricultural and forested system in Georgia.

Woody habitats.--Managed pine stands and brushy thickets probably supply critical winter habitat at a time when dead herbaceous vegetation in field borders and weedrows likely provides less protective cover (Wellendorf et al. 2002*a*). Such habitats are also used during all seasons for food and cover (e.g. escape, thermal, or roosting) resources (Stoddard 1931, Rosene 1969, Yoho and Dimmick 1972, Roseberry and Klimstra 1984, Johnson and Guthrey 1988, Williams et al. 2000). Smith (2001) documented high bobwhite preference for woody habitats on a grassland/agricultural site in Mississippi. In a mixed agricultural and forested system in Georgia, open-canopy pine plantations with an early successional understory (produced by silvicultural thinning) were preferred by bobwhite over closed-canopy pine stands and agricultural habitats (Parnell et al. 2002).

Woody habitat quality for bobwhite is greatly influenced, however, by stand characteristics and composition. Though certain woody habitats are used by bobwhite, they may not be of optimal value. In Georgia, Lewis (1999) documented reoccurring mortality locations of radio-marked bobwhite in closed-canopy pine plantations, suggesting that these habitats may be ecological traps (Gates and Gysel 1978). However, it was not certain that these areas were where mortality actually occurred. In Smith (2001), small woody patches interspersed with other habitats appeared relatively beneficial, while large blocks of woody habitat appeared to be detrimental due to low survival associated with high predation rates in these habitats. More research is warranted to assess optimal management strategies for landscape-level habitat patch configuration in the context of bobwhite management.

Research Objectives

With the development of the BQI program, several research goals were established. It was hoped that a long-term, cost efficient bobwhite population monitoring technique could be developed that provided valid estimates of bobwhite covey density. Concurrent with research on monitoring methods, bobwhite populations were to be measured on managed and unmanaged sites so that population responses to BQI management could be evaluated. Several researchers (e.g., Warner 1992, Potts and Robertson 1994) have stressed the importance of long-term data sets and experiments that result in testable hypotheses relating to changes in gamebird populations due to habitat manipulations. Thus, it was hoped that this study would serve as a foundational starting point for a long-term bobwhite population monitoring and research program.

Review of Population Estimators

To evaluate population trends and characteristics, some estimator must be used to collect information on the population of interest. Both absolute population counts and population indices have been used to make bobwhite population estimates. However, consensus on one good estimator for bobwhite abundance or density in the Southeast has been problematic (Curtis et al. 1989), and this may be true for many of the Galliformes worldwide (Conroy and Carroll 2001).

Bobwhite population estimates are made to establish harvest regulations, predict harvest trends, monitor population changes, or evaluate the impact of management actions. The following review pertains to population estimators related to bobwhite and similar Galliformes [excluding most estimators used for larger Galliformes species (e.g. turkeys and pheasants) which may be influenced by different assumptions than those associated with smaller Galliformes species].

Direct Counts.--In the early history of gamebird management, population measurements were made with drive counts or area searches. Such counts generally attempted to completely census a particular management unit and often utilized hunting dogs to aid in searching areas of interest. Bennet and Hendrickson (1938) outlined a formal procedure for sampling fall bobwhite covey numbers in Iowa using bird dogs. Yocom (1943) used area searches to survey gray partridge populations and suggested that area searches aided by dogs performed best during covey periods and that drive counts performed best during the prenesting period. Several studies [e.g. Kozicky et al. (1956), Vance and Ellis (1972), and Roseberry and Klimstra (1972,1984)] have utilized some type of area search to estimate and evaluate trends in bobwhite populations.

In France, Pepin and Birkan (1981) found a close relationship between gray partridge density estimated by area searches and strip transects. Line transect surveys were reported to perform reasonably well as population estimators for bobwhite in rangeland habitats (Guthrey 1988) and for similar species such as mountain quail (Brennan and Block 1986) and gray partridge (Ratti et al. 1983). Guthrey and Shupe (1989) compared bobwhite density estimates produced by line transect and capture-removal estimates and found little difference in the results of the two estimators.

A few other direct methods to evaluate bobwhite populations have also been reported. Hickey (1955) briefly described the use of farmers' reports to evaluate gamebird population trends. Stanford (1972) outlined a method to evaluate bobwhite abundance through standardized data collection based on daily field observations. Wells and Sexson (1982) believed that in Kansas, rural mail carrier surveys and brood counts of bobwhite provided the best information about a subsequent hunting season because these two surveys correlated well with harvest activity and were inexpensive. In Texas, Shupe et al. (1987) compared bobwhite density estimates from line transects surveyed by helicopter to density estimates obtained from both walking line transects and capture-removal. They concluded that, though more research is warranted, helicopter transects were apparently a time and cost efficient method to estimate bobwhite density in rangeland (with the possibility of conducting such counts in conjunction with helicopter surveys for deer).

Though the methods previously described are often widely used, they may lack precision and accuracy or may not be appropriate for a given objective or situation.

Following is a brief review of research investigating the performance and utility of the more common direct estimators.

Evaluation of Direct Counts.--Kellogg et al. (1982) evaluated the use of hunting dogs as an aid to estimating bobwhite abundance and concluded that the technique was unreliable for a number of reasons. Some of the reasons this technique as unreliable included extra variability introduced by using dogs and possible detection bias introduced by changes in bobwhite behavior in response to repeated disturbance. Sisson et al. (1997) utilized radio telemetry to evaluate the performance of hunting dogs in locating bobwhite coveys and suggested that using hunting dogs for abundance estimation performed poorly, but that the technique may be useful to evaluate population trends.

Dimmick et al. (1982) found drive counts to be negatively biased compared to capture-removal estimates. Line transect surveys for bobwhite have produced poor results when survey areas are small and population densities are low (Kuvlesky et al. 1989) and are believed to have low precision (Guthrey and Shupe 1989). Janvrin et al. (1991) evaluated bobwhite drive counts using radio-tagged birds and found them to be highly variable. In Janvrin et al. (1991), behavioral monitoring of radio-tagged bobwhite during drive counts indicated the potential violation of several key assumptions pertinent to line transect sampling. Hernández et al. (2002) concluded that drive counts for Montezuma quail required a large number of observers spaced relatively close together, since birds only flushed when observers were within less than one meter.

O'Brien et al. (1985) believed that capture-recapture estimators were negatively biased compared to capture-removal estimates. Curtis et al. (1989) indicated that while capture-removal estimators seem to provide good bobwhite population estimates for relatively small areas, these estimators are very labor and cost intensive and are likely impractical for use on a broad scale.

Indirect Counts.--Breeding season call-counts of male gamebirds have been used extensively as a population index. Several studies [e.g. Rosene (1957), Ellis et al. (1972), Rosene and Rosene (1972), Curtis et al. (1989)] have found relationships between bobwhite whistle-counts and either fall/winter covey numbers or hunting success. Smith and Gallizioli (1965) found spring call-counts of Gambel's quail (*Callipepla gambelii*) to be good predictors of fall hunting success and possibly juvenile recruitment due to correlation between call-counts and percent juveniles harvested. Brown et al. (1978) reported that call-counts had the potential to be a good predictor of scaled quail (*Callipepla squamata*) harvest since a correlation was found between call-counts and harvest. Panek (1998) found a significant relationship between average numbers of calling male gray partridge and population density estimated by area searches.

Other research on the utility of spring bobwhite whistle-counts, however, has suggested that relatively little inference can be drawn from these counts. Norton et al. (1961) concluded that bobwhite whistle-counts were unreliable indices to fall/winter populations. Schwartz (1974) found bobwhite whistle-counts to be only weakly correlated to hunting success.

Robel et al. (1969) investigated the use of regression coefficients that incorporated "meteorological and time factors" to improve bobwhite whistle-count surveys. This study found that time and weather variables apparently influenced calling activity, but did not address reliability of the index to population estimation. During morning call-counts of male gray partridge in Wisconsin, March and Church (1980) found that playing recorded calls of males during surveys increased response rates. Haroldson and Kimmel (1990) attempted to improve summer call-count response of gray partridge groups in Minnesota by playback of recorded chick calls. Though more groups were counted overall when using playback, there was no difference in the number of groups counted per hour of survey with or without playback (thus, survey efficiency was really not improved by using playback). Hansen and Guthrey (2001) investigated the effects of time, weather, and call-playback on bobwhite whistling activity. They found time and weather effects to be important, but call-playback did not appear to contribute to the efficiency of the whistle-count index. As a result of their research, Hansen and Guthrey (2001) provided several suggestions to increase the value of whistle-count data, though their objectives did not include direct evaluation of population estimates obtained from whistle-counts.

Fall covey-call-counts have also been used to make estimates of autumn bobwhite populations. Roseberry and Klimstra (1984) reported use of covey-calls, in a very limited capacity, as a method of bobwhite population survey during one year when certain portions of their study area were inaccessible for direct surveys. In Louisiana, covey-call-counts have been conducted on a statewide basis to monitor fall bobwhite population trends (Anonymous. 1986. Upland survey: V-I, bobwhite fall whistling survey, Louisiana Department of Wildlife and Fisheries, Baton Rouge, Louisiana, USA). In a study on gray partridge, Rotella and Ratti (1986) were able to correlate morning call-counts with density estimates obtained from line transect surveys. In North Carolina, Robinette (1990) evaluated covey-call-counts as a potential estimator of bobwhite population trends. Radio-tagged bobwhite coveys were monitored to evaluate covey-call rates and optimal survey time frame. However, Robinette's (1990) evaluation of covey-call-counts was limited to one year of investigation due to limited time and budget. DeMaso et al. (1992) used single observer covey-call-counts in an attempt to model a relationship between mean number of calling coveys and density estimated by line transect samples. They concluded that covey-call-counts were a weak index of covey density, due to poor relationships between call-counts and estimated density and possible violation of assumptions associated with call-counts. Both the Louisiana and North Carolina study of covey-call-counts used playback of recorded covey-calls in an attempt to elicit greater call response. Wellendorf et al. (2001) suggested that playback might be useful in areas of low covey densities or on days with poor weather conditions, but potential survey problems associated with playback might outweigh its potential benefits.

A multiple observer covey-call-count technique (described in Chapters 2 and 3), developed at Tall Timbers Research Station (TTRS), appears to provide a valid index of bobwhite density (W. Palmer and S. Wellendorf, TTRS, personal communications) in certain situations. This technique utilizes a quadrat sample requiring at least four observers and is labor intensive for use on a broad scale. Furthermore, it seems best suited for sampling large expanses of homogeneous habitat where bobwhite coveys are randomly distributed. Other researchers who reported using this technique to estimate bobwhite population density include Smith (2001) in Mississippi, Seiler (2001) in Missouri, and Wellendorf et al. (2002*b*) in several southeastern states.

Most of the techniques I have previously described are not practical (or applicable in many cases) to quantify bobwhite population response to BQI habitat management, which was the ultimate goal of this research. Covey-call-count techniques were the most feasible technique to monitor bobwhite populations on a large scale. Thus, I investigated ways to improve the quality of covey-call-count techniques as a large-scale and long-term population monitoring method for the BQI program.

STUDY AREA

The BQI program was initiated with three focus areas that included 17 counties in the Upper Coastal Plain of Georgia (Figure 1.1). The three focus areas were composed of East (Bulloch, Burke, Jenkins, and Screven Counties), Central (Bleckley, Dodge, Emanuel, Houston, Laurens, and Truetlen Counties), and Southwest Regions (Colquitt, Crisp, Dougherty, Lee, Mitchell, Sumter, and Terrell Counties). This research was conducted on sites in all counties except Colquitt, Crisp, Houston, and Mitchell Counties.

Major land uses in all three regions consisted of intensive row crop agriculture and timber/fiber production. Agricultural row crop production was dominated by cotton, peanuts, soybeans, corn, and winter wheat. Center-pivot irrigation was commonly used to irrigate crops in the Southwest and Central Regions, and was used less frequently to irrigate crops in the East Region. Tables 1.1, 1.2, and 1.3 present various agricultural characteristics and land use parameters for each county in the East, Central, and Southwest BQI regions, respectively. Tables 1.4, 1.5, and 1.6 present various land use parameters associated with forestry for each county in the East, Central, and Southwest BQI regions, respectively.

Row crop fields in the study area tended to be large in size and had little or inadequate transition zones capable of providing suitable bobwhite habitat. For example, historically fencerows or hedgerows that were once composed mainly of scattered trees and shrubs with an abundance of grassy and weedy understory separated two or more fields. Today, the vegetative structure of these transition zones have grown to become unsuitable bobwhite habitat or have been eliminated altogether to create one contiguous crop field out of two or more smaller fields. A similar situation occurred in Great Britain, where hedgerows were removed or managed in a manner so as to have detrimental effects on gray and red-legged partridge production (Rands 1986*a*, 1987). Forest production in the study area was dominated by plantations of loblolly pine (*Pinus taeda*) and slash pine (*Pinus elliotti*), although longleaf pine (*Pinus palustris*) plantings were increasing in all regions. In the first three to five years after pine plantations are established, good bobwhite habitat often exists. Afterwards, pine plantations become too dense to allow adequate understory vegetation growth, and bobwhite habitat is lost until thinning and prescribed fire or other soil disturbance can be applied to increase herbaceous understory (Rosene 1969). Pine stands in the sawtimber age class are generally easier to manage for bobwhite habitat. In sawtimber stands, thinning usually results in a monetary profit, and there is less chance of damage to residual trees when applying prescribed fire. However, the majority of pine stands in the study area had basal area and understory vegetation characteristics that did not constitute suitable bobwhite habitat.

LITERATURE CITED

Basore, N. S., L. B. Best, and J. B. Wooley, Jr. 1986. Bird nesting in Iowa no-tillage and tilled cropland. Journal of Wildlife Management 50:19-28.

_____, _____, and _____. 1987. Arthropod availability to pheasant broods in no-tillage fields. Wildlife Society Bulletin 15:229-233.

Bennett, J. L. and G. O. Hendrickson. 1938. Censusing quail in early fall. Journal of Wildlife Management 2:169-171.

Best, L. B. 1986. Conservation tillage: ecological traps for nesting birds? Wildlife Society Bulletin 14:308-317.

Boatman, N. D. and M. H. Brockless. 1998. The Allerton Project: farmland management for partridges (*Perdix perdix*, *Alectoris rufa*) and pheasants (*Phasianus colchicus*). Gibier Faune Sauvage 15:563-574.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544-555.

_____. 1999. Northern bobwhite. Birds of North America 397:1-28.

_____ and W. M. Block. 1986. Line transect estimates of mountain quail density. Journal of Wildlife Management 50:373-377.

Brown, D. E., C. L. Cochran, and T. E. Waddell. 1978. Using call-counts to predict hunting success for scaled quail. Journal of Wildlife Management 42:281-287.

Burger, L. W. 2002. Quail management: issues, concerns, and solutions for public and private lands-a southeastern perspective. National Bobwhite Quail Symposium Proceedings 5:20-34.

_____, D. A. Miller, and R. I. Southwick. 1999. Economic impact of northern bobwhite hunting in the southeastern United States. Wildlife Society Bulletin 27:1010-1018.

Castrale, J. S. 1985. Responses of wildlife to various tillage conditions. Transactions of the North American Wildlife and Natural Resources Conference 50:142-156.

Carroll, J. P. and R. D. Crawford. 1991. Roadside nesting by gray partridge in north-central North Dakota. Wildlife Society Bulletin 19:286-291.

_____, R. D. Crawford, and J. W. Schultz. 1990. Nesting and brood-rearing ecology of gray partridge in North Dakota. Perdix V Symposium 5:272-294.

Cederbaum, S. B. 2002. The effects of alternative and conventional management systems in cotton agriculture on avian and arthropod populations in the Upper Coastal Plain of Georgia. Thesis, University of Georgia, Athens, Georgia, USA.

Conroy, M. J. and J. P. Carroll. 2001. Estimating abundance of Galliformes: tools and applications. Proceedings of the International Galliformes Symposium 2:197-204.

Church, K. E. 1983. Nesting biology of gray partridge in east-central Wisconsin. Perdix III Symposium 3:46-53.

Curtis, P. D., P. D. Doerr, R. M. Oates, and K. H. Pollock. 1989. Whistling-cock indices as a measure of northern bobwhite harvest in North Carolina. Proceedings of the

Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 43:253-259.

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

Dimmick, R. W., F. E. Kellogg, and G. L. Doster. 1982. Estimating bobwhite population size by direct counts and the Lincoln index. National Bobwhite Quail Symposium Proceedings 2:13-18.

Ellis, J. A., K. P. Thomas, and P. Moore. 1972. Bobwhite whistling activity and population density on two public hunting areas in Illinois. National Bobwhite Quail Symposium Proceedings 1:282-288.

Exum, J. H., R. W. Dimmick, and B. L. Dearden. 1982. Land use and bobwhite populations in an agricultural system in West Tennessee. National Bobwhite Quail Symposium Proceedings 2:6-12.

Gates, J. E. and L. W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology 59:871-883.

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

______ and T. E. Shupe. 1989. Line transect vs. capture-removal estimates of bobwhite density. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 43:248-252.

Hanson, H. M. and F. S. Guthrey. 2001. Calling behavior of bobwhite males and the call-count index. Wildlife Society Bulletin 29:145-152.

Haroldson, K. J. and R. O. Kimmel. 1990. Responses of ring-necked pheasants and gray partridge to tape-recorded calls. Perdix V Symposium 5:144-151.

Hernández, F., L. A. Harveson, and C. Brewer. 2002. Efficacy of line drives to located Montezuma quail at Elephant Mountain Wildlife Management Area. National Bobwhite Quail Symposium Proceedings 5:117 (*Abstract*).

Hickey, J. J. 1955. Some American population research on gallinaceous birds. Pages 326-396 *in* A. Wolfson, editor. Recent studies in avian biology. University of Illinois Press, Urbana, Illinois, USA.

Janvrin, J. A., E. P. Wiggers, and T. V. Dailey. 1991. Evaluation of drive counts for estimating northern bobwhite densities. Wildlife Society Bulletin 19:475-481.

Jenny, M., B. Lugrin, and J. L. Regamey. 1998. Habitat restoration programme for agricultural-land breeding birds in Switzerland. Gibier Faune Sauvage 15:547-554.

Johnson, D. B. and F. S. Guthrey. 1988. Loafing coverts used by northern bobwhites in subtropical environments. Journal of Wildlife Management 52:464-469.

Kellogg, F. E., G. L. Doster, W. R. Davidson, W. M. Martin. 1982. Efficiency of dogs in locating bobwhites. National Bobwhite Quail Symposium Proceedings 2:31-34.

Kozicky, E. L., R. J. Jessen, G. O. Hendrickson, and E. B. Speaker. 1956. Estimation of fall quail populations in Iowa. Journal of Wildlife Management 20:97-104.

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

Lewis, L. A. 1999. Responses of herbaceous vegetation and northern bobwhite (*Colinus virginianus*) populations to thinned CRP pine plantations. Thesis, University of Georgia, Athens, Georgia, USA.

March, J. R. and K. E. Church. 1980. Use of roadside calling counts as an index to spring gray partridge abundance. Perdix II Symposium 2: 87-100.

McCrow, V. P. 1980. Habitat use by gray partridge in north-central Iowa. Perdix II Symposium 2:101-116.

Minser, W. G. and R. W. Dimmick. 1988. Bobwhite quail use of no-till versus conventionally planted crops in western Tennessee. Journal of Soil and Water Conservation 43:270-272.

Norton, H. W., T. G. Scott, W. R. Hanson, and W. D. Klimstra. 1961. Whistling-cock indices and bobwhite populations in autumn. Journal of Wildlife Management 25:398-403.

O'Brien, T. G., K. H. Pollock, W. R. Davidson, and F. E. Kellogg. 1985. A comparison of capture-recapture with capture-removal for quail populations. Journal of Wildlife Management 49:1062-1066.

Panek, M. 1998. Use of call counts for estimating spring density of the grey partridge *Perdix perdix*. Acta Ornithologica 33:143-148.

Parnell, I. B., III, S. H. Schweitzer, C. G. White, and L. A. Lewis. 2002. Northern bobwhite habitat use in a forest-dominated system. National Bobwhite Quail Symposium Proceedings 5:158 (*Abstract*).

Pepin, D. and M. Birkan. 1981. Comparative total- and strip-census estimates of hares and partridges. Acta Ecologica 2:151-160.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, Jr., and T. L. Sharpe. 1995. Bobwhite nesting ecology and modern agriculture: a management experiment. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:505-515.

_____, _____, _____, _____, and _____. 2000. Effects of filter strips on habitat use and home range of northern bobwhites on Alligator River National Wildlife Refuge. National Bobwhite Quail Symposium Proceedings 4:26-31.

Potts, G. R. and P. A. Robertson. 1994. Gamebird research in North America and Europe: the way forward, a critique and a plea. Transactions of the North American Wildlife and Natural Resources Conference 59:415-420.

Rands, M. R. W. 1985. Pesticide use on cereals and the survival of grey partridge chicks: a field experiment. Journal of Applied Ecology 22:49-54.

_____. 1986*a*. Effect of hedgerow characteristics on partridge breeding densities. Journal of Applied Ecology 23:479-487.

_____. 1986*b*. The survival of gamebird (Galliformes) chicks in relation to pesticide use on cereals. Ibis 128:57-64.

_____. 1987. Hedgerow management for the conservation of partridges *Perdix perdix* and *Alectoris rufa*. Biological Conservation 40:127-139.

Ratti, J. T., L. M. Smith, J. W. Hupp, and J. L. Laake. 1983. Line transect estimates of density and the winter mortality of gray partridge. Journal of Wildlife Management 47:1088-1096.

Robel, R. J., D. J. Dick, and G. F. Krause. 1969. Regression coefficients used to adjust bobwhite quail whistle count data. Journal of Wildlife Management 33:662-668.

Robinette, C. F. 1990. The influence of hunting on mortality and movements of northern bobwhite quail in the North Carolina Sandhills. Thesis, North Carolina State University, Raleigh, North Carolina, USA.

Roseberry, J. L. and W. D. Klimstra. 1972. Some aspects of the dynamics of a hunted bobwhite population. National Bobwhite Quail Symposium Proceedings 1:268-282.

_____ and _____. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, Illinois, USA.

Rosene, Jr., W. 1957. A summer whistling cock count of bobwhite quail as an index to wintering populations. Journal of Wildlife Management 21:153-158.

_____ and J. M. Rosene. 1972. Interrelationships between various quail population measurements. National Bobwhite Quail Symposium Proceedings 1:294-301.

Rosene, W. 1969. The bobwhite quail: its life and management. Rutgers University Press, New Brunswick, New Jersey, USA.

Rotella, J. J. and J. T. Ratti. 1986. Test of a critical density index assumption: a case study with gray partridge. Journal of Wildlife Management 50:532-539.

Sauer, J. R., J. E. Hines, and J. Fallon. 2001. The North American Breeding Bird Survey, results and analysis 1966-2000. Version 2001.2. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Schwartz, C. C. 1974. Analysis of survey data collected on bobwhite in Iowa. Journal of Wildlife Management 38:674-678.

Seiler, T. P. 2001. Test of the morning covey call count technique for estimating population densities of northern bobwhites in Missouri. Thesis, University of Missouri, Columbia, Missouri, USA.

Shupe, T. E., F. S. Guthrey, and S. L. Beasom. 1987. Use of helicopters to survey northern bobwhite populations on rangeland. Wildlife Society Bulletin 15:458-462.

Sisson, D. C., H. L. Stribling, and D. W. Speake. 1997. Efficiency of pointing dogs in locating northern bobwhite coveys. National Bobwhite Quail Symposium Proceedings (*Abstract*) 4:109.

Smith, M. D. 2001. Response of northern bobwhite to intensive habitat development on a prairie site in Mississippi. Thesis, Mississippi State University, Mississippi State, Mississippi, USA.

Smith, R. H. and S. Gallizioli. 1965. Predicting hunter success by means of a spring call count of Gambel quail. Journal of Wildlife Management 29:806-813.

Sotherton, N. W. 1991. Conservation headlands: a practical combination of intensive cereal farming and conservation. Pages 373-397 *in* Firbank, L. G., N. Carter, J. F. Derbyshire, and G. R. Potts, editors. The ecology of temperate cereal fields. Blackwell Scientific Publications, Oxford, United Kingdom.

_____ and P. A. Robertson. 1990. Indirect impacts of pesticides on the production of wild gamebirds in Britain. Perdix V Symposium 5:84-102.

Stanford, J. A. 1972. Bobwhite quail population dynamics: relationships of weather, nesting, production patterns, fall population characteristics, and harvest in Missouri quail. National Bobwhite Quail Symposium Proceedings 1:115-139.

Stinnett, D. P. and D. A. Klebenow. 1986. Habitat use of irrigated lands by California quail in Nevada. Journal of Wildlife Management 50:368-372.

Stoddard, H. L. 1931. The bobwhite quail, its habits, preservation, and increase. Charles Scribner's Sons. New York, New York, USA.

Vance, D. R. and J. A. Ellis. 1972. Bobwhite populations and hunting on Illinois public hunting areas. National Bobwhite Quail Symposium Proceedings 1:165-174.

Warburton, D. B. and W. D. Klimstra. 1984. Wildlife use of no-till and conventionally tilled corn fileds. Journal of Soil and Water Conservation 39:327-330.

Warner, R. E. 1992. Long-term perspectives of upland game bird research in North America. Pages 709-717 *in* D. R. McCullough and R. H. Barrett, editors. Wildlife 2001: populations. Alden Press, Oxford, United Kingdom.

_____ and G. B. Joselyn. 1986. Responses of Illinois ring-necked pheasant populations to block roadside management. Journal of Wildlife Management 50:525-532.

Wellendorf, S. D, W. E. Palmer, and P. T. Bromley. 2001. Effect of call stimulation on rates of covey calling by northern bobwhite. Proceedings of the International Galliformes Symposium 2:191-195.

_____, _____, and _____. 2002*a*. Habitat selection of northern bobwhite coveys on two intensive agricultural landscapes in eastern North Carolina. National Bobwhite Quail Symposium Proceedings 5:191 (*Abstract*).

_____, _____, and _____. 2002*b*. Estimating calling rates of northern bobwhite coveys and censusing populations. Journal of Wildlife Management *In Press*.

Wells, R. and K. Sexson. 1982. Evaluation of bobwhite quail surveys in Kansas. National Bobwhite Quail Symposium Proceedings 2:19-30.

Williams, C. K., R. S. Lutz, R. D. Applegate, and D. H. Rusch. 2000. Habitat use and survival of northern bobwhite (*Colinus virginianus*) in cropland and rangeland ecosystems during the hunting season. Canadian Journal of Zoology 78:1562-1566.

Yates, S. W., D. C. Sisson, H. L. Stribling, and D. W. Speake. 1995. Northern bobwhite brood habitat use in South Georgia. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 49:498-504.

Yocom, C. F. 1943. The Hungarian partridge in the Palouse Region, Washington. Ecological Monographs 13:167-202.

Yoho, N. S. and R. W. Dimmick. 1972. Habitat utilization by bobwhite quail during winter. National Bobwhite Quail Symposium Proceedings 1:90-99.

Table 1.1. Agricultural land use statistics for the BQI East focus area, Georgia (http://www.georgiastats.uga.edu/, February 2002).

	Bulloch County	Burke County	Jenkins County	Screven County	Region Means
	Hectares Harvested (Year 2000)				
Row and Forage Crops					
Barley	0	0	0	0	0
Corn	6,480	3,645	1,280	3,832	2,919
Cotton	17,618	17,618	7,753	10,520	11,963
Hay	2,025	4,050	2,430	1,094	2,525
Oats	608	608	466	484	519
Peanuts	15,390	3,038	1,231	3,038	2,435
Rye	1,418	1,678	406	1,856	1,339
Silage	0	1,418	1,904	41	1,121
Sorghum	0	77	37	33	49
Soybeans	6,075	3,888	772	3,590	2,750
Tobacco	648	0	15	14	9
Wheat	3,038	3,443	970	550	1,654
Totals	53,298	39,460	17,261	25,051	27,284
Fruits & Nuts	626	1,426	243	895	855
Vegetables	696	60	0	178	234
	Census of Agriculture[a] (Year 1997)				
Number of Farms	524	346	248	325	306
% Change in Number of Farms, 1992-97	-6%	10%	39%	15%	15%
Mean Farm Size in Hectares	155	245	152	205	201
% of Farms with < 10 Hectares	5%	3%	2%	4%	4%
Hectares of Land in Farms	80,971	84,932	37,703	66,719	63,118
% of Total Land in Farms	46%	40%	42%	40%	42%
Hectares of Harvested Cropland	48,048	36,946	13,240	26,984	25,723
	Miscellaneous (Year 2000)				
Hectares of Irrigated Farm Land	7,719	11,148	4,955	9,987	8,697
Hectares of Land in CRP/WRP[b]	3,607	4,318	1,778	2,603	2,899

[a] Farms can include non-farmed lands.

[b] CRP = Conservation Reserve Program/WRP = Wetland Reserve Program.

Table 1.2. Agricultural land use statistics for the BQI Central focus area, Georgia (http://www.georgiastats.uga.edu/, February 2002).

	Bleckley County	Dodge County	Emanuel County	Houston County	Laurens County	Treutlen County	Region Means
	Hectares Harvested (Year 2000)						
Row and Forage Crops							
Barley	0	0	0	15	0	0	3
Corn	458	1,013	1,217	486	2,430	84	948
Cotton	7,172	6,683	10,689	5,581	5,002	1,357	6,080
Hay	1,013	1,823	2,025	631	4,050	142	1,614
Oats	84	162	253	192	1,033	85	302
Peanuts	1,348	2,835	1,053	1,673	2,203	0	1,519
Rye	115	203	98	175	1,337	122	341
Silage	0	0	0	365	203	0	95
Sorghum	21	81	6	412	324	34	146
Soybeans	754	263	365	2,099	3,483	87	1,175
Tobacco	0	61	258	0	47	115	80
Wheat	879	365	713	2,941	3,038	81	1,336
Totals	11,845	13,487	16,676	14,568	23,148	2,107	13,638
Fruits & Nuts	306.585	351.945	412.695	1352.7	326.025	32.4	464
Vegetables	35	826	17	11	334	71	216
	Census of Agriculture[a] (Year 1997)						
Number of Farms	221	491	441	249	688	157	375
% Change in Number of Farms, 1992-97	10%	25%	16%	12%	15%	35%	19%
Mean Farm Size in Hectares	130	128	141	142	117	109	128
% of Farms with < 10 Hectares	5%	3%	3%	17%	3%	1%	5%
Hectares of Land in Farms	28,713	63,045	62,056	35,261	80,362	17,021	47,743
% of Total Land in Farms	51%	49%	35%	36%	38%	33%	40%
Hectares of Harvested Cropland	14,102	14,706	18,291	16,735	22,252	2,512	14,767
	Miscellaneous (Year 2000)						
Hectares of Irrigated Farm Land	7,270	8,639	2,602	4,480	5,858	486	4,889
Hectares of Land in CRP/WRP[b]	1,093	3,746	5,091	1,191	3,532	484	2,523

[a] Farms can include non-farmed lands.

[b] CRP = Conservation Reserve Program/WRP = Wetland Reserve Program.

Table 1.3. Agricultural land use statistics for the BQI Southwest focus area, Georgia (http://www.georgiastats.uga.edu/, February 2002).

	Colquitt County	**Crisp County**	**Dougherty County**	**Lee County**	**Mitchell County**	**Sumter County**	**Terrell County**	**Region Means**
	Hectares Harvested (Year 2000)							
Row and Forage Crops								
Barley	0	0	0	0	0	0	0	0
Corn	1,247	551	636	2,877	3,677	3,443	1,952	2,055
Cotton	27,503	14,580	4,304	13,159	21,648	14,884	6,963	14,720
Hay	2,179	2,025	284	1,418	810	1,823	0	1,220
Oats	82	194	34	35	244	255	512	194
Peanuts	5,050	5,396	2,012	4,136	8,411	5,873	5,167	5,149
Rye	693	288	0	253	274	324	163	285
Silage	101	0	0	0	810	608	0	217
Sorghum	114	336	202	234	115	344	423	253
Soybeans	776	458	0	161	413	1,782	365	565
Tobacco	798	8	2	0	354	0	0	166
Wheat	252	782	290	1,517	211	4,617	2,896	1,509
Totals	38,796	24,617	7,764	23,789	36,969	33,951	18,442	26,332
Fruits & Nuts	501	1,621	6,278	3,647	7,291	1,944	663	3,135
Vegetables	7,562	2,652	41	1,823	4,914	5,165	16	3,167
	Census of Agriculture[a] (Year 1997)							
Number of Farms	634	213	139	157	464	314	174	299
% Change in Number of Farms, 1992-97	-9%	7%	-16%	15%	0%	0%	-13%	-2%
Mean Farm Size in Hectares	147	220	243	356	193	241	323	246
% of Farms with < 10 Hectares	6%	6%	10%	5%	5%	5%	5%	6%
Hectares of Land in Farms	92,835	46,733	33,723	55,882	89,548	75,530	56,135	64,341
% of Total Land in Farms	65%	66%	40%	61%	68%	60%	65%	61%
Hectares of Harvested Cropland	45,094	28,121	14,161	26,720	46,417	41,208	30,456	33,168
	Miscellaneous (Year 2000)							
Hectares of Irrigated Farm Land	16,147	8,727	9,214	18,264	35,170	17,637	11,696	16,694
Hectares of Land in CRP/WRP[b]	1,553	1,564	508	2,363	2,532	4,948	6,857	2,904

[a] Farms can include non-farmed lands.

[b] CRP = Conservation Reserve Program/WRP = Wetland Reserve Program.

Table 1.4. Forest characteristics (1997) for the BQI East focus area, Georgia (http://www.georgiastats.uga.edu/, February 2002).

	Bulloch County	Burke County	Jenkins County	Screven County	Region Means
Total Area, Square Kilometers	1,784	2,163	913	1,698	1,639
Forest Land, % of All Land	57%	64%	68%	63%	63%
			Hectares		
Total Area	17,681	21,513	9,061	16,799	16,263
Forest Land	10,146	13,707	6,127	10,542	10,130
Forest Type, Longleaf/ Slash	1,416	364	413	619	703
Forest Type, Lobllolly/ Shortleaf	2,622	4,249	2,036	3,703	3,153
Forest Type, Oak/ Pine	1,938	2,724	692	635	1,497
Forest Type, Oak/ Hickory	704	2,416	826	1,437	1,346
Forest Type, Oak/ Gum-Cypress	3,153	3,849	1,991	3,173	3,041
All Sawtimber Stands	4,217	3,909	2,100	4,306	3,633
All Poletimber Stands	1,906	2,853	886	1,801	1,862
All Sapling/ Seedling Stands	3,711	6,839	3,104	3,557	4,303
All Timberland	10,146	13,707	6,091	10,012	9,989
All Timberland, NIPL*	8,648	9,385	3,646	7,021	7,175
All Timberland, Corporate	668	842	631	1,388	882
All Timberland, Government	830	3,480	1,813	1,603	1,931

* NIPL = Non-Industrial Private Landowner.

Table 1.5. Forest characteristics (1997) for the BQI Central focus area, Georgia (http://www.georgiastats.uga.edu/, February 2002).

	Bleckley County	Dodge County	Emanuel County	Houston County	Laurens County	Treutlen County	Region Means
Total Area, Square Kilometers	568	1,303	1,788	984	2,120	524	1,214
Forest Land, % of All Land	57%	64%	71%	51%	60%	80%	64%
				Hectares			
Total Area	5,629	12,966	17,766	9,757	21,048	5,200	12,061
Forest Land	3,181	8,284	12,687	4,974	12,634	4,184	7,657
Forest Type, Longleaf/ Slash	571	2,392	2,416	0	2,068	2,331	1,630
Forest Type, Lobllolly/ Shortleaf	975	1,781	3,857	2,048	4,140	785	2,264
Forest Type, Oak/ Pine	206	923	2,185	571	809	223	819
Forest Type, Oak/ Hickory	623	1,141	1,611	1,109	2,529	223	1,206
Forest Type, Oak/ Gum-Cypress	757	1,874	2,323	1,000	2,809	623	1,564
All Sawtimber Stands	1,267	2,962	4,783	1,384	3,796	1,825	2,670
All Poletimber Stands	1,461	2,384	3,266	1,542	2,853	1,125	2,105
All Sapling/ Seedling Stands	453	2,764	4,338	2,048	5,904	1,234	2,790
All Timberland	3,181	8,284	12,638	4,974	12,634	4,184	7,649
All Timberland, NIPL*	2,327	6,410	8,211	2,266	8,956	3,626	5,299
All Timberland, Corporate	206	1,012	1,271	1,081	502	0	679
All Timberland, Government	648	862	3,157	1,627	3,177	558	1,671

* NIPL = Non-Industrial Private Landowner.

Table 1.6. Forest characteristics (1997) for the BQI Southwest focus area, Georgia (http://www.georgiastats.uga.edu/, February 2002).

	Colquitt County	**Crisp County**	**Dougherty County**	**Lee County**	**Mitchell County**	**Sumter County**	**Terrell County**	**Region Means**
Total Area, Square Kilometers	1,441	728	867	938	1,331	1,276	874	1,065
Forest Land, % of All Land	48%	40%	52%	44%	37%	52%	48%	46%
	Hectares							
Total Area	14,306	7,094	8,539	9,215	13,262	12,570	8,689	10,525
Forest Land	6,847	2,821	4,464	4,039	4,917	6,552	4,172	4,830
Forest Type, Longleaf/ Slash	3,080	453	198	166	2,525	372	368	1,023
Forest Type, Lobllolly/ Shortleaf	206	142	1,425	728	672	2,829	1,036	1,005
Forest Type, Oak/ Pine	1,170	502	429	291	312	1,105	591	628
Forest Type, Oak/ Hickory	271	308	235	1,323	789	599	389	559
Forest Type, Oak/ Gum-Cypress	1,445	1,214	2,015	1,335	469	1,550	1,744	1,396
All Sawtimber Stands	2,663	1,246	2,189	1,234	1,728	1,874	1,635	1,796
All Poletimber Stands	1,461	352	749	1,024	1,720	1,773	376	1,065
All Sapling/ Seedling Stands	2,084	1,024	1,372	1,590	1,319	2,813	2,121	1,760
All Timberland	6,831	2,772	4,464	4,015	4,917	6,552	4,172	4,818
All Timberland, NIPL*	5,771	2,347	2,153	2,461	4,112	3,853	3,545	3,463
All Timberland, Corporate	696	235	1,619	1,311	732	1,890	372	979
All Timberland, Government	364	190	692	243	73	809	255	375

* NIPL = Non-Industrial Private Landowner.

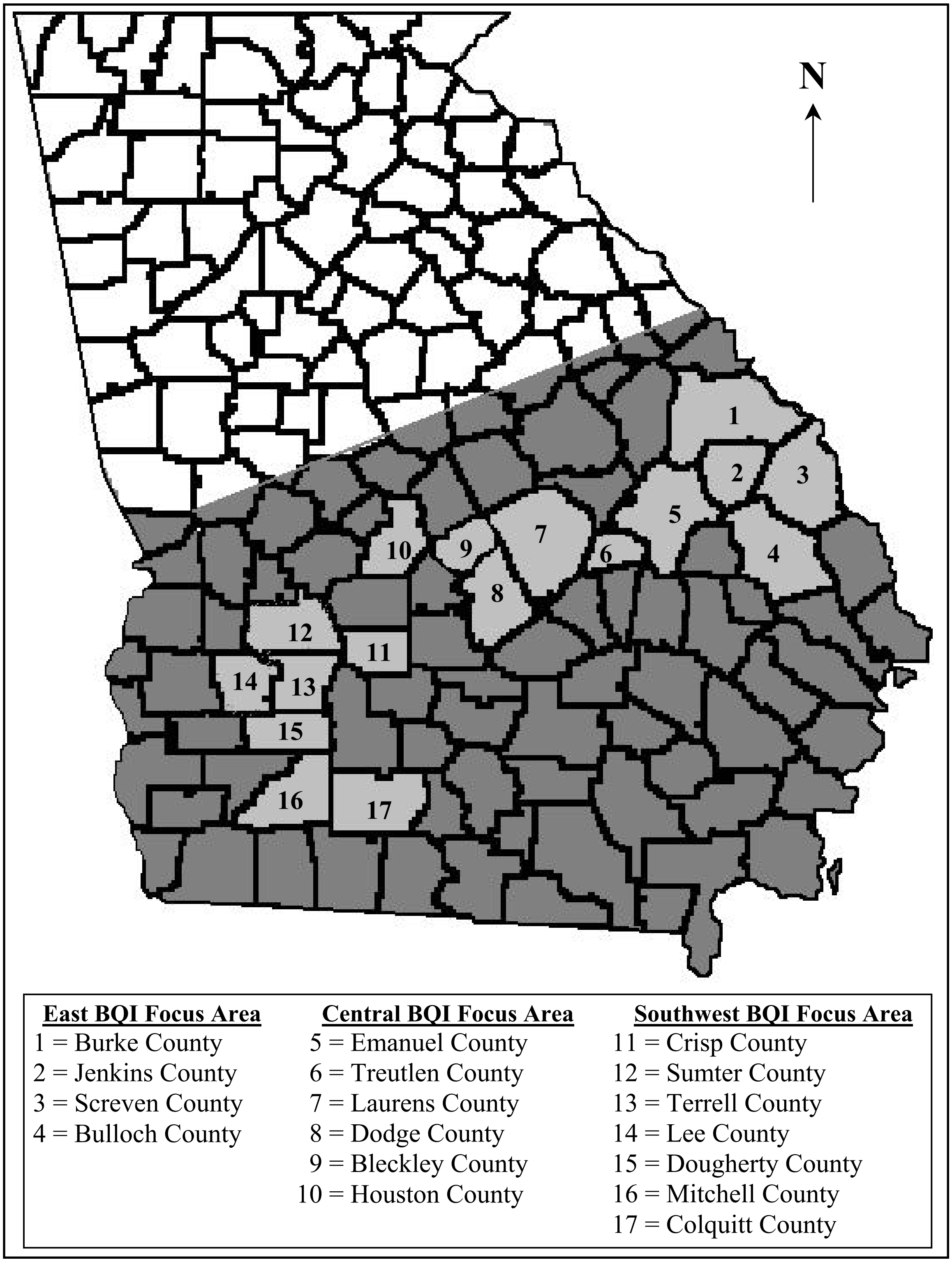

Figure 1.1. Map of the three BQI focus areas and counties within each focus area in the Upper Coastal Plain of Georgia, USA (shaded area represents the approximate extent of the Coastal Plain in Georgia).

CHAPTER 2

DEVELOPMENT OF NORTHERN BOBWHITE COVEY-CALL-COUNT INDICES

INTRODUCTION

To evaluate population trends and characteristics, some estimator must be used to quantify the population of interest. Consensus on one good estimator of northern bobwhite (*Colinus virginianus*) (hereafter, bobwhite) abundance or density in the Southeast has been problematic (Curtis et al. 1989). In recent years, covey-call-counts have received more attention as a method for estimating fall bobwhite populations. Covey-call-counts are an indirect population index, and their utility depends on population estimation objectives. Although it may not always be possible to convert call-count indices to estimates of absolute population abundance or density, spatial and temporal population trends may be evaluated provided that the index is the same across spatial and temporal scales. Thus, count statistics obtained from indices must be corrected when detection rates differ in order for accurate population estimates (increasing or decreasing trends, abundance, density) to be made (Lancia et al. 1994). Detection rates may vary by observer, species, habitat, species abundance, etc. (e.g. Bibby et al. 1992). If detection rates vary, counts will be biased, and subsequent management decisions based on biased counts could have serious negative consequences.

Detection issues related to covey-call-count indices

Perhaps the most prevalent detection issue associated with the covey-call-count index is that often, the proportion of the sample population that is potentially detectable by the index is unknown [Stoddard (1931) commented on this point when he described covey-calling behavior]. In other words, the average proportion of coveys that call (given that a covey is actually present) on a given morning is unknown. Several studies have recently estimated covey-calling rates with radio-tagged bobwhite. Wellendorf et al. (2002*b*) reported an overall covey-calling rate of 58% from several sites in North Carolina, Florida, and Tennessee. In Mississippi, Smith (2001) also found overall calling rates of 58%. A study in Missouri found an overall covey-calling rate of 79.5% (Seiler 2001, Seiler et al. 2002). For brevity, I have reported overall average estimates from these studies. It should be noted, however, that there was some temporal and spatial variation among call-rate estimates in all of these studies. Such investigations into the proportion of coveys calling over space, time, and varying weather conditions and population densities are essential in order for call-count indices to be used as reliable population estimators.

A second detection issue associated with call-count indices is the proportion of the target species detected by observers. Observer skill at detecting a species may vary due to a number of factors, and observer detection rates need to be estimated in order to make index count statistics useful population estimators. Assumptions about observer detection rates have been addressed by development of new techniques to estimate bird population abundance from call-count indices (Nichols et al. 2000, Thompson 2002). My approach was similar to Nichols et al. (2000), but incorporated many components of an approach suggested by Thompson (2002). I evaluated whether detection rates of calling-coveys differed among observers during multiple, independent-observer covey-call-count surveys.

A third detection issue associated with call-count indices is miscounting the target species due to misidentification (mistaking the target species for another species or vice versa) or repetitive counting of the same individuals or groups. Utilizing experienced observers, adequate observer training, or using multiple, dependent observers (where at least one observer is experienced) is likely the best way to reduce bias associated with these miscounting issues. I was not able to directly evaluate this issue with my data.

Covey-call-count Survey Techniques

Numerous methods have been utilized to make bobwhite population estimates (see "Review of Population Estimators" in Chapter 1). These methods vary by estimate objectives, estimate precision, and/or labor intensity. Thus, an estimator that provides relatively accurate, precise, and cost-efficient results will have greater utility to anyone responsible for monitoring bobwhite populations (though ultimately, estimator utility is still dependent on the management objective). Provided that detection issues are addressed, covey-call-count indices may provide a reasonable estimate of bobwhite population density or abundance. However, research is still needed to effectively validate the index.

Currently, there have been two published methods used for conducting covey-call-counts. The original method is a single-observer point count (e.g. DeMaso et al. 1992). A more quantitative method, developed at Tall Timbers Research Station, requires multiple observers and makes use of quadrat sampling methodology (hereafter, quadrat) [the typical use of this technique for bobwhite population density estimation was described by Seiler (2001), Smith (2001), and Wellendorf et al. (2002*b*)]. I utilized quadrat surveys to evaluate alternative, reduced-observer covey-call-count survey methods.

The objectives of this research were to evaluate observer detection rates of calling coveys and to determine if there were suitable relationships among the full-observer quadrat surveys and reduced-observer survey techniques developed from quadrat surveys. Observer detection is an important consideration when using indices to evaluate population changes over time and space. Reduced-observer call-count techniques would be less labor intensive and more cost effective if they were reasonable predictors of full-observer covey density. The overall goal of this research was to develop existing call-count methodology for an optimal long-term bobwhite population monitoring plan for the Bobwhite Quail Initiative (BQI), a program developed primarily to improve bobwhite breeding habitat in row crop agricultural ecosystems.

STUDY AREA

The BQI program was initiated with three focus areas that included 17 counties in the Upper Coastal Plain of Georgia. The three focus areas were composed of East (Bulloch, Burke, Jenkins, and Screven Counties), Central (Bleckley, Dodge, Emanuel, Houston, Laurens, and Truetlen Counties), and Southwest Regions (Colquitt, Crisp, Dougherty, Lee, Mitchell, Sumter, and Terrell Counties). This research was conducted on sites in all counties except Colquitt, Crisp, Houston, and Mitchell Counties.

Major land uses in all three regions consisted of intensive row crop agriculture and timber/fiber production. Agricultural row crop production was dominated by cotton, peanuts, soybeans, corn, and winter wheat. Row crop fields in the study area tended to be large in size and had little or inadequate transition zones capable of providing suitable bobwhite habitat. For example, historically fencerows or hedgerows that were once composed mainly of scattered trees and shrubs with an abundance of grassy and weedy understory separated two or more fields. Today, the vegetative structure of these transition zones have grown to become unsuitable bobwhite habitat or have been eliminated altogether to create one contiguous crop field out of two or more smaller fields. Forest production in the study area was dominated by plantations of loblolly pine (*Pinus taeda*) and slash pine (*Pinus elliotti*), although longleaf pine (*Pinus palustris*) plantings were increasing in all regions. The majority of pine stands in the study area did not have basal area or understory vegetation characteristics that constituted suitable bobwhite habitat.

METHODS

The quadrat call-count technique was used to survey calling bobwhite coveys at the agricultural field(s) level over a broad regional scale (13 counties) on sample sites in 1999 and 2000. During call-count surveys, observers listened for the "koi-lee" covey-calls (Stoddard 1931) given by bobwhite (almost always before sunrise) during autumn. 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.

The quadrat technique utilizes a 0.25 square kilometer (500 x 500 meter) quadrat to survey calling coveys. A total of four observers were used, with an observer positioned along the midpoint of each quadrat side (Figure 2.1a). An additional observer was positioned in the middle of quadrats in 1999 (Figure 2.1b). Observers recorded compass bearings, estimated distances, and approximate locations on standardized data sheets and field maps for each calling covey heard. A standardized survey protocol was used each year (see Chapter 3). Once the survey period expired, observers met to compare results in order to determine individual covey locations. Each unique covey location was plotted on a final field map. For each covey that was heard by more than one observer, the intersection of compass bearings to the covey was used to plot the approximate location. If only one observer detected a particular covey, the estimated distance to the covey along the compass bearing was used to plot the approximate location. These quadrat surveys were used to estimate observer detection rates of calling coveys and to evaluate alternative survey designs.

Estimation of Detection Probabilities from Call-count Surveys

Individual "capture histories", like those used with typical capture-recapture methods (Williams et al. 2002), were developed for each covey detected during quadrat surveys. Each observer (five in 1999 and four in 2000) was treated as a unique capture occasion. Capture history data were analyzed using Program MARK (White and Burnham 1999). Capture histories for each covey detected during each quadrat survey were summarized in matrix form (with each column representing a unique observer and each row representing a unique covey) by assigning a "1" if the observer detected the covey or a "0" if the observer did not detect the covey.

In each year a unique set of observers conducted surveys in the East BQI focus area, while another unique set of observers conducted surveys in the Central and Southwest BQI focus areas. Thus, four different observer-groups were formed. In Program MARK, the following four observer-groups were defined: 1999 Central and Southwest, 1999 East, 2000 Central and Southwest, 2000 East. I ran predefined models in Program MARK, treating the data as captures from a fully closed population with both heterogeneity (assuming each covey could potentially have a unique capture probability which remained constant over observers) and no heterogeneity (assuming each covey had a constant and equal capture probability) (Lancia et al. 1994).

Models in the fully closed captures with heterogeneity data type contained the following parameters: mixture probability (probability associated with potential heterogeneity in capture probabilities among individual coveys), capture probability (probability that at least one observer detects a covey), recapture probability (probability that an observer detects a covey given it was detected at least once before), and population abundance. Models in the fully closed captures with no heterogeneity data type contained the same parameters except the mixture probability. Any model parameter could vary or remain constant with respect to observer-group or individual observer. Recapture probability and abundance were not considered useful parameters (nuisance parameters) in this analysis. The study was not designed to estimate abundance in a capture-recapture context such as this, and recapture probability was not a meaningful parameter in my analysis. Inclusion of these nuisance parameters in the models was necessary, however, for program MARK to estimate the other parameters of interest. I was only interested in estimates of capture probability, which would provide estimates of detection rates for observers. The mixture probability (for the fully closed captures with heterogeneity models) was considered a relevant parameter if there was sufficient weight of evidence for heterogeneity among individual coveys.

Program MARK uses an information-theoretic approach to model selection and maximum likelihood methods to estimate parameters. A good discussion of the information-theoretic approaches can be found in detail in Burnham and Anderson (1998) and more briefly in Anderson et al. (2000). The best approximating model in a set of *a priori* candidate models is determined by model fit given the data. Model fit is determined by a value called AIC (or one of its alternative forms AICc, QAIC, or QAICc). The general equation for AIC is,

$$\text{AIC} = -2\log_e(\ell(\hat{\theta} \mid data)) + 2K,$$

where $\log_e(\ell(\hat{\theta} \mid data)$ is the maximized log-likelihood over estimated parameters (θ) given a particular data set and model, and K is the number of parameters in the given model (Burnham and Anderson 1998, Anderson et al. 2000). AICc is an alternative form of AIC, which includes an additional term added to the above equation when the number of model parameters is large relative to sample size (n / $K < 40$). QAIC and QAICc are alternative forms of AIC where a variance inflation or overdispersion factor, estimated from the global model, is incorporated into the AIC or AICc equations (Burnham and Anderson 1998). An AIC (hereafter, AIC will generically imply any form of AIC) value is computed for each model, and the model with the lowest AIC value is considered to be the best approximating model given the data.

After AIC values are computed, a set of candidate models can be ranked from best to poorest approximating model by,

$$\Delta\text{AIC}_i = \text{AIC}_i - \text{minAIC},$$

where AIC_i is the AIC value of model i and minAIC is the lowest AIC value in the set of candidate models. Furthermore, model likelihoods given the data are computed by $\exp[-0.5(\Delta\text{AIC}_i)]$. Model weights are computed by dividing the particular model likelihood by the sum of all model likelihoods. These model weights are a measure of weight of evidence that a given model is the best model in the set of candidate models

(Anderson et al. 2000). To account for model uncertainty, parameter estimates (and their estimated variance) can be averaged over all candidate models that include the parameter of interest.

Modified Covey-call-count Techniques

Modified bobwhite covey-call-counts, derived from the quadrat technique, were evaluated to potentially develop call-count techniques that were sufficiently accurate and precise, but less labor intensive and more cost efficient. The quadrat technique performs best when multiple, random samples are taken from large expanses of homogeneous habitat where covey densities are relatively high, and coveys are randomly distributed. In my study area, covey densities were expected to be low (based on Southeastern bobwhite population trends), and covey distributions were assumed to be nonrandom since bobwhite likely select and use edge habitats in greater proportions than other available habitats in agricultural systems (Wellendorf et al. 2002*a*). Traditional quadrat density estimates are calculated by dividing the number of coveys detected inside of quadrats by the total area sampled. However, I developed several alternatives to the standard estimates of quadrat density, because most calling coveys in my study were heard outside of quadrats. In 1999, 9 coveys were detected inside of quadrats and 96 were detected outside of quadrats. In 2000, 15 coveys were detected inside of quadrats and 76 were detected outside of quadrats. These alternative estimates attempted to account for coveys heard outside of quadrats and were used to relax the violation of the assumption that coveys are randomly distributed across the landscape. These alternative estimates of covey density were obtained using truncated and non-truncated observations from quadrat surveys. In this sense, “truncated” means that the area in which calling coveys were detected was restricted by angle and distance to covey observations. "Non-truncated" means that the area in which calling coveys were detected was unrestricted other than by the assumed maximum hearing distance of 500 meters. Reduced-observer estimates of covey density were obtained using truncated observations from 350-meter pairs and 500-meter pairs of observers from quadrat surveys, and observations from each individual observer (treated as a single-observer point count) from quadrat surveys. Since bobwhite covey densities were low throughout the study area, all density estimates were computed in square kilometers (km^2).

Extended Quadrat Designs.--To incorporate coveys heard outside of the quadrat, additional area was extended around the four observers. Based on an assumed maximum hearing distance of 500 meters (W. E. Palmer, Tall Timbers Research Station, personal communication), two different methods were used to classify coveys inside of an effective detection area. First, each unique covey observation for each quadrat was assumed to be within a 1.6 km^2 area extended beyond the normal bounds of the quadrat (Figure 2.2). Alternatively, each unique covey observation obtained from combined two-observer designs (see the following section "Two-observer Designs") was assumed to be within a 0.86 km^2 area, obtained from combining the assumed rectangular detection areas around each pair of observers (Figure 2.3). Only coveys heard and plotted by multiple observers were counted as detections in the 0.86 km^2 area analysis. Detections were further restricted by distance and angle to observation requirements (see the following section "Two-observer Designs") in this analysis. It was assumed that all calling coveys within the effective detection area were detected and that all calling coveys detected were within the effective detection area. Observations made by middle observers from 1999 quadrat surveys were not used in density estimates.

Two-observer Designs.--Covey detections for each pair of observers from quadrat surveys were evaluated as two-observer surveys. Two different survey designs were evaluated. In the first design, observers were spaced 500 meters apart (500-meter design), and in the second design, observers were spaced approximately 350 meters apart (350-meter design). Thus, there were typically two pairs of observers that were 500 meters apart and four pairs of observers that were approximately 350 meters apart for each quadrat survey (Figure 2.4).

The area that two observers could effectively hear calling coveys was assumed to be a 0.35 km^2 rectangle (Figures 2.5 and 2.6) for both 350- (350 x 1000 meters) and 500-meter (500 x 700 meters) designs. This detection area was calculated based on the assumption that observers could detect coveys at a maximum distance of 500 meters. The dimensions of the rectangle were first formulated by extending a 500-meter radius from each pair of observer points. Next, the rectangular area was constructed by extending a line through each pair of observer points, so that the two lines were parallel to each another. Finally, the rectangular area was completed by extending a line through the two points where each of the 500-meter radii intersected and perpendicular to the two lines that extended through each observer point. This process was used for each pair of observers in both the 350- and 500-meter designs. Some of the area towards the outer corners of the rectangles exceeded 500 meters from an observer, but it was assumed that calling coveys within the rectangles were detected by both observers. Only coveys that were detected by both observers in the pair were used to estimate covey density.

Observations were truncated according to distance and angle to covey. If the intersection of compass bearings resulted in an observation outside of the 0.35 km^2 rectangle, the observation was not included in the density estimate. To estimate density, all coveys detected within the rectangle by both observers in the pair were divided by 0.35 km^2. Observations made by middle observers from 1999 quadrat surveys were not used in density estimates.

Point Count Method.--Each observer on the sides of a quadrat was also evaluated as a point count survey. For point counts, it was assumed that observers detected all calling coveys within 500 meters of the survey point (W. E. Palmer, Tall Timbers Research Station, personal communication). This assumption resulted in an effective detection area of 0.79 km^2 (Figure 2.7). To estimate density, all coveys detected by a particular observer were divided by 0.79 km^2. Observations made by middle observers from 1999 quadrat surveys were not used in density estimates, but as a further method to evaluate point count performance. The number of coveys detected by the middle quadrat observer was compared to the overall number of unique coveys detected by all quadrat observers.

Evaluation of Modified Covey-call-count Techniques

Capture probabilities estimated from Program MARK provided estimates of the relative amount of information collected by a single observer in relation to the total number of observers participating in a quadrat survey. Given this capture probability ($\hat{p}$) for a single observer in relation to all other observers present, a relative measure of information collected by any number of observers could be calculated by the formula,

$$\hat{p}_k = 1 - (1 - \hat{p}_{\text{1-observer}})^k,$$

where k is the number of observers of interest. I used the model-averaged estimates of $\hat{p}$ from the analysis where the data were treated as fully closed captures with heterogeneity and the above equation to evaluate $\hat{p}$ for k observers. I determined the relative amount of information collected by increasing the number of call-count observers to 2, 3, 4 and 5 for the 1999 Central and Southwest, 1999 East, 2000 Central and Southwest, 2000 East observer-groups.

In order to assess the utility of covey-call-count estimators, I compared density estimates produced by the two-observer and point count methods to density estimates produced by the more intensive, quadrat methods. It was assumed that the extended quadrat designs would yield a reasonably accurate estimate of covey density at a particular site. Linear regression analysis was used to determine whether suitable relationships existed among the call-count methods. Three different dependent variables were considered. The first dependent variable was covey density estimated by the traditional 0.25 km^2 quadrat (hereafter, TTRS) developed at Tall Timbers Research Station. The next two dependent variables were covey densities estimated from the 1.6 km^2 (hereafter, NOTRUN) and 0.86 km^2 (hereafter, TRUN) area extended quadrat designs. The independent variables were covey densities estimated from the two-observer and point count methods.

Since each of the independent variable estimates were subsamples from the overall quadrat, two separate approaches were taken to determine the relationship between quadrat estimates and the two-observer and point count estimates. First, the mean density estimate from each set of 350-meter two-observer pairs (hereafter, 350_PAIR), 500-meter two-observer pairs (hereafter, 500_PAIR), and point counts (hereafter, PTCT) was compared with its respective, overall quadrat density estimate. Thus for a typical quadrat, a mean density would be calculated for four 350_PAIR's, two 500_PAIR's, and four PTCT's, which would then be compared with its respective quadrat density estimate. Second, each individual density estimate from a 350_PAIR, 500_PAIR, and PTCT was compared with its respective, overall quadrat density estimate. Thus for a typical quadrat, a density estimate for four 350_PAIR's, two 500_PAIR's, and four PTCT's would each be compared to its respective quadrat density estimate. For the 350_PAIR and 500_PAIR mean density variables, models with a polynomial term (second order) were also considered based on evaluation of scatter plots. When a polynomial term was used, the independent variable was centered as in Montgomery and Peck (1992), and the regression equation became

$$y = \beta_0 + \beta_1(x - \bar{x}) + \beta_2(x - \bar{x})^2 + \varepsilon.$$

Some zero-intercept models were evaluated when intercepts were not significant ($\alpha < 0.05$), and the regression equation became

$$y = \beta_1(x) + \varepsilon.$$

Using mean covey density estimates from the 350_PAIR, 500_PAIR, and PTCT methods, six models were evaluated to predict TTRS covey density, five models were evaluated to predict NOTRUN covey density, and six models were evaluated to predict TRUN covey density. The models evaluated for predicting TTRS covey density were

1.) TTRS = $\beta_0 + \beta_1$(350_PAIR) + ε,

2.) TTRS = β_1(350_PAIR) + ε,

3.) TTRS = $\beta_0 + \beta_1$(500_PAIR) + ε,

4.) TTRS = β_1(500_PAIR) + ε,

5.) TTRS = $\beta_0 + \beta_1$(PTCT) + ε,

6.) TTRS = β_1(PTCT) + ε.

The models evaluated for predicting NOTRUN covey density were

1.) NOTRUN = $\beta_0 + \beta_1$(350_PAIR) + ε,

2.) NOTRUN = $\beta_0 + \beta_1(350\_PAIR - \bar{x}) + \beta_2(350\_PAIR - \bar{x})^2 + \varepsilon$,

3.) NOTRUN = $\beta_0 + \beta_1$(500_PAIR) + ε,

4.) NOTRUN = $\beta_0 + \beta_1(500\_PAIR - \bar{x}) + \beta_2(500\_PAIR - \bar{x})^2 + \varepsilon$,

5.) NOTRUN = $\beta_0 + \beta_1$(PTCT) + ε.

The models evaluated for predicting TRUN covey density were

1.) TRUN = $\beta_0 + \beta_1$(350_PAIR) + ε,

2.) TRUN = $\beta_0 + \beta_1(350\_PAIR - \bar{x}) + \beta_2(350\_PAIR - \bar{x})^2 + \varepsilon$,

3.) TRUN = $\beta_0 + \beta_1$(500_PAIR) + ε,

4.) TRUN = $\beta_0 + \beta_1(500\_PAIR - \bar{x}) + \beta_2(500\_PAIR - \bar{x})^2 + \varepsilon$,

5.) TRUN = $\beta_0 + \beta_1$(PTCT) + ε,

6.) TRUN = β_1(PTCT) + ε.

Using each covey density estimate from the 350_PAIR, 500_PAIR, and PTCT methods, three models were evaluated to predict NOTRUN covey density and three models were evaluated to predict TRUN covey density. The dependent variable TTRS covey density was not evaluated with each predictor estimate because of relatively poor model utility when TTRS covey density was estimated from mean covey density of the 350_PAIR, 500_PAIR, and PTCT methods. The models evaluated for predicting NOTRUN covey density were

1.) NOTRUN = $\beta_0 + \beta_1$(350_PAIR) + ε,

2.) NOTRUN = $\beta_0 + \beta_1$(500_PAIR) + ε,

3.) NOTRUN = $\beta_0 + \beta_1$(PTCT) + ε.

The models evaluated for predicting TRUN covey density were

1.) TRUN = $\beta_0 + \beta_1$(350_PAIR) + ε,

2.) TRUN = $\beta_0 + \beta_1$(500_PAIR) + ε,

3.) TRUN = $\beta_0 + \beta_1$(PTCT) + ε.

Model adjusted R-square ($adj\text{-}R^2$) and estimated mean squared error ($\widehat{MSE}$) values were used to evaluate how well reduced-observer call-count techniques predicted density estimates produced by the more intensive, extended quadrat methods. Regression analyses were performed with the PROC REG procedure of SAS® software[a].

To evaluate the number of coveys detected in 1999 by the middle quadrat observer, the proportion of coveys detected by the middle observer was compared to the overall number of coveys detected by all quadrat observers. The percentage of coveys detected by the middle observer was calculated in relation to total number of coveys detected by the four observers positioned along the sides of the quadrat. The percentage of coveys detected by the middle observer was calculated for coveys detected inside of the quadrat, outside of the quadrat, and inside and outside of the quadrat combined.

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RESULTS

Estimation of Detection Probabilities from Covey-call-count Surveys

When the data were treated as captures from a fully closed population with heterogeneity, two models were equally likely to be the best approximating model based on model weights (w_i). Both of these models (w_i = 0.1889) had constant capture probabilities ($\hat{p}$) among observers and observer-groups. However, one model had a constant mixture probability (π) while the other had π varying by observer-groups. Additionally, several models with constant π and $\hat{p}$ varying by observer-group were equally plausible models (w_i = 0.1770). Models utilized by Program MARK and model selection criteria are summarized in Table 2.1. Since some models indicated that $\hat{p}$ varied by observer groups, each model specific estimate of $\hat{p}$ was provided for each observer group (Table 2.2). To account for model uncertainty, overall model-averaged estimates of $\hat{p}$ were produced for each observer group. The model-averaged estimates of $\hat{p}$ for the 1999 Central and Southwest, 1999 East, 2000 Central and Southwest, and 2000 East observer groups are provided in Table 2.3.

When the data were treated as captures from a fully closed population with no heterogeneity, the best approximating models based on model weights had constant $\hat{p}$ (Table 2.4). Models and associated model selection criteria utilized by Program MARK are summarized in Table 2.4. Since some models indicated that $\hat{p}$ varied by observer-groups and individual observers, each model specific estimate of $\hat{p}$ was provided for each individual observer within the 1999 Central and Southwest (Table 2.5), 1999 East (Table 2.6), 2000 Central and Southwest (Table 2.7), and 2000 East (Table 2.8) observer-groups. To account for model uncertainty, overall model-averaged estimates of $\hat{p}$ were produced for each individual observer within their respective groups. The model-averaged estimates of $\hat{p}$ for observers 1, 2, 3, 4, and 5 in the 1999 Central and Southwest group and for observers 1, 2, 3, 4, and 5 in the 1999 East group are given in Table 2.9. The model-averaged estimates of $\hat{p}$ for observers 1, 2, 3, and 4, in the 2000 Central and Southwest group and for observers 1, 2, 3, and 4 in the 2000 East group are given in Table 2.9.

Evaluation of Modified Covey-call-count Techniques

Once estimates of $\hat{p}$ for one observer in relation to all observers participating in a quadrat survey were obtained from Program MARK, I evaluated the relative amount of information collected by increasing the number of observers in a covey-call-count survey. By adding an additional observer (one observer to two observers), the estimated $\hat{p}$ increased from 0.4011 to 0.6413, 0.2128 to 0.3804, 0.3416 to 0.5665, and 0.3582 to 0.5881 for the 1999 Central and Southwest, 1999 East, 2000 Central and Southwest, and 2000 East observer-groups, respectively. By adding three additional observers (one observer to four observers), the estimated $\hat{p}$ increased from 0.4011 to 0.8714, 0.2128 to 0.6161, 0.3416 to 0.8121, and 0.3582 to 0.8303 for the 1999 Central and Southwest, 1999 East, 2000 Central and Southwest, and 2000 East observer-groups, respectively. Figure 2.8 depicts the increasing trend in $\hat{p}$ (relative percentage of information gained) as the number of observers was increased from one up to five in the 1999 Central and Southwest and 1999 East observer-groups. Figure 2.9 depicts the increasing trend in $\hat{p}$ (relative percentage of information gained) as the number of observers was increased from one up to five in the 2000 Central and Southwest and 2000 East observer-groups.

Based on $\hat{MSE}$, the best predictor of TTRS density was the mean covey density estimate from the 350_PAIR, no-intercept 350_PAIR, no-intercept PTCT, PTCT, 500_PAIR, and no-intercept 500_PAIR model, respectively (Table 2.10). Table 2.11 summarizes the model parameter estimates. Figure 2.10 depicts the relationship of the dependent variable TTRS covey density and the mean density estimates of the independent variables.

Based on $\widehat{MSE}$, the best predictor of NOTRUN covey density was the mean covey density estimate from the PTCT, 350_PAIR polynomial, 350_PAIR, 500_PAIR polynomial, and 500_PAIR model, respectively (Table 2.10). Table 2.11 summarizes the model parameter estimates. Figure 2.11 depicts the relationship of the dependent variable NOTRUN covey density and the mean density estimates of the independent variables.

The best predictor of TRUN covey density was the mean covey density estimate from the 350_PAIR polynomial, no-intercept PTCT, 350_PAIR, PTCT, 500_PAIR polynomial, and 500_PAIR model, respectively (Table 2.10), considering $\widehat{MSE}$. Table 2.11 summarizes the model parameter estimates. Figure 2.12 depicts the relationship of the dependent variable TRUN covey density and the mean density estimates of the independent variables.

Based on $\widehat{MSE}$, when each independent variable covey density estimate was used, the PTCT model was the best predictor of NOTRUN density, followed by the 350_PAIR and 500_PAIR models, respectively (Table 2.12). Table 2.13 summarizes the model parameter estimates. Figure 2.13 depicts the relationship of the dependent variable NOTRUN covey density and each density estimate of the independent variables.

Based on $\widehat{MSE}$, when each independent variable covey density estimate was used, the PTCT model was the best predictor of TRUN density, followed by the 350_PAIR and 500_PAIR models, respectively (Table 2.12). Table 2.13 summarizes the model parameter estimates. Figure 2.13 depicts the relationship of the dependent variable TRUN covey density and each density estimate of the independent variables.

Means of the dependent and independent covey density variables are summarized in Table 2.14. Associated measures of dispersion are also provided. Means of both the means of subsamples and each subsample as independent variables are summarized in this table.

When evaluating the number of coveys detected by the middle quadrat observer in 1999, the middle observer detected 66.67% of all coveys detected inside of quadrats (*n* = 9), 39.58% of all coveys detected outside of quadrats (*n* = 96), and 41.90% of all coveys detected both inside and outside of quadrats (*n* = 105) (Figure 2.14).

DISCUSSION

Estimation of Detection Probabilities from Covey-call-count Surveys

Anderson (2001) deemed the use of indices unreliable when uncorrected with a more intensive sampling method in order to estimate parameters and associated precision. Call-count indices are currently the only feasible technique available to assess effects of BQI habitat management on bobwhite populations. Given the low densities of bobwhite and the fragmented nature of habitats in my study area, other more direct methods to estimate bobwhite populations (e.g. line transects) would not be appropriate (Curtis et al. 1989, Kuvlesky et al. 1989) and would likely be no more reliable than call-count indices. By quantifying temporal and spatial observer detection rates, covey-call-count indices were useful for evaluating trends in covey numbers over time and space.

My estimates of observer detection rates from Program MARK suggested that within-group observer detection rates did not differ in either 1999 or 2000 when the data were analyzed as fully closed captures with heterogeneity. The overall best models (based on AIC value ranks) indicated constant capture probability across observer-groups and observers, suggesting that observer detection rates did not differ by any observer or year. However, several models with capture probability varying by observer-group were also plausible models, based on model weights, suggesting that at least one observer-group might have differed. Based on capture probability estimates, only the East 1999 observer-group appeared to be different. When the data were treated as captures from a fully closed population with no heterogeneity, Program MARK estimates of observer detection rates suggested that observer and observer-group rates were not different in 1999 or 2000. All of the most plausible models, based on model weights, suggested that observers and observer-groups did not differ with respect to detection rate.

Slightly different interpretations about the importance of observer detection were made depending on how the data were treated, and a decision about the best way to treat the data should be carefully considered. Given any observer's and covey's location on the landscape, it seems that there is the potential for some calling coveys to have heterogeneous capture rates regardless of an observer's ability to detect calling coveys. Thus, I relied on the closed captures with heterogeneity analysis to evaluate observer detection in my study. A plausible model from the closed captures with heterogeneity set of models suggested mixture probability differing by observer-groups. It is not certain why these probabilities differed by observer-groups, but it is possible that the landscape distribution of coveys across regions contributed to differences in mixture probabilities.

Evaluation of Modified Covey-call-count Techniques

In the case of the BQI program, there were a large number of managed fields that are distributed over a large spatial scale (17 counties, potentially). Thus, a less labor-intensive survey to monitor bobwhite populations at the field level would be highly desirable. Results of the Program MARK analysis of capture probabilities within and among observer groups suggest that observers (in the first two years of my study) were relatively equal in their ability to detect and count calling coveys. Although no measure of miscounting is available, the capture probability estimates suggest that call-count surveys were constant proportion indices in these years. It appears that by increasing the number of covey-call-count observers from one to two, there was not a substantial increase in the number of coveys counted relative to increased survey effort (double the amount of personnel needed to survey equal number of single-observer point counts). By increasing the number of observers from one to four, there appears to be a substantial increase in the number of coveys counted, however the increased survey effort associated with increasing the number of observers may be too great in many cases.

When mean covey density estimates using the 350-PAIR, 500-PAIR, and PTCT methods were used as predictors of TTRS covey density, all of the reduced-observer models had large $\widehat{MSE}$ and $adj\text{-}R^2 < 0.50$. This is a result of the TTRS method of density estimation performing poorly as a field level monitoring technique. In my study, almost no coveys were detected inside of a given quadrat, whereas several coveys may have been heard calling outside of the quadrat. Thus, the extended quadrat (NOTRUN and TRUN) approaches were developed to account for calling coveys outside of the quadrat.

When predicting NOTRUN covey density using mean covey density estimates from the 350-PAIR, 500-PAIR, and PTCT methods, the PTCT seemed to be the best estimator of covey density. The 350-PAIR and 500-PAIR methods appeared to be poor estimators of NOTRUN density, as all of the models had relatively large $\widehat{\text{MSE}}$ and *adj-*R^2 < 0.40. The point count method was probably a better estimator of NOTRUN density because it was less spatially restricted than the two-observer counts. This may be an important consideration since coveys were not assumed to be randomly distributed in my study area.

Predicting TRUN covey density using mean covey density estimates from the 350-PAIR, 500-PAIR, and PTCT methods, the 350-PAIR polynomial seemed to be the best reduced-observer estimator of covey density. However, the no-intercept PTCT, 350-PAIR, and PTCT methods also seemed to be adequate estimators of TRUN density. All of these models had similar $\widehat{\text{MSE}}$ and *adj-*$R^2 > 0.60$. Both the 500-PAIR and 500_PAIR polynomial models appeared to be poor predictors of TRUN density as these models had relatively large $\widehat{\text{MSE}}$ and *adj-*$R^2 < 0.40$.

When each covey density estimate from the 350-PAIR, 500-PAIR, and PTCT methods were used as predictor variables, the PTCT seemed to be the best overall estimator of the NOTRUN and TRUN covey densities. However, all predictors of TRUN covey density were similar based on $\widehat{\text{MSE}}$ and *adj-*R^2. Again, the point count method was probably a better estimator of overall quadrat densities because it was less spatially restricted than the two-observer counts. This further suggests that coveys were not randomly distributed in my study area.

Under the TRUN extended quadrat design, the 350_PAIR method seemed to be a reasonable predictor of covey density while the 500_PAIR method seemed to be a poor predictor of any of the quadrat density estimates. Observers in the 500_PAIR method may have been positioned too far apart from one another for both observers to detect a sufficient number of coveys within the area of truncation. The PTCT method appeared to be the most robust estimator of any of the overall quadrat density estimates. In my study area, the fragmented nature of habitats made it difficult to implement a random sample of call-count surveys within a well-defined unit of area (e.g. a cooperator's property). Much of the habitat on a typical cooperator's property is poor bobwhite habitat, aside from modest amounts of field-level BQI habitat on managed sites. Most of the available early successional habitat available to bobwhite was composed of agricultural fields, pastures, and areas of recent timber harvest, and the availability, juxtaposition, and quality of any of these habitats varied greatly from site to site. Habitat quality may change dramatically from spring and summer to fall and winter. For these reasons, it was assumed that coveys were not randomly distributed across the landscape during this study, and thus a population index that is too spatially limited (e.g. TTRS, 500_PAIR) would be expected to perform poorly.

When monitoring at the field level, the two-observer techniques may be too restrictive (based on truncation properties) to adequately sample non-randomly distributed calling coveys. However, the utility of two-observer survey techniques as a sampling method for large blocks of habitat in which coveys are randomly distributed [as the quadrat has been typically applied; Seiler (2001), Smith (2001), and Wellendorf et al. (2002*b*)] rather than as a field-level sampling method may warrant more evaluation.

CONCLUSIONS

Based on estimates of detection rates using Program MARK, there was not strong evidence suggesting that these rates were completely constant when the data where treated as closed captures with heterogeneity. The use of two observers compared to a single observer to conduct covey-call-counts does not appear to sufficiently increase numbers of coveys counted during a survey in order to justify the extra expense of solely using two-observer counts. This extra expense comes in the form of either increasing personnel or sacrificing the number of sample points surveyed. Using two observers, however, would provide the opportunity to estimate observer detection rates. Thus, for the BQI program it is suggested that a new approach be used for monitoring long-term bobwhite population trends. Rather than using very labor intensive quadrats to estimate observer detection rates, I suggest using two observers in enough surveys to estimate detection rates, and then using single-observer point counts to survey as many remaining sites as possible. The increased cost of using some multi-observer surveys to estimate detection rates seems more justifiable to increase survey quality, and therefore a mixture of single- and two-observer counts would provide a compromise to achieve survey efficiency and quality. Estimates of observer detection rates and effective hearing distance could possibly be used to develop density estimates from point count indices. One way to estimate effective hearing distances for observers may be, at least, to use recorded calls (Conroy 1996) in field tests. A more realistic way to estimate effective hearing distances for observers may be to utilize radio-marked coveys in field tests. Such field tests could possibly be used to develop models of detection distance incorporating weather, vegetation, topography, and other pertinent variables.

LITERATURE CITED

Anderson, D. R. 2001. The need to get the basics right in wildlife fields studies. Wildlife Society Bulletin 29:1294-1297.

_____, K. P. Burnham, and W. L. Thompson. 2000. Null hypothesis testing: problems, prevalence, and an alternative. Journal of Wildlife Management 64:912-923.

Burnham, K. P. and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer, New York, New York, USA.

Bibby, C. J., N. D. Burgess, and D. A. Hill. 1992. Bird census techniques. Academic Press, San Diego, California, USA.

Conroy, M. J. 1996. Techniques for estimating abundance and species richness: abundance indices. Pages 179-192 *in* Wilson, D. E., F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster, editors. Measuring and monitoring biological diversity. Smithsonian Institution Press, Washington, D.C., USA.

Curtis, P. D., P. D. Doerr, R. M. Oates, and K. H. Pollock. 1989. Whistling-cock indices as a measure of northern bobwhite harvest in North Carolina. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 43:253-259.

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

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

Lancia, R. A., J. D. Nichols, and K. H. Pollock. 1994. Estimating the number of animals in wildlife populations. Pages 215-253 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. Fifth Edition. The Wildlife Society, Bethesda, Maryland, USA.

Montgomery, D. C. and E. A. Peck. 1992. Introduction to linear regression analysis. Second Edition. John Wiley and Sons, New York, New York, USA.

Nichols, J. D., J. E. Hines, J. R. Sauer, F. W. Fallon, J. E. Fallon, and P. J. Heglund. 2000. A double-observer approach for estimating detection probability and abundance from point counts. Auk 117:393-408.

Seiler, T. P. 2001. Test of the morning covey call count technique for estimating population densities of northern bobwhites in Missouri. Thesis, University of Missouri, Columbia, Missouri, USA.

_____, R. D. Drobney, and T. V. Dailey. 2002. Use of weather variables for predicting fall covey calling rates of northern bobwhites. National Bobwhite Quail Symposium Proceedings 5:91-98.

Smith, M. D. 2001. Response of northern bobwhite to intensive habitat development on a prairie site in Mississippi. Thesis, Mississippi State University, Mississippi State, Mississippi, USA.

Stoddard, H. L. 1931. The bobwhite quail, its habits, preservation, and increase. Charles Scribner's Sons. New York, New York, USA.

Thompson, W. L. 2002. Towards reliable bird surveys: accounting for individuals present but not detected. Auk 119:18-25.

Wellendorf, S. D., W. E. Palmer, and P. T. Bromley. 2002*a*. Habitat selection of northern bobwhite coveys on two intensive agricultural landscapes in eastern North Carolina (*Abstract*). National Bobwhite Quail Symposium Proceedings 5:191.

_____, _____, and _____. 2002*b*. Estimating calling rates of northern bobwhite coveys and censusing populations. Journal of Wildlife Management *In Press*.

White, G. C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Supplement, 120-138.

Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. Analysis and management of animal populations. Academic Press. San Diego, California, USA.

Table 2.1. Fully closed captures with heterogeneity models used in Program MARK to estimate observer detection probabilities of calling northern bobwhite coveys and the associated model selection criteria (lowest AICc value indicates best approximating model). "Captures" were calling coveys detected with multi-observer, quadrat covey-call-count surveys from all BQI regions and both treatment and control sites in Georgia, 1999-2000 (*n* = 196 coveys detected).

Model[a]	AICc	ΔAICc	Model Weight	Model Likelihood	*K*[b]	Deviance
{pi(.) p(.) c(g) N(.)}	108.4100	0.0000	0.1889	1.0000	6	251.4630
{pi(g) p(.) c(g) N(.)}	108.4100	0.0000	0.1889	1.0000	6	251.4630
{pi(.) p(g) c(g) N(g)}	108.5400	0.1300	0.1770	0.9371	12	239.3570
{pi(.) p(g) c(g) N(t)}	108.5400	0.1300	0.1770	0.9371	12	239.3570
{pi(.) p(g) c(g) N(g)}	108.5400	0.1300	0.1770	0.9371	12	239.3570
{pi(.) p(g) c(g) N(.)}	111.3000	2.8900	0.0445	0.2357	9	248.2540
{pi(.) p(.) c(g) N(g)}	114.0040	5.5900	0.0115	0.0610	9	250.9580
{pi(.) p(.) c(g) N(t)}	114.0040	5.5900	0.0115	0.0610	9	250.9580
{pi(g) p(.) c(g) N(g)}	114.0040	5.5900	0.0115	0.0610	9	250.9580
{pi(g) p(.) c(g) N(t)}	114.0040	5.5900	0.0115	0.0610	9	250.9580
{pi(.) p(.) c(.) N(.)}	123.0060	14.6000	0.0001	0.0007	3	272.1210
{pi(g) p(.) c(.) N(.)}	123.0060	14.6000	0.0001	0.0007	3	272.1210
{pi(.) p(g) c(.) N(g)}	123.0610	14.6500	0.0001	0.0006	9	260.0150
{pi(.) p(g) c(.) N(t)}	123.0610	14.6500	0.0001	0.0006	9	260.0150
{pi(.) p(g) c(.) N(.)}	125.8590	17.4500	0.0000	0.0002	6	268.9120
{pi(.) p(.) c(.) N(g)}	128.5630	20.1500	0.0000	0.0001	6	271.6160
{pi(.) p(.) c(.) N(t)}	128.5630	20.1500	0.0000	0.0001	6	271.6160
{pi(g) p(.) c(.) N(g)}	128.5630	20.1500	0.0000	0.0001	6	271.6160
{pi(g) p(.) c(.) N(t)}	128.5630	20.1500	0.0000	0.0001	6	271.6160

[a] pi = mixture probability associated with heterogeneity among individuals captured; p = capture probability; c = recapture probability; N = abundance; (.) = constant across groups and observers; (g) = observer-group effect; (t) = observer effect.
[b] Number of parameters

Table 2.2. Model specific estimated calling northern bobwhite capture probabilities ($\hat{p}$) from fully closed captures with heterogeneity models used in Program MARK for the 1999 Central and Southwest (*n* = 53 coveys detected), 1999 East (*n* = 52 coveys detected), 2000 Central and Southwest (*n* = 53 coveys detected), and 2000 East (*n* = 38 coveys detected) quadrat covey-call-count observer-groups in Georgia. Observer-groups were specific to BQI focus areas and consisted of five observers in year 1999 and four observers in year 2000 quadrat surveys. Central and Southwest Regions were pooled because they were monitored by the same observers within years.

	Observer-group							
	1999 Central and Southwest		**1999 East**		**2000 Central and Southwest**		**2000 East**	
Model*	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**
{pi(.) p(.) c(g) N(.)}	0.3286	0.0371	0.3286	0.0371	0.3286	0.0371	0.3286	0.0371
{pi(g) p(.) c(g) N(.)}	0.3286	0.0371	0.3286	0.0371	0.3286	0.0371	0.3286	0.0371
{pi(.) p(g) c(g) N(g)}	0.4604	0.0655	0.1140	0.0877	0.3514	0.0707	0.3843	0.0816
{pi(.) p(g) c(g) N(t)}	0.4604	0.0655	0.1140	0.0877	0.3514	0.0707	0.3843	0.0816
{pi(.) p(g) c(g) N(g)}	0.4604	0.0655	0.1140	0.0877	0.3514	0.0707	0.3843	0.0816
{pi(.) p(g) c(g) N(.)}	0.3873	0.0565	0.2924	0.0407	0.3514	0.0500	0.3309	0.0586
{pi(.) p(.) c(g) N(g)}	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375
{pi(.) p(.) c(g) N(t)}	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375
{pi(g) p(.) c(g) N(g)}	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375
{pi(g) p(.) c(g) N(t)}	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375
{pi(.) p(.) c(.) N(.)}	0.3286	0.0371	0.3286	0.0371	0.3286	0.0371	0.3286	0.0371
{pi(g) p(.) c(.) N(.)}	0.3286	0.0371	0.3286	0.0371	0.3286	0.0371	0.3286	0.0371
{pi(.) p(g) c(.) N(g)}	0.4604	0.0655	0.1140	0.0877	0.3514	0.0707	0.3843	0.0816
{pi(.) p(g) c(.) N(t)}	0.4604	0.0655	0.1140	0.0877	0.3514	0.0707	0.3843	0.0816
{pi(.) p(g) c(.) N(.)}	0.3873	0.0565	0.2924	0.0407	0.3514	0.0500	0.3309	0.0586
{pi(.) p(.) c(.) N(g)}	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375
{pi(.) p(.) c(.) N(t)}	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375

Table 2.2 (Continued).

	Observer-group							
	1999 Central and Southwest		1999 East		2000 Central and Southwest		2000 East	
Model*	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**
{pi(g) p(.) c(.) N(g)}	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375
{pi(g) p(.) c(.) N(t)}	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375	0.3260	0.0375

* pi = mixture probability associated with heterogeneity among individuals captured; p = capture probability; c = recapture probability; N = abundance; (.) = constant across groups and observers; (g) = observer-group effect; (t) = observer effect.

Table 2.3. Model-averaged (to account for model uncertainty) estimated calling northern bobwhite capture probabilities ($\hat{p}$) from fully closed captures with heterogeneity models in Program MARK for the 1999 Central and Southwest, 1999 East, 2000 Central and Southwest, and 2000 East quadrat covey-call-count observer-groups in Georgia. Observer-groups were specific to BQI focus areas and consisted of five observers in year 1999 and four observers in year 2000 quadrat surveys. Central and Southwest Regions were pooled because they were monitored by the same observers within years.

Observer-group	% Variation Attributable to Model Variation	$\hat{p}$	SE	95% CI Lower	95% CI Upper
1999 Central and Southwest	60.27%	0.4011	0.0842	0.2521	0.5710
1999 East	73.92%	0.2128	0.1257	0.0585	0.5405
2000 Central and Southwest	4.78%	0.3416	0.0569	0.2401	0.4601
2000 East	19.08%	0.3582	0.0686	0.2372	0.5004

Table 2.4. Fully closed captures (no heterogeneity) models and associated model selection criteria used in Program MARK to estimate observer detection probabilities of calling northern bobwhite coveys and the associated model selection criteria (lowest QAICc value indicates best approximating model). "Captures" were calling coveys detected with multi-observer, quadrat covey-call-count surveys from all BQI regions and both treatment and control sites in Georgia, 1999-2000 (n = 196 coveys detected).

Model[a]	QAICc[b]	ΔQAICc	Model Weight	Model Likelihood	K[c]	Deviance
{p(.) c(t) N(.)}	41.5080	0.0000	0.5550	1.0000	18	55.6620
{p(.) c(g) N(.)}	43.6680	2.1600	0.1885	0.3396	6	82.4470
{p(.) c(.) N(.)}	44.3790	2.8700	0.1321	0.2380	3	89.2200
{p(g) c(t) N(.)}	46.7090	5.2000	0.0412	0.0742	21	54.6100
{p(.) c(t) N(g)}	47.5950	6.0900	0.0265	0.0477	21	55.4960
{p(g) c(g) N(.)}	48.7150	7.2100	0.0151	0.0272	9	81.3950
{p(g) c(.) N(.)}	49.3890	7.8800	0.0108	0.0194	6	88.1680
{p(.) c(g) N(g)}	49.6010	8.0900	0.0097	0.0175	9	82.2810
{p(g) c(t) N(g)}	50.0840	8.5800	0.0076	0.0137	24	51.6920
{p(.) c(.) N(g)}	50.2750	8.7700	0.0069	0.0125	6	89.0540
{p(g) c(g) N(g)}	51.9350	10.4300	0.0030	0.0054	12	78.4780
{p(g) c(.) N(g)}	52.5710	11.0600	0.0022	0.0040	9	85.2510
{p(t) c(t) N(.)}	54.7600	13.2500	0.0007	0.0013	34	35.1070
{p(t) c(g) N(.)}	56.0840	14.5800	0.0004	0.0007	22	61.8920
{p(t) c(.) N(.)}	56.5920	15.0800	0.0003	0.0005	19	68.6650

[a] p = capture probability; c = recapture probability; N = abundance; (.) = constant across groups and observers; (g) = observer-group effect; (t) = observer effect.
[b] QAICc incorporates an estimated variance inflation factor, $\hat{c}$, into the AICc value ($\hat{c}$= 3.05).
[c] Number of parameters.

Table 2.5. Model specific estimated calling northern bobwhite capture probabilities ($\hat{p}$) from fully closed captures (no heterogeneity) models used in Program MARK for the five, quadrat covey-call-count observers in the 1999 Central and Southwest observer-group in Georgia (n = 53 calling coveys detected). Observer-groups were specific to BQI focus areas. Central and Southwest Regions were pooled because they were monitored by the same observers within years.

	Observer									
	1		2		3		4		5	
Model*	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**
{p(.) c(t) N(.)}	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648
{p(.) c(g) N(.)}	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648
{p(.) c(.) N(.)}	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648
{p(g) c(t) N(.)}	0.3873	0.0986	0.3873	0.0986	0.3873	0.0986	0.3873	0.0986	0.3873	0.0986
{p(.) c(t) N(g)}	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655
{p(g) c(g) N(.)}	0.3873	0.0986	0.3873	0.0986	0.3873	0.0986	0.3873	0.0986	0.3873	0.0986
{p(g) c(.) N(.)}	0.3873	0.0986	0.3873	0.0986	0.3873	0.0986	0.3873	0.0986	0.3873	0.0986
{p(.) c(g) N(g)}	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655
{p(g) c(t) N(g)}	0.4604	0.1143	0.4604	0.1143	0.4604	0.1143	0.4604	0.1143	0.4604	0.1143
{p(.) c(.) N(g)}	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655
{p(g) c(g) N(g)}	0.4604	0.1143	0.4604	0.1143	0.4604	0.1143	0.4604	0.1143	0.4604	0.1143
{p(g) c(.) N(g)}	0.4604	0.1143	0.4604	0.1143	0.4604	0.1143	0.4604	0.1143	0.4604	0.1143
{p(t) c(t) N(.)}	0.4340	0.1189	0.4667	0.1591	0.7500	0.1891	0.5000	0.4366	1.0000	0.0000
{p(t) c(g) N(.)}	0.4340	0.1189	0.4667	0.1591	0.7500	0.1891	0.5000	0.4366	1.0000	0.0001
{p(t) c(.) N(.)}	0.4340	0.1189	0.4667	0.1591	0.7500	0.1891	0.5000	0.4366	1.0000	0.0000

* p = capture probability; c = recapture probability; N = abundance; (.) = constant across groups and observers; (g) = observer group-effect; (t) = observer effect.

Table 2.6. Model specific estimated calling northern bobwhite capture probabilities ($\hat{p}$) from fully closed captures (no heterogeneity) models used in Program MARK for the five, quadrat covey-call-count observers in the 1999 East observer-group in Georgia (n = 38 calling coveys detected). Observer-groups were specific to BQI focus areas.

	Observer									
	1		**2**		**3**		**4**		**5**	
Model*	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**
{p(.) c(t) N(.)}	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648
{p(.) c(g) N(.)}	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648
{p(.) c(.) N(.)}	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648
{p(g) c(t) N(.)}	0.2924	0.0710	0.2924	0.0710	0.2924	0.0710	0.2924	0.0710	0.2924	0.0710
{p(.) c(t) N(g)}	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655
{p(g) c(g) N(.)}	0.2924	0.0710	0.2924	0.0710	0.2924	0.0710	0.2924	0.0710	0.2924	0.0710
{p(g) c(.) N(.)}	0.2924	0.0710	0.2924	0.0710	0.2924	0.0710	0.2924	0.0710	0.2924	0.0710
{p(.) c(g) N(g)}	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655
{p(g) c(t) N(g)}	0.1140	0.1532	0.1140	0.1532	0.1140	0.1532	0.1140	0.1532	0.1140	0.1532
{p(.) c(.) N(g)}	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655
{p(g) c(g) N(g)}	0.1140	0.1532	0.1140	0.1532	0.1140	0.1532	0.1140	0.1532	0.1140	0.1532
{p(g) c(.) N(g)}	0.1140	0.1532	0.1140	0.1532	0.1140	0.1532	0.1140	0.1532	0.1140	0.1532
{p(t) c(t) N(.)}	0.2500	0.1049	0.2051	0.1129	0.4839	0.1568	0.5000	0.2183	1.0000	0.0000
{p(t) c(g) N(.)}	0.2500	0.1049	0.2051	0.1129	0.4839	0.1568	0.5000	0.2183	1.0000	0.0001
{p(t) c(.) N(.)}	0.2500	0.1049	0.2051	0.1129	0.4839	0.1568	0.5000	0.2183	1.0000	0.0000

* p = capture probability; c = recapture probability; N = abundance; (.) = constant across groups and observers; (g) = observer group-effect; (t) = observer effect.

Table 2.7. Model specific estimated calling northern bobwhite capture probabilities ($\hat{p}$) from fully closed captures (no heterogeneity) models used in Program MARK for the four, quadrat covey-call-count observers in the 2000 Central and Southwest observer-group in Georgia (n = 53 calling coveys detected). Observer-groups were specific to BQI focus areas. Central and Southwest Regions were pooled because they were monitored by the same observers within years.

	Observer							
	1		**2**		**3**		**4**	
Model*	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**
{p(.) c(t) N(.)}	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648
{p(.) c(g) N(.)}	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648
{p(.) c(.) N(.)}	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648
{p(g) c(t) N(.)}	0.3514	0.0873	0.3514	0.0873	0.3514	0.0873	0.3514	0.0873
{p(.) c(t) N(g)}	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655
{p(g) c(g) N(.)}	0.3514	0.0873	0.3514	0.0873	0.3514	0.0873	0.3514	0.0873
{p(g) c(.) N(.)}	0.3514	0.0873	0.3514	0.0873	0.3514	0.0873	0.3514	0.0873
{p(.) c(g) N(g)}	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655
{p(g) c(t) N(g)}	0.3514	0.1235	0.3514	0.1235	0.3514	0.1235	0.3514	0.1235
{p(.) c(.) N(g)}	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655
{p(g) c(g) N(g)}	0.3514	0.1235	0.3514	0.1235	0.3514	0.1235	0.3514	0.1235
{p(g) c(.) N(g)}	0.3514	0.1235	0.3514	0.1235	0.3514	0.1235	0.3514	0.1235
{p(t) c(t) N(.)}	0.3962	0.1173	0.2500	0.1337	0.5833	0.1758	1.0000	0.0000
{p(t) c(g) N(.)}	0.3962	0.1173	0.2500	0.1337	0.5833	0.1758	1.0000	0.0000
{p(t) c(.) N(.)}	0.3962	0.1173	0.2500	0.1337	0.5833	0.1758	1.0000	0.0000

* p = capture probability; c = recapture probability; N = abundance; (.) = constant across groups and observers; (g) = observer-group effect; (t) = observer effect.

Table 2.8. Model specific estimated calling northern bobwhite capture probabilities ($\hat{p}$) from fully closed captures (no heterogeneity) models used in Program MARK for the four, quadrat covey-call-count observers in the 2000 East observer-group in Georgia (n = 53 calling coveys detected). Observer-groups were specific to BQI focus areas.

	Observer							
	1		**2**		**3**		**4**	
Model*	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**	$\hat{p}$	**SE**
{p(.) c(t) N(.)}	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648
{p(.) c(g) N(.)}	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648
{p(.) c(.) N(.)}	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648	0.3286	0.0648
{p(g) c(t) N(.)}	0.3309	0.1024	0.3309	0.1024	0.3309	0.1024	0.3309	0.1024
{p(.) c(t) N(g)}	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655
{p(g) c(g) N(.)}	0.3309	0.1024	0.3309	0.1024	0.3309	0.1024	0.3309	0.1024
{p(g) c(.) N(.)}	0.3309	0.1024	0.3309	0.1024	0.3309	0.1024	0.3309	0.1024
{p(.) c(g) N(g)}	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655
{p(g) c(t) N(g)}	0.3843	0.1425	0.3843	0.1425	0.3843	0.1425	0.3843	0.1425
{p(.) c(.) N(g)}	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655	0.3260	0.0655
{p(g) c(g) N(g)}	0.3843	0.1425	0.3843	0.1425	0.3843	0.1425	0.3843	0.1425
{p(g) c(.) N(g)}	0.3843	0.1425	0.3843	0.1425	0.3843	0.1425	0.3843	0.1425
{p(t) c(t) N(.)}	0.4474	0.1409	0.1905	0.1496	0.5882	0.2085	1.0000	0.0000
{p(t) c(g) N(.)}	0.4474	0.1409	0.1905	0.1497	0.5882	0.2085	1.0000	0.0001
{p(t) c(.) N(.)}	0.4474	0.1409	0.1905	0.1496	0.5882	0.2085	1.0000	0.0000

* p = capture probability; c = recapture probability; N = abundance; (.) = constant across groups and observers; (g) = observer-group effect; (t) = observer effect.

Table 2.9. Model-averaged (to account for model uncertainty) estimated calling northern bobwhite capture probabilities ($\hat{p}$) from fully closed captures (no heterogeneity) models in Program MARK for each of the observers in the 1999 Central and Southwest, 1999 East, 2000 Central and Southwest, and 2000 East quadrat covey-call-count observer-groups in Georgia. Observer-groups were specific to BQI focus areas and consisted of five observers in year 1999 and four observers in year 2000 quadrat surveys. Central and Southwest Regions were pooled because they were monitored by the same observers within years.

		% Variation Attributable			**95% CI**	
Observer-group	**Observer**	**to Model Variation**	$\hat{p}$	**SE**	**Lower**	**Upper**
1999 Central and Southwest	1	5.39%	0.3343	0.0697	0.2137	0.4812
1999 Central and Southwest	2	5.43%	0.3343	0.0698	0.2137	0.4814
1999 Central and Southwest	3	6.31%	0.3347	0.0701	0.2135	0.4826
1999 Central and Southwest	4	5.34%	0.3344	0.0701	0.2132	0.4823
1999 Central and Southwest	5	7.86%	0.3351	0.0704	0.2133	0.4836
1999 East	1	5.83%	0.3232	0.0684	0.2055	0.4686
1999 East	2	5.94%	0.3231	0.0685	0.2054	0.4686
1999 East	3	5.96%	0.3235	0.0686	0.2056	0.4691
1999 East	4	5.93%	0.3236	0.0686	0.2055	0.4693
1999 East	5	8.24%	0.3243	0.0692	0.2054	0.4712
2000 Central and Southwest	1	0.72%	0.3304	0.0674	0.2136	0.4727
2000 Central and Southwest	2	0.73%	0.3302	0.0674	0.2134	0.4726
2000 Central and Southwest	3	1.20%	0.3307	0.0676	0.2135	0.4735
2000 Central and Southwest	4	3.41%	0.3313	0.0681	0.2133	0.4751
2000 East	1	0.59%	0.3295	0.0686	0.2110	0.4747
2000 East	2	0.63%	0.3292	0.0687	0.2106	0.4744
2000 East	3	0.92%	0.3297	0.0688	0.2109	0.4753
2000 East	4	3.14%	0.3303	0.0693	0.2107	0.4769

Table 2.10. Regression analyses using northern bobwhite covey density estimates from full-observer quadrat covey-call-counts as dependent variables. Independent variables were covey density estimates from reduced-observer quadrat subsamples. Each full-observer quadrat density estimate was paired with the mean of subsamples of the corresponding reduced-observer density estimate (typically, PTCT = four subsamples, 350_PAIR = four subsamples, and 500_PAIR = two subsamples). Analyses included all BQI regions and both treatment and control sites in Georgia, 1999-2000.

MSE Rank[a]	**Model**[b]	***n***	**df**	**$\widehat{MSE}$**	**CV**	***F***	***P***	***R^2***	***Adj-R^2***
1	NOTRUN = β_0 + PTCT	107	1	0.1967	43.80%	589.30	<0.0001	0.8488	0.8473
2	NOTRUN = β_0 + 350_PAIR + 350_PAIR^2	107	2	0.8378	90.39%	29.50	<0.0001	0.3620	0.3497
3	NOTRUN = β_0 + 350_PAIR	107	1	0.8657	91.88%	52.76	<0.0001	0.3344	0.3281
4	NOTRUN = β_0 + 500_PAIR + 500_PAIR^2	107	2	0.9140	94.41%	22.71	<0.0001	0.3040	0.2906
5	NOTRUN = β_0 + 500_PAIR	107	1	0.9872	98.12%	33.35	<0.0001	0.2410	0.2338
1	TRUN = β_0 + 350_PAIR + 350_PAIR^2	107	2	0.3157	90.71%	116.61	<0.0001	0.6916	0.6857
2	TRUN = PTCT	107	1	0.3818	99.76%	280.31	<0.0001	0.7256	0.7230
3	TRUN = β_0 + 350_PAIR	107	1	0.3844	100.10%	171.90	<0.0001	0.6208	0.6172
4	TRUN = β_0 + PTCT	107	1	0.3853	100.22%	171.28	<0.0001	0.6200	0.6163
5	TRUN = β_0 + 500_PAIR + 500_PAIR^2	107	2	0.6244	127.58%	33.24	<0.0001	0.3899	0.3782
6	TRUN = β_0 + 500_PAIR	107	1	0.6503	130.20%	58.68	<0.0001	0.3585	0.3524
1	TTRS = β_0 + 350_PAIR	107	1	2.4224	219.13%	64.26	<0.0001	0.3796	0.3737
2	TTRS = 350_PAIR	107	1	2.4235	219.18%	85.46	<0.0001	0.4464	0.4411
3	TTRS = PTCT	107	1	2.7815	234.81%	60.82	<0.0001	0.3646	0.3586
4	TTRS = β_0 + PTCT	107	1	2.7971	235.46%	41.59	<0.0001	0.2837	0.2769
5	TTRS = β_0 + 500_PAIR	107	1	3.0000	243.85%	31.68	<0.0001	0.2318	0.2244
6	TTRS = 500_PAIR	107	1	3.0834	247.22%	44.48	<0.0001	0.2956	0.2890

[a] Rank of model utility based on estimated mean squared error.

[b] NOTRUN = non-truncated, extended quadrat surveys with total detection area of 1.6 km^2, TRUN = truncated, extended quadrat survey with total detection area of 0.86 km^2, TTRS = traditional quadrat survey with total detection area of 0.25 km^2, PTCT = single-observer point count, 350_PAIR = two-observer count where observers were 350 meters apart, 500_PAIR = two-observer count where observers were 500 meters apart, β_0 = indicates whether the model included an intercept.

Table 2.11. Parameter estimates from regression analyses using northern bobwhite covey density estimates from full-observer quadrat covey-call-counts as dependent variables. Independent variables included covey density estimates from reduced-observer quadrat subsamples. Each full-observer quadrat density estimate was paired with the mean of subsamples of the corresponding reduced-observer density estimate (typically, PTCT = four subsamples, 350_PAIR = four subsamples, and 500_PAIR = two subsamples). Analyses included all BQI regions and both treatment and control sites in Georgia, 1999-2000.

Model*	$\hat{\beta}_0$	**SE**	***t***	***P***	$\hat{\beta}_1$	**SE**	***t***	***P***	$\hat{\beta}_2$	**SE**	***t***	***P***
NOTRUN = β_0 + PTCT	0.1708	0.0551	3.10	0.0025	0.9368	0.0386	24.28	<0.0001	**	**	**	**
NOTRUN = β_0 + 350_PAIR + 350_PAIR^2	1.1447	0.1083	10.57	<0.0001	1.3064	0.2477	5.27	<0.0001	-0.2185	0.1032	-2.12	0.0366
NOTRUN = β_0 + 350_PAIR	0.7193	0.0986	7.30	<0.0001	0.8405	0.1157	7.26	<0.0001	**	**	**	**
NOTRUN = β_0 + 500_PAIR + 500_PAIR^2	1.1642	0.1048	11.11	<0.0001	1.1479	0.2027	5.66	<0.0001	-0.1836	0.0599	-3.07	0.0028
NOTRUN = β_0 + 500_PAIR	0.8038	0.1026	7.83	<0.0001	0.6103	0.1057	5.77	<0.0001	**	**	**	**
TRUN = β_0 + 350_PAIR + 350_PAIR^2	0.8063	0.0664	12.14	<0.0001	1.6707	0.1520	10.99	<0.0001	-0.3094	0.0633	-4.89	<0.0001
TRUN = PTCT	**	**	**	**	0.6999	0.0418	16.74	<0.0001	**	**	**	**
TRUN = β_0 + 350_PAIR	0.2665	0.0657	4.06	<0.0001	1.0110	0.0771	13.11	<0.0001	**	**	**	**
TRUN = β_0 + PTCT	-0.0158	0.0772	-0.21	0.8379	0.7069	0.0540	13.09	<0.0001	**	**	**	**
TRUN = β_0 + 500_PAIR + 500_PAIR^2	0.7139	0.0866	8.24	<0.0001	0.9926	0.1675	5.93	<0.0001	-0.1145	0.0495	-2.31	0.0226
TRUN = β_0 + 500_PAIR	0.3945	0.0833	4.74	<0.0001	0.6571	0.0858	7.66	<0.0001	**	**	**	**
TTRS = β_0 + 350_PAIR	0.1688	0.1649	1.02	0.3085	1.5517	0.1936	8.02	<0.0001	**	**	**	**
TTRS = 350_PAIR	**	**	**	**	1.6328	0.1766	9.24	<0.0001	**	**	**	**
TTRS = PTCT	**	**	**	**	0.8799	0.1128	7.80	<0.0001	**	**	**	**
TTRS = β_0 + PTCT	-0.1330	0.2080	-0.64	0.5237	0.9385	0.1455	6.45	<0.0001	**	**	**	**
TTRS = β_0 + 500_PAIR	0.3555	0.1789	1.99	0.0495	1.0370	0.1843	5.63	<0.0001	**	**	**	**
TTRS = 500_PAIR	**	**	**	**	1.1660	0.1748	6.67	<0.0001	**	**	**	**

* NOTRUN = non-truncated, extended quadrat surveys with total detection area of 1.6 km^2, TRUN = truncated, extended quadrat survey with total detection area of 0.86 km^2, TTRS = traditional quadrat survey with total detection area of 0.25 km^2, PTCT = single-observer point count, 350_PAIR = two-observer count where observers were 350 meters apart, 500_PAIR = two-observer count where observers were 500 meters apart, β_0 = indicates whether the model included an intercept.

Table 2.12. Regression analyses using northern bobwhite covey density estimates from full-observer quadrat covey-call-counts as dependent variables. Independent variables included covey density estimates from reduced-observer quadrat subsamples. Each full-observer quadrat density estimate was paired with each corresponding subsample from the reduced-observer density estimate (typically, PTCT = four subsamples, 350_PAIR = four subsamples, and 500_PAIR = two subsamples). Analyses included all BQI regions and both treatment and control sites in Georgia, 1999-2000.

MSE Rank[a]	**Model**[b]	***n***	**df**	**$\hat{MSE}$**	**CV**	***F***	***P***	***R^2***	***Adj-R^2***
1	NOTRUN = β_0 + PTCT	428	1	0.5338	75.78%	621.02	<0.0001	0.5931	0.5922
2	NOTRUN = β_0 + 350_PAIR	409	1	1.0385	101.76%	94.52	<0.0001	0.1885	0.1865
3	NOTRUN = β_0 + 500_PAIR	233	1	1.1056	101.87%	38.95	<0.0001	0.1443	0.1406
1	TRUN = β_0 + PTCT	428	1	0.6234	120.79%	282.03	<0.0001	0.3983	0.3969
2	TRUN = β_0 + 350_PAIR	409	1	0.6692	132.62%	203.54	<0.0001	0.3334	0.3317
3	TRUN = β_0 + 500_PAIR	233	1	0.7753	141.16%	65.75	<0.0001	0.2216	0.2182

[a] Rank of model utility based on estimated mean squared error.

[b] NOTRUN = non-truncated, extended quadrat surveys with total detection area of 1.6 km^2, TRUN = truncated, extended quadrat survey with total detection area of 0.86 km^2, PTCT = single-observer point count, 350_PAIR = two-observer count where observers were 350 meters apart, 500_PAIR = two-observer count where observers were 500 meters apart, β_0 = indicates whether the model included an intercept.

Table 2.13. Parameter estimates from regression analyses using northern bobwhite covey density estimates from full-observer quadrat covey-call-counts as dependent variables. Independent variables included covey density estimates from reduced-observer quadrat subsamples. Each full-observer quadrat density estimate was paired with each corresponding subsample from the reduced-observer density estimate (typically, PTCT = four subsamples, 350_PAIR = four subsamples, and 500_PAIR = two subsamples). Analyses included all BQI regions and both treatment and control sites in Georgia, 1999-2000.

Model*	$\hat{\beta}_0$	**SE**	***t***	***P***	$\hat{\beta}_1$	**SE**	***t***	***P***
NOTRUN = β_0 + PTCT	0.4002	0.0419	9.54	<0.0001	0.6723	0.0269	24.92	<0.0001
NOTRUN = β_0 + 350_PAIR	0.8405	0.0530	15.85	<0.0001	0.4614	0.0475	9.72	<0.0001
NOTRUN = β_0 + 500_PAIR	0.9047	0.0719	12.59	<0.0001	0.3779	0.0605	6.24	<0.0001
TRUN = β_0 + PTCT	0.2430	0.0453	5.36	<0.0001	0.4896	0.0292	16.79	<0.0001
TRUN = β_0 + 350_PAIR	0.4272	0.0426	10.03	<0.0001	0.5435	0.0381	14.27	<0.0001
TRUN = β_0 + 500_PAIR	0.4851	0.0602	8.06	<0.0001	0.4111	0.0507	8.11	<0.0001

* NOTRUN = non-truncated, extended quadrat surveys with total detection area of 1.6 km^2, TRUN = truncated, extended quadrat survey with total detection area of 0.86 km^2, PTCT = single-observer point count, 350_PAIR = two-observer count where observers were 350 meters apart, 500_PAIR = two-observer count where observers were 500 meters apart, β_0 = indicates whether the model included an intercept.

Table 2.14. Means and associated measures of dispersion for dependent and independent variable northern bobwhite covey density (per km^2) estimates from quadrat covey-call-count surveys conducted in all BQI regions and both treatment and control sites in Georgia, 1999-2000.

		Mean Subsample as Independent					**Each Subsample as Independent**				
Variable*	**Variable Type**	**Mean**	**SE**	**±95% CI**	**Min**	**Max**	**Mean**	**SE**	**±95% CI**	**Min**	**Max**
NOTRUN	Dependent	1.0105	0.1097	0.2150	0.00	5.00	1.0105	0.1097	0.2150	0.00	5.00
TRUN	Dependent	0.6194	0.0968	0.1898	0.00	4.65	0.6194	0.0968	0.1898	0.00	4.65
TTRS	Dependent	0.7103	0.1901	0.3727	0.00	8.00	**	**	**	**	**
350_PAIR	Independent	0.3399	0.0725	0.1421	0.00	3.57	0.3487	0.0525	0.1030	0.00	7.14
500_PAIR	Independent	0.3381	0.0878	0.1722	0.00	5.71	0.3373	0.0747	0.1464	0.00	8.57
PTCT	Independent	0.9286	0.1115	0.2185	0.00	4.17	0.8746	0.0639	0.1252	0.00	6.37

* NOTRUN = non-truncated, extended quadrat surveys with total detection area of 1.6 km^2, TRUN = truncated, extended quadrat survey with total detection area of 0.86 km^2, TTRS = traditional quadrat survey with total detection area of 0.25 km^2, PTCT = single-observer point count, 350_PAIR = two-observer count where observers were 350 meters apart, 500_PAIR = two-observer count where observers were 500 meters apart.

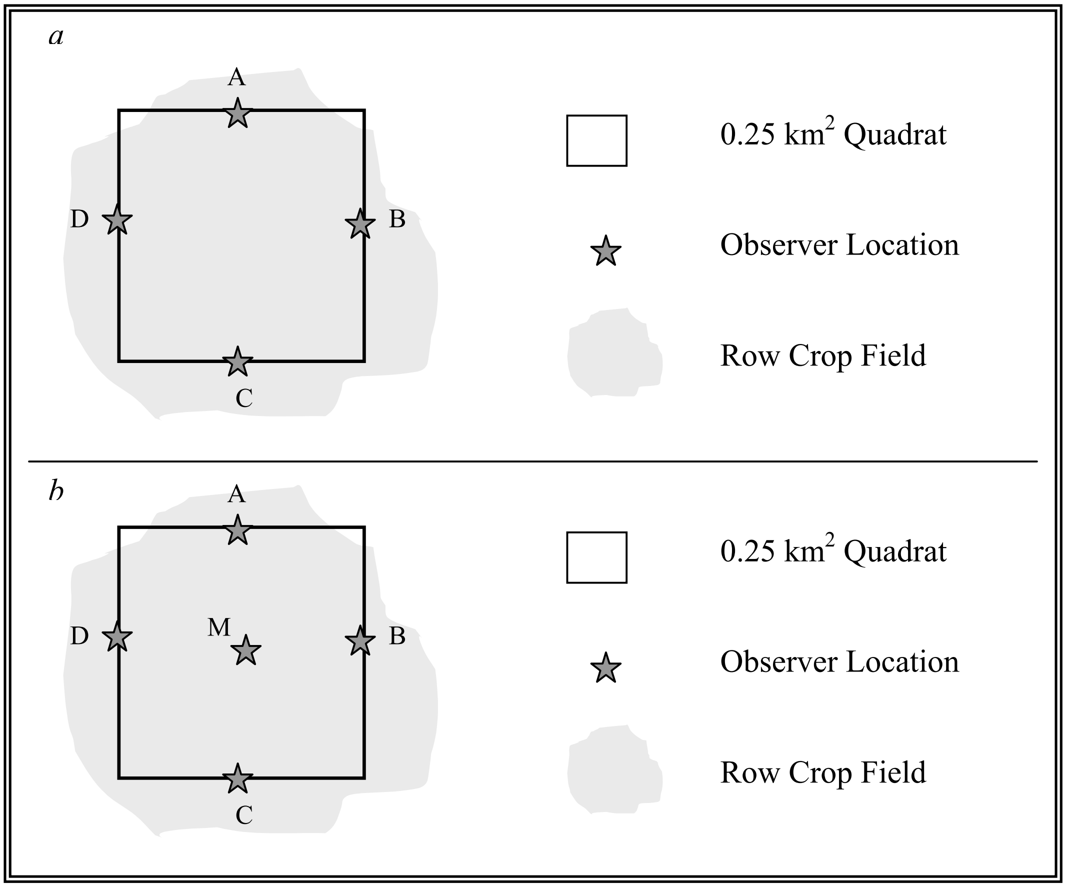

Figure 2.1. Example layout of (*a*) typical quadrat surveys utilizing four observers in 2000 and (*b*) the quadrat technique utilizing five observers in 1999 (middle observer was used to evaluate one observer in relation to the entire quadrat) for northern bobwhite covey-call-count surveys used at samples of treatment and control sites in all BQI focus areas in Georgia.

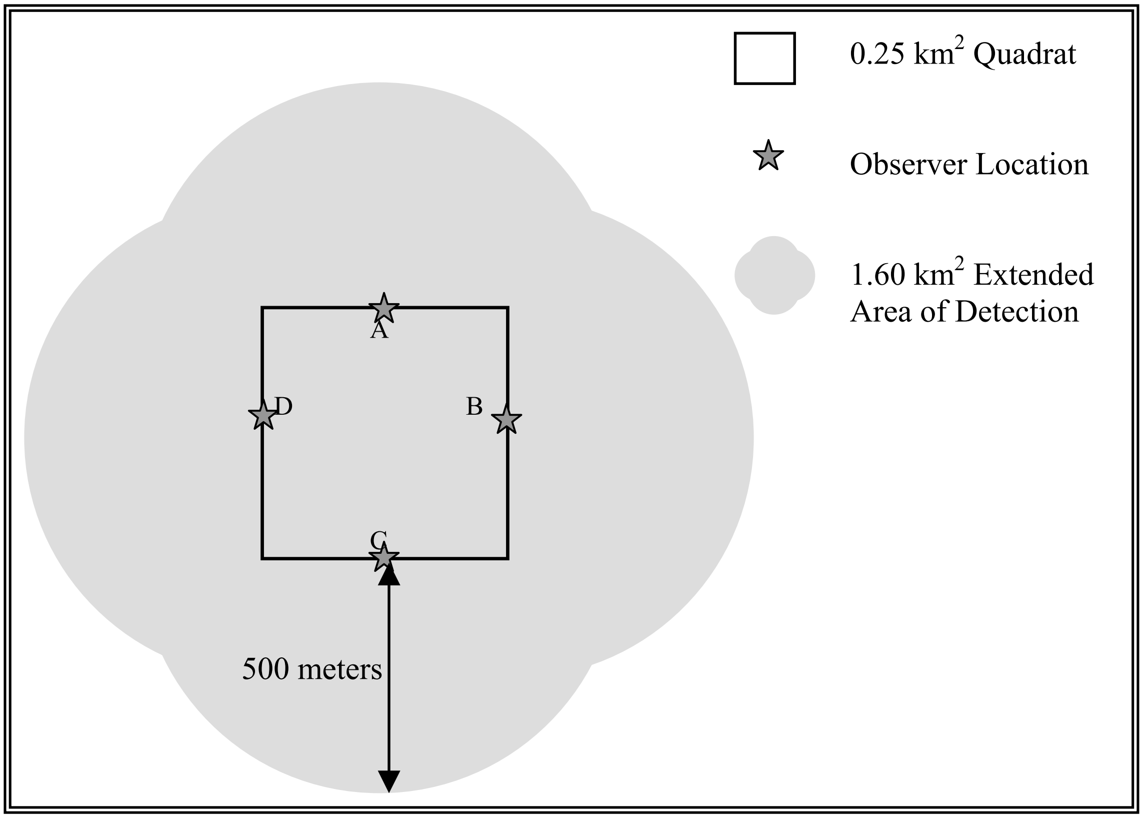

Figure 2.2. Example of how the area of a typical northern bobwhite covey-call-count quadrat survey (see Figure 2.1) was extended to incorporate calling coveys detected outside of quadrats. All unique coveys detected were assumed to be within the 1.60 km^2 area of detection to estimate covey density. Quadrat surveys were used at samples of treatment and control sites in all BQI focus areas in Georgia, 1999-2000.

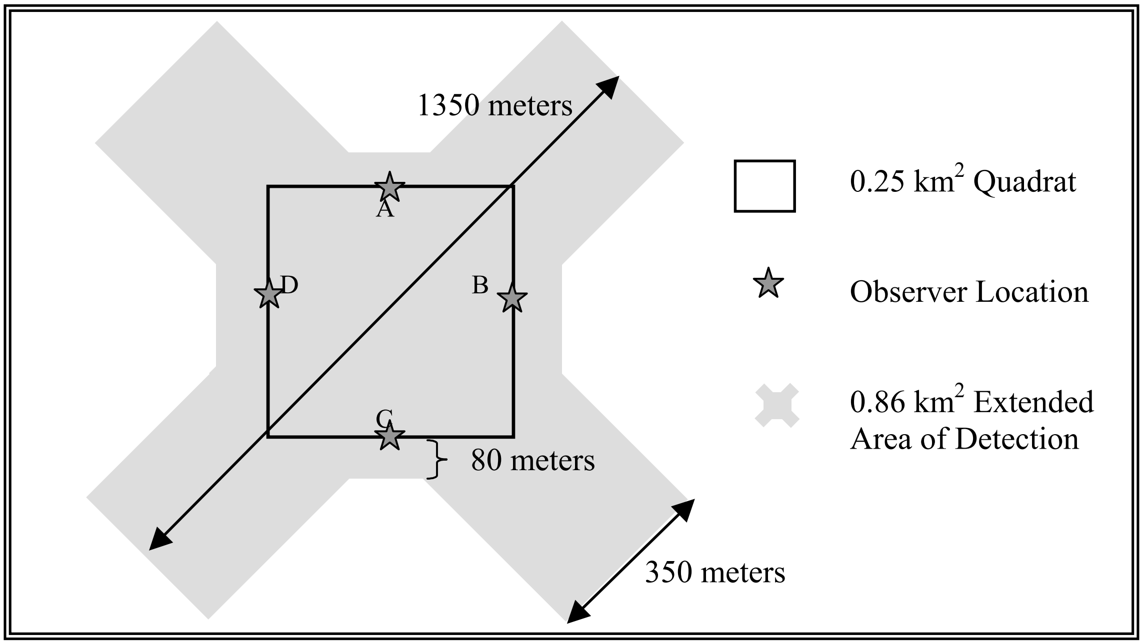

Figure 2.3. Example of how the area of a typical northern bobwhite covey-call-count quadrat survey (see Figure 2.1) was extended, but truncated (by distance and angle) around all observer pairs 350 and 500 meters apart (Figure 2.4) from one another, to incorporate calling coveys detected outside of quadrats. Only unique coveys detected within the 0.86 km^2 area of detection, via triangulation, were used to estimate covey density. Quadrat surveys were used at samples of treatment and control sites in all BQI focus areas in Georgia, 1999-2000.

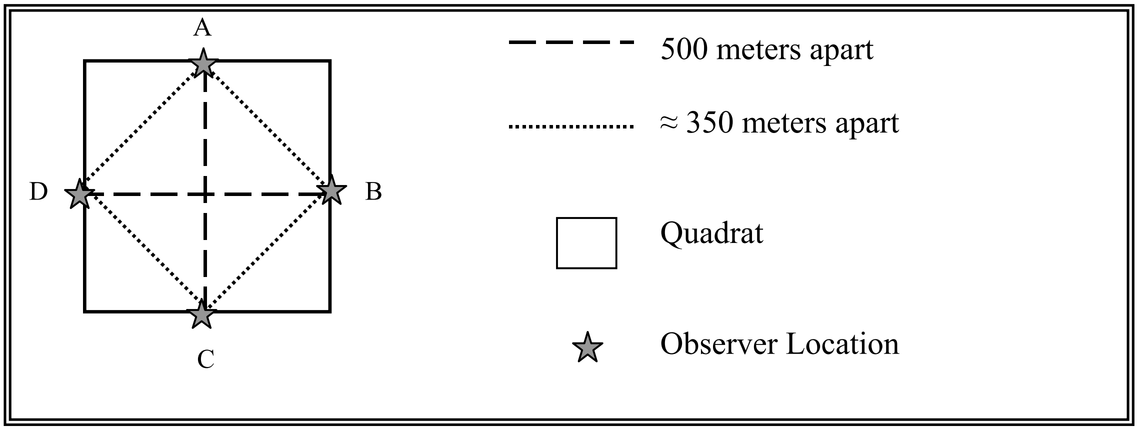

Figure 2.4. Distances (meters) between pairs of observers, based on observer location along the quadrat sides, from a typical northern bobwhite covey-call-count quadrat survey (see Figure 2.1). Quadrat surveys were used at samples of treatment and control sites in all BQI focus areas in Georgia, 1999-2000.

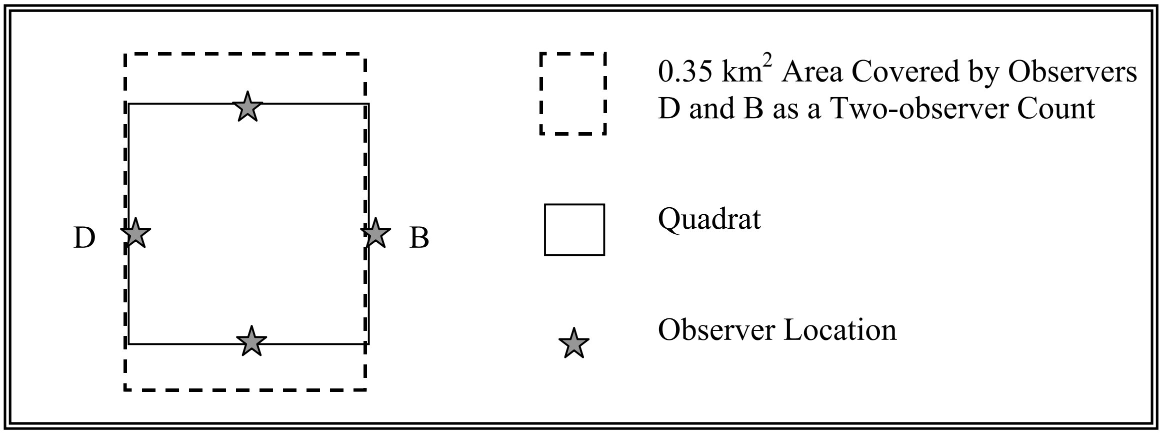

Figure 2.5. Example of how a truncated area of detection was constructed around pairs of observers, 500 meters apart, from a typical northern bobwhite covey-call-count quadrat survey in order to evaluate a two-observer call-count design. Only coveys detected within the 0.35 km^2 area of detection, via triangulation, were used to estimate covey density. Quadrat surveys were used at samples of treatment and control sites in all BQI focus areas in Georgia, 1999-2000.

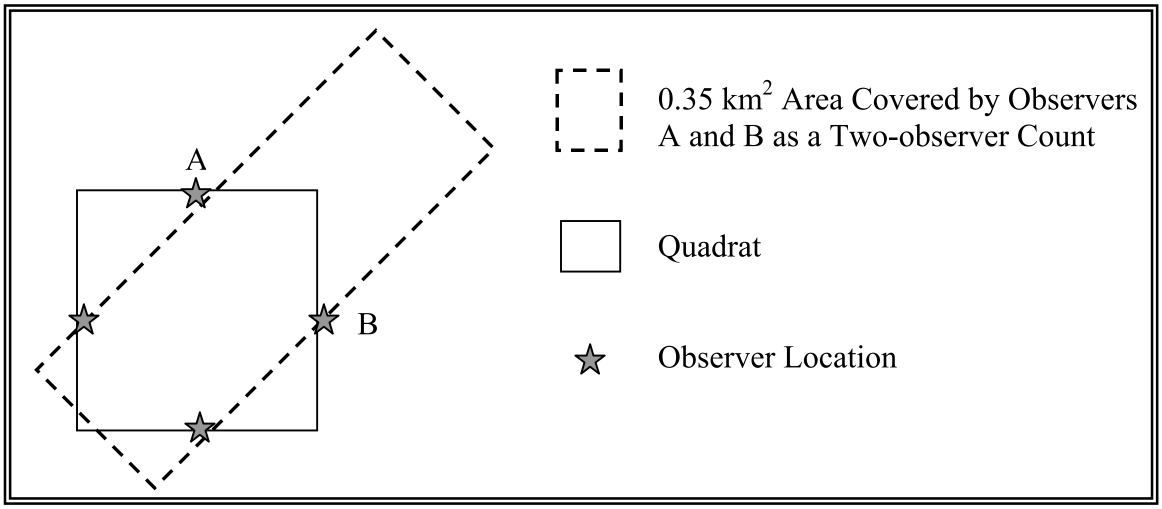

Figure 2.6. Example of how a truncated area of detection was constructed around pairs of observers, 350 meters apart, from a typical northern bobwhite covey-call-count quadrat survey in order to evaluate a two-observer call-count design. Only coveys detected within the 0.35 km^2 area of detection, via triangulation, were used to estimate covey density. Quadrat surveys were used at samples of treatment and control sites in all BQI focus areas in Georgia, 1999-2000.

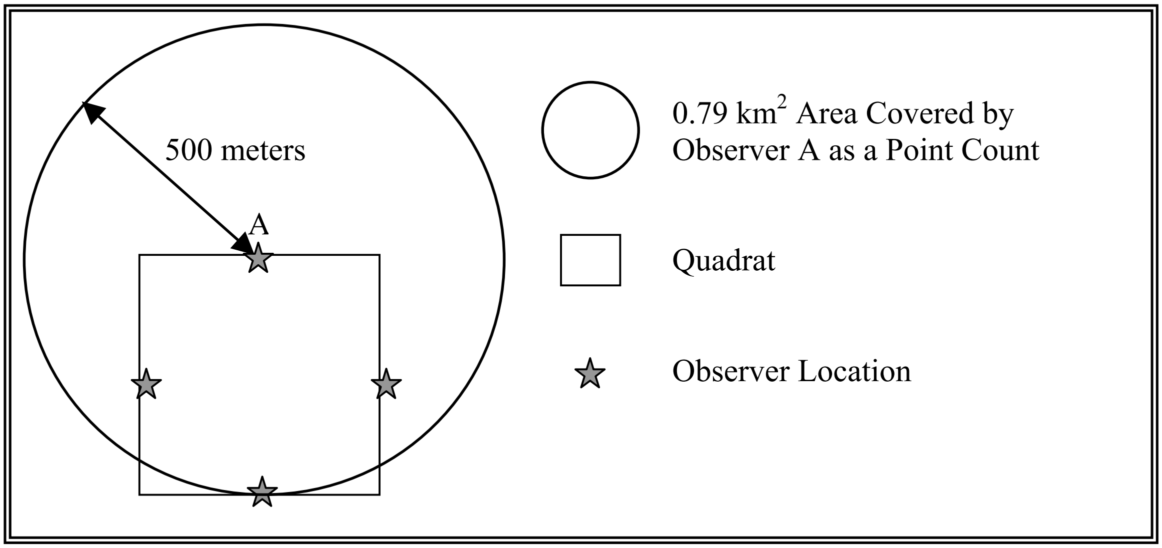

Figure 2.7. Example of how individual observers from a typical northern bobwhite covey-call-count quadrat survey were treated as a point count in order to evaluate a single-observer call-count design. All unique coveys detected by an observer were assumed to be within the 0.79 km^2 area of detection to estimate covey density. Quadrat surveys were used at samples of treatment and control sites in all BQI focus areas in Georgia, 1999-2000.

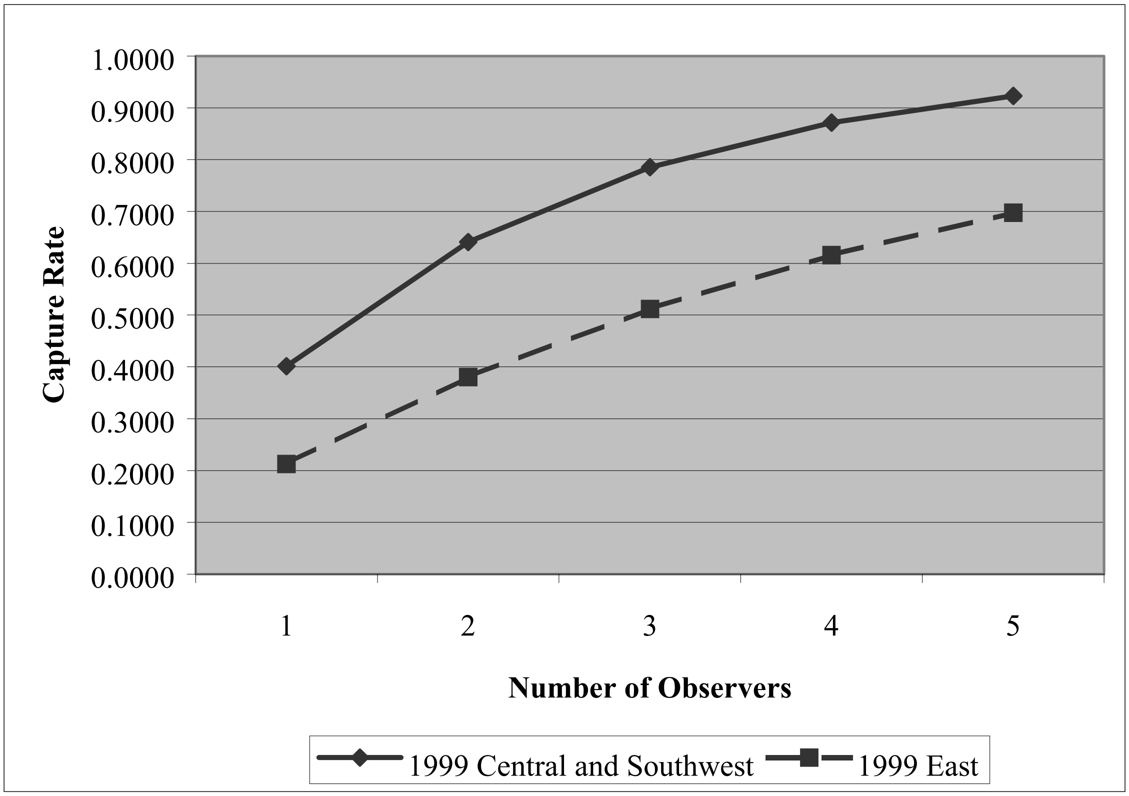

Figure 2.8. Estimated capture rates ($\hat{p}$) of calling northern bobwhite coveys for 1 covey-call-count observer (estimated from Program MARK, data treated as fully closed captures with heterogeneity), and subsequent estimates for 2, 3, 4, and 5 observers derived from the equation $\hat{p}_k = 1 - (1 - \hat{p}_{\text{1-observer}})^k$, where k is the number of observers of interest. Estimates were made for the 1999 Central and Southwest and 1999 East observer-groups in Georgia. Observer-groups were specific to BQI focus areas. Central and Southwest Regions were pooled because they were monitored by the same observers within years.

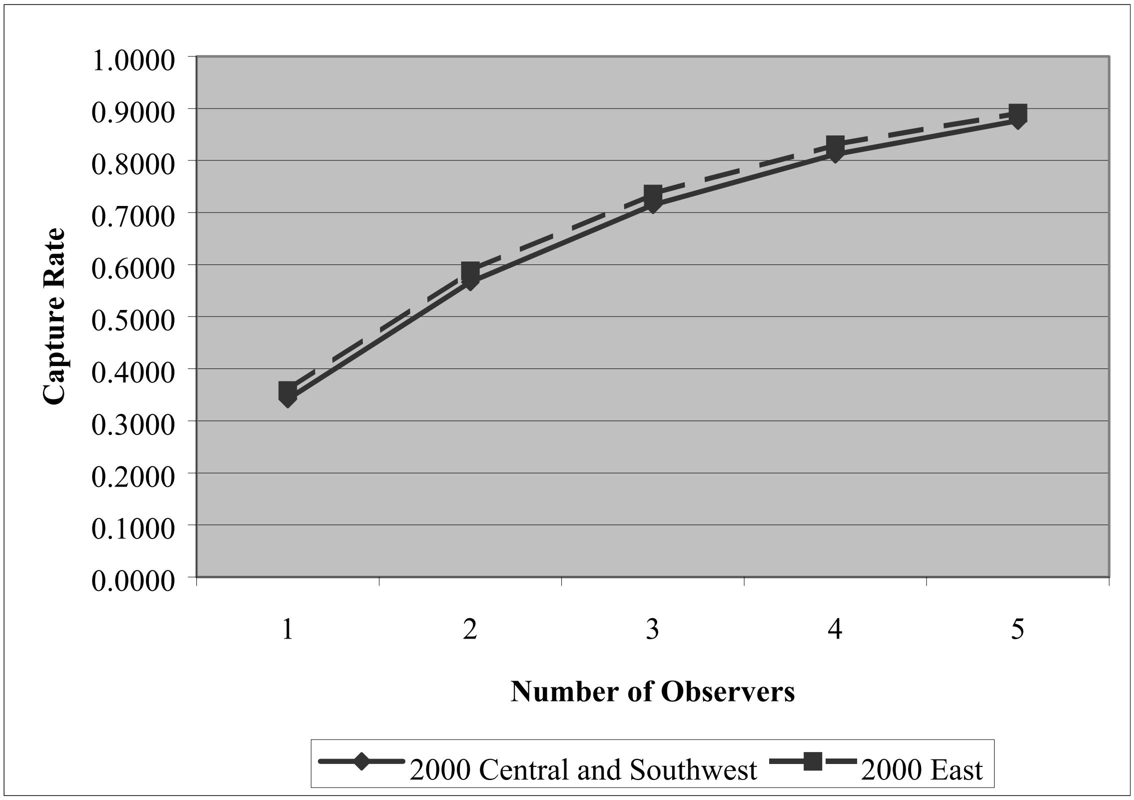

Figure 2.9. Estimated capture rates ($\hat{p}$) of northern bobwhite calling coveys for 1 covey-call-count observer (estimated from Program MARK, data treated as fully closed captures with heterogeneity), and subsequent estimates for 2, 3, 4, and 5 observers derived from the equation $\hat{p}_k = 1 - (1 - \hat{p}_{\text{1-observer}})^k$, where k is the number of observers of interest. Estimates were made for the 2000 Central and Southwest and 2000 East observer-groups in Georgia. Observer-groups were specific to BQI focus areas. Central and Southwest Regions were pooled because they were monitored by the same observers within years.

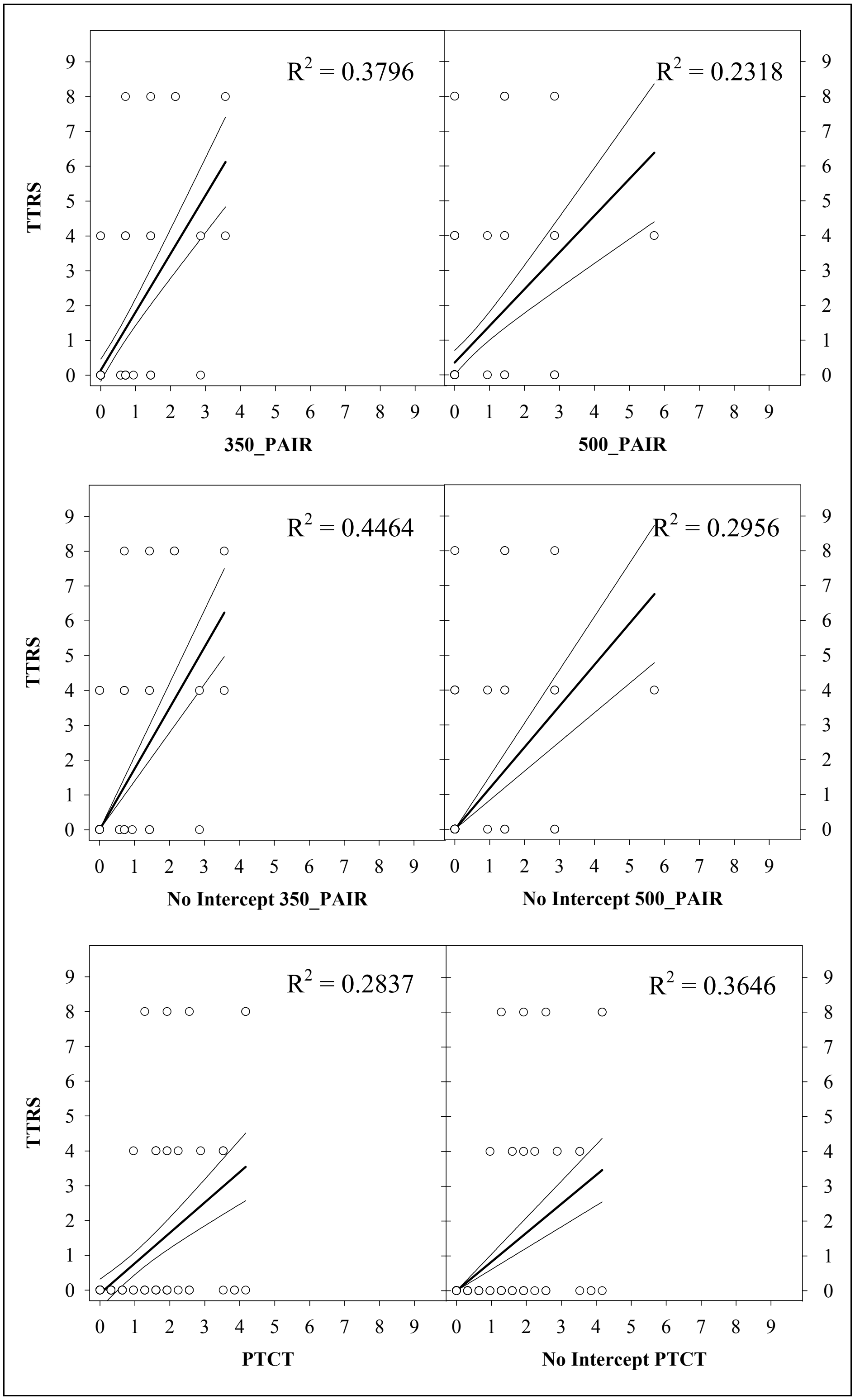

Figure 2.10. Relationship (±95% prediction interval) between northern bobwhite covey density (km^2) estimates from the TTRS full-observer quadrat covey-call-count and means of reduced-observer quadrat covey-call-count subsamples. Analyses included all BQI regions and both treatment and control sites in Georgia, 1999-2000.

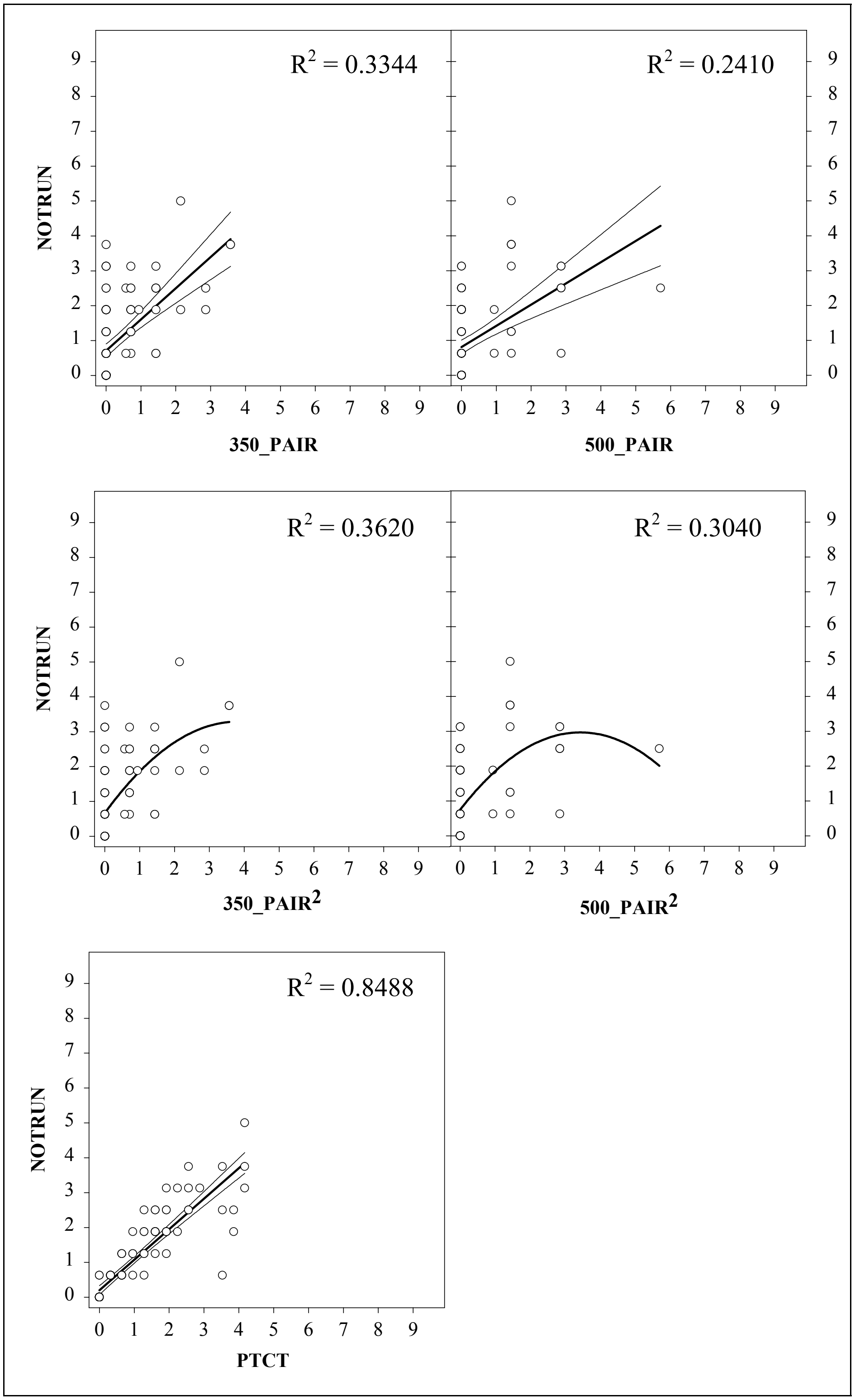

Figure 2.11. Relationship (±95% prediction interval) between northern bobwhite covey density (km^2) estimates from the NOTRUN full-observer quadrat covey-call-count and means of reduced-observer quadrat covey-call-count subsamples. Analyses included all BQI regions and both treatment and control sites in Georgia, 1999-2000.

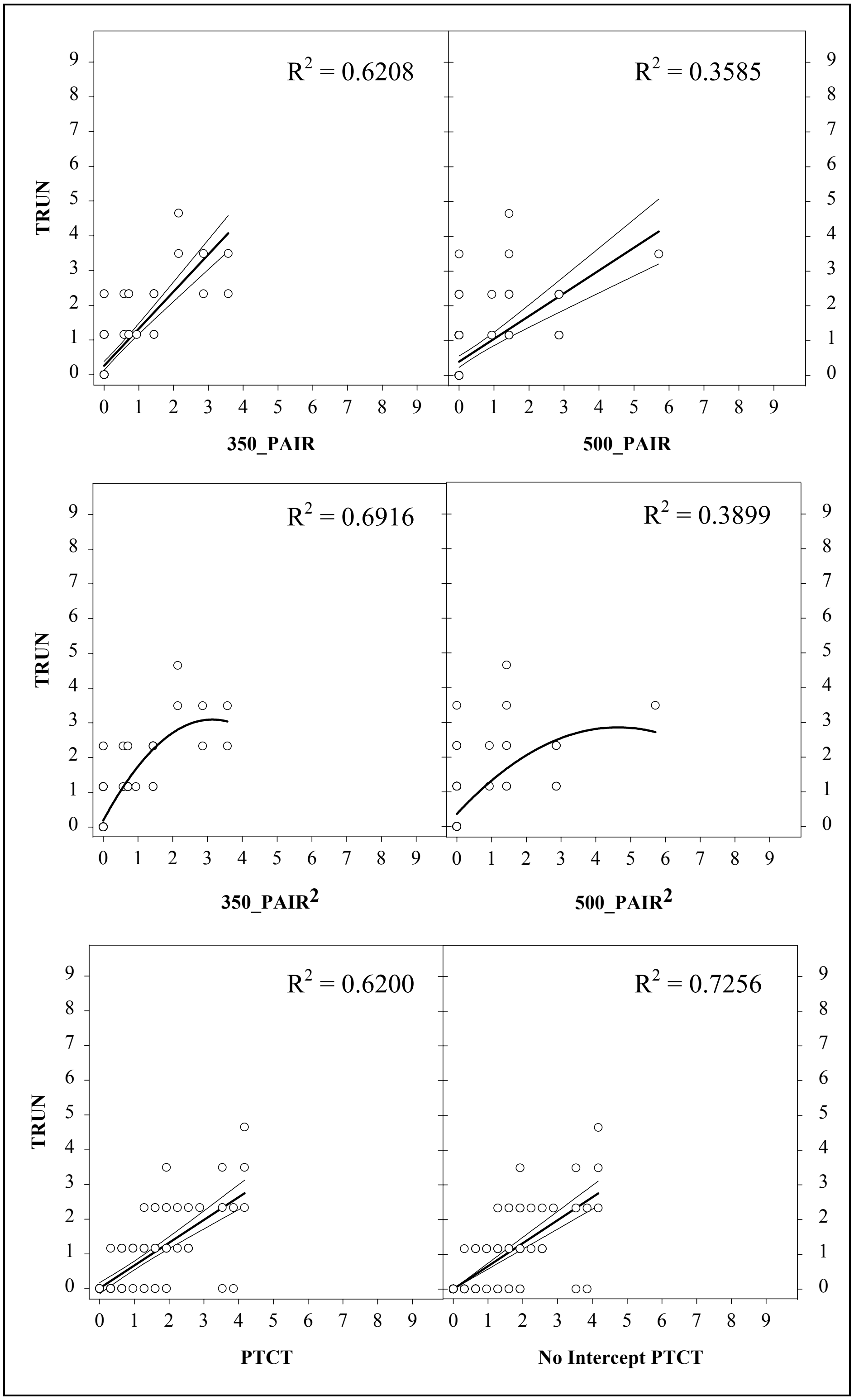

Figure 2.12. Relationship (±95% prediction interval) between northern bobwhite covey density (km^2) estimates from the TRUN full-observer quadrat covey-call-count and means of reduced-observer quadrat covey-call-count subsamples. Analyses included all BQI regions and both treatment and control sites in Georgia, 1999-2000.

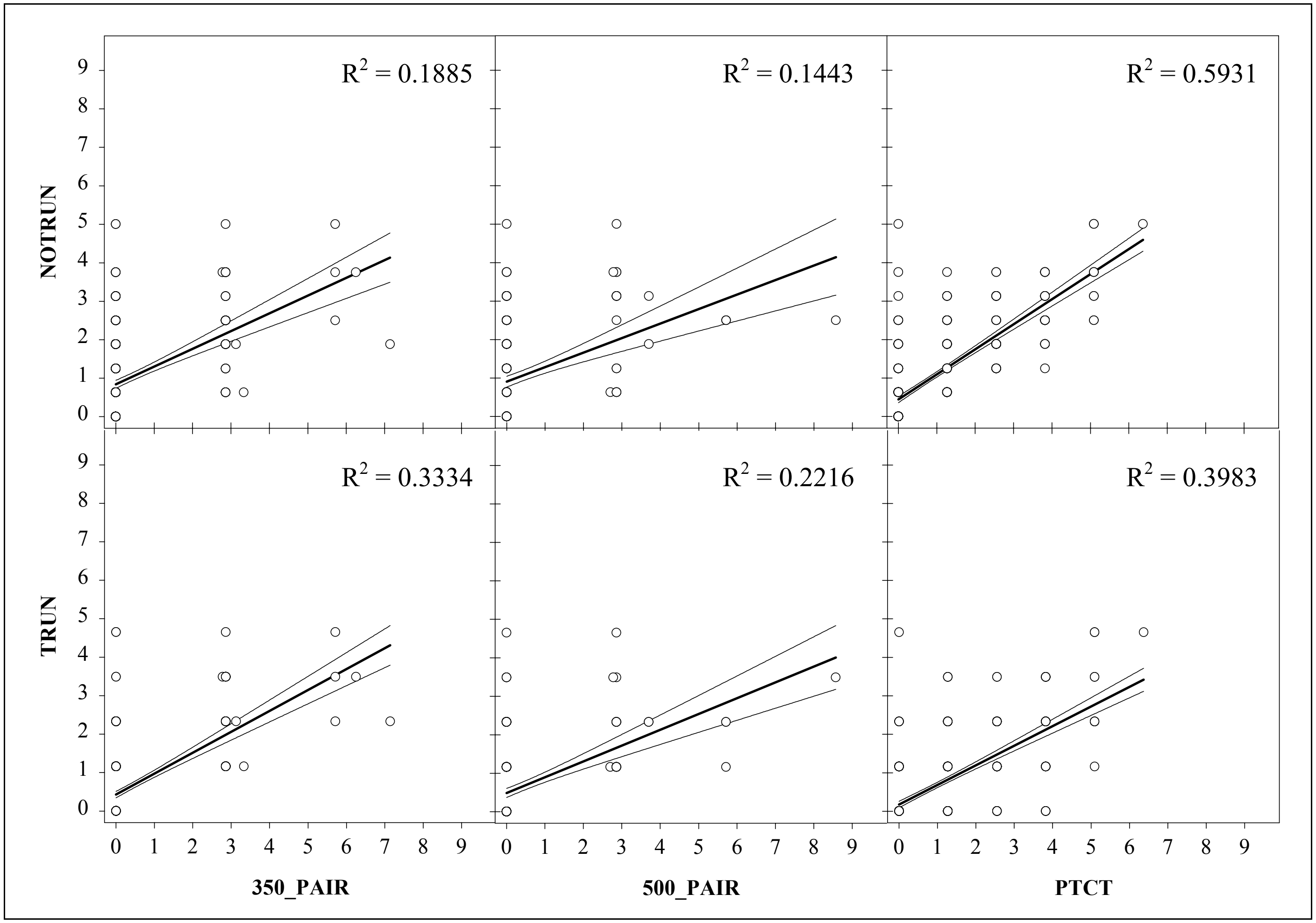

Figure 2.13. Relationship (±95% prediction interval) between northern bobwhite covey density (km^2) estimates from the TRUN and NOTRUN full-observer quadrat covey-call-counts and each of the reduced-observer quadrat covey-call-count subsamples. Analyses included all BQI regions and both treatment and control sites in Georgia, 1999-2000.

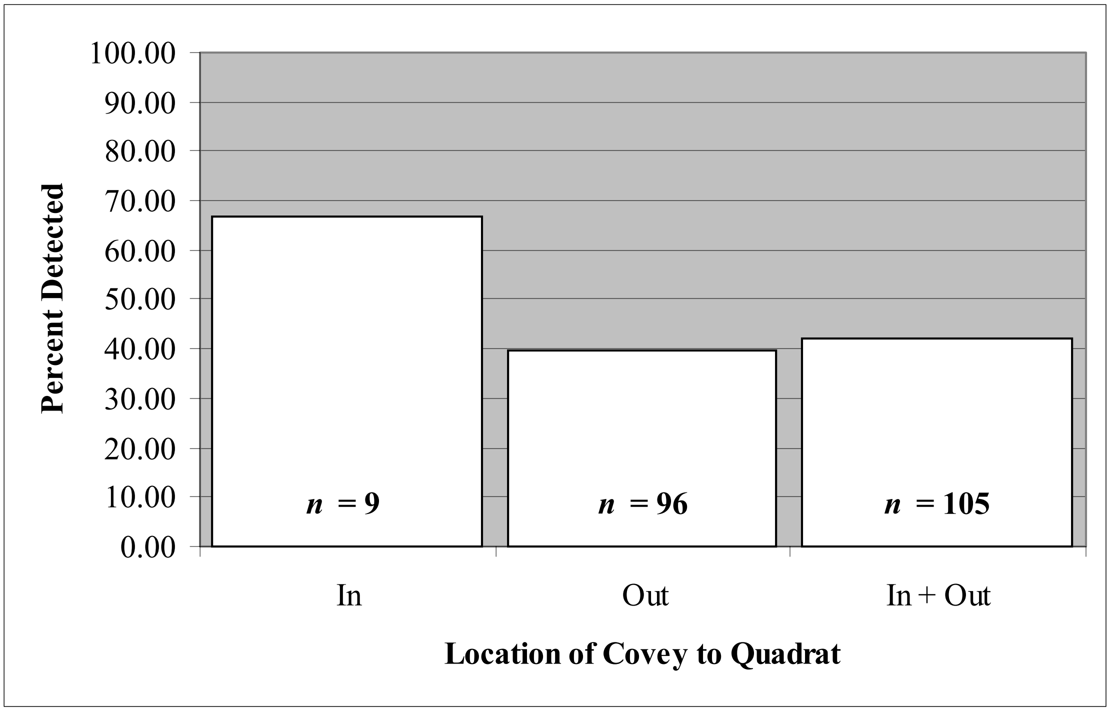

Figure 2.14. Percentage of total number of northern bobwhite coveys detected (*n*) inside of the quadrat, outside of the quadrat, and inside and outside of the quadrat combined, by an observer positioned in the middle of quadrats during 1999 quadrat covey-call-count surveys (see Figure 2.1). Quadrat surveys were used at samples of treatment and control sites in all BQI focus areas in Georgia.

CHAPTER 3

COMPARISON OF NORTHERN BOBWHITE POPULATION TRENDS BEFORE AND AFTER FARMLAND HABITAT MANAGEMENT

INTRODUCTION

In 1999, the Bobwhite Quail Initiative (BQI) program was created in Georgia to develop early successional habitat associated with row crop agriculture for the declining northern bobwhite (*Colinus virginianus*) (hereafter, bobwhite). With the development of the BQI program, a plan was needed to monitor bobwhite population response to BQI habitat management. To evaluate long-term bobwhite population trends at BQI and non-BQI sites over time, covey-call-count indices could be used effectively (provided that indices did not vary spatially or temporally). Although some of the assumptions associated with call-count indices remain untested, several of the most critical assumptions have been evaluated.

Call-count Index Assumptions

Several researchers have estimated covey-calling rates with radio-tagged bobwhite in order to correct population estimates for the proportion of coveys that do not call on a given morning. Wellendorf et al. (2002*b*) reported an overall covey-calling rate of 58% from several sites in North Carolina, Florida, and Tennessee. In Mississippi, Smith (2001) also found overall calling rates of 58%. A study in Missouri found an overall covey-calling rate of 79.5% (Seiler et al. 2002). I only reported overall average estimates from these studies, however the authors presented call rates for time intervals throughout autumn. These investigations into the proportion of coveys calling over space, time, and varying weather conditions and population densities address important assumptions associated with the covey-call-count index. I was not able to estimate covey-calling rates in my study area.

An observer's ability to detect a species may vary by a number of factors, and observer detection rates need to be estimated in order to make index count statistics useful population estimators. Assumptions about observer detection rates have been addressed by development of new techniques to estimate bird populations from call-count indices (Nichols et al. 2000, Thompson 2002). I evaluated whether observer detection rates of calling-coveys differed during multiple, independent observer covey-call-count surveys in 1999 and 2000. My approach was similar to a hypothetical approach suggested by Thompson (2002). I had no reason to assume that detection rates varied significantly by habitat, since all sites surveyed were relatively open, agricultural habitats. Topography across regional survey sites did not vary substantially (however, modeling topographic effects may be worth investigating in future studies). Habitat management practices were not intensive enough to result in high population density differences among years and sites, thus population density should not have affected covey-call rates or observer detection rates.

A final detection issue associated with call-count indices is miscounting the target species due to misidentification or repetitive counting of the same individuals or groups. Utilizing experienced observers, rigorous observer training, or using multiple, dependent observers (where at least one observer is experienced) are likely good ways to reduce bias associated with these miscounting issues. I was not able to evaluate this issue with my data. However, I do not believe that it was a major source of bias since only bobwhite covey-calls were being recorded (and covey-calls are fairly distinctive). Thus, it was assumed that all calling coveys counted were correctly identified.

The objectives of this research were to evaluate changes in numbers of bobwhite coveys at sample BQI (habitat management) and non-BQI (no habitat management) sites. More specifically, a model-based approach to estimate the effects of BQI habitat management on bobwhite population trends was used. The overall goal of this research was to obtain preliminary estimates of bobwhite population trends for long-term evaluation and modification (if necessary) of BQI management practices.

STUDY AREA

The BQI program was initiated with three focus areas that included 17 counties in the Upper Coastal Plain of Georgia. The three focus areas were composed of East (Bulloch, Burke, Jenkins, and Screven Counties), Central (Bleckley, Dodge, Emanuel, Houston, Laurens, and Truetlen Counties), and Southwest Regions (Colquitt, Crisp, Dougherty, Lee, Mitchell, Sumter, and Terrell Counties). This research was conducted on sites in all counties except Colquitt, Crisp, Houston, and Mitchell Counties.

Major land uses in all three regions consisted of intensive row crop agriculture and timber/fiber production. Agricultural row crop production was dominated by cotton, peanuts, soybeans, corn, and winter wheat. Row crop fields in the study area tended to be large in size and had little or inadequate transition zones capable of providing suitable bobwhite habitat. For example, historically fencerows or hedgerows that were once composed mainly of scattered trees and shrubs with an abundance of grassy and weedy understory separated two or more fields. Today, the vegetative structure of these transition zones have grown to become unsuitable bobwhite habitat or have been eliminated altogether to create one contiguous crop field out of two or more smaller fields. Forest production in the study area was dominated by plantations of loblolly pine (*Pinus taeda*) and slash pine (*Pinus elliotti*), although longleaf pine (*Pinus palustris*) plantings were increasing in all regions. The majority of pine stands in the study area did not have basal area or understory vegetation characteristics that constituted suitable bobwhite habitat.

METHODS

Covey-call-count indices were used to evaluate bobwhite populations at the field-level on sample BQI and non-BQI sites, but the overall monitoring program was conducted over a broad regional scale (13 of 17 potential counties). During covey-call-counts, observers listen for the "koi-lee" covey-calls (Stoddard 1931) given by bobwhite (almost always before sunrise) during autumn. Before conducting call-count surveys, 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.

Covey-call-count surveys were conducted from mid-October to mid-December on a sample of fields enrolled in the BQI program from 1999 to 2001. Fields that were enrolled in the BQI program were considered treatments while fields that were not managed for bobwhite habitat were monitored as controls (the majority of control fields were managed by non-BQI affiliated cooperators). At least 500 meters separated treatment and control fields to reduce the chance of detecting calling coveys in the vicinity of treatment fields while conducting control surveys. Also, at least 500 meters separated each survey point to minimize duplicate observations between surveys conducted in the same area. Survey points were set up at least one day in advance of the survey to ensure that observers could locate points the morning of the survey. Observers were instructed to minimize disturbance when traveling to survey points on the morning of the survey. Surveys were not conducted during periods of sustained rainfall.

Covey-call-count techniques

Quadrat Surveys.--The quadrat technique utilizes a 0.25 square kilometer (25 hectares, 500 x 500 meter) quadrat to survey calling coveys. A total of four observers are required, with one observer positioned along the midpoint of each quadrat line (Figure 3.1). These surveys were primarily used to estimate observer detection rates of calling-coveys and test and develop alternative call-count techniques, but quadrat survey results were also used to evaluate population responses to habitat management.

Observers were instructed to arrive at survey points at least 45 minutes before sunrise, and surveys officially began 40 minutes before sunrise. Observers recorded compass bearings, estimated distances, and approximate locations for each calling covey detected on standardized data sheets and field maps. Once the first call was detected, calling coveys were recorded for a 10-minute interval in order to minimize duplicate observations (as coveys often begin to move and initiate their daily activities soon after calling) and to standardize survey methods. Once the survey period expired, observers met to compare results in order to determine individual covey locations. Each unique covey location was plotted on a final field map. For each covey that was detected by more than one observer, the intersection of compass bearings to the covey was used to plot the approximate location. If only one observer detected a particular covey, the estimated distance to the covey along the compass bearing was used to plot the approximate location. Surveys were ended at the official time of sunrise if no calls were detected by this time.

Point Count Surveys.--In addition to the quadrat technique, point counts (single-observer call-counts), were used to survey bobwhite populations on remaining sample sites in 1999 and 2000, and all sample sites in 2001. It was assumed that an observer could hear calling coveys at a distance of up to 500 meters (W. E. Palmer, Tall Timbers Research Station, personal communication). A single observer was positioned where as much of the area of interest as possible was covered by the assumed maximum hearing distance (Figure 3.2). Survey protocol for point counts was the same as for quadrat surveys (except the estimated distance along the compass bearing to each calling covey detected was used to plot approximate covey locations).

Two-observer Surveys.--In 2000, a few two-observer call-count surveys were used in addition to quadrats and point counts. However, these made up a very small portion (about 13%) of the total number of call-count surveys conducted in 2000. Going into the 2000 field season, it was assumed that the 350-meter two-observer design would be a reasonably quantitative and less labor-intensive survey method compared to the quadrat method. Time constraints prohibited employment of many such surveys, and this technique was discontinued by 2001. Observers were spaced approximately 350 meters apart (Figure 3.3). Survey protocol for two-observer surveys was the same as for quadrat surveys.

Observer Detection Rates.--For survey points that utilized quadrats, the number of unique coveys detected by all four observers along the quadrat sides was used as the total number of coveys detected for the particular survey point. For survey points that utilized two-observer counts, the number of unique coveys detected by both observers was used as the total number of coveys detected for the particular survey point. Observer detection rates (more detail is given in Chapter 2) were estimated from Program MARK (White and Burnham 1999). I set up quadrat survey data in a capture-recapture matrix form in order to estimate the probability of detecting a covey if only one observer had been present, rather than all observers on the quadrat. Individual "capture histories" like those used with typical capture-recapture methods (Williams et al. 2002) were developed for each covey detected in quadrat surveys. Each observer (five in 1999 and four in 2000) was treated as a unique capture occasion. The capture history matrix was created by assigning a "1" if the observer detected the covey or a "0" if the observer did not detect the covey (each column represented a unique observer and each row represented a unique covey).

In each year a unique set of observers conducted surveys in the East BQI focus area, while another unique set of observers conducted surveys in the Central and Southwest BQI focus areas. Thus, four different observer groups were formed. In Program MARK, the following four observer groups were defined: 1999 Central and Southwest, 1999 East, 2000 Central and Southwest, 2000 East. I ran predefined models in Program MARK, treating the data as captures from a fully closed population with both heterogeneity (assuming each covey had a unique capture probability which remained constant over observers) and no heterogeneity (assuming each covey had a constant capture probability) (Lancia et al. 1994). Program MARK produced estimates of capture probability ($\hat{p}$) for each observer-group. Estimates obtained from Program MARK suggested that both observers and observer-groups had relatively equal $\hat{p}$ (see Chapter 2 for estimates). No estimates of observer detection rates were made in 2001, so it was assumed that observer detection rates were also relatively constant in 2001.

Treatment Comparison Analyses

Two replicate counts (a minimum of five days apart) were made at most sample points within a season, however, the count with the greater number of coveys detected was used in final analyses. Maximum replicate count values were used because there were not enough replicate counts to derive a mean value for each sample point. Survey points comprised of fields enrolled in BQI for one or more growing seasons were considered treatments. Any survey points comprised entirely of fields not under active quail habitat management at the time of survey were considered controls.

Due to variable BQI cooperator participation, some survey points were lost between sample years (e.g. cooperator decided not to enroll some or all fields in BQI and access to property restricted). There were a number of cooperators that entered late in the first year of BQI enrollment, after call-count surveys were ended. Thus, there were numerous treatment surveys conducted in 2000 that lacked pre-treatment data. During fall 2000, practically all fields enrolled in BQI for one growing season (spring and summer 2000) and a small number of fields proposed for BQI enrollment (pre-treatments) were monitored with call-counts. Additional control fields were also surveyed in 2000. In all comparisons, I evaluated differences in numbers of coveys detected by year and treatment category.

Rather than relying on arbitrary significance tests, an information-theoretic approach was used to estimate relevant effects and develop point estimates with associated measures of precision. A good discussion of the information-theoretic approaches can be found in detail in Burnham and Anderson (1998) and more briefly in Anderson et al. (2000). The best approximating model in a set of *a priori* candidate models is determined by model fit given the data. Model fit is determined by a value called AIC (or one of its derivatives AICc, QAIC, or QAICc). The general equation for AIC is,

$$\text{AIC} = -2\log_e(\ell(\hat{\theta} \mid \textit{data})) + 2K,$$

where $\log_e(\ell(\hat{\theta} \mid \textit{data})$ is the maximized log-likelihood over estimated parameters (θ) given a particular data set and model, and K is the number of parameters in the given model (Burnham and Anderson 1998, Anderson et al. 2000). AICc is a derivative of AIC, which includes an additional term added to the above equation when the number of model parameters is large relative to sample size ($n / K < 40$). QAIC and QAICc are derivatives of AIC, where a variance inflation or overdispersion factor, estimated from the global model, is incorporated into the AIC or AICc equations (Burnham and Anderson 1998). An AIC value (or one of its derivatives) is computed for each model, and the model with the lowest AIC value is considered to be the best approximating model.

After AIC values are computed, a set of candidate models can be ranked from best to poorest approximating model by,

$$\Delta\text{AIC}_i = \text{AIC}_i - \text{minAIC},$$

where AIC_i is the AIC value of model i and minAIC is the lowest AIC value in the set of candidate models. Furthermore, model likelihoods given the data are computed by $\exp[-0.5(\Delta\text{AIC}_i)]$. Model weights ($w_i$) are computed by dividing the particular model likelihood by the sum of all model likelihoods. These model weights are a measure of weight of evidence that a given model is the best model in the set of candidate models (Anderson et al. 2000). To account for model uncertainty, parameter estimates (and variance) can be averaged over all candidate models that include the parameter of interest.

Poisson regression was used (since count data typically follow this distribution) to estimate treatment (TRT), year (YEAR), survey method (SURV), bi-week (BIWK), and relative interaction effects on numbers of calling bobwhite coveys detected at treatment and control sites. TRT, YEAR, and SURV were considered class variables, where levels of: TRT were "T" (treatment) and "C" (control), YEAR were "1999", "2000", and "2001" (dependent on years used in analysis), and SURV were "P" (point count), "Q" (quadrat), and "T" (two-observer). BIWK was considered as a continuous effect variable, with levels of 1, 2, 3, 4, or 5, dependent on which two-week interval that a survey was conducted in (see Table 3.1 for date intervals corresponding to bi-week level). Effects were estimated by contrasts between means. A set of eight candidate models was developed to obtain maximum likelihood estimates (MLE's) of these effects. The same models were used to obtain MLE's of covey numbers at treatment and control sites during each survey year. I used the PROC GENMOD procedure of SAS® software[a] with a Poisson distribution and log link function to perform these analyses. A SAS macro (J. T. Peterson, University of Georgia, personal communication) was used to compute QAICc values from model likelihoods in which to evaluate candidate models.

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The macro also computed model-averaged estimates of effect sizes and their unconditional standard errors (to account for model selection uncertainty).

The same eight models were used for comparisons with four different data sets. Effects variables used in each of the eight models can be found in Table 3.2, 3.5, 3.8, or 3.11. Since a log link function was used, model-averaged MLE's of covey numbers were on a natural log (ln) scale, and for reporting purposes means and 95% confidence interval (CI) endpoints were back-transformed by taking the antilogarithm (e^x) of the estimate. The 95% CI was asymmetrical after back-transformation. The first comparison was made between treatment and control (some pre-treatment BQI fields were considered controls for within year comparisons of 2000 data) sites surveyed in 2000 and 2001. The next three comparisons were repeated measures between yearly replicated treatment and control survey sites from 1999-2001 (one data set) and 2000-2001 (two data sets). For the 1999-2001 repeated measures data set, all sites were pre-treatment in 1999, and all treatment sites were one- and two-year post-treatment in 2000 and 2001, respectively. For the 2000-2001 repeated measures data sets, one data set included only treatment sites that had practiced bobwhite habitat management for two years at year 2001 (2POST). The other data set included treatment sites that had practiced bobwhite habitat management for both one and two years at year 2001 (1-2POST) by adding one-year post-management survey data to the previous data set and considering these as a single treatment class. The same control surveys were used in both of these data sets. Baseline data was not available for the 2000-2001 repeated measures analyses.

RESULTS

Estimates of Effects

Models of effects and their selection criteria can be found in Tables 3.2, 3.5, 3.8, and 3.11 for the 2000 and 2001 treatment and control, 1999-2001 repeated measures, 2000-2001 repeated measures 2POST, and 2000-2001 repeated measures 1&2POST comparisons, respectively. Based on model weights, TRT effects appeared to have the greatest influence on numbers of calling coveys detected in all analyses. However, model weights indicated that two TRT effect models that included YEAR and YEAR*TRT effects and YEAR, YEAR*TRT, and BIWK effects were also equally plausible models in all analyses except the 1999-2001 repeated measures analysis. Only TRT effects appeared to explain differences in numbers of calling coveys detected in the 1999-2001 repeated measures surveys. There were no apparent SURV effects on numbers of coveys detected by quadrat, point count, or two-observer call-count survey methods in any of the analyses. Parameter estimates of effect size are summarized in Tables 3.3, 3.6, 3.9, and 3.12 for the 2000 and 2001 treatment and control, 1999-2001 repeated measures, 2000-2001 repeated measures 2POST, and 2000-2001 repeated measures 1-2POST comparisons, respectively.

General Treatment by Year Comparisons

The mean number of coveys (95% CI endpoints) from 2000 treatment surveys (n = 50) was 1.1979 (0.9635, 1.4892) and 2000 control surveys (n = 76) was 1.1289 (0.9544, 1.3353) (Figure 3.4). The mean number of coveys from 2001 treatment surveys (n = 52) was 1.3009 (0.9889, 1.7113) and 2001 control surveys (n = 43) was 1.0996

(0.9117, 1.3262) (Figure 3.4). The ln scale and back-transformed MLE's of covey numbers are summarized in Table 3.4.

Repeated Measures Treatment by Year Comparisons

For repeated comparisons among treatment (n = 20) and control (n = 8) sites monitored across years 1999-2001, the mean number of coveys from 1999 treatment surveys was 1.0603 (0.9233, 1.2175) and 1999 control surveys was 1.1085 (0.9326, 1.3176) (Figure 3.5). The mean number of coveys detected in 2000 treatment surveys was 1.0880 (0.9328, 1.2690) and 2000 control surveys was 1.0389 (0.8785, 1.2285) (Figure 3.5). The mean number of coveys detected in 2001 treatment surveys was 1.0959 (0.9325, 1.2879) and 2001 control surveys was 0.8816 (0.6636, 1.1711) (Figure 3.5). The ln scale and back-transformed MLE's of covey numbers are summarized in Table 3.7.

For 2POST repeated comparisons among treatment (n = 43) and control (n = 42) sites monitored across years 2000-2001, the mean number of coveys detected in 2000 treatment surveys was 1.2588 (0.9656, 1.6411) and 2000 control surveys was 1.2089 (0.9314, 1.5692) (Figure 3.6). The mean number of coveys detected in 2001 treatment surveys was 1.3245 (0.9934, 1.7660) and 2001 control surveys was 1.1345 (0.8656, 1.4871) (Figure 3.6). The ln scale and back-transformed MLE's of covey numbers are summarized in Table 3.10.

For 1-2POST repeated comparisons among treatment (n = 51) and control (n = 42) sites monitored across years 2000-2001, the mean number of coveys detected in 2000 treatment surveys was 1.2855 (0.7955, 2.0772) and 2000 control surveys was 1.2069 (0.7383, 1.9730) (Figure 3.7). The mean number of coveys detected in 2001 treatment surveys was 1.3859 (0.8499, 2.2598) and 2001 control surveys was 1.1304 (0.6721, 1.9011) (Figure 3.7). The ln scale and back-transformed MLE's of covey numbers are summarized in Table 3.13.

DISCUSSION

Since detection rates estimated from Program MARK suggested that there was little difference among observers and observer-groups, it was assumed that detection rates were constant across years and sites (and thus were not included as effects in comparative models). I did not assess observer detection rates in 2001, although evaluation is planned for future monitoring with methods similar to those described by Nichols et al. (2000). The constant detection assumption was extended to 2001 surveys. I was unable to estimate covey-calling rates in my study area. However, other researchers have estimated these rates (Smith 2001, Wellendorf et al. 2002*b*, Seiler et al. 2002) and suggest that calling rates are relatively high throughout October to mid-November. The BIWK variable in models that I used to estimate covey numbers was incorporated to address temporal call variation throughout the covey-calling season.

Post-treatment survey areas had greater mean covey numbers compared to control survey areas. Few other studies have evaluated fall bobwhite populations in moderately managed farmland habitats. Bromley et al. (2002) reported greater numbers of coveys detected in fall call-count surveys on sites with field borders compared to sites without field borders in North Carolina farmland. It appears that the types of early successional habitats produced by BQI management have positively affected bobwhite populations. However, the mechanisms contributing to these increases, if any, are still largely unknown. Most fields enrolled in BQI likely provide good nesting and brooding habitat, but may only provide marginal fall and winter habitat. Some coveys may be selecting alternative habitats during fall and winter (Wellendorf et al. 2002*a*). In a study using pen-raised bobwhite, Oakley et al. (2002) reported lower fall survival on farms with buffer strips than farms without buffer strips. The survivability of pen-raised bobwhites in the wild is known to be poor, but such results suggest that more information is needed on the value of herbaceous, linear strip-cover as winter habitat for wild bobwhite. It is unclear whether the apparent increases in covey numbers in my study resulted from increased production and recruitment of new individuals, or whether coveys were moving to BQI habitats during fall and winter. Conversely, it is possible that reproduction was significantly improved on many BQI sites, but if there were high rates of fall dispersal, I may have underestimated fall covey numbers. Despite having little information on bobwhite population parameters in the study area, the apparently increasing trend in covey numbers at treatment sites was encouraging. Depending on which of the four analyses was considered, there were 1% to 9% increases in covey numbers at BQI sites and 3% to 15% declines in covey numbers at non-BQI sites from years 2000-2001. More research is needed to quantify the mechanisms that are causing these apparent population changes in order to update management strategies, if necessary and possible, to address barriers to population productivity.

The current spatial scale of BQI habitat management units (the program has relatively few spatial restrictions) has posed somewhat of a challenge to bobwhite population monitoring efforts. To enroll fields in BQI, a cooperator must have at least 20 contiguous hectares of property, and crop fields proposed for enrollment must be at least 4 hectares in size. There is no minimum number of fields that a cooperator must enter into BQI (a BQI management unit may only consist of a single field), but there are maximum monetary incentive payments that a cooperator may receive. Adjacent habitat is almost certainly an important factor affecting bobwhite covey distribution around any given crop field. Currently, BQI habitat management is only required at the field level, though there are cost-share and bonus scoring (to meet eligibility requirements) incentives for adjacent habitat management (e.g. prescribed burning of open-canopy pine stands). Some BQI fields are, to an extent, isolated by adjacent habitats. Currently, even most of the largest managed field complexes (multiple BQI managed fields that have transition zones that allow bobwhite to move efficiently between managed units) are still relatively small-scale management units in the typical context of bobwhite management. The magnitude of bobwhite population changes is probably influenced to a large degree by the scale of BQI management units and adjacent habitat. With the information gained from this pilot study, more comprehensive investigation of bobwhite population response to BQI habitat management is planned for the future.

CONCLUSIONS

Additional aspects of bobwhite population dynamics, in addition to abundance, in these farmland systems need to be assessed. Current and future studies will provide more insight into the mechanisms that are affecting bobwhite populations in farmland habitats of the Upper Coastal Plain of Georgia. The BQI program is still developing, and it is hoped that over time newly enrolling cooperators will increase the area of existing management units on a scale that will significantly increase localized bobwhite populations. Even though BQI field-level habitat management has created relatively small-scale habitat changes, there appear to be some positive benefits to localized bobwhite populations. Long-term population monitoring is planned to continue for the duration of the BQI program. With ongoing abundance monitoring and forthcoming research investigating bobwhite population productivity parameters in these farmland systems, more comprehensive models of bobwhite population dynamics can be developed and tested for making management decisions.

Evaluating bobwhite population responses to moderate intensity habitat management, such as BQI, is not easy. These often fragmented habitats and low population densities result in high variation and limited sample sizes. However, such moderate intensity habitat management is often the only feasible means to increase bobwhite habitat on the majority of private lands. Most private landowners cannot afford to intensively manage for bobwhite, or cannot or will not sacrifice land used for agricultural or forestry production. In much of the Southeast, if any serious, broad-scale bobwhite (or other early successional wildlife) population increases are going to be incurred, they will likely be the result of programs like BQI, whose ultimate goal is to develop moderate-intensity habitat management units on private land. However, these programs must impact enough of these management units across the landscape in order to be effective. Thus, it is imperative that quality research be conducted in these more realistic settings to determine mechanisms that positively and negatively affect bobwhite populations in these systems.

LITERATURE CITED

_____, K. P. Burnham, and W. L. Thompson. 2000. Null hypothesis testing: problems, prevalence, and an alternative. Journal of Wildlife Management 64:912-923.

Bromley, P. T., S. D. Wellendorf, W. E. Palmer, and J. F. Marcus. 2002. Effects of field borders and mesomammal reduction on northern bobwhite and songbird abundance on three farms in North Carolina. National Bobwhite Quail Symposium Proceedings 5:71 (*Abstract*).

Burnham, K. P. and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer, New York, New York, USA.

Lancia, R. A., J. D. Nichols, and K. H. Pollock. 1994. Estimating the number of animals in wildlife populations. Pages 215-253 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. Fifth Edition. The Wildlife Society, Bethesda, Maryland, USA.

Nichols, J. D., J. E. Hines, J. R. Sauer, F. W. Fallon, J. E. Fallon, and P. J. Heglund. 2000. A double-observer approach for estimating detection probability and abundance from point counts. Auk 117:393-408.

Oakley, M. J., D. L. Bounds, T. A. Mollett, and E. C. Soutiere. 2002. Survival and home range estimates of pen-raised northern bobwhites in buffer strip and non-buffer strip habitats. National Bobwhite Quail Symposium Proceedings 5:74-80.

Seiler, T. P., R. D. Drobney, and T. V. Dailey. 2002. Use of weather variables for predicting fall covey calling rates of northern bobwhites. National Bobwhite Quail Symposium Proceedings 5:91-98.

Smith, M. D. 2001. Response of northern bobwhite to intensive habitat development on a prairie site in Mississippi. Thesis, Mississippi State University, Mississippi State, Mississippi, USA.

Stoddard, H. L. 1931. The bobwhite quail, its habits, preservation, and increase. Charles Scribner's Sons. New York, New York, USA.

Thompson, W. L. 2002. Towards reliable bird surveys: accounting for individuals present but not detected. Auk 119:18-25.

Wellendorf, S. D., W. E. Palmer, and P. T. Bromley. 2002*a*. Habitat selection of northern bobwhite coveys on two intensive agricultural landscapes in eastern North Carolina. National Bobwhite Quail Symposium Proceedings 5:191 (*Abstract*).

_____, _____, and _____. 2002*b*. Estimating calling rates of northern bobwhite coveys and censusing populations. Journal of Wildlife Management *In Press*.

White, G.C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Supplement, 120-138.

Williams, B. K., J. D. Nichols, and M. J. Conroy. 2002. Analysis and management of animal populations. Academic Press. San Diego, California, USA.

Table 3.1. Date intervals corresponding to the level of bi-week variable over which northern bobwhite covey-call-count surveys were conducted for all sites and BQI focus areas in Georgia, 1999-2001.

Year	Bi-Week Level	Bi-Week Date Interval
1999	1	10/10/99-10/23/99
1999	2	10/24/99-11/6/99
1999	3	11/7/99-11/20/99
1999	4	11/21/99-12/4/99
1999	5	12/5/99-12/18/99
2000	1	10/8/00-10/21/00
2000	2	10/22/00-11/4/00
2000	3	11/5/00-11/18/00
2000	4	11/19/00-12/2/00
2000	5	12/3/00-12/16/00
2001	1	10/7/01-10/20/01
2001	2	10/21/01-11/3/01
2001	3	11/4/01-11/17/01
2001	4	11/18/01-12/1/01
2001	5	12/2/01-12/15/01

Table 3.2. Models and associated selection criteria (lowest QAICc value indicates best approximating model) used to estimate numbers of northern bobwhite coveys from covey-call-count surveys conducted at treatment (one and two-year post-treatment sites at year 2001, pooled) and control sites for all BQI focus areas in Georgia, 2000-2001.

Model[a]	**QAICc**[b]	**ΔQAICc**	**Model Weight**	***K***[c]	**df**
INT + TRT	204.4450	0.0000	0.4751	4	219
INT + TRT + YEAR + YEAR*TRT	205.9340	1.4887	0.2257	10	217
INT + TRT + YEAR + YEAR*TRT + BIWEEK	207.1410	2.6953	0.1235	11	216
INT + TRT + YEAR + YEAR*TRT + BIWEEK + BIWEEK*TRT	208.0460	3.6009	0.0785	13	215
INT + TRT + YEAR + YEAR*TRT + BIWEEK + BIWEEK*YEAR	208.3350	3.8895	0.0680	13	215
INT + TRT + YEAR + YEAR*TRT + SURVEY	211.3060	6.8607	0.0154	13	215
INT + TRT + YEAR + YEAR*TRT + SURVEY + BIWEEK	212.1930	7.7472	0.0099	14	214
INT + TRT + YEAR + SURV + BIWK + YEAR*BIWK + YEAR*TRT + TRT*BIWK	214.0150	9.5699	0.0040	18	212

[a] INT = intercept, TRT = treatment effects, YEAR = year effects, SURV = call-count survey method effects, BIWK = bi-week effects (two-week time intervals during survey months), * indicates interaction.
[b] QAICc incorporates an estimated variance inflation factor, $\hat{c}$, into the AICc value ($\hat{c} = 1.29$).
[c] Number of parameters.

Table 3.3. Model-averaged estimates and unconditional standard errors and confidence intervals (estimates are on natural log scale) of effects on numbers of calling northern bobwhite coveys detected from covey-call-count surveys conducted at treatment (one and two-year post-treatment sites at year 2001, pooled) and control sites for all BQI focus areas in Georgia, 2000-2001 (see Table 3.2 for model descriptions).

Effect	Estimate	SE	±95% CI
Intercept	0.5287	0.1917	0.3757
Year	-0.0371	0.1533	0.3004
Treatment	-0.1346	0.1950	0.3823
Survey	-0.0639	0.4396	0.8616
Bi-week	-0.0744	0.0961	0.1884

Table 3.4. Model-averaged estimates (original units are on natural log scale) of northern bobwhite covey numbers at treatment (one and two-year post-treatment sites at year 2001, pooled) and control sites estimated from covey-call-count surveys conducted over all BQI focus areas in Georgia, 2000-2001.

							95% CI*	
Site	**Year**	***n***	**Mean**	**SE**	**±95% CI**	**Mean***	**Lower**	**Upper**
Control	2000	76	0.1212	0.0857	0.1679	1.1289	0.9544	1.3353
Treatment	2000	50	0.1805	0.1111	0.2177	1.1979	0.9635	1.4892
Control	2001	43	0.0950	0.0956	0.1874	1.0996	0.9117	1.3262
Treatment	2001	52	0.2630	0.1399	0.2742	1.3009	0.9889	1.7113

* Back-transformed means and 95% confidence interval endpoints (asymmetrical after back-transformation) by antilogarithm (e^x).

Table 3.5. Models and associated selection criteria (lowest QAICc value indicates best approximating model) used to estimate numbers of northern bobwhite coveys from repeated covey-call-count surveys conducted at treatment and control sites for all BQI focus areas in Georgia, 1999-2001.

Model[a]	QAICc[b]	ΔQAICc	Model Weight	K[c]	df
INT + TRT	88.5220	0.0000	0.8083	4	82
INT + TRT + YEAR + YEAR*TRT	93.0420	4.5198	0.0844	11	78
INT + TRT + YEAR + YEAR*TRT + BIWEEK	94.1340	5.6114	0.0489	12	77
INT + TRT + YEAR + YEAR*TRT + BIWEEK + BIWEEK*TRT	95.3670	6.8450	0.0264	14	76
INT + TRT + YEAR + YEAR*TRT + BIWEEK + BIWEEK*YEAR	96.5250	8.0026	0.0148	14	75
INT + TRT + YEAR + YEAR*TRT + SURVEY	97.1970	8.6741	0.0106	13	77
INT + TRT + YEAR + YEAR*TRT + SURVEY + BIWEEK	98.3730	9.8505	0.0059	14	76
INT + TRT + YEAR + SURV + BIWK + YEAR*BIWK + YEAR*TRT + TRT*BIWK	102.2500	13.7270	0.0008	18	73

[a] INT = intercept, TRT = treatment effects, YEAR = year effects, SURV = call-count survey method effects, BIWK = bi-week effects (two-week time intervals during survey months), * indicates interaction.
[b] QAICc incorporates an estimated variance inflation factor, $\hat{c}$, into the AICc value ($\hat{c}$ = 1.20).
[c] Number of parameters.

Table 3.6. Model-averaged estimates and unconditional standard errors and confidence intervals (estimates are on natural log scale) of effects on numbers of calling northern bobwhite coveys detected from repeated covey-call-count surveys conducted at treatment and control sites for all BQI focus areas in Georgia, 1999-2001 (see Table 3.5 for model descriptions).

Effect	Estimate	SE	±95% CI
Intercept	0.4252	0.1798	0.3523
Year	-0.0786	0.3042	0.5962
Treatment	-0.2139	0.3374	0.6612
Survey	-0.5287	0.5613	1.1001
Bi-week	-0.0218	0.1332	0.2612

Table 3.7. Model-averaged estimates (original units are on natural log scale) of northern bobwhite covey numbers at treatment and control sites estimated from repeated covey-call-count surveys conducted over all BQI focus areas in Georgia, 1999-2001.

		1999			2000			2001		
Site	***n***	**Mean**	**SE**	**±95% CI**	**Mean**	**SE**	**±95% CI**	**Mean**	**SE**	**±95% CI**
Control	8	0.1030	0.0882	0.1728	0.0381	0.0855	0.1677	-0.1260	0.1449	0.2840
Treatment	20	0.0585	0.0706	0.1383	0.0844	0.0785	0.1539	0.0916	0.0824	0.1615
			95% CI*			**95% CI***			**95% CI***	
		Mean*	**Lower**	**Upper**	**Mean***	**Lower**	**Upper**	**Mean***	**Lower**	**Upper**
Control	8	1.1085	0.9326	1.3176	1.0389	0.8785	1.2285	0.8816	0.6636	1.1711
Treatment	20	1.0603	0.9233	1.2175	1.0880	0.9328	1.2690	1.0959	0.9325	1.2879

* Back-transformed means and 95% confidence interval endpoints (asymmetrical after back-transformation) by antilogarithm (e^x).

Table 3.8. Models and associated selection criteria (lowest QAICc value indicates best approximating model) used to estimate numbers of northern bobwhite coveys from repeated covey-call-count surveys conducted at treatment (two-year post-treatment sites at year 2001, only) and control sites for all BQI focus areas in Georgia, 2000-2001.

Model[a]	**QAICc**[b]	**ΔQAICc**	**Model Weight**	***K***[c]	**df**
INT + TRT	147.7180	0.0000	0.4200	4	166
INT + TRT + YEAR + YEAR*TRT	149.1710	1.4529	0.2031	11	164
INT + TRT + YEAR + YEAR*TRT + BIWEEK	150.1190	2.4005	0.1265	12	163
INT + TRT + YEAR + YEAR*TRT + BIWEEK + BIWEEK*TRT	150.9010	3.1826	0.0855	14	162
INT + TRT + YEAR + YEAR*TRT + BIWEEK + BIWEEK*YEAR	151.0100	3.2919	0.0810	14	162
INT + TRT + YEAR + YEAR*TRT + SURVEY	152.2470	4.5291	0.0436	13	162
INT + TRT + YEAR + YEAR*TRT + SURVEY + BIWEEK	153.1120	5.3937	0.0283	14	161
INT + TRT + YEAR + SURV + BIWK + YEAR*BIWK + YEAR*TRT + TRT*BIWK	154.8360	7.1175	0.0120	18	159

[a] INT = intercept, TRT = treatment effects, YEAR = year effects, SURV = call-count survey method effects, BIWK = bi-week effects (two-week time intervals during survey months), * indicates interaction.
[b] QAICc incorporates an estimated variance inflation factor, $\hat{c}$, into the AICc value ($\hat{c}$ = 1.37).
[c] Number of parameters.

Table 3.9. Model-averaged estimates and unconditional standard errors and confidence intervals (estimates are on natural log scale) of effects on numbers of calling northern bobwhite coveys detected from repeated covey-call-count surveys conducted at treatment (two-year post-treatment sites at year 2001, only) and control sites for all BQI focus areas in Georgia, 2000-2001 (see Table 3.8 for model descriptions).

Effect	**Estimate**	**SE**	**±95% CI**
Intercept	0.5212	0.2371	0.4646
Year	-0.0163	0.1503	0.2946
Treatment	-0.1140	0.1862	0.3650
Survey	-0.1137	0.4331	0.8488
Bi-week	-0.0704	0.1031	0.2021

Table 3.10. Model-averaged estimates (original units are on natural log scale) of northern bobwhite covey numbers at treatment (two-year post-treatment sites at year 2001, only) and control sites estimated from repeated covey-call-count surveys conducted over all BQI focus areas in Georgia, 2000-2001.

		2000			2001		
Site	***n***	**Mean**	**SE**	**±95% CI**	**Mean**	**SE**	**±95% CI**
Control	42	0.1897	0.1331	0.2608	0.1262	0.1380	0.2706
Treatment	43	0.2302	0.1353	0.2652	0.2811	0.1468	0.2877
			95% CI*			**95% CI***	
		Mean*	**Lower**	**Upper**	**Mean***	**Lower**	**Upper**
Control	42	1.2089	0.9314	1.5692	1.1345	0.8656	1.4871
Treatment	43	1.2588	0.9656	1.6411	1.3245	0.9934	1.7660

* Back-transformed means and 95% confidence interval endpoints (asymmetrical after back-transformation) by antilogarithm (e^x).

Table 3.11. Models and associated selection criteria (lowest QAICc value indicates best approximating model) used to estimate numbers of northern bobwhite coveys from repeated covey-call-count surveys conducted at treatment (one- and two-year post-treatment sites at year 2001, pooled) and control sites for all BQI focus areas in Georgia, 2000-2001.

Model[a]	**QAICc**[b]	**ΔQAICc**	**Model Weight**	***K***[c]	**df**
INT + TRT	159.6470	0.0000	0.4328	4	180
INT + TRT + YEAR + YEAR*TRT	161.1910	1.5442	0.2000	11	178
INT + TRT + YEAR + YEAR*TRT + BIWEEK	162.0470	2.3994	0.1304	12	177
INT + TRT + YEAR + YEAR*TRT + BIWEEK + BIWEEK*TRT	162.8970	3.2499	0.0852	14	176
INT + TRT + YEAR + YEAR*TRT + BIWEEK + BIWEEK*YEAR	163.0070	3.3599	0.0807	14	176
INT + TRT + YEAR + YEAR*TRT + SURVEY	164.5600	4.9129	0.0371	13	176
INT + TRT + YEAR + YEAR*TRT + SURVEY + BIWEEK	165.4120	5.7650	0.0242	14	175
INT + TRT + YEAR + SURV + BIWK + YEAR*BIWK + YEAR*TRT + TRT*BIWK	167.2800	7.6331	0.0095	18	173

[a] INT = intercept, TRT = treatment effects, YEAR = year effects, SURV = call-count survey method effects, BIWK = bi-week effects (two-week time intervals during survey months), * indicates interaction.
[b] QAICc incorporates an estimated variance inflation factor, $\hat{c}$, into the AICc value ($\hat{c}$ = 1.33).
[c] Number of parameters.

Table 3.12. Model-averaged estimates and unconditional standard errors and confidence intervals (estimates are on natural log scale) of effects on numbers of calling northern bobwhite coveys detected from repeated covey-call-count surveys conducted at treatment (one- and two-year post-treatment sites at year 2001, pooled) and control sites for all BQI focus areas in Georgia, 2000-2001 (see Table 3.8 for model descriptions).

Effect	**Estimate**	**SE**	**±95% CI**
Intercept	0.5628	0.2151	0.4217
Year	-0.0331	0.1562	0.3062
Treatment	-0.1439	0.2062	0.4041
Survey	-0.1686	0.4618	0.9050
Bi-week	-0.0250	0.0924	0.1812

Table 3.13. Model-averaged estimates (original units are on natural log scale) of northern bobwhite covey numbers at treatment (one- and two-year post-treatment sites at year 2001, pooled) and control sites estimated from repeated covey-call-count surveys conducted over all BQI focus areas in Georgia, 2000-2001.

Site	***n***	**2000**			**2001**		
		Mean	**SE**	**±95% CI**	**Mean**	**SE**	**±95% CI**
Control	42	0.1880	0.1288	0.2525	0.1226	0.1348	0.2643
Treatment	51	0.2511	0.1380	0.2705	0.3263	0.1591	0.3119
			95% CI*			**95% CI***	
		Mean*	**Lower**	**Upper**	**Mean***	**Lower**	**Upper**
Control	42	1.2069	0.9376	1.5536	1.1304	0.8679	1.4723
Treatment	51	1.2855	0.9808	1.6849	1.3859	1.0146	1.8930

* Back-transformed means and 95% confidence interval endpoints (asymmetrical after back-transformation) by antilogarithm (e^x).

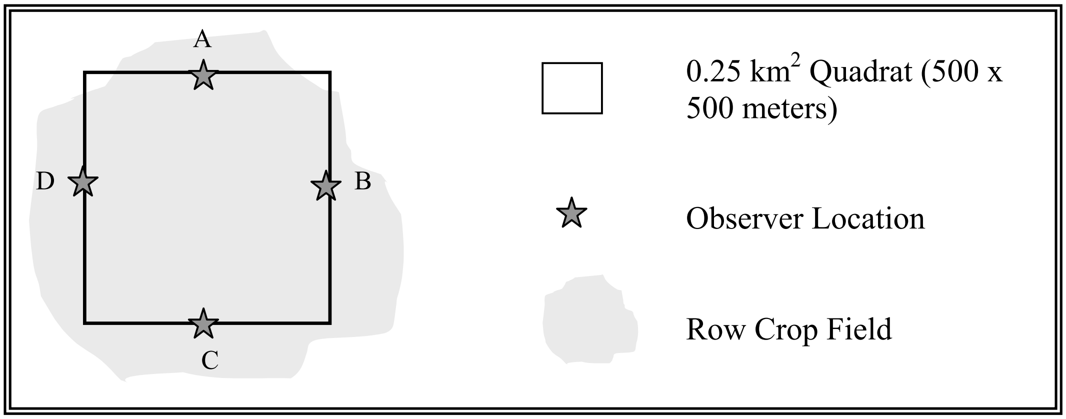

Figure 3.1. Example of the quadrat covey-call-count technique, utilizing four observers, used to survey calling northern bobwhite coveys at samples of treatment and control sites in all BQI focus areas in Georgia, 1999-2000.

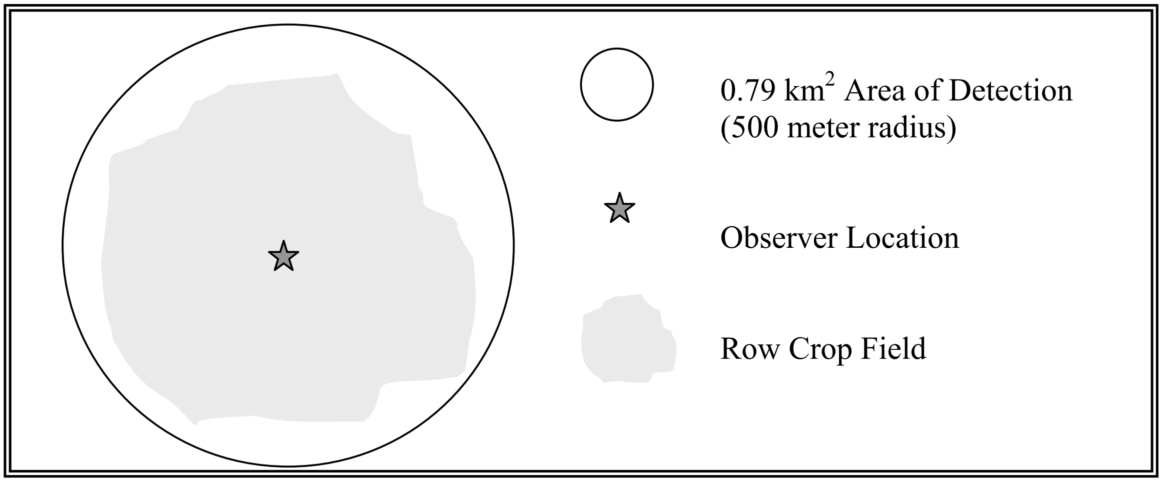

Figure 3.2. Example of the single-observer point count covey-call-count technique used to survey calling northern bobwhite coveys at samples of treatment and control sites in all BQI focus areas in Georgia, 1999-2001.

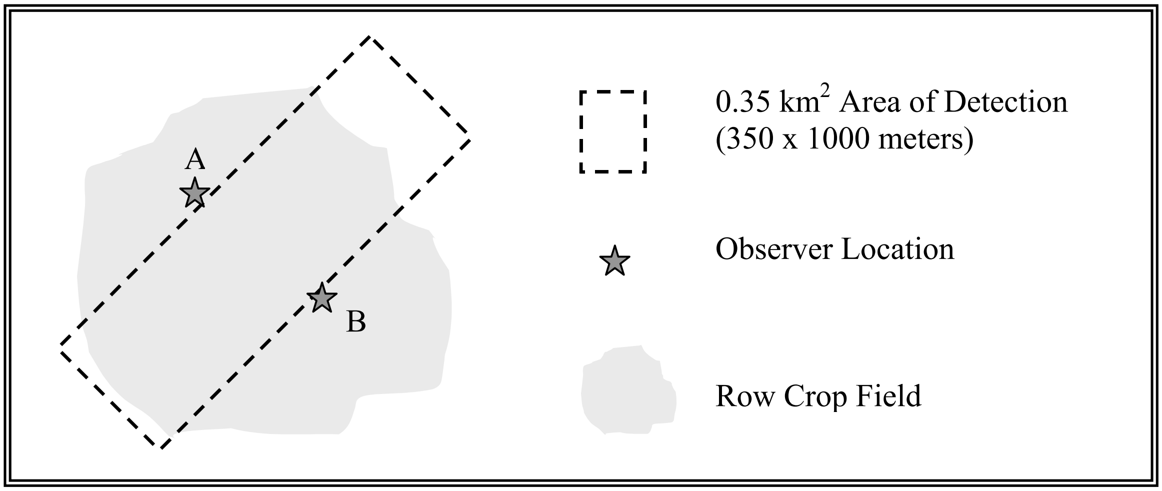

Figure 3.3. Example of the two-observer covey-call-count technique used to survey calling northern bobwhite coveys at samples of treatment and control sites in the BQI East and Central focus areas in Georgia, 2000.

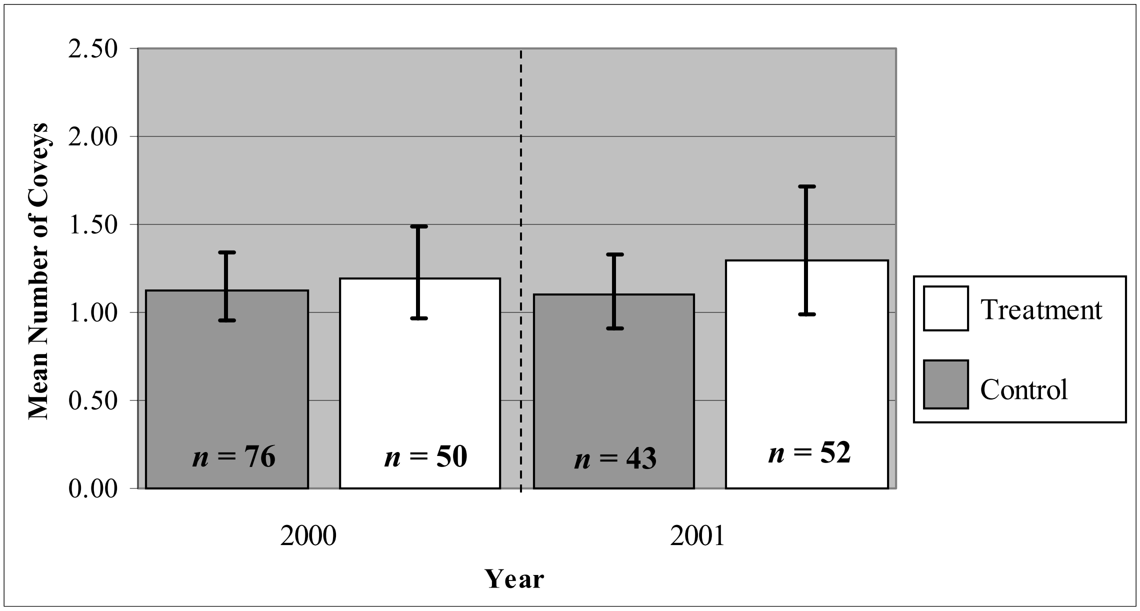

Figure 3.4. Model-averaged estimates of mean (±95% CI) northern bobwhite covey numbers at treatment (one and two-year post-treatment sites at year 2001, pooled) and control sites estimated from covey-call-count surveys conducted over all BQI focus areas in Georgia, 2000-2001.

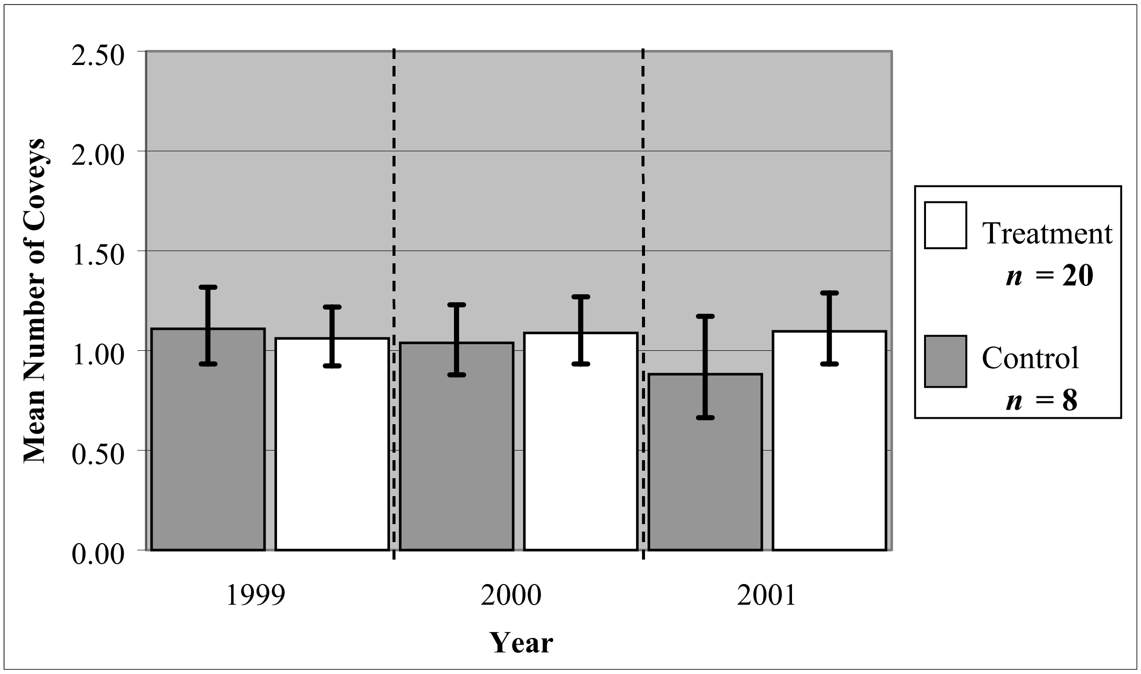

Figure 3.5. Model-averaged estimates of mean (±95% CI) northern bobwhite covey numbers at treatment and control sites estimated from repeated covey-call-count surveys conducted over all BQI focus areas in Georgia, 1999-2001.

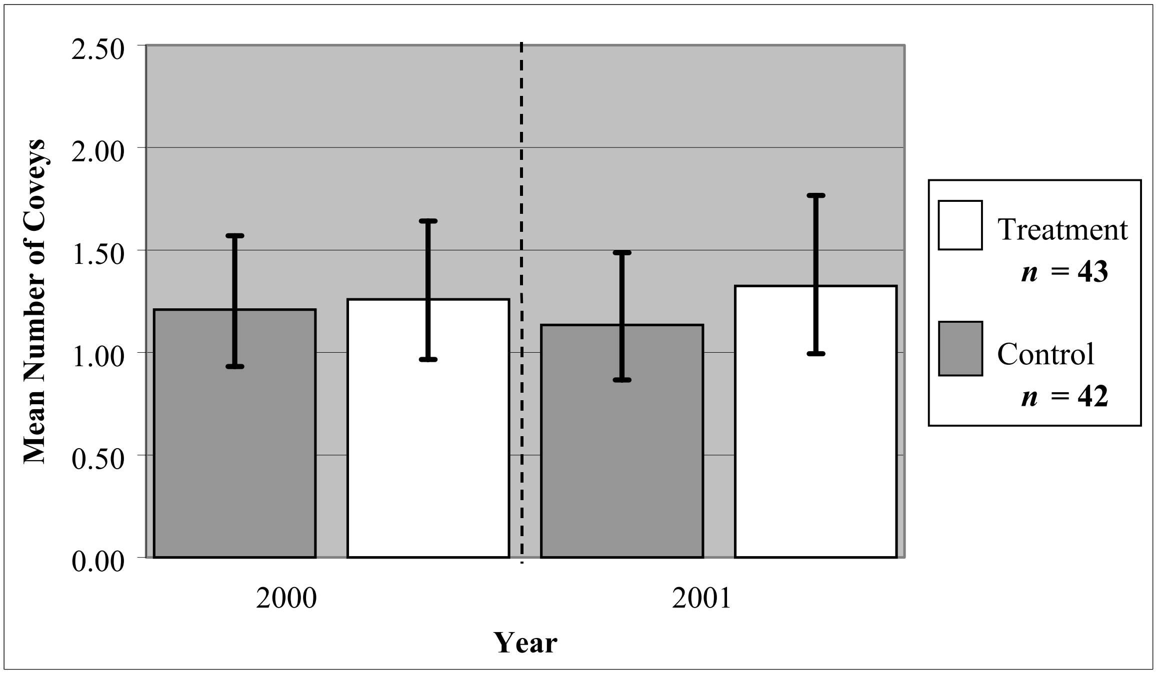

Figure 3.6. Model-averaged estimates of mean (±95% CI) northern bobwhite covey numbers at treatment (two-year post-treatment sites at year 2001, only) and control sites estimated from repeated covey-call-count surveys conducted over all BQI focus areas in Georgia, 2000-2001.

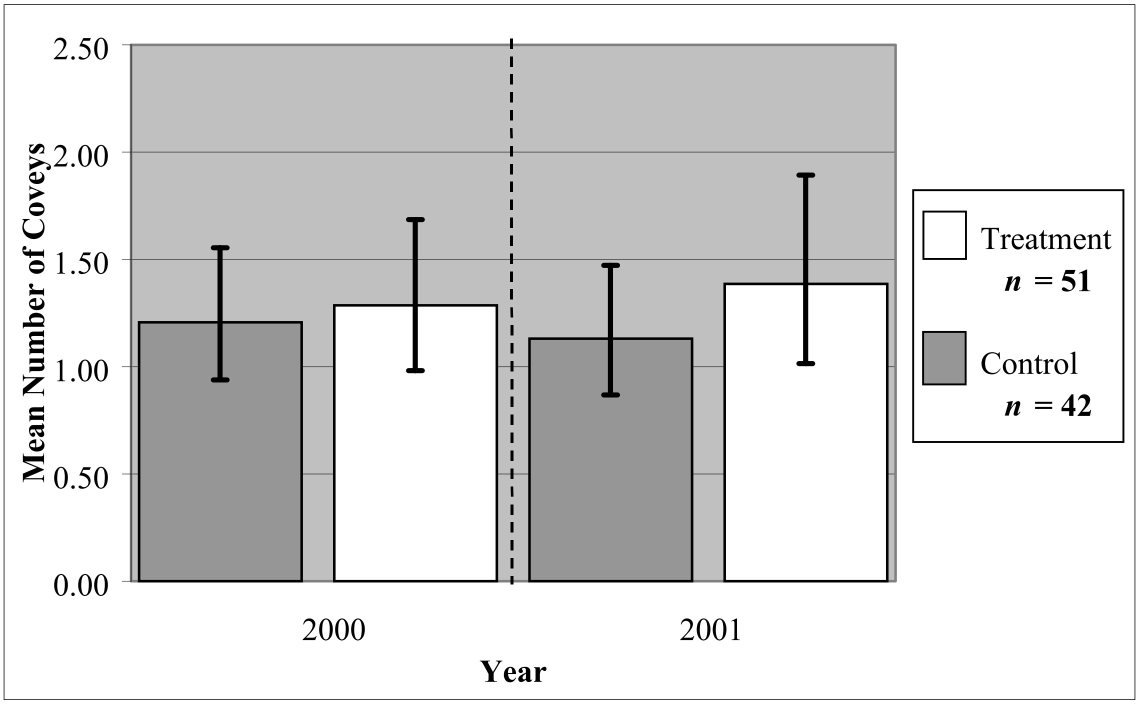

Figure 3.7. Model-averaged estimates of mean (±95% CI) northern bobwhite covey numbers at treatment (one- and two-year post-treatment sites at year 2001, pooled) and control sites estimated from repeated covey-call-count surveys conducted over all BQI focus areas in Georgia, 2000-2001.

APPENDIX

ADDITIONAL OBSERVATIONS ASSOCIATED WITH NORTHERN BOBWHITE COVEY-CALL-COUNT INDICES

INTRODUCTION

Covey-call-counts for surveying northern bobwhite (*Colinus virginianus*) (hereafter, bobwhite) populations have received increased interest in recent years. Investigations into factors affecting covey-calling behavior have addressed some of the critical assumptions of covey-call-count indices, and have aided in developing call-count survey design and protocol. This chapter summarizes ancillary observations obtained from the covey-call-count research presented in previous chapters. I evaluated temporal covey-calling activity, time of first covey-calls heard on survey mornings, and distances that observers detected calling coveys.

Estimates of covey-calling activity and initial calling times are useful for developing call-count survey protocols. It is often difficult to accurately quantify the distance at which observers are able to hear calling coveys. Estimates of distances to calling coveys provide a means for quantifying maximum distance observers can hear calling coveys, which could allow development of less subjective covey density estimates from point count surveys. This study was not designed to address aspects of temporal covey-calling behavior or to estimate distances that observers could effectively hear calling coveys, thus the reader should be aware of this when interpreting the results presented in this chapter.

METHODS

Covey-call-count techniques were used to survey calling bobwhite coveys at the agricultural field(s) level over a broad regional scale (13 counties in the Upper Coastal Plain of Georgia) on sample sites in 1999 to 2001. During call-count surveys, observers listened for the "koi-lee" covey-calls (Stoddard 1931) given by bobwhite (almost always before sunrise) during autumn. 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. Surveys were conducted on fields enrolled in the Bobwhite Quail Initiative (BQI), a program developed primarily to improve bobwhite breeding habitat in row crop agricultural ecosystems, and on fields that were not being managed for bobwhite habitat. Fields enrolled in BQI were considered treatments and fields that were not actively managed for bobwhites were considered controls. A brief explanation of call-count methods follows, however a more detailed explanation can be found in Chapter 3.

Covey-call-count techniques

Quadrat Surveys.--The quadrat technique utilizes a 0.25 square kilometer (25 hectares, 500 x 500 meter) quadrat to survey calling coveys. A total of four observers are required, with one observer positioned along the midpoint of each quadrat line. Observers were instructed to arrive at survey points at least 45 minutes before sunrise, and surveys officially began 40 minutes before sunrise. Observers recorded compass bearings, estimated distances, and approximate locations for each calling covey heard on standardized data sheets and field maps. Once the first call was heard, calling coveys were recorded for a 10-minute interval in order to minimize duplicate observations (as coveys often begin to move and initiate their daily activities soon after calling) and to standardize survey methods. Once the survey period expired, observers met to compare results in order to determine individual covey locations. Each unique covey location was plotted on a final field map. For each covey that was heard by more than one observer, the intersection of compass bearings to the covey was used to plot the approximate location. If only one observer detected a particular covey, the estimated distance to the covey along the compass bearing was used to plot the approximate location. Surveys were ended at the official time of sunrise if no calls were heard by this time.

Point Count Surveys.--In addition to the quadrat technique, point counts (single-observer call-counts), were used to survey bobwhite populations on remaining sample sites in 1999 and 2000, and all sample sites in 2001. It was assumed that an observer could hear calling coveys at a distance of up to 500 meters (W. E. Palmer, Tall Timbers Research Station, personal communication). A single observer was positioned where as much of the area of interest as possible was covered by the assumed maximum hearing distance. Survey protocol for point counts was the same as for quadrat surveys (except the estimated distance along the compass bearing to each calling covey heard was used to plot approximate covey locations).

Two-observer Surveys.--In 2000, a few two-observer call-count surveys were used in addition to quadrats and point counts. However, these made up a very small portion of the total number of call-count surveys. Observers were spaced approximately 350 meters apart. Survey protocol for two-observer surveys was the same as for quadrat surveys.

Temporal Calling Activity

I evaluated temporal covey-calling activity from covey-call-count surveys conducted on a sample of treatment and control sites over two-week intervals (bi-week) from October to December, 1999 to 2001. Five bi-week periods (see Table A.1 for year-specific bi-week class date intervals) were developed from the dates of call-count surveys in each year. I modeled classification of bi-week periods after Wellendorf (2000). Calling activity was assessed by evaluating numbers of call-count surveys in which at least one covey was detected.

Time of First Calls

I evaluated time of first covey-calls heard by an observer from covey-call-count surveys conducted on a sample of treatment and control sites from October to December in 1999, 2000, 2001, and all years pooled. I also evaluated time of first covey-calls heard by an observer from covey-call-count surveys conducted on a sample of treatment and control sites by two-week intervals (bi-week, see "Temporal Calling Activity" above) from October to December in 1999, 2000, 2001, and all years pooled. For multi-observer quadrat surveys in 1999 and 2000 and two-observer surveys in 2000, I considered time of first covey-call heard (if any) by each individual observer as an independent observation since any observer could potentially hear different initial covey-calls. This analysis was performed to complement other research (e.g. Wellendorf 2000) on covey-calling behavior.

Estimated Distances to Calling Coveys

Distances to covey locations were calculated by intersection of azimuths (when possible) for each pair of quadrat observers that heard a particular covey. Quadrat observers formed four sets of 350-meter pairs and two sets of 500-meter pairs per quadrat (see Chapter 2 for more description on observer pairings). For each pair of observers, each intersecting azimuth at a calling covey was converted to a triangle with base equal to the linear azimuth and distance between observers and sides equal to the linear azimuth and distance from the observers to the covey. The angle from each observer to the covey was calculated from the observer azimuth and the base azimuth. Finally, the angle of intersection at the covey was calculated by subtracting the sum of the two angles from each observer to the covey from 180 degrees. The equation used to determine distance to coveys from a particular observer was

$$\text{Distance from Observer } x = [DBO \times \text{Sine}(AOO)]/\text{Sine}(ACL),$$

where *DBO* is the linear distance between both observers, *AOO* is the angle formed by the azimuth at the opposite observer, and *ACL* is the angle formed at the covey location by intersection of azimuths. Figure A.1 depicts how angles and distances to coveys were calculated.

Angles were calculated and entered into a computer spreadsheet program, and the above formula was applied to calculate distance to covey estimates. It should be noted that spreadsheet programs might convert the sine of an angle to radians (if this is the case, then the angle should be multiplied by $\pi/180$ before taking the sine of the angle).

RESULTS

Temporal Calling Activity

Overall percentages of surveys in which at least one covey was detected by bi-week in 1999, 2000, 2001, and all years pooled are summarized in Table A.1. Figures

A.2, A.3, A.4, and A.5 show the frequency of surveys in which at least one covey was detected by five bi-week classes in 1999, 2000, 2001, and all years pooled, respectively.

Time of First Calls

In 1999, the mean time of the first covey-call heard (n = 138) by an observer was 30.28"0.94 ("95% CI) (range = 17 to 40) minutes before sunrise (MBS). In 2000, the mean time of the first covey-call heard (n = 176) by an observer was 24.74"1.06 (range = 1 to 40) MBS. In 2001, the mean time of the first covey-call heard (n = 125) by an observer was 27.82"1.31 (range = 7 to 40) MBS. For all years pooled, the mean time of the first covey-call heard by an observer was 27.36"0.41 MBS. Overall mean times of the first covey-call heard by observers by year are summarized in Table A.2. Mean times (MBS) of the first covey-call heard by the five bi-week classes in 1999, 2000, 2001, and all years pooled are summarized in Table A.3. Figures A.6, A.7, A.8, and A.9 show the frequency distributions of first call-times in several MBS intervals for 1999, 2000, 2001, and all years pooled, respectively.

Estimated Distances to Calling coveys

Figure A.10 summarizes the frequency distribution, in 50-meter intervals, of calculated distances to calling coveys from 350-meter pairs of quadrat observers. Figure A.11 summarizes the frequency distribution, 50-meter intervals, of calculated distances to calling coveys from 500-meter pairs of quadrat observers. The distance distributions from both sets of observer pairs seemed to indicate that the majority of calling coveys were detected within 600 meters of observers.

DISCUSSION

I was unable to estimate covey-calling rates in my study area. However, other researchers have estimated these rates (Smith 2001, Wellendorf et al. 2002, Seiler et al. 2002) and suggest that calling rates are relatively high throughout October to mid-November. My analysis of temporal calling activity indicated that covey-calling activity was relatively consistent throughout October and November. However, my analysis of bi-week effects on covey-calling activity should be interpreted with caution. This study was not designed specifically to evaluate temporal calling activity. For instance, it was not known if a covey was actually present or not when no coveys were detected. However, some interesting trends were found. Although I was not able to assess calling rates, the pooled-year trends in mean numbers of surveys with $1 covey detected over bi-weekly periods suggested trends similar to those found in other studies investigating temporal calling activity. Wellendorf et al.'s (2002) research on covey-calling rates in several southeastern states indicated that the highest covey-calling rates occurred from mid-October to mid-November. In Missouri, Seiler et al. (2002) evaluated covey-calling rates on weekly intervals and found the last week of October to be the peak of calling rates, with high calling rates occurring over the last two weeks of September to the first two weeks of November. Seiler et al. (2002) did not evaluate calling activity beyond mid-November. Wellendorf et al. (2002) suggested that the peak of covey-calling rates vary from year to year, and made recommendations for determining peak calling activity. Unfortunately, with limited personnel and broad areas to survey, managers may not always be able to survey within the highest peaks of covey-calling activity. The temporal calling activity trends from my research suggested that covey-call-counts should not be conducted past the end of November. Surveys should be limited to within the peak calling periods if possible. However, if this is not feasible, I recommend conducting covey-call-counts from mid-October through no later than the last week of November on sites in the Upper Coastal Plain of Georgia.

Research by Wellendorf (2000) and Wellendorf et al. (2002) in Florida, North Carolina, and Tennessee found that overall, the majority of coveys called about 23 to 24 minutes before sunrise. In Missouri, Seiler et al. (2002) reported time of first covey-calls over a range of 9 to 48 minutes before sunrise. Overall, it appears there was not much difference in the time of first calls between my study area and those reported by other researchers. Survey protocol prevented calls from being recorded prior to 40 minutes before sunrise in my study, thus 40 minutes was the earliest time at which a call could be recorded. However, based on ancillary observations of coveys calling less than 40 minutes before sunrise, these coveys appeared to call repeatedly enough to be detected within the 40-minute before sunrise criteria.

The distributions of distances to calling coveys seemed to suggest that 500 to 600 meters might be reasonable estimates of the maximum distance that observers could hear calling coveys. The distance to covey estimates, via triangulation, in my study provided some evaluation of assumptions associated with maximum distance observers could hear calling coveys (most pertinent to point count assumptions). Other researchers that have used point counts have suggested 500 meters (W. E. Palmer, Tall Timbers Research Station, personal communication) and 700 meters (DeMaso et al. 1992) as an average maximum hearing distance for calling coveys. The trends in my data seemed consistent with previous estimates of maximum hearing distance. The most extreme estimated distances to covey observations (>1000 meters) were almost certainly a function of azimuth error. The greater the distance to calling coveys, the greater the degree of error associated with azimuth readings was likely to be.

Unfortunately, low sample sizes and lack of control over azimuth error did not allow me to effectively evaluate observer-specific effective hearing distance. However, it is recommended that effective hearing distance be evaluated to accurately develop density estimates from point counts (provided detection rates are also evaluated). One way to estimate effective hearing distances for observers may be to use recorded calls (Conroy 1996) or radio-marked coveys, which could be utilized to develop models of detection distance incorporating weather, vegetation, topography, and other pertinent variables.

LITERATURE CITED

Conroy, M. J. 1996. Techniques for estimating abundance and species richness: abundance indices. Pages 179-192 *in* Wilson, D. E., F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster, editors. Measuring and monitoring biological diversity. Smithsonian Institution Press, Washington, D.C., USA.

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

Seiler, T. P., R. D. Drobney, and T. V. Dailey. 2002. Use of weather variables for predicting fall covey calling rates of northern bobwhites. National Bobwhite Quail Symposium Proceedings 5:91-98.

Smith, M. D. 2001. Response of northern bobwhite to intensive habitat development on a prairie site in Mississippi. Thesis, Mississippi State University, Mississippi State, Mississippi, USA.

Stoddard, H. L. 1931. The bobwhite quail, its habits, preservation, and increase. Charles Scribner's Sons. New York, New York, USA.

Wellendorf, S. D. 2000. Factors influencing early morning covey calling in northern bobwhites. Thesis, North Carolina State University, Raleigh, North Carolina, USA.

_____, W. E. Palmer, and P. T. Bromley. 2002. Estimating calling rates of northern bobwhite coveys and censusing populations. Journal of Wildlife Management *In Press*.

Table A.1. Percentage of all covey-call-count surveys (*n* = number of surveys conducted) in which at least one calling northern bobwhite covey was detected by bi-week class from all BQI regions and both treatment and control sites in Georgia, 1999-2001 and all years pooled.

Year	*n*	Bi-Week Class	Bi-Week Date Interval	% Surveys with ≥1 Covey	SE	±95% CI
1999	2	1	10/10/99-10/23/99	0.00%	**	**
1999	14	2	10/24/99-11/6/99	57.14%	13.73%	26.90%
1999	46	3	11/7/99-11/20/99	41.30%	7.34%	14.39%
1999	33	4	11/21/99-12/4/99	51.52%	8.83%	17.32%
1999	39	5	12/5/99-12/18/99	43.59%	8.04%	15.77%
2000	33	1	10/8/00-10/21/00	60.61%	8.64%	16.93%
2000	45	2	10/22/00-11/4/00	68.89%	6.98%	13.68%
2000	46	3	11/5/00-11/18/00	52.17%	7.45%	14.60%
2000	46	4	11/19/00-12/2/00	45.65%	7.43%	14.55%
2000	23	5	12/3/00-12/16/00	26.09%	9.36%	18.35%
2001	38	1	10/7/01-10/20/01	57.89%	8.12%	15.91%
2001	74	2	10/21/01-11/3/01	51.35%	5.85%	11.47%
2001	60	3	11/4/01-11/17/01	60.00%	6.38%	12.50%
2001	39	4	11/18/01-12/1/01	61.54%	7.89%	15.47%
2001	23	5	12/2/01-12/15/01	21.74%	8.79%	17.24%
Pooled	73	1	Years Pooled	57.53%	5.83%	11.42%
Pooled	133	2	Years Pooled	57.89%	4.30%	8.42%
Pooled	152	3	Years Pooled	51.97%	4.07%	7.97%
Pooled	118	4	Years Pooled	52.54%	4.62%	9.05%
Pooled	85	5	Years Pooled	32.94%	5.13%	10.05%

Table A.2. Times (minutes before sunrise) of first northern bobwhite calls detected during covey-call-count surveys from all BQI regions and both treatment and control sites in Georgia, 1999-2001 and all years pooled.

Year	***n***	**Mean**	**SE**	**±95% CI**	**Minimum**	**Maximum**
1999	138	30.28	0.48	0.94	17	40
2000	176	24.74	0.54	1.06	1	40
2001	125	27.82	0.67	1.31	7	40
Pooled	439	27.36	0.21	0.41	1	40

Table A.3. Times (minutes before sunrise) of first northern bobwhite calls detected by five bi-week classes during covey-call-count surveys from all BQI regions and both treatment and control sites in Georgia, 1999-2001 and all years pooled.

Year	*n*	Bi-Week Class	Bi-Week Date Interval	Mean	SE	±95% CI	Minimum	Maximum
1999	0	1	10/10/99-10/23/99	**	**	**	**	**
1999	24	2	10/24/99-11/6/99	26.88	0.89	1.74	22	36
1999	50	3	11/7/99-11/20/99	31.14	0.74	1.45	18	40
1999	40	4	11/21/99-12/4/99	32.45	0.82	1.60	23	40
1999	24	5	12/5/99-12/18/99	28.29	1.30	2.55	17	40
2000	33	1	10/8/00-10/21/00	23.21	1.22	2.40	14	40
2000	47	2	10/22/00-11/4/00	25.13	0.84	1.65	13	35
2000	42	3	11/5/00-11/18/00	23.24	1.36	2.67	1	38
2000	39	4	11/19/00-12/2/00	27.21	1.05	2.05	15	39
2000	15	5	12/3/00-12/16/00	24.67	1.58	3.09	15	33
2001	22	1	10/7/01-10/20/01	28.23	1.35	2.64	19	40
2001	38	2	10/21/01-11/3/01	28.11	1.13	2.21	11	40
2001	36	3	11/4/01-11/17/01	27.39	1.24	2.43	10	40
2001	24	4	11/18/01-12/1/01	28.54	1.94	3.81	7	40
2001	5	5	12/2/01-12/15/01	23.40	3.14	6.15	16	31
Pooled	55	1	Years Pooled	25.22	0.96	1.89	14	40
Pooled	109	2	Years Pooled	26.55	0.59	1.15	11	40
Pooled	128	3	Years Pooled	27.49	0.70	1.37	1	40
Pooled	103	4	Years Pooled	29.55	0.71	1.39	7	40
Pooled	44	5	Years Pooled	26.50	0.98	1.93	15	40

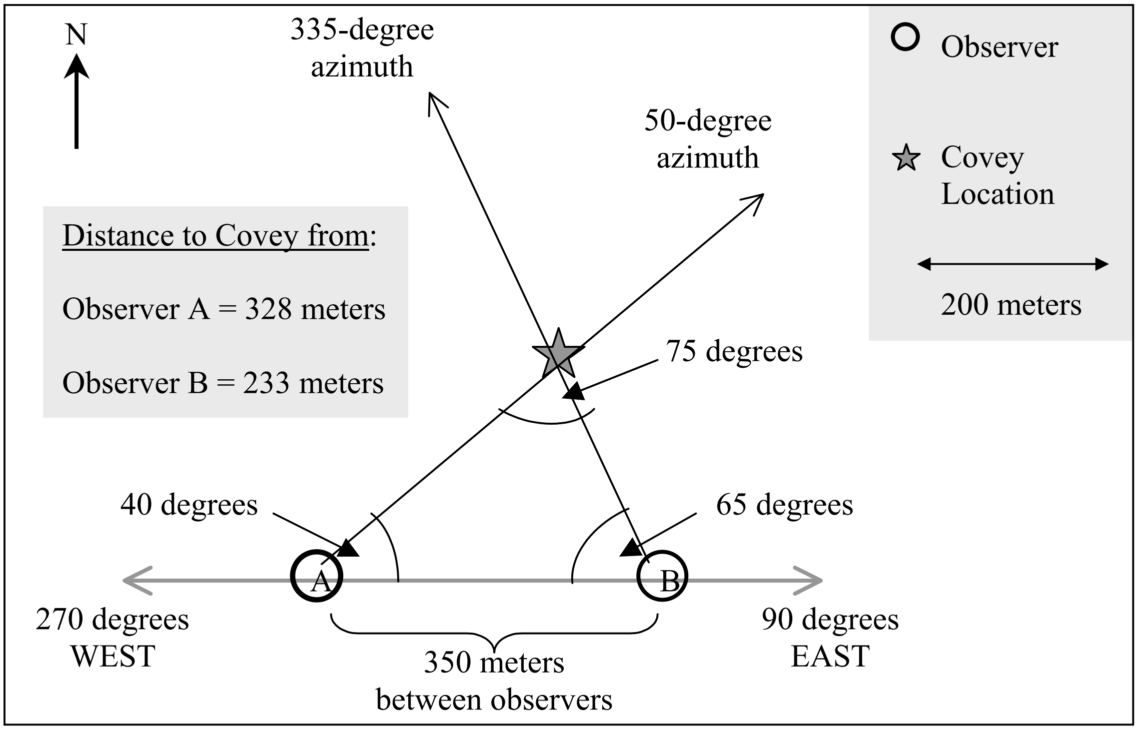

Figure A.1. Example of how angles from multiple-observer azimuths to calling northern bobwhite covey locations, taken during call-count surveys, were calculated in order to estimate distances from observers to calling coveys.

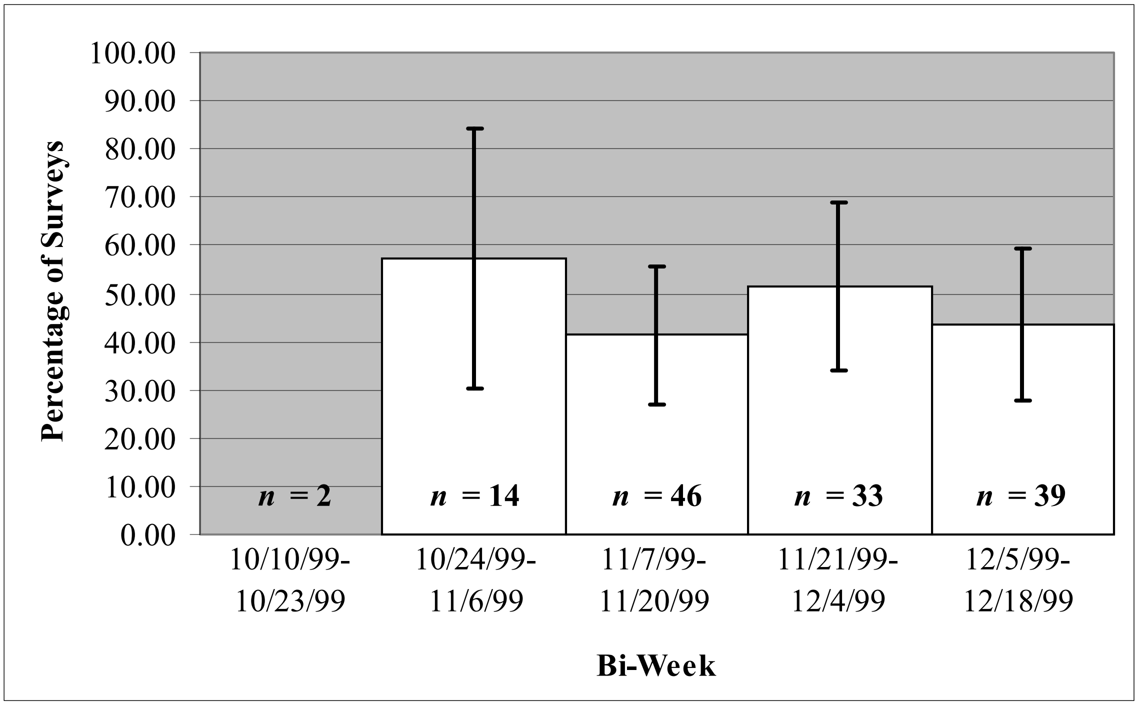

Figure A.2. Percentages (±95%CI) of covey-call-count surveys in which at least one calling northern bobwhite covey was detected by bi-week class from all BQI regions and both treatment and control sites in Georgia, 1999.

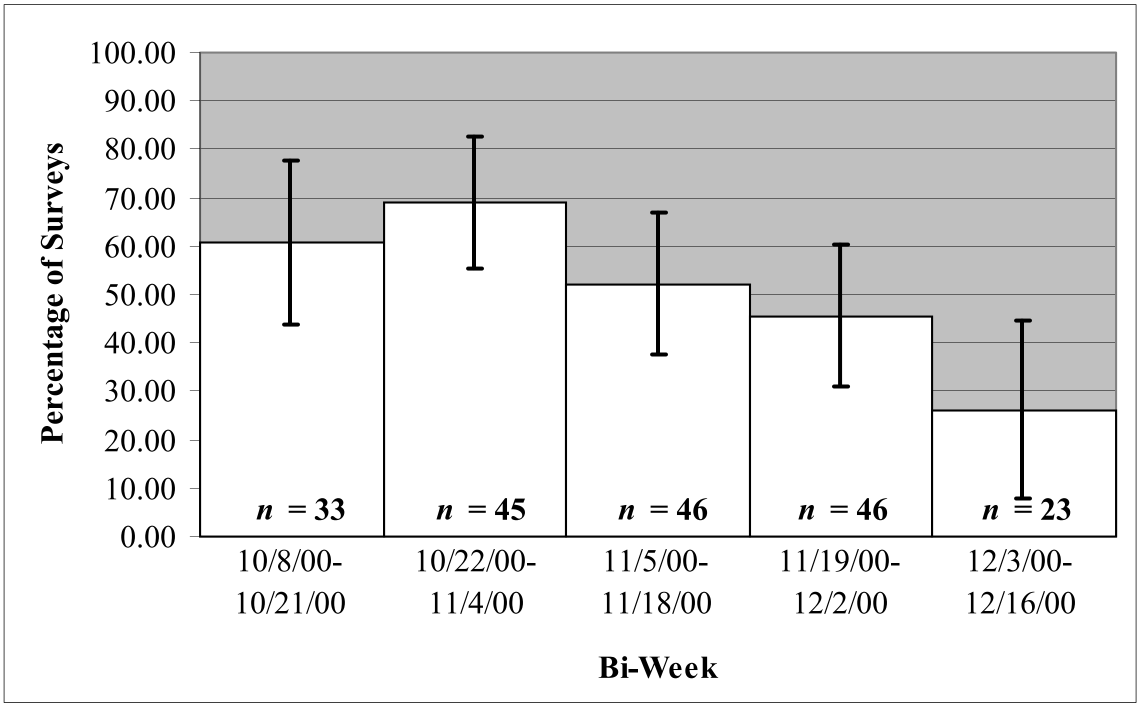

Figure A.3. Percentages (±95%CI) of covey-call-count surveys in which at least one calling northern bobwhite covey was detected by bi-week class from all BQI regions and both treatment and control sites in Georgia, 2000.

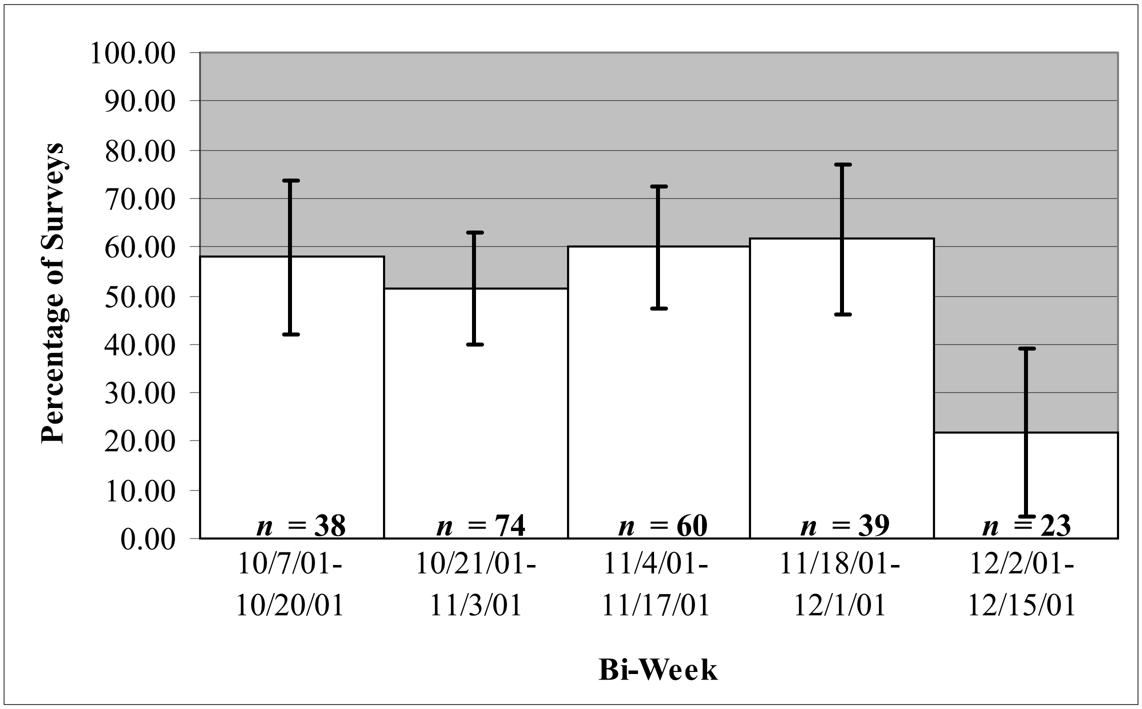

Figure A.4. Percentages (±95%CI) of covey-call-count surveys in which at least one calling northern bobwhite covey was detected by bi-week class from all BQI regions and both treatment and control sites in Georgia, 2001.

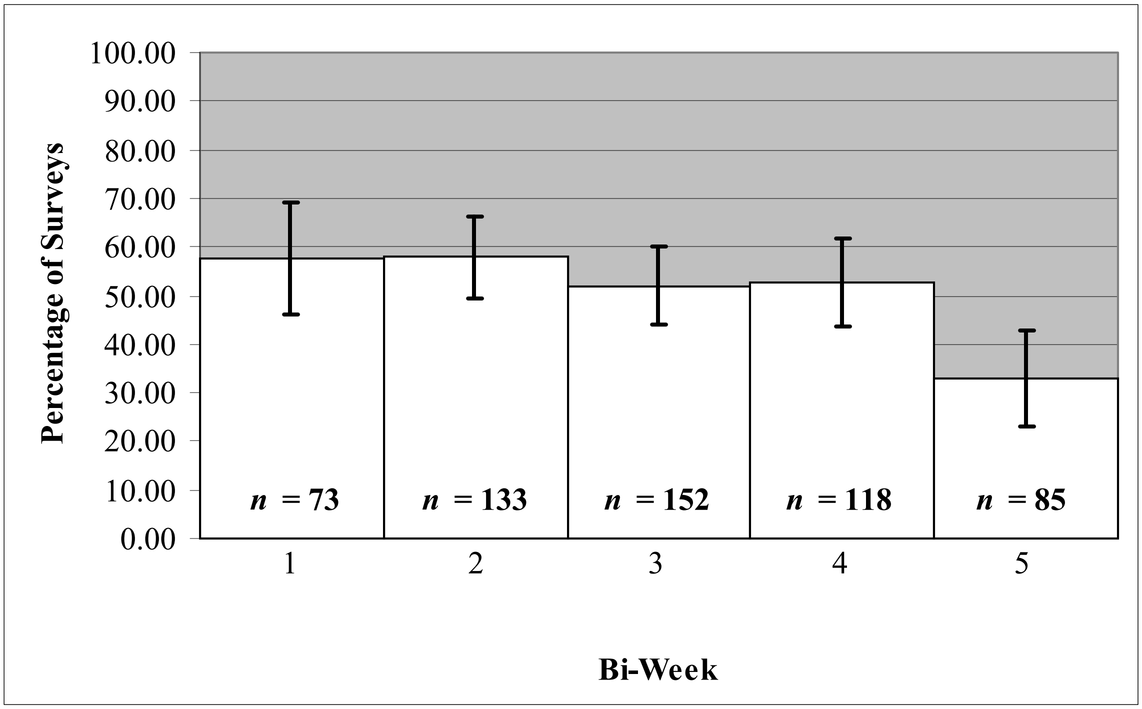

Figure A.5. Percentages (±95%CI) of covey-call-count surveys in which at least one calling northern bobwhite covey was detected by bi-week class (classified by date intervals in previous graphs) from all BQI regions and both treatment and control sites in Georgia, 1999-2001 pooled.

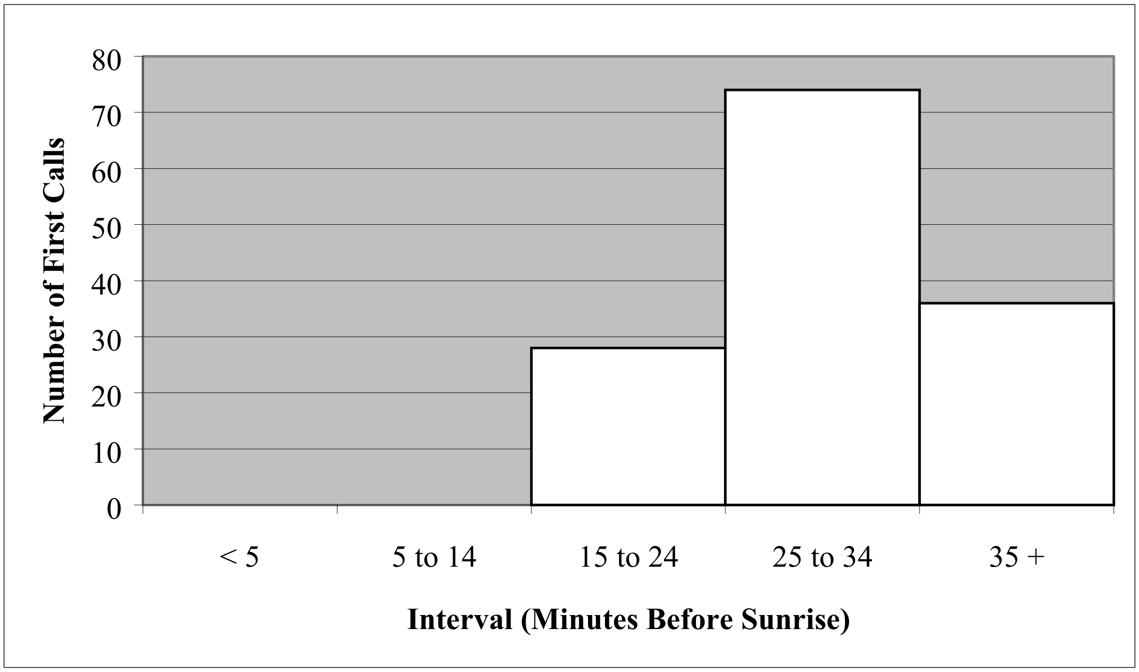

Figure A.6. Frequency of first call-times for northern bobwhite covey-call-count surveys from all BQI regions and both treatment and control sites in Georgia, 1999.

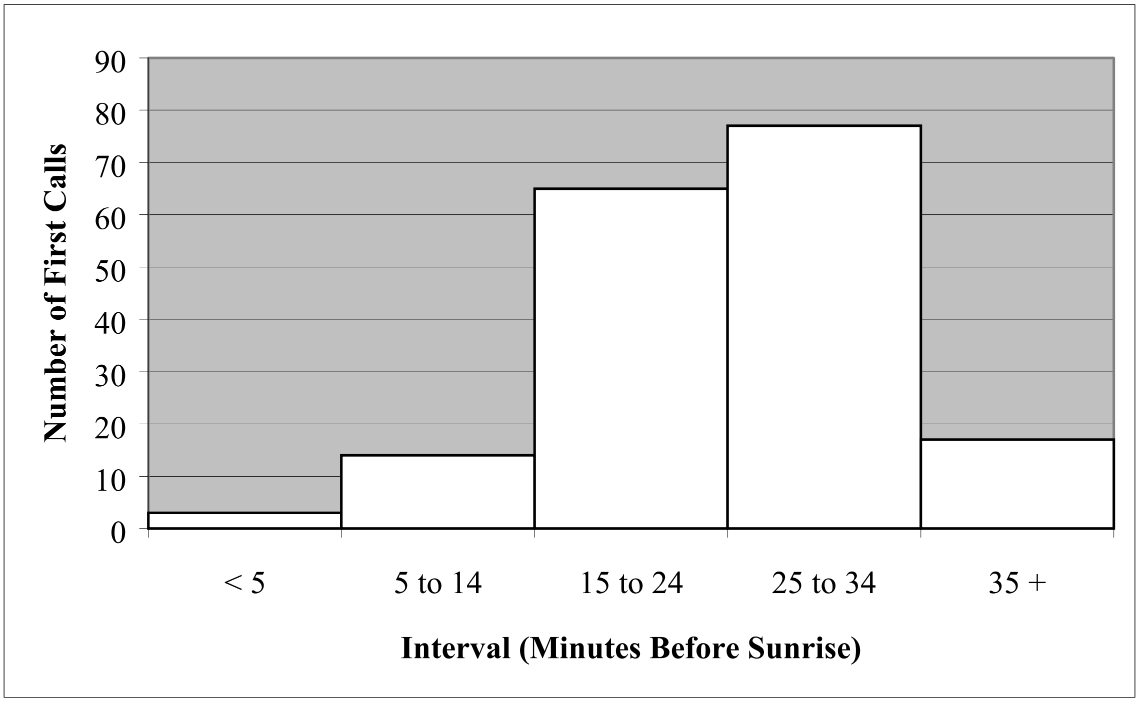

Figure A.7. Frequency of first call-times for northern bobwhite covey-call-count surveys from all BQI regions and both treatment and control sites in Georgia, 2000.

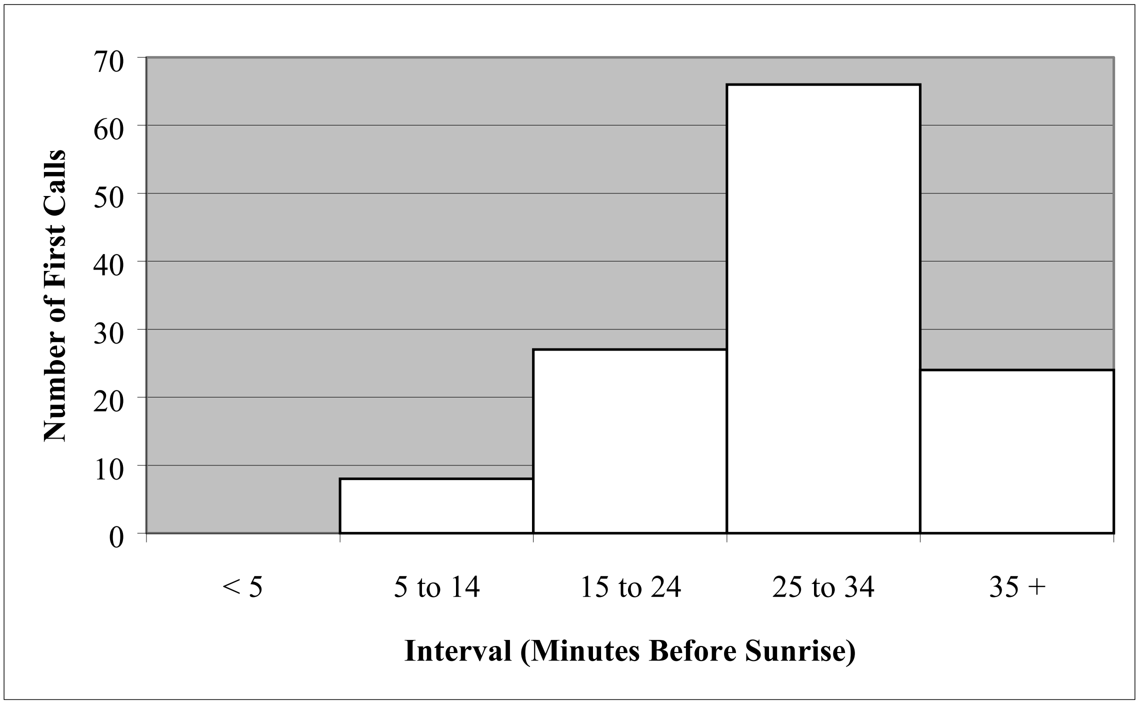

Figure A.8. Frequency of first call-times for northern bobwhite covey-call-count surveys from all BQI regions and both treatment and control sites in Georgia, 2001.

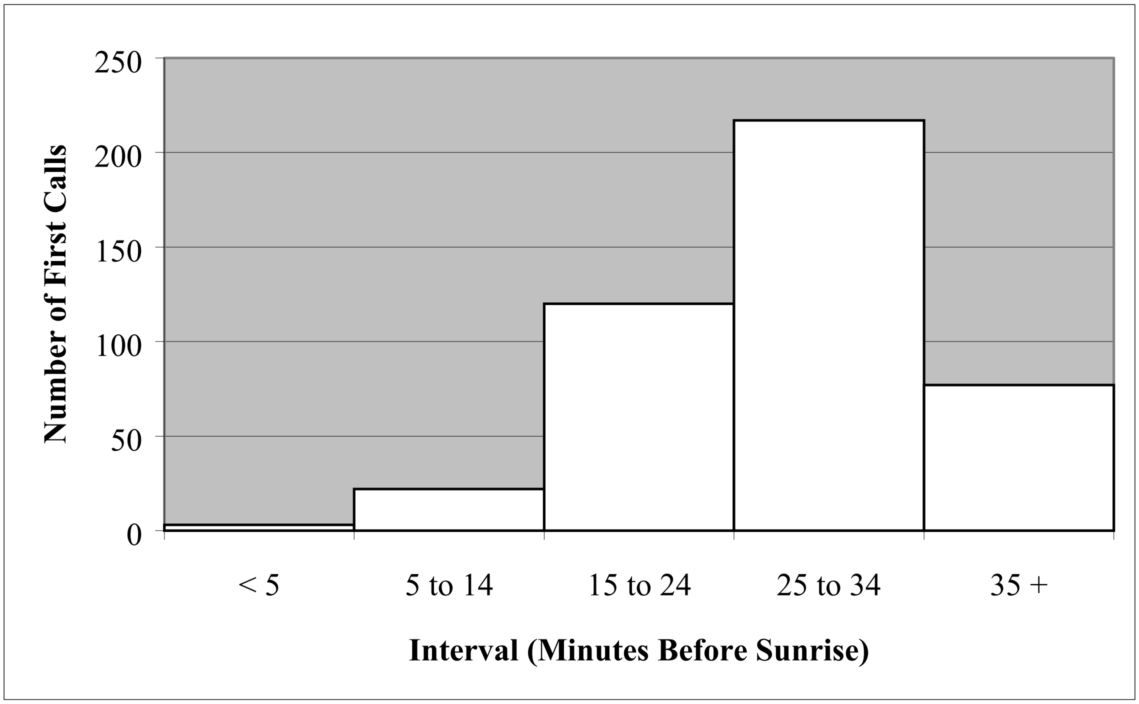

Figure A.9. Frequency of first call-times for northern bobwhite covey-call-count surveys from all BQI regions and both treatment and control sites in Georgia, 1999-2001 pooled.

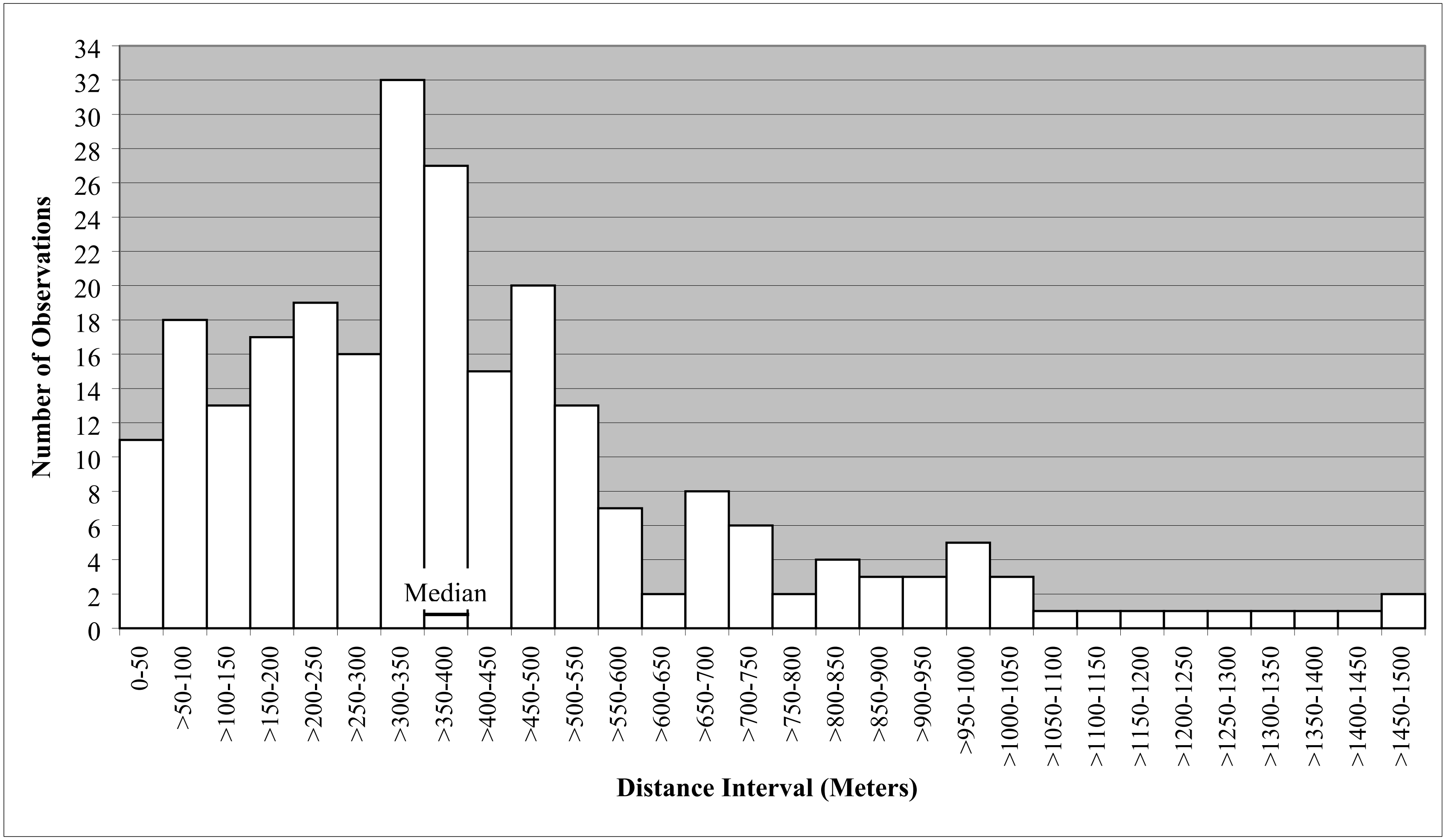

Figure A.10. Frequency distribution of distances to calling northern bobwhite coveys, calculated by triangulation, from pairs of observers 350-meters apart in 1999-2000 pooled covey-call-count quadrat surveys from all BQI regions and both treatment and control sites in Georgia.

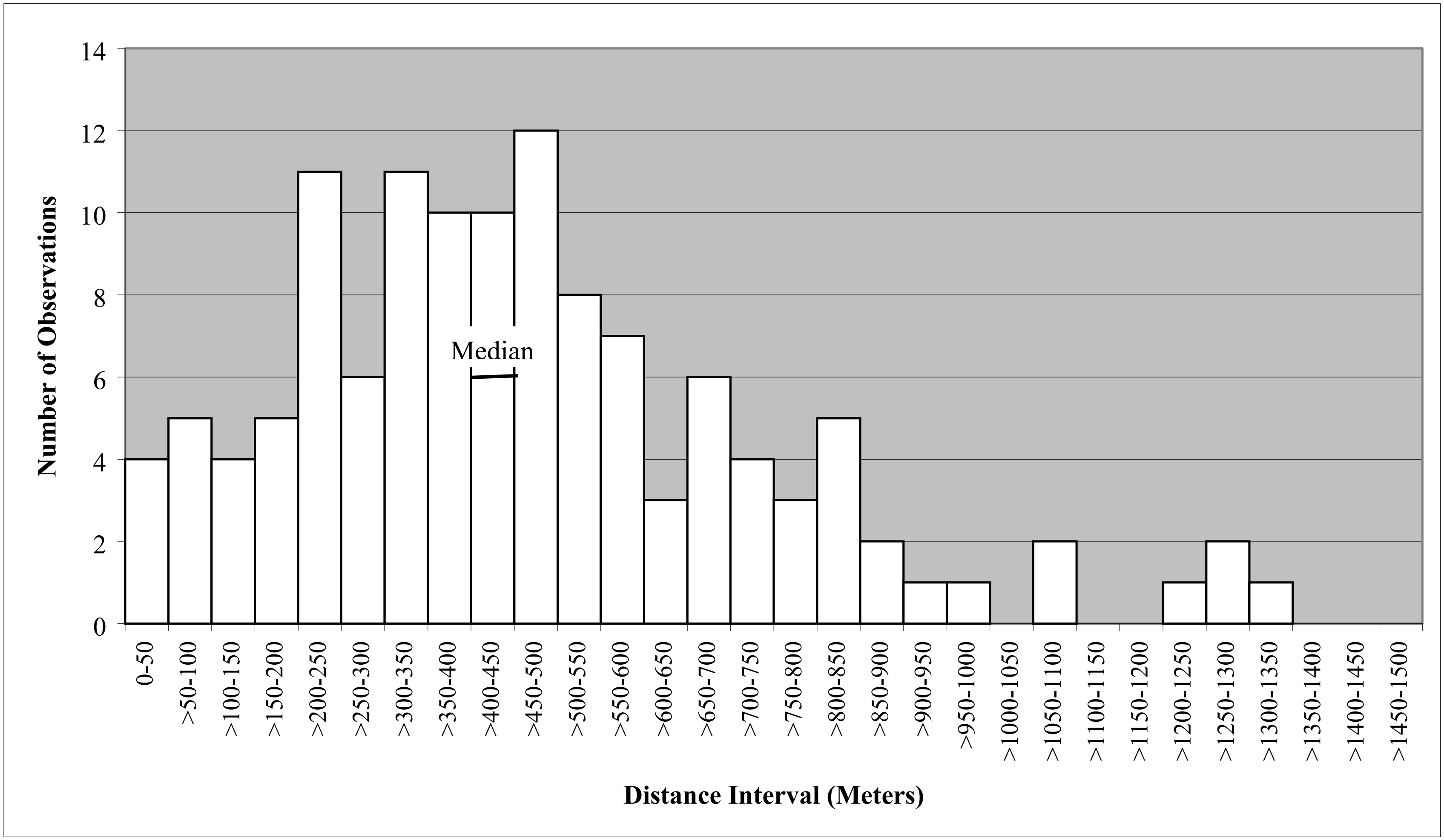

Figure A.11. Frequency distribution of distances to calling northern bobwhite coveys, calculated by triangulation, from 500-meter pairs of observers in 1999-2000 pooled covey-call-count quadrat surveys from all BQI regions and both treatment and control sites in Georgia.