Demographics of Northern Bobwhite on Agricultural and Intensively-managed Bobwhite Plantation Landscapes

Daymond W. Hughes, *Albany Quail Project, Route 1 Box 115, Newton, GA 39870*

Theron M. Terhune, *Albany Quail Project, University of Georgia, Warnell School of Forestry and Natural Reources, Athens, GA 30602*

D. Clay Sisson, *Albany Quail Project, Route 1 Box 115, Newton, GA 39870*

H. Lee Stribling, *School of Forestry and Wildlife Sciences, 602 Duncan Drive, Auburn University, AL 36849*

Abstract: The declining bobwhite populations evident throughout the Southeast are cause for concern. Whereas habitat loss and/or intensified agriculture have been implicated as two potential causal mechanisms for these declines, few studies have directly compared bobwhite demographics between agricultural and managed bobwhite plantation landscapes. Therefore, we monitored northern bobwhite (*Colinus virginianus;* hereafter, bobwhite) via radiotransmitters ($N = 472$) on a center-pivot irrigated agricultural landscape ($N = 154$) and an adjacent, intensively-managed bobwhite plantation ($N = 318$) to evaluate differences in home range, habitat use, survival, and nest survival between these two landscapes. Winter covey home ranges were larger during fall–winter 1998–99 on the agriculture site ($P < 0.001$). Coveys on the agricultural landscape used young planted pines (*Pinus* spp.) greater than expected ($P < 0.05$) during both years. Annual survival did not differ between sites during 1997–98 ($P = 0.199$) but was lower on the agriculture site (0.081, SE = 0.04) than the plantation (0.297, SE = 0.05) during 1998–99 ($P < 0.001$). Daily nest survival was lower on the agriculture site (0.939, SE = 0.02) than the plantation (0.979, SE = 0.01) during the 1998 nesting season ($P = 0.030$) but not during 1997 ($P = 0.782$). We surmised that large home ranges, low over-winter survival, and low nest survival observed on the agriculture site was related to poor habitat conditions and subsequent limited food resources. Thus, when agricultural landowner objectives are to benefit bobwhite, management endeavors should focus on augmenting habitat in agricultural fields, particularly during fall and winter, and, improving existing habitats (e.g., dry corners, young planted pines).

Key words: agriculture, center-pivot, *Colinus virginianus*, Georgia, habitat use, home range, nest survival, survival, northern bobwhite, quail plantation

Proc. Annu. Conf. Southeast. Assoc. Fish and Wild. Agencies 59:30–42

Northern bobwhite (*Colinus virginianus;* hereafter, bobwhite) populations have been declining since the mid-20th century (Brennan 1991, Church et al. 1993). The

Breeding Bird Survey has indicated range-wide declines of almost 3%/year since 1966 (Sauer et al. 2004). Numerous factors have been implicated for the decline, but the two most prevalent are major landscape changes which negatively affect bobwhite habitat (Vance 1976, Exum et al. 1982, Rollins and Carroll 2001) and changing predator dynamics (Hurst et al. 1996). Agricultural landscapes once supported high densities of bobwhite across the Southeast by providing "good" habitat as an accidental by-product of agricultural management (Brennan 1991). However, since the 1970s, farmers have adopted agricultural practices, such as clean fence rows, larger fields, and increased pesticide use that have resulted in loss of small, low impact farming upon which bobwhite once depended (O'Conner and Shrubb 1986, Brennan 1991, Rollins and Carroll 2001). Additionally, modern-day agricultural fields generally provide little to no crop residue and/or weedy habitat which is known to be critical for brood rearing (Yates et al. 1995).

Southwest Georgia has experienced these landscape changes (Exum et al. 1982, Odum and Turner 1987). As the size of agricultural fields in this region has increased, so has the advent of center-pivot irrigation systems. Due to its circular nature, many areas (i.e., dry corners) of square agriculture fields do not receive irrigation. During the 1980s, the Conservation Reserve Program (CRP) promoted planting pines (*Pinus* spp.) in these "dry corners" of irrigated fields via monetary incentives. In the short term, this practice likely benefited bobwhite by creating fallow areas for about five to seven years; however, long-term consequences proved detrimental. The high stocking density recommended for fiber production and failure/inability to thin these young pines resulted in canopy closure and rapidly diminishing quality bobwhite habitat (Brennan 1991, 1993).

We had access to a unique situation in which bobwhite inhabiting an intensively-managed bobwhite plantation and center-pivot agriculture landscape could be examined on the same property where only a paved highway divided the respective management regimes. Therefore, during this study we contrasted bobwhite demographics within an agricultural ecosystem to an intensively-managed bobwhite plantation that maintained a stable/increasing population of wild bobwhites.

Study Area

We conducted our study on private agricultural land (1,520 ha) that was intensively managed for row-crop farming in Baker County, Georgia. The upland portion consisted of approximately 1,200 ha and was dominated by nine center-pivot irrigated fields comprising 65% of the study area. Pivot fields were planted on annual spring rotations of cotton, corn, soybeans, and peanuts. Occasionally winter grains and cover crops including wheat, oats, and lupine also were grown at a smaller scale. However, most of the land area was disked and the ground left bare during fall and winter months. The remainder of the area was comprised of hedgerows, dry corners, and hardwood dominated creek bottoms. Dry corners varied in size from 4.4 to 49 ha and were planted in slash (*Pinus ellioti*) and/or longleaf (*P. palustris*) pine during 1993. Herbaceous ground cover in dry corners consisted primarily of Bermuda grass (*Cyn-*

odon dactylon) and blackberry (*Rubus* spp.). Hedgerows were 10–30 m wide and were dominated by mature slash pine and live oak (*Quercus virginiana*) with an understory comprised predominately of sassafras (*Sassafras albidum*), oak scrub (*Quercus* spp.), broomsedge (*Andropogon* spp.) and blackberry. Additionally, hedgerows were burned in small sections on a two-year rotation to control hardwood encroachment.

Our adjacent study area (8,097 ha) was an intensively-managed bobwhite plantation typical of many landholdings in the area which focused primarily on wild bobwhite production and hunting. This site was in the Upper Coastal Plain physiographic region and was characterized by old-field pine forests with relatively low basal area. Intensive habitat management regimes typically included annual prescribed burning, seasonal disking, drum-chopping and mowing, supplemental feeding, and mammalian nest predator control (see Yates et al. 1995, Sisson et al. 2000*a*, *b*). Typical field management consisted of autumn and late winter disking to stimulate annual weed production and arthropods. As a result of these intense management regimes, this area maintained abundant wild bobwhite populations ranging from 4.2 birds/ha to >7.41 birds/ha (D. C. Sisson, unpublished data).

Methods

We trapped bobwhites twice annually (February–March and October–November) on each study area using standard, baited funnel traps (Stoddard 1931). Annual time-periods were delineated via two seasons: over-winter season (fall–spring; 1 October–March 31) and breeding season (spring–fall; 1 April–30 September). Bobwhites were outfitted with a pendant-style radiotransmitter (6.4 g) equipped with an activity switch (Holohil Systems Ltd., Ontario, Canada) and leg banded, weighed (g), aged (Leopold 1939), and released at their capture site. We monitored radiotagged birds ≥3 times weekly. All bird locations were determined using the "homing" method (White and Garrott 1990) and were recorded on aerial photographs. Specific causes of mortality were determined when possible by evidence at the kill site and condition of the radiotransmitter (Curtis et al. 1988). Trapping, handling, and marking procedures were consistent with the guidelines and approved protocol of the Auburn University Institutional Animal Care and Use Committee (IACUC, Protocol Review Number: 2002–0364).

Home Range and Habitat Selection

Telemetry locations were marked on an aerial photograph for use in determining home range and habitat preference/avoidance (Yates 1997). Winter covey home ranges were estimated via the 95% Minimum Convex Polygon (MCP) using a planimeter. Kenward (2001:231) reported that a minimum of 30 locations was needed for home range size to stabilize. Thus, home ranges with ≥30 locations were estimated via the 95% MCP as described by Mohr (1947). We divided the agriculture study area into four categories for analyzing habitat use: 1) hedgerows, 2) young (≤5 years old) planted pines (in dry corners), 3) swamp, and 4) center-pivot irrigated crop fields. The plantation site was delineated into two categories: 1) piney woods and 2) fallow fields.

Difference in home range size was determined using an unbalanced 2-way analysis of variance (ANOVA) in a general linear model (PROC GLM; SAS. 2002). Further examination between site and year was evaluated using least significant-difference (LSD) separation methods to identify differences among means following a significant F-test ($P < 0.05$; CONTRAST and LSMEANS, SAS. 2002). We examined habitat use with second (individual home range as used versus study area composition as available) and third (telemetry locations as used versus individual home range as available) order habitat selection (Johnson 1980) for individual coveys using compositional analysis (CA; Aebischer et al. 1993*a*, Manley et al. 2000). Second order availability was defined for individual coveys ($N > 3$, radio-tagged bobwhites/covey). The size of each polygon was determined randomly based on random numbers generated from the mean and standard deviation of home range sizes of coveys. The average habitat proportions within these polygons was calculated and considered to be second order availability. Second order use was defined as the proportions of each habitat type within home ranges. We defined third order availability as the proportion of each habitat type within home ranges and habitat use as the proportion of individual radiolocations within each habitat type. Prior to analysis, we replaced zero values for use with the value 0.001 (Aebischer et al. 1993*a*). When a habitat was not available for use, we replaced missing values in each log-ratio with the mean of all non-missing values for the respective log-ratio (Aebischer et al. 1993*a*,*b*). All habitat selection analyses were conducted using Compos Analysis (version 5.1; Smith 2003).

Survival

We estimated survival for each site by season, year, and pooled across factors using the Kaplan-Meier product limit method via staggered entry design (Kaplan and Meier 1958, Pollock et al. 1989). Whereas bobwhites have been reported to be differentially susceptible to mortality agents relative to gender (Pollock et al. 1989, Burger et al. 1995), male and female survival was not different during this study (Hughes 2003). Thus, we pooled male and female bobwhites to compare survival estimates across sites and years. To account for potential capture and radio effects, mortalities occurring within one week of radiotransmitter attachment and release were censored. Radiotransmitters lost due to radio failure were censored on the day following the last day of known contact. Hunting occurred from mid-November to 28 February on the plantation whereas no hunting occurred on the agriculture site. Long-term studies on the plantation site indicated that hunting mortality was 5%–10% annually (Burger et al. 1998, T. M. Terhune unpublished data). We compared survival distributions using log rank and end-point estimates of survival using Chi-square tests via program CONTRAST (Hines and Sauer 1989, Pollock et al. 1989, Sauer and Williams 1989).

Nest Survival

We assumed female bobwhites were nesting when observed in the same location on two consecutive days during the breeding season. We approached inactive females (5–10 m) and marked their location with flagging tape and recorded the location on an aerial photograph. We determined exact nest location and number of eggs when radiotelemetry indicated the incubating female was away from the nest. We monitored nests daily and nest fate was determined as abandoned, successful, or unsuccessful. A depredated nest was any nest in which ≥1 egg was destroyed and the adult bird did not return to incubate the remaining clutch. An abandoned nest was a nest in which the female did not complete incubation and all of the eggs were left still intact, i.e., there was no sign of depredation. A successful nest was defined as a nest that hatched ≥1 egg.

We estimated nest survival using the maximum likelihood estimator via the Mayfield method (Bart and Robson 1982). Because we generally were unable to detect nesting activity until incubation, we used initiation of incubation as the measurable onset of nesting activity. Consequently, our estimates may have over-estimated nest success and under-estimated nest production (number of nests produced per hen). However, based on backdating successful nests we determined that 96% of the nests were found within the first three days of incubation. We compared daily survival rates (DSR) between sites using Chi-square tests. Nest survival was based on a 23-day incubation period (i.e., DSR^{23}; Roseberry and Klimstra 1984).

Results

Home Range and Habitat Selection

We monitored 13 and 18 coveys on the agricultural (hereafter, farm) and plantation sites, respectively during the 1997–98 (farm: $N = 6$, plantation: $N = 10$) and the 1998–99 (farm: $N = 7$, plantation: $N = 8$) fall–spring seasons. During 1998–99 on the farm site, one covey left the study area and was not used for home range or habitat use analyses. Two coveys had no radiotransmitters left three months prior to the end of the season and were not used in analysis of home range.

Home range.—Home range size had a significant site and year interaction ($F_1 = 12.83$, $P = 0.002$). Whereas covey home ranges did not differ during 1997–98 ($N = 10$, $\bar{x} = 7.71$ ha) or 1998–99 ($N = 8$, $\bar{x} = 6.99$ ha) on the plantation ($F_1 = 0.22$, $P = 0.646$), covey home range size ($\bar{x} = 11.76$ ha, SE = 1.94) did differ between years ($F_1 = 16.83$, $P < 0.001$) on the farm. There was no difference between sites during the 1997–98 season ($F_1 = 0.13$, $P = 0.726$). However, farm home ranges ($\bar{x} = 16.94$ ha, SE = 2.875) were larger than the plantation ($\bar{x} = 6.99$ ha, SE = 0.62) during the 1998–99 season (Table 1).

Habitat Selection.—Second order analyses revealed that habitats were used at rates different than expected on the farm site when compared to their occurrence within the study area during both 1997–98 ($\chi_3^2 = 43.52$, $P < 0.01$) and 1998–99 ($\chi_3^2 = 25.44$, $P < 0.01$). During the 1997–98 over-winter season, coveys utilized both hedgerows ($t_5 = 4.05$, $P = 0.01$) and young planted pines ($t_5 = 4.51$, $P = 0.01$) at a

Table 1. Over-winter (1 October–31 March) covey home range estimates for northern bobwhite on an agricultural landscape (farm) and an intensively managed bobwhite plantation at the Albany Study area, Albany, Georgia, 1997–99.

Year	Site	*N*	HR[a]	SE[b]	*P*[c]
1997–98	Farm	6	8.31	1.42	0.726
	Plantation	10	7.71	0.91	
1998–99	Farm	4	16.94	2.87	<0.001
	Plantation	8	6.99	0.62	
Pooled	Farm	10	12.62	1.94	
	Plantation	18	7.35	0.56	

a. Home range (HR) is the mean home range for all coveys during the winter.
b. Standard error.
c. Significant test was not conducted for pooled factors because annual variation was evident during 1998–99.

rate significantly higher than pivot fields. During the second study season, 1998–99, young planted pines were preferentially used compared to hedgerows ($t_5 = 4.17$, $P = 0.01$) and pivot fields ($t_5 = 3.16$, $P = 0.02$). We did not detect a difference between habitat use for winter-coveys on the plantation during either 1997–98 ($\chi_1^2 = 1.66$, $P = 0.197$) or 1998–99 ($\chi_1^2 = 1.21$, $P = 0.272$).

Third order analyses suggested no differences in habitat use, within covey home ranges, for 1997–98 ($\chi_3^2 = 3.89$, $P = 0.27$) or 1999–99 ($\chi_3^2 = 7.42$, $P = 0.06$) on the farm site. However, habitat use by winter-coveys monitored on the plantation differed significantly from random during 1997–98 ($\chi_1^2 = 29.93$, $P < 0.001$) and 1998–99 ($\chi_1^2 = 31.81$, $P < 0.001$). Winter-coveys preferentially used piney woods on the plantation site during 1997–98 ($t_9 = 13.06$, $P = 0.001$) and 1998–99 ($t_7 = 19.13$, $P = 0.006$).

Survival

We monitored survival of 154 and 318 bobwhites during the two-year study on the farm and plantation sites, respectively. Survival did not differ between plantation bobwhites and farm bobwhites during 1997–98 (Table 2). Annual survival of plantation bobwhites (0.297, SE = 0.04) was higher than farm bobwhites (0.081, SE = 0.03) during 1998–99 ($\chi_1^2 = 14.26$, $P < 0.001$; Table 2). Whereas seasonal variation in survival was evident for the over-winter period during 1998–99 ($\chi_1^2 = 52.479$, $P < 0.001$), breeding season survival did not vary significantly during either 1997–98 ($\chi_1^2 = 0.169$, $P = 0.681$), 1998–99 ($\chi_1^2 = 3.454$, $P = 0.063$), or pooled across years ($\chi_1^2 = 1.856$, $P = 0.173$).

Nest Survival

Daily nest survival rate did not differ between the farm (0.964, SE = 0.01) and the plantation (0.960, SE = 0.007) during 1999 ($\chi_1^2 = 0.076$, 1 df, $P = 0.782$; Table 3). When pooled across years, nest survival during the 23-day incubation period for

Table 2. Breeding, over-winter, and annual survival estimates for northern bobwhite on an agricultural landscape (farm) and an intensively-managed bobwhite plantation at Albany study areas, Albany, Georgia, 1997–1999.

		Farm			Plantation				
Year	Season[a]	*N*	Surv[b]	SE[c]	*N*	Surv	SE	χ^{2d}	*P*
1997–1998	Overwinter	31	0.36	0.08	76	0.51	0.04	2.769	0.096
	Breeding	33	0.44	0.10	96	0.49	0.06	0.169	0.680
	Annual	64	0.16	0.05	148	0.24	0.04	1.62	0.202
1998–1999	Overwinter	47	0.25	0.03	86	0.58	0.03	52.479	<0.001
	Breeding	44	0.33	0.09	116	0.53	0.06	3.454	0.063
	Annual	90	0.08	0.04	170	0.29	0.05	14.26	<0.001
Pooled	Overwinter	78	0.31	0.04	162	0.58	0.03		
	Breeding	77	0.38	0.07	212	0.48	0.04	1.857	0.173
	Annual	154	0.12	0.03	318	0.27	0.03		

a. Season; Overwinter = 1 October–31 March, Breeding = 1 April–30 September.
b. Survival estimates derived via the Kaplan-Meier method.
c. SE = Standard error.
d. χ^2-test, difference between farm and plantation bobwhites; significant test was not conducted across pooled factors because annual variation in survival was evident.

Table 3. Daily (DSR) nest survival estimates on an agricultural landscape (farm) and an intensively-managed bobwhite plantation on the Albany study area, Albany, Georgia, 1998–1999.

		MLE Survival				
Year	Site	DSR[a]	Surv.[b]	SE	χ^{2c}	*P*
1998	Farm	0.9387	0.2334	0.017	4.733	0.029
	Plantation	0.9793	0.6184	0.005		
1999	Farm	0.9639	0.4293	0.013	0.076	0.782
	Plantation	0.9599	0.3901	0.007		
Pooled	Farm	0.9526	0.3273	0.011		
	Plantation	0.9692	0.4870	0.004		

a. DSR is the daily survival rate.
b. Survival (surv) is the probability that a nest will survive the period of study; $(dsr)^t$, t = 23 days.
c. χ^2 -test, difference between daily survival rate for farm and plantation bobwhites; significant test was not conducted across pooled factors because annual variation in nest survival was evident.

farm and plantation birds was 32.73% ± 9.58 and 48.70% ± 5.34, respectively (Table 3). During 1998, daily survival rate was higher ($\chi_1^2 = 4.733$, 1 df, $P = 0.030$) on the plantation (0.979, SE = 0.005) than the farm (0.939, SE = 0.02; Table 3).

Discussion

Results from our study indicated that variation in home range size was dependent on a site and year interaction, suggesting that site influenced home range size temporally. Therefore, environmental factors (e.g., predator dynamics, food availability, habitat quality, etc.) which fluctuate temporally relative to site likely altered home range size. Sisson et al. (2000*a*) reported that habitat quality potentially regulates home range size of bobwhites where as quality of habitat decreases, home range size increases. Size of the home ranges are often contingent on resource availability and when a particular resource is limited or in abundance the animal(s) under investigation will adjust by increasing or decreasing their home range size, respectively. The first year of the study revealed that winter coveys on the farm maintained home ranges similar to those of plantation coveys. However, this may have been attributable to a high acorn yield that year which has been shown to reduce home range size (Curtis et al. 1988). Comparatively, the plantation's small home range size, observed during both years, may be attributed to supplemental feeding regimes (Frye 1954, Landers and Mueller 1986, Sisson et al. 2000*a*).

Although second order analyses determined that winter coveys used planted pines greater than other habitats compared to relative habitat availability, this finding was not unexpected because much of the available habitat (i.e., disked pivot fields) provided little to no winter cover. Hedgerow and hardwood-dominated creek swamp use by winter coveys varied between years and was likely due to a combination of food availability (e.g., hardwood acorns) during a given year. Pivot fields were distributed throughout the farm but rarely used by winter coveys due to lack of cover in these disked fields.

Annual average survival on the farm (11.6% ± 2.9) was low compared to annual average survival on the plantation (26.9 ± 3.0). Long-term average annual survival on bobwhite plantations including and surrounding our study area have been reported at 20.0%–22.76% (Burger et al. 1998, T. M. Terhune unpublished data). These long-term survival estimates are higher than those observed on the farm and lower than those observed on the plantation. Over-winter survival was implicated as the primary cause for low annual survival estimates on the farm compared to the plantation during both years. Additionally, despite an additional 5%–10% per year hunting mortality the plantation still maintained higher annual survival (Burger et al. 1998, T. M. Terhune unpublished data). In contrast, Robinette and Doerr (1993) reported consistently greater survival estimates for non-hunted than hunted areas during a three-year study in North Carolina. Notably, survival was least (8.1% ± 3.5) and greatest (29.7 ± 4.5) when home range size was largest (16.94 ha ± 2.88) and smallest (6.99 ha ± 0.62), respectively. We surmised that increased home range size and subsequent reduced survival was likely resource dependent (Sisson et al. 2000*a*, *b*). During the first year of our study, a high acorn yield was prevalent and therefore bobwhites did not need to traverse as much area to find food. During this winter period (1997–98), home range size was cut in half on the farm and similar to the plantation and survival was nearly doubled. When bobwhites are forced to increase their home range on highly fragmented sites (i.e., farm), traversing unsuitable habitat to get to suitable habitat, increased predation may result. Each year a large portion (approximately 65%) of habitat was eliminated after harvesting and disking of pivot fields. As a result, bobwhite which were using nearly 100% of the farm during the spring and the summer were forced to use only 35% of that area during the fall and winter months. Guthery (1997:294) suggested, based on the usable space hypothesis, "management practices aimed at increasing usable space should result in increased mean density of bobwhites." The paucity of usable space (Guthery 1997) on the farm site may be mitigated by implementing simple farm practice changes, such as leaving corn and peanut stubble for a longer period of time after harvest.

During both years, bobwhite nested almost exclusively in two habitats on the farm site. Ninety-seven percent of all nests occurred in hedgerows and young planted pine stands, which comprised 2% and 12% of the habitat, respectively. This indicated that bobwhite were dependent on these scarce habitats for nesting in agricultural environments. We observed that average nest survival on the farm was lower (32.73 ± 9.59) than the plantation (48.70% ± 4.84). Our estimates were higher on the farm and plantation than those reported (21.0%) by Taylor and Burger (1997). Although Burger et al. (1995) reported nest success (43.7%) in Missouri that was similar to the plantation site and higher than the farm site; Puckett et al. (1995) reported nest success of 34% in North Carolina that was similar to the farm and lower than the plantation. Mammalian nest predators were controlled on the plantation site but not on the farm. Previous research has suggested that more efficient foraging via nest predators may be evident due to small and/or narrow nesting habitats (Puckett et al. 1995). Thus, the farm site may benefit by improving nest habitat quality and quantity. Recent research corroborates this notion where study sites which implemented field borders, hedgerows, and riparian buffers increased nesting habitat availability and subsequently resulted in higher nest production and nest success (Puckett et al. 1995, D. C. Sisson, Albany Quail Project, unpublished data). In addition to low nest survival observed on the farm site, low overall over-winter survival exacerbated the poor reproductive output compared to the plantation.

In conclusion, bobwhite on the farm site were dependent on the amount, or lack thereof, of usable space for bobwhites. During both years we observed slightly lower nest survival on the farm than the plantation; however, the primary disparity in overall reproductive effort likely lies in the number of females available to reproduce during a given year. Further, number of breeding females was limited on the farm site due to low overall over-winter survival as compared to the plantation. Moreover, covey home range size during the winter was dictated by deficient cover and native food resources. Hence, when acorns were abundant, home range size was smaller and survival was greater than during years when these resources were limiting. Therefore, increasing usable space (Guthery 1997) and available food resources during over-winter months may potentially decrease home range size, improve survival; thereby, increasing number females available for reproduction and ultimately increasing population levels.

Management Implications

The species and spacing of planted pines in dry corners can drastically affect amount, duration, and type of habitat. The time from planting to canopy closure can be extended by planting pines at larger spacing and wider rows. Additionally, utilizing management practices such as burning, thinning, and limb pruning can further inhibit canopy closure while stimulating desirable early succession vegetation. Planting longleaf pines instead of loblolly or slash permits prescribed fire to be utilized earlier to aid in de-limbing and control of unwanted scrub and vegetation. Second, increasing amount and quality of cover available during the fall and winter may potentially improve habitat conditions and over-winter survival. This may be accomplished via utilizing conservation buffers, introducing and maintaining linear habitats, and improving existing agricultural fields with conservation tillage and fallow field management. Conservation tillage, field borders or filter strips, and fallow field management can improve winter cover and over-winter survival. Recent research has shown benefits to quail chick foraging by strip or no till planting which leaves crop residue (Palmer et al. 2001). Hamrick (2002) found that bobwhite abundance was higher on farms with field borders and other linear habitats than those without linear habitats and field borders. Additionally, Puckett et al. (1995) reported that bobwhites were attracted to crop fields with filter strips and showed that these habitats had positive effects on nest production. Borders, if laid out correctly, may reduce fragmentation by connecting habitat patches and hedgerows and increasing usable space (Guthery 1997). Additionally, leaving fields or portions of pivot-fields fallow for one year on a rotation may improve cover and survival of bobwhites.

Finally, two management practices that were employed on the plantation that could help maintain, or even increase, bobwhite densities on the farm are supplemental feeding and predator control. However, supplemental feeding and predator management are not "silver bullets" that will remedy all the problems associated with farm landscapes, rather these techniques should be used in conjunction with other management practices discussed when funding is not limited, and, these practices are compatible with landowner objectives. Essentially, bobwhite management on large scale farms can potentially be successful with little sacrifice to farming practices. Whereas some practices such as supplemental feeding and predator control can be started immediately, other practices such as establishing field borders and vegetation control take time. In the long run, bobwhite can benefit from many of these management practices, especially when used in combination.

Acknowledgments

We are greatly indebted to the landowners for their generous contribution of the study area and funding for the project. We thank the plantation managers and their staff for their help and support throughout the project. We also would like to thank the entire Albany Quail Project staff for their diligent efforts and contributions in collecting the data: Jerald Sholar, Steven Mitchell, Chris Juergens. The authors would also like to thank B. Palmer, D. Miller, T. Seiler, and M. Smith for comments and review of early drafts of this manuscript.

Literature Cited

Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993*a*. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313–1325.

______, V. Marstrom, R. E. Kenward, and M. Karlbom. 1993*b*. Survival and habitat utilization: a case for compositional analysis. Pages 343–353 *in* J. D. Lebreton and P. M. North, editors. Marked individuals in the study of bird populations. Birkhauser-Verlag, Basel, Switzerland.

Bart, J. and D. S. Robson. 1982. Estimating survivorships when the subjects are visited periodically. Ecology 63:1078–1090.

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

______. 1993. Strategic plan for quail management and research in the United States: Introduction and background. Pages 160–169 *in* K. E. Church and T. V. Dailey, editors. Quail III: Proceedings of the Third National Bobwhite Quail Symposium. Kansas Department of Wildlife and Parks, Pratt.

Burger, L. W. Jr., D. C. Sisson, H. L. Stribling, and D. W. Speake. 1998. Northern bobwhite-survival and cause-specific mortality on an intensively managed plantation. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 52:174–190.

______, L. W., T. V. Dailey, E. W. Kurzejeski, and M. R. Ryan. 1995. Survival and cause specific mortality of northern bobwhite in Missouri. Journal of Wildlife Management 59:401–410.

Church, K., J. Sauer, and S. Droege. 1993. Population trends of quails in North America. Pages 44–54 *in* Church, K. and T. Dailey editors. Quail III: National Quail Symposium. Kansas Department of Wildlife and Parks, Pratt.

Curtis, P. D., B. S. Mueller, P. D. Doerr, and C. F. Robinette. 1988. Seasonal survival of radio-marked northern bobwhite quail from hunted and non-hunted populations. Biotelemetry X: International Radio-Telemetry Symposium 10:263–275.

Exum, J. H., R. W. Dimmick, and B. L. Deardon. 1982. Land use and bobwhite populations in an agricultural system in west Tennessee. Pages 6–12 *in* F. Schitosky Jr., E. C. Schitosky, and L. G. Talent, editors. Proceedings of the Second National Bobwhite Quail Symposium. Oklahoma State University, Stillwater.

Frye, E. O. 1954. Studies of automatic quail feeders in Florida. Transactions of the North American Wildlife Conference 19:298–315.

Guthery, F.S. 1997. A Philosophy of habitat management for northern bobwhites. Journal of Wildlife Management. 61:291–301.

Hamrick, R. G. 2002. Evaluation of northern bobwhite (*Colinus virginianus*) population monitoring methods and population trends in agricultural systems in the upper Coastal Plain of Georgia. Master's Thesis. University of Georgia, Athens.

Hines, J. E. and J. R. Sauer. 1989. Program CONTRAST – a general program of the analysis of several survival or recovery estimates. U.S. Fish and Wildlife Service, Fish and Wildlife Technical Report 24.

Hughes, D. W. 2003. Northern bobwhite survival, nesting success, home range and habitat use in a center pivot dominated agricultural landscape. Master's Thesis. Auburn University, Auburn, Alabama.

Hurst, G. A., L. W. Burger, and B. D. Leopold. 1996. Predation and galliforme recruitment: an old issue revisited. Transactions North American Wildlife and Natural Resources Conference 61:61–76.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

Kaplan, E. L. and P. Meier. 1958. Nonparametric estimation from incomplete observation. Journal of American Statistical Association. 53:457–481.

Kenward, R. E. 2001. A manual for wildlife radio tagging. Academic Press, San Diego, California.

Landers, J. L., and B. S. Mueller. 1986. Bobwhite quail management: a habitat approach. Miscellaneous Publication 6. Tall Timbers Research Station. Tallahassee, Florida.

Leopold, A. S. 1939. Age-determination in quail. Journal of Wildlife Management 3:261–265.

Manley, S. W., J. M. Lee, R. S. Fuller, J. P. Carroll, and L. A. Brennan. 2000. Comparison of two methods for quantifying northern bobwhite habitat use. Pages 213–218 *in* L. A. Brennan, W. E. Palmer, L. W. Burger Jr., and T. L. Pruden, editors. Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, Florida.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37:223–249.

O'Conner, R. J. and M. Shrubb. 1986. Farming and birds. Cambridge University Press, Cambridge, UK.

Odum, E. P. and M. G. Turner. 1987. The Georgia landscape: a changing resource. Institute of Ecology. University of Georgia, Athens.

Palmer, W. E., M. W. Lane II, and P. T. Bromley. 2001. Human-imprinted Northern Bobwhite chicks and indexing arthropod foods in habitat patches. Journal of Wildlife Management 65:861–869.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis of telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7–15.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, 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.

Robinette, C. F. and P. D. Doerr. 1993. Survival of northern bobwhite on hunted and nonhunted study areas in the North Carolina sandhills. Pages 74–78 *in* Church, K. E. and T. V. Dailey, editors. Quail III: Proceedings of the Third National Quail Symposium. Kansas Department of Wildlife and Parks, Pratt.

Rollins, D. and J. P. Carroll. 2001. Impacts of predation on northern bobwhite and scaled quail. Wildlife Society Bulletin 29:39–51.

Roseberry, J. L. and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, Illinois.

SAS Institute, Inc. 2002. SAS procedures guide. Version 8.2. SAS Institute, Inc., Cary, North Carolina.

Sauer, J. E. Hines, I. Thomas, J. Fallon, and G. Gouch. 2004. The North American breeding bird survey, results, and analysis, 1966–1999. Version 98.1, U.S. Geological Service, Patuxent Wildlife Research Center, Laurel, Maryland.

______ and B. K. Williams. 1989. Generalized procedures for testing hypothesis about survival or recovery rates. Journal of Wildlife Management 53:137–142.

Sisson, D. C., H. L. Stribling, and D. W. Speake. 2000*a*. Effects of supplemental feeding on home range size and survival of northern bobwhites in South Georgia. Pages 128–131 *in* L. A. Brennan, W. E. Palmer, L. W. Burger Jr., and T. L. Pruden, editors. Quail IV:

Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, Florida.

______, D. W. Speake, and H. L. Stribling. 2000*b*. Survival of northern bobwhites on areas with and without liberated bobwhites. Pages 92–94 *in* L. A. Brennan, W. E. Palmer, L. W. Burger Jr., and T. L. Pruden, editors. Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, Florida.

Smith, P. G. 2003. Compos Analysis, version 5.1 plus [software]. Smith Ecology Ltd., Abergavenny, UK.

Stoddard, Herbert L. 1931. The bobwhite quail: its habits, preservation, and increase. Charles Scribner Sons. New York, New York.

Taylor, J. D. and L. W. Burger Jr. 1997. Reproductive effort and success of northern bobwhite in Mississippi. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 51:329–341.

Vance, R. V. 1976. Changes in land use and wildlife populations in southeastern Illinois. Wildlife Society Bulletin 4:11–15.

White, G. C. and R. A. Garrott. 1990. Analysis of radio-tracking data. Academic Press, New York, New York.

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.

______. 1997. Northern bobwhite brood habitat use on intensively managed lands in southwest Georgia. Master's Thesis. Auburn University, Auburn, Alabama.