NORTHERN BOBWHITE HABITAT USE AND NESTING ECOLOGY IN A FOREST- AND AGRICULTURE-DOMINATED SYSTEM

by

IRA BYRD PARNELL, III

(Under the direction of Sara H. Schweitzer)

ABSTRACT

Changes in land use that reduce habitat availability and quality for Northern bobwhites (*Colinus virginianus*) are thought to be the major cause of Southeastern bobwhite population declines. Increased conversion of open habitats to densely stocked pine plantations (*Pinus* spp.) has contributed to this habitat loss. We examined the habitat use and nesting ecology of a bobwhite population in the upper coastal plain of Georgia to determine what role pine plantations, including those established as part of the 1985 Farm Bill's Conservation Reserve Program (CRP), have within bobwhite habitat use and nesting ecology. Using radio-telemetry, we monitored 164 radio-marked bobwhites from 1997-2000 and documented habitat use, nest locations and fates, habitat surrounding nests, and adult mortality locations. Our results suggest that recommendations of the 1996 Farm Bill to thin and create openings within established CRP pine stands would potentially increase habitat for bobwhites within this landscape.

INDEX WORDS: Bobwhite, *Colinus virginianus*, CRP, Early successional, Georgia, Habitat use, Nesting ecology, Pine plantation, Quail, Radio-telemetry, Survival

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DEDICATION

I would like to dedicate this document to my wife, Michelle. Without her support and encouragement I would never have finished this thesis. She has listened to more observations and frustrations concerning quail management than any woman should. Thank you and I love you, honey. I must also give glory to God for the many blessings He has provided for me during my life – His Son and my Savior Jesus Christ, my wonderful wife, and a family that is second to none.

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I would like to express my gratitude to the Georgia Department of Natural Resources, Wildlife Resources Division, Game Management Section, for their support both with personnel and facilities that made this project possible. In particular, I would like to acknowledge the staff at Di-Lane Plantation Wildlife Management Area. Without John Bearden's assistance and cooperation, my life would have been much more difficult.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Northern bobwhite (*Colinus virginianus*), hereafter bobwhite, populations in the Southeast have been declining since the 1920s, and have dropped by 66% from 1966 to 1999 (Sauer et al. 2001). Proposed reasons for this decline include: 1) loss of habitat as a result of changing land use practices (Frye 1961, Exum et al. 1982, Klimstra 1982), 2) increases in avian and mammalian predator populations (Rollins and Carroll 2001, Sauer et al. 2001), 3) introduction of fire ants (*Solenopsis invicta*) (Allen et al. 1993, Brennan 1993, Allen et al. 1995, Pedersen et al. 1996), and 4) increased use of pesticides (Percival et al. 1973, Palmer et al. 1998). Loss of habitat due to changing land use practices has been suggested as the primary reason contributing to this decline (Brennan 1991, Rollins and Carroll 2001). Many former low intensity farms are now intensively managed for agriculture and timber production (Rollins and Carroll 2001). Large areas of intensive agriculture and timber management fragmented what little early successional habitat remained. Within this landscape, we hypothesized that improving habitat for bobwhites by thinning pine stands would be a practical method to reverse declines in bobwhite populations. Further, habitat improvement is the first step that an average landowner should take to increase numbers of bobwhites on their land (Stoddard 1931, Taylor et al. 1999).

Bobwhites require specific nesting habitat, brood-rearing habitat, feeding areas, roosting areas, and appropriate escape cover to survive (Stoddard 1931, Rosene 1969). Early successional habitat, areas disturbed every 1-4 years, meets these life requirements

(Stewart et al. 1997). Many acres of agricultural and idle lands in the Southeast have been planted to loblolly pines (*Pinus taeda*) through the Conservation Reserve Program (CRP). The CRP was a voluntary program created by the 1985 Food Security Act, also known as the Farm Bill (McKenzie 1997). The CRP was a federal program that was originally designed to control crop commodity supply and soil erosion (Isaacs and Howell 1988, McKenzie 1997). It accomplished these objectives by offering financial incentives to landowners in return for planting vegetative cover. In the Southeast, this planted vegetation was almost entirely loblolly pine. Most of these pine plantations were managed for wood fiber production. Silvicultural systems that maximize wood fiber production contribute to wildlife habitat loss (Brennan 1991). Since 1985, approximately 609,410 ha of marginal farmland in the Southeast have been converted into dense (≥1,793 trees/ha) loblolly pine plantations through the CRP (Appendix A). Unthinned pine plantations (>6 years) do not provide early successional habitat because they are devoid of understory vegetation and, therefore, do not meet the life requirements of bobwhites (Brunswig and Johnson 1972, Jackson 1990, Stauffer et al. 1990, Capel et al. 1995, Carmichael 1997).

Congress changed the goals of the CRP through revisions in 1990, 1995, and 1996. The 1996 program gave equal status to 3 major objectives: improvement of water quality, decreased soil erosion, and improvement of wildlife habitat (McKenzie 1997). To be considered eligible for the program, land had to meet certain criteria. The land must have been farmed 3 out of 5 years and have met a potential erosion threshold (Erosion Index [EI]). Each field was given a score for environmental benefits called the Environmental Benefits Index (EBI). The EBI score was an objective method of quantifying the environmental benefits that could be realized if the proposed conservation practice(s) was implemented. One method landowners could use to improve a field's EBI was through selection of Conservation Practices (CP). Conservation Practices ranged from planting introduced grasses to hardwood or softwood tree planting. Fields were selected in a competitive ranking process where those fields with the highest EBIs, relative to other applications, were offered 10-15 year contracts after which they may be eligible for re-enrollment. As encouragement to enroll, landowners whose contracts were accepted received incentives (annual rental payments) for each acre enrolled in the CRP plus a 50% cost-share on the CP that they installed (McKenzie 1997). In the Southeast, most landowners chose CP3 and opted to plant loblolly pine on their land enrolled in the CRP (Allen 1993). Landowners received more than rental payments and cost-sharing for the tree planting; they were also allowed to keep the profit from harvesting the trees after the contract expired.

Closed canopy pine plantations can be manipulated to provide understory vegetation beneficial to northern bobwhites and other wildlife species by row-thinning and/or strip-thinning, to allow sunlight to reach the ground (Conroy et al. 1982). Lack of understory vegetation can be detrimental to many wildlife species in the Southeast; consequently, biologists lobbied for changes to the 1985 Farm Bill that would change the CRP guidelines so that CRP lands might be more beneficial to wildlife.

The 1996 CRP guidelines for re-enrolling pine plantations assigned the highest priority to thinning and the creation of wildlife openings in pine plantations, thus improving the habitat for wildlife. These changes in the CRP guidelines had the potential to affect more than 261,510 ha (Appendix B) of planted pines in Georgia alone. Over

70% of landowners surveyed with acreage in CRP stated that they would like to improve wildlife habitat on their land (Miller and Bromley 1989). If research can demonstrate that bobwhites select thinned planted pines (open canopy planted pines) over unthinned pines (closed canopy planted pines), then more landowners might consider thinning and 609,410 ha (Appendix A) of pine plantation habitat in the Southeast could be improved for bobwhites and other species also associated with early successional habitat.

Study Area

Two study areas were selected for this project that were representative of agricultural land found in the Upper Coastal Plain ecological region of eastern Georgia: Di-Lane Plantation Wildlife Management Area (WMA) and Alexander WMA. Both areas were located in Burke County, Georgia and were selected because of their location within the Upper Coastal Plain ecological region, their proximity to each other, and the presence of CRP and CRP-like pine plantations on the properties.

Di-Lane Plantation WMA, hereafter Di-Lane, was a 3,278-ha area located 24 km south of Waynesboro, Georgia. Historically, Di-Lane was privately owned and managed as a bobwhite hunting plantation then, for approximately 10 years before state control of Di-Lane, it was managed as a working agricultural farm. Any land that would qualify (286 ha) was enrolled into the CRP and planted with loblolly pine seedlings. All other open land (849 ha) was rented to local farmers for agricultural production. In 1992, the Georgia Department of Natural Resources (GA DNR) began to manage Di-Lane through an agreement with the United States Army Corps of Engineers (COE). The COE acquired the property as mitigation land for a dam project. Di-Lane became a multiple use area, but the main wildlife focus was bobwhite management. The Di-Lane study area included 11,680 ha that encompassed all radio-locations of bobwhites monitored from 1997-2000. Di-Lane consisted of 4 dominant habitat types ($\bar{x} \pm$ SD): hardwoods (4,246 ± 51 ha), agricultural areas (3,355 ± 74 ha), pine plantations (2,554 ± 110 ha), and fallow fields (1,483 ± 79 ha).

The Alexander WMA, hereafter Alexander, was a 555-ha area located 16 km southeast of Waynesboro, Georgia. It was acquired by the GA DNR in 1997 and management for wildlife began in 1998. The Alexander study area included 3,287 ha and was expanded to encompass all radio-locations of bobwhites. It also was composed of 4 dominant habitat types ($\bar{x} \pm$ SD): pine plantations (1,401 ± 16 ha), hardwoods (1,152 ± 15 ha), agricultural areas (849 ± 4 ha), and fallow fields (366 ± 30 ha).

In 1997, 3 experimental CRP pine stands on Di-Lane were selected, and 3 experimental pine stands were selected on Alexander in 1998. One of 3 treatments (no manipulation (control), row-thin (33% thinning), row- and strip-thin (53% thinning)) was randomly assigned to each experimental stand. Treatments were implemented during spring 1998. Baseline data on bobwhite habitat use, survival rates, and reproductive rates were gathered on Di-Lane during the 1997 field season and compared to post treatment data.

Objectives

The purposes of this study were to monitor the use of habitat types by bobwhites, to estimate rates of survival, and to determine nesting success and nest site habitat within an intensively managed landscape of agriculture and forestry. I hypothesized that bobwhites would select early successional habitat (i.e., fallow fields, agricultural fields, and open-canopy planted pines) more often than other available habitats (i.e., hardwoods, closed-canopy planted pines), and that the silvicultural treatments encouraged under the 1996 CRP guidelines would improve habitat conditions for bobwhites. The objectives of our study were achieved by answering the following questions and testing the hypotheses associated with them:

1) Within this forest-dominated system, what specific habitat types were bobwhites using for home ranges and was selection also occurring within home ranges?

> H_0: Bobwhites used habitat as it was available on the study area for home ranges and home range habitat also was used according to availability.
>
> H_a: Bobwhites used early successional habitat (fallow fields and open-canopy planted pines) for home ranges and also used these habitats selectively within home range.

2) At the home range level, did bobwhites use open canopy planted pine stands more often than closed canopy planted pine stands?

> H_o: There was no difference in the habitat use of open-canopy versus closed-canopy planted pine stands.
>
> H_a: There was greater habitat use of open-canopy planted pine stands than closed-canopy planted pine stands.

3) Did bobwhite nest site habitat differ among measured microhabitat variables?

> H_o: Nest site habitat was random relative to measured microhabitat variables.
>
> H_a: Nest sites habitat was non-random relative to measured microhabitat variables.

4) Were bobwhite mortality locations found in each habitat type equal to the proportion that the habitat was used?

H_o: Bobwhite mortality locations were found in equal proportion to habitat used.

H_a: Bobwhite mortality locations were found in higher proportions than expected in late successional habitats.

Literature Cited

Allen, A. W. 1993. Wildlife habitat criteria in relation to future use of CRP lands. Proceedings of the Great Plains Agricultural Council Annual Meeting. June 2-4, 1993. Rapid City, South Dakota, USA.

Allen, A. W. 1994. Regional and state perspectives on Conservation Reserve Program contributions to wildlife habitat. Federal Aid Report. United States Fish and Wildlife Service. National Ecology Research Center, Fort Collins, Colorado, USA.

Allen, C. R., R. S. Lutz, and S. Demarais. 1993. What about fire ants and northern bobwhites? Wildlife Society Bulletin 21: 349-351.

Allen, C. R., R. S. Lutz, and S. Demarais. 1995. Red imported fire ant impacts on northern bobwhite populations. Ecological Applications 5: 632-638.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544-545.

Brennan, L. A. 1993. Fire ants and northern bobwhites: a real problem or a red herring? Wildlife Society Bulletin 21: 351-355.

Brunswig, N. L., and A. S. Johnson. 1972. Bobwhite quail foods and populations on pine plantations in the Georgia piedmont during the first seven years following site preparation. Annual Conference of the Southeastern Association of Game and Fish Commissioners 26:96-107.

Capel, S., B. Carmichael, M. Gudlin, and D. Long. 1995. Wildlife habitat needs assessment, Southeast region. Transactions of the North American Wildlife and Natural Resources Conference 60:288-299.

Carmichael, D. B., Jr. 1997. The Conservation Reserve Program and wildlife habitat in the southeastern United States. Wildlife Society Bulletin 25:773-775.

Conroy, M. J., R. G. Oderwald, and T. L. Sharik. 1982. Forage production and nutrient concentrations in thinned loblolly pine plantation. Journal of Wildlife Management 46:719-727.

Exum, J. H., Dimmick, R. W., and B. L. Dearden. 1982. Land use and bobwhite populations in an agricultural system in west Tennessee. Pages 6-12 *in* F. Schitoskey, Jr., E .C. Schitoskey, and L. G. Talent, editors. Proceedings of the second national bobwhite quail symposium. Stillwater, Oklahoma, USA.

Farm Service Agency. 1997. The Conservation Reserve Program. United States Department of Agriculture. Washington, DC, USA.

Frye, O. E., Jr. 1961. A review of bobwhite quail management in eastern North America. Transactions of the North American Wildlife Conference 26:273-281.

Isaacs, B., and D. Howell. 1988. Opportunities for enhancing wildlife benefits through the Conservation Reserve Program. Transactions of the North American Wildlife and Natural Resources Conference 53:222-231.

Jackson, J. 1990. Bobwhite quail and the southern pine plantation. Forest Farmer 49:22-23.

Johnson, A. S., J. L. Landers, and T. D. Atkeson. 1974. Wildlife in young pine plantations. Pages 147-159 *in* W. E. Balmer, editor. Proceedings of the Symposium on Management of Young Pines. United States Department of Agriculture, Forest Service. Charleston, South Carolina, USA.

Klimstra, W. D. 1982. Bobwhite quail and changing land use. Pages 1-5 *in* F. Schitoskey, Jr., E. C. Schitoskey, and L. G. Talent, editors. Proceedings of the second national bobwhite quail symposium. Stillwater, Oklahoma, USA.

McKenzie, D. F. 1997. A wildlife manager's field guide to the Farm Bill. United States Department of Agriculture. Wildlife Management Institute Report, Washington, DC, USA.

Miller, E. J., and P. B. Bromley. 1989. Wildlife management on Conservation Reserve Program land: The farmer's view. Transactions of the North American Wildlife and Natural Resources Conference 54:377-381.

Palmer, W. E., K. M. Puckett, J. R. Anderson, and P. T. Bromley. 1998. Effects of foliar insecticides on survival of northern bobwhite quail chicks. Journal of Wildlife Management 62:1565-1573.

Percival, H. F., L. G. Webb, and J. K. Reed. 1973. Concentrations of selected chlorinated hydrocarbon insecticides in bobwhite quail in South Carolina. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 26:108-117.

Pedersen, E. K., W. E. Grant, and M. T. Longnecker. 1996. Effects of red imported fire ants on newly-hatched northern bobwhite. Journal of Wildlife Management 60:164-169.

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

Rosene, W. 1969. The bobwhite quail: its life and management. The Sun Press, Hartwell, Georgia, USA.

Sauer, J. R., J. E. Hines, I. Thomas, J. Fallon, and G. Gough. 1999. The North American Breeding Bird Survey, Results and Analysis 1966-1998. Version 98.1, United States Geologic Survey, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Stauffer, D. F., G. A. Cline, and M. J. Tonkovich. 1990. Evaluating potential effects of CRP on bobwhite quail in Piedmont Virginia. Transactions of the North American Wildlife and Natural Resources Conference 55:57-67.

Stewart, D., D. Godwin, and L. W. Burger, Jr. 1997. Ecology and management of the northern bobwhite, part II. Quail Unlimited Magazine 16:8-11.

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

Taylor, J. S., K. E. Church, D. H. Rusch, and J. R. Cary. 1999. Macrohabitat effects on summer survival, movements, and clutch success of northern bobwhite in Kansas. Journal of Wildlife Management 63:675-685.

CHAPTER 2

NORTHERN BOBWHITE HABITAT USE IN A FOREST- AND AGRICULTURE-DOMINATED SYSTEM[1]

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[1]Parnell, Ira B., III, S. H. Schweitzer, C. G. White, L. A. Lewis and J. P. Carroll. To be submitted to *Wildlife Society Bulletin*.

Abstract: Changes in land use that reduce habitat availability and quality for northern bobwhite (*Colinus virginianus*) are thought to be the major cause of bobwhite population decline in the Southeast. Increased conversion of open habitats to densely stocked pine plantations (*Pinus* spp.) has contributed to habitat loss. We examined the habitat use of a bobwhite population in the Upper Coastal Plain of Georgia, a landscape dominated by intensively managed forests and agriculture. Purposes of this study were to monitor habitat selection by bobwhites in this forest and agriculture system and to determine the importance of pine plantations, including those established as a conservation practice of the Conservation Reserve Program (CRP), relative to other available habitats. To date little research has been conducted to determine bobwhite habitat selection within an intensively managed forest- and agriculture-dominated system. Previous bobwhite research studies in the Southeast have been most often undertaken on lands managed specifically for bobwhites. The average landowner does not have the resources necessary to manage their lands exclusively for bobwhites, and this study was conducted on lands managed for multiple uses, such as agriculture, timber, and wildlife. We determined average home range size and habitat selection of 61 radio-marked bobwhites during 1997-2000. Selection of habitats by radio-marked bobwhites ($\lambda = 0.35$, $P \leq 0.001$) supported our hypotheses that they would prefer early-successional habitats within the forest-dominated study area. Bobwhites selected open-canopy planted pine and fallow field habitats in preference to closed-canopy planted pine and agricultural areas. Thinning to create open-canopy planted pine stands will benefit bobwhites by providing additional early successional habitat. Our results suggest that managing for bobwhites with fallow fields and open-canopy planted pines will provide preferred habitat within this landscape. We believe that thinning pine stands is a management practice that is feasible for the average landowner to implement. Habitat improvement is the first step that a landowner should take to increase numbers of bobwhites on their land.

Key words: bobwhite, *Colinus virginianus*, Conservation Reserve Program, early successional, Georgia, habitat use, pine plantations, quail, radiotelemetry, Southeast, survival

Northern bobwhite (hereafter, bobwhite) populations in the southeastern United States have been declining since the 1920s, and have dropped by 66% from 1966 to 1999 (Sauer et al. 2001). Proposed reasons for this decline include loss of habitat due to changing land use practices (Frye 1961, Exum et al. 1982, Klimstra 1982), increases in avian and mammalian predator populations (Rollins and Carroll 2001, Sauer et al. 2001), introduction of fire ants (*Solenopsis invicta*) (Allen et al. 1993, Brennan 1993, Allen et al. 1995, Pedersen et al. 1996), and increased use of pesticides (Percival et al. 1973, Palmer et al. 1998). Loss of habitat due to changing land use practices has been proposed as a primary factor contributing to this decline (Stoddard 1931, Frye 1961, Exum et al. 1982, Klimstra 1982).

Bobwhites require nesting habitat, brood-rearing habitat, feeding areas, roosting areas, and appropriate escape cover to survive (Stoddard 1931, Rosene 1969). Early successional habitats are areas disturbed every 1-4 years and they meet the life requirements of bobwhites (Stewart et al. 1997). Periodic disturbance sets back plant succession so that it is maintained in annual and perennial vegetation. Areas disturbed in the past 1-2 years are composed of annuals, such as ragweed (*Ambrosia artimisiifolia*), partridge pea (*Cassia nictitans* and *C. fasciculata*), and beggarweed (*Desmodium* spp.). These areas provide brood-rearing habitat by offering overhead cover from the sun and predators while still being open enough in the understory for broods to move about freely and forage for insects (Stoddard 1931, Moser and Palmer 1997). Areas disturbed 3-4 years prior are composed of more perennials, such as blackberry (*Rubus* spp.) and broomsedge (*Andropogon virginicus*), and provide escape cover, roosting areas, and nesting habitat (Stoddard 1931, Rosene 1969).

Intensive silvicultural practices that maximize wood fiber production contribute to wildlife habitat loss, and subsequently, to bobwhite population declines (Brennan 1991, Rollins and Carroll 2001) because trees are planted at high stocking rates leading to early canopy closure (5-6 years; Brennan 1991, Capel et al. 1995, Carmichael 1997). After canopy closure, little vegetation in the understory persists to provide food, escape cover, brood habitat, or nesting cover for bobwhites (Brunswig and Johnson 1972, Johnson et al. 1974, Jackson 1990, Stauffer et al. 1990, Allen 1994). In addition to habitat losses attributed to intensive silvicultural practices, 609,410 ha of marginal farmland in the southeastern United States were converted into dense (≥726 trees/acre; ≥1,793 trees/ha) loblolly pine (*Pinus taeda*) plantations through the Conservation Reserve Program (CRP) of the Farm Bill starting in 1985 (Farm Service Agency 1997; Appendix A). There were more than 261,510 ha of CRP pine plantations in Georgia as of 1992 (Appendix B). Closed-canopy pine plantations can be manipulated to provide understory vegetation beneficial to bobwhites and other wildlife species by thinning or creating openings in the tree canopy allowing sunlight to reach the ground (Rosene 1969, Conroy et al. 1982).

We investigated bobwhite habitat use within an agricultural landscape that had several thousand hectares of marginal cropland planted to loblolly pines (*Pinus taeda*) at ≥1,793 trees/ha as part of the 1985 CRP. We wanted to determine if these densely-planted CRP stands were used or avoided by bobwhites, and if modifications to these stands would increase their use by bobwhites thereby increasing the amount of useable habitat in this landscape. Impacts on bobwhites of the 1985 CRP, as implemented in the Southeast, had not been investigated prior to our study.

Many bobwhite research studies have been undertaken on lands managed intensively for bobwhites in the southeastern U.S. Most landowners do not have the resources necessary to manage their lands exclusively for bobwhites. This study was conducted in a landscape where landowners had multiple objectives in mind, such as agriculture, timber, and wildlife. With a better understanding of bobwhite habitat selection within this system, we can provide these individuals with practical management recommendations for their land. We hypothesized that bobwhites would select early successional habitat, including thinned pine stands, and would avoid dense forest habitats, particularly closed-canopy pine plantations.

Study Area

Our 2 study areas (Di-Lane Plantation Wildlife Management Area (WMA) and Alexander WMA) included land that was representative of agricultural lands that had been planted in pines after the 1985 CRP sign-up period. The landscape surrounding these pine plantations was an interspersion of row-crop fields, pastures, and bottomland hardwoods along streams and creeks and was typical of habitat found throughout the Upper Coastal Plain ecological region of eastern Georgia. The average temperature was 25.8 degrees Celsius during the summer and 8.9 degrees Celsius in the winter; the average annual precipitation was 1,137.7 mm (Georgia State Climate Center 2002). The predominant soil types of this region were sandy clay loams of the Dothan, Fuquay, and Tifton soil series (Paulk 1986).

Di-Lane Plantation WMA (32 58’ 07” N, 82 05’ 04” W), hereafter Di-Lane, was a 3,278-ha area located 24 km south of Waynesboro, Burke County, Georgia. Historically, Di-Lane was managed as a private bobwhite hunting area. However, from 1976-1991, Di-Lane was a working agricultural farm. It enrolled 286 ha in the CRP and those areas were planted in loblolly pine in 1988. All other open land (849 ha) was rented to local farmers for agricultural production. In 1992, the property was purchased by the United States Army Corps of Engineers as mitigation land and given to the Georgia Department of Natural Resources (GA DNR) to manage for public use. The GA DNR determined that the primary wildlife focus would be bobwhite management.

Radio-marked bobwhites moved beyond the original study area boundaries; therefore, the Di-Lane study area was expanded to 11,680 ha to encompass and buffer (800 m) all radio-locations of bobwhites monitored from 1997-2000. Di-Lane consisted of 4 predominant habitat types ($\bar{x}$ ± SD): hardwoods (4,246 ± 51 ha), agricultural areas (3,355 ± 74 ha), pine plantations (2,554 ± 110 ha), and fallow fields (1,483 ± 79 ha).

Alexander WMA (33 00' 22" N, 81 54' 57" W) was a 555-ha area located 16 km southeast of Waynesboro, in Burke County, Georgia. It had been mostly a row-crop agricultural area, but like Di-Lane, much of it was converted to loblolly pine plantations in the mid-1980s. The property was acquired by the GA DNR in 1997 and was used as a small game and archery-only deer (*Odocoileus virginianus*) hunting area. Bobwhites radio-marked on the Alexander WMA also traveled beyond the original study area boundaries; hence the study area was expanded to incorporate and buffer (800 m) all locations of radio-marked bobwhites (3,786 ha). Although in different proportions, the Alexander study area consisted of the same 4 predominant habitat types ($\bar{x}$ ± SD) present on Di-Lane: pine plantations (1,401 ± 16 ha), hardwoods (1,152 ± 15 ha), agricultural areas (849 ± 4 ha), and fallow fields (366 ± 30 ha). Habitat types on the study area were delineated by referencing U. S. Geologic Survey 1993 Digital Orthophoto Quarter

Quadrangle (DOQQ) maps and were correctly classified using our knowledge of the study area, on-site inspection, and remote imagery. Habitat types on our study areas were digitized at a scale ≥1:3,000 m using the ArcView™ (Environmental Systems Research Institute, Inc. 1992) geographic information system (GIS) computer program overlaid onto the DOQQ maps.

Methods

Bobwhites were captured and radio-marked from January-June, 1997-2000. Bobwhites were captured using 2.5-cm x 5-cm mesh wire funnel traps baited with cracked and whole kernel corn (Stoddard 1931). Traps were set in early January and were checked in mid-morning and late afternoon to reduce stress, exposure to predation, and injury to captured birds. All bobwhites captured were handled and released in accordance with the procedures of The University of Georgia Institutional Animal Care and Use Committee (IACUC Protocol No. A960216C2).

After capture, the sex, weight, and age of each bird were recorded, and a size 3 aluminum leg band and 6.1-g necklace-style radio transmitter (Holohil Systems, Ontario, Canada) were fitted on each bird. Transmitters had a battery life of >6 months and were replaced after failure, when recapture was possible, to continue monitoring a marked bird.

Following release, bobwhites were allowed 1 day to acclimate to the transmitter and thereafter were located once every 1-3 days, using a R4000 receiver equipped with a 3-element Yagi antenna (Advanced Telemetry Systems, Anoka, Minnesota). The homing technique (Mech 1983) was used to locate radio-marked bobwhites. The type of habitat bobwhites used was recorded and each location was marked with flagging. A

Geoexplorer II hand-held global positioning system (GPS) receiver (Trimble Navigation Ltd., Sunnyvale, California) was used to obtain Universal Transverse Mercator (UTM) coordinates of each flagged location. Birds were flushed about once a week to determine which marked birds were paired with unmarked mates during the breeding season. Location times were staggered throughout the day and results were used to determine individual home range, habitat use, and survival from late April to early September. We followed the "one variable for every 10 observations" rule as a guideline (Burnham and Anderson 1998). Habitat types were separated into 6 categories: fallow field, open-canopy planted pine (OCPP: pine stands thinned in 1994, in 1998, and planted pines that were <5 years old), closed-canopy planted pine (CCPP: unthinned planted pines that were 6-20 years old and mature natural pines), hardwood, hedgerow, and agricultural areas (including row-crops, pastures, hayfields, and pecan orchards).

In 1997, 3 CRP experimental pine stands on Di-Lane were selected, and 3 experimental pine stands were selected on Alexander WMA in 1998. One of 3 treatments (no manipulation (control), row-thin (33% thinning), row- and strip-thin (53% thinning)) was randomly assigned to each experimental stand. Treatments were implemented on both study areas during spring 1998. Baseline data on bobwhite habitat use, survival rates, and reproductive rates were gathered on Di-Lane Plantation WMA during the 1997 field season and compared to post treatment data.

Nests were found by locating a radio-marked bird in the same position for several consecutive days. Nesting success was determined using the Mayfield method (Mayfield 1961), defining a successful nest as one in which at least one egg hatched. Nests were monitored daily to determine nest fates. Adult survival rates were estimated using the

Stagkam staggered entry survival program (Kulowiec 1988). Cause of mortality was determined when possible from bird remains and damage found on the transmitter. We also recorded the habitat type where the dead bird was found. A Chi-square (χ^2) goodness-of-fit test and a Bonferroni *z*-statistic (Neu *et al*. 1974) were used to test for statistical significance ($P \leq 0.05$) between the observed number of dead bobwhites in each habitat type and the number of dead bobwhites that we would have expected to find in each habitat based on its use by radio-marked individuals. The end of each field season was 1 September.

Global positioning system coordinates were imported into the ArcView GIS. The Hooge and Eichenlaub (1999) ArcView home range extension was used to construct individual home ranges as 100% minimum convex polygons. Compositional analysis (Aebischer et al. 1993) of daily habitat locations and home ranges was conducted using the MacComp 0.90 program (J. P. Carroll, University of Georgia) to detect significant departures from random habitat use by bobwhites. We used 2 levels of comparison in our compositional analysis. The first level compared proportions of each habitat type available for use on the study area to proportions of those habitat types found within a home range. The second compared proportions of individual radio-locations in each habitat type within each home range to the availability of that habitat type within each home range. The SYSTAT® statistical package was used to determine whether year effects were present at each level of compositional analysis (SYSTAT 1992).

Results

One hundred and fifty-one bobwhites were captured (52 in 1997, 35 in 1998, 31 in 1999, and 33 in 2000) on Di-Lane and 13 bobwhites were captured (4 in 1998, 4 in

1999, and 5 in 2000) on Alexander. Only birds that had ≥14 radio-locations after separation from their covey were used in habitat selection analyses. Data from 55 bobwhites on Di-Lane and 6 from Alexander from the 1997-2000 field seasons were used in habitat analyses. Because few birds were captured on the Alexander study area, they were incorporated into the Di-Lane dataset. Habitat types found on the study areas were similar, but their availability was different. These differences were accounted for within the compositional analysis program. We assumed that the compositional analysis program was robust enough to handle combining these datasets without compromising the integrity of the overall dataset.

Nest Success

Nesting began in mid-May and continued until late September (I. B. Parnell, University of Georgia, personal observation). Thirty-one nests of radio-marked bobwhites were located from 1997-2000. Nesting success varied widely from 1997-2000 (35% in 1997, 51% in 1998, 83% in 1999, and 16% in 2000). Twelve nests were located in fallow fields, 5 in open-canopy planted pines (OCPP), 12 in closed-canopy planted pines (CCPP), 1 in agricultural fields, and 1 in young upland hardwoods. At least 1 successful nest was found in each habitat type except young upland hardwoods. In all field seasons, nests located in CCPP stands were located <15 m from an edge.

Adult Survival

The percentage of radio-marked bobwhites that survived ($\bar{x}$ ± SD) on Di-Lane and Alexander from capture to 23 August was 13 ± 0.05% (1997, n = 52), 18 ± 0.08% (1998, n = 35), 25 ± 0.08% (1999, n = 35), and 11 ± 0.04% (2000, n = 38). Most mortality of radio-marked bobwhites was due to predation (83%, 1997-2000), except 4 were hunterkilled, 5 died in traps, 1 died due to entanglement in the transmitter harness, and 1 died from lead toxicosis (Lewis and Schweitzer 2000). Ninety-five mortality locations were collected from January – August 1997-2000. Forty-five of these were found from 15 April – August 1997-2000, the same time period that habitat use by individual birds was monitored. Mortalities were located in all habitat types in varying proportions. Twelve dead bobwhites were found in fallow fields, 10 in CCPP, 10 in OCPP, 9 in hardwoods, 2 in hedgerows, and 2 in agricultural areas. The χ^2 analysis did not detect a difference between observed and expected locations of dead birds ($\chi^2 = 5.34$; df = 5; $P = 0.38$).

Home Range and Habitat Selection

The average minimum convex polygon home range size ($\bar{x} \pm$ SD) for bobwhites from May-August was 40 ± 47 ha (8-203 ha) in 1997, 98 ± 92 ha (14-257 ha) in 1998, 134 ± 159 ha (12-611 ha) in 1999, and 116 ± 167 ha (8-693 ha) in 2000. The median home range for each year (1997-2000) was 21, 54, 85, and 42 ha, respectively. In compositional analysis, year effects were present at the study area versus home range level of comparison ($F = 2.94$; df = 15, 146; $P \leq 0.001$), but not at the home range versus radio-location level ($F = 1.21$; df = 15, 146; $P = 0.27$). Proportions of each delineated habitat category available on our study areas differed from habitat proportions found within individual bobwhites' home range in each study year except 2000 (Table 2.1; 1997 $\lambda = 0.14$, $P \leq 0.001$; Table 2.2; 1998 $\lambda = 0.15$, $P = 0.01$; Table 2.3; 1999 $\lambda = 0.19$, $P = 0.01$, 2000 $\lambda = 0.49$, $P = 0.37$). Bobwhite home range selection for 1997-1999 favored fallow fields and open canopy pines, avoided agricultural areas, hedgerows and closed canopy pines, and used hardwoods intermediately. In 2000, home range selection was not different from random within the study area. Because there was no year effect at the home range versus radio-location level of comparison (*P* = 0.27), data were pooled over years. Habitat use differed from random (Table 2.4; $\lambda = 0.35$, $P \leq 0.001$) at this level; bobwhite habitat selection within their home ranges favored open-canopy pines and fallow fields, but avoided agricultural areas and hedgerows. Closed-canopy pines and hardwoods were used intermediately.

Treatment pine stands comprised 9.4% of the OCPP category and 1.3% of the CCPP category. During 1997-1998, there were no radio-locations of marked bobwhites in experimental stands (Lewis 1999); however, 13 marked bobwhites included experimental stands in their home ranges. In 1999-2000, there were 2 documented locations of coveys and 2 individual bobwhite locations within the row- and strip-thinned experimental stands. Nineteen bobwhite home ranges encompassed treatment stands during the study. In 1997, before treatment implementation, 7 of 18 home ranges included experimental stands; in 1998, also before treatment implementation, 6 of 10 home ranges included experimental stands; in 1999, post treatment implementation, 3 of the 13 individual home ranges included the row- or strip-thinned stands and none included the control stand; and in 2000, 3 of the 20 marked birds' home ranges contained the row-thinned or row- and strip-thinned treatment stands and 1 home range contained a control stand.

Discussion

Nest Success

We documented wide variation in nest success among years (16-83%). This variation in nesting success could be attributed to the number of nests that we monitored (*n*=31). We expected to find the greatest number of nests in fallow fields (*n*=12) because of the clumped broomsedge habitat found there (Washburn et al. 2000, Madison et al. 2001), but we did not expect to find as many nests located in CCPP stands (*n*=12). Closed-canopy planted pine stands had little understory vegetation, particularly broomsedge, in the interior but did have limited vegetation growth along the stand edges (S. H. Schweitzer and P. E. Hale, University of Georgia, unpublished data). Although the CCPP habitat was not preferred at the home range level, bobwhites nested successfully in CCPP in all field seasons. Eleven of 12 nests located within CCPP were found <15 m (50 feet) of an edge, and, based on observations of radio-marked birds, adults moved the chicks to other habitat types shortly after hatching. Our observations supported the findings of Rosene (1969) who noted in his studies that most bobwhite nests were located within 50 feet (15 m) of an edge. The observation of bobwhites moving their broods out of the CCPP habitat type shortly after hatching suggested that while edges of CCPP functioned as adequate nesting habitat, these stands were not providing brood-rearing habitat for bobwhites because they were lacking bare ground and necessary vegetative structure (Taylor et al. 1999*b*, Washburn et al. 2000).

Adult Survival

Annual adult bobwhite survival rates during our study were comparable to those documented in other studies (Stoddard 1931, Rosene 1969, Burger et al. 1995). Locations of dead, radio-marked birds were not found in the proportions one might expect according to habitat use (Figure 2.1). If locations of dead birds were distributed in proportion to the habitat use, we would have found the greatest number of dead birds in fallow fields and OCPP. Fallow fields did contain the greatest number of dead birds. However, we documented more dead birds in CCPP and hardwoods than we would have expected based on habitat use. We cannot be certain that the area where a dead bobwhite was located was the actual site where the bird was killed. It is possible that bobwhites were killed in adjacent habitat types, then taken by a predator or scavenger to the areas in which we found the remains. However, the location of the mortality site could still be important; the juxtaposition of certain habitat types may make bobwhites more susceptible to depredation. Lewis (1999) noted that if bobwhites were being depredated when using the CCPP habitat, then the CCPP could be acting as an ecological trap. On our study area, bobwhites had to travel through areas with little understory vegetation (CCPP, mature hardwood bottomlands, and open agricultural fields) when moving between patches of early successional habitat. Increasing connectivity and creating more patches of early successional habitat as a result of thinning CCPP may provide better vegetative cover and travel corridors for bobwhites. By providing more early successional habitat and connecting areas of existing cover, adult survival rates should increase and the local population might begin to rebound (Taylor et al. 1999*a*).

Home Ranges and Habitat Selection

Although average home range sizes for bobwhites on our study areas were comparable to those found in the literature (Taylor et al. 1999*a*), few other studies have documented home range sizes of radio-marked individuals during the breeding season. Average home range size increased from 40 ha to 134 ha from the first year to the third year of our study, then dropped down to 116 ha in the fourth year. This increase in home range size could be attributed to deficiencies in the available habitat towards meeting the daily life requirements of breeding bobwhites on our study area. If the habitat in a given area was not meeting these life requirements, then presumably, the birds would have to travel in search of habitat that did meet these needs.

Bobwhites selected specific habitat types within our study area for their home ranges. Further evidence for selection of habitat types within their home ranges was shown by individual radio-locations. Bobwhites showed preference for early successional habitat, specifically, open-canopy pines and fallow fields. Bobwhites demonstrated avoidance of hedgerows and agricultural areas (Tables 2.2 and 2.4; Figures 2.2 and 2.3). Other research determined that bobwhites were an open land species that thrived in agricultural fields broken up by hedgerows (Stoddard 1931, Rosene 1969). Bobwhite avoidance of hedgerows could be explained by the composition of these habitat types on our study area. Most hedgerows that were visible on aerial photographs during the digitizing process were actually narrow strips of either large hardwood or pine trees. The extensive size of our study area limited our ability to ground-truth all herbaceous strips of vegetation that may also have served as hedgerow habitat. Bobwhites exhibited avoidance of agricultural areas as well. Agricultural areas included pecan orchards, cultivated (row-crop) fields, hay fields, and pastureland: areas that received frequent disturbance either through mechanical means (mowing and disking) or by grazing (livestock). Previous research detected bobwhites selecting agricultural areas extensively, particularly when field edges were managed for weedy habitat (Rosene 1969, Puckett et al. 2000). Our results differed from these studies likely because agricultural areas in our region were not improved for bobwhites. Bobwhite avoidance of these areas could be explained by the modern farming practices employed in our study area. Most agricultural fields were large in size and had hard edges. Research has shown that bobwhites do not thrive in or around fields with hard edges, but instead, fields that have weedy borders or transition zones (Rosene 1969, Puckett et al. 2000).

Loblolly pine plantations comprised 26% of our study area and were divided into 2 habitat categories – open-canopy and closed-canopy – because of the difference in the amount of understory vegetation (S. H. Schweitzer and P. E. Hale, University of Georgia, unpublished data). Most pine plantations within the study area were CCPP enrolled in the CRP. These CCPP stands had very little vegetation in the understory, but had some moderate plant growth around their edges (S. H. Schweitzer and P. E. Hale, University of Georgia, unpublished data). Closed-canopy planted pine stands were neither preferred nor avoided at the home range and radio-location levels of analysis. Our results supported Lewis' (1999) observation that bobwhites used CRP pines stands (majority of the CCPP category) for nesting sites. Eleven of 12 nests located within CCPP stands were ≤15 m of the stand edge, likely due to the vegetation growth found around these stand edges.

We documented a preference for OCPP and fallow field habitats, consistent with other studies on bobwhite habitat use (Stoddard 1931, Rosene 1969, Lee 1994). Our research also supported the findings that bobwhites prefer fallow field habitat (Dixon et al. 1996) over other habitats that might be available in their home ranges. It appeared that the presence of understory vegetation in the OCPP was preferred by bobwhites over the lack of understory vegetation in the CCPP.

Our study area, and many landscapes similar to it, had a much lower density of bobwhites (~0.1 birds/ha) than areas previously researched in the Southeast (e.g., Eric Staller, Tall Timbers Research Station, personal communication, ~3 birds/ha at the Tall

Timbers Research Station; Clay Sisson, Albany Area Quail Management Project, personal communication, 5 birds/ha on private plantations in the Albany, Georgia area). Bobwhites in forest- and agriculture-dominated landscapes had to travel through areas with little understory vegetation (CCPP, mature hardwood bottomlands, and open agricultural fields) to move between patches of early successional habitat. Increasing connectivity and creating more patches of early successional habitat as a result of thinning CCPP would provide better vegetative cover and travel corridors for bobwhites. By providing more early successional habitat and connecting areas of existing cover, adult and chick survival rates could be increased and the local population could begin to rebound.

Our findings support the recommendations of the 1996 Farm Bill to improve the wildlife habitat quality of CRP pine stands by thinning. Bobwhites incorporated OCPP pine stands into their home ranges, and bobwhites showed a preference for early successional habitat. These observations, coupled with the high percentage of total dead bobwhites found in CCPP, suggest that thinning densely-planted pine stands will provide improved habitat for bobwhites. However, thinning provides only temporary habitat. As trees grow in response to thinning, the canopy will eventually close and understory vegetation will again be lost. The thinning process must be repeated periodically to continue providing improved habitat for bobwhites. Other management techniques that should be considered in addition to thinning for understory manipulation are winter disking, prescribed burning and herbicide use.

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Literature Cited

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

Allen, A. W. 1994. Regional and state perspectives on conservation reserve program contributions to wildlife habitat. United States Fish and Wildlife Service, National Ecology Research Center, Fort Collins, Colorado, USA.

Allen, C. R., R. S. Lutz, and S. Demarais. 1993. What about fire ants and northern bobwhites? Wildlife Society Bulletin 21:349-351.

Allen, C. R., R. S. Lutz, and S. Demarais. 1995. Red imported fire ant impacts on northern bobwhite populations. Ecological Applications 5:632-638.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544-545.

Brennan, L. A. 1993. Fire ants and northern bobwhites: a real problem or a red herring? Wildlife Society Bulletin 21:351-355.

Burger, L. W., Jr., 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.

Brunswig, N. L., and A. S. Johnson. 1972. Bobwhite quail foods and populations on pine plantations in the Georgia piedmont during the first seven years following site preparation. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 26:96-107.

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

Capel, S., B. Carmichael, M. Gudlin, and D. Long. 1995. Wildlife habitat needs assessment, Southeast region. Transactions of the North American Wildlife and Natural Resources Conference 60:288-299.

Carmichael, D. B., Jr. 1997. The Conservation Reserve Program and wildlife habitat in the southeastern United States. Wildlife Society Bulletin 25:773-775.

Conroy, M. J., R. D. Oderwald, and T. L. Sharik. 1982. Forage production and nutrient concentrations in thinned loblolly pine plantation. Journal of Wildlife Management 46:719-727.

Dixon, K. R., M. A. Horner, S. R. Anderson, W. D. Henriques, D. Durham, and R. J. Kendall. 1996. Northern bobwhite habitat use and survival on a South Carolina plantation during winter. Wildlife Society Bulletin 24:627-635.

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

Farm Service Agency. 1997. The Conservation Reserve Program. United States Department of Agriculture, Washington, D.C., USA.

Frye, O. E., Jr. 1961. A review of bobwhite quail management in eastern North America. Transactions of the North American Wildlife Conference 26:273-281.

Georgia State Climate Center. 2002. <http://climate.enrg.uga.edu/waynesboro>.

Hooge, P. N., and B. Eichenlaub. 1999. Animal movement extension to ArcView. Version 2.04. Alaska Biological Center, United States Geological Survey, Anchorage, Alaska, USA.

Jackson, J. 1990. Bobwhite quail and the southern pine plantation. Forest Farmer 49:22-23.

Johnson, A. S., J. L. Landers, and T. D. Atkeson. 1974. Wildlife in young pine plantations. Pages 147-159 *in* W. E. Balmer, editor. Proceedings of the Symposium on Management of Young Pines. United States Department of Agriculture, Forest Service. Charleston, South Carolina, USA.

Klimstra, W. D. 1982. Bobwhite quail and changing land use. Pages 1-5 *in* F. Schitoskey, Jr., E. C. Schitoskey, and L. G. Talent, editors. Proceedings of the second national bobwhite quail symposium. Stillwater, Oklahoma, USA.

Kulowiec, T. D. 1988. Stagkam: Kaplan-Meier survivorship analysis program 1.0. Missouri Department of Conservation. Columbia, Missouri, USA.

Lee, J. M. 1994. Habitat ecology of the northern bobwhite on Copiah County Wildlife Management Area. Thesis, Mississippi State University, Starkville, Mississippi, USA.

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.

Lewis, L. A., and S. H. Schweitzer. 2000. Lead poisoning in a northern bobwhite in Georgia. Journal of Wildlife Diseases 36:180-183.

Madison, L. A., T. G. Barnes, and J. D. Sole. 2001. Effectiveness of fire, disking, and herbicide to renovate tall fescue fields to northern bobwhite habitat. Wildlife Society Bulletin 29:706-712.

Mayfield, H. F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255-261.

Mech, L. D. 1983. Handbook of animal radio-tracking. University of Minnesota Press, Minneapolis, Minnesota, USA.

Moser, W. K., and W. E. Palmer. 1997. Quail habitat and forest management: what are the opportunities? Forest Landowner Manual. March-April: 56-63.

Palmer, W. E., K. M. Puckett, J. R. Anderson, and P. T. Bromley. 1998. Effects of foliar insecticides on survival of northern bobwhite quail chicks. Journal of Wildlife Management 62:1565-1573.

Paulk, H. L. 1986. Soil Survey of Burke County, Georgia. United States Department of Agriculture, Soil Conservation Service, Washington, D.C., USA.

Percival, H. F., L. G. Webb, and J. K. Reed. 1973. Concentrations of selected chlorinated hydrocarbon insecticides in bobwhite quail in South Carolina. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 26:108-117.

Pedersen, E. K., W. E. Grant, and M. T. Longnecker. 1996. Effects of red imported fire ants on newly-hatched northern bobwhite. Journal of Wildlife Management 60:164-169.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, and T. L. Sharpe. 2000. Effects of filter strips on habitat use of northern bobwhites on Alligator River National Wildlife Refuge. Proceedings of the National Quail Symposium 4:26-31.

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

Rosene, W. 1969. The bobwhite quail: its life and management. The Sun Press, Hartwell, Georgia, USA.

Sauer, J. R., J. E. Hines, and J. Fallon. 2001. The North American Breeding Bird Survey, Results and Analysis 1966-2000. Version 2001.2, United States Geologic Survey Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Stauffer, D. F., G. A. Cline, and M. J. Tonkovich. 1990. Evaluating potential effects of CRP on bobwhite quail in piedmont Virginia. Transactions of the North American Wildlife and Natural Resources Conference 55:57-67.

Stewart, D., D. Godwin, and L. W. Burger, Jr. 1997. Ecology and management of the northern bobwhite, part II. Quail Unlimited Magazine 16:8-11.

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

SYSTAT. 1992. Statistics, Version 5.2 Edition. SYSTAT, Inc., Evanston, Illinois, USA.

Taylor, J. S., K. E. Church, D. H. Rusch, and J. R. Cary. 1999*a*. Macrohabitat effects on summer survival, movements, and clutch success of northern bobwhite in Kansas. Journal of Wildlife Management 63:675-685.

Taylor, J. S., K. E. Church, and D. H. Rusch. 1999*b*. Microhabitat selection by nesting and brood-rearing northern bobwhite in Kansas. Journal of Wildlife Management 63:686-694.

Walker, L. C., and B. P. Oswald. 2000. The Southern forest: geography, ecology, and silviculture. CRC Press, Boca Raton, Florida, USA.

Washburn, B. E., T. G. Barnes, and J. D. Sole. 2000. Improving northern bobwhite habitat by converting tall fescue fields to native warm-season grasses. Wildlife Society Bulletin 28:97-104.

Table 2.1. Mean (SE) log-ratio difference matrix of all pairings for habitat proportions in study area (available) versus home ranges (use) for individual northern bobwhites (n=18) on Di-Lane Plantation Wildlife Management Area, Burke County, Georgia, USA, May-August, 1997.

	Habitat type					
Habitat type	Fallow field	OCPP[1]	CCPP[2]	Hardwood	Agricultural areas	Hedgerow
Fallow field		-0.40[3] (0.63)	-1.72 (<0.01)*[4]	-2.61 (<0.01)*	-4.92 (<0.01)*	-2.37 (<0.01)*
OCPP[1]	+0.40 (0.63)		-1.32 (0.23)	-2.21 (0.04)*	-4.66 (<0.01)*	-1.96 (0.02)*
CCPP[2]	+1.72 (<0.01)*	+1.32 (0.23)		-0.89 (<0.01)*	-3.20 (0.01)*	-0.65 (0.43)
Hardwood	+2.61 (<0.01)*	+2.21 (0.04)*	+0.89 (<0.01)*		-2.30 (0.06)	+0.25 (0.73)
Agricultural areas	+4.92 (<0.01)*	+4.52 (<0.01)*	+3.20 (0.01)*	+2.30 (0.06)		+2.55 (0.05)*
Hedgerow	+2.37 (<0.01)*	+2.11 (0.02)*	+0.65 (0.43)	-0.25 (0.73)	-2.55 (0.04)*	
Rank[5]	1	2	3	5	6	4

[1] Open Canopy Planted Pines

[2] Closed Canopy Planted Pines

[3] A negative value indicates that the row habitat was used more than the column habitat. A positive value indicates the opposite.

[4] An asterisk (*) denotes a statistical significance at $P \leq 0.05$ as determined by a t-test comparison of use of habitat types.

[5] Ranks were determined by comparing relative use of each habitat with all other habitats. Smallest ranking indicates the habitat type was selected most frequently, and the largest ranking indicates the habitat type was selected least frequently.

Table 2.2. Mean (SE) log-ratio difference matrix of all pairings for habitat proportions in study area (available) versus home ranges (use) for individual northern bobwhites (n=10) on Di-Lane Plantation and Alexander Wildlife Management Areas, Burke County, Georgia, USA, May-August, 1998.

	Habitat type					
Habitat type	Fallow field	OCPP[1]	CCPP[2]	Hardwood	Agricultural areas	Hedgerow
Fallow field		-0.58[3] (0.63)	-1.35 (0.02)*[4]	-1.35 (0.08)	-3.70 (<0.01)*	-2.12 (0.02)*
OCPP[1]	+0.58 (0.63)		-0.78 (0.44)	-0.77 (0.47)	-3.12 (<0.01)*	-1.55 (0.07)
CCPP[2]	+1.35 (0.02)*	+0.78 (0.44)		-0.006 (0.99)	-2.34 (0.18)	-0.77 (0.44)
Hardwood	+1.35 (0.08)	+0.77 (0.47)	+0.006 (0.99)		-2.35 (0.14)	-0.77 (0.52)
Agricultural areas	+3.70 (<0.01)*	+3.12 (<0.01)*	+2.34 (0.18)	+2.35 (0.14)		+1.58 (0.25)
Hedgerow	+2.12 (0.02)*	+1.55 (0.07)	+0.77 (0.44)	+0.77 (0.52)	-1.58 (0.25)	
Rank[5]	1	2	4	3	6	5

[1] Open Canopy Planted Pines

[2] Closed Canopy Planted Pines

[3] A negative value indicates that the row habitat was used more than the column habitat. A positive value indicates the opposite.

[4] An asterisk (*) denotes a statistical significance at $P \leq 0.05$ as determined by a t-test comparison of use of habitat types.

[5] Ranks were determined by comparing relative use of each habitat with all other habitats. Smallest ranking indicates the habitat type was selected most frequently, and the largest ranking indicates the habitat type was selected least frequently.

Table 2.3. Mean (SE) log-ratio difference matrix of all pairings for habitat proportions in study area (available) versus home ranges (use) for individual northern bobwhites (n=13) on Di-Lane Plantation and Alexander Wildlife Management Areas, Burke County, Georgia, USA, May-August, 1999.

	Habitat type					
Habitat type	Fallow field	OCPP[1]	CCPP[2]	Hardwood	Agricultural areas	Hedgerow
Fallow field		+0.42[3] (0.67)	-2.78 (0.06)	-0.23 (0.74)	-1.46 (0.22)	-0.35 (0.59)
OCPP[1]	-0.42 (0.67)		-3.20 (<0.01)*[4]	-0.65 (0.48)	-1.88 (<0.01)*	-0.77 (0.35)
CCPP[2]	+2.78 (0.06)	+3.20 (<0.01)*		+2.55 (0.04)*	+1.32 (0.27)	+2.43 (0.07)
Hardwood	+0.23 (0.74)	+0.65 (0.48)	-2.55 (0.04)*		-1.23 (0.33)	-0.11 (0.86)
Agricultural areas	+1.46 (0.22)	+1.88 (<0.01)*	-1.32 (0.27)	+1.23 (0.33)		+1.11 (0.23)
Hedgerow	+0.35 (0.59)	+0.77 (0.35)	-2.43 (0.07)	+0.11 (0.86)	-1.11 (0.23)	
Rank[5]	2	1	6	3	5	4

[1] Open Canopy Planted Pines

[2] Closed Canopy Planted Pines

[3] A negative value indicates that the row habitat type was used more than the column habitat type. A positive value indicates the opposite.

[4] An asterisk (*) denotes a statistical significance at $P \leq 0.05$ as determined by a t-test comparison of use of habitat types.

[5] Ranks were determined by comparing relative use of each habitat with all other habitats. Smallest ranking indicates the habitat type was selected most frequently, and the largest ranking indicates the habitat type was selected least frequently.

Table 2.4. Mean (SE) log-ratio difference matrix of all pairings for habitat proportions in home range (available) versus radio-locations (use) for individual northern bobwhites (n=61) on Di-Lane Plantation and Alexander Wildlife Management Areas, Burke County, Georgia, USA, May-August, 1997-2000.

	Habitat type					
Habitat type	Fallow field	OCPP[1]	CCPP[2]	Hardwood	Agricultural areas	Hedgerow
Fallow field		+0.12[3] (0.82)	-0.77 (0.10)	-0.90 (0.08)	-3.18 (<0.01)*[4]	-1.13 (0.06)
OCPP[1]	-0.12 (0.82)		-0.39 (0.36)	-0.89 (0.16)	-3.49 (<0.01)*	-2.09 (<0.01)*
CCPP[2]	+0.77 (0.10)	+0.39 (0.36)		-0.13 (0.79)	-3.23 (<0.01)*	-0.93 (0.20)
Hardwood	+0.90 (0.08)	+0.89 (0.16)	+0.13 (0.79)		-2.73 (<0.01)*	-0.17 (0.80)
Agricultural areas	+3.18 (<0.01)*	+3.49 (<0.01)*	+3.23 (<0.01)*	+2.73 (<0.01)*		+1.77 (0.03)*
Hedgerow	+1.13 (0.06)	+2.09 (<0.01)*	+0.93 (0.20)	+0.17 (0.80)	-1.77 (0.03)*	
Rank[5]	2	1	3	4	6	5

[1] Open Canopy Planted Pines

[2] Closed Canopy Planted Pines

[3] A negative value indicates that the row habitat type was used more than the column habitat type. A positive value indicates the opposite.

[4] An asterisk (*) denotes a statistical significance at $P \leq 0.05$ as determined by a t-test comparison of use of habitat types.

[5] Ranks were determined by comparing relative use of each habitat with all other habitats. Smallest ranking indicates the habitat type was selected most frequently, and the largest ranking indicates the habitat type was selected least frequently.

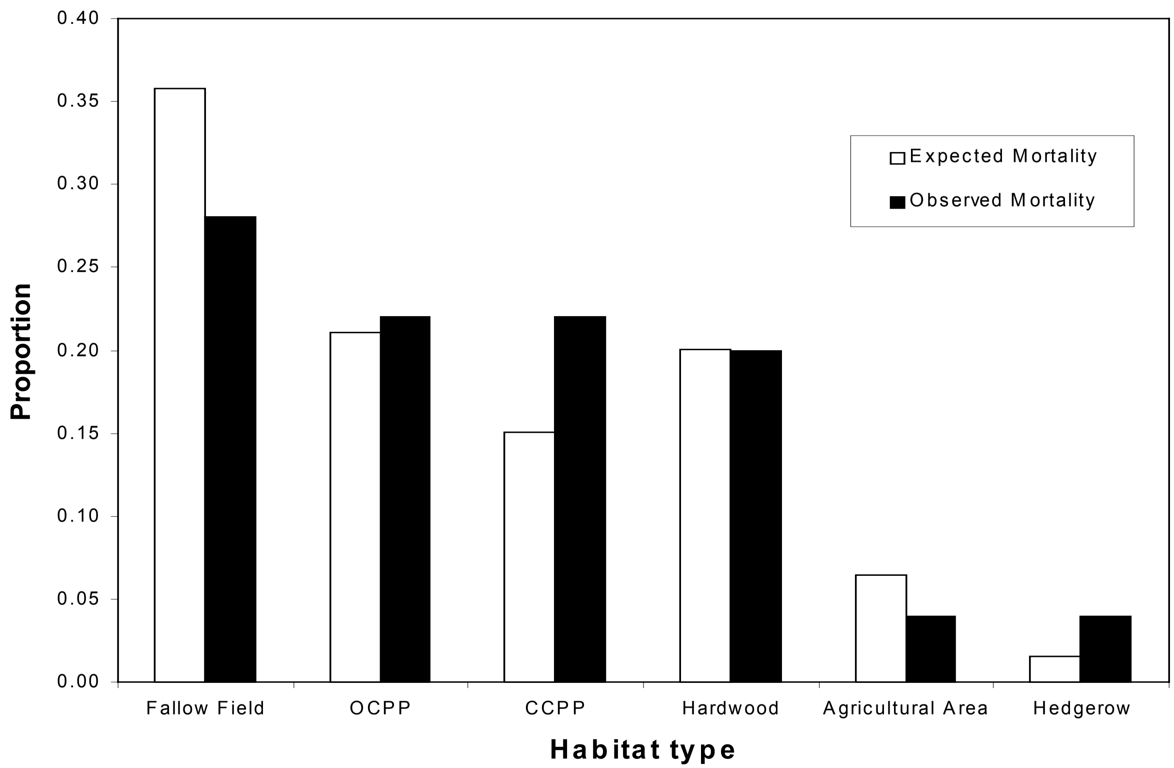

Figure 2.1. Expected (habitat use x total number of dead bobwhites) and observed locations of dead northern bobwhites for each habitat type on the study areas (Di-Lane Plantation and Alexander Wildlife Management Areas, Burke County, Georgia) from May – August 1997-2000 (OCPP = Open-Canopy Planted Pine; CCPP = Closed-Canopy Planted Pine).

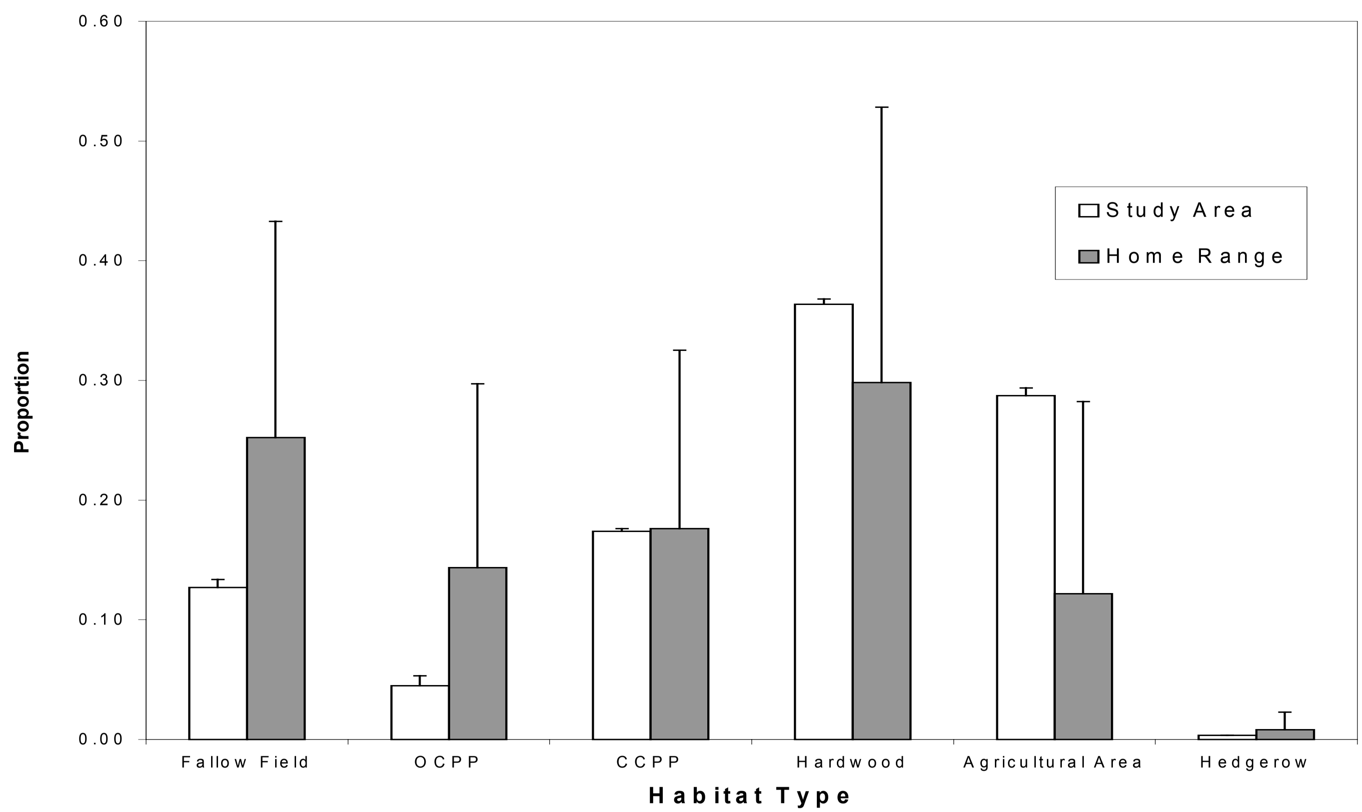

Figure 2.2. Mean proportion of habitat types available on our study areas (Di-Lane Plantation and Alexander Wildlife Management Areas, Burke County, Georgia) relative to mean proportion of habitat types encompassed in northern bobwhites home ranges, May – August 1997-2000 (OCPP = Open-Canopy Planted Pine; CCPP = Closed-Canopy Planted Pine). Error bars indicate standard deviation.

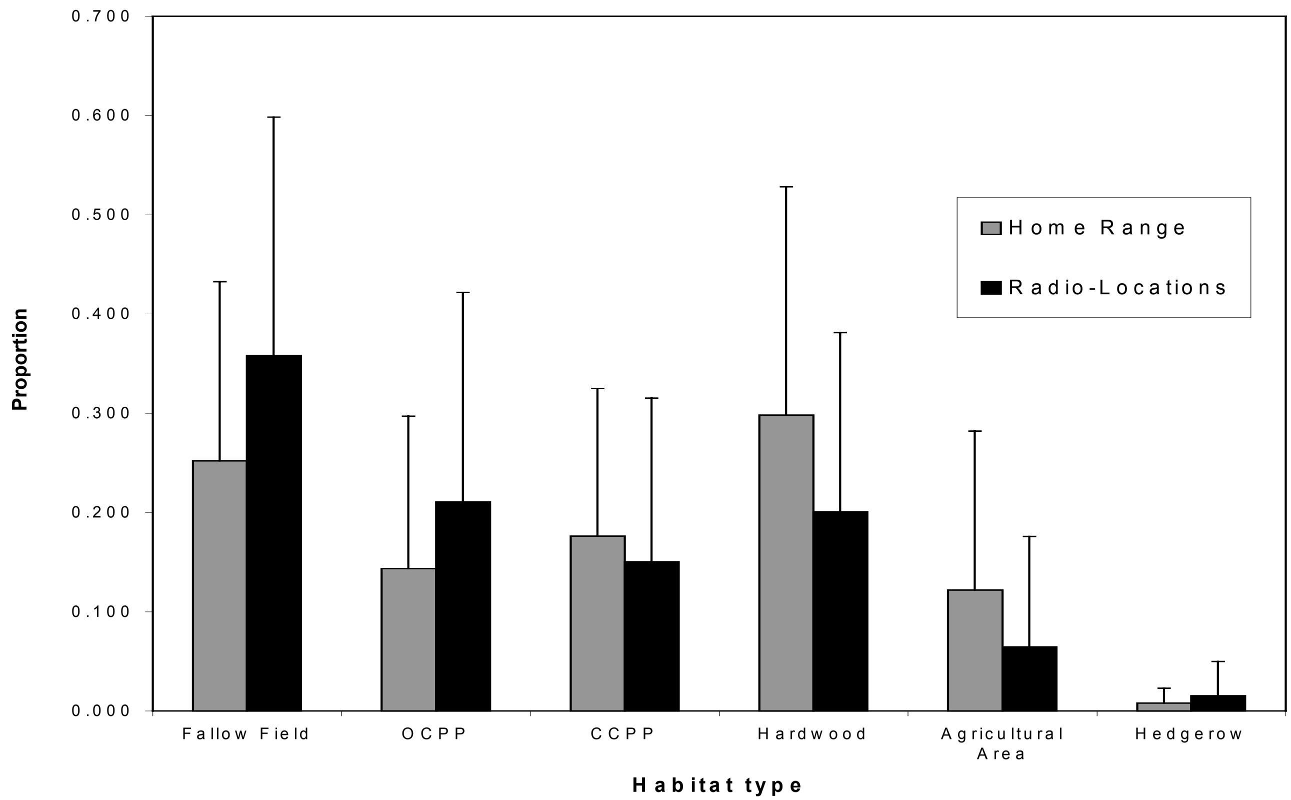

Figure 2.3. Mean proportion of habitat types available within northern bobwhite home ranges relative to mean proportion of radio-locations of marked bobwhites within habitat types encompassed in home ranges, May – August 1997-2000 (Di-Lane Plantation and Alexander Wildlife Management Areas, Burke County, Georgia; OCPP = Open-Canopy Planted Pine; CCPP = Closed-Canopy Planted Pine). Error bars indicate standard deviation.

CHAPTER 3

NORTHERN BOBWHITE NESTING ECLOLOGY IN A FOREST- AND AGRICULTURE-DOMINATED SYSTEM[1]

[1]Parnell, Ira B., III, S. H. Schweitzer, C. G. White, and L. A. Lewis. To be submitted to *Wildlife Society Bulletin*.

Abstract: We investigated the nesting ecology of a declining population of northern bobwhites (*Colinus virginianus*) in the Upper Coastal Plain region of Georgia. Because many agricultural fields and pastures in this region were converted to densely stocked (≥1,793 trees/ha) pine plantations (*Pinus* spp.) with assistance from the Conservation Reserve Program (CRP), we hypothesized that nest sites of northern bobwhites would be restricted to remaining early successional habitats, young plantations, or forest gaps. We located nests of radio-marked bobwhites, monitored nests for success or failure, determined causes of failure, compared micro-habitat features around nests with the same features at associated random points, and recorded adult mortality and cause of mortality. Eighteen of 31 nests were successful. Nest failure was due to depredation (n = 12) or abandonment (n = 1). Nests were found in fallow fields (n = 12), edges of closed canopy planted pine stands (n = 12), open canopy planted pine stands (n = 6), and along the edge of an agricultural field (n = 1). Of 81 radio-marked adults monitored during the nesting season, 51 were lost to predation. Because northern bobwhites selected fallow fields and edges of planted pine stands for a majority of their nest sites (24/31), it appeared that new recommendations of the CRP to thin and create openings within established pine stands would increase available nesting habitat for northern bobwhites. Losses of nests and adults were due primarily to predators that likely benefitted from the increase in forested acreage, such as black rat snakes (*Elaphe obsoleta obsoleta*), raccoons (*Procyon lotor*), gray fox (*Urycyon cinereoargenteus*), Cooper's hawks (*Accipiter cooperii*), and barred owls (*Strix varia*). Objectives were to assess the reproductive response of the population to reforestation of the study area.

Key words: *Colinus virginianus*, Georgia, habitat, nest site selection, nest success, northern bobwhite, quail, reproductive ecology

Northern bobwhite, hereafter bobwhite, populations have declined significantly throughout the Southeast since the 1960s (Sauer et al. 2001). Some proposed reasons for this population decline are changes in habitat due to land use practices (Frye 1961, Brennan 1991), increases in predator populations (Rollins and Carroll 2001, Sauer et al. 2001), and hunter-harvest impacts on depressed bobwhite populations (Guthery et al. 2000). Modifying current land use practices is perhaps the most efficient method for average landowners to rectify declining bobwhite populations on their property (Stoddard 1931, Taylor et al. 1999*a*). The CRP is responsible for the conversion of much marginally productive agricultural land in the Southeast to closely-spaced loblolly pine (*Pinus taeda*) plantations. Since 1985, 609,410 ha have been converted into dense (≥1,793 trees/ha) loblolly pine plantations through this program (Farm Service Agency 1997; Appendix A). Although the CRP has been beneficial to gamebird populations in the Midwest because of the emphasis on grassland conservation practices (Hayes et al. 1989), the CRP in the Southeast emphasized tree plantings that, after canopy closure, do not benefit bobwhites (Stauffer et al. 1990, Brennan 1991, Carmichael 1997). We hypothesized that conversion of agricultural lands to closed-canopy planted pines throughout the Southeast contributed to recent declines in bobwhite populations. Bobwhite nesting habitat research has been conducted primarily in the grassland-dominated areas of the Midwest (Burger et al. 1990, Taylor et al. 1999*b*, Townsend et al. 2001). Few researchers have analyzed bobwhite nest site characteristics relative to available habitat in the forest- and agriculture-dominated Upper Coastal Plain region of the Southeast. We compared habitat characteristics at nest sites with unused sites and we attempted to correlate adult bobwhite survival and nest success with the location of nests on our study area.

Study area

Upland portions of study areas selected for this project, Di-Lane Plantation Wildlife Management Area (WMA; 32 58’ 07” N, 82 05’ 04” W) and Alexander WMA (33 00’ 22” N, 81 54’ 57” W), were representative of typical pine plantation habitat found in the Upper Coastal Plain ecological region of the southeastern United States (Walker and Oswald 2000). Both WMAs were located in Burke County, Georgia. The average temperature was 25.8 C during the summer and 8.9 C in the winter; the average annual precipitation was 1,137.7 mm (Georgia State Climate Center 2002). The predominant soil types of this region were sandy clay loams of the Dothan, Fuquay, and Tifton soil series (Paulk 1986).

During 4 years of study (1997-2000), early successional habitat (agricultural fields, fallow fields, and open pine plantations) decreased by 320 ha and late successional habitat (hardwoods and closed pine plantations) increased by the same amount on our study areas. The Di-Lane Plantation WMA study area (11,680 ha) consisted of 4 predominant habitat types ($\bar{x} \pm$ SD): mature hardwoods (4,246 ± 51 ha), agricultural areas (3,355 ± 74 ha), pine plantations (2,554 ± 110 ha), and fallow fields (1,483 ± 79 ha). Although in different proportions, the Alexander study area consisted of the same 4 predominant habitat types ($\bar{x} \pm$ SD) present on Di-Lane: pine plantations (1,401 ± 16 ha), hardwoods (1,152 ± 15 ha), agricultural areas (849 ± 4 ha), and fallow fields (366 ± 30 ha).

Habitat types on the study area were delineated by referencing U. S. Geologic Survey 1993 Digital Orthophoto Quarter Quadrangle (DOQQ) maps and were correctly classified using our knowledge of the study area, on-site inspection, and remote imagery. Habitat types on our study areas were digitized at a scale ≥1:3,000 m using the ArcView™ (Environmental Systems Research Institute, Inc. 1992) geographic information system (GIS) computer program overlaid onto the DOQQ maps.

Methods

All bobwhites were trapped and radio-marked on Di-Lane Plantation WMA and Alexander WMA, but many moved outside WMA boundaries during the study. The Di-Lane Plantation WMA study area (3,278 ha) was expanded to include an additional 8,402-ha, thus encompassing all bobwhite radio-locations and enlarging the overall Di-Lane Plantation WMA study area to 11,680 ha. Similarly, the Alexander WMA (480 ha) was expanded to 3,786 ha. Bobwhites were captured using funnel traps baited with cracked and whole kernel corn (*Zea mays*) (Stoddard 1931). Upon capture, bobwhites were sexed, weighed, aged, and fitted with a size 3 aluminum leg band and 6.1-g necklace-style radio transmitter (Holohil Systems, Ontario, Canada). All bobwhites captured were handled and released in accordance with the procedures of The University of Georgia Institutional Animal Care and Use Committee (IACUC Protocol No. A960216C2). We used the homing technique (Mech 1983) to determine daily locations of radio-marked bobwhites as well as monitor adult survival, locate nest sites, and determine nest success. The habitat category for each nest located was recorded and compared to overall habitat use. Nest success was determined using the Mayfield method (Mayfield 1961), where a successful nest was defined as one in which ≥1 egg hatched.

Micro-habitat characteristics were measured within an 11-m radius plot centered on located nests and paired, nearby (35 m) random sites (Ralph et al. 1993). We used a modification of the breeding bird (BBIRD) habitat sampling protocol for ground-nesting birds (Martin et al. 1997). Additional measurements included: height to overhead cover above the nest structure (cm); visual obstruction (%; vegetation profile board) estimations at 0-0.5 m, 0.5-1 m, and 1-2.5 m above ground level in each cardinal direction, 5 m and 11 m from plot center; distance to nearest habitat edge (m); presence of fire ant (*Solenopsis invicta*) mounds within 5 m of plot center; total vegetation intercepts at 0-0.5 m, 0.5-1 m, and 1-2.5 m above ground level in each cardinal direction, 5 m and 11 m from plot center; and canopy closure (%) measured with a spherical densiometer.

We measured these micro-habitat variables in an effort to develop a logistic regression model that would allow us to predict habitat selected for nest sites. By determining which variables were important in nest site selection, we could then manage other areas for these characteristics and improve overall nesting habitat on our study area. Forty-one variables were measured at the micro-habitat level at each nest and paired plot. Arcsine transformations were performed on all percentage data. All analyses were conducted using the Statistical Analysis System® software (SAS 1990; SAS Institute Inc., Cary, North Carolina) unless otherwise stated. We determined that most of our data did not meet assumptions of normality (PROC UNIVARIATE). Therefore, nonparametric statistical procedures were used on all data. The pool of variables was narrowed objectively and subjectively by using a correlation table (PROC CORR) and performing Wilcoxon Sign Rank tests on nest site and paired random plot variables (PROC UNIVARIATE). If 2 variables were highly correlated ($r \geq 0.70$), then one variable was selected and the other was eliminated. Variables that were not potentially biologically significant for bobwhites (as demonstrated in other research studies), and those that were not statistically different ($P \geq 0.30$) when compared between the nest and paired plots also were eliminated. Remaining variables were then entered into a SAS macro (C. T. Moore, University of Georgia, Athens, Georgia) to perform stepwise logistic regression that yielded an Akaike's Information Criterion (AIC) score (Akaike 1973). We used the "one variable for every 10 observations rule" (Burnham and Anderson 1998) to determine the number of variables to keep in models. The most efficient 1, 2, and 3 variable models were selected based on their AIC scores and tested in SAS with a macro (C. T. Moore, University of Georgia, Athens, Georgia) that used a Monte Carlo cross-validation technique. The cross-validation technique was used to test the models' efficiency at predicting nests and paired plots. The number of cross-validation iterations was set at ≥1,000 and 50% of the data was withheld from the validation.

Results

Of the 151 bobwhites captured from 1997-2000, 81 survived to the beginning of nesting season (15 April). Thirty of 81 bobwhites monitored survived to the end of our field season (1 September). During our study, 31 nests were recorded. Up to 50% of nests were incubated by male bobwhites each year. Eighteen nests were successful. Failure of the remaining 13 nests was due to depredation (n = 12) or abandonment (n = 1). Forty-one micro-habitat vegetation characteristics were measured at nests (n = 15) and paired plots (n = 15) during 1999-2000 (Appendix C). Seven variables were eliminated from analysis because they were highly correlated with another variable, measured similar characteristics, or contained missing values. The remaining 34 variables were entered in logistic regression analysis. We limited our models to ≤ 3 variables because we surveyed 30 total vegetation plots. No model adequately predicted nest site selection much greater than random chance (50%; AIC = 43.7). The variables that had the lowest AIC score and appeared in most models were nest cover (visual obstruction of the nest from all sides) and brush ground litter (percentage of ground covered by brush within 5 m of plot center). The best 1-variable model identified nest cover as the variable with the lowest AIC score (AIC = 42.1) and correctly predicted a nest or paired random plot 60.0% of the time. The best 2-variable model included nest cover and brush ground litter (AIC = 41.0) and had a 73.3% prediction rate for nest site or paired random plot. The best 3-variable model identified nest cover, brush ground litter, and number of snags (diameter breast height >12 cm) as predictive variables and had the lowest AIC score (38.2). This 3-variable model had a prediction rate of 80.0%. After cross-validation, these models correctly predicted a nest or paired random plot 55.0%, 65.5%, and 67.6% of the time, respectively.

Discussion

Bobwhite populations experience high mortality rates in each life stage (egg to adult; Burger et al. 1995). Mortality rates during our study were comparable, but slightly higher, to those documented in other studies (Burger et al. 1995). Average nesting success (47%) also was comparable to that observed by other researchers in the Southeast (Eric Staller, Tall Timbers Research Station, personal communication, ~45%; Clay Sisson, Albany Area Quail Management Project, personal communication, 45-65%). The nesting success observed on our study area may be misleading because, even though nest success was relatively high, fewer total nests may have been incubated due to depredation of adults during the laying process (Clay Sisson, Albany Area Quail Management Project, personal communication). Therefore, relatively high nesting success did not necessarily translate into a positive trend in the number of birds entering a population. Additionally, our study area, and many landscapes similar to it, had a much lower density of bobwhites (~0.1 birds/ha) than areas previously researched in the Southeast (e.g., Eric Staller, Tall Timbers Research Station, personal communication, ~3 birds/ha at the Tall Timbers Research Station; Clay Sisson, Albany Area Quail Management Project, personal communication, 5 birds/ha on private plantations in the Albany, Georgia area). Because our study area had a much lower population density, comparable mortality rates and nesting success might not be enough for this local population to increase. On our study area, bobwhites had to travel through areas with little understory vegetation (CCPP, mature hardwood bottomlands, and open agricultural fields) to move between patches of early successional habitat. Increasing connectivity and creating more patches of early successional habitat as a result of thinning CCPP would provide better vegetative cover and travel corridors for bobwhites. By providing more early successional habitat and connecting areas of existing cover, adult and chick survival rates could be increased and the local population could begin to rebound (Cantu and Everett 1982, Taylor et al. 1999*a*).

Other researchers have identified nest site characteristics that were accurate predictors of bobwhite nest sites for their studies (Taylor et al. 1999*b*, Townsend et al. 2001). Bobwhites in western Oklahoma selected sites with a greater coverage of grass and woody vegetation but with a lower percentage of bare ground than random vegetation plots (Townsend et al. 2001). Taylor et al. (1999*b*) documented bobwhite nests in Kansas where nest sites were associated with taller vegetation, greater visual obstruction, and more litter cover than was available at random vegetation plots. We found that nest cover (i.e., visual obstruction of the nest from all sides) was a common factor present in all of the models we tested indicating that this habitat characteristic strongly influenced nest site selection in our study area. The greater amount of nest cover, or visual obstruction of the nest, likely provided greater protection from predators during the breeding season (Taylor et al. 1999*b*).

With such a low density of bobwhites on our study area (~0.1 birds/ha), it is possible that suitable nesting habitat was not the limiting factor. There were several potential reasons why our models did not accurately predict nest sites including: 1) small sample size – we were not able to sample enough nest sites and paired vegetation plots to demonstrate which variables were the most predictive for nest site selection; 2) not measuring the most important variable for predicting nest site selection – we did not feel that this was a plausible explanation of our results because we sampled 41 micro-habitat variables at each nest site, therefore, missing the most predictive variables was unlikely; or 3) nesting habitat may not have been the most limiting factor affecting the bobwhite population on our study area – there may have been inadequate access to other important habitats in the immediate vicinity of nest sites (i.e., brood rearing habitat or escape cover; Taylor et al. 1999*a*). More simply stated, there was a lack of enough contiguous early successional habitat distributed throughout our study area. Early successional habitat on our study area was separated by large row-crop agriculture fields, CCPP stands, and hardwood bottomlands. Additionally, the predominance of hardwoods and CCPP stands adjacent to non-contiguous blocks of early successional habitat may have increased the presence of certain suites of predators (i.e., mesomammals and forest raptors). Thinning CCPP stands would increase the availability of early successional habitat and aid in connecting other patches of adequate bobwhite habitat present on the landscape.

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Literature Cited

Akaike, H. 1973. Information theory as an extension of the maximum likelihood principle. Pages 267-281 *in* B. N. Petrov and F. Csaki, editor. Second International Symposium on Information Theory. Akademiai Kiado, Budapest, Hungary.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544-545.

Burger. L. W., Jr., E. W. Kurzejeski, T. V. Dailey, and M. R. Ryan. 1990. Structural characteristics in CRP fields in northern Missouri and their suitability as bobwhite habitat. Transactions of the North American Wildlife and Natural Resources Conference 55:74-83.

Burger, L. W., Jr., 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.

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

Cantu, R., and D. D. Everett. 1982. Reproductive success and brood survival of bobwhite quail as affected by grazing practices. Pages 79-83 *in* F. Schitoskey, Jr., E. C. Schitoskey, and L. G. Talent, editors. Proceedings of the second national bobwhite quail symposium. Stillwater, Oklahoma, USA.

Carmichael, D. B., Jr. 1997. The Conservation Reserve Program and wildlife habitat in the southeastern United States. Wildlife Society Bulletin 25:773-775.

Frye, O. E., Jr. 1961. A review of bobwhite quail management in eastern North America. Transactions of the North American Wildlife Conference 26:273-281.

Farm Service Agency. 1997. The Conservation Reserve Program. United States Department of Agriculture, Washington, D.C., USA.

Georgia State Climate Center. 2002. <http://climate.enrg.uga.edu/waynesboro>.

Guthery, F. S., M. J. Peterson, and R. R. George. 2000. Viability of northern bobwhite populations. Journal of Wildlife Management 64:646-662.

Hayes, R. L., R. P. Webb, and A. H. Farmer. 1989. Effects of the Conservation Reserve Program on wildlife habitat: results of 1988 monitoring. Transactions of the 54th North American Wildlife and Natural Resources Conference 54:365-376.

Kulowiec, T. D. 1988. Stagkam: Kaplan-Meier survivorship analysis program 1.0. Missouri Department of Conservation. Jefferson City, Missouri, USA.

Martin, T. E., C. R. Paine, C. J. Conway, W. M. Hochachka, P. Allen, and W. Jenkins. BBIRD field protocol: breeding biology research and monitoring database program. Montana Cooperative Wildlife Research Unit, University of Montana, Missoula, Montana, USA.

Mayfield, H. F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255-261.

Mech, L. D. 1983. Handbook of animal radio-tracking. University of Minnesota Press, Minneapolis, Minnesota, USA.

Paulk, H. L. 1986. Soil Survey of Burke County, Georgia. United States Department of Agriculture, Soil Conservation Service, Washington, D.C., USA.

Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Handbook of field methods for monitoring landbirds. United States Forest Service Report PSW-GTR-444. Washington, D.C., USA.

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

Sauer, J. R., J. E. Hines, and J. Fallon. 2001. The North American Breeding Bird Survey, Results and Analysis 1966-2000. Version 2001.2, United States Geologic Survey Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Statistical Analysis Systems. 1990. SAS Institute, Cary, North Carolina, USA.

Stauffer, D. F., G. A. Cline, and M. J. Tonkovich. 1990. Evaluating potential effects of CRP on bobwhite quail in piedmont Virginia. Transactions of the North American Wildlife and Natural Resources Conference 55:57-67.

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

Taylor, J. S., K. E. Church, D. H. Rusch, and J. R. Cary. 1999*a*. Macrohabitat effects on summer survival, movements, and clutch success of northern bobwhite in Kansas. Journal of Wildlife Management 63:675-685.

Taylor, J. S., K. E. Church, and D. H. Rusch. 1999*b*. Microhabitat selection by nesting and brood-rearing bobwhite in Kansas. Journal of Wildlife Management 63:686-694.

Townsend, D. E. II, R. E. Masters, R. L. Lochmiller, D. M. Leslie, Jr., S. J. Demaso, and A. D. Peoples. 2001. Characteristics of nest sites of northern bobwhites in western Oklahoma. Journal of Range Management 54:260-264.

Walker, L. C., and B. P. Oswald. 2000. The Southern forest: geography, ecology, and silviculture. CRC Press, Boca Raton, Florida, USA.

CHAPTER 4

CONCLUSIONS

Nesting Ecology

Average nest success also was comparable for our study (48%) to that observed by other researchers in the Southeast (Eric Staller, personal communication, ~45% at the Tall Timbers Research Station; Clay Sisson, personal communication, 45-65% on private plantations in the Albany, Georgia area). The nesting success observed on our study area may be misleading because even though nest success was relatively high, fewer total nests may have been incubated due to depredation of adults during the laying process (Clay Sisson, personal communication). Therefore, relatively high nest success did not necessarily translate into a positive trend in the number of birds entering a population. Because our study area had a much lower population density, comparable mortality rates and nesting success might not be enough for this local population to increase. On our study area, bobwhites had to travel through areas with little understory vegetation (CCPP, mature hardwood bottomlands, and open agricultural fields) when moving between patches of early successional habitat. Increasing connectivity and creating more patches of early successional habitat as a result of thinning CCPP would provide better vegetative cover and travel corridors for bobwhites. Increasing the amount and availability of brood habitat in close proximity to nesting habitat could help to increase brood survival (Taylor et al. 1999). Increased survival of broods and adults could allow the local population to rebound.

Other researchers have identified nest site characteristics that were accurate predictors of bobwhite nest sites for their studies. Bobwhites in western Oklahoma selected sites with a greater coverage of grass and woody vegetation but with a lower percentage of bare ground than random vegetation plots (Townsend et al. 2001). Taylor et al. (1999) documented bobwhite nests in Kansas where nest sites were associated with taller vegetation, greater visual obstruction, and more litter cover than was available at random vegetation plots. We found that nest cover (i.e., visual obstruction of the nest from all sides) was a common factor present in all of the models we tested indicating that this habitat characteristic strongly influences nest site selection in our study area. The greater amount of nest cover, or visual obstruction of the nest, likely provided greater protection from predators during the breeding season.

With such a low density of bobwhites on our study area (~0.1 birds/ha), it is possible that suitable nesting habitat was not the limiting factor. There were several other potential reasons that our models did not accurately predict nest sites. These reasons include small sample size and not measuring the most important variable for predicting nest site selection. It was also possible that the most important variables were measured and our models correctly illustrated that nesting habitat may not be the most limiting factor affecting the bobwhite population on our study areas. There may have been inadequate access to other important habitats in the immediate vicinity of nest sites (i.e., brood rearing habitat or escape cover). More simply stated, there was a lack of enough contiguous early successional habitat distributed throughout our study area. Early successional habitat present on our study area was separated by large row-crop agriculture fields, CCPP stands, and hardwood bottomlands. Additionally, the predominance of hardwoods and CCPP stands adjacent to non-contiguous blocks of early successional habitat may have increased the presence of certain suites of predators (i.e., mesomammals and forest raptors). Thinning CCPP stands would increase the availability of early successional habitat and aid in connecting other patches of adequate bobwhite habitat present on the landscape.

Adult Survival

Adult bobwhite survival rates during our study were comparable to those documented in other studies (Stoddard 1931, Rosene 1969, Burger et al. 1995). Locations of dead, radio-marked birds were not found in the proportions one might expect according to habitat use (Figure 4.1). If locations of dead birds were distributed in proportion to the habitat use, we would have found the greatest number of dead birds in fallow fields and OCPP. Fallow fields did contain the greatest number of dead birds. However, we documented more dead birds in CCPP and hardwoods than we would have expected based on habitat use. We cannot be certain that the area where a dead bobwhite was located was the actual site where the bird was killed. It is possible that bobwhites died or were killed in an adjacent habitat type and then carried by predators or scavengers to the area where we found the remains. However, the location of the mortality site could still be important in that the juxtaposition of certain habitat types may make bobwhites more susceptible to depredation. Lewis (1999) noted that if bobwhites were being depredated when using the CCPP habitat, then the CCPP could be acting as an ecological trap.

Home Range and Habitat Use

Average minimum convex polygon home range sizes for individual bobwhites on our study areas were larger than those reported elsewhere (e.g., Taylor et al. 1999), although few other studies have documented home range size of radio-marked individuals during the breeding season. Large home ranges could be a result of deficiencies in the available habitat towards meeting the daily life requirements of breeding bobwhites. If the habitat in a given area was not meeting their life requirements, then presumably, the birds would have to travel in search of habitat that did meet these needs.

Bobwhites selected specific habitat types within our study area for their home ranges. Further evidence for selection of habitat types within their home ranges was shown by individual radio-locations. Bobwhites showed preference for early successional habitat or, more specifically, open canopy pines and fallow fields (Figures 4.2 and 4.3). Bobwhites also demonstrated an avoidance of hedgerows and agricultural areas. Other research has shown that bobwhites are an open land species that thrives in agricultural fields broken up by hedgerows (Stoddard 1931, Rosene 1969). Our observations could be explained by the composition of these habitat types on our study area. Bobwhite avoidance of hedgerows could be explained by the composition of these habitat types on our study area. Most hedgerows that were visible on aerial photographs during the digitizing process were actually narrow strips of either large hardwood or pine trees. The extensive size of our study area limited our ability to ground-truth all herbaceous strips of vegetation that may also have served as hedgerow habitat. Bobwhites exhibited avoidance of agricultural areas as well. Agricultural areas included pecan orchards, cultivated (row-crop) fields, hay fields, and pastureland: areas that received frequent disturbance either through mechanical means (mowing and disking) or by grazing (livestock). Previous research detected bobwhites selecting agricultural areas extensively, particularly when field edges were managed for weedy habitat (Rosene 1969, Puckett et al. 2000). Our results differed from these studies likely because agricultural areas in our region were not improved for bobwhites.

Loblolly pine plantations comprised 26% of our study area and were divided into 2 habitat categories – open-canopy and closed-canopy – because of the vast difference in the amount of understory vegetation (Schweitzer and Hale, unpublished data). Most of the pine plantations within the study area were CCPP enrolled in the CRP. These CCPP stands had very little understory vegetation but had moderate plant growth around their edges (Schweitzer and Hale, unpublished data). Closed-canopy planted pine stands were neither preferred nor avoided at the home range and radio-location levels of analysis. Our results supported Lewis' (1999) observation that bobwhites used CRP pines stands (majority of the CCPP category) for nesting sites. Eleven of 12 nests located within CCPP stands were ≤15 m of the stand edge, likely due to the vegetation growth found around these stand edges.

We documented significant use of OCPP and fallow field habitats, consistent with other studies on bobwhite habitat use (Stoddard 1931, Rosene 1969, Lee 1994). Our research also supports the findings that bobwhites prefer fallow field habitat undergoing succession (Dixon et al. 1996) over other habitats that might be available for their home range and at the landscape level. It would appear that the understory vegetation component of the OCPP was preferred by bobwhites over that found in the CCPP.

Decreased inclusion of treatment pine stands into bobwhite home ranges was not an expected result in our study. This observation could be a result of different capture locations of bobwhites between years. Although we tried to capture birds from the same areas each year, this was not always possible because of variation in covey home ranges between years. Since we also observed decreased inclusion of the control stands over the same time period, avoidance of the treatment stands was not likely a result of the habitat manipulation. Vegetation response to the thinning was noticeable, but no manipulations (e.g., disking or burning) were implemented to encourage establishment of high quality bobwhite food and cover vegetation. Our study was limited due to logistical constraints, i.e., most CCPP pine stands on our study area were too young for merchantable timber harvest.

Our study area, and many landscapes similar to it, had a much lower density of bobwhites (~0.1 birds/ha) than areas previously researched in the Southeast (e.g., Eric Staller, Tall Timbers Research Station, personal communication, ~3 birds/ha at the Tall Timbers Research Station; Clay Sisson, Albany Area Cooperative Quail Project, personal communication, 5 birds/ha on private plantations in the Albany, Georgia area). Bobwhites in forest- and agriculture-dominated landscapes had to travel through areas with little understory vegetation (CCPP, mature hardwood bottomlands, and open agricultural fields) to move between patches of early successional habitat. Increasing connectivity and creating more patches of early successional habitat as a result of thinning CCPP may provide better vegetative cover and travel corridors for bobwhites. Increasing the acreage and interspersion of early successional habitat on the landscape would provide more brood range and nesting habitat and could help to increase both brood and adult survival (Taylor et al. 1999). The increased cover provided by this mosaic of early successional habitat also could improve adult survival. Providing more early successional habitat and connecting areas of existing cover by thinning CCPP stands could increase adult and brood survival rates so that the local population could begin to rebound (Cantu and Everett 1982).

Our findings support the recommendations of the 1996 Farm Bill to improve the wildlife habitat quality of CRP pine stands by thinning. Bobwhites showed a preference for early successional habitat both within the study area and their home ranges each year (Figure 4.2 and 4.3). These observations, coupled with the high percentage of dead bobwhites documented in CCPP, suggest that thinning densely-planted pine stands will provide improved habitat for bobwhites. However, thinning provides only temporary habitat. As trees grow in response to thinning, the canopy will eventually close and understory vegetation will be lost. The thinning process will have to be repeated to continue providing improved habitat for bobwhites. Other management techniques that should be considered in addition to thinning for understory manipulation are winter disking, prescribed burning and herbicide use.

Literature Cited

Burger, L. W., Jr., 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.

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

Cantu, R., and D. D. Everett. 1982. Reproductive success and brood survival of bobwhite quail as affected by grazing practices. Pages 79-83 *in* F. Schitoskey, Jr., E. C. Schitoskey, and L. G. Talent, editors. Proceedings of the second national bobwhite quail symposium. Stillwater, Oklahoma, USA.

Dixon, K. R., M. A. Horner, S. R. Anderson, W. D. Henriques, D. Durham, and R. J. Kendall. 1996. Northern bobwhite habitat use and survival on a South Carolina plantation during winter. Wildlife Society Bulletin 24:627-635.

Lee, J. M. 1994. Habitat ecology of the northern bobwhite on Copiah County Wildlife Management Area. Thesis, Mississippi State University, Starkville, Mississippi, USA.

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.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, and T. L. Sharpe. 2000. Effects of filter strips on habitat use of northern bobwhites on Alligator River National Wildlife Refuge. Proceedings of the National Quail Symposium 4:26-31.

Rosene, W. 1969. The bobwhite quail: its life and management. The Sun Press, Hartwell, Georgia, USA.

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

Taylor, J. S., K. E. Church, D. H. Rusch, and J. R. Cary. 1999. Macrohabitat effects on summer survival, movements, and clutch success of northern bobwhite in Kansas. Journal of Wildlife Management 63:675-685.

Townsend, D. E. II, R. E. Masters, R. L. Lochmiller, D. M. Leslie, Jr., S. J. Demaso, and A. D. Peoples. 2001. Characteristics of nest sites of northern bobwhites in western Oklahoma. Journal of Range Management 54:260-264.

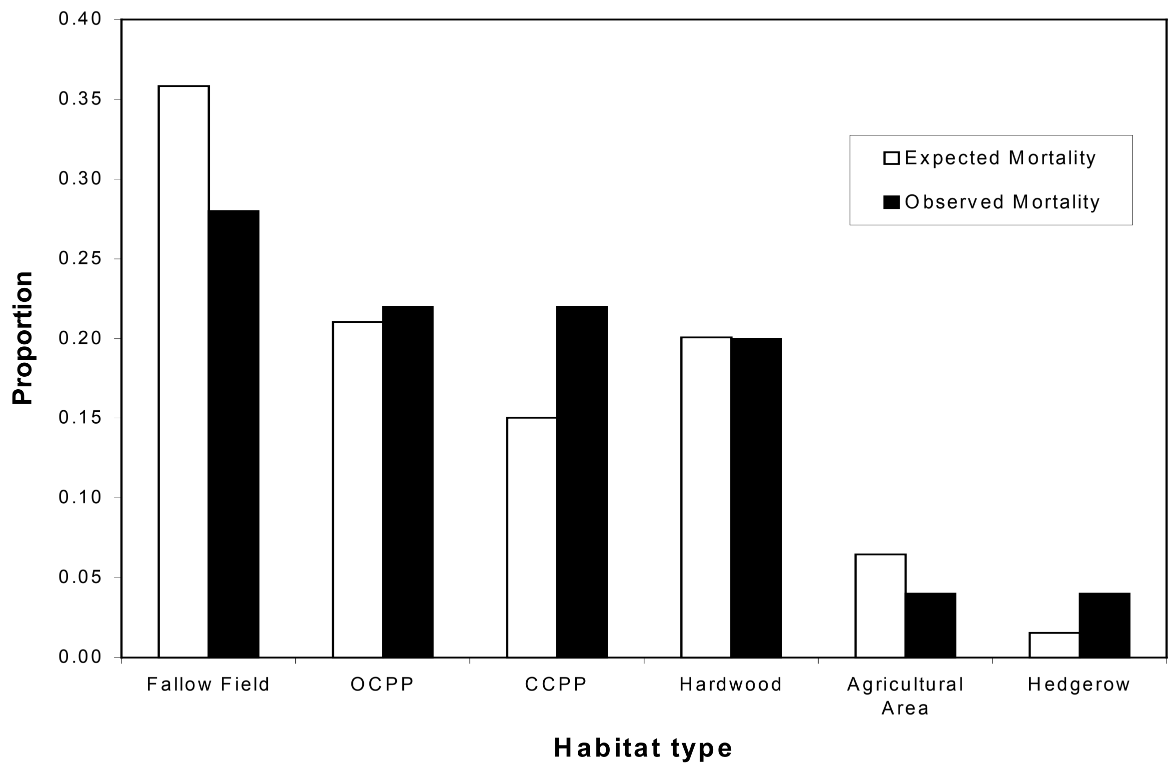

Figure 4.1. Expected (habitat use x total number of dead bobwhites) and observed locations of dead northern bobwhites for each habitat type on the study areas (Di-Lane Plantation and Alexander Wildlife Management Areas, Burke County, Georgia) from May – August 1997-2000 (OCPP = Open-Canopy Planted Pine; CCPP = Closed-Canopy Planted Pine).

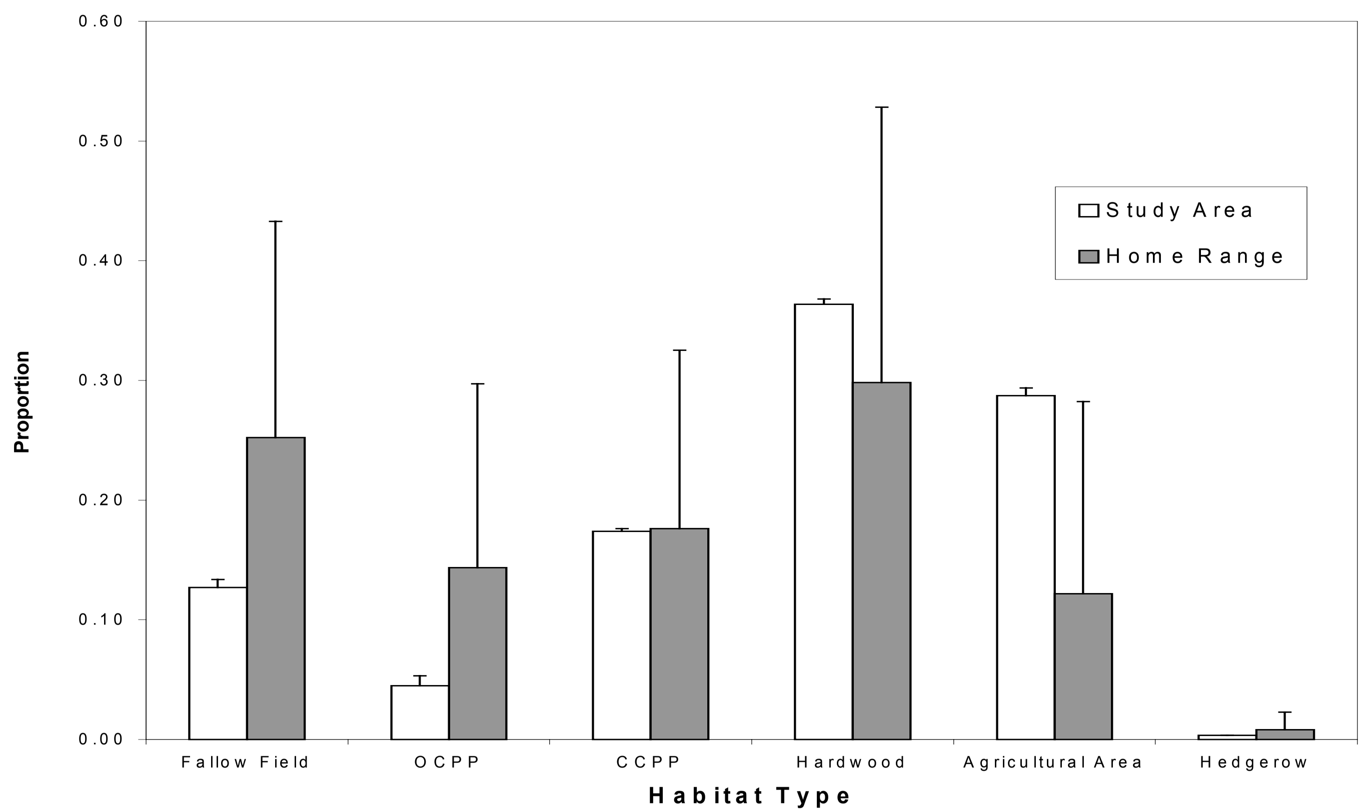

Figure 4.2. Mean proportion of habitat types available on our study areas (Di-Lane Plantation and Alexander Wildlife Management Areas, Burke County, Georgia) relative to mean proportion of habitat types encompassed in northern bobwhites home ranges, May – August 1997-2000 (OCPP = Open-Canopy Planted Pine; CCPP = Closed-Canopy Planted Pine). Error bars indicate standard deviation.

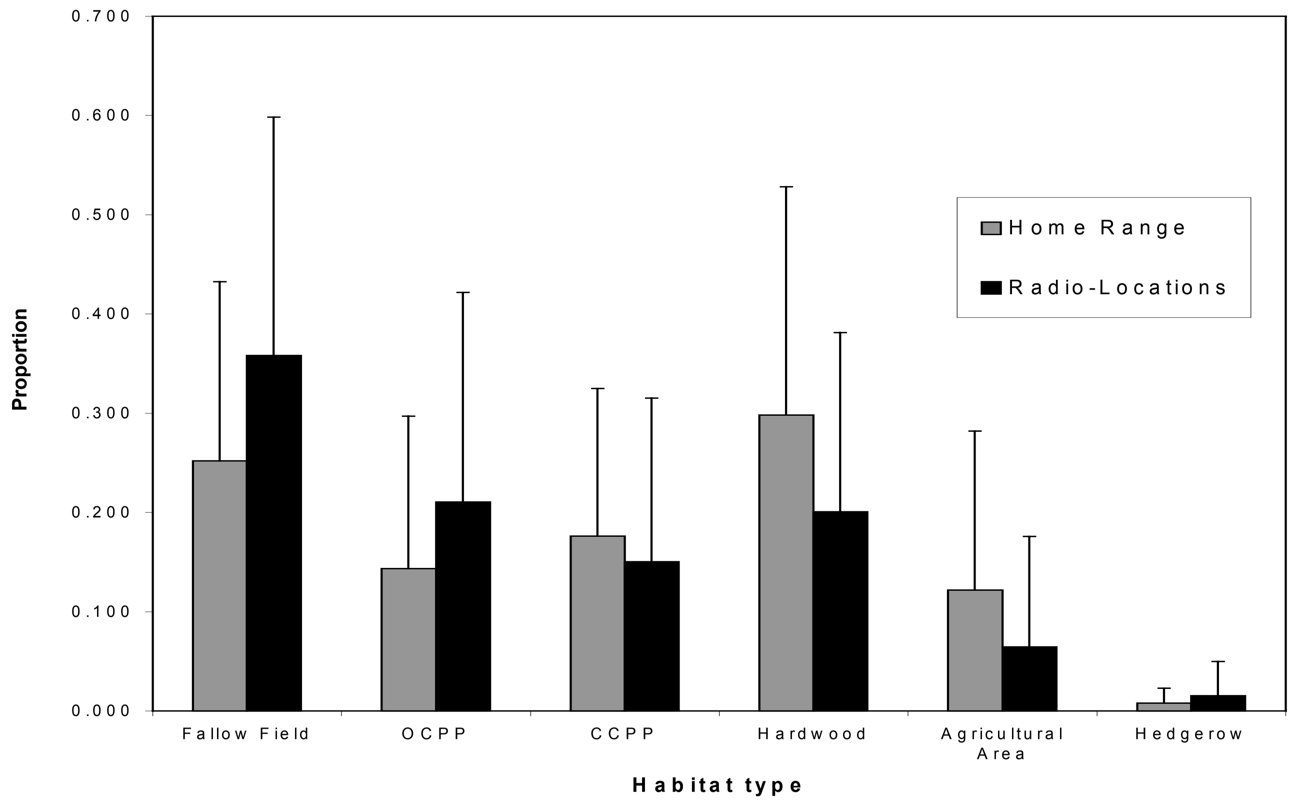

Figure 4.3. Mean proportion of habitat types available within northern bobwhite home ranges relative to mean proportion of radio-locations of marked bobwhites within habitat types encompassed in home ranges, May – August 1997-2000 (Di-Lane Plantation and Alexander Wildlife Management Areas, Burke County, Georgia; OCPP = Open-Canopy Planted Pine; CCPP = Closed-Canopy Planted Pine). Error bars indicate standard deviation.

APPENDICES

APPENDIX A

CRP land use practices in the southeastern United States as taken from a United States Department of Agriculture website (www.fsa.usda.gov/crpstorpt/05approved/r1sumyr/us) on 10 July 2000.

National
Report ID – MEPRTN-R1

U.S. Department of Agriculture – Farm Service Agency
Conservation Reserve Program – Monthly Contract Report
Summary for Active Contracts for All Program Years (1986-2001)

State Name	Total CRP Acres	Average Rental Rate	Tree Practice Acres
Alabama	457,592.9	$44.10	304,841.3
Georgia	286,623.2	$38.97	265,616.0
Florida	87,459.1	$36.94	80,800.9
Mississippi	791,836.8	$38.92	600,446.3
North Carolina	93,127.3	$48.97	52,991.2
South Carolina	204,149.7	$33.95	154,186.6
Tennessee	232,203.4	$52.46	28,355.3
Virginia	44,056.8	$41.85	18,003.8
Total	2,197,049.2	$42.02	1,505,241.4

APPENDIX B

Conservation Reserve Program enrollment for March 1986– June 1992 (Sign-up periods 1-12) as taken from The University of Georgia College of Agriculture and Environmental Sciences website (www.bugwood.caes.uga.edu/crp/landuse) on 21 May 2002.

The University of Georgia – College of Agriculture and Environmental Sciences
Conservation Reserve Program – Signup periods 1-12
Summary for Land Use 1986-1992

Area	**Tree Practice Acres (Hectares)**
Georgia	645,931 (261,510.5)
Southeast	1,297,565 (525,366.8)

APPENDIX C

Variables measured using the breeding bird (BBIRD) protocol for ground nesting birds for comparison between nest sites and paired random vegetation plots.

Trees >8 cm dbh within 11.3 m of plot center

Shrubs >50 cm tall within 5 m of plot center

Tree Canopy Height (m)

Dominant Canopy Plant Species

Co-dominant Canopy Plant Species

Total Canopy Cover (%) in cardinal directions

Aspect (degrees)

Slope (%)

Percent Cover within 5 m of plot center

All green vegetation cover 0-15 cm tall	Grass/Sedge <50 cm tall
All green vegetation cover 15-50 cm tall	Shrub <50 cm tall
Forb <50 cm tall	Fallen logs >12 cm dbh
Leaf litter for pine, deciduous, and brush	Water (Absent or Present)
Bare ground	Ant mounds (# active or inactive)

Litter depth at 1.5, 3 and 5 m from plot center

All green vegetation cover 0.5-2 m tall

All green vegetation cover 2-7 m tall

Distance to edge including the type of edge

Overhead cover description

Species	Distance to nest (cm)
DBH (cm)	Height to overhead canopy (m)

Percent cover within 1 m of plot center

Grass	Sedge
Blackberry	Trumpet Creeper
Other species	

Vertical vegetation intercepts (#) at 5 and 11.3 m from plot center

0-1 m tall	1-2 m tall
2-3 m tall	3-4 m tall
4-5 m tall	

Vegetation density board (%) at 5 and 11.3 m from plot center

0-0.5 m tall	0.5-1 m tall
1-2.5 m tall	

Nest cover (%)

Overhead	Average from all sides

APPENDIX D

Bobwhite Population Demography on Di-Lane Plantation and Alexander Wildlife Management Areas
Bobwhites Trapped January – June 1997-2000

Sex (age)	**1997**	**1998**	**1999**	**2000**
Male (Juvenile)	32 (18)	22 (13)	27 (20)	22 (10)
Female (Juvenile)	20 (17)	16 (13)	8 (7)	16 (12)
Total (Juvenile)	52 (35)	39 (26)	35 (27)	38 (22)

Average Weight for Bobwhites Captured on Di-Lane Plantation and Alexander Wildlife Management Areas
Bobwhites Trapped January – June 1997-2000

Age and Sex	**1997**	**1998**	**1999**	**2000**
Adult Male (Juvenile)	170 (172)	179 (173)	181 (172)	180 (168)
Adult Female (Juvenile)	171 (172)	172 (168)	170 (166)	195 (171)
Adult Total (Juv. Total)	171 (172)	176 (170)	176 (169)	187 (180)

APPENDIX E

Sample datasheet for radio-telemetry locations

Bobwhite Radio-Telemetry Locations
Pineland Stewards Project
Di-Lane and Alexander WMAs

Band #	Date	Transmitter Frequency	Time	Wind Direction	Temperature (F)	Cloud Cover (%)	Rain	Habitat Type	Distance to Type of Different Habitat	Active or Stationary	GPS File Name	Comments