Northern Bobwhite Habitat Use, Survival, and Nest Success in a Forest- and Agriculture-dominated Landscape

Ira B. Parnell III,[1] *D. B. Warnell School of Forest Resources, University of Georgia, Athens, GA 30602*

Lynn A. Lewis-Weis,[2] *D. B. Warnell School of Forest Resources, University of Georgia, Athens, GA 30602*

Sara H. Schweitzer, *D. B. Warnell School of Forest Resources, University of Georgia, Athens, GA 30602*

Craig G. White,[3] *D. B. Warnell School of Forest Resources, University of Georgia, Athens, GA 30602*

John P. Carroll, *D. B. Warnell School of Forest Resources, University of Georgia, Athens, GA 30602*

Abstract: Changes in land use that reduce habitat availability and quality for northern bobwhite (*Colinus virginianus*) are primarily responsible for a significant bobwhite population decline in the Southeast. Establishment of densely stocked pine plantations (*Pinus* spp.) on agricultural lands, encouraged by federal assistance programs of the 1980s, likely adversely affected northern bobwhite. To understand how bobwhite habitat my be improved on such land, we examined habitat selection by northern bobwhite (N = 61) during 1997–2000 in the Upper Coastal Plain of Georgia in a forest- and agriculture-dominated landscape. Selection of habitats ($\lambda = 0.35$, $P \leq 0.001$) indicated northern bobwhite preferred early-successional habitats within the study area. Northern bobwhite preferred open canopy planted pine and fallow field habitats over closed canopy planted pine and agricultural areas. Increasing proportion of fallow fields and open-canopy planted pines in a landscape context similar to our area may enhance habitat quality for northern bobwhite. Thinning pine stands is a management practice feasible for the average landowner to improve already established, closed canopy pine stands for northern bobwhite.

Key words: Colinus virginianus, Georgia, habitat use, home range, survival, nest success, northern bobwhite, pine plantations, *Pinus* spp.

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Northern bobwhite (*Colinus virginianus;* hereafter, bobwhite) populations in the southeastern United States declined by 66% from 1966 to 1999 (Sauer et al.

1. Current address: Georgia Department of Natural Resources, Game Management Section, 142 Bob Kirk Road, Thomson, GA 30824.
2. Current address: National Wild Turkey Federation, P.O. Box 530, Edgefield, SC 29824.
3. Current address: Idaho Department of Fish and Game, 3101 S. Powerline Rd., Nampa, ID 83686.

2001). Proposed reasons for this decline include loss of habitat due to changing land use practices (Klimstra 1982), increases in avian and mammalian predator populations (Sauer et al. 2001), introduction of fire ants (*Solenopsis invicta*) (Allen et al. 1993, Pedersen et al. 1996), and increased use of pesticides (Palmer et al. 1998). While it is probable that no single factor is responsible for the bobwhite decline, habitat change clearly is a primary cause (Brennan 1991, Guthery et al. 2000, Burger 2002).

Intensive silvicultural practices that maximize wood fiber production by planting trees at very high densities may contribute to bobwhite population declines (Rollins and Carroll 2001) by leading to early canopy closure (5–6 years; Carmichael 1997). After canopy closure, little understory vegetation persists to provide necessary habitat conditions for bobwhites (Allen 1994).

Many wildlife biologists suspected that conversion of row-crop agricultural lands to pine plantations contributed to declines of local bobwhite populations through encouragement of dense pine plantings by federal programs such as the Conservation Reserve Program (Hays and Farmer 1990, Stauffer et al. 1990). Once these plantations reach mid-rotation (12–16 years), they can be thinned to improve habitat conditions for bobwhites. Thinning, or creating openings in the tree canopy, allows sunlight to reach the ground, stimulating understory vegetation beneficial to bobwhites (Rosene 1969, Conroy et al. 1982).

We investigated bobwhite habitat use within a landscape used primarily for pine production and row-crop agriculture. Several thousand hectares of marginal cropland in this area were planted to loblolly pines at ≥1,793 trees/ha as part of the 1985 CRP. We investigated bobwhite use of habitat types within this landscape. 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 study was conducted on Di-Lane Plantation (325807N 820504W) and Alexander (330022N 815457W) Wildlife Management Areas (WMAs) and surrounding lands in Burke County, Georgia. Di-Lane Plantation WMA was a 3,278-ha area working agricultural farm from 1976–1991. In 1988 managers enrolled 286 ha in the CRP and planted loblolly pine. Local farmers rented the remaining land (849 ha) for agricultural production. In 1992, the property was purchased by the U.S. Army Corps of Engineers as mitigation land, and management responsibility was given to Georgia Department of Natural Resources (GA DNR). Management focus of GA DNR was enhancement of habitat to benefit bobwhite populations. We expanded the Di-Lane area to 11,680 ha to encompass all radiolocations of bobwhites monitored during 1997–2000. There were four predominant habitat types ($\bar{x}$ ± SD) on Di-Lane at the time of this study: 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 was a 555-ha area, predominately in row-crop agriculture until the 1980s when much of it was converted to loblolly pine plantations. In 1997, GA DNR acquired the property and began managing it for small game and archery-only hunting for white-tailed deer (*Odocoileus virginianus*). We expanded this area to 3,786 ha to encompass all radiolocations of bobwhites monitored during 1997–2000. The four predominant habitat types ($\bar{x}$ ± SD) on Alexander WMA were pine plantations (1,401 ± 16 ha), hardwoods (1,152 ± 15 ha), agricultural areas (849 ± 4 ha), and fallow fields (366 ± 30 ha).

Di-Lane and Alexander WMAs were 12 km apart and within a landscape of fallow fields, agricultural fields, residential areas, pecan (*Carya illinoenis*) orchards, pine plantations, and upland and bottomland hardwoods. Area boundaries around the WMAs were arbitrarily delineated based on roads and rights-of-way that were ≥800 m outside any recorded bobwhite location (White et al. 2005). When an unbroken land cover patch extended ≥1,000 m beyond a recorded bobwhite location without an arbitrary delineation, a logical cut-off within the land cover patch was used, such as a narrow area within the patch. Because WMA boundaries did not limit movement of bobwhites, areas delineated around the WMAs were relatively close together (<6 km), and WMAs were in similar cover types, we considered WMAs and surrounding area as one study area. These areas were representative of the Upper Coastal Plain physiographic region of Eastern Georgia.

Methods

We sorted habitat types into six classes: fallow field, open canopy planted pine (OCPP: pine stands that had been thinned 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). We delineated habitat types by referencing U.S. Geological Survey 1993 Digital Orthophoto Quarter Quadrangle (DOQQ) maps and using our knowledge of the study area, on-site inspection, and remote imagery. We digitized habitat types at a scale ≥1:3,000 m using the ArcView (ESRI 1999) geographic information system (GIS) software.

We captured bobwhites during January–June 1997–2000 using wire funnel traps baited with cracked corn (Stoddard 1931). After capture we recorded gender, weight (g), and age (juvenile, adult) (Rosene 1969) of each bird, and attached a size 3 aluminum leg band and 6.1-g necklace-style radiotransmitter (Holohil Systems, Ontario, Canada; IACUC Protocol No. A960216C2). Radiotransmitters had a battery life of >6 months and were replaced after failure when possible.

Following release, we allowed bobwhites one day to acclimate to radiotransmitters and thereafter located them during staggered times, once every 1–3 days, using a R4000 receiver and 3-element Yagi antenna (Advanced Telemetry Systems, Anoka, Minnesota). We used homing (Mech 1983) to locate radiomarked bobwhites. We tracked bobwhites from one day post-capture to 23 August of each field season for survival analyses. We estimated adult survival rates using the Stagkam Kaplan-Meier staggered entry survival program (Kaplan and Meier 1958, Kulowiec 1988).

Bobwhites that did not survive for ≥7 days post-capture were not included in survival analyses. We recorded habitat types where dead bobwhites were found and we used a Chi-square (χ^2) goodness-of-fit test and a Bonferroni z-statistic (Neu et al. 1974) to detect differences ($P \leq 0.05$) between observed and expected number of dead bobwhites in each habitat based on its use.

We only used those birds with ≥14 locations obtained after covey breakup (approximately 15 April) for home range assessment, habitat use, and nesting analyses. We recorded habitat type and Universal Transverse Mercator (UTM) coordinates (Geoexplorer II hand-held global positioning system [GPS] receiver; Trimble Navigation Ltd., Sunnyvale, California) associated with each bobwhite location.

We estimated individual home ranges using 100% minimum convex polygons based on UTM coordinates obtained from radiomarked bobwhite locations. To construct individual home ranges, we used the Hooge and Eichenlaub (1999) ArcView Animal Movement extension in ArcView. We used compositional analysis (Aebischer et al. 1993) using the MacComp 0.90 program (J. P. Carroll, University of Georgia) to detect significant departures from random habitat use by bobwhites. Two habitat selection scales (Johnson 1980) were used 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 radiolocations in each habitat type within each home range to availability of that habitat type within each home range. We replaced non-available habitat values with 1/10 of our smallest habitat value, and fallow field habitat type was used as the denominator in our analysis. All other assumptions for compositional analysis were followed according to Aebischer et al. (1993). We used a multivariate analysis of variance (MANOVA) with the SYSTAT program to determine if year effects were present at each level of compositional analysis (SYSTAT 1992).

We located nests by homing on radiomarked bobwhites that had not moved for 2–3 consecutive days. We considered a nest to be successful if at least one egg hatched and we estimated daily survival of nests using the modified Mayfield method (Mayfield 1961, Mayfield 1975, Bart and Robson 1982). We monitored nests daily to determine fate.

Results

We captured 159 bobwhites on our study area (1997, N = 52; 1998, N = 37; 1999, N = 35; 2000, N = 35). We obtained ≥14 locations from 61 bobwhites during the 1997–2000 field seasons. Therefore, information from these 61 bobwhites was used in home range assessment, habitat use, and nest success analyses.

Adult Survival

Percentages of radiomarked bobwhites that survived ($\bar{x} \pm$ SD) ≥7 days post-capture to 23 August was 13 ± 0.05% (1997, N = 52), 18 ± 0.07% (1998, N = 37), 25 ± 0.08% (1999, N = 35), and 11 ± 0.04% (2000, N = 35). We monitored a daily average of 13.2 (1997), 12.5 (1998), 13.7 (1999), and 15.3 (2000) bobwhites. We

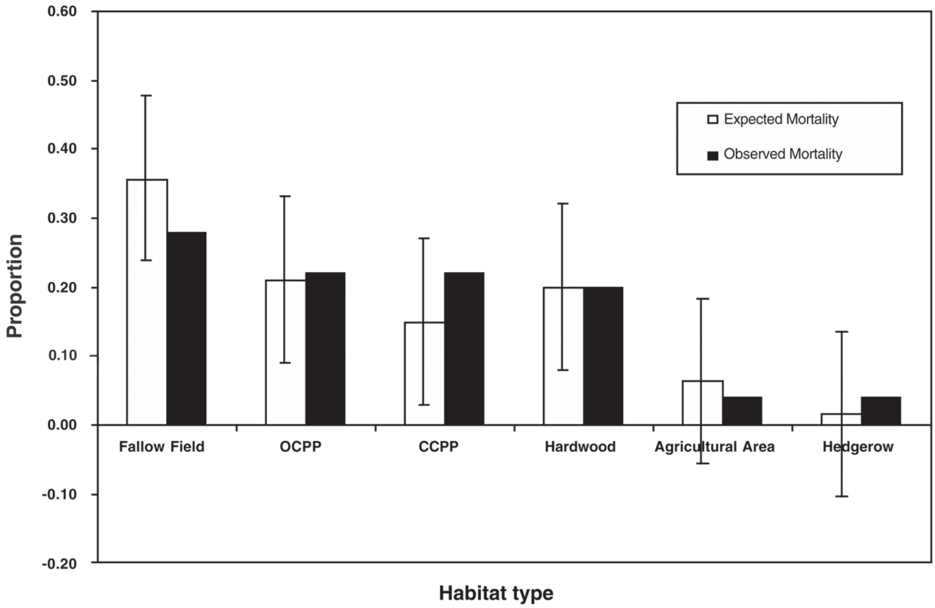

Figure 1. Expected (habitat use by number of dead bobwhites) and observed locations of dead northern bobwhites for each habitat type on Burke County, Georgia, study area from 15 April–1 September 1997–2000 (OCPP = Open-Canopy Planted Pine; CCPP = Closed-Canopy Planted Pine). Error bars indicate confidence intervals at *P* = 0.05.

documented 95 bobwhite mortalities from January–1 September 1997–2000. Most mortality (83%, 1997–2000) of radiomarked bobwhites was due to predation, except 4 were hunter-killed, 5 died during trapping, 1 died due to entanglement in the radiotransmitter harness, and 1 died from lead toxicosis (Lewis and Schweitzer 2000). We removed 6 bobwhites from our survival analysis (5 trap-related and one transmitter harness-related mortality) because our interference was directly tied to their mortality. We documented the habitat type where mortality locations of bobwhites were found from 15 April–1 September 1997–2000 for comparison with expected mortality values based on habitat use. Of 45 bobwhites found dead during this time period, 12 were found in fallow fields, 10 in CCPP, 10 in OCPP, 9 in hardwoods, 2 in hedgerows, and 2 in agricultural areas. There was no difference between observed and expected locations of dead bobwhites ($\chi^2_5 = 5.34$; $P = 0.38$). Bonferroni z-statistics with confidence intervals calculated for the expected number of mortality locations in each habitat type are as follows: fallow field (0.36 ± 0.12), OCPP (0.21 ± 0.12), CCPP (0.15 ± 0.12), hardwoods (0.20 ± 0.12), agricultural areas (0.06 ± 0.12), and hedgerows (0.02 ± 0.12) (Fig. 1).

Table 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 Burke County, Georgia, study area, 15 April–1 September 1997.

Habitat used	Fallow field	OCPP[a]	CCPP[b]	Hardwood	Agricultural areas	Hedgerow
Fallow field		–0.40[c] (0.63)	–1.72 (<0.01)[d]	–2.61 (<0.01)*	–4.92 (<0.01)*	–2.37 (<0.01)*
OCPP[a]	+0.40 (0.63)		–1.32 (0.23)	–2.21 (0.04)*	–4.66 (<0.01)*	–1.96 (0.02)*
CCPP[b]	+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[e]	1	2	3	5	6	4

a. Open canopy planted pines
b. Closed canopy planted pines
c. A negative value indicates that the row habitat was used more than the column habitat. A positive value indicates the opposite.
d. An asterisk (*) denotes a statistical significance at $P \leq 0.05$ as determined by a *t*-test comparison of use of habitat types.
e. 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. 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 Burke County, Georgia, study area, 15 April–1 September 1998.

Habitat used	Fallow field	OCPP[a]	CCPP[b]	Hardwood	Agricultural areas	Hedgerow
Fallow field		–0.58[c] (0.63)	–1.35 (0.02)*[d]	–1.35 (0.08)	–3.70 (<0.01)*	–2.12 (0.02)*
OCPP[a]	+0.58 (0.63)		–0.78 (0.44)	–0.77 (0.47)	–3.12 (<0.01)*	–1.55 (0.07)
CCPP[b]	+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[e]	1	2	4	3	6	5

a. Open canopy planted pines
b. Closed canopy planted pines
c. A negative value indicates that the row habitat was used more than the column habitat. A positive value indicates the opposite.
d. An asterisk (*) denotes a statistical significance at $P \leq 0.05$ as determined by a *t*-test comparison of use of habitat types.
e. 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.

Home Range and Habitat Selection

Average home range size ($\bar{x}$ ± SD) for bobwhites from 15 April–1 September 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. In compositional analysis, year effects were present at the study area versus home range level of comparison ($F_{15,\ 146}$ = 2.94; $P \leq 0.001$), but not at the home range versus radiolocation level ($F_{15,\ 146}$ = 1.21; P = 0.27). Proportions of available habitat on our study area differed from habitat proportions found within individual bobwhites' home range in each study year except 2000 (Table 1, 1997 λ = 0.14, $P \leq 0.001$; Table 2, 1998 λ = 0.15, P = 0.01; Table 3, 1999 λ = 0.19, P = 0.01; Table 4, 2000 λ = 0.49, P = 0.37). Bobwhite home range selection for 1997–1999 favored fallow fields and OCPP, avoided agricultural areas, hedgerows, and CCPP, and used hardwoods intermediately. Because there was no year effect at the home range versus radiolocation level of comparison, we pooled data over years. Habitat use differed from random (λ = 0.35, $P \leq 0.001$) at this level. Bobwhites within their home ranges favored OCPP and fallow fields, avoided agricultural areas and hedgerows, and used CCPP and hardwoods intermediately.

Nest Success

Nesting occurred from 12 May until 7 September on our study area. We located 31 nests of radiomarked bobwhites during 1997–2000. Nests were located in fallow fields (*N* = 12, 7 successful), CCPP (*N* = 12, 6 successful), OCPP (*N* = 5, 3 successful), agricultural fields (*N* = 1, successful), and hardwoods (*N* = 1, unsuccessful). Nest success rates varied from 1997–2000 (35% in 1997, 51% in 1998, 83% in 1999, and 16% in 2000). Nests located in CCPP stands were <25 m from edge of the stand.

Discussion

Adult Survival

Annual adult bobwhite survival rates during our study were comparable to those documented in other studies (e.g., Burger et al. 1995). Locations of dead, radiomarked bobwhites were not found where expected based on habitat use (Fig. 1), although there was no statistical difference detected using the Neu et al. (1974) method. Even though location of a dead bobwhite may not be the area of initial depredation, mortality sites could still be important as juxtaposition of certain habitat types may make bobwhites more susceptible to depredation.

Home Range and Habitat Selection

Although average home range sizes for bobwhites on our study areas were comparable to those found in the literature (e.g., Taylor et al. 1999*a*), few other studies have documented home range sizes of radiomarked individuals during nesting season using the minimum convex polygon method. Average home range size increased from 40 ha to 134 ha from the first year to the third year of our study, then dropped

Table 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 Burke County, Georgia, study area, 15 April–1 September 1999.

Habitat used	Fallow field	OCPP[a]	CCPP[b]	Hardwood	Agricultural areas	Hedgerow
Fallow field		+0.42[c] (0.67)	–2.78 (0.06)	–0.23 (0.74)	–1.46 (0.22)	–0.35 (0.59)
OCPP[a]	–0.42 (0.67)		–3.20 (<0.01)*[d]	–0.65 (0.48)	–1.88 (<0.01)*	–0.77 (0.35)
CCPP[b]	+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[e]	2	1	6	3	5	4

a. Open canopy planted pines
b. Closed canopy planted pines
c. A negative value indicates that the row habitat type was used more than the column habitat type. A positive value indicates the opposite.
d. An asterisk (*) denotes a statistical significance at $P \leq 0.05$ as determined by a *t*-test comparison of use of habitat types.
e. 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 4. Mean (SE) log-ratio difference matrix of all pairings for habitat proportions in home range (available) versus radiolocations (use) for individual northern bobwhites (*N*=61) on Burke County, Georgia, study area, 15 April–1 September 1997–2000.

Habitat used	Fallow field	OCPP[a]	CCPP[b]	Hardwood	Agricultural areas	Hedgerow
Fallow field		+0.12[c] (0.82)	–0.77 (0.10)	–0.90 (0.08)	–3.18 (<0.01)*[d]	–1.13 (0.06)
OCPP[a]	–0.12 (0.82)		–0.39 (0.36)	–0.89 (0.16)	–3.49 (<0.01)*	–2.09 (<0.01)*
CCPP[b]	+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[e]	2	1	3	4	6	5

a. Open canopy planted pines
b. Closed canopy planted pines
c. A negative value indicates that the row habitat type was used more than the column habitat type. A positive value indicates the opposite.
d. An asterisk (*) denotes a statistical significance at $P \leq 0.05$ as determined by a *t*-test comparison of use of habitat types.
e. 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.

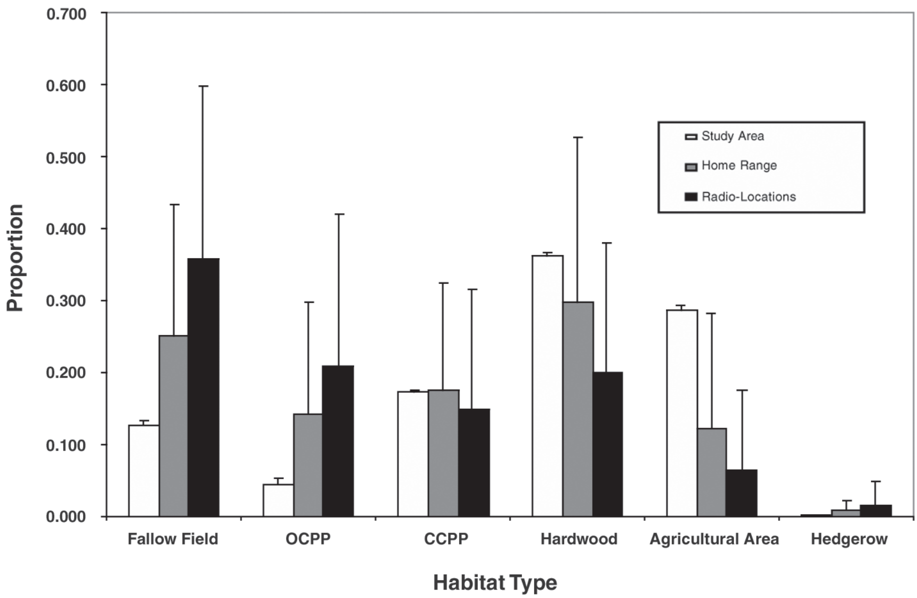

Figure 2. Mean proportion of habitat types available on our study area in Burke County, Georgia, relative to mean proportion of habitat types encompassed in northern bobwhites home ranges and mean proportion of radiolocations of marked bobwhites within habitat types encompassed in home ranges, 15 April–1 September 1997–2000 (OCPP = Open-Canopy Planted Pine; CCPP = Closed-Canopy Planted Pine). Error bars indicate standard deviation.

to 116 ha in the fourth year. Possibly, bobwhites increased their home range sizes in response to decreased availability of food and nesting sites during breeding seasons as a result of the dry conditions in eastern Georgia during 1999–2000.

Relative to types of habitat available in our study area, bobwhite home ranges selectively included fallow fields and OCPP. Our results reinforce the expectation that bobwhites selected early successional habitat, albeit our study was in a different landscape context than others (Rosene 1969, Lee 1994, Dixon et al. 1996, Cook 2004). Our results also indicated an avoidance of hedgerows and agricultural areas, a contradiction to early research that determined bobwhites thrived in agricultural fields broken up by hedgerows (Stoddard 1931, Rosene 1969). However, agricultural areas today do not reflect the same landscape that was present in the early to mid-1900s. Hedgerows in our landscape are composed of mainly mature hardwoods with little understory vegetation (I.B. Parnell, personal observation) in contrast to the hedgerows of the early 1900s that were composed of weeds and briars (Stoddard 1931). In our study area, agricultural lands included pecan orchards, cultivated (row-crop) fields, hay fields, and pastureland. These areas 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). In our study area, agricultural areas were not improved for bobwhites, were large in size, and had few weeds around field edges (Lewis 1999).

Closed-canopy planted pine stands were used intermediately, but we documented high use of CCPP for nest sites (12 of 31 nests). These findings contradict common ideas about bobwhite use of CCPP habitats. However, most nests located within the CCPP category were ≤25 m from the edge of the stand, likely due to light penetration into the stand and growth of understory vegetation (S. H. Schweitzer and P. E. Hale, unpublished data), hence their use as nest sites may be due to an edge effect rather than the habitat type itself. Overall, however, it appeared that presence of understory vegetation in the OCPP was preferred by bobwhites over lack of understory vegetation in CCPP.

Nest Success

We documented wide variation in nest success among years (16%–83%). We located 12 nests in fallow fields and 12 nests in CCPP. We expected to find greatest number of nests in fallow fields because of presence of clumped broomsedge (*Andropogon* spp.) (Washburn et al. 2000, Madison et al. 2001), but we did not expect to find as many nests located at edges (≤25 m) of CCPP stands. Our observations were similar to those of Rosene (1969) who noted that most bobwhite nests were located within 15 m of an edge. We observed bobwhites moving their broods out of CCPP habitat shortly after hatching. This observation suggests that while edges of CCPP functioned as adequate nesting habitat, these stands were not providing brood-rearing habitat (Taylor et al. 1999*b*). Other data from multi-scale analysis found nest sites were associated with OCPP and greater patch density (White et al. 2005).

Management Implications

We recognize that our research has low sample sizes for conducting survival, habitat use, and nesting analyses and could lead to spurious conclusions. However, this research was conducted in a farm landscape common to many landowners and wildlife managers. Therefore, we believe that our research has much to offer to these land managers.

Our study area, similar to that found in much of the Southeast, was a forest- and agriculture-dominated landscape with little or no bobwhite habitat management and low bobwhite densities (0.1 bobwhites/ha, I. B. Parnell, personal observation). Bobwhites likely traveled through areas with little understory vegetation (CCPP, mature hardwoods, and agricultural fields) to move between patches of early successional habitat. Our findings support creating more patches of early successional habitat by thinning CCPP. By providing more early successional habitat and connecting areas of existing cover, survival and reproductive rates could increase, helping local populations.

Our findings support recommendations made by wildlife managers to improve bobwhite habitat quality in unthinned pine stands by thinning. Bobwhites incorporated OCPP pine stands into their home ranges and showed a preference for early successional habitat in general. These observations suggest that thinning densely-planted pine stands would provide improved habitat for bobwhites. Thinning stands to allow light to reach the understory must be continued as stands age and canopies close (Allen 1994, Conroy et al. 1982). Additional management techniques (winter disking, prescribed burning, herbicide application, planting native warm season grasses and legumes), not evaluated in this study, would likely further improve habitat conditions for bobwhites.

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