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Northern Bobwhite Brood Habitat Selection in South Florida

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During the past 3 decades, Northern Bobwhite (*Colinus virginianus*; hereafter, bobwhite(s)) populations have decreased throughout most of their distribution. A variety of factors have been attributed as the cause for this decline including changes in land use, agricultural intensification, increased predation, and high chick mortality. We assessed fourth-order habitat selection of broods in south Florida to develop predictions of management strategies that favor bobwhite brood success. We analyzed canopy coverage at actual brood locations versus both random-within MCP home range locations and random-outside MCP home range locations. Average home range size was 5.53 ± 2.43 ha. Our data suggests that no single vegetation type can be used to predict use by bobwhite broods. The models we evaluated using Akaike's Information Criterion (AIC) supports this belief. We also observed sod-forming grasses and forbs as the most prevalent vegetation types at brood and random-within MCP home range locations. Broad-leaved woody vegetation and legumes were more prevalent at brood locations than random locations. Our research demonstrates that plant community diversity is likely more important than a single functional group of plants. We believe that, at the ranch level, a combination of vegetation management within pastures, as well as large-scale management increasing interspersed of desirable vegetation communities will provide bobwhites quality habitat during all periods of their life cycle.

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Key words: brood, *Colinus virginianus*, Florida, habitat selection, northern bobwhite, quail

Introduction

During the past 3 decades Northern Bobwhite (*Colinus virginianus*; hereafter, bobwhite[s]) populations have markedly decreased throughout most of their distribution (Droege and Sauer 1990, Brennan 1991, Church et al. 1993). In the southeastern U.S.A., bobwhite populations declined by 66% during 1966 to 1999 (Sauer et al. 2000). This decline has been attributed to changes in land-use associated with reforestation, suburban and urban sprawl, and agricultural intensification (Brennan 1991, Roseberry 1993). Still other reasons have been proposed for these declining trends including increases in avian and mammalian predators ((Rollins and Carroll 2001), introduction of the red-imported fire ants (RIFA; *Solenopsis invicta*), and increased use of pesticides among agricultural ecosystems (Palmer et al. 1998).

It is crucial to provide habitat that induces the

recruitment of offspring into the population if that population experiences high rates of annual mortality such as bobwhites (Yates et al. 1995). Bobwhites experience high annual mortality in the Southeast; mortality rates range from 70%-80% (Speake 1967, Simpson 1976). Therefore, adequate chick survival is critical to the sustain bobwhite populations. The use of certain habitats does not necessarily mean higher survival in those habitats, but assumptions can be made about the importance of those habitats to bobwhites. It is important for landowners and wildlife biologists to know and understand more about brood habitat throughout the bobwhite's range so populations can be better managed for both conservation and recreation.

Micro-habitat selection of broods is the least-studied component of bobwhite ecology, and south Florida is perhaps the least-studied area of bobwhite range. Determining the most valuable habitat

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Table 1: Sum and average patch size of various cover types on the 2x4 Ranch near Arcadia, Florida, USA, 2005.

Cover type	Sum (ha)	Mean patch size (ha)
Fallow	177.72	4.44
Improved Pasture	1456.32	34.67
Other	35.09	3.9
Semi-improved Pasture	187.56	46.89
Wet Area	163.55	1.84
Wood	263.62	8.5
Young Grove	87.62	43.81

for bobwhite broods on this landscape will possibly lead to better management and higher population densities.

The objective of this study is to examine fourth-order habitat selection by bobwhites in southern Florida. Johnson (1980) describes a hierarchical nature of habitat selection: first-order selection is the geographical range of a species; second-order selection is the home range of an individual or social group; third-order selection is the use of habitat components within the home range; and fourth-order selection is micro-site plant species cover and composition selected from those available at the location. We predicted that broods would utilize habitats with more bunchgrass, forbs, and legumes and habitats with little to no sod-forming pasture grasses.

Study Area

This study was conducted on the 2x4 Ranch, which is located southeast of the peninsular town of Arcadia in Desoto County, Florida, U.S.A. The ranch supports a cattle operation with approximately 1,000 head of brood Brangus cows. The cattle are managed under an intensive rotationally grazed system. The ranch is dominated by improved pasture with the remaining portions being a mix of fallow, woody, wetland, and citrus groves (Table 1). Bahia grass (*Paspalum notatum*) is the dominant vegetation type

throughout the improved pastureland (Table 1). The topography of the landscape is predominantly flat with a maximum change in relief of 3 meters. The presence of surface water continually changes depending on the day and season and is often altered mechanically by the use of irrigation ditches. Annual rainfall averages 135 cm. Since acquiring the land in the early 1980s, the landowners have anecdotally reported drastic declines in bobwhite populations.

Methods

During February 2005 to April 2005, we captured bobwhites using standard wire walk-in funnel traps baited with grain sorghum (Stoddard 1931). We banded and fitted birds with a 6.4-6.9 g pendant-style radio transmitter and released them. We located radio-marked bobwhites using homing techniques (White and Garrott 1990) about 5 days per week and approached them to within 10-25 m. When we found a bird in the same location two days in a row, we assumed it to be nesting. We marked and monitored the nest daily. We verified the presence of the nest and recorded the number of eggs when the bird was absent from the nest. After hatching, we monitored the brood daily. At 14 days, we flushed the brood to assure the adult bird was still attending the chicks. Only broods with verified chicks at 14 days were included in the study-chicks

Table 2: Description of variables measured for Northern bobwhite broods in Florida, USA 2005.

Variable	Description
BLACK	Blackberry; <i>Rubus</i> spp.
SOFG	Sod-forming grasses; Bahia grass (<i>Paspalum notatum</i>), Bermuda grass (<i>Cynodon dactylon</i>)
FORB	Forbs; Queen Anne Delight (<i>Stillingia sylvatica</i>), Dogfennel (<i>Eupatorium capillifolium</i>)
BUGR	Bunchgrasses; Wire grass (<i>Aristida stricta</i>), Broomsedge (<i>Andropogon virginicus</i>)
BLWD	Broad-leaf woody; Wax myrtle (<i>Myrica cerifera</i>)
LEGM	Legumes: Partridgepea, Desmodium, Sesbania (<i>Chameacrista</i> , <i>Desmodium</i> , <i>Sesbania</i> spp.)
LITT	Litter
BARE	Bare ground

at this age can fly fairly well and subsequent survival is perceived to be much higher.

We used the 100% minimum convex polygon extension in ArcView[®] 3.2 to map home ranges of each brood (Mohr 1947). Each brood had a minimum of 14 locations used in creating the home range. We assigned 10 random points within each home range and 10 random points outside of each home range for each of the five successful broods in this study. We measured the vegetation at both the observed locations and the random points using canopy coverage. We placed a 1-m² quadrat on the ground at the center of each point. We estimated percent canopy coverage for each of the following classes: bare ground, blackberry, bunch grass, broad-leaf woody, forb, legume, litter, and sod-forming grass (Table 2). *A priori* we believed blackberry to be an important component of brood habitat because of the cover/food resources it provides. We placed the quadrat at each of the four cardinal directions 3 m from the center point to account for potential telemetry error for the location. The mean percentages for each of the 5 quadrats were used to represent the vegetative characteristics for each location.

Data Analysis

Prior to analysis, we transformed data using arc-sin transformations to normalize the percentage data. However, descriptive statistics are reported, untransformed. Prior to modeling, we used a Pear-

son Correlation test statistic for each pair of predictor variables. Variables that were deemed correlated if $r^2 > 0.30$, thus, were eliminated from the analysis to avoid multicollinearity because multicollinearity creates unnecessary redundancy and over-fitting in models.

We used forward stepwise logistic regression ($P < 0.05$) to assess bobwhite brood habitat selection to random points at two spatial scales, within 100% MCP home range and outside home range to address two orders of habitat selection (third and fourth orders; Johnson 1980). The 100% MCP technique was used because of our limited sample size. This technique does not eliminate any locations from the sample. We conducted all regression analyses using PROC LOGISTIC (SAS Institute, Inc. 2003). We set the significance level at $P \leq 0.05$ within the stepwise procedure.

We used logistic regression analysis (Weisberg 1985) under a model selection (AIC) framework (Burnham and Anderson 2002). We developed *a priori* habitat models based on our experience and the ecology and biology of bobwhites. Our models only contained variables found to be significant in the stepwise procedure.

We used an information theoretic-approach ((Burnham and Anderson 2002), to evaluate how plausible the logistic regression models were at explaining brood habitat use. A global model was

Table 3: Mean ground cover (%) and 95% confidence interval of observed locations, random within MCP home-range, and random outside MCP home-range for brood rearing northern bobwhites in Florida, 2005. See Table 1 for variable descriptions.

Variable	Brood Location		RandIn		RandOut	
	Mean	CI	Mean	CI	Mean	CI
BLACK	2.64	9.52	1.16	9.02	0.78	12.59
SOFG	47.12	8.08	33.47	4.97	18.62	3.28
FORB	27.70	3.85	19.30	1.06	26.70	0.76
BUGR	17.56	5.29	11.08	5.24	21.40	4.53
BLWD	11.26	6.80	5.90	5.58	4.16	6.10
LEGM	4.66	1.96	1.14	0.54	0.58	0.39
LITT	5.66	2.70	8.98	2.67	6.38	2.31
BARE	8.90	3.47	8.53	2.85	5.64	3.11

constructed that included all non-correlated variables. Thirty two subsets of the global model were constructed to represent combinations of factors believed to influence brood habitat use (Table 1). Therefore, 32 models were assessed on how well they fit the data using Akaike's Information Criterion (AIC; Burnham and Anderson 2002). Akaike's Information Criterion (AIC) is an extension of likelihood theory, and AIC is a relative distance between model pairs (Burnham and Anderson 2002). The distance is related to the Kullback-Leibler distance of information theory (Burnham and Anderson 2002). This distance is a measure of entropy (i.e. information lost) for models used to approximate truth (Burnham and Anderson 2002). We modified the AIC values because of low sample sizes to AIC_c (Burnham and Anderson 2002). The relative fit of each candidate model was assessed by calculating Akaike weights (Burnham and Anderson 2002), weighting of models with a value from 0 to 1, with the best-fitting candidate model having the greatest Akaike weight. All models were assessed for goodness of fit using Hosmer-Lemeshow tests (models with p -values ≥ 0.05 did not fit the data) using the lack-fit details option in SAS. We analyzed all data using SAS (SAS Institute, Inc. 2003).

Results

During 2005, we obtained 58 brood locations for 5 unique broods. These were the only broods that had chicks remaining after 14 days. The average MCP home range size of broods was 5.53 ± 2.43 ha. We evaluated a total of 51 locations for both random-within and random-outside points for a total of 102 random locations. The most common vegetation type found among individual habitat parameters was sod-forming grasses in both brood and random-within locations (Table 3). Bunchgrasses and forbs also were major components at all 3 location types. We observed small amounts of blackberry during sampling; however, it was frequently observed at brood locations when available. Broad-leaf woody vegetation and legumes also were found more frequently at brood locations than random-within and random-out locations. More grass-litter was detected at random-within locations than brood and random-out locations. Bare ground, litter, or broad-leaf woody vegetation were not significantly different among the 3 location types (Table 3). Stepwise logistic regression retained all of the habitat parameters at both levels of analysis except blackberry and litter (Tables 4, 5).

We examined 16 hypothesized models using 58

Table 4: Significant predictors of probability of northern bobwhite brood use in Florida, USA 2005, based on a stepwise logistic regression model contrasting habitat measured at used locations and random locations within MCP Home-range. See Table 2 for parameter descriptions.

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	$Pr > \chi^2$
Intercept	1	-17.0223	3.6527	21.7177	<0.0001
sofg	1	8.7960	2.1073	17.4231	<0.0001
forb	1	9.3797	2.3936	15.3564	<0.0001
bugr	1	6.9192	1.6978	16.6085	<0.0001
blwd	1	6.3663	1.8276	12.1335	0.0005
legm	1	9.1853	2.9079	9.9777	0.0016
bare	1	9.0291	2.5216	12.8214	0.0003

brood locations and 51 random locations within the MCP home range. The best approximating model ($w_1=0.94$) for predicting brood versus random-within locations included all significant habitat variables: bird identification (a blocking variable), sod-forming grasses, forbs, bunchgrasses, broadleaf-woody legumes, and bare ground (Table 6). All other models were poor at predicting brood use; no competing models were within 2 AIC_C of the best model.

The best approximating model ($w_1=0.94$) for predicting brood versus random-outside locations included all significant variables except bird identification (Table 7). All other models were poor at predicting brood use; no competing models were within 2 AIC_C of the best model.

Discussion

These results should be interpreted with caution because our study suffered from a small sample size, limiting our ability to draw upon conclusions from our results with high statistical confidence. We believe, however, that the data and results presented elucidate, or minimally highlight, some interesting occurrences regarding brood habitat use in pastureland.

Interpretation of our data suggests, while based on small sample size, that at the microhabitat scale no single vegetation type can be used to predict

use of habitat by bobwhite broods. This may indicate that areas with a variety of microhabitat (i.e. habitat diversity is high) characteristics favor brood use. This observation is consistent with Burger et al. (1993); they found that optimal brood-rearing habitat should contain high plant species richness favoring forbs. Yates et al. (1995) also found mosaic-type land cover beneficial to broods.

Sod-forming grass was a major component of habitat at brood locations and is an anomaly in terms of bobwhite ecology. Dense vegetation has been found to impede chick mobility (DeVos and Mueller 1993), as well as act as a fatal heat trap (Burkhart 2004). We believe a couple mechanisms potentially caused this result: (1) the ranch is dominated by Bahia grass pastures comprised mainly of sod-forming grasses making it so available and virtually unavoidable by brooding bobwhites; and (2) because of the low mobility of broods, the small patches of other types of vegetation available are not generally accessible by broods. A reduction in cattle grazing on the study area in July 2005, as a result of ownership change, may have resulted in higher percentages of sod-forming grasses at bird locations than other years.

We also found broad-leaved woody vegetation, forbs and legumes to be more prevalent at brood locations than at random-within and random-out loca-

Table 5: Significant predictors of probability of northern bobwhite brood use in Florida, USA, 2005, based on a stepwise logistic regression model contrasting habitat measured at used locations and random locations outside MCP home range. See Table 2 for parameter descriptions.

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	$Pr > \chi^2$
Intercept	1	-20.4338	4.5853	19.8588	<0.0001
sofg	1	14.1201	3.3034	18.2706	<0.0001
forb	1	7.0954	2.126	11.1384	0.0008
bugr	1	11.2451	2.9462	14.5685	0.0001
blwd	1	7.5642	2.5648	8.6982	0.0032
legm	1	13.5051	5.1516	6.8725	0.0088
bare	1	11.1869	3.2356	11.9537	0.0005

tions. Jackson et al. (1987) found that brood-rearing habitat was most dependent on invertebrate abundance. During the first 2-3 weeks post-hatching, bobwhite chicks consume >80% invertebrates that provide essential nutrients for growth and survival (Handley 1931, Nestler 1940). Broad-leaved woody vegetation, forbs, and legumes provide good habitat for insects, and thus an abundant food supply for bobwhite chicks. The structure of broad-leaved woody vegetation also provides dense cover from rain and avian predation, further increasing the probability of brood survival. Broods also selected habitats with a higher woody component for roosting and possible escape cover from predators (Johnson and Guthery 1988).

Bunchgrass was also found more frequently at brood locations than at random-within locations. Bunchgrasses provide excellent nesting habitat but can impede brood mobility when stands are too dense. This further exemplifies the impact of spatial scale on broods-hens often choose to nest in bunchgrass because of its benefits regardless of the effect it can have on broods. Post-hatching, brood mobility is limited and may be further impeded by bunchgrass if a hen chooses to nest in it. The diversity of plants within bunchgrass patches creates a more suitable environment than a solid bunchgrass stand.

We believe the key component is spatial scale

of landscape compared to mobility of broods. Bobwhites select habitats at many spatial scales (James Martin, unpublished data). Throughout their range they prefer early seral stages of habitat, and within those habitats bobwhites prefer a of diversity microhabitats. However, bobwhites have relatively poor dispersal and mobility-limiting their ability to occupy more suitable sites when large distances from their hatch site. Cook (2004) found that one-fourth to one-third of bobwhites in southern Georgia dispersed up to nearly 2,200 m prior to the breeding season. The remaining bobwhites retained a home range in the same area as their brood home range. More broadly, two-thirds to three-quarters of bobwhites remain in habitat that is spatially close to or the same as the habitat they inhabited as chicks. Consequently, they are confined to that habitat into which they hatch. Comparing brood locations to random-within locations therefore reveals much about the preferred vegetation for brood habitat use at the fourth-order scale (Johnson 1980). However, these data reveal little to how bobwhites are affected at larger spatial and temporal scales.

The combination of variables (i.e. diverse habitat) included in the best approximating model for predicting brood versus random-within locations favor brood use. Our data suggest that a diversity of vegetative type among canopy coverage is crit-

Table 6: Logistic Regression Models predicting brood locations ($n = 58$) versus random within MCP home range ($n = 51$) using ground cover data collect in Florida, USA, 2005. See Table 2 for variable descriptions.

Model	Hosmer-Lemeshow					
	DF	χ^2	P-Value	K	AIC_c	Δw_i
intercept + birdid + sofg + forb + bugr + blwd + legm + bare	8	6.06	0.64	8	87.33	0.00
intercept + sofg + forb + bugr + blwd + legm + bare	8	14.19	0.08	7	93.05	5.72
intercept + birdid + sofg + forb + bugr + legm + bare	8	6.75	0.56	7	102.64	15.32
intercept + birdid + sofg + forb + bugr	8	4.88	0.77	5	107.81	20.48
intercept + sofg + bugr + blwd + legm + bare	8	8.82	0.36	6	115.20	27.87
intercept + sofg + bugr + blwd + legm + bare	8	7.13	0.52	5	119.42	32.09
intercept + sofg + bugr + blwd + bare	8	4.88	0.77	4	121.89	34.56
intercept + sofg + bugr	8	8.19	0.42	3	127.45	40.12
intercept + birdid + sofg + bugr	6	12.04	0.06	3	144.69	57.36
intercept + birdid + legm	6	13.53	0.04	2	148.88	61.55
intercept + bugr	7	16.31	0.02	3	149.10	61.77
intercept + bugr + blwd	8	9.23	0.32	3	149.91	62.59
intercept + birdid + sofg	4	1.97	0.74	2	150.59	63.27
intercept + blwd	8	5.45	0.60	4	152.86	65.54
intercept + birdid + bugr + blwd	8	4.41	0.73	3	154.15	66.82
intercept + birdid + blwd	8	4.45	0.73	3	157.61	70.28

Table 7: Logistic Regression Models predicting brood locations ($n = 58$) versus random outside MCP homerange ($n = 51$) using ground cover data collected in Florida, USA, 2005. Model, df, Hosmer-Lemeshow goodness-of-fit statistics, number of parameters (K), AIC_c , Δ , and w_i values are presented.

Model	Hosmer-Lemeshow					Δ	w_i
	DF	χ^2	P-Value	K	AIC_c		
intercept + sofg + forb + bugr + blwd + legm + bare	8	3.79	0.80	7	59.46	0.00	0.95
intercept + birdid + sofg + forb + bugr + blwd + legm + bare	8	4.40	0.82	8	65.30	5.83	0.05
intercept + birdid + sofg + forb + bugr + legm + bare	8	12.94	0.11	7	72.22	12.75	0
intercept + sofg + bugr + blwd + legm + bare	8	4.60	0.80	6	73.15	13.68	0
intercept + sofg + bugr + blwd + bare	8	4.18	0.84	5	80.04	20.58	0
intercept + sofg + bugr	7	5.86	0.56	3	107.92	48.46	0
intercept + birdid + sofg + forb + bugr	8	4.79	0.78	5	111.60	52.13	0
intercept + birdid + sofg + bugr	8	7.24	0.51	4	111.68	52.22	0
intercept + birdid + sofg	8	5.06	0.75	3	125.02	65.56	0
intercept + birdid + legm	6	5.87	0.44	3	128.03	68.57	0
intercept + blwd	5	10.39	0.06	2	148.75	89.28	0
intercept + bugr + blwd	8	25.38	0.00	3	150.54	91.08	0
intercept + bugr	6	25.58	0.00	2	152.58	93.11	0
intercept + birdid + blwd	7	6.81	0.45	3	155.46	96.00	0
intercept + birdid + bugr + blwd	8	15.43	0.05	4	156.84	97.38	0
intercept + birdid + bugr	7	14.15	0.05	3	159.77	100.31	0

ical to brood use. Past bobwhite research agrees with this conjecture because bobwhites favor early-successional habitat which is diverse in terms of both canopy structure and plant community.

Management Implications

The management implications of this study are limited because of our lack of sample size and the inability to draw conclusions from the data with high statistical precision. However, our results suggest that managing habitat to create a diverse plant community will increase the probability of use by bobwhite broods. Furthermore, usage of these habitats by broods may increase chances for survival; future studies incorporating brood use into survival estimation models is needed to examine how habitats used affect chick survival. Managing habitat across large scales (>1000 ha) will improve accessibility to favorable habitats for entire populations of bobwhites, but managers should not overlook fine-scale habitat management, particularly regarding that of brood habitats, to improve conditions for bobwhite chicks.

Future research with larger sample sizes is warranted to substantiate our results. Also, it would be helpful for researchers to examine how habitat(s) used may affect the success of the brood itself (i.e. chick survival).

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