Nest Site Selection of Resident and Translocated Northern Bobwhites in Florida Rangelands

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Abstract: As throughout most of their range, northern bobwhite (*Colinus virginianus*; hereafter bobwhite or quail) populations have been declining throughout much of Florida, most likely the result of habitat loss and degradation. Restoration and management of bobwhites in Florida may be hindered by a lack of knowledge of the subspecies that occupies most of the state and its distinctive habitat. Further, little is known about the efficacy of translocating quail to restored habitat; a possible population restoration tool. Our objective was to examine nest success and site selection by resident and translocated Florida bobwhites (*C. v. floridanus*) at microhabitat (nest), home range, and landscape levels in the unique Florida rangelands. We used standard capture (i.e., baited wire funnel traps), radio telemetry, and vegetation sampling methods to obtain and monitor bobwhites resident and translocated into our study area and their habitat during 2007–2008. We trapped 288 bobwhites (153 M, 135 F); 176 were translocated (93 M, 83 F) and 112 resident (60 M, 52 F) birds. We located 40 nests; 25 of translocated and 15 of resident quail. Most of the selected nest microhabitat features were associated with greater visual obstruction (i.e., nest concealment) with resident birds occasionally selecting for greater cover than translocated quail. At all scales, nest sites (all birds) were located closer to fencerows, and at both the home range and landscape levels bobwhites nested further from habitat edges and canals. At the home range level, bobwhites selected for areas closer to burns and ungrazed areas but at the landscape level selected areas further from burned areas. Whereas bobwhites were selecting for several distance-based habitat features at these different scales, they had little effect on nest success. Additionally, neither bird origin (i.e., resident vs. translocated) or scale affected habitat type selection (e.g., dry prairie or natural pineland). Management through grazing reductions and the use of backing fires to stimulate growth of warm season bunchgrasses and forbs while leaving some unburned areas should provide the best quail habitat. Translocated and resident bobwhites selected for slightly different nesting habitat, but differences did not affect nest success. Therefore, translocated birds may be a viable option for restoring populations of bobwhites in Florida rangelands.

Key words: Florida, habitat, nest, northern bobwhite, rangeland, reproduction, translocation

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Although found throughout the state, it is in central and south Florida, often characterized as rangelands and flatwoods, where there may be the greatest potential to restore and enhance habitat for northern bobwhites (*Colinus virginianus*; hereafter bobwhite or quail; Giuliano et al. 2007). Although bobwhites are generally very well studied, very little is known of Florida bobwhites (*C. v. floridanus*), the subspecies in these unique habitats of the peninsular Florida part of the range (see Giuliano et al. 2007 for a review). A lack of understanding of bobwhite-habitat relationships in these distinctive habitats, particularly given the intensive agricultural land-uses in the area (i.e., range management and livestock production), may limit bobwhite conservation and restoration efforts (Giuliano et al. 2007).

Another factor potentially limiting bobwhite conservation is their poor dispersal ability, coupled with isolated, remnant populations throughout much of their range (Burger 2001, Giuliano et al. 2007). As a result, if habitat is restored, it may take decades, if ever, for birds to re-colonize these areas. Translocating wild birds from source populations into enhanced habitats may be a viable means of restoring local bobwhite populations. However, very few studies have examined nesting ecology of translocated wild bobwhites and no studies on the Florida subspecies (see Murray and Frye 1964 [in Florida], Liu et al. 2002 [in Texas], Terhune et al. 2006 [in Georgia], Giuliano et al. 2007 [a review], and Schad 2009 [in Florida]).

The high reproductive potential of bobwhites allows their populations to exist in marginal habitats and withstand naturally high annual mortality (DeVos and Mueller 1993, Giuliano et al. 2007). A better understanding of bobwhite nesting ecology and how nest site selection and reproductive success of translocated birds may differ from resident birds will better inform management and restoration decisions. Therefore, our objective was to examine nest success and site selection by resident and translocated Florida bobwhites at microhabitat (nest), home range, and landscape levels in Florida rangelands.

Study Area

Our 800-ha study area was centered on the North and South Prairie pastures of the Devil's Garden/Alico Ranch in Hendry

County, Florida. The area contained a mix of semi-improved pasture, with widely scattered pine (*Pinus* sp.) stands, oak (*Quercus* sp.) hammocks, and wetlands. Dominant herbaceous vegetation included Bahia grass (*Paspalum notatum*), bluestems (*Andropogon spp.*), smutgrass (*Sporobolus indicus*), goldenrods (*Solidago spp.*), and dog fennel (*Eupatorium capillifolium*); shrubs included saw palmetto (*Serenoa repens*) and wax myrtle (*Morella cerifera*); and the under- and overstory included sabal palm (*Sabal palmetto*), live oak (*Q. virginiana*), laurel oak (*Q. laurifolia*), and slash pine (*P. elliotti*). Average annual minimum and maximum temperatures were 16 and 30 C, respectively, and rainfall 137 cm, with most occurring during the wet season (May-October). From June 2006–August 2008, habitat management and improvements were conducted, including strip disking, herbicide application to kill non-native grasses, prescribed burning, and reductions in livestock stocking rate (including the establishment of eight 20-ha fenced areas without livestock).

Methods

During December-March of 2006–2007 and 2007–2008, bobwhites were captured using standard wire funnel traps baited with corn, weighed, sexed, and aged based on standard feather criteria (Giuliano et al. 2007), banded, and released. Hens ≥140 g were fitted with a 5-g necklace-style radio transmitter with a mortality sensor (Braun 2005). Resident quail (i.e., those initially captured in our study area) were released at the capture location. Wild bobwhites were obtained for translocation from other portions of the ranch where they were found in areas facing habitat destruction (e.g., conversion to sugar cane production or water impoundment). They then were released as capture groups at random locations with suitable (based on a review of the literature; Giuliano et al. 2007) mixtures of warm season bunchgrass, forb, and shrub cover in the same study area as resident birds. Areas from which translocated birds were obtained were ≥8 km from the study area and different from the rangeland community where they were released, and included primarily agricultural production areas (e.g., sugar cane and citrus fields [especially the fringes and associated ditches and canals] and water impoundments that were typically a mix of wet prairie, pine stands, and palmetto flats.

From March-August each year, radio equipped birds were located daily (diurnally) by triangulation from three known (i.e., global positioning system [GPS]), fixed, receiving locations (Millspaugh and Marzluff 2001, Braun 2005). When monitoring indicated a female had initiated incubation (i.e., found repeatedly in the same location), nests were visually located and eggs counted. To minimize disturbance when visiting a nest, care was taken not to touch or disturb vegetation, with all disturbed vegetation returned to its original position after the visit. Nests were marked using a GPS. We attempted to check nests every three days, when the hen was away from the nest, to determine fate. When incubation ceased, as determined via nest visits, we recorded the fate of the nest and number of eggs hatched. We considered all nests hatching ≥1 egg successful.

For microhabitat assessments, at each nest and a paired random location (i.e., 100 m distant in a random direction, but same habitat type), vegetation composition and structure were examined in several strata (i.e., overstory, understory, shrub, and herbaceous/ground levels; Dueser and Shugart 1978) using a nested plot design. Vegetation measurements were taken at both nest and paired sites within 3 days of when the nest fate was determined. All overstory (woody vegetation ≥7.5 cm diameter at breast height [DBH]) and understory (woody vegetation <7.5 cm DBH, >2.0 m in height) plants were counted and DBH measured within a 0.03-ha circular plot to estimate density, basal area (individual species and all combined), and species richness (i.e., number of species). Overstory and understory canopy closure were estimated for each strata from 41 evenly spaced, vertical ocular tube sightings along two perpendicular 20-m transects centered in the 0.03-ha plot (James and Shugart 1970). Shrubs (woody vegetation ≤2.0 m in height) were counted, maximum height determined for each species, and horizontal shrub cover measured along two perpendicular 2- x 10-m transects centered on the 0.03-ha plot to estimate horizontal shrub density, coverage, and species richness.

Coverage (ocular estimate) and maximum height of each species of herbaceous plant, coverage and depth of litter, and the amount of bare ground were determined in a 1-m^2 plot centered on the nest or random site and in four 1-m^2 plots, one randomly located in each quadrant of the 0.03 ha plot. Habitat attributes from these 1-m^2 plots were handled in two ways in all analyses: the single plot centered on the site (referred to as the nest site) and the mean of all five plots located within the 0.03-ha sampling area (referred to as the nest plot). In addition, herbaceous vegetation was grouped into all graminoids, bunchgrasses, and forbs for all analyses. To assess vertical vegetation structure from 0-2 m above ground (in four separate, 50-cm sections), a cover pole (Griffin and Youtie 1988) was centered on the nest or random location, with readings taken from 5 m and 10 m from each of the cardinal directions. The plant species most closely associated with the nest location was recorded, as well as the total number of red imported fire ant mounds present within the 0.03-ha plot (Schad 2009; Table 1).

We plotted nest and random site locations in a geographic information system (GIS) and measured distance from these sites to several features including fenced ungrazed areas, canals, habitat edge (i.e., distance to the border of the habitat type where the site

Table 1. Microhabitat characteristics of northern bobwhite nest ($n = 39$) and paired random ($n = 39$) sites in Florida rangelands, 2007–2008.

	Nest sites		Paired random sites		
Characteristic	**Mean**	**SE**	**Mean**	**SE**	***P***
Forb cover at the nest site (%)	0.19	0.03	0.18	0.03	0.741
Forb height at the nest site (cm)	62.0	6.0	45.8	4.2	0.029
Graminoid (all) cover at the nest site (%)	0.61	0.03	0.66	0.04	0.271
Graminoid (all) height at the nest site (cm)	109.4	4.5	113.0	4.6	0.574
Bunchgrass cover at the nest site (%)	0.38	0.04	0.36	0.03	0.608
Bunchgrass height at the nest site (cm)	91.4	8.6	108.5	6.2	0.112
Shrub cover at the nest site (%)	0.03	0.01	0.02	0.01	0.597
Shrub height at the nest site (cm)	14.4	5.9	10.6	3.6	0.583
Litter cover at the nest site (%)	0.11	0.03	0.07	0.01	0.196
Bare ground at the nest site (%)	0.04	0.01	0.06	0.02	0.349
Litter depth at the nest site (cm)	2.2	0.3	1.5	0.2	0.085
Herbaceous plant richness at the nest site (*n*)	5.4	0.3	5.5	0.3	0.725
Forb cover in the nest plot (%)	0.18	0.02	0.20	0.02	0.578
Forb height in the nest plot (cm)	91.8	6.1	73.3	5.7	0.030
Graminoid (all) cover in the nest plot (%)	0.55	0.03	0.58	0.03	0.496
Graminoid (all) height in the nest plot (cm)	121.0	3.9	118.1	4.3	0.634
Bunchgrass cover in the nest plot (%)	0.21	0.02	0.16	0.02	0.051
Bunchgrass height in the nest plot (cm)	107.7	7.5	117.0	4.6	0.297
Shrub cover in the nest plot (%)	0.01	0.01	0.03	0.01	0.151
Shrub height in the nest plot (cm)	31.4	7.5	31.0	6.5	0.970
Litter cover in the nest plot (%)	0.14	0.02	0.10	0.01	0.095
Bare ground in the nest plot (%)	0.08	0.02	0.07	0.02	0.749
Litter depth in the nest plot (cm)	1.9	0.2	1.6	0.2	0.352
Herbaceous plant richness in the nest plot (*n*)	11.0	0.6	10.9	0.5	0.914
Vertical obstruction from 5 m, 0–50 cm above the ground (%)	0.88	0.02	0.85	0.02	0.331
Vertical obstruction from 5 m, 51–100 cm above the ground (%)	0.29	0.04	0.16	0.03	0.015
Vertical obstruction from 5 m, 101–150 cm above the ground (%)	0.11	0.03	0.03	0.02	0.013
Vertical obstruction from 5 m, 151–200 cm above the ground (%)	0.07	0.02	0.02	0.01	0.030
Vertical obstruction from 10 m, 0–50 cm above the ground (%)	0.94	0.01	0.90	0.02	0.308
Vertical obstruction from 10 m, 51–100 cm above the ground (%)	0.47	0.05	0.29	0.04	0.005
Vertical obstruction from 10 m, 101–150 cm above the ground (%)	0.23	0.04	0.12	0.03	0.023
Vertical obstruction from 10 m, 151–200 cm above the ground (%)	0.14	0.03	0.08	0.03	0.165
Shrub cover (%)	0.06	0.01	0.05	0.01	0.875
Shrub density (n/m^2)	0.070	0.013	0.084	0.016	0.501
Shrub species richness (*n*)	3.6	0.3	3.6	0.4	0.908
Understory cover (%)	0.03	0.01	0.02	0.01	0.491
Understory density (n/m^2)	0.003	0.001	0.001	0.001	0.255
Understory species richness (*n*)	0.4	0.1	0.2	0.1	0.386
Overstory cover (%)	0.05	0.02	0.02	0.01	0.071
Overstory density (n/m^2)	0.002	0.001	0.002	0.001	0.689
Overstory species richness (*n*)	0.4	0.1	0.3	0.1	0.299
Distance to nearest ungrazed area (m)	249.8	52.3	244.6	53.2	0.887
Distance to nearest canal (m)	428.8	41.4	415.1	44.7	0.868
Distance to nearest habitat edge (m)	44.0	7.1	51.6	6.5	0.452
Distance to nearest wetland (m)	62.3	7.2	73.7	7.2	0.283
Distance to nearest burned area (m)	1299.7	160.2	1249.4	162.3	0.637
Distance to nearest fencerow (m)	113.6	18.4	119.2	15.4	0.620
Distance to nearest road (m)	342.0	33.6	316.3	36.8	0.616
Red imported fire ant mound density (n/m^2)	0.006	0.001	0.009	0.001	0.036

was located), wetlands, burned areas, fencerows, and roads using the ArcView 3.3 Nearest Feature extension. Layers of desired attributes were created using GPS locations of variable vertices, digitized U.S. Geological Survey digital orthophoto quadrangles, and Florida Fish and Wildlife Conservation Commission Habitat and Landcover datasets. Habitat type at nest and random locations were determined using ArcGIS 9.0 and the habitat classifications outlined in the Florida Fish and Wildlife Conservation Commission Comprehensive Wildlife Conservation Strategy. Habitat classifications included agriculture, disturbed/transitional, dry prairie, freshwater marsh/wet prairie, grassland/improved pasture, hardwood hammock forest, mixed hardwood-pine forest, natural pineland, and shrub swamp (Florida Fish and Wildlife Conservation Commission 2005).

To analyze habitat selection (i.e., use compared with availability of habitats or components) at the home range level, we established a 50-ha buffer around each nest site using the Hawth's Tools extension in ArcGIS 9.0. Fifty hectares is an approximate mean home range size for both resident and translocated bobwhites during the nesting season (W. M. Giuliano, University of Florida, unpublished data; Liu et al. 2002). Fifty random points were then generated, using Hawth's Tools, within each bird's buffer (home range), and distances from the 50 random points to the same features described above and habitat type classification were determined using the ArcView 3.3 Nearest Feature extension. To assess habitat selection at the landscape level, we generated 1000 random points throughout the study area, and distances from the 1000 random points to the same features described above and habitat type classification were determined using the aforementioned methods (Schad 2009; Table 1).

We used a blocked analysis of variance (ANOVA) as an exploratory analysis to compare individual habitat variables between nest and paired random sites at the microhabitat level, and nest and paired features (i.e., pair = mean of the 50 locations within the buffer) at the home range level. Analysis of variance was used to compare individual variables between successful and unsuccessful nests, nest and random sites at the landscape level, and nests of resident and translocated birds.

We used discriminant function analyses (DFA) to determine which combination of variables best discriminated nests from paired random sites (microhabitat), nests from those of associated random sites at the home range and landscape levels, nests of resident from those of translocated birds, and successful from unsuccessful nests. Methods described by Noon (1981) and McGarigal et al. (2000) were used to reduce multicolinearity problems and the number of variables considered in each DFA model, by removing highly correlated ($r > 0.7$) variables. All DFA models were fit using a stepwise forward procedure with tolerance = 0.001, *F*-to-enter = 0.15 and *F*-to-remove = 0.15. Since the order in which variables are entered into the model can affect final model selection, and there is no accepted method of determining the order of variable entry into a model (McGarigal et al. 2000, SYSTAT 2007), we entered variables into the model based on effect size (Cohen 1988) in ANOVA comparisons (i.e., the variable with the largest effect size was entered first and the variable with the smallest effect size was entered last). We assumed effect size was positively associated with biological importance. In no case did the number of variables entered in to the model exceed the maximum appropriate for the particular test, which is based on sample size (McGarigal et al. 2000). We assessed the relative importance of each variable in the final model by examining the standardized canonical discriminate functions (SCDF). Variables with higher SCDF values made greater contributions to the discriminating power of the model (McGarigal et al. 2000).

Likelihood ratio analyses were used to examine dependence between nest vegetation use (i.e., species of plant most closely associated with the nest) and bird origin (i.e., resident or translocated), and between habitat type and bird origin at microhabitat, home range, and landscape levels. Likelihood ratio analyses were also used to examine dependence between nest success and habitat type, grazing regime (i.e., grazed or ungrazed), and nest vegetation type (SYSTAT 2007).

We considered all tests significant at $P \leq 0.05$. If necessary, Fisher's LSD tests were used for post-hoc comparisons (SYSTAT 2007). Because of the large number of comparisons for most univariate analyses, data (e.g., mean, SE, *P*) are presented only for those with statistically significant effects. We examined all birds, translocated birds only, and resident birds only in each analysis, where appropriate. For all tests, test assumptions were checked using appropriate methods (e.g., Levene's Test and plots of normal distribution; SYSTAT 2007).

Results

During the study, we trapped 288 bobwhites (153 M, 135 F); 176 were translocated (93 M, 83 F) and 112 resident (60 M, 52 F). Eighty-seven females were fitted with radio transmitters; 53 were translocated and 34 residents. We located 40 nests; 25 of translocated (10 successful, 13 unsuccessful, and 2 unknown) and 15 of resident quail (5 successful and 10 unsuccessful).

At the microhabitat level, bobwhites (all) selected nest sites with taller forbs, greater vertical visual obstruction, and a lower density of fire ant mounds than at paired random sites (Table 1). The best combination of variables that discriminated nests from paired random sites, in order of importance, was vertical visual obstruction from 5 m between 101 and 150 cm (SCDF = 0.700), overstory canopy closure (SCDF = 0.680), maximum height of bunchgrasses (SCDF = –0.644), maximum shrub height (SCDF = –0.608), amount of bare ground (SCDF = –0.510), distance to the nearest fencerow (SCDF = –0.439), and vertical obstruction from 10 m between 0 and 50 cm (SCDF = 0.360; 69% correct jackknifed classification rate; canonical correlation = 0.698; $P \leq 0.001$). Habitat type at the site was independent of the site type (i.e., nest or paired random site) for all nests ($P = 0.664$), nests of translocated birds ($P = 0.972$), and nests of resident birds ($P = 0.117$), with 77% of nests in improved pasture, 15% in dry prairie, and 8% in freshwater marsh/wet prairie.

Comparing nest site microhabitat use between resident ($n = 15$) and translocated ($n = 24$) bobwhites, nest sites of resident quail had taller maximum height of forbs (84 ± 9 cm [mean ± SE] vs. 47 ± 6 cm; $P = 0.001$), greater overstory canopy closure (0.08 ± 0.03 % vs. 0.02 ± 0.01 %; $P = 0.049$), were further from ungrazed areas (452 ± 92 m vs. 124 ± 48 m; $P = 0.001$), and closer to burned areas (614 ± 145 m vs. 1,857 ± 154 m; $P \leq 0.001$) than translocated birds. The best combination of variables that discriminated resident from translocated bobwhite nest sites, in order of importance, was distance to burned areas (SCDF = 1.737), understory density (SCDF = 1.435), bunchgrass density (SCDF = –0.902), and vertical obstruction from 10 m between 101 and 150 cm (SCDF = –0.538; 96% correct jackknifed classification rate; canonical correlation = 0.905; $P \leq 0.001$).

Nest vegetation type used depended on whether quail were translocated or resident birds ($P=0.009$); but small counts precluded post hoc analyses. Habitat type at the nest was independent of whether it belonged to a resident or translocated bobwhite ($P=0.817$).

At the microhabitat level, successful nests ($n=15$) had greater forb cover (0.24 ± 0.04 % vs. 0.14 ± 0.01 %; $P=0.009$) and taller bunchgrasses at the nest plot (133 ± 8 cm vs. 94 ± 11 cm; $P=0.046$) than unsuccessful nests ($n=23$). The best combination of variables that discriminated successful from unsuccessful nests, in order of importance, was forb cover (SCDF = 0.963), overstory canopy closure (SCDF = –0.616), and distance to habitat edge (SCDF = –0.590; 75% correct jackknifed classification rate; canonical correlation = 0.709; $P=0.003$). Whether a nest was successful or unsuccessful was independent of which habitat type the nest was located in for all nests ($P=0.394$), nests of translocated birds ($P=0.918$), and nests of resident birds ($P=0.140$). Nest success did not depend on whether a nest was found in a grazed or ungrazed area for all nests ($P=0.959$), nests of translocated birds ($P=0.831$), or nests of resident birds ($P=0.999$), or what type of nest vegetation nests were located in for all nests ($P=0.875$), nests of translocated birds ($P=0.361$), or nests of resident birds ($P=0.282$).

At the home range level, nest sites ($n=39$) were closer to ungrazed areas (250 ± 52 m vs. 281 ± 50 m; $P\leq0.001$), further from canals (429 ± 41 m vs. 392 ± 38 m; $P=0.002$), closer to burned areas (1300 ± 160 m vs. 1322 ± 157 m; $P=0.003$), and closer to fencerows (114 ± 18 m vs. 133 ± 14 m; $P=0.039$) than random locations ($n=39$). The best combination of variables that discriminated nests from random sites, in order of importance, was distance to edge (SCDF = –0.760) and fencerows (SCDF = 0.594; 49% correct jackknifed classification rate; canonical correlation = 0.272; $P=0.045$). Habitat type was independent of whether or not the site was a nest or random site at the home range level for all nests ($P=0.447$), nests of translocated birds ($P=0.886$), and nests of resident birds ($P=0.966$). At the home range level, when comparing successful and unsuccessful nest sites, and resident and translocated nest sites, we did not find any differences in habitat variables using univariate or multivariate analyses ($P>0.05$).

Nest sites ($n=39$) were further from habitat edge (44 ± 7 m vs. 32 ± 1 m; $P=0.021$) and burned areas (1300 ± 160 m vs. 783 ± 22 m; $P\leq0.001$) than random points ($n=1000$) at the landscape level. However, the best combination of variables to discriminate nests from random sites at this level, in order of importance, was distance to burned areas (SCDF = 0.746), distance to habitat edge (SCDF = 0.486), distance to fencerows (SCDF = –0.473), and distance to canals (SCDF = 0.309; 74% correct jackknifed classification rate; canonical correlation = 0.166; $P\leq0.001$). The habitat type a site was located in was independent of whether it was a nest or random point for all nests ($P=0.175$), nests of translocated birds ($P=0.617$), and nests of resident birds ($P=0.889$). At the landscape level, when comparing successful and unsuccessful nest sites, and resident and translocated nest sites, we did not find any differences in habitat variables using univariate or multivariate analyses ($P>0.05$).

Discussion

Most of the selected nest microhabitat features were associated with greater visual obstruction of the nest site, which probably serves to conceal the nest from predators and possibly provides thermal protection for incubating hens. This is consistent with previous findings of nest microhabitat selection (Taylor et al. 1999, Townsend et al. 2001, Arredondo et al. 2006) and use of habitats for thermal protection by bobwhites (Guthery et al. 2005). Whereas we did not find any relationship between vertical obstruction and nest success, Townsend et al. (2001) found that successful nests had greater concealment cover than unsuccessful nests. Bobwhites selected for more overstory canopy closure and shorter bunchgrasses at the nest site, but successful nests had less canopy cover and taller bunchgrasses at the nest site than unsuccessful nests. The reason for this incongruity is unclear. Arredondo et al. (2006) reported bobwhites selecting for taller bunchgrasses at the nest site than were available in the surrounding area and both Taylor et al. (1999) and Lusk et al. (2006) found that successful nests were associated with taller vegetation than unsuccessful nests. Our results may have differed from Arredondo et al. (2006) because average bunchgrass height at nest sites in south Florida (91.4 cm) was much greater than the average bunchgrass height of nest sites found in Texas (23.7 cm). This suggests that habitat structure may be different in these two areas, leading bobwhites to select for different nest habitat characteristics, or that after some height threshold, selection may no longer be associated with success or may be associated with declining success. Bobwhites selected nest sites with less bare ground, which is consistent with the findings of Townsend et al. (2001), and may lead to additional visual obstruction of the nest. Whereas we did not find a relationship between bare ground and nest success, Townsend et al. (2001) reported less bare ground at successful nest sites, while Lusk et al. (2006) found that successful nests were associated with greater levels of bare ground than random sites.

Nest sites had lower densities of red imported fire ant mounds than random sites, possibly because bobwhites were avoiding this predator of quail chicks. We did not find evidence of fire ant depredation at the nest sites (W. M. Giuliano, University of Florida, unpublished data), which is supported by Johnson's (1961) findings that fire ants did not influence quail production. However, Lehman (1947) found several cases in which newly hatched chicks were killed at the nest by red imported fire ants and Giuliano et al. (1996) found that exposure to fire ants can reduce chick survival.

Resident bobwhites selected nest sites with habitat characteristics more closely associated with greater visual obstruction than nest sites of translocated birds. Taller vegetation and greater visual obstruction at the nest site may lead to increased nest success (Taylor et al. 1999, Townsend et al. 2001, Hernandez et al. 2003, Lusk et al. 2006). This may suggest that resident bobwhites were selecting for nest sites that were more likely to be successful than translocated quail. However, we did not find that nest success was dependent on whether a bobwhite was resident or translocated, which is consistent with the findings of Terhune et al. (2006).

When examining selection related to various habitat distance measures, there were similarities among scales (i.e., microhabitat, home range, and landscape levels). At all levels, nest sites were located closer to fencerows, possibly because fencerows provide better escape and foraging cover than the surrounding habitats. However, Baskett (1947) found ring-necked pheasants nesting in fencerows had poor nest success due to high levels of predation, and such areas may be travel corridors for predators (Barding and Nelson 2008). Similarly, at both the home range and landscape levels, bobwhites nested further from habitat edges and canals, possibly to avoid nest predators, which may use these locations as travel corridors. White et al. (2005) also noted a negative relationship between edge and nest site selection at larger spatial scales in Georgia. Barding and Nelson (2008) found that meso-predators such as raccoons tended to follow linear habitat features such as habitat edge and trails when foraging, and meso-predators incorporate more levees and roads into their home range than expected (Frey and Conover 2006). This is contrary to our finding, albeit weak, that birds nesting closer to habitat edges had slightly higher nest success. At the home range level, bobwhites selected for areas closer to burns, but the opposite was true at the landscape level. The reason for this discrepancy is unknown, as burned areas typically have abundant forbs and less litter, which provide good foraging and brood-rearing habitat (see Giuliano et al. 2007 for review). It is possible that quail nests were further from burned areas at the landscape scale because of natural spacing by birds and relatively few burned areas in the study area. It is important to note that while bobwhites were selecting for several distance-based habitat features at these different scales, only one (i.e., distance to habitat edge) had a weak affect on nest success. Additionally, neither bird origin or scale affected the selection of specific habitat types (e.g., dry prairie or natural pineland), suggesting that these birds are somewhat of a generalist in terms of selecting a habitat type for nesting. This is consistent with White et al. (2005) finding that quail, at several spatial scales, did not select nest sites in habitat types present on our study area.

Resident bobwhites nested closer to burned areas than translocated quail. Burned areas provided more forb cover than unburned areas, and resident bobwhites may have been able to select nest sites near these areas because they were more familiar with the habitat and study area. Liu et al. (2002) suggested that it required approximately 4 months for translocated bobwhites to become familiar with their new habitat. Being moved only a short time before the nesting season (~1–10 weeks), translocated bobwhites may not have been able to find burned areas before selecting a nest site or nest site selection may have been delayed until such birds had sufficient time to find mates. Translocated birds nested closer to ungrazed areas than resident bobwhites, possibly because the thicker, ungrazed vegetation at these sites more closely resembled the habitat from where they were trapped than the grazed habitats in the remainder of the study area.

Regardless of habitat type, management should create habitat conditions with increased density and height of herbaceous vegetation. Additionally, less bare ground should be provided at potential nesting sites to create better visual obstruction which other studies suggest may improve nest success. This could be achieved using backing fires to stimulate growth of warm season bunchgrasses and forbs, and leaving some unburned areas. This would provide areas of thicker residual vegetation mixed with other habitat components, which would be ideal for bobwhite nesting. Decreasing grazing rates during the nesting/growing season would allow bunchgrasses and forbs, important to nesting, to grow taller and more dense, and improve nesting habitat. At the home range scale, areas should be managed for increased heterogeneity of nesting vegetation, since nest success was improved by being closer to habitat edge. Again, this may be accomplished by periodic, slow backing fires that leave a patchy mix of burned and unburned habitat. Although birds selected nest sites closer to fencerows, these areas as well as roads and canals may be potential linear travel corridors for predators and should be minimized in areas of suitable nesting cover. Translocated and resident bobwhites may select for slightly different nesting habitat, but none of these differences affected nest success. As it may require several months for quail to learn new habitats or find mates, translocation of birds several months prior to the nesting season may be desirable. Because they may use similar habitat and have comparable nest success to resident birds, translocated birds may be a viable option for restoring populations of bobwhites in Florida rangelands as a supplement to existing resident populations. However, given the relatively small sample sizes and the exploratory nature of the study, these findings should be viewed cautiously, and we suggest further study.

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