

SPACE USE, HABITAT AND NEST-SITE SELECTION BY NORTHERN BOBWHITES IN  
SOUTH FLORIDA

By

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To Akshara

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Abstract of Thesis Presented to the Graduate School  
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SPACE USE, HABITAT AND NEST-SITE SELECTION BY NORTHERN BOBWHITES IN  
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The manner by which animals use space and select resources can have important management consequences. Harvest records indicate that the northern bobwhite quail (*Colinus virginianus*) population in Babcock-Webb Wildlife Management Area in Charlotte County, Florida, USA has been declining steadily since the 1970's. This decline has occurred despite the economic importance of the northern bobwhite as a game species and extensive efforts to maintain and improve its population welfare. Using data from radio-tagged bobwhites monitored from 2002-2007 at the Babcock-Webb Wildlife Management Area, I examined factors influencing home-range dynamics, habitat and nest-site selection, and the relation of nest success with landscape composition and structure surrounding nest sites.

The mean ( $\pm 1$  SE) annual home range size, estimated using the Kernel density method, was 88.43 ( $\pm 6.16$ ) ha, and did not differ between genders. Winter home ranges of bobwhites ( $69.27 \pm 4.92$  ha) were generally larger than summer home ranges ( $53.90 \pm 4.93$  ha). Annual and winter home ranges were smaller for bobwhites whose ranges contained food plots, compared to those that did not; however, the presence of food plots did not influence summer home ranges. Using a distance-based method, I investigated habitat selection by bobwhites within home ranges. Bobwhites preferred food plots, pine palmetto and dry prairie habitats, and avoided wet

prairies and roads grades. This pattern was generally consistent between genders and across years.

There was also strong evidence that bobwhites exhibited nesting habitat selection. Bobwhites preferred to establish nests closer to food plots ( $P < 0.0001$ ) and farther away from water bodies ( $P = 0.0003$ ); other habitat types were neither preferred nor avoided. Habitat composition and landscape features differed between random points and nest-sites, and landscape features that quantified connectedness and diversity significantly influenced the probability of nesting on a given site. Of a total of 365 nests monitored, only 208 (56.99%) were successful. Nesting success did not differ among habitat types, and none of the habitat and landscape variables we measured significantly influenced the probability of nesting success. These results suggest that random nest predation by meso-mammalian predators, rather than habitat variables, may ultimately determine fates of bobwhite nests in south Florida. The results also provide further evidence for the importance of food plots.

## CHAPTER 1 INTRODUCTION

Effective management of wildlife populations requires knowledge of how the species utilizes available landscape, and selects resources within it. Landscapes are inherently heterogeneous, and the choice of habitat can influence an individual's survival and reproduction, as well as individual fitness (Fretwell and Lucas 1970, Holt 1985, Pulliam 1988). Quantifying behavioral responses to habitat heterogeneity may help identify essential resources and environmental conditions that affect population dynamics and may aid in the management of wildlife populations (Sutherland 1996, Boyce and McDonald 1999). Furthermore, reproductive success in many species of birds is influenced by nest-site selection (Hatchwell et al. 1999). This is because placement and attributes of nest-sites can affect risk of predation, access to food resources, and microclimate experienced by the developing embryos (Crabtree et al. 1989, Martin 1993, Lusk et al. 2006, Barea 2008).

Populations of northern bobwhites have experienced substantial range-wide declines in the past decades (Brennan 1991, Sauer et al. 2004, Williams et al. 2004, Brennan and Kuvlesky 2005). Harvest records indicate that the bobwhite population on Babcock-Webb Wildlife Management Area (hereafter, WMA) in Charlotte County, Florida, has been declining steadily since the 1970's (Dimmick et al. in press). Loss and degradation of habitat have been suggested to be an important cause of bobwhite population declines (Dimmick et al. 2002). Knowing how bobwhites utilize space and select resources could, therefore, contribute to management efforts to reverse the population declines. However, data on space and habitat use patterns, and nesting ecology of bobwhites on Babcock-Webb WMA remain relatively unknown.

The overall goal of my thesis research is to provide information on space and habitat use by bobwhites, and to investigate the nesting ecology of bobwhites on the Babcock-Webb WMA. In Chapter 2, I first present estimates of the size of annual and seasonal home ranges, and investigate factors influencing home range sizes. Further, I test for habitat selection within home ranges by bobwhites, and examine variations in the pattern of habitat use over time and between genders. In Chapter 3, I test for the selection of nesting habitat by bobwhites and evaluate the influence of landscape and habitat characteristics on nest site selection. I then examine the influence of habitat composition and structure on nesting success. Finally, in Chapter 4, I summarize main findings of the study, and provide recommendations for the management of bobwhites on the WMA based on my findings.

CHAPTER 2  
PATTERNS OF SPACE AND HABITAT USE BY NORTHERN BOBWHITES IN SOUTH  
FLORIDA

**Introduction**

Population declines of the northern bobwhite have been widely documented throughout southeastern United States (Brennan 1991, Sauer et al. 2004, Williams et al. 2004, Brennan and Kuvlesky 2005). These declines have occurred despite the economic importance of the northern bobwhite as a game species and extensive efforts to maintain and improve its population welfare. Hypotheses proposed to explain local or regional declines include reduction in fledgling survival due to predation by imported fire ants (Allen et al. 1995, Giuliano et al. 1996, Pedersen et al. 1996, Mueller et al. 1999), loss and fragmentation of habitat (FenskeCrawford and Niemi 1997, Fleming and Giuliano 2001), extreme weather events (Robel and Kemp 1997, Guthery et al. 2000, Lusk et al. 2001, Hernandez et al. 2005), and hunting pressure (Burger et al. 1999, Peterson 2001, Madison et al. 2002, Guthery et al. 2004a). An exhaustive review of the dramatic range-wide population declines of bobwhites in the southeastern range of the species conducted by the Southeastern Quail Study Group concluded that habitat losses including qualitative changes (conversion of native warm season grasses to exotic cool season and warm season species), and quantitative habitat losses to urban expansion and transportation structures have been the most universally significant causes (Dimmick et al. 2002).

The way that bobwhites utilize space and resources are important aspects of the species' ecology, and thus have significant management implications (Webb and Guthery 1983, Guthery 1997, Guthery et al. 2004b, Williams et al. 2004). Previous studies suggest that home range sizes of bobwhites vary regionally, and also are influenced by several intrinsic and extrinsic factors (e.g. Yoho and Dimmick 1972, Bell et al. 1985, Taylor et al. 1999, Terhune et al. 2006). Furthermore, resource selection and the proximate cues used by bobwhites in habitat

selection may vary across spatial scales. Although bobwhites occupy a wide variety of habitats across their range in the United States (Roseberry et al. 1994, Taylor and Guthery 1994, Barnes et al. 1995, Dixon et al. 1996) they may demonstrate an affinity for specific habitat types on a local scale. Furthermore, energetic demands for thermoregulation and nutritional requirements of bobwhites may vary among seasons (Townsend et al. 1999). A variety of foods is required to meet the special requirements of growing chicks, breeding hens, and all sex-age classes during fall and winter (Dimmick 1992). Cover that affords protection from weather, predators, and hunters is paramount in fall, winter, and early spring. Good nesting cover consists of vegetation suitable for building the nest and concealing it and the clutch of eggs. The degree of interspersed components of food and cover is a major determinant of the quality of the bobwhite's habitat. Thus, knowledge of site-specific patterns of space use and habitat selection is necessary for evaluating the suitability of different land cover types, and for managing habitat to enhance bobwhite survival and reproduction. However, prior to the initiation of this study, data on space and habitat use by bobwhites in south Florida were scarce.

Harvest records indicate that the bobwhite population in Babcock-Webb Wildlife Management Area in Charlotte County, Florida, USA (hereafter, Babcock-Webb WMA) has declined steadily since the 1970's (Dimmick et al. in press). The numbers of bobwhites in the area remain low despite a significant effort to reverse this trend. Management of bobwhites in south Florida could benefit from an understanding of the patterns of space and habitat use in this ecoregion. However, information on home range sizes and habitat preferences of bobwhites in south Florida is currently incomplete. Our goal was to fill this gap in knowledge and provide information on space and habitat use by bobwhites on the Babcock-Webb WMA. Specifically, we estimated the size of annual and seasonal home ranges, and investigated factors influencing

home range sizes. Secondly, we tested for habitat selection within home ranges by bobwhites, and examined variations in the pattern of habitat use over time and between genders.

## **Study Area and Methods**

### **Study Area**

The study was conducted on the Babcock-Webb WMA in Charlotte County, FL. The WMA is located in south Florida, its western border about 8 km east of the town of Punta Gorda (Fig.2-1). The WMA comprises 26,818 ha, encompassing 3 major and 5 minor habitat types (Table 2-1). The most significant plant communities included dry prairie (9,737 ha), pine-palmetto (9,145 ha) and wet prairie (7,047 ha). Vegetation on our study site was described in detail by Frye (1954). *Sesbania sp.* food plots, planted in 3m wide strips, comprise 0.56% (151 ha) of the area of the WMA.

Topography is flat, and the soil is sandy. The surface floods periodically following heavy rains, but drains rapidly when rainfall ceases. The area is subject to prolonged drought, sometimes lasting several years. Water depths of several centimeters may cover more than 50% of the surface for several days. Both of these weather extremes likely affect bobwhite habitat selection, survival, and reproduction.

Currently, controlled burning and roller chopping are the primary habitat management activities conducted on the WMA. During the last 2 decades, several kilometers of *Sesbania sp.* strips were planted in concentrated areas throughout the area. These strips are rejuvenated and fertilized as needed on an annual basis. Some regulated grazing occurs in various places on the area under lease agreements with local ranchers. Efforts to reduce or eliminate noxious non-native plants are ongoing, and have been successful.

## **Trapping and Radio-Telemetry**

We captured bobwhites during all months of the year from October 2002 through March 2007, except in areas where the bobwhite hunting season was in progress. We used baited funnel traps during the non-breeding season. We used the same traps to capture birds during the breeding season; however, we placed a female in a small enclosure in the main trap to entice males (call-back trapping). The call-back trapping was enhanced by playing recordings of females using tape-players capable of playing a continuous loop of calls. Cast nets approximately 3 m in diameter were used to capture birds throughout the year. The cast nets were modified by removing the drawstrings and doubling the number of weights on the lead line. During daylight hours birds were located with radios and cast nets were used to capture unmarked birds that were associated with them. We used birddogs to locate bobwhites when radio-marked birds were not in an area where we wished to capture birds. At night we located radio-marked birds on their roost and captured them and their associated covey mates with the cast net. All trapping and handling protocols were approved by the University of Florida Institutional Animal Care and Use Committee (protocol number A-794).

We located radio-marked birds using hand-held receivers and Yagi antennas. We searched for individual birds at 3-5 day intervals, traversing the area with 4-wheel drive all-terrain vehicles and trucks. Truck-mounted whip antennas were used to locate birds that went missing for several days. This was effective for relocating birds that had traversed long distances from their established home ranges, or from the capture site. The location of each radio-marked bird was established using the homing procedure and logged into a GPS unit for later transfer to an office-based computer. All data were stored in a database management system with the individual entries controlled by a 5-digit leg-band number. Birds were weighed to the nearest gram, aged, sexed, and leg-banded. Birds weighing at least 130 g were fitted with a necklace-

style transmitter with a mortality sensor weighing 6 g. Antenna length was 22 cm. Transmitters had an expected battery life of 365 days, and a signal range of about 500 to 1000 m in the WMA habitat. Left-align text throughout (ragged right). While many of you prefer the look of justified text, research has shown that ragged-right text is easier to read than justified text. Both the irregular shape of the text on the right that gives the eye a reference point and the regular word and character spacing of unjustified text make life easier on the reader.

## **Data Analysis**

**Home Range Sizes:** We monitored 1245 radio-tagged bobwhites for 19,467 radio-days from October 2002 to March 2007. These data were used to investigate factors influencing annual and seasonal home range sizes and habitat selection.

To analyze annual home ranges, we used radio locations collected from October 1 of year 1 to September 30 of year 2. The annual period thus spanned both winter (1<sup>st</sup> October – 31<sup>st</sup> March) and summer (1<sup>st</sup> April – 30<sup>th</sup> September) seasons. Annual home ranges were estimated for birds that had  $\geq 30$  radiolocations spanning at least 3 months in each season. We did not include data for 2006-07 for these analyses because they included radiolocations from the winter season only. We estimated annual home ranges using the 95% Kernel density method (Worton 1989, Seaman and Powell 1996) using the least cost cross-validation procedure in ArcView® Animal Movement Analyst (Hooze and Eichenlaub 2000). For comparison purposes, we also calculated 95% minimum convex polygon home ranges (White and Garrott 1990). To analyze seasonal home ranges, we selected all birds that had  $\geq 20$  radiolocations within a season and estimated home ranges as described previously.

We log-transformed estimates of home range size prior to analyses, and analyzed annual and seasonal home ranges separately. We first tested separately for the effect on annual home range size of gender, year of study (2002-03, 2003-04, 2004-05, 2005-06), and a variable

describing whether a home range intersected a food plot using 2-sample t-tests or ANOVAs, as appropriate. For these analyses, we considered the effect of one variable at a time. Next, we fitted a series of general linear models (GLMs), and tested for all main and 2-way interaction effects of the aforementioned variables (Slade et al. 1997, Moyer et al. 2007). We sequentially removed non-significant ( $\alpha = 0.05$ ) interaction terms in a step-wise fashion such that the least significant interaction term was removed each time. The models were refitted sequentially until all main effects and only significant interaction effects remained in the model (Slade et al. 1997, Moyer et al. 2007). We further explored the significant interaction effects in the final models using the least squares means (lsmeans) multiple comparison procedures. Seasonal home ranges were analyzed similarly except that season (summer or winter) was included as an effect, and we also included data collected during winter of 2006-07.

**Habitat Selection:** We used a distance-based method (Conner et al. 2003) to investigate habitat selection, and to examine if the pattern of habitat selection differed between genders and seasons, and varied across years. We preferred this method because two of our habitat types (food plots, and road grades) were essentially linear features; this precluded the use of methods that require area-based estimates of habitat availability (e.g. compositional analysis, Aebischer et al. 1993). The distance-based approach compares observed distances from radio-locations to a given habitat type with the expected distance to that habitat type in order to test the hypothesis that habitat types are used in proportion to their availabilities (Conner et al. 2003, Perkins and Conner 2004, Conner et al. 2005). When compared to classification-based methods, inferences based on the distance-based analysis are more robust with respect to habitat misclassifications (Bingham and Brennan 2004).

Random points were generated inside the home range of each bird with a uniform distribution at the density of 200 points per km<sup>2</sup> using custom scripts written in ArcView®. This density of points was selected because it was where the variance of the average distance to a given habitat type began to stabilize (Figure 2-2). These points defined habitat availability. Habitat ‘use’ was defined by the actual radiolocations of each bird within its home range.

The distance from each random point was measured in each home range to the nearest patch of each habitat type. We created vectors of distances of these random points to each habitat type (**r**). Entries in **r** represented expected values of distances under the null hypothesis of no habitat selection (Conner et al. 2003). We also created a vector **u**; entries in **u** represented distances from radiolocations to each habitat type. Entries in **u** represented habitat use. A vector of ratios (**d**) was created by dividing each entry in **u** by the corresponding entry in **r**. Entries equaling 1.0 in **d** indicated that habitat use equaled habitat availability for a given habitat type. These ratios were averaged over all individual quail to produce a vector **p**. The null hypothesis that **p** is not significantly different from a vector of 1’s was tested using multivariate analysis of variance (MANOVA). Rejection of the null hypothesis of no habitat selection indicated that use differed from availability for at least one habitat type. If the null hypothesis was rejected, we used a paired t-test to compare each entry in **p** to 1.0 to determine which habitat types were used differently than expected (Conner et al. 2003). When an entry in **p** was < 1, radiolocations were closer than expected (indicating preference), and when an entry in **p** was > 1, radiolocations were farther away than expected (indicating avoidance). The entries in **p** were then used to rank the habitat types in order of preference. Significant differences among habitat types were determined using a paired *t*-test (Conner et al. 2003). We tested for habitat selection using all data to examine the pattern of overall habitat selection. We then repeated the analyses by year, gender,

and season to test for annual, gender-specific, and seasonal patterns of habitat selection, respectively. Arabic numerals (1, 2, 3, etc.) centered at the bottom of each page. Every page is counted and numbered. The major issue with page numbers is when you have to use a broadside (or Landscape) orientation. In this case the page is rotated 90 degrees clockwise and the page number is placed in the same relative position it would be on a portrait page. One-half inch from the left edge, centered vertically and rotated 90 degrees clockwise.

## **Results**

### **Annual Home Ranges**

Data were adequate for estimating annual home ranges for 174 birds. The mean ( $\pm 1$  SE) size of annual home ranges varied from  $82.25 \pm 9.84$  ha in 2005-2006 to  $97.30 \pm 23.29$  ha in 2002-2003, with an overall mean of  $88.43 \pm 6.16$  ha (Table 2-2). Annual home ranges estimated by the minimum convex polygon method ranged from  $50.81 \pm 8.77$  ha in 2003-04 to  $68.74 \pm 18.09$  ha in 2002-03, and were generally smaller than those obtained from the Kernel density method (Table 2-2).

When the effect of each factor was tested separately, we found that annual home ranges did not differ significantly between genders ( $t = 1.12$ ,  $P = 0.266$ ), nor did they vary across years of study ( $F = 1.34$ ,  $P = 0.2630$ ). However, home ranges of bobwhites that contained food plots ( $80.50 \pm 6.24$  ha) were significantly smaller ( $t = 3.27$ ,  $P = 0.0013$ ) than those that did not contain food plots ( $133.57 \pm 19.02$  ha; Table 2-2).

When the effect of year, gender, and the presence of food plots was evaluated simultaneously, we found that the main effect of year ( $F = 4.46$ ,  $P = 0.0049$ ) and gender ( $F = 8.03$ ,  $P = 0.0052$ ) was significant. Moreover, the interaction effect of year and the presence of food plots was significant ( $F = 5.06$ ,  $P = 0.0074$ ; Table 2-4), indicating that the influence of food plots on home range size varied across years. Least-square mean comparison procedures

revealed that, in 2004-05 home ranges that did not contain food plots were significantly larger ( $146.66 \pm 21.94$ ) than those that did ( $73.17 \pm 6.14$ ;  $P = 0.0022$ ); the small number of home ranges without food plots in other years precluded similar comparisons ( $N = 0, 2, \text{ and } 3$  in 2002-2003, 2003-2004, and 2005-2006, respectively). The interaction effect of gender and year also was significant ( $P = 0.0022$ ; Table 2-4); however, neither males nor females had consistently larger (or smaller) home ranges during all years of study (Fig. 2-3B).

### **Seasonal Home Ranges**

The mean size of summer home range was  $53.90 \pm 4.93$  ha and that of winter home range was  $69.27 \pm 4.92$  ha (Table 2-3). Summer and winter home ranges estimated by the minimum convex polygon method were  $27.96 \pm 1.84$  ha and  $37.28 \pm 2.67$  ha, respectively and were generally smaller than those obtained from the kernel density method (Table 2-3).

Tests of single factor effects revealed that winter home range size did not differ between bobwhites whose home range did or did not contain food plots ( $t = 1.64$ ,  $P = 0.103$ ). However, winter home ranges varied significantly across years ( $F = 2.45$ ,  $P = 0.0483$ ) with larger home ranges during 2002-03 than in 2006-07 (Table 2-3); there were no other statistically significant differences. When the effect of all factors was evaluated simultaneously, the main effect of the presence of food plots was significant ( $F = 7.16$ ,  $P = 0.0082$ ); winter home ranges that contained food plots were significantly smaller than those that did not (Table 2-3). The main effect of year was also significant ( $F = 3.26$ ,  $P = 0.0133$ ), with larger winter home ranges in 2002-03 than in 2006-07 ( $P = 0.0390$ ). None of the interaction effects was significant (Table 2-4).

Single factor analysis revealed that summer home ranges differed significantly between genders ( $t = 2.36$ ,  $P = 0.021$ ), with males ( $55.33 \pm 3.82$  ha) maintaining larger summer home ranges than females ( $51.51 \pm 11.6282$  ha; Table 2-3). Annual differences in summer home range size also were significant ( $F = 2.73$ ,  $P = 0.0469$ ), with smaller summer home ranges during

2003-04 than most other years (Table 2-3). The effect of food plots on summer home range size was not significant. When the effect of all factors was tested simultaneously, the only significant main effect was that of gender ( $F = 5.88, P = 0.0168$ ) wherein males had larger home ranges than females (Table 2-3). None of the interaction effects was significant.

### **Habitat Selection**

Distance ratios analyzed using the MANOVA procedure revealed that bobwhite radiolocations differed significantly from random locations overall ( $F = 166.6, P < 0.0001$ ), and when considered separately for each gender ( $F = 150.12, P < 0.0001$ ), season, ( $F = 209.56, P < 0.0001$ ), and year ( $F = 198.75, P < 0.0001$ ; Table 2-5). Thus, bobwhites exhibited strong habitat selection, indicating that some habitats were used more or less than expected by chance alone.

Food plots were strongly preferred by both males and females, in both seasons and across all years of study (Tables 2-6, 2-7). Pine-palmetto habitat was preferred by male bobwhites, but not by females (Table 2-6). Pooled across genders, pine-palmetto habitat was preferred by bobwhites across both seasons (Table 2-6), and in all years except 2002-03 and 2004-05 (Table 2-7). Dry prairie habitat was generally preferred by bobwhites but the pattern of selection was not consistent across genders, seasons or years. Females preferred dry prairie habitat but males did not (Table 2-6). When data were pooled across genders, bobwhites strongly preferred dry prairie habitat in winter, but not in summer (Table 2-6). Across years, dry prairie habitat was preferred in 2002-03 and 2004-05 and avoided in 2003-04. Dry prairie was used randomly in 2005-06 (Table 2-7).

Bobwhites generally avoided wet prairie habitat but the pattern of selection varied. Male bobwhites were found farther than expected from wet prairie habitats; however, females used wet prairies randomly (Table 2-6). Across seasons, wet prairie habitats were preferred in winters but avoided in summers. Across years, bobwhites generally avoided wet prairie habitats except

in the year 2004-05 (Tables 2-6 and 2-7). Bobwhites were generally found farther than expected from water bodies, road grades and odd areas; the pattern was consistent across genders and seasons (Table 2-6). Water bodies and road grades were avoided throughout the study period except in 2004-05 when they were preferred (Table 2-7). Similarly, odd areas were preferred only in year 2002-03 (Table 2-7).

### **Discussion**

Effective management of game species requires knowing how the species utilizes available landscape, and selects resources within it. Landscapes are inherently heterogeneous, and the choice of habitat can influence an individual's survival and reproduction, as well as individual fitness (Fretwell and Lucas 1970, Holt 1985, Pulliam 1988). Quantifying behavioral responses to habitat heterogeneity may help identify essential resources and environmental conditions that affect population dynamics and may aid in the management of wildlife populations (Sutherland 1996, Boyce and McDonald 1999).

During the period of this study the bobwhite population on the majority of the Babcock-Webb WMA existed at a very low density in contrast with many other managed habitats across the species' range (Dimmick et al. in press). The population reached this very low density following several decades of decline from its zenith in the 1970's when annual harvests often exceeded 5000 birds per year (Florida Fish and Wildlife Conservation Commission, unpublished data). The population decline almost surely reflected deterioration in the quality of the habitat, and this deterioration may have been facilitated by various changes in management practices as well as other activities occurring on the area or its perimeter. It is also possible that the population has been over-harvested, particularly during recent years when legal harvest removed birds at a rate believed to be unsustainable (Dimmick et al. in press). Efforts to reverse the downward spiral in the bobwhite population are currently underway; our goal was to assist the

Florida Fish and Wildlife Conservation Commission in this effort by providing data on space and habitat use by bobwhites on the WMA.

Characteristically, bobwhites occupy home ranges as small as  $\leq 5$  ha in excellent habitat (Wiseman and Lewis 1981, Sisson et al. 2000), and  $\leq 40$  ha in good habitat (Bell et al. 1985, Dixon et al. 1996, Guthery et al. 2004b, Haines et al. 2004, Terhune et al. 2006). The mean annual home range size in our study area was  $88.43 \pm 6.16$  ha, which is substantially larger than most previously reported bobwhite home ranges. Resource availability and habitat productivity have been shown to have tremendous influences on home-range sizes in many wildlife species (Samson and Huot 1998, Koehler and Pierce 2003, Moyer et al. 2007), and extremely large bobwhite home ranges observed in our study most likely reflects that some component of the habitat is poor on the WMA.

Several intrinsic and extrinsic environmental factors, alone or in concert, can influence annual or seasonal home range sizes (e.g. Badyaev et al. 1996, Slade et al. 1997, Moyer et al. 2007, Whitaker et al. 2007). For example, stochastic variation in the environment can influence home range size but the pattern of influence can vary depending on other factors, such as gender and resource availability. We found that there was a significant interaction between gender and year, but the difference in home range size between genders was not consistent across years (Fig. 2-3). Likewise, there was no gender difference in winter home ranges as would be expected because they are in coveys. However, males maintained larger summer home ranges than females. Taylor et al. (1999) found that male bobwhites had significantly larger home ranges than females in one study site, but the pattern was reversed in another study site. Thus, bobwhites apparently do not follow systematic gender differences in home range size observed in many species of birds and mammals (Oka 1992, Begg et al. 2005, Favaron et al. 2006)

We believe that the generally larger home ranges during winter than in summer observed in our study are primarily a consequence of food-resource limitation, particularly limited availability of slough grass (*Spartina pectinata*; an important food source for bobwhites in our study area). Animals tend to roam more widely during seasons of lower resource abundance in search of scarce and patchily distributed resources, which would lead to larger home ranges (e.g. Yo et al. 1992, Chapman et al. 1993, Ndithia and Perrin 2006). Another possibility is that larger home ranges during winter may also be due to hunting-induced disturbances, as is commonly observed in other game birds (Whitaker et al. 2007).

Bobwhites showed a strong response to food plots in our study area. Annual home ranges were generally smaller for birds whose ranges contained food plots compared to those that did not; Sisson et al. (2000) and W.E. Palmer (Tall Timbers Research Station, pers. comm. 2009) both observed a similar response to supplemental feeding. The fact that there were few home ranges that did not intersect food plots is itself an indication that food plots markedly influenced the habitat chosen by bobwhites on the WMA in years other than 2004-05. The same pattern was observed for winter home ranges as well. Although summer home ranges that contained food plots were larger than home ranges that did not, the effect was not significant. Food plots and supplemental feeding are widely used practices for managing bobwhite populations in North America (Townsend et al. 1999, Guthery et al. 2004b, Haines et al. 2004) In our study area, the provision of food plots seemed to stabilise resource availability for bobwhites, thereby contributing to reduction in home range size. This suggestion is further supported by the fact that food plots significantly contributed to reduction in size of winter, but not summer, home ranges.

Our results, along with those of Guthery et al. (2004b), suggest that bobwhite home ranges are strongly influenced by food availability such that bobwhites inhabiting poor quality habitat

(or within a site, during seasons of lower food availability) typically need larger home ranges to satisfy their resource needs (Sisson et al. 2000 , and W.E. Palmer, Tall Timbers Research Station, pers. comm. 2009). The effects of supplemental food on home range size may vary, depending perhaps on local habitat conditions (e.g., Haines et al. 2004).

Bobwhites were generally found closer to food plots as compared to other habitat types, indicating a preference for this habitat type. This may have resulted from the concentration of coveys around supplemental food sources (Guthery et al. 2004b, Haines et al. 2004). Other habitat types preferred by bobwhites included pine palmetto and dry prairie, and these patterns were consistent between sexes and seasons.

Table 2-1. Description of habitat types represented and area occupied by each habitat type in Babcock-Webb Wildlife Management Area, Florida.

| Habitat <sup>a</sup> | Description   | Area (ha) | %Area   |
|----------------------|---|-----------|---------|
| Dry Prairie (DP)     | Herbaceous and low shrub communities on seldom flooded, sandy soil areas very similar to pine- palmetto, differing from them mainly by their lack of pines and sparse palmetto. Utilized by quail throughout the year for nesting, brood-rearing, and roosting.   | 9736.96   | 36.308  |
| Pine-Palmetto (PP)   | Open stands of slash pine ( <i>Pinus caribaea</i> ) on poorly drained soils, with an understory of saw palmetto ( <i>Serenoa repens</i> ), wire grass ( <i>Aristida stricta</i> ), broomsedge ( <i>Andropogon spp.</i> ) and other grasses. Various panic grasses ( <i>Panicum spp.</i> ), slough grass ( <i>Scleria setacea</i> ), and dwarf wax myrtle ( <i>Cerothanmus pumilus</i> ) are used by quail for feeding and/or nesting. | 9145.19   | 34.101  |
| Wet prairie (WP)     | Herbaceous communities on low seasonally flooded transitional areas between permanent wetlands and drier communities. Important to quail primarily because of the abundant slough grass. Use is limited when they are flooded but commonly utilized when wet but not flooded.   | 7046.93   | 26.277  |
| Odd Area (OA)        | Buildings and other human use areas not generally considered quail habitat.   | 508.09    | 1.895   |
| Water (WA)           | Permanent ponds, natural and man-made, surrounded by emergent aquatic plants.   | 192.35    | 0.717   |
| Food Plot (FP)       | Continuous serpentine stands of <i>Sesbania sp.</i> , an erect legume approximating 2-3 m in height. Width of the food plots is about 7 m. Ground cover beneath the plants is generally open and sandy.   | 151.21    | 0.564   |
| Road Grade (RG)      | Roads prepared by grading to create a surface approximately 1+ m above the surrounding habitat.   | 18.75     | 0.07    |
| Road (RD)            | Field roads not elevated above the surrounding surface  | 18.42     | 0.069   |
| TOTAL                |   | 26817.90  | 100.000 |

<sup>a</sup> Description of habitat types adopted from Frye (1954), with modifications.

Table 2-2. Estimates of home range size (mean  $\pm$  1 SE) of the northern bobwhite quail at the Babcock-Webb Wildlife Management Area, Florida (2002-2006)

|                                       | n   | No. of locations | Mean home range size (ha)                |                   |
|---------------------------------------|-----|------------------|--|-------------------|
|                                       |     |                  | 95% Kernel density estimates (range ha.) | 95% MCP estimates |
| A. By year                            |     |                  |  |                   |
| 2002-03                               | 10  | 38.60 $\pm$ 1.77 | 97.30 $\pm$ 23.29 (5.69 - 235.64)        | 68.74 $\pm$ 18.09 |
| 2003-04                               | 44  | 38.86 $\pm$ 1.01 | 84.30 $\pm$ 16.33 (10.69 - 544.30)       | 50.81 $\pm$ 8.77  |
| 2004-05                               | 78  | 37.24 $\pm$ 0.74 | 92.96 $\pm$ 8.36 (9.07 - 475.83)         | 62.33 $\pm$ 5.00  |
| 2005-06                               | 42  | 37.95 $\pm$ 0.96 | 82.25 $\pm$ 9.84 (14.02 - 331.47)        | 56.91 $\pm$ 5.65  |
| B. By gender                          |     |                  |  |                   |
| Female                                | 75  | 38.89 $\pm$ 0.83 | 84.06 $\pm$ 8.58 (5.69 - 362.93)         | 59.00 $\pm$ 5.88  |
| Male                                  | 99  | 37.15 $\pm$ 0.58 | 91.74 $\pm$ 8.69 (9.07 - 544.30)         | 58.08 $\pm$ 4.47  |
| C. Home range intersected a food plot |     |                  |  |                   |
| Yes                                   | 148 | 38.32 $\pm$ 0.54 | 80.50 $\pm$ 6.24 (5.69 - 544.30)         | 52.16 $\pm$ 3.81  |
| No                                    | 26  | 35.50 $\pm$ 1.10 | 133.57 $\pm$ 19.02 (10.69 - 475.83)      | 82.67 $\pm$ 8.16  |
| Overall                               | 174 | 37.90 $\pm$ 0.49 | 88.43 $\pm$ 6.16 (5.69 - 544.30)         | 58.48 $\pm$ 3.58  |

Table 2-3. Estimates of seasonal home range sizes of northern bobwhites at the Babcock-Webb Wildlife Management Area, Florida (2002-2006)

|                          |         | n   | No. of locations | Mean home range size (ha)                |                   |
|--------------------------|---------|-----|------------------|--|-------------------|
|                          |         |     |                  | 95% Kernel density estimates (range ha.) | 95% MCP estimates |
| <b>A. Overall</b>        |         |     |                  |  |                   |
|                          | Summer  | 123 | 23.81 ± 0.31     | 53.90 ± 4.93 (5.28- 530.06)              | 27.96 ± 1.84      |
|                          | Winter  | 167 | 26.03 ± 0.27     | 69.27 ± 4.92 (5.59- 401.57)              | 37.28 ± 2.67      |
|                          | Overall | 290 | 25.10 ± 0.22     | 62.75 ± 3.55 (5.28 - 530.06)             | 33.03 ± 1.74      |
| <b>B. Winter</b>         |         |     |                  |  |                   |
| Gender                   | Female  | 72  | 26.14 ± 0.37     | 62.25 ± 7.30 (5.59-278.71)               | 34.74 ± 4.21      |
|                          | Male    | 95  | 25.95 ± 0.39     | 74.59 ± 6.63 (5.59-401.58)               | 39.21 ± 3.46      |
| Intersected a food plot? | Yes     | 124 | 25.73 ± 0.33     | 66.84 ± 5.83 (5.59-401.58)               | 34.31 ± 2.94      |
|                          | No      | 43  | 26.88 ± 0.44     | 76.29 ± 9.11 (9.25-223.33)               | 42.06 ± 5.09      |
| Year                     | 2002-03 | 5   | 23.40 ± 1.54     | 160.28 ± 66.20 (33.64-401.58)            | 83.16 ± 34.47     |
|                          | 2003-04 | 36  | 26.44 ± 0.80     | 79.35 ± 11.31 (10.40-278.71)             | 40.14 ± 5.68      |
|                          | 2004-05 | 75  | 26.41 ± 0.35     | 69.15 ± 6.97 (5.59-236.86)               | 38.74 ± 4.09      |
|                          | 2005-06 | 13  | 24.23 ± 0.63     | 58.79 ± 9.95 (29.21-141.94)              | 29.14 ± 5.25      |
|                          | 2006-07 | 38  | 25.84 ± 0.52     | 51.57 ± 7.50 (6.60-188.29)               | 34.74 ± 4.21      |
| <b>C. Summer</b>         |         |     |                  |  |                   |
| Gender                   | Female  | 46  | 24.17 ± 0.60     | 51.51 ± 11.62 (5.28-530.06)              | 26.36 ± 3.82      |
|                          | Male    | 77  | 23.60 ± 0.35     | 55.33 ± 3.82 (9.59-148.38)               | 28.92 ± 1.86      |
| Intersected a food plot? | Yes     | 113 | 21.80 ± 0.71     | 54.60 ± 5.26 (5.28-530.06)               | 28.36 ± 1.96      |
|                          | No      | 10  | 23.99 ± 0.33     | 46.06 ± 12.95 (7.23-148.38)              | 24.91 ± 5.31      |
| Year                     | 2002-03 | 14  | 27.21 ± 1.56     | 58.54 ± 10.13 (5.28-114.99)              | 35.01 ± 5.96      |
|                          | 2003-04 | 23  | 21.70 ± 0.30     | 35.31 ± 5.95 (7.23-113.48)               | 18.84 ± 2.95      |
|                          | 2004-05 | 40  | 24.00 ± 0.33     | 64.07 ± 12.81 (10.10-530.06)             | 30.79 ± 4.03      |
|                          | 2005-06 | 46  | 23.67 ± 0.50     | 52.95 ± 5.41 (9.68-148.38)               | 27.93 ± 2.36      |

Table 2-4. Results of generalized linear models (GLM) investigating factors influencing the size of annual and seasonal home ranges of northern bobwhites in Babcock-Webb Wildlife Management Area, Florida

|          | Source          | df | Mean Square | F    | P      |
|----------|-----------------|----|-------------|------|--------|
| Annual   |                 |    |             |      |        |
|          | Gender          | 1  | 4.485       | 8.03 | 0.0052 |
|          | Year            | 3  | 2.492       | 4.46 | 0.0049 |
|          | FP <sup>#</sup> | 1  | 0.220       | 0.39 | 0.5311 |
|          | FP*Year         | 2  | 2.824       | 5.06 | 0.0074 |
|          | Gender*Year     | 3  | 2.827       | 5.06 | 0.0022 |
| Seasonal |                 |    |             |      |        |
| Winter   |                 |    |             |      |        |
|          | Gender          | 1  | 1.352       | 1.89 | 0.1710 |
|          | Year            | 4  | 2.333       | 3.26 | 0.0133 |
|          | FP              | 1  | 5.120       | 7.16 | 0.0082 |
| Summer   |                 |    |             |      |        |
|          | Gender          | 1  | 3.371       | 5.88 | 0.0168 |
|          | Year            | 3  | 1.513       | 2.64 | 0.0527 |
|          | FP              | 1  | 0.132       | 0.23 | 0.6318 |

FP<sup>#</sup>: Factor describing whether home range intersects food plot

Table 2-5. Results of MANOVA analysis testing for the difference between the vector  $\rho$  and a vector of 1s

|         | F      | df | P      |
|---------|--------|----|--------|
| Overall | 166.60 | 8  | <.0001 |
| Gender  | 150.12 | 8  | <.0001 |
| Season  | 209.56 | 8  | <.0001 |
| Year    | 198.75 | 8  | <.0001 |

Table 2-6. Results of t-tests following MANOVA analyses, results are presented as overall and stratified by gender and season

| Habitat <sup>a</sup> | By Gender |        |      |        |        |      |        |        |      | By Season |        |      |        |        |      |
|----------------------|-----------|--------|------|--------|--------|------|--------|--------|------|-----------|--------|------|--------|--------|------|
|                      | Overall   |        |      | Female |        |      | Male   |        |      | Summer    |        |      | Winter |        |      |
|                      | t         | P      | Rank | t      | P      | Rank | t      | P      | Rank | t         | P      | Rank | t      | P      | Rank |
| DP                   | -2.35     | 0.019  | 4    | -2.26  | 0.0241 | 3    | -1.18  | 0.2381 | 3    | 0.56      | 0.5773 | 4    | -3.65  | 0.0003 | 4    |
| FP                   | -33.53    | <.0001 | 1    | -12.77 | <.0001 | 1    | -37.62 | <.0001 | 1    | -58.06    | <.0001 | 1    | -12.03 | <.0001 | 1    |
| OA                   | 21.56     | <.0001 | 8    | 14.24  | <.0001 | 8    | 16.2   | <.0001 | 8    | 20.18     | <.0001 | 8    | 11.86  | <.0001 | 8    |
| PP                   | -7.12     | <.0001 | 2    | -1.57  | 0.1174 | 5    | -8.33  | <.0001 | 2    | -8.42     | <.0001 | 2    | -2.72  | 0.0066 | 7    |
| RD                   | -3.95     | <.0001 | 3    | -9.29  | <.0001 | 2    | 2.03   | 0.0423 | 4    | -2.73     | 0.0064 | 3    | -2.86  | 0.0043 | 6    |
| RG                   | 9.22      | <.0001 | 7    | -1.82  | 0.069  | 4    | 12.11  | <.0001 | 7    | 17.17     | <.0001 | 6    | -3.71  | 0.0002 | 3    |
| WA                   | 7.49      | <.0001 | 6    | 2.03   | 0.0423 | 7    | 7.99   | <.0001 | 6    | 19.43     | <.0001 | 7    | -5.22  | <.0001 | 2    |
| WP                   | 3.36      | 0.0008 | 5    | -0.29  | 0.7708 | 6    | 4.54   | <.0001 | 5    | 8.3       | <.0001 | 5    | -3.33  | 0.0009 | 5    |

<sup>a</sup>DP = Dry Prairie, FP = Food Plot, OA = Odd Area, PP = Pine Palmetto, RD = Road, RG = Road Grade, WA = Water, WP = Wet prairie

Table 2-7. Results of t-tests following MANOVA analyses stratified by year.

| Habitat <sup>a</sup> | 2002-03 |        |      | 2003-04 |        |      | 2004-05 |        |      | 2005-06 |        |      |
|----------------------|---------|--------|------|---------|--------|------|---------|--------|------|---------|--------|------|
|                      | t       | P      | Rank |
| DP                   | -6.71   | <.0001 | 3    | 4.86    | <.0001 | 3    | -5.1    | <.0001 | 6    | -0.35   | 0.7289 | 4    |
| FP                   | -32.04  | <.0001 | 1    | -180.51 | <.0001 | 1    | -8.28   | <.0001 | 3    | -26.37  | <.0001 | 1    |
| OA                   | -20.93  | <.0001 | 2    | 14.98   | <.0001 | 7    | 11.51   | <.0001 | 8    | 15.26   | <.0001 | 8    |
| PP                   | 0.2     | 0.8391 | 4    | -15.57  | <.0001 | 2    | -0.75   | 0.4542 | 7    | -4.27   | <.0001 | 3    |
| RD                   | 16.64   | <.0001 | 6    | 13.02   | <.0001 | 6    | -18.5   | <.0001 | 1    | -7.63   | <.0001 | 2    |
| RG                   | 21.37   | <.0001 | 8    | 18.95   | <.0001 | 8    | -7.74   | <.0001 | 4    | 4.02    | <.0001 | 7    |
| WA                   | 17.39   | <.0001 | 7    | 12.44   | <.0001 | 5    | -9.72   | <.0001 | 2    | 2.92    | 0.0036 | 6    |
| WP                   | 11.85   | <.0001 | 5    | 8       | <.0001 | 4    | -6.66   | <.0001 | 5    | 2.47    | 0.0138 | 5    |

<sup>a</sup>DP = Dry Prairie, FP = Food Plot, OA = Odd Area, PP = Pine Palmetto, RD = Road, RG = Road Grade, WA = Water, WP = Wet prairie

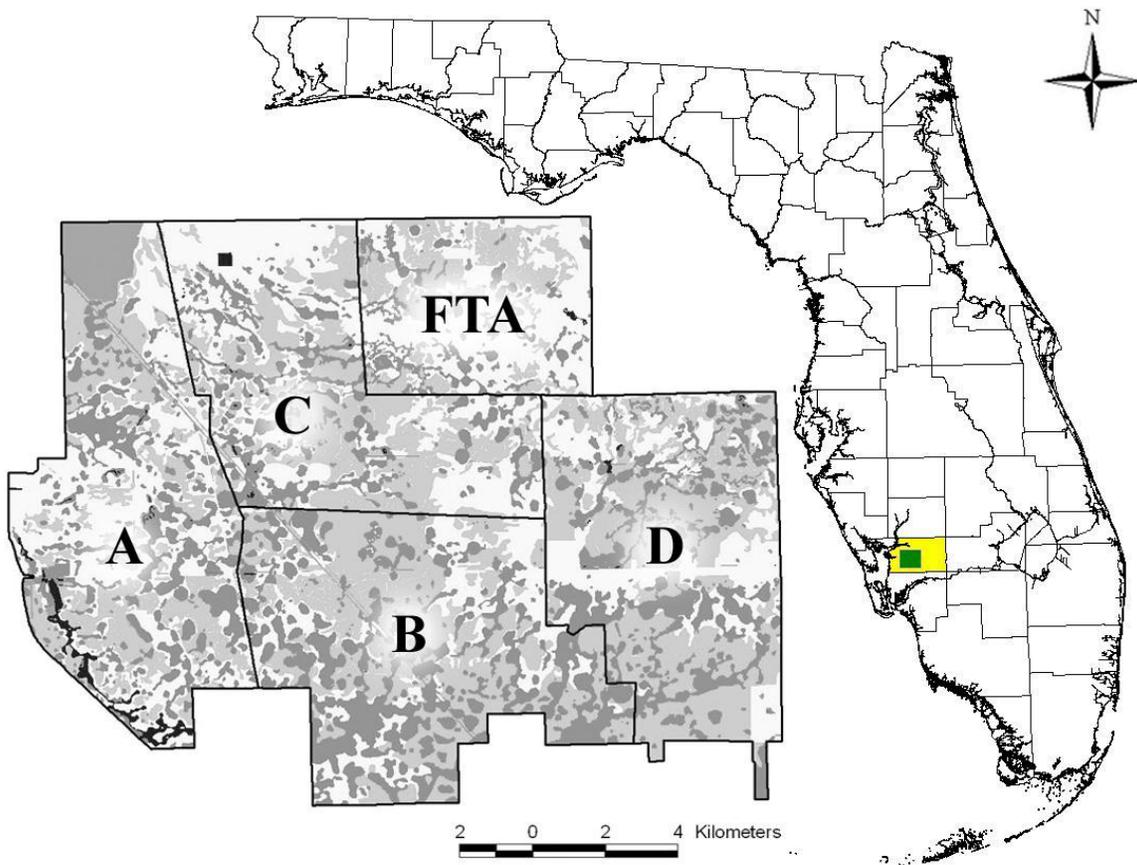


Figure 2-1. Location of the Webb-Babcock Wildlife Management Area in Charlotte County, south Florida. Five management zones are indicated by bold, upper case letters

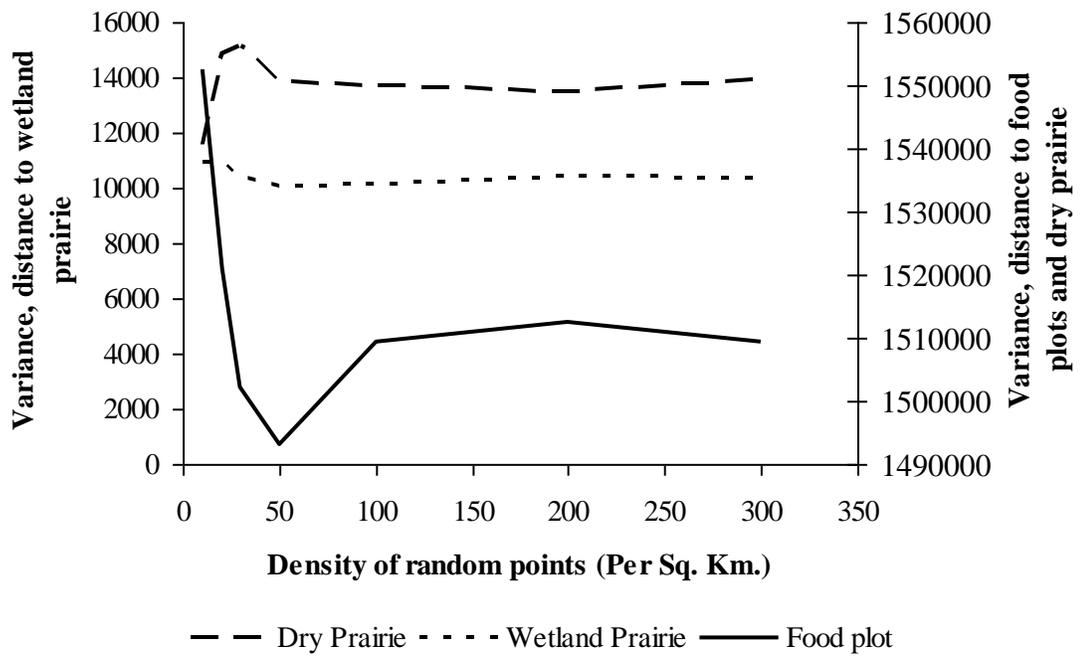


Figure 2-2. Relationship between the density of random points per square kilometer and the variance of the average distance to habitat features

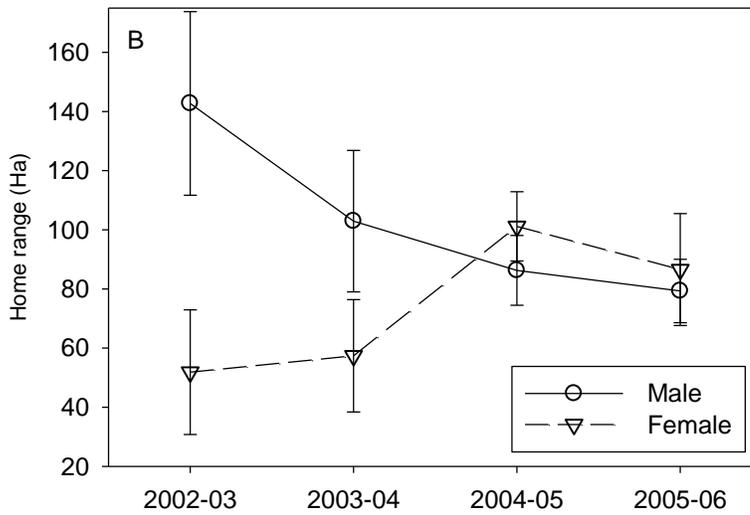
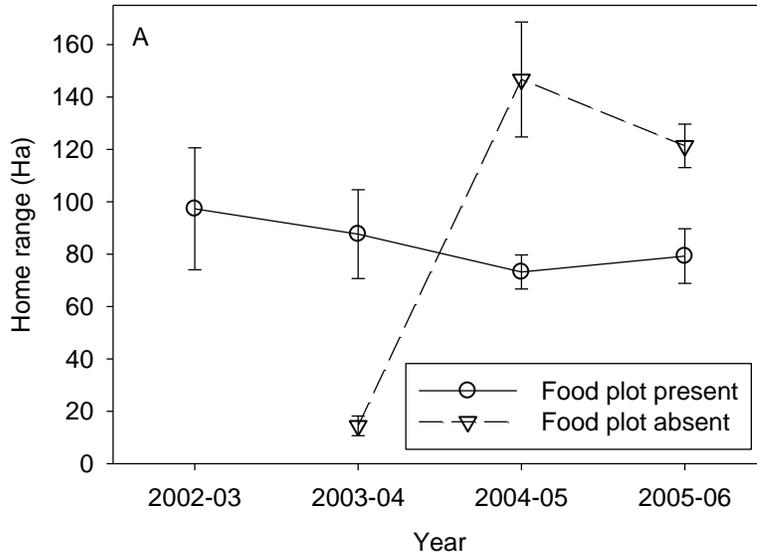


Figure 2-3. Size of bobwhite annual home ranges (ha; mean  $\pm$  1 SE) for each year of the study in Babcock-Webb Wildlife Management Area, FL. A) Home ranges stratified by whether a home range contained a food plot and, B) stratified by gender.

CHAPTER 3  
THE INFLUENCE OF NEST-SITE SELECTION ON BOBWHITE NESTING SUCCESS IN  
SOUTH FLORIDA

**Introduction**

Reproductive success in many species of birds is heavily influenced by nest-site selection (Hatchwell et al. 1999). This is because placement and attributes of nest-sites can affect risk of predation, access to food resources, and microclimate experienced by the developing embryos (Crabtree et al. 1989, Martin 1993, Lusk et al. 2006, Barea 2008). Nest-sites that offer protection from predators and weather elements is especially crucial for the reproductive success of ground-nesting birds such as northern bobwhites (*Colinus virginianus*), because predation or abandonment of ground nests can lead to a complete reproductive failure. Thus, nest-site selection can have important population-dynamic consequences, particularly in species characterized by early maturity and large clutch size. This is because population growth rates in such species are highly sensitive to reproductive parameters (Heppell et al. 2000, Saether and Bakke 2000, Stahl and Oli 2006).

Populations of northern bobwhites have experienced substantial range-wide declines (Brennan 1991, Sauer et al. 2004, Williams et al. 2004, Brennan and Kuvlesky 2005). Consistent with the range-wide trend, harvest records indicate that the bobwhite population in Babcock-Webb Wildlife Management Area in Charlotte County, Florida, USA (hereafter, Babcock-Webb WMA) has been declining steadily since the 1970's (Dimmick et al. in press). Management of this population could benefit from knowledge of nesting ecology of bobwhites on the WMA, but information on nest-site selection and factors influencing nest-site selection and nesting success are currently not available.

Our goal was to investigate nesting ecology of bobwhites on the WMA. Specifically, our objectives were to: 1) test for the selection of nesting habitat by bobwhites; 2) evaluate the influence of landscape and habitat characteristics on nest site selection, and 3) investigate factors influencing nesting success.

### **Study Area**

The study was conducted on the Babcock-Webb WMA in Charlotte County, FL. The WMA is located in south Florida, its western border about 8 km east of the town of Punta Gorda (Fig.3-1). The WMA comprises 26,818 ha, encompassing 3 major and 5 minor habitat types (Table 3-1). The most significant plant communities included dry prairie (9,737 ha), pine-palmetto (9,145 ha) and wet prairie (7,047 ha). Vegetation on our study site was described in detail by Frye (1954). *Sesbania sp.* food plots, planted in 3m wide strips, comprise 0.56% (151 ha) of the area of the WMA.

Topography is flat, and the soil is sandy. The surface floods periodically following heavy rains, but drains rapidly when rainfall ceases. The area is subject to prolonged drought, sometimes lasting several years. Water depths of several centimeters may cover more than 50% of the surface for several days. Both of these weather extremes likely affect bobwhite habitat selection, survival, and reproduction.

Currently, controlled burning and roller chopping are the primary habitat management activities conducted on the WMA. During the last 2 decades, several kilometers of *Sesbania sp.* strips were planted in concentrated areas throughout the area. These strips are rejuvenated and fertilized as needed on an annual basis. Some regulated grazing occurs in various places on the area under lease agreements with local ranchers. Efforts to reduce or eliminate noxious non-native plants are ongoing, and have been successful.

## Methods

### Trapping and Radio-Telemetry

We captured bobwhites during all months of the year from October 2002 through March 2007, except in areas where the bobwhite hunting season was in progress. We used baited funnel traps during the non-breeding season. The same traps were used to capture birds during the breeding season; however we used call-back trapping using caged female quail to entice males. We used cast nets approximately 3 m in diameter to capture birds throughout the year. During daylight hours we located birds with radios and cast the nets to capture unmarked birds that were associated with them. At night we located radio-marked birds on their roost and captured them and their associated covey mates with the cast net. Radio-marked birds were located using hand-held receivers and Yagi antennas. Individual birds were searched for at 3-5 day intervals by traversing the area with 4-wheel drive all-terrain vehicles and trucks. We used a truck-mounted whip antenna to locate birds that went missing for several days. This was effective for relocating birds that had traversed long distances from their established home ranges, or from the capture site. Other details of the trapping protocol are described in detail elsewhere (Singh et al. *in prep*). All trapping and handling protocols were approved by the University of Florida Institutional Animal Care and Use Committee.

### Nest Locations and Nesting Success

All nests monitored during the study were located by tracking radio-tagged birds. We located nests from the middle of March through the middle of October. If a bobwhite was located in the same area >2 days during the nesting season, the area was thoroughly searched for possible nests. On locating a nest, we noted habitat characteristics (e.g., habitat type, burn history), and recorded GPS coordinates. We took two photographs, one up close and one covering the wider view of the surrounding habitat. We attempted to check each nest at least

every third day from the time it was located until its fate. We categorized the fate of nests into three discrete categories, hatched (successful), destroyed or abandoned. We determine a 'hatched' status when we found a distinctive 'cap' cut off out of the bottom of an egg (by the chick). However, nests occasionally get disturbed by other animals after the eggs hatch. On encountering a nest that seemed destroyed, we termed it as a hatched nest if at least one of such caps were found on the nest location. Destroyed nests either have no eggs left in them or there is sufficient evidence of crushed eggs in and around the nest's vicinity. Finally, in some occasions adults would leave a nest during egg laying or incubation and would never come back. Such nests were termed abandoned.

Locations of all nest sites were entered in a geographical information system (GIS) compatible database and projected to a common projection system and datum (Albers, GRS 1980). Throughout, we followed Florida Geographic Data Library (FGDL) GIS metadata standards. We subsequently analyzed data in two complementary ways: to test for the selection of nest-sites and to identify landscape-level attributes associated with the fate of the nests.

### **Testing for Nest-Site Selection**

We used the distance-based method of Conner et al (2003) to test for the nest-site selection. The distance-based method has received wide application in a number of contexts (Parra 2006, Xu et al. 2007, Elfstrom et al. 2008, Riedle et al. 2008). We preferred this method because three of our habitat types (food plots, road, and road-grade) were essentially linear features; this precluded the use of methods that require area-based estimates of habitat availability (e.g. compositional analysis, Aebischer et al. 1993). The distance-based approach compares observed distances from nest-locations to a given habitat type with the expected distance to that habitat type in order to test the hypothesis that habitat types are used for nesting in proportion to their availabilities (Conner et al. 2003, Perkins and Conner 2004, Conner et al.

2005). When compared to classification-based methods, inferences based on the distance-based analysis are more robust with respect to habitat misclassifications (Bingham and Brennan 2004).

We defined the area ‘available’ for nesting as the region defined by a 95% Kernel density polygon (Worton 1989) encompassing all nest locations. The 95% Kernel density polygon was estimated using the least squares cross validation procedure in ArcView® Animal Movement Analyst (Hooge and Eichenlaub 2000). We generated random points across the 95% Kernel density polygon at a density of ~5 points per hectare. These random points therefore defined habitat ‘availability’. ‘Usage’, on the other hand, was defined by the actual location of nests.

We measured the distance from each random point to the nearest patch of each habitat. We created vectors of distances of these random points to each habitat type ( $\mathbf{r}$ ). Entries in  $\mathbf{r}$  represented expected values of distances under the null hypothesis of no habitat selection (Conner et al. 2003). We also created a vector  $\mathbf{u}$ ; entries in  $\mathbf{u}$  represented distances from nest-sites to each habitat type. Entries in  $\mathbf{u}$  represented habitat use. A vector of ratios ( $\mathbf{d}$ ) was created by dividing each entry in  $\mathbf{u}$  by the corresponding entry in  $\mathbf{r}$ . Entries equaling 1.0 in  $\mathbf{d}$  indicated that habitat use equaled habitat availability for a given habitat type. These ratios were averaged over all nest-sites to produce a vector  $\mathbf{p}$ . The null hypothesis that  $\mathbf{p}$  is not significantly different from a vector of 1’s was tested using multivariate analysis of variance (MANOVA). Rejection of the null hypothesis of no nest-site selection indicated that use differed from availability for at least one habitat type. If the null hypothesis was rejected, we used a paired t-test to compare each entry in  $\mathbf{p}$  to 1.0 to determine which habitat types were used differently than expected (Conner et al. 2003). When an entry in  $\mathbf{p}$  was  $< 1$ , nests were closer than expected (indicating preference), and when an entry in  $\mathbf{p}$  was  $> 1$ , nests were farther away than expected (indicating avoidance). The entries in  $\mathbf{p}$  were then used to rank the habitat types in order of preference. Significant

differences among habitat types were determined using a paired *t*-test (Conner et al. 2003). We first tested for nest-site selection using all data to examine the pattern of overall selection. We then repeated the analyses with data stratified by nest fate to test for differences between successful, abandoned and destroyed nests and stratified by year to test for annual patterns of nest-site selection.

### **Quantification of Landscape Structure and Composition**

To derive landscape composition metrics, we converted the land cover map to a gridded raster with a spatial resolution of 30 meters. We used Fragstats 3.0 (McGarigal et al. 2002) to calculate the proportion of each land cover type around each cell within a circular moving window. We used 30m as the grid cell resolution to match the spatial resolution of the Landsat satellite sensor (NASA 2008) used to derive the land cover data (FFWCU 1994). The radius of the moving window was fixed at 157m corresponding to the radius described by a circle of an area equal to the mean core summer home range of bobwhites ( $7.724 \pm 0.731$  ha, calculated as 50% Kernel density estimates of all radiolocations). Densities of linear features (road, road grade, food plots) were derived using the feature density function in ArcGIS 9.2® software. To derive landscape structure, we used a moving-window approach similar to the one used for deriving landscape composition to calculate several landscape metrics from the gridded land cover map. Metrics with similar or overlapping behaviors were selected to build redundancy in the landscape structure information. The following metrics were selected: aggregation, contagion, cohesion, interspersion and juxtaposition, percentage of like adjacencies, patch richness and Shannon's diversity (McGarigal and Marks 1995, Riitters et al. 1996, Gustafson 1998, He et al. 2000, McGarigal et al. 2002).

## **Testing for the Effect of Landscape Composition and Structure on Nest-Site Selection and Nesting Success**

Preliminary analyses revealed that the landscape metrics were highly correlated. Thus, we first conducted a principal component analysis (PCA) of landscape structure attributes, and retained 3 principal components (PCs) that cumulatively explained  $\geq 90\%$  of variation in data (Clark et al. 1999); these 3 PCs were used for all subsequent analyses. Next, we compared differences in landscape composition and structure around all nest-locations and random points using MANOVAs. Finally, we modeled the probability of nest-site selection as a function of landscape and habitat characteristics using logistic regression (Hosmer and Lemeshow 1989).

We used MANOVA to test for differences in landscape structure and composition around successful and failed nests as described previously. Logistic regression was used to test for the influence of habitat and landscape features on the probability of nesting success.

## **Results**

### **Nest Site Selection**

Of 365 nests monitored, 37.8% were located in dry prairie and 34.5% were located in pine palmetto habitats (Fig. 3-2). Distance ratios analyzed using the MANOVA procedure revealed that nesting habitat selection occurred, suggesting that some habitats were used more or less for nesting than could be expected by chance alone ( $F = 5.81, P < 0.0001$ ). Specifically, bobwhites preferred to place nests closer to food plots ( $P < 0.0001$ ) and farther away from water bodies ( $P = 0.0003$ ). Other habitat types were neither selected nor avoided (Table 3-2).

### **Effect of Habitat Composition and Structure on Nest-Site Selection**

The first three components (PC1-PC3) extracted from the principal component analysis of habitat and landscape structure variables explained 92.84% of the variation in the data. The patch

cohesion and percentage of like adjacency metrics had high positive loadings on PC1 and explained 69.4% of the variation in the data. Contagion, interspersion and juxtaposition, and patch richness metrics had high positive loadings on PC2 and explained 13.18% of the variation. The aggregation and Shannon's diversity metrics had the highest positive loadings on PC3 and explained 10.18% of the variation in the data. We interpret PC1 as an index of connectedness between different land cover types in a given patch, PC2 as an index of highly aggregated yet diverse land cover types and PC3 in a manner similar to PC2 but with increased sensitivity to rare land cover classes.

Nest sites differed significantly from random points in terms of habitat composition and landscape structure (Hotelling - Lawley trace = 0.0192,  $F = 6.94$ ,  $P < 0.0001$ ). Among landscape composition variables, density of food plots ( $F = 51.40$ ,  $P < 0.0001$ ; Fig. 3-3a), pine palmetto habitat ( $F = 4.50$ ,  $P = 0.034$ ; Fig. 3-3b), density of roads ( $F = 4.01$ ,  $P = 0.045$ ; Fig. 3-3a) and water ( $F = 5.32$ ,  $P = 0.021$ ; Fig. 3-3c) differed significantly between nest sites and random points. All landscape structure variables (PCs) differed significantly between random points and nest locations (all  $P < 0.01$ , Fig. 3-3d). The logistic regression model revealed that PC1 (an index of high interconnectedness of patches), PC2 (an index of diverse land cover types in the neighborhood of a site), density of food plots and pine palmetto habitat significantly influenced probability of nest site selection (all  $P < 0.05$ , Table 3-3).

### **Factors Influencing Nesting Success**

Only 56.99% ( $n = 365$ ) of nests we monitored were successful, and there was no obvious pattern of nesting success based on nesting habitat (Fig. 3-2). Nesting success did not differ among habitat types ( $\chi^2 = 2.274$ ,  $P = 0.685$ ), across years ( $\chi^2 = 5.46$ ,  $P = 0.362$ ) or based on burn history of habitat patches ( $\chi^2 = 3.88$ ,  $P = 0.274$ ).

Neither the habitat composition nor landscape structure variables differed significantly between successful and failed nests (Hotelling - Lawley trace = 0.0203,  $F = 0.65$ ,  $P = 0.7811$ , Figure 3-4). Furthermore, logistic regression analysis revealed that none of the habitat composition or landscape structure variables significantly influenced probability of nesting success (all  $P > 0.05$ ).

## Discussion

The widespread declines in grassland bird populations across North America over the past decades have been widely documented, and loss and degradation of breeding habitats are suggested to have contributed to these declines (Askins 1993, Herkert 1995, Peterjohn and Sauer 1999). Loss and degradation of habitat also are thought to have contributed to the range-wide declines in bobwhite populations (Brennan 1991, Dimmick et al. 2002, Sauer et al. 2004, Williams et al. 2004, Brennan and Kuvlesky 2005). An understanding of nesting habitat ecology, therefore, can help reverse the declining trends in bobwhite populations. Although bobwhite nesting ecology has been studied in parts of their range (Taylor et al. 1999, Townsend et al. 2001, Lusk et al. 2006, Ransom et al. 2008), little is known about nest-site selection, and factors influencing nest-site selection and nesting success in south Florida. Our goal was to assist efforts to reverse the bobwhite population declines in south Florida by providing data on nesting ecology and selection of nest-sites by bobwhites on Webb WMA.

We found that bobwhites on Webb WMA preferred to place nests significantly closer to food plots than would be expected by chance alone. Food plots are widely used management practices and are known to affect various aspects of bobwhite ecology (Sisson et al. 2000, Madison et al. 2000, W.E. Palmer, Tall Timbers Research Station, pers. comm. 2009). Our findings are consistent with studies that have shown that food resources do influence nest-site selection in bobwhites (e.g., Chalfoun and Martin 2007) and a number of other bird species (e.g.

pheasants Genovesi et al. 1999, bearded and griffon vultures Gavashelishvili and McGrady 2006). The fact that bobwhites in our study area preferred to nests in proximity of food plots, and also establish home ranges intersecting food plots (Singh et al., in review) suggest the fact that our study population may be experiencing food resource limitation. We speculate that strips of *Sesbania* offer provision of food and cover on the WMA where the quality of habitat is generally suboptimal. Bobwhites preferred to nest farther away from water body, most likely to avoid the possibility of nest failure due to flooding (Applegate et al. 2002).

Our results also revealed that nest sites differed significantly from random points in terms of habitat composition and landscape structure. Specifically, nest sites were more likely to be found in patches where different habitat types were highly inter-connected. Also, regions around nest locations were more likely to have a higher diversity of land cover types and better food resources (such as food plots). Our results are in agreement with those of Roseberry and Sudkamp's (1998) and White et al.'s (2005) in that landscape structural attributes influence nest-site selection. These results also are consistent with the idea that results of nest-site selection studies may depend on spatial scales (Kotliar and Wiens 1990, Orians and Wittenberger 1991, Clark et al. 1999). For example, when looking at actual location of nests, we found that bobwhites preferred to nest closer to food plots and farther away from water bodies; no other habitat was selected for or against. However, when we tested for the factors influencing nest site selection at local scales (habitat composition and landscape characteristics surrounding nest sites), it was evident and nest sites and random points differed significantly in terms of habitat composition and landscape structure variables (Table 3-2). These results have significant management implications because habitat management practices are generally implemented at

scales larger than the location of nests, and also because they demonstrate the importance of the compositional and structural diversity of habitat in nest-site selection by bobwhites.

Nesting success was generally low in our study area (56.99%). There was no difference in nesting success among habitat types or years, and none of the habitat or landscape variable we measured significantly influenced nesting success of bobwhites on the WMA. Studies investigating the effect of habitat and landscape attributes on nesting success have reported mixed results. For example Townsend et al. (2001) and Rader et al. (2007) found no evidence for the effect of nest site habitat attributes on nesting success, but Lusk et al. (2006) and Taylor et al. (1999) found that nests built under higher canopies and more shrub cover were more successful. Chalfoun et al. (2007) have recently shown that, at the landscape scale, food availability may influence nesting success. The lack of evidence for the influence of habitat and landscape features on nesting success is suggestive of the fact that random nest predation by meso-mammalian predators may be important in our study area, but we do not currently have conclusive evidence for it. We believe that nest fate in our study area is a more complex phenomenon that needs data beyond landscape attributes, and at multiple spatial scales.

Table 3-1. Description of habitat types represented and area occupied by each habitat type in Babcock-Webb Wildlife Management Area, Florida

| Habitat <sup>a</sup> |      | Description   | Area (ha) | %Area  |
|----------------------|------|---|-----------|--------|
| Dry Prairie          | (DP) | Herbaceous and low shrub communities on seldom flooded, sandy soil areas very similar to pine- palmetto, differing from them mainly by their lack of pines and sparse palmetto. Utilized by quail throughout the year for nesting, brood-rearing, and roosting.   | 9736.96   | 36.308 |
| Pine- Palmetto       | (PP) | Open stands of slash pine ( <i>Pinus caribaea</i> ) on poorly drained soils, with an understory of saw palmetto ( <i>Serenoa repens</i> ), wire grass ( <i>Aristida stricta</i> ), broomsedge ( <i>Andropogon spp.</i> ) and other grasses. Various panic grasses ( <i>Panicum spp.</i> ), slough grass ( <i>Scleria setacea</i> ), and dwarf wax myrtle ( <i>Cerothamnus pumilus</i> ) are used by quail for feeding and/or nesting. | 9145.19   | 34.101 |
| Wetland prairie      | (WH) | Herbaceous communities on low seasonally flooded transitional areas between permanent wetlands and drier communities. Important to quail primarily because of the abundant slough grass. Use is limited when they are flooded but commonly utilized when wet but not flooded.   | 7046.93   | 26.277 |
| Odd Area             | (OA) | Buildings and other human use areas not generally considered quail habitat.   | 508.09    | 1.895  |
| Water                | (WA) | Permanent ponds, natural and man-made, surrounded by emergent aquatic plants.   | 192.35    | 0.717  |
| Food Plot            | (FP) | Continuous serpentine stands of <i>Sesbania sp.</i> , an erect legume approximating 2-3 m in height. Width of the food plots is about 7 m. Ground cover beneath the plants is generally open and sandy.   | 151.21    | 0.564  |
| Road Grade           | (RG) | Roads prepared by grading to create a surface approximately 1+ m above the surrounding habitat.   | 18.75     | 0.07   |
| Road                 | (RD) | Field roads not elevated above the surrounding surface  | 18.42     | 0.069  |
| TOTAL                |      |   | 26817.90  | 100.00 |

<sup>a</sup> Description of habitat types adopted from Frye (1954), with modifications.

Table 3-2. Results of t-tests following MANOVA analyses testing for nest-site selection. The *t*-tests test for differences between the vector of ratios of the average distances of random points and distances of nest-sites to each habitat type and a vector of 1s. Values of *t*-statistic and associated *P* values are presented. Negative *t*-statistics indicate that nest sites were found closer to the corresponding habitat type (in rows) than by chance, the magnitude of *t*-statistics signifies the strength of the association. Non-significant *P*-values indicate the vector of ratios was not significantly different from a vector of 1s (no evidence of preference/avoidance). Significant *P* values are shown in bold typeface.

| Habitat <sup>a</sup> | t     | P      | Rank |
|----------------------|-------|--------|------|
| DP                   | -0.41 | 0.679  | 4    |
| FP                   | -5.73 | <.0001 | 1    |
| OA                   | 1.72  | 0.086  | 7    |
| PP                   | 1.52  | 0.129  | 6    |
| RD                   | -1.91 | 0.057  | 2    |
| RG                   | -0.29 | 0.769  | 5    |
| WA                   | 3.66  | 0.0003 | 8    |
| WH                   | -0.93 | 0.354  | 3    |

<sup>a</sup>DP = Dry Prairie, FP = Food Plot, OA = Odd Area, PP = Pine Palmetto, RD = Road, RG = Road Grade, WA = Water, WH = Wetland prairie

Table 3-3. Results of logistic regression analysis testing for the influence of habitat composition and landscape structure on nest-site selection.

|                                    | $\beta$ | S.E.   | $\chi^2$ | P      |
|------------------------------------|---------|--------|----------|--------|
| Intercept                          | 2.583   | 0.095  | 741.693  | <.0001 |
| Principal component 1              | 0.076   | 0.028  | 7.310    | 0.0069 |
| Principal component 2              | -0.237  | 0.068  | 12.300   | 0.0005 |
| Food plot density                  | -37.136 | 10.542 | 12.407   | 0.0004 |
| Percentage landscape pine palmetto | -0.005  | 0.002  | 5.129    | 0.0235 |
| Percentage landscape water         | 0.268   | 0.141  | 3.589    | 0.0582 |

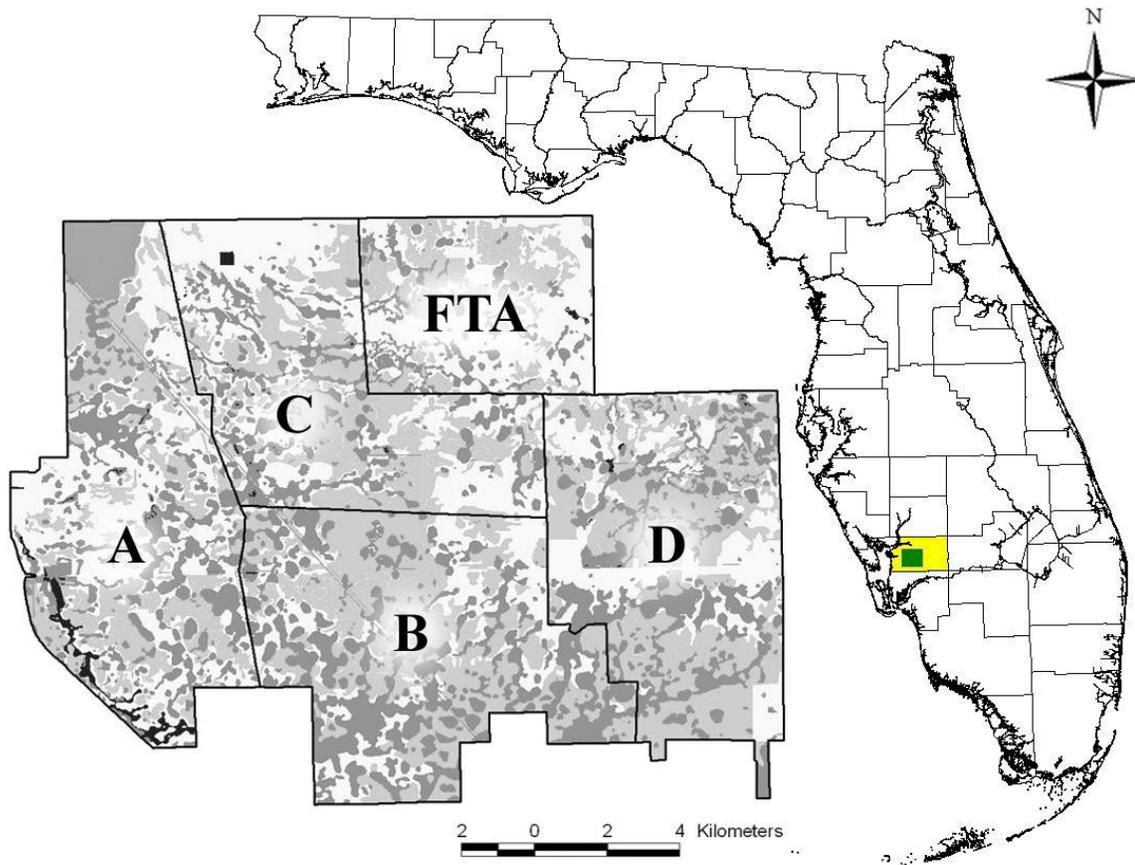


Figure 3-1. Location of the Webb-Babcock Wildlife Management Area in Charlotte County, south Florida. Five management zones are indicated by bold, upper case letters.

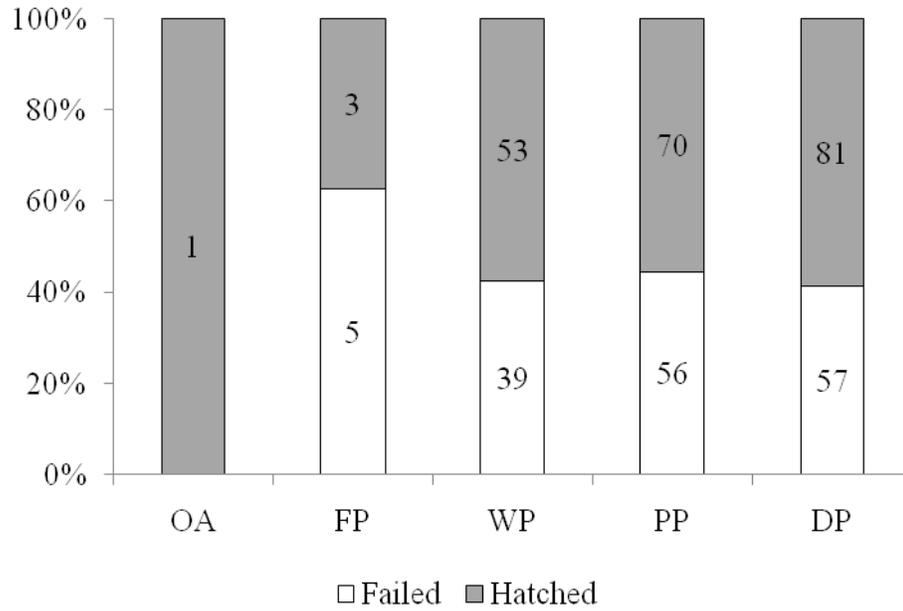


Figure 3-2. Number of nests found in various land cover types arranged in ascending order stratified by nest fate. Habitat type codes are: DP: Dry prairie, FP = Food plot, OA = Odd area, PP = Pine palmetto, WP = Wetland prairie. No nests were found in road, road grade or water.

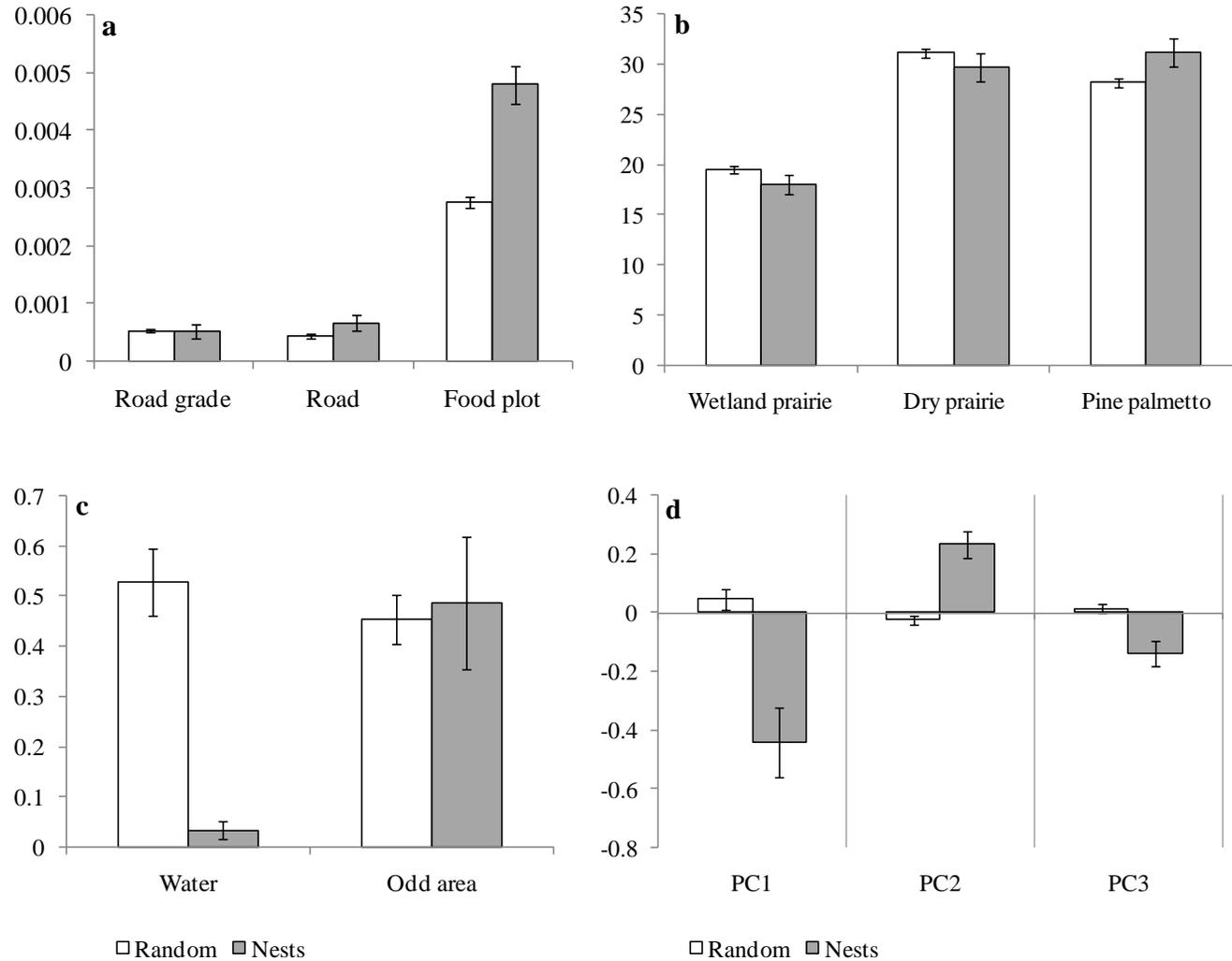


Figure 3-3. Comparison of habitat composition and landscape structure around random points and nest locations (means  $\pm$ 1 SE). A) Differences in linear feature density (road, road-grade, and food plots, calculated within a 157 m window), B and C) Means of percentage land cover, D) means of standardized principal component scores for PCs 1, 2 and 3

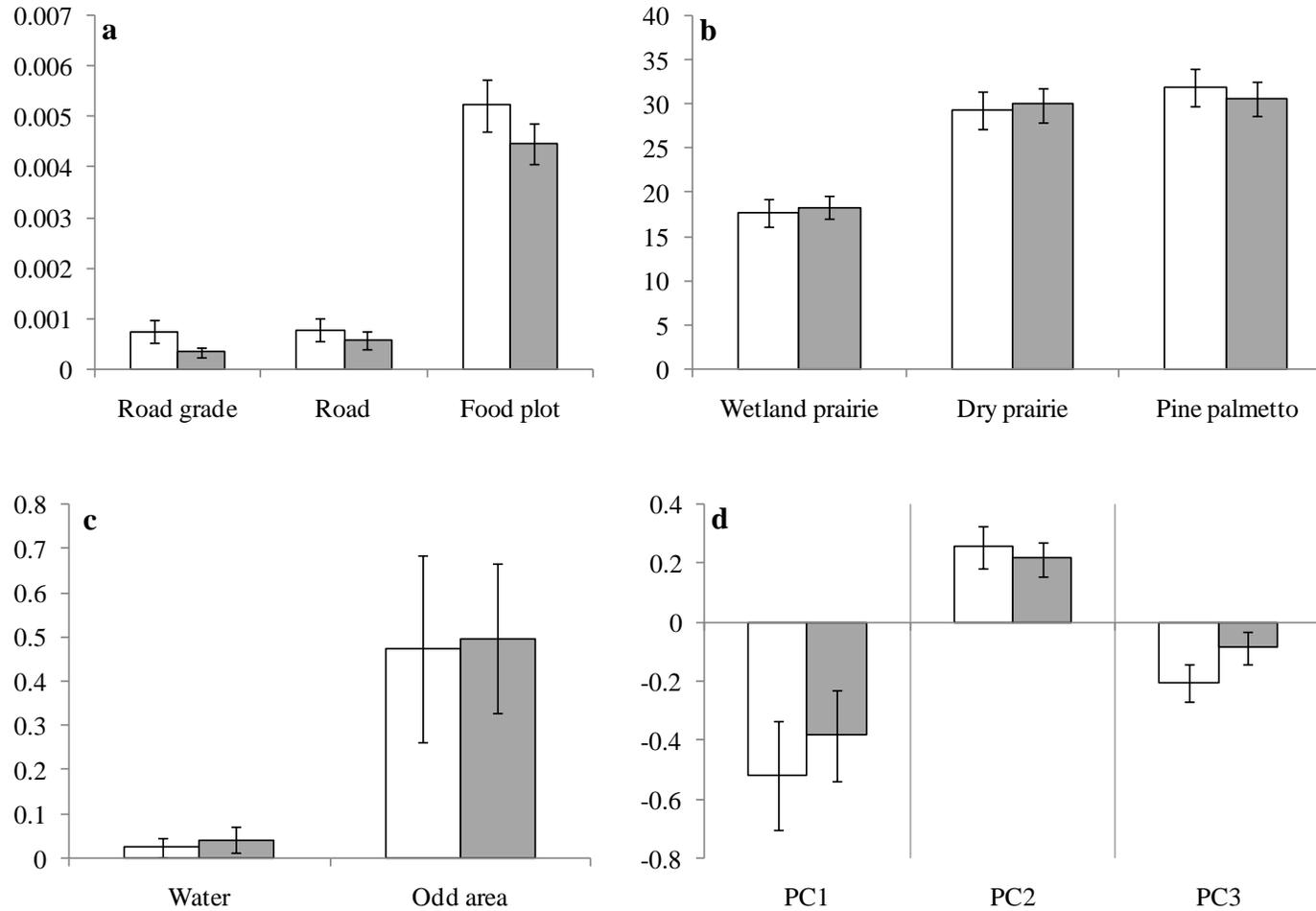


Figure 3-4. Comparison of habitat composition and landscape structure around successful and failed nests (means  $\pm$ 1 SE). A) Differences in linear feature density (road, road-grade, and food plots, calculated within a 157 m window), B and C) Means of percentage land cover, D) means of standardized principal component scores for PCs 1, 2 and 3

## CHAPTER 4 CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

During the period of this study the bobwhite population on the majority of the Babcock-Webb WMA existed at a very low density in contrast with many other managed habitats across the species' range (Dimmick et al. in press). The population reached this very low density following several decades of decline from its zenith in the 1970's when annual harvests often exceeded 5000 birds per year (Florida Fish and Wildlife Conservation Commission, unpublished data). The population decline almost surely reflected deterioration in the quality of the habitat, and this deterioration may have been facilitated by various changes in management practices as well as other activities occurring on the area or its perimeter. It is also possible that the population has been over-harvested, particularly during recent years when legal harvest removed birds at a rate believed to be unsustainable (Dimmick et al. in press). Efforts to reverse the downward spiral in the bobwhite population are currently underway. In this thesis, I examined several aspects of the spatial ecology of bobwhite quail at the Babcock-Webb WMA in South Florida. I estimated space use and habitat and nest-site selection by bobwhites and investigated the influence of landscape composition and structure on bobwhite nesting success. My goal was to assist managers reverse the bobwhite population declines in south Florida by providing data on the habitat ecology and nesting ecology of bobwhites on the Babcock-Webb WMA.

### **Conclusions**

Literature review suggests that bobwhites typically occupy small home ranges, ranging from approximately 5ha in excellent habitat to 40 ha in good habitat (Wiseman and Lewis 1981, Sisson et al. 2000; Bell et al. 1985, Dixon et al. 1996, Guthery et al. 2004b, Haines et al. 2004, Terhune et al. 2006). The mean annual home range size in the Babcock-Webb WMA was 88.43 ± 6.16 ha, which is substantially larger than most previously reported bobwhite home ranges.

Extremely large bobwhite home ranges observed in this study most likely reflects that some component of the habitat is poor on the WMA. Annual home ranges were generally smaller for birds whose ranges contained food plots compared to those that did not. The fact that there were few home ranges that did not intersect food plots is itself an indication that food plots markedly influenced the habitat chosen by bobwhites on the WMA. Furthermore, food plots significantly contributed to reduction in size of winter, but not summer, home ranges.

Bobwhites on Webb WMA preferred to place nests closer to food plots than would be expected by chance alone. The fact that bobwhites in the study area preferred to nests in proximity of food plots, and also establish home ranges intersecting food plots suggest that the bobwhite population on the Webb WMA may be experiencing food resource limitation. I speculate that strips of *Sesbania* offer provision of food and cover on the WMA where the quality of habitat is generally suboptimal.

The results revealed that nest sites were more likely to be found in habitat patches where habitat diversity was high and different habitat types were highly inter-connected. These results also suggest that results of nest-site selection studies may depend on spatial scales (Kotliar and Wiens 1990, Orians and Wittenberger 1991, Clark et al. 1999). For example, when looking at actual location of nests, I found that bobwhites preferred to nest closer to food plots and farther away from water bodies. However, when testing for factors influencing nest site selection at scales surrounding nest sites, it was evident that nest sites and random points differed significantly in terms of habitat composition and landscape structure.

Nesting success was generally low in the study area (56.99%). There was no difference in nesting success among habitat types or years, and none of the habitat or landscape variable I measured significantly influenced nesting success of bobwhites on the WMA. The lack of

evidence for the influence of habitat and landscape features on nesting success is suggestive of the fact that random nest predation by meso-mammalian predators may be important in our study area, but we do not currently have conclusive evidence for it. I believe that nest fate in our study area is a more complex phenomenon that needs data beyond landscape attributes, and at multiple spatial scales.

### **Management Recommendations**

Bobwhites in our study site had substantially larger home ranges compared to those in other parts of their range. If larger home ranges are indicative of lower habitat quality, as is typically assumed, the quality of habitat in our study site in south Florida may be considered suboptimal, most likely due to limited abundance of food resources. There may be other habitat issues but food resources are clearly identified as an important factor by the data reported here. This is supported by the observation that bobwhites whose ranges contained food plots had substantially smaller home ranges compared to those that did not, and that bobwhites exhibited a strong preference for food plots. Management practices that will lead to an increase in quantity and quality of food (e.g., through fertilization and rejuvenation) interspersed within well-managed dry prairie and pine palmetto habitats will most likely have a positive impact on bobwhite populations in south Florida. This strategy would help release the bobwhite population from food limitations, while avoiding potential negative effects of highly localized feeders (e.g. Frye 1954, Oberheu and Dabbert 2001).

As the study site is located near the southern edge of the bobwhites' geographic range, and there are indications of food resource limitation, it is not surprising that bobwhites generally established home ranges intersecting food plots, and preferred to place nests closer to food plots. Furthermore, the results point to the importance of a compositionally and structurally diverse habitat that can provide a diversity of food and cover resources throughout the year. Thus,

management practices aimed at increasing quantity and quality of food plots (e.g., through fertilization and rejuvenation) interspersed within well-managed pine palmetto and other habitats that offer adequate food and cover will most likely have a positive impact on bobwhite population in South Florida. Guthery (1997) suggested that the goal of habitat management should be to maximize the proportion of landscape usable by bobwhites through time. Creation and maintenance of early successional native plant communities and augmentation of food and cover through food plots could contribute substantially to bobwhite population recovery in south Florida.

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