Does nest-site selection influence bobwhite nesting success in south Florida?

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Abstract

Context. Nest-site selection can influence nesting success, and thus population dynamics, of many species of ground-nesting birds. Despite the economic importance as a game species, populations of northern bobwhites have been declining throughout the southern United States. This paper reports the nesting ecology of northern bobwhites (*Colinus virginianus*) on Babcock-Webb Wildlife Management Area, Florida, USA, and illustrates the influence of landscape composition and structure on bobwhite nest-site selection and nest fate.

Aim. To investigate nest-site selection by bobwhites, to evaluate the influence of landscape composition and structure on nest-site selection, and to identify factors influencing nesting success.

Methods. We used distance-based habitat-selection methods and logistic regression to test for nest-site selection and to investigate the influence of landscape characteristics on nesting success.

Key results. Bobwhites preferred to establish nests closer to food plots and farther away from water bodies than expected; other habitats were neither preferred nor avoided. Nesting success did not vary across years, differ among habitats or among burn treatments, and none of the habitat and landscape variables we measured significantly influenced the probability that a nest would be successful.

Conclusions. Bobwhites preferred to place nests closer to food plots. However, habitat features of nest sites did not influence bobwhite nesting success. These results may indicate that random nest predation by meso-mammalian predators may currently determine fates of bobwhite nests in south Florida, or that population density is low enough that only suitable nesting sites are occupied.

Implications. Our results suggest that increasing the density of linear food plots, and maintaining a structurally diverse pine–palmetto and dry prairie habitat that provides adequate nesting cover could contribute to augmenting bobwhite nesting habitat.

Additional keywords: bobwhite reproductive biology, *Colinus virginianus*, Florida, nesting habitat, nesting success, nest-site selection, northern bobwhites.

Introduction

Reproductive success in many species of birds is heavily influenced by nest-site selection (Martin 1993*a*, 1995; Flaspohler *et al.* 2001). 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*b*; Lusk *et al.* 2006; Barea 2008). Although protection from predators and from weather elements is crucial for the reproductive success of all avian species, it is particularly crucial for ground-nesting birds such as the northern bobwhite (*Colinus virginianus*), characterised 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).

The declines in grassland bird populations across North America over the recent 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). 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 1970s, and it has been suggested that overharvest, habitat degradation and loss of brood-rearing habitat may have contributed to these declines (Brennan 1991; Dimmick *et al.* 2002; Sauer *et al.* 2004; Williams *et al.* 2004; Brennan and Kuvlesky 2005). As an important part of the quail recovery strategy, the Northern Bobwhite Conservation Initiative has recommended increasing the quantity and quality of nesting and brood-rearing habitats (Dimmick *et al.* 2002). Although bobwhite nesting ecology has been studied in parts of their range (Taylor *et al.* 1999*a*; Townsend *et al.* 2001; Lusk *et al.* 2006; Ransom *et al.* 2008), little is known about whether bobwhite select nest sites and factors influencing nest-site selection and nesting success in south Florida ranchlands. Our goal was to investigate the nesting ecology of bobwhites on the WMA. Specifically, our objectives were (1) to test for the selection of nesting habitat by bobwhites, and (2) to investigate habitat characteristics that influenced nesting success.

Materials and methods

Study area

The study was conducted on the Babcock-Webb WMA in Charlotte County, Florida, situated ~8 km east of the town of Punta Gorda (Fig. 1). The WMA comprises 26 818 ha, encompassing three major and four minor types of habitat (Table 1). The predominant plant communities included dry prairie (9737 ha), pine–palmetto (9145 ha) and wet prairie (7047 ha). During the last two decades, 3-m-wide *Sesbania* sp. food plots have been planted in concentrated areas throughout the WMA. These strips comprise 0.56% (151 ha) of the area and are rejuvenated and fertilised on an annual basis. Descriptions of types of habitat follow those of Frye (1954). Prescribed burns are typically carried out during the dormant season (1 October–31 March), and about half of the study site is burnt annually.

Topography of the WMA 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 centimetres may cover more than 50% of the surface for several days. Both of these weather extremes likely affect bobwhite nest-site selection and nesting success.

Trapping and radio-telemetry

We captured bobwhites during all months of the year from October 2002 through March 2007. We used baited funnel traps during the breeding and non-breeding seasons to capture both male and female bobwhites; however, in the breeding season we also 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 made on tape-players capable of playing a continuous loop of calls. Cast nets ~3 m in diameter were used to capture birds throughout the year. During daylight hours birds were located by radio-telemetry and cast nets were used to capture associated unmarked birds. At night we located radio-tagged birds on their roost and captured them and their associated covey mates with the cast net. We searched for individual radio-tagged birds at 3–5-day intervals using hand-held receivers and Yagi antennas. The location of each radio-tagged bird was established using the homing procedure (the signal was followed until the bird was first observed) and the bird's position was logged into a GPS unit.
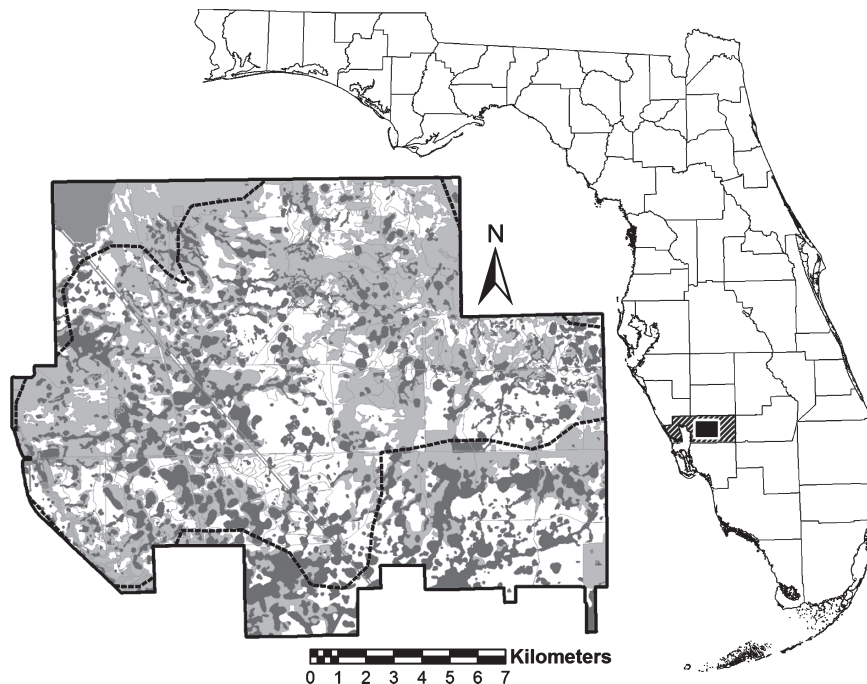

Fig. 1.   Location of the Webb-Babcock Wildlife Management Area in Charlotte County, south Florida, USA. A schematic map showing the configuration of different habitat types is presented overlaid with a 95% kernel density polygon encompassing nest locations.

Table 1. Description, area occupied, and percentage of habitats represented in Babcock-Webb Wildlife Management Area, Florida

Percentage of the habitats represented in a 95% kernel density polygon encompassing all nest sites are shown in parentheses. Descriptions of habitat types are modified from Frye (1954)

Habitat		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. Utilised by quail throughout the year for nesting, brood-rearing, and roosting.	9736.96	36.33 (37.87)
Pine–palmetto	PP	Open stands of slash pine (*Pinus caribaea*) on poorly drained soils, with an understorey of saw palmetto (*Serenoa repens*), wire grass (*Aristida stricta*), broomsedge (*Andropogon* spp.) and other grasses. Various panic grasses (*Panicum* spp.), slough grass (*Scleria setacea*), and dwarf wax myrtle (*Cerothanmus pumilus*) are used by quail for feeding and/or nesting.	9145.19	34.12 (35.37)
Wetland 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 utilised when wet but not flooded.	7046.93	26.30 (24.44)
Odd area	OA	Buildings and other human-use areas not generally considered quail habitat.	508.09	1.90 (0.56)
Water	WA	Permanent ponds, natural and man-made, surrounded by emergent aquatic plants.	192.35	0.72 (0.85)
Food plot	FP	Continuous serpentine stands of *Sesbania* sp., an erect legume ~2–3 m in height. Width of the food plots is ~7 m. Ground cover beneath the plants is generally open and sandy.	151.21	0.56 (0.77)
Road grade	RG	Roads prepared by grading to create a surface ~1 m above the surrounding habitat.	18.75	0.07 (0.08)
Total			26 799.5	100.00

All trapping and handling protocols were approved by the University of Florida Institutional Animal Care and Use Committee (Protocol number A-794).

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 each year. If a bobwhite of either sex was located in the same area for more than two successive visits during the nesting season, the area was searched thoroughly for possible nests. On locating a nest, we noted habitat characteristics (e.g. vegetation type, burn history derived from prescribed burn logs), and recorded GPS coordinates. We checked each nest at least every third day from the time it was located until its fate was identified. We categorised the fate of nests into three discrete categories: hatched (successful), destroyed, or abandoned. We considered a nest 'hatched' when we found a distinctive 'hatching cap' cut from the blunt end of an egg. Destroyed nests had either no eggs left in them or there was evidence of crushed eggs in and around the nest's vicinity. On some occasions adults would leave a nest during egg laying or incubation and not return. Such nests were considered abandoned, and produced no chicks. Locations of all nest sites were entered in a geographical information system (GIS) following Florida Geographic Data Library (FGDL) GIS metadata standards.

Statistical analysis

Two broad categories of analysis were conducted. We used the distance-based method of Conner *et al.* (2003) to test for selection of habitat for nest placement. We selected this method because two out of seven of our habitats (food plots and road-grade) were essentially linear features, and this precluded use of methods that require area-based estimates of habitat availability (e.g. compositional analysis: Aebischer *et al.*

1993). Further, the method has been applied in a wide variety of contexts (Parra 2006; Xu *et al.* 2007; Elfström *et al.* 2008; Riedle *et al.* 2008) and inferences based on the distance-based analysis are more robust than classification-based methods with respect to habitat misclassifications (Bingham and Brennan 2004). Following the distance-based approach, we tested the hypothesis that habitats were used for nesting in proportion to their availabilities by comparing distances of nest-locations to each habitat with the expected distance to that habitat type (Conner *et al.* 2003, 2005; Perkins and Conner 2004). Use locations were the actual locations of nests. 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, which corresponded to the density of radio-locations within the core summer home range of bobwhites.

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 type of habitat (**r**), which represented expected values of distances under the null hypothesis of no habitat selection (Conner *et al.* 2003). We also created a vector of use (**u**) where entries in **u** represented distances from nest sites to each type of habitat. A vector of ratios (**d**) was created by dividing each entry in **u** by the mean of the vector **r** of the corresponding habitat type. Entries equaling 1.0 in **d** indicated that habitat use equaled habitat availability for a given type of habitat. These ratios were averaged over all nest sites to produce a vector **ρ**. The null hypothesis that **ρ** is not significantly different from a vector of 1's was tested using multivariate analysis of variance (MANOVA) and rejected if use differed from availability for at least one type of habitat. If the null hypothesis were rejected, we used a paired *t*-test to compare each entry in **ρ** to 1.0 to determine

which type of habitat was used differently than expected (Conner *et al.* 2003). Thus, for each habitat type the appropriate entry in **ρ** was paired with 1.0. When an entry in **ρ** was <1, nests were closer than expected (indicating selection), and when an entry in **ρ** was >1, nests were farther away than expected (indicating avoidance). The entries in **ρ** were then used to rank the habitat types in order of preference. Significant differences among habitat types were determined using a paired *t*-test such that each habitat type was paired with all other habitat types (Conner *et al.* 2003).

Quantification of landscape composition and structure

To derive landscape composition metrics, we converted the habitat map to a gridded raster with a spatial resolution of 30 m. We used 30 m as the grid cell resolution to match the spatial resolution of the Landsat Enhanced Thematic Mapper (ETM+) satellite sensor (NASA 2008) used to derive the habitat data (FFWCU 1994). We used Fragstats 3.0 (McGarigal *et al.* 2002) to calculate the proportion of each habitat type within a 157-m window around each cell, which corresponded to the radius described by a circle of an area equal to the mean 50% Kernel density home range of summer radio-locations of each bird (7.72 ± 0.73 ha: Singh 2009). Densities of linear features (roads, road grade, food plots) were derived using the feature density function in ArcGIS 9.2® software (Environmental Systems Research Institute Inc., Redlands, CA, USA). Elevation above mean sea level for all locations was extracted from the National elevation dataset (Gesch *et al.* 2009). In addition to landscape composition, we calculated edge density (the length of edge between any two habitat types in a 157-m moving window recorded as linear $km\ km^{-2}$) using Fragstats 3.0. Fenske-Crawford and Niemi (1997) investigated predation of artificial ground nests placed in medium-to-old forests at various distances to hard (regenerating forest, vegetation height <2 m) and soft (young forest, vegetation height 2–8 m) forest edges. They found that nest predation was higher when nearer to 'soft' than 'hard' edges, indicating that nesting success may depend on proximal types of habitat in addition to the type of habitat in which the nest was situated and distance from the edge thereof. We tested for differences in habitat composition (in terms of percentage of types of habitat and linear feature density within a 7.72-ha area around a nest site) and structure (in terms of edge density) between nest sites and random locations using two-sample *t*-tests.

Nest success

We hypothesised that nest success varied across years due to weather conditions, habitat features (including food and cover around a nest site), and burn history of the patch where the nest was located. To this effect, we modelled the probability of a nest successfully hatching at least one egg (nest success) as a function of eight variables using logistic regression; we considered main effects and two-way interactions between all variables (Hosmer and Lemeshow 1989). The variables included year (2000–07), burn treatment of the block in the previous year (1, not burned; 2, block burned but immediate nest location not burned; and 3, nest site burned), and type of habitat in which the nest was located as categorical variables. Factors representing food and cover availability (density of food plots, extent of dry prairie and palmetto habitat), flooding risk (elevation and distance to water)

and predation risk (edge density) were included as continuous variables. We used the stepwise variable selection procedure (*slentry* = 0.1, *slstay* = 0.15) to select the most parsimonious model.

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. 2). Distance ratios analysed using the MANOVA procedure revealed that nesting habitat selection occurred ($F = 5.81$, $P < 0.0001$). Overall, bobwhites preferred to place nests closer to food plots ($t = 0.41$, $P < 0.0001$) and farther away from water bodies ($t = 3.66$, $P = 0.0003$) than expected by chance. Although nests were found closer to roads and farther away from man-made
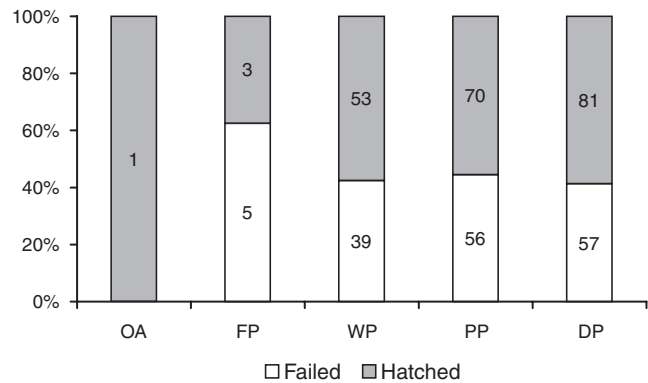
Fig. 2. Number of nests found in various types of habitat arranged in ascending order and stratified by nest fate. Habitat codes are: DP, dry prairie; FP, food plot; OA, odd area; PP, pine–palmetto; WP, wetland prairie. No nests were found in road grade or water.

Table 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 that 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

Vegetation type	Overall ($n = 365$)		
	t	*P*	Rank
Dry prairie	–0.41	0.679	4
Food plot	**–5.73**	**<0.0001**	**1**
Odd area[A]	1.72	0.086	7
Pine palmetto	1.52	0.129	6
Road	–1.91	0.057	2
Road grade	–0.29	0.769	5
Water	**3.66**	**<0.0001**	**8**
Wetland prairie	–0.93	0.354	3

[A]Area comprising buildings and parking lots, presumed non-habitat for bobwhites.

structures (such as parking lots, buildings; 'odd areas' in Table 1), the effect was only weakly significant ($P = 0.057$ and $P = 0.086$, respectively) (Table 2). Other habitat types were neither selected for nor avoided (all $P > 0.05$) (Table 2, Fig. 3*a*).

Two-sample *t*-tests comparing the proportion of habitat types, linear feature densities, elevation and edge density between nest sites and random locations revealed that the area around nest sites had a higher proportion of pine–palmetto habitat ($t = 4.50$, $P = 0.0340$) and a lower proportion of water bodies ($t = 5.32$, $P = 0.0211$) (Fig. 4*a*) in the area than would be expected by chance. Nest sites were located in areas of higher food plot density ($t = 51.40$, $P < 0.0001$) and road density ($t = 4.01$, $P = 0.0452$) (Fig. 5*a*) than random locations. Nest sites were found on significantly higher elevations than random locations (difference = 0.35 m, $t = 8.15$, $P = 0.0043$). Nest sites were located

in areas of higher edge density than were random locations (difference = 21.27 m m^{-2}, $t = 5.63$, $P < 0.0001$).

Nesting success

Of 365 nests we monitored, broods hatched successfully from only 57%. Logistic regression analysis revealed that none of the variables we measured were associated with the probability that a nest would be successful (all $P > 0.05$).

Discussion

We found that bobwhites on Webb WMA preferred to establish nests significantly closer to food plots than would be expected by chance alone. Creation of food plots is a widely used management practice, which is known to affect various aspects of bobwhite ecology (e.g. home-range size and survival: Sisson *et al.* 2000;
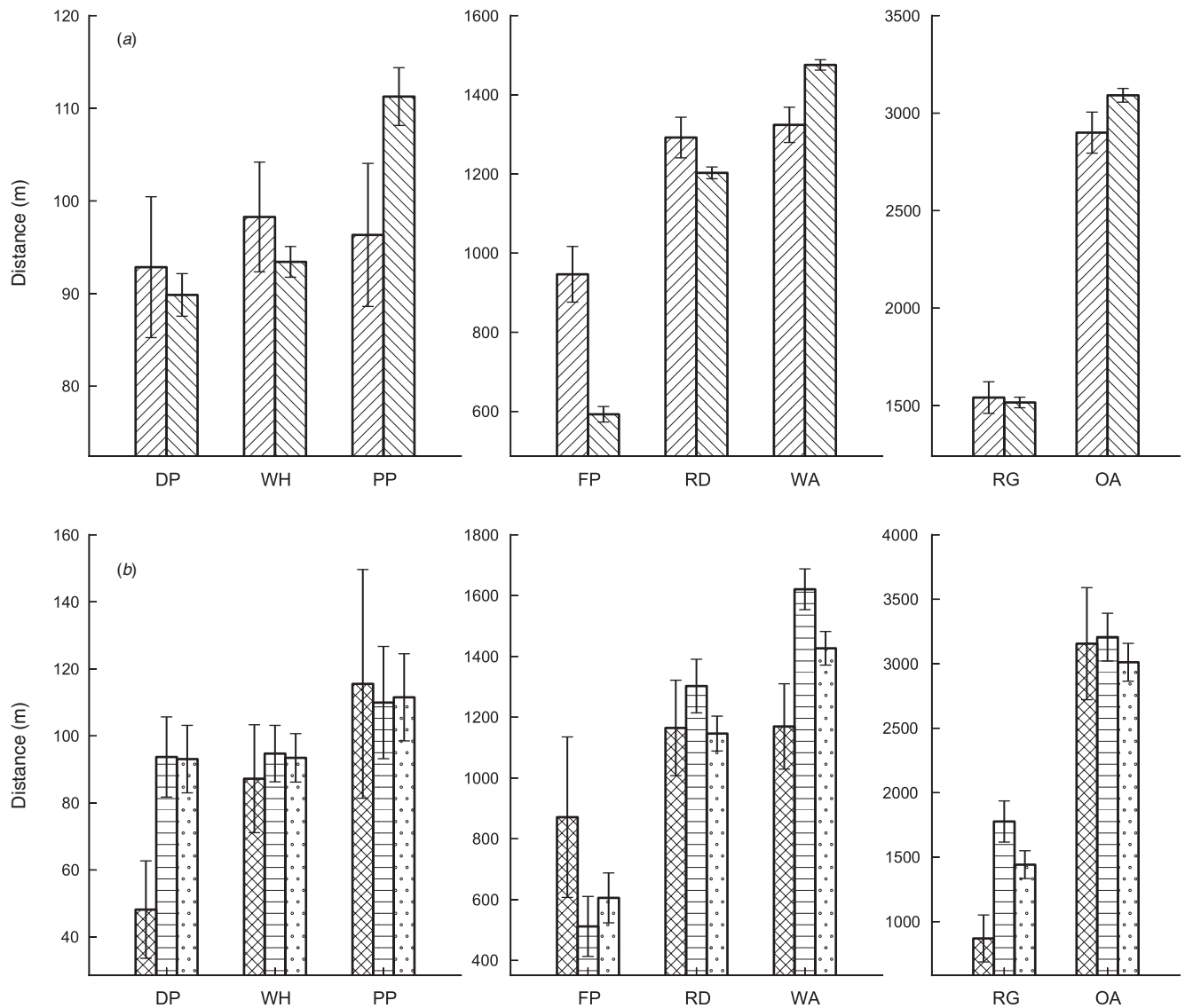

Fig. 3. Comparison of distances of habitat types to: (*a*) random points and nests, and (*b*) abandoned, destroyed and hatched (successful) nests. Means (in metres) are presented with ±1 standard error bars. Land cover type codes are: DP, dry prairie; WH, wetland hammock; PP, pine–palmetto; FP, food plots; RD, roads; WA, water; RG, road grade; OA, odd areas. Note different *y*-axis scales.
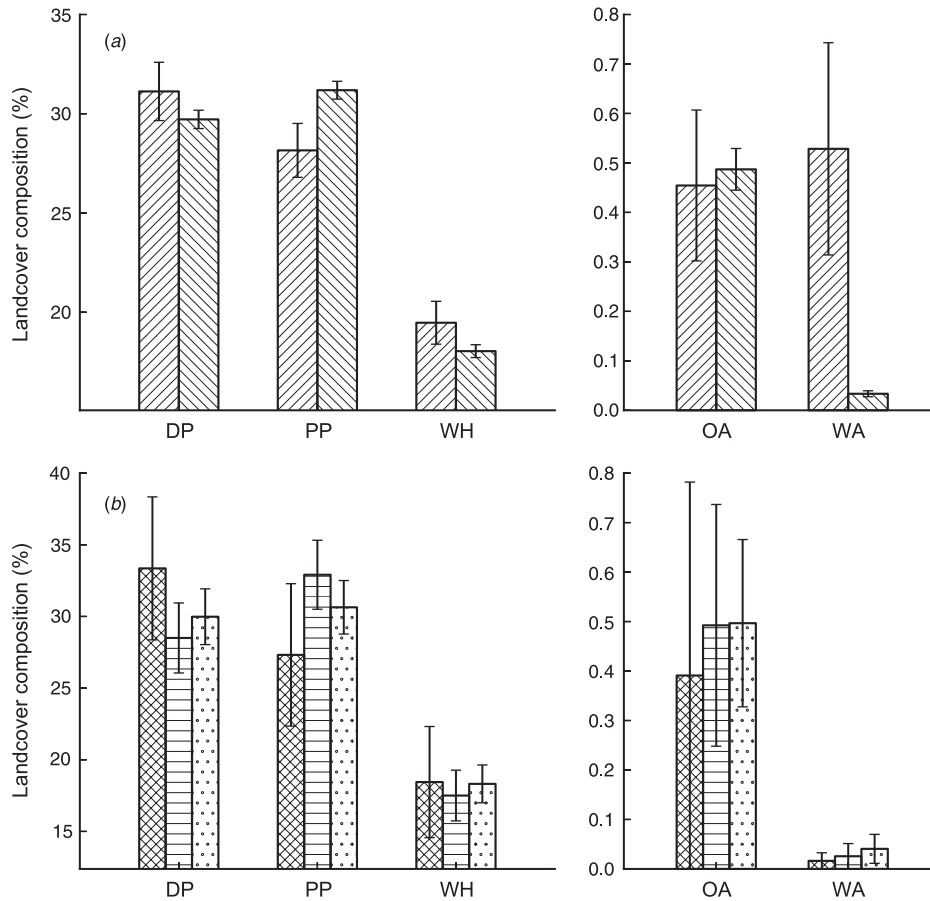
Fig. 4. Comparison of percentage land cover composition between: (*a*) random points and nests, and (*b*) abandoned, destroyed and hatched (successful) nests. Means (in percentage points) are presented with ±1 standard error bars. Land cover type codes are: DP, dry prairie; WH, wetland hammock; PP, pine–palmetto; WA, water; OA, odd areas. Note different *y*-axis scales.

hunting mortality and overwinter survival: Madison *et al.* 2002). The food plots on the Webb WMA have been laid out in a largely linear configuration and one food plot may intersect multiple types of habitat, creating a variety of edge habitats. Although several studies have reported that food resources influence nest-site selection in number of bird species (e.g. pheasants: Genovesi *et al.* 1999; bearded and griffon vultures: Gavashelishvili and McGrady 2006), results from bobwhites studies are ambiguous (e.g. Guthery 1997). Bobwhites in our study area preferred to nest near food plots, and preferred to establish home ranges intersecting food plots (Singh *et al.* in press). It is possible that bobwhites establish nests near food plots and areas of high edge density because these areas provide good brood habitat and higher insect abundance; however, direct support for this hypothesis is not available. The precise mechanism by which food plots influence selection of nest sites therefore remains unclear. It was also found that bobwhites preferred to nest farther away from water bodies, likely to avoid the possibility of nest failure due to flooding (Applegate *et al.* 2002).

Our results also reveal that bobwhites select nest sites on the basis of habitat composition and landscape characteristics surrounding nest sites out to ~150 m. When comparing the habitat

features surrounding bobwhite nests to random locations, our results indicate the preference of quail to place nests in areas characterised by a higher proportion of pine–palmetto habitat intermeshed with a network of food plots. Our results broadly agree with those of Roseberry and Sudkamp (1998) and White *et al.* (2005) in that landscape structural attributes influence nest-site selection.

Nest success in our study area was 57%, which is comparable to estimates from other areas (Dimmick 1974; Suchy and Munkel 1993; Burger *et al.* 1995; Palmer *et al.* 1998; Taylor *et al.* 1999*b*; Cox *et al.* 2005; Hernández *et al.* 2005; Lusk *et al.* 2006; Terhune *et al.* 2006). There was no difference in nesting success among types of habitat or years, and none of the habitat or landscape variables we measured significantly influenced nest success of bobwhites on the WMA. Studies investigating the effect of habitat and landcape attributes on nesting success have reported mixed results. For example, Townsend *et al.* (2001) and Rader *et al.* (2007) found no evidence that specific attributes of nesting habitat influenced nesting success, but Lusk *et al.* (2006) and Taylor *et al.* (1999*a*) found that nests built by bobwhites under higher canopies and more shrub cover were more successful. Chalfoun and Martin (2007) have recently shown that for a
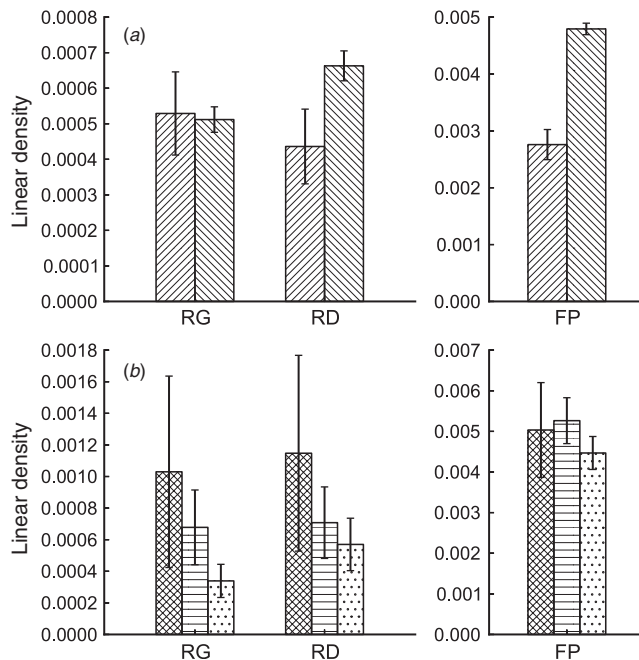
Fig. 5. Comparison of linear feature densities within a 157-m radius between: (*a*) random points and nests, and (*b*) abandoned, destroyed and hatched (successful) nests. Means (in $m\,m^{-2}$) are presented with ± 1 standard error bars. Linear feature codes are: FP, food plots; RD, roads; RG, road grade. Note different *y*-axis scales.

prairie nesting bird, the Brewer's seaside sparrow, food availability may influence nesting success at the landscape, territory and nest patch scales. Nest predation by predators may be important in our study area, or metrics other than those we evaluated could be influencing predation. It is also possible that, in our study area, population density is low enough that only suitable nesting sites are occupied; consequently, there was little spatial variation in nesting success.

Acknowledgements

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