RESPONSE OF NORTHERN BOBWHITES

TO MANAGED FOREST

LANDSCAPES

By

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Abstract: My objectives were to obtain descriptive data on habitat selection, home ranges, movements, and cause specific mortality of northern bobwhites (*Colinus virginianus*) in forests intensively managed for the endangered red-cockaded woodpecker (*Picoides borealis*). Bobwhites were monitored using radio telemetry during 2000–2003. In addition, I obtained data on over- and understory vegetation characteristics in control and treated pine plantations and riparian areas. Soil temperature readings and habitat variables were collected in 7 habitat types to determine stand and exposure effects on ground-surface temperatures and to what degree plant community attributes affected ground-surface temperatures during summer. I compared available space using all radiolocations during the study to usable space inferred from use-availability data. I used habitat selection results to determine if a range of habitat types was suitable for bobwhites. Mean (± SE) home range estimates for the breeding season were 60.4 ± 11.8 ha for males (n = 31) and 48.0 ± 11.7 ha for females (n = 6). Covey season home ranges (sexes pooled) averaged 52.6 ± 11.4 ha (n = 12). Bobwhites selected a range of understory structures, stand types, and basal areas with apparent selection for wildlife stand improvement treatments 1–3 years post-burn. Usable space averaged 38.6 ± 4.7% SE of available space for data averaged over seasons and years. Percent frequencies for soil surface temperatures showed hyperthermic temperatures were present; however, no large-scale areas were thermally intolerable. My results supported the hypothesis (slack) that a variety of habitat types and configurations may be equally valuable for bobwhites.
Key words: Arkansas, bobwhite, *Colinus virginianus*, fire ecology, habitat, home range, *Picoides borealis*, pine-grassland restoration, red-cockaded woodpecker, usable space

INTRODUCTION

Fire-maintained pine (*Pinus* spp.)-grassland (*Andropogon* spp.) communities were once characteristic of the southeastern United States (Waldrop et al. 1992, Masters et al. 1995). However, years of fire exclusion in these communities allowed hardwood encroachment, subsequently eliminating park-like conditions (Masters et al. 1995, Wilson et al. 1995). The increased stand density suppressed growth of herbaceous plants and forage for many wildlife species (Sparks et al. 1998).

Red-cockaded woodpeckers (RCW) are endemic to pine-grassland communities (Masters et al. 1995; 1996*b*, Wilson et al. 1995, Sparks et al. 1999). However, extensive logging in the 1930's and decades of fire exclusion diminished pine-grassland communities in the Ouachita Mountain landscapes (Masters et al. 1996*b*), resulting in a sharp decline of RCW populations (Neal and Montague 1991). For >2 decades the U.S. Forest Service has taken measures to manage ecosystems and improve habitat conditions for RCW populations. A beginning step in the renewal process is Wildlife Stand Improvement (WSI), which removes midstory and codominant pine and hardwood species. Prescribed fire is then implemented 1– 3 years after treatment and remains on a 3-year rotation to maintain open conditions.

In past years controversy has arisen over the amount of money and land used for single-species management, such as for the RCW (Brennan 1991, Masters et al. 1996*b*). Various studies have been conducted to assess the influence of management practices for the RCW on flora and fauna. Results have shown an increase in diversity of herbaceous species, white-tailed deer (*Odocoileus virginianus*) forage production, small mammals, and breeding birds (Wilson et al. 1995, Masters et al. 1996*b*, 1998; Sparks et al. 1998).

These studies indicated ecosystem management for target species (RCW) can positively affect non-target species such as the bobwhite.

Native grasslands, pine-grasslands, and brushy prairie provide high quality areas for bobwhites (Brennan 1999, Guthery 2001*a*). However, loss of these habitats has caused a considerable decline in bobwhite populations (Brennan 1991). Habitat loss is attributed to urbanization and changes in agricultural and silvicultural practices (Brennan 1991, 1999; Roseberry and Sudkamp 1998, Guthery et al. 2000*a*). The intense habitat management for the RCW provides the desirable early successional and brushy habitats for bobwhites.

Years of research have focused on determining the optimal habitat features for bobwhites. However, given its wide geographic range, bobwhites are adapted to a wide range of values for habitat features (Spears et al. 1993, Kopp et al. 1998, Guthery 1999). Recent concepts such as the usable space hypothesis and slack in the configuration of habitat patches (Guthery 1997, 1999) have helped to unify principles of bobwhite habitat management. The range of understory structures of the pine-grassland area potentially fits within the concept of slack: different patch configurations with ranges of values for habitat features may provide optimal habitat in the landscape. If the concept of slack holds, then a range of understories within pine-grassland restoration area potentially provides fully usable space in time.

Studies have also shown that temperature plays a role in habitat use and reproductive success of bobwhites. Operative temperatures >39 °C can lead to hyperthermia in bobwhites (Guthery 2002). Warmer ground temperatures render some areas thermally intolerable, thus decreasing usable space (Forrester et al. 1998, Guthery

2001*c*). Forrester et al. (1998) showed the mean operative temperature at random points was warmer than at points used by bobwhites. Guthery et al. (2000*b*) also speculated that global warming may have negatively affected quail reproduction, subsequently decreasing bobwhite populations. Therefore, providing habitat characteristics such as increased vegetation structure or mid-day coverts can reduce heat stress on bobwhites (Forrester et al. 1998, Guthery 2001*c*), increase brood survival and renesting attempts, and ultimately increase annual production.

Seasonal movements of bobwhites may be attributed to habitat quality, habitat configuration, or usable space (Brennan 1991, Guthery 1997), which can decrease or increase home range size of quail. Differing stand treatments within the pine-grassland restoration area may provide different seasonal needs of bobwhites, thus resulting in increased or decreased home range sizes. Understanding habitat use and home range can lead to management implications for habitat configuration (i.e., juxtaposition) that increases usable space. My objectives were:

1). To obtain descriptive data on habitat selection by bobwhites across various treatments,

2). To obtain descriptive data on movements and home range size of bobwhites within managed forests,

3). To characterize over- and understory structure in control and treated regeneration stands and drainages,

4). To estimate the quantity of usable space within the study area and within non-selected habitat types,

5). To determine stand and exposure effects on ground-surface temperature and whether and to what degree plant community attributes affect ground-surface temperature during summer, and

6). To determine if different stand treatments give rise to slack not limiting bobwhites to certain habitat types.

STUDY AREA

The study area was the 60,000-ha shortleaf pine (*P. echinata*)-grassland renewal area in the Ouachita Mountains on the Poteau Ranger District in the Ouachita National Forest (ONF), Arkansas. The mountains generally run east-west with broad north and south-facing slopes. Shortleaf pine tends to dominate south-facing slopes and oaks (*Quercus* spp.) dominate north-facing slopes (Foti and Glenn 1991). Soils in the study area, which developed from sandstone and shales, are thin and drought-prone. The climate is subhumid to humid with hot summers and mild winters. The maximum annual precipitation is >150 cm and the minimum annual precipitation is <100 cm.

Limited forest management for the RCW was conducted on the ONF beginning in 1979 (Masters et al. 1996*b*). Limited management entailed fire and wildlife stand improvement (WSI) near active RCW clusters. However, in 1990 the project was expanded to an ecosystem level (Masters et al. 1996*b*). The restoration project broadened the use of WSI and prescribed fire to return the landscape to stand conditions existing at the time of settlement.

METHODS

Experimental Design

Stands were comprised of control (no treatment); WSI-no burn (WSI); WSI-burn, first growing season after burn (WSI-B1); WSI-burn, second growing season after burn

(WSI-B2); WSI-burn, third growing season after burn (WSI-B3); and drainages. Regeneration stands included WSI no burn (WSI-regen), and stands 1, 2, and 3 growing seasons after burn (B1-, B2-, B3-regen). Because some stands were not burned after 3 years they were designated as WSI-B4, WSI-B5 and WSI-B6.

Restored stands were predominantly shortleaf pine with limited hardwood composition in contrast to control stands, which were dense pine-hardwood stands. The target conifer basal area after WSI was 13 m^2/ha, which is similar to the pre-settlement basal area of 14 m^2/ha (Foti and Glenn 1991). Drainages within the study area were mixed hardwood species. Regeneration stands were young pine stands which were once harvested and later replanted with shortleaf pine. These stands were also burned on 3-year rotation. The understories within restored pine stands had distinct successional changes after thinning and growing seasons following fire. Woody sprouts, grasses, and dead stem cover (slash from WSI) characterized the understory following WSI only. Grasses, forbs, and legumes were the dominate ground cover in the first growing season following fire. The understory in the second growing season following fire was herbaceous with increasing woody cover. Ground cover in the third growing season following fire was dominated by woody stems <2 m tall (Cram et al. 2002).

Capture

During 2000–2003, bobwhites were captured using modified Stoddard funnel traps (Stoddard 1931) baited with cracked corn, call-back trapping, and night netting (Labisky 1968). Night netting and baited funnel traps were used during winter. In spring and summer, call-back trapping was conducted using modified funnel traps. A wire cylinder was placed in traps and a live pen-reared bobwhite was placed inside to attract wild bobwhites.

Captured bobwhites were weighed with a spring scales (Pesola AG, Baar, Switzerland) and given a uniquely numbered leg band. Sex was determined by upper throat and eye stripe coloration (Stoddard 1931). Age class (juv or ad) was determined by shape and color of the tips of the primary coverts (Rosene 1969). Birds > 140 g were fitted with a < 7-g mortality sensing radio collar (American Wildlife Enterprises, Monticello, Florida, USA). Transmitters operated at 150–151 MHz frequency with a battery life of approximately 240 days. Trapping and handling procedures were approved by the Oklahoma State University Institutional Animal Care and Use Committee.

Telemetry

Radiomarked birds were located ≥ 2 times a week. A 3-element Yagi antenna and radio receiver (Wildlife Materials, Carbondale, Illinois, USA) was used to locate radiomarked birds. During 2000–2001, triangulation was used to locate radiomarked individuals (White and Garrott 1990). Azimuths were taken from fixed telemetry stations and angles were between 45° and 135° to minimize error. A modification of homing as described by White and Garrott (1990) was used in tracking radiomarked birds during 2002–2003. Radiomarked birds were approached on foot until the signal strength indicated the observer was approximately 20 m from the bird. The birds were circled to determine an exact location and a distance and azimuth was taken in the direction of the bird. The distance and azimuth were entered into a Trimble GeoExplorer 3 (Trimble Navigation, Sunyvale, California, USA; accuracy of 1–5 m), which collected UTM coordinates for the bird location. When a mortality signal was detected, the transmitter was located and the observer determined proximate cause of mortality from transmitter condition and evidence at the site (Dumke and Pils 1973). GPS data were differentially corrected to reduce location error of recorded locations.

Home Range

Home ranges were calculated using the fixed kernel density estimator with the smoothing parameter *h* determined by least squares cross validation. The kernel density estimators were reported to be accurate and practical in estimating home range sizes (Worton 1989, Seaman and Powell 1996). Both studies found the least squares cross validation choice of *h* provided the best results and were essential in accurate home range estimates. Home ranges were estimated using the animal movement extension in ArcView GIS v 3.2 (Environmental System Research Institute, Redlands, California, USA).

I estimated home ranges for birds with ≥ 10 radiolocations for 3 covey seasons (2 Oct 2000–4 Apr 2001, 1 Oct 2001–13 Apr 2002, 22 Oct 2002–31 Mar 2003) and 4 breeding seasons (13 Apr–15 Sep 2000, 29 Apr–16 Sep 2001, 25 Apr–30 Sep 2002, and 5 Apr–1 Aug 2003). The 50 and 95% use areas were determined for each season with the 50% level considered the core area. I estimated the mean distance between arithmetic centers of seasonal activity using the animal movement extension in ArcView v 3.2.

Habitat Availability

Habitat use was evaluated through integration of GIS and telemetry locations. Habitat type data were gathered from the U.S. Forest Service office on the Poteau Ranger District. These maps provided appropriate polygon coverage for stand type, treatment type, stand age, basal area, roads, and streams. Habitat and treatment type maps were overlayed to develop a single map coverage of the study area. I used a 95% kernel home range to estimate available habitat using all bird locations ($n = 2{,}322$) collected during the study. Basal area data (total conifer and hardwood) were used to determine selection-avoidance of a range of basal areas. The area within ranges of 12.6–14.9, 15.0–17.2, 17.3–19.5, 19.6–21.8, 21.9–24.1 and >24.1 m^2/ha was estimated from the available habitat coverage using ArcView v 3.2.

Usable Space

With telemetry data on habitat use and GIS data on habitat availability, I estimated p_i = the proportional use of habitat type i and a_i = the proportional availability of habitat type i. Here I derive an interpretation of p_i relative to usable space. Let u_i = the unknown proportion of space that is usable in habitat type i and A_i = the area of habitat type i. Then usable space (U) is by definition

$$U = \sum_{i=1}^{c} u_i A_i$$

where c = the number of habitat types available. Under the assumption that individuals or coveys distribute themselves randomly or systematically in usable space, I obtain the expected value

$$p_i = \frac{u_i A_i}{U}.$$

The above equation implies algebraically that

$$U = \frac{u_i A_i}{p_i}. \qquad (1)$$

Equation (1) contains 2 variables for which estimates are not available, U and u_i, and there is no way to uniquely solve for either based on data available (p_i, A_i). However, selection ratios (p_i/a_i; Manly et al. 1993) provide quantitative information on the usability of space in available habitat types. It is rational to suppose, for example, that selected habitat types consist of a high proportion of usable space. If an assumption that $u_m = 1$ for some habitat type or set of habitat types m that are selected (i.e., the lower 95% CL on p_i/a_i is >1; Manly et al. 1993) is tenable, then it is possible to solve for u_i and U. Under the assumption,

$$U = \frac{A_m}{p_m}.$$

In estimating var(U) I assumed $u_m = 1$ is estimated without error. I assumed that selected habitat types were fully usable. Then

$$\mathrm{var}(U) = A_m^{\ 2}\left[\frac{\mathrm{var}(p_m)}{p_m^{\ 4}}\right],$$

where

$$\mathrm{var}(p_m) = \frac{p_m(1-p_m)}{n}.$$

Note that A_i was measured without error in the ONF data.

Given $u_m = 1$, it is possible to estimate the fraction of space usable in each habitat type i:

$$u_i = \frac{A_m p_i}{A_i p_m}.$$

I estimated the variance of u_i using years as replicates. I estimated usable space (U) and the fraction of space usable in habitat types (u_i) for individual seasons across years. I report the mean, SE, and 95% CLs for the fraction of usable space (u_i) within habitat types across years.

Thermal Properties

Ground-surface temperatures were collected with an infrared thermometer (Omega Engineering, Stamford, Connecticut, USA) during June–August 2002. Two stands from control, WSI, WSI-B1, WSI-B3, B1-regen, B3-regen, and drain were randomly selected with 1 stand on a north- and the other on a south-facing slope (except for drain, which had no aspect). Five 200-m transect lines were randomly established in each stand-slope class and temperature readings were taken at 40-m intervals, resulting in n = 25/stand-slope class/month. Temperature readings were taken between 1200 and 1500 hr.

I also measured structure variables at the 25 points/stand-slope class with the goal of modeling ground-surface temperature as a function of these variables on a monthly basis (the structure variables, however, were measured once). Canopy cover (%) was measured with a spherical densiometer (Lemmon 1957), basal area (m^2/ha) with a 10-factor prism (Avery 1967), and screening cover (disc of vulnerability; m^2) following Kopp et al. (1998).

Vegetation Sampling

Previous studies on the ONF did not assess stand conditions of untreated (i.e., unthinned and unburned) and treated (i.e., thinned and burned) regeneration stands and drainages; therefore, I characterized overstory and understory structure in these stands. I randomly selected 4 stands from each type during July 2003 (n = 12). I estimated woody stem density within 30 fixed-radius plots (radius 3.59 m)/stand located at 30-m intervals along 3–5 transect lines. I estimated basal area using a 10-factor prism and percent canopy cover with a spherical densiometer. Visual obstruction was estimated using the disc of vulnerability following Kopp et al. (1998). I estimated percent cover for categorical groups using a cover scale from Cram (2001) that was modified after Daubenmire (1959).

Data Analyses

Home Range Estimates.—I report $\bar{x}$ and SE for home range estimates. Breeding season estimates were reported for males, females, and sexes pooled. Winter home ranges were reported for individual coveys.

Habitat Selection-avoidance.—Habitat selection was based on the proportion of radiolocations within each habitat type compared with its availability (Neu et al. 1974). Habitat use was evaluated at the study area and home range levels following study designs II and III of Manly et al. (1993).

To determine selection-avoidance at the study area level, bird locations were pooled for each year and season. Because habitat types changed annually (Table 1), the proportion of each habitat type was calculated separately for each year for analysis. I used a selection ration from Manly et al. (1993)

$$w_i = p_i / a_i.$$

I then constructed simultaneous 95% CLs on this ratio using the Bonferroni inequality to adjust for multiple comparisons (Neu et al. 1974, Manly et al. 1993:47). Avoidance was assumed if the upper CL was <1, selection was assumed if the lower CL was >1, and neutral use assumed if the CLs bracketed 1.

Habitat selection within the home range was evaluated using a linear selection index (Strauss 1979) calculated as

$$l_i = p_i - a_i.$$

The index values ranged from -1 to 1, with negative values indicating avoidance and positive values indicating preference. A value of zero indicated random use or use in proportion to availability. Due to an unknown probability distribution of *I* values, I used bootstrapping (Mooney and Duval 1993) to determine habitat selection within home ranges (Suedkamp 2000, Guthery et al. 2001*b*, Puckett 2002). Bootstrapping involved random sampling with replacement from the set of *I* values for each habitat type within each season. To increase sample size for bootstrapping and to draw inference across years, I pooled home ranges across years for the 2 seasons (breeding, covey). Habitat types occurring in ≤ 3 home ranges were not subjected to bootstrapping due to small samples; thus, I report conclusions drawn from the I_i values. I used SYSTAT version 8.0 (SPSS 1998) to generate 1,000 samples of *n* (number of home ranges containing habitat type *i*) for each habitat type within each season. ProStat version 2.0 (Poly Software International 1999) was used to construct histograms illustrating the distribution of bootstrap means (sampling distribution). Selection was assumed if ≥ 95% of the distribution was >0 and avoidance was assumed if ≥ 95% of the distribution was <0. Otherwise random use was assumed.

Thermal Properties.—Following Burnham and Anderson (2002), I created a global model for predicting ground-surface temperature (*T*) as a function of structure variables. I combined basal area (*BA*) and disc of vulnerability (*DISC*) into the variable $BD = 0.5\ (BA + DISC)$ because *BA* and *DISC* were correlated, leading to problems with multicollinearity. The global model was

$$T = A + WSI\text{-}B1(CAN) + WSI\text{-}B2(CAN^2) + WSI\text{-}B3(BA) + WSI\text{-}B4(BA^2) + WSI\text{-}B5(DISC) + WSI\text{-}B6(DISC^2) + B_7(BD) + B_8(BD^2),$$

where CAN = canopy cover. I partitioned the global model into 13 submodels containing $\{CAN\}$, $\{CAN^2\}$, $\{BA\}$, $\{BA^2\}$, $\{DISC\}$, $\{DISC^2\}$, $\{BD\}$, $\{BD^2\}$, $\{CAN + BD\}$, $\{CAN + CAN^2\}$, $\{BA + BA^2\}$, $\{DISC + DISC^2\}$, and $\{BD + BD^2\}$. The best model for a month was selected from the 14 candidate models based on the small-sample Akaike Information Criterion, AIC_c (Burnham and Anderson 2002).

Slack.—The selection-avoidance analysis was used to test the concept of slack within the restored pine-grassland study area. The concept allows patch configurations (i.e., addition, subtraction, or change in dispersion) and composition (e.g., percent woody or herbaceous cover) to change without affecting the quantity of usable space in an area. The disc of vulnerability values reported by Cram et al. (2002) vary across stand types; however, they are less than the domain of selection of <425 m^2 reported by Kopp et al. (1998). Other habitat types such as regeneration stands and drainages not included in the previous studies may also be usable by bobwhites. Therefore, although the stand and understory types are structurally different, they may be functionally equivalent (Guthery 1999). Moreover, the possible addition, subtraction, or change in juxtaposition of these habitats may not alter usable space in time (Guthery 1999).

RESULTS

Capture and Telemetry

From January 2000 to August 2003, 128 (30 F, 98 M) bobwhites were captured and radiomarked. Average mass (± SE) was 170.4 ± 1.1 g for adults and 165.4 ± 1.7 g for juveniles. I collected 2,322 telemetry locations for analysis.

Fifty-five of the 127 radiomarked birds had a presumed fate. Sixteen deaths were attributed to mammalian predators, 9 to avian predators, 27 to unknown predators, and 2 to capture-related mortality. Fifty-six losses were attributed to transmitter failure or loss of collar, and 16 birds were alive when data collection ended.

Home Range

Home range estimates were calculated for 37 individuals (31 M, 6 F) for the breeding season and 12 coveys for winter (Table 2). Based on overlapping 95% CLs, I found no evidence of sex effects on home range during the breeding season, or differences between breeding and covey season. The pooled mean estimate of home range size over sexes and seasons was 57.7 ± 7.7 ha ($n = 49$).

Habitat Use

Study Area Level.—Breeding season selection-avoidance results indicated control and WSI-regen were avoided during all years (Table 3). Habitats avoided in some years and used neutrally in others included WSI, WSI-B4, WSI-B5, WSI-B6, drain, and B4-regen. During all years, WSI-B1, B1-regen, and WSI-B3 were selected or used in proportion to availability. Results indicated WSI-B2 and B2-regen were selected in some years and avoided in others.

During the covey season, control, WSI-B4, WSI-B5, B5-regen, and B6-regen were avoided during all years (Table 4). Habitats avoided in some years and neutrally used in others included WSI-B2, WSI-B3, WSI-regen, B3-regen, and B4-regen. Habitats selected in some years and used in proportion to availability in others included drain, WSI-B6, B1-regen, and B2-regen. Results indicated WSI and WSI-B1 were selected, avoided, and neutrally used. Bobwhites also selected a range of basal areas across years and seasons (Table 5).

Home Range Level.—During the breeding season, the only selected habitat across the 4 breeding seasons was WSI-B2 stands (Fig. 1). Habitats with random use or use in proportion to availability were WSI, WSI-B1, WSI-B3, WSI-B5, B1-regen, B2-regen, and B3-regen. The only avoided habitat type was drainages. Avoided habitat types that were not included in bootstrapping were WSI-B6, B5-regen, B6-regen, WSI-regen, and control. Neutrally used habitats were WSI-B4 and B4-regen.

During the covey season, WSI, WSI-B1, B1-regen, B2-regen, and drainages were the only habitats included in bootstrapping analysis (Fig 2). Results indicated use in proportion to availability for each of these habitats. Drains showed increased use during the covey season, which reflected the results from the study-area-level analysis. Other habitats showing use in proportion to availability were WSI-B2, WSI-B3, WSI-B5, WSI-B6, B3-regen, and WSI-regen. Avoided habitat types included control, B4-regen, and B6-regen.

Movements

Estimates for distances between arithmetic centers of seasonal home ranges were calculated for 12 individuals. These included 6 covey-to-breeding season and 6 breeding-to-covey season home ranges. Mean (± SE) distance from covey-to-breeding season home range centers was 607.3 ± 217.6 m; the mean was 450.6 ± 79.7 m for breeding-to-covey season. Mean distance for seasons pooled was 528.9 ± 113 m.

I also obtained anecdotal evidence on movements of bobwhites following fire. For example, 2 regeneration stands in a covey's home range were burned on 5 February 2003. The surrounding stands were not burned until 9 March. Following this burn, the covey did not shift its home range or make any large movements. Rather, it used 1 of the previously burned regeneration stands until covey breakup.

Usable Space

Available space was estimated at 5,560.4 ha based on 2,322 radiolocations obtained during 2000–2003. Selected habitat types, including WSI, WSI-B1–WSI-B3, WSI-B1–B3-regen, and drains, were used as individual types in analysis. Because control, WSI-B4–WSI-B6, and B4–B6-regen were consistently avoided or used neutrally, I combined them into the habitat type "other". I pooled data for selected types ($u_m = 1$ for all selected types) within seasons to estimate the proportion of usable space in non-selected types.

Habitat types WSI-B1–WSI-B3 and B1–B3-regen had the highest usability during the breeding season across years. During the covey season, usability largely decreased for WSI-B2, WSI-B3, and B3-regen. Usability was similar within WSI, drains and "other" for the covey and breeding seasons across years (Table 6). Usable space ranged from 18.7% of available space during the covey season of 2000–2001 to 51.9% during the breeding season of 2003 (Table 7). Usable space averaged 38.6 ± 4.7% SE of available space with data pooled over seasons and years. The percent of total usable space contributed by avoided habitat types ranged from 10.8% during the 2001–2002 covey season to 57.5% during the 2002 breeding season.

Thermal Properties

Data pooled over stand-slope classes revealed the expected increase in ground-surface temperatures with month. Means (± SE) were 28.7 ± 0.28 °C for June, 33.0 ± 0.29 °C for July, and 36.9 ± 0.32 °C for August (n = 350/month). The percentage frequencies of ground-surface temperatures >42 °C were 1.7 ± 0.69 for June, 5.1 ± 1.18 for July, and 14.0 ± 1.85 for August. These frequencies estimate the percentage of ground space that would serve as a heat source (long-wave radiation) because ground-surface temperatures exceeded the approximate core body temperature of bobwhites. In a complimentary fashion, the balance of space would serve as a heat sump for bobwhites.

For data pooled over stands (excluding drain), I detected weak or non-existent effects of exposure on ground-surface temperature. Means (± SE) for respective north and south slopes were 27.8 ± 0.42 and 30.0 ± 0.47 °C in June, 33.2 ± 0.42 and 33.4 ± 0.43 °C in July, and 36.1 ± 0.5 and 37.6 ± 0.50 °C in August (n = 150/slope/month).

Stand-, slope-, and month-specific data revealed no general patterns in ground-surface temperature (Table 8). That is, the data revealed no consistent effect of slope and stand among months, except that mean ground-surface temperatures tended to increase from June through August independent of stand and slope.

The Akaike-best models for predicting ground-surface temperature based on stand properties changed with month. For June, the model was

$$T = 32.9 - 0.000635CAN^2 \; (R^2 = 0.048).$$

This model suggested that ground-surface temperature declined in proportion to the square of canopy coverage in June. The global model was best in July,

$$T = 29.2 - 0.11(CAN) + 0.00041(CAN^2) - 0.0016(BA) - 0.0597(BA^2) + 0.0619(DISC) - 0.033(DISC^2) - 0.0222(BD) + 0.09(BD^2) \; (R^2 = 0.061),$$

and August,

$$T = 24.7 + 0.575(CAN) + 0.004(CAN^2) - 1.195(BA) + 0.04(BA^2) + 0.3727(DISC) - 0.0033(DISC^2) - 0.38(BD) + 0.0104(BD^2) \; (R^2 = 0.081).$$

None of these models was particularly useful based on the low R^2 values (<8.2% of the variation in ground-surface temperature explained).

Vegetation Measurements

Results from stand overstory and understory measurements showed distinct changes between treated and untreated regeneration stands. Treated stands showed a 23.8% decrease in total basal area subsequently reducing percent canopy cover (36%) (Table 9). Following thinning and fire, grasses, forbs, woody stems, and bare ground increased, while vines, litter layer, and dead stems decreased (Table 10). The creation of a suitable understory structure resulted in a 3-fold decrease in the disc of vulnerability. Drainages had a higher hardwood basal area with an understory of primarily forbs and grasses.

DISCUSSION

Home Range

Breeding season home range estimates averaged 59.3 ± 9.6 ha for males and females. Although large, the estimates fell within the reported ranges of 6.39 ± 1.7 SE ha for nesting females in Illinois (Urban 1972) to 103 ± 11 SE ha for males in Kansas (Taylor et al. 1999). Puckett (2002) showed mean male home ranges were larger than that of females; however, my results suggested mean male home range estimates were similar to that of females. Reduced home range size of males during the breeding season has been attributed to males having mates, incubating nests, or rearing broods (Urban 1972, Curtis et al. 1993).

Mean covey season home ranges were 52.6 ± 11.4 ha and fell within reported ranges of 4.4 ± 0.6 SE ha in Oklahoma (Wiseman and Lewis 1981) to 58.4 ha in Louisiana (Bell et al. 1985). Madison et al. (2000) reported home range sizes of 7–117 ha, which were larger than reported ranges of 4.2–33.0 ha in South Carolina (Dixon et al.

1996), 4.0–11.7 ha in Tennessee (Yoho and Dimmick 1972), and 14.0–28.1ha in S. Illinois (Roseberry 1965). My ranges of 8.2–124.6 ha were similar to that of Madison et al. (2000).

Traditionally, large home range estimates have been attributed to lack of suitable or quality habitat. Lee (1994) reported breeding season ranges of 9.9–281.8 ha in Mississippi where suitable habitat had deteriorated. However, Madison et al. (2000) reported large winter home range estimates in areas with adequate usable space. Habitat properties reported by Cram et al. (2002) and my selection-avoidance results indicated multiple habitat types were suitable for bobwhites within the study area. Bell et al. (1985) attributed large winter home ranges to a decrease in food abundance and availability. Conversely, Cram (2001) found that food abundance was likely not a limiting factor for bobwhites following pine-grassland restoration. Therefore, the premise that home range size reflects habitat quality or lack of usable space may not hold for my study area. Other explanations for large home ranges are predator avoidance, distance from preferred roosting habitat to foraging areas, and hunting pressure (Dimmick and Yoho 1972).

Habitat Use

During the breeding season, Cram et al. (2002) found bobwhite abundance was highest in WSI only and WSI-B3 stands. However, bobwhites selected various habitat types throughout the breeding season at the study area and home range level (Tables 2, 3; Figs. 1, 2). For example, bobwhites selected stands in earlier and later successional stages (e.g., WSI-B1 or WSI-B3). The WSI-B2 and WSI-B3 stands provided dead grasses from the previous growing season that may be optimal nesting cover (Bidwell et al. 1991). Simpson (1972) found that 503 of 842 (60%) of quail nests were in areas in the second growing season postburn. The WSI-B1 stands provided increased bare ground, herbaceous vegetation, and increased orthopteran mass (Cram 2001), which is optimal brood-foraging habitat (Hurst 1972).

In addition, longer burn rotations greatly reduce desirable forb and grass cover in managed pine stands (Bowman et al. 1999). Subsequently, food abundance and availability is reduced and the increased litter layer and dense plant community may not be suitable brood habitat (Hurst 1972). Simpson (1972) found only 8% of all nests were in areas more than 2 yrs postburn. Brennan (1991) indicated burning should be conducted every 1–2 yrs to be effective. My results showed bobwhites did not select stands past the 3 growing seasons following fire, which indicated additional growing seasons are not necessary (Tables 2, 3).

During winter, bobwhites also selected various habitat types at the study area and home range level (Tables 2, 3; Figs. 1, 2). Bobwhites selected areas with a higher hardwood composition, which included drainages, small hardwood mottes within pine stands, and small hardwood stands. Wiseman and Lewis (1981) found covey use of woodland areas was highest during winter and declined in spring. Hard mast may be an important food source for bobwhites during winter (Bidwell et al. 1991, Brennan 1999). For example, post oak (*Q. stellata*) acorns are small and may be readily used by quail (Masters et al. 1996*a*). Thus, while hardwood midstory removal is necessary to maintain pine-grassland habitats, retention of dominant overstory stems may be important. Bowman et al. (1999) suggested hard mast would not be limiting in RCW areas if they were juxtaposed to hardwood areas such as streamside management zones.

Conversely, Dixon et al. (1996) found hardwoods were generally not selected during winter. Hunt (1991) reported little use of oak forests by coveys in Arkansas. The hardwood stands on their study areas may have been closed canopy with little understory strucuture. Yoho and Dimmick (1972) stated understory structure largely influenced covey use of hardwood areas. Suitable understory structure created by rescribed fire on the ONF allowed bobwhites to use hardwood areas during winter.

Regeneration stands were also strongly selected during the covey season. Typically, regeneration stands have a dense overstory and little ground vegetation (Brennan 1991). Moore (1972) stated densely stocked pine plantations are "biological deserts" and are of little value to quail. Hunt (1991) stated lack of suitable understory cover probably accounted for low use of pine plantations in Arkansas. However, pre-commercial thinning and fire created a suitable understory structure on the ONF (Table 10). Treatment of these stands created an additional 964 ha of potential usable space within my study area. In Alabama, Speake (1966) found bobwhite populations were highest in an area with annually burned pine plantations compared to unburned areas.

Basal area also varied across stands selected by bobwhites during the breeding and covey seasons. Fuller (1994) found bobwhites selected areas with lower basal areas during the breeding season in areas managed for RCWs. Subsequently, percent canopy cover of understory vegetation was lower in these stands, which may have affected bobwhite use. Conversely, my results showed bobwhites selected stands with a total basal area ranging from 12.6 to 24.1 m^2/ha. My findings indicated a range of basal areas may be acceptable, given a suitable understory structure.

Movements

During the breeding season, Fies et al. (2002) suggested that bobwhites dispersed more in fragmented versus large contiguous blocks of habitat. Their results indicated 24.7% of bobwhites on their study area dispersed > 2 km. In a similar study, Townsend et al. (2003) found 41% of bobwhites dispersed > 2 km from their original place of capture. I did not observe bobwhites dispersing > 2 km between seasonal home ranges. Thus, my results indicated that while usable space varied temporally (Table 7), the study area was not highly fragmented.

Usable Space

Usable space is defined as "habitat compatible with the physical, behavioral, and physiological adaptations of bobwhites in a time-unlimited sense" (Guthery 1997:294). Guthery (1997) argued, based on the historical record of management success and failure, that habitat management for bobwhites was more likely to be successful if it increases usable space in time rather than if it focuses on improving the perceived quality (edge density, food supplies, interspersion, diversity) of existing habitat.

The metric I used provided an estimate of usable space relative to available space on a given area with time controlled and the contribution to usable space by non-selected habitat types (Tables 5, 6). Given these estimates, a potential population increase could be estimated supposing space not usable was subjected to habitat management. Results from my data suggested the population could be increased by about $1.5\times$. Selection-avoidance analysis (Tables 2, 3; Figs. 1, 2) indicated creating more usable space would involve conversion of more space to a successional stage of 1–3 years post-burn.

Because the usable space hypothesis (Guthery 1997) has only recently been formalized, I know of no published estimates of usable space relative to available space in northern bobwhite management. Unpublished data from a ranch in north Texas (F. S. Guthery, Department of Forestry, Oklahoma State University, personal communication) indicated that about 28.6% of available space (796 ha) was fully usable.

Thermal Properties

I view the data on ground-surface temperature as largely descriptive because certain effects (month, slope) are not in question. Moreover, given slope and month, the expectation is that stands with less canopy cover will have higher ground-surface temperatures than those with more canopy cover because the ground surface will receive more solar radiation in the more open stands. The descriptive data provided information on the magnitudes of these effects.

However, I detected substantial heterogeneity in ground-surface temperatures across months, slopes, and stands. The heterogeneity undoubtedly arose because of sun-shade dynamics and ground-surface properties at sample points. The surface properties would affect the quantity of solar radiation absorbed, reflected, or intercepted.

The models developed to predict ground-surface temperature based on properties of stands, though highly significant in a statistical sense, were not useful in a practical sense. That is, the models explained a small portion (<8.2%) of the variation in mid-day ground-surface temperatures. Development of more useful models would necessitate measurement of more independent variables such as absorptivity of the ground-surface and total quantity of solar radiation from morning to time of sampling.

I know of no published data on ground-surface temperatures relative to bobwhite thermoregulation. Unpublished data (F. S. Guthery, Department of Forestry, Oklahoma

State University, Stillwater, USA) from the Texas Panhandle suggest that in a cover type (sand plum-skunkbush; *Prunus angustifolia-Rhus aromatica*) selected by bobwhites, 100% of the ground surface may exceed 42 °C on hot summer days. I observed a maximum of 14% in August. My results suggested a moderate thermal environment for bobwhites in ONF as judged by ground-surface temperatures. Moreover, the birds would seem to have had ample opportunity to dump or absorb heat (long-wave radiation) according to thermoregulatory needs.

Slack

The slack concept explains why composition and configuration of habitat objects can change without affecting the quantity of usable space. The amount of usable space changed across years and seasons (Table 7). Therefore, it seems there were boundaries where usable space declined within the study area. These may occur where too much woody cover or too little herbaceous cover exists (Guthery 1999).

Within the areas of usable space, habitat properties (i.e., percent woody and herbaceous cover or height of woody cover) varied among habitat types, consistent with the slack construct. For example, during the breeding season, Wilson et al. (1995) and Cram et al. (2002) stated grasses and forbs dominated the understory in WSI-B1 stands, whereas woody cover dominated the understory in WSI and WSI-B3 stands. Cram et al. (2002) showed percent woody cover <2 m tall was 56% and 76% higher in WSI and WSI-B3 stands, respectively, than in WSI-B1 stands. In addition, herbaceous vegetation dominated the understory of thinned and burned regeneration stands and drains (Table 10). Percent grass and forb cover was 2 and 3 times higher than woody cover in drains and treated regeneration stands, respectively.

Increased woody cover decreased the disc of vulnerability in WSI, WSI-B2 and WSI-B3 stands (Cram et al. 2002). They stated WSI-B1 stands were void of suitable woody screening cover <1 m tall (large disc areas). Kopp et al. (1998) explained ideal landscapes for bobwhites would exhibit high relative variability in habitat variables. This was evidenced by the variation in the disc of vulnerability and percent woody cover among habitats (e.g., WSI-B1 versus WSI-B3). Guthery (1999) further explained percent woody cover may vary among patches, yet still be functionally equivalent. Thus, although the disc was largest in WSI-B1 stands, selection of this type across years indicated woody and herbaceous cover were structurally acceptable. xxxIn addition, the smallest disc of vulnerability occurred in thinned and burned regeneration stands (Table 9). The higher percent cover of herbaceous vegetation in these stands may have provided an appropriate surrogate to woody screening cover (Guthery 1999).

The existence of slack was also evidenced by variable selection of habitats among years (Tables 2, 3). For example, WSI-B3 stands were avoided during the 2000–2001 covey season and selected during the 2002 breeding season. Available hectares of this type was 56.5 ha and 423.6 ha during the covey and breeding season, respectively. Thus, opportunities for selection increased or decreased as proportional availability varied among habitats. However, slack permitted selection of other habitats as availability varied and did not limit bobwhites to certain habitats.

MANAGEMENT IMPLICATIONS

Pine-grassland restoration for the RCW provides suitable habitat for bobwhites. Although WSI is a necessary first step in restoration, rotational burning must be applied to maintain open pine stands. Based on the estimated population response (Cram et al.

2002) and a selection response (this study), a 3-year rotation is optimal for bobwhites. Because stands past the third growing season postburn were not selected and decreased usable space, longer burn rotations are not recommended. Regeneration stands should be considered in management plans, as they provided increased usable space on the ONF. Juxtaposition of recently burned and older burned stands (e.g., WSI-B1 and WSI-B3) should also be considered to provide optimal nesting and brood rearing conditions (Masters et al. 1996).

Although lower basal area (11–16 m^2/ha) may be optimal, bobwhites may select higher basal areas if prescribed fire is used to maintain suitable ground structure. In addition, a hardwood component should be retained within or around pine stands to provide hard mast (e.g., acorns) as a possible winter food source. This may be accomplished by leaving hardwoods along riparian areas or a certain basal area of dominant stems within pine stands. Prescribed fire should also be used in these areas to reduce litter layer and stimulate growth of forbs and grasses.

Bobwhites selected habitat types with substantial differences in vegetation structure, which was consistent with the concept of slack in habitat configurations. Thus, a variety of habitat types and configurations may be acceptable. The usable-space metric can be used to estimate the quantity of usable space in an area and within non-selected habitat types. Results provide information about where habitat management should be applied and an estimate of a potential population increase.

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Table 1. Habitat availability (ha) by season and year for bobwhites on the Ouachita National Forest, Arkansas, 2000–2003.

Habitat Type[a, b]	Breeding (Apr–Sep)				Covey (Oct–Mar)		
	2000	2001	2002	2003	2000–2001	2001–2002	2002–2003
Control	1321	1245	1216	1213	1321	1245	1216
Drain	877	877	877	877	877	877	877
WSI	673	1342	1085	399	673	1342	1085
WSI-regen	459	459	385	369	459	459	385
B1	502	15	449	1687	517	15	506
B1-regen	399		148	326	399		148
B2	57	502	15	449	57	502	15
B2-regen		399		125		399	
B3	15	57	424	15		57	325
B3-regen	23		325		23		559
B4	1152				1152		
B4-regen	84	23		78	84	23	
B5		559				559	

Table 1. Continued.

Habitat Type[a, b]	Breeding (Apr–Sep)				Covey (Oct–Mar)		
	2000	2001	2002	2003	2000–2001	2001–2002	2002–2003
B5-regen		84	23			84	23
B6			559				367
B6-regen			55	23			55

[a] Habitats with blanks did not occur within that year.

[b] Control = unthinned, unburned; drain = ephemeral upland streams; WSI = wildlife stand improvement, no burn; WSI-regen = thinned only, no burn; WSI-B1, WSI-B2, WSI-B3, WSI-B4, WSI-B5, WSI-B6 = first-, second-, third-, fourth-, fifth-, and sixth- growing season following burn; WSI-B1, WSI-B2, WSI-B3, WSI-B4, WSI-B5, B6-regen = regeneration stands in first-, second-, third-, fourth-, fifth-, and sixth growing season following burn.

Table 2. Mean home range (ha) estimated using the fixed kernel estimator for bobwhites on the Ouachita National Forest, Arkansas, USA, 2000–2003.

Season Class	n	50%		95%	
		$\bar{x}$	SE	$\bar{x}$	SE
Breeding[a]					
M	31	8.8	1.4	60.4	11.8
F	6	6.0	2.5	48.0	11.7
Pooled	37	8.4	1.3	59.3	9.6
Covey[b]	12	10.3	2.9	52.6	11.4
Composite[c]	49	8.8	1.2	57.7	7.7

[a] Apr–Sep.

[b] Oct–Mar.

[c] Sexes and seasons pooled.

Table 3. Habitat selection indices for bobwhites during the breeding season (Apr–Sep) on the Ouachita National Forest, Arkansas, 2000–2003 ("–" indicates avoidance, "+" indicates selection, and "o" indicates neutral use).

Habitat[a,b]	2000 (*n* = 271)[c]	2001 (*n* = 300)	2002 (*n* = 292)	2003 (*n* = 578)
Control	0.0 (–)	0.0 (–)	0.0 (–)	0.0 (–)
Drain	1.2 (o)	0.7 (o)	1.2 (o)	0.7 (–)
WSI	1.5 (o)	0.5 (–)	0.7 (o)	0.1 (–)
WSI-regen	0.1 (–)	0.0 (–)	0.0 (–)	0.0 (–)
WSI-B1	4.4 (+)	32.7 (+)	1.2 (o)	1.5 (+)
B1-regen	0.8 (o)		2.9 (+)	2.1 (+)
WSI-B2	0.0 (–)	3.9 (+)	19.3 (+)	2.2 (+)
B2-regen		2.6 (+)		0.3 (–)
WSI-B3	22.2 (+)	1.3 (o)	2.2 (+)	26.1 (+)
B3-regen	0.0 (–)		2.1 (+)	
WSI-B4	0.5 (–)			
B4-regen	0.4 (o)	0.0 (–)		0.6 (o)

Table 3. Continued.

Habitat[a,b]	2000 (n = 271)	2001 (n = 300)	2002 (n = 292)	2003 (n = 578)
WSI-B5		1.1 (o)		
B5-regen		0.0 (–)	0.0 (–)	
WSI-B6			1.1 (o)	
B6-regen			0.0 (–)	0.0 (–)

[a] Habitats with blanks did not occur within that year.

[b] Control = unthinned, unburned; drain = ephemeral upland streams; WSI = wildlife stand improvement, no burn; WSI-regen = thinned only, no burn; WSI-B1, WSI-B2, WSI-B3, WSI-B4, WSI-B5, WSI-B6 = first-, second-, third-, fourth-, fifth-, and sixth- growing season following burn; WSI-B1, WSI-B2, WSI-B3, WSI-B4, WSI-B5, B6-regen = regeneration stands in first-, second-, third-, fourth-, fifth-, and sixth growing season following burn.

[c] 21 birds in 2000, 16 birds in 2001, 19 birds in 2002, and 26 birds in 2003.

Table 4. Habitat selection indices for bobwhites during the covey season (Oct–Mar) on the Ouachita National Forest, Arkansas, 2000–2003 ("–" indicates avoidance, "+" indicates selection, and "o" indicates neutral use).

Habitat[a, b]	2000–2001 (n = 129)[c]	2001–2002 (n = 270)	2002–2003 (n =130)
Control	0.0 (–)	0.0 (–)	0.0 (–)
Drain	0.5 (o)	0.9 (o)	1.8 (+)
WSI	0.0 (–)	1.4 (+)	0.4 (o)
WSI-regen	0.0 (–)	0.0 (–)	0.6 (o)
WSI-B1	8.0 (+)	0.0 (–)	1.4 (o)
B1-regen	2.0 (o)		10.9 (+)
WSI-B2	0.0 (–)	1.2 (o)	0.0 (–)
B2-regen		4.6 (+)	
WSI-B3		0.0 (–)	0.3 (o)
B3-regen	0.0 (–)		0.9 (o)
WSI-B4	0.0 (–)		
B4-regen	0.0 (–)	0.8 (o)	

Table 4. Continued.

Habitat[a, b]	2000–2001 (n = 129)	2001–2002 (n = 270)	2002–2003 (n =130)
WSI-B5		0.4 (–)	
B5-regen		0.0 (–)	0.0 (–)
WSI-B6			0.7 (o)
B6-regen			0.0 (–)

[a] Habitats with blanks did not occur within that year.

[b] Control = unthinned, unburned; drain = ephemeral upland streams; WSI = wildlife stand improvement, no burn; WSI-regen = thinned only, no burn; WSI-B1, WSI-B2, WSI-B3, WSI-B4, WSI-B5, WSI-B6 = first-, second-, third-, fourth-, fifth-, and sixth- growing season following burn; WSI-B1, WSI-B2, WSI-B3, WSI-B4, WSI-B5, B6-regen = regeneration stands in first-, second-, third-, fourth-, fifth-, and sixth growing season following burn.

[c] 3 coveys in 2000–2001, 4 coveys in 2001–2002, and 5 coveys in 2002–2003.

Table 5. Basal area (conifer and hardwood) selection indices for bobwhites on the Ouachita National Forest, Arkansas, 2000–2003 ("–" indicates avoidance, "+" indicates selection, and "o" indicates neutral use; $n = 2172$ radiolocations).

Basal area (m^2/ha)	Selection index
12.5–15.0	2.3 (+)
15.1–17.2	0.8 (–)
17.3–19.5	0.6 (–)
19.6–21.8	1.6 (+)
21.9–24.1	1.7 (+)
>24.1	0.4 (–)

Table 6. Mean proportion of usable space (ha) within habitat types across 4 breeding seasons (Apr–Sep) and 3 covey seasons (Oct–Mar) for northern bobwhites on the Ouachita National Forest, Arkansas, 2000–2003 (n = 1,531 radiolocations for 82 birds in the breeding season and n = 529 radiolocations for 12 coveys).

Season	Proportion usable		95% CL	
Habitat types[a, b]	$\bar{x}$	SE	Lower	Upper
Covey				
WSI	0.40	0.31	0.00	1.00
WSI-B1	0.67	0.33	0.00	1.00
WSI-B2	0.33	0.33	0.00	1.00
WSI-B3	0.07	0.05	0.00	0.17
B1-regen	1.00	0.00	1.00	1.00
B2-regen	1.00			
B3-regen	0.15	0.15	0.00	0.47
Drain	0.52	0.26	0.00	1.00
Other[c]	0.06	0.03	0.00	0.13
Breeding				
WSI	0.38	0.21	0.00	0.80
WSI-B1	0.87	0.13	0.61	1.00
WSI-B2	0.75	0.25	0.25	1.00
WSI-B3	0.84	0.17	0.50	1.00
B1-regen	0.78	0.19	0.38	1.00
B2-regen	0.60	0.29	0.02	0.77

Table 6. Continued.

Season Habitat types[a, b]	Proportion usable		95% CL	
	$\bar{x}$	SE	Lower	Upper
B3-regen	0.50	0.35	0.00	1.00
Drain	0.51	0.17	0.15	0.85
Other	0.08	0.03	0.02	0.13

[a] Habitat types with no SE and CLs only occurred in 1 year.

[b] WSI = wildlife stand improvement, no burn; WSI-B1, WSI-B2, WSI-B3 = first-, second-, and third growing season following burn; WSI-B1, WSI-B2, B3-regen = regeneration stands in first-, second-, and third growing season following burn; drain = riparian areas.

[c] Includes experimental control, stands in fourth-, fifth-, and sixth growing season following burn and regenerations stands in fourth-, fifth-, and sixth growing season following burn.

Table 7. Estimates of usable space for northern bobwhites by season and year on 5,560.4 ha of available space, Ouachita National Forest, Arkansas, 2000–2003.

Season Year	Birds	Locations	Usable space (ha)	SE	95% CL Lower	95% CL Upper
Breeding						
2000	21	271	2,554	65.3	2,423	2,685
2001	16	300	1,461	65.1	1,169	1,753
2002	19	292	2,146	146.2	1,854	2,439
2003	26	578	2,885	48.8	2,788	2,983
Covey						
2000–2001	3	129	1,027	31.6	964	1,090
2001–2002	4	270	2,816	86.7	2,643	2,990
2002–2003	5	130	2,163	121.9	1,919	2,407

Table 8. Summer trends in ground-surface temperature (°C) during 1200–1500 hrs according to slope and stand type, Ouachita National Forest, Arkansas, 2002 (n = 25/slope/stand type/month).

Stand Slope	Jun		Jul		Aug	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
WSI-B1						
North	28.8	1.1	32.5	0.9	38.1	1.5
South	35.0	1.7	30.0	0.5	31.8	0.9
B1-regen						
North	26.0	0.8	28.7	0.6	34.0	0.6
South	28.8	0.8	34.5	0.6	40.4	0.6
WSI-B3						
North	28.0	0.8	35.0	1.1	41.4	1.3
South	30.1	0.8	32.5	0.9	38.1	0.7
B3-regen						
North	27.8	1.1	31.3	1.1	31.8	1.1
South	31.4	0.6	32.6	0.7	39.2	1.1
Control						
North	24.9	0.7	37.6	1.0	34.1	0.8
South	24.9	0.7	35.3	0.7	37.8	1.5
WSI						
North	31.5	1.0	34.2	0.9	37.3	0.8
South	29.6	0.8	38.6	1.1	38.7	1.4

Table 8. Continued.

Stand Slope	Jun		Jul		Aug	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Drain[a]	27.8	0.4	31.0	0.6	37.1	0.8

[a]n = 50/slope/stand type/month; no variation in slope.

Table 9. Stand characteristics of control and treated regeneration stands and drainages on the Ouachita National Forest, Arkansas, Jul 2003 (n = 4 for each stand type).

	Control[a]		Treated[b]		Drainages	
Habitat characteristic	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Canopy cover (%)	91.3	0.8	67.1	6.4	88.0	2.4
Pine basal area (m^2/ha)	13.8	1.9	14.1	1.5	7.9	1.7
Hardwood basal area (m^2/ha)	4.7	0.6	0.9	0.5	8.8	0.8
Total basal area (m^2/ha)	18.7	1.5	15.1	1.6	16.9	1.9
Disc of vulnerability (m^2)	95.7	15.3	23.4	1.9	59.3	6.6
Woody stem density (stems/plot)	292.4	63.4	307.6	35.1	323.1	47.3

[a] Unthinned and unburned regeneration stands.

[b] Thinned and burned regeneration stands.

Table 10. Understory characteristics (% cover) of control and treated regeneration stands and drainages on the Ouachita National Forest, Arkansas, Jul 2003 ($n = 4$ for each stand type).

	Control[a]		Treated[b]		Drainages	
Cover	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Grasslike	10.8	3.1	31.4	3.9	16.8	2.1
Forb	4.0	0.4	33.5	4.5	24.5	4.6
Vine	7.1	3.6	5.6	2.0	7.1	2.3
Woody	5.5	2.3	16.4	3.0	15.3	1.4
Litter	67.9	3.1	28.1	3.0	46.8	7.1
Rock	2.1	1.3	2.3	0.9	5.5	0.3
Soil	1.0	0.4	2.4	1.0	7.3	1.9
Stem	3.5	0.4	1.9	0.2	4.5	0.5

[a] Unthinned and unburned regeneration stands.

[b] Thinned and burned regeneration stands.

Fig. 1. Frequency distribution of bootstrap means (1,000 replications of size *n*) for selection index (*I*) values indicating within home range selection-avoidance exhibited by bobwhites for different habitat types during the breeding season in the pine-grassland restoration area of the Ouachita National Forest, Arkansas, 2000–2003. Size *n* refers to the number of home ranges that contained each habitat type. Vertical lines appear at zero. Values >0 indicate selection, <0 indicate avoidance, and values of zero indicate random use.

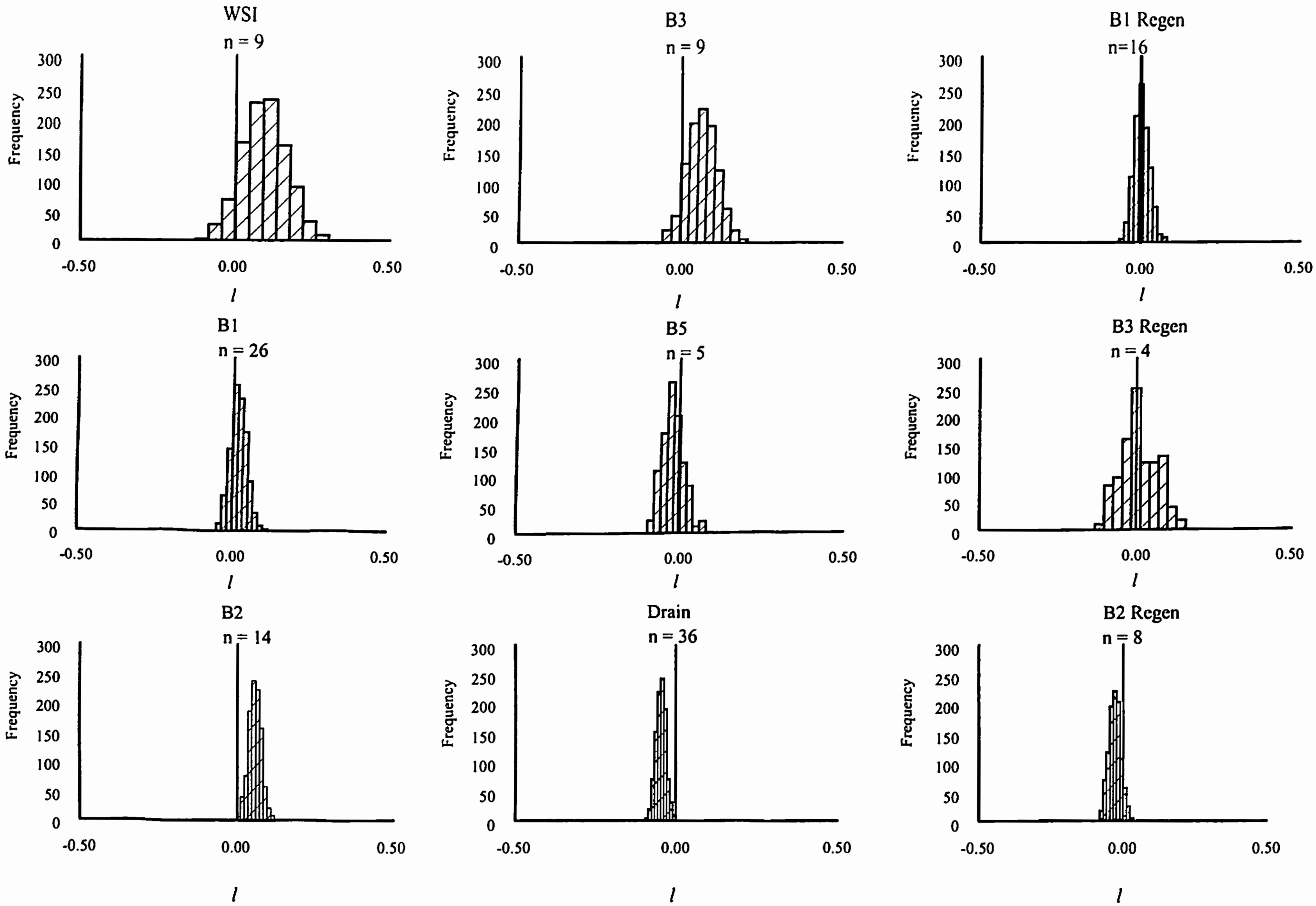
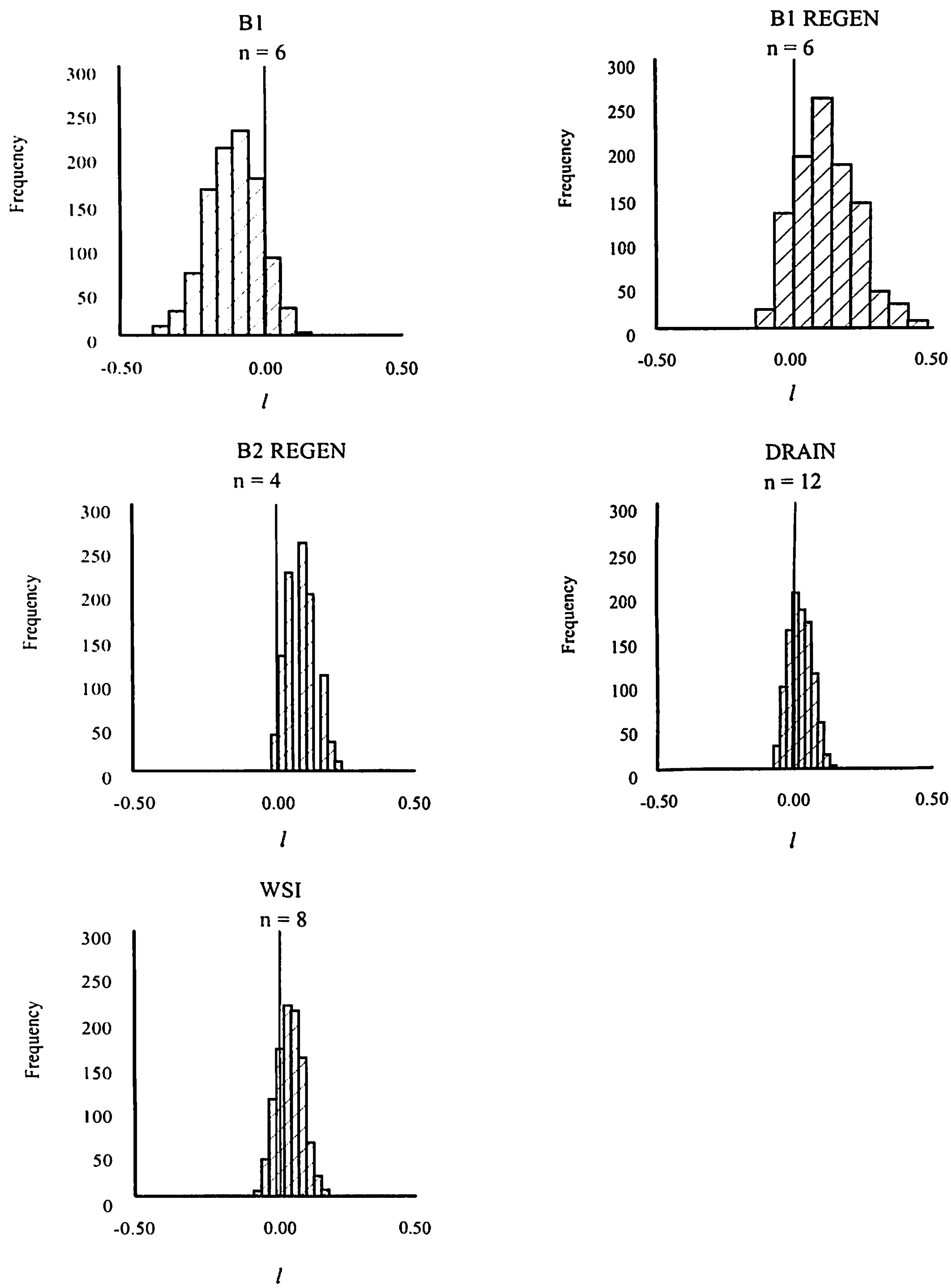

WSI
n = 9
B3
n = 9
B1 Regen
n=16
B1
n = 26
B5
n = 5
B3 Regen
n = 4
B2
n = 14
Drain
n = 36
B2 Regen
n = 8
Frequency
300
250
200
150
100
50
0
-0.50
0.00
0.50
I

Fig. 2. Frequency distribution of bootstrap means (1,000 replications of size *n*) for selection index (*I*) values indicating within home range selection-avoidance exhibited by bobwhites for different habitat types during the covey season in the pine-grassland restoration area of the Ouachita National Forest, Arkansas, 2000–2003. Size *n* refers to the number of home ranges that contained each habitat type. Vertical lines appear at zero. Values >0 indicate selection, <0 indicate avoidance, and values of zero indicate random use.


B1
n = 6
Frequency
300
250
200
150
100
50
0
-0.50
0.00
0.50
I
B1 REGEN
n = 6
Frequency
300
250
200
150
100
50
0
-0.50
0.00
0.50
I
B2 REGEN
n = 4
Frequency
300
250
200
150
100
50
0
-0.50
0.00
0.50
I
DRAIN
n = 12
Frequency
300
250
200
150
100
50
0
-0.50
0.00
0.50
I
WSI
n = 8
Frequency
300
250
200
150
100
50
0
-0.50
0.00
0.50
I

Appendix A. Sex, age class, and mass (g) for bobwhites captured on the Ouachita National Forest, Arkansas, 2000–2003.

Sex	Age class	Mass
female	adult	180
female	adult	170
female	adult	162
female	adult	152
female	adult	168
female	adult	180
female	adult	180
female	adult	160
female	adult	187
female	adult	162
female	adult	173
female	adult	170
female	adult	174
female	adult	171
female	adult	163
female	adult	175
female	adult	176
female	adult	180
female	subadult	179
female	subadult	162
female	subadult	150
female	subadult	168
female	subadult	175
female	subadult	140
female	subadult	158
female	subadult	162
female	subadult	160
female	subadult	167
female	subadult	179
female	subadult	176
male	adult	172
male	adult	168
male	adult	165
male	adult	160
male	adult	190
male	adult	172
male	adult	172
male	adult	188
male	adult	164

Appendix A. (continued)

Sex	Age class	Mass
male	adult	164
male	adult	170
male	adult	154
male	adult	152
male	adult	172
male	adult	152
male	adult	174
male	adult	160
male	adult	158
male	adult	162
male	adult	174
male	adult	141
male	adult	179
male	adult	162
male	adult	170
male	adult	160
male	adult	185
male	adult	170
male	adult	160
male	adult	180
male	adult	165
male	adult	175
male	adult	180
male	adult	180
male	adult	170
male	adult	155
male	adult	185
male	adult	168
male	adult	165
male	adult	174
male	adult	178
male	adult	160
male	adult	180
male	adult	186
male	adult	174
male	adult	162
male	adult	182
male	adult	165
male	adult	184
male	adult	167
male	adult	172
male	adult	161

Appendix A. (continued)

Sex	Age class	Mass
male	adult	172
male	adult	156
male	adult	173
male	adult	177
male	adult	164
male	adult	170
male	adult	159
male	adult	167
male	adult	176
male	adult	166
male	adult	190
male	subadult	160
male	subadult	160
male	subadult	180
male	subadult	185
male	subadult	168
male	subadult	169
male	subadult	180
male	subadult	175
male	subadult	180
male	subadult	170
male	subadult	158
male	subadult	150
male	subadult	152
male	subadult	139
male	subadult	155
male	subadult	148
male	subadult	153
male	subadult	154
male	subadult	172
male	subadult	175
male	subadult	169
male	subadult	186
male	subadult	177
male	subadult	172
male	subadult	192
male	subadult	172
male	subadult	168
male	subadult	169
male	subadult	170
male	subadult	188
male	subadult	159

Appendix A. (continued)

Sex	Age class	Mass
male	subadult	172
male	subadult	167
male	subadult	161
male	subadult	147
male	subadult	157

VITA (1)

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Master of Science

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