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From 1993 to 2005, we conducted 13 years of early breeding season call counts at Avon Park Air Force Range, in south-central Florida. Historically, this area has been an open, frequently burned landscape with a rainy summer season and a dry spring. We used call count data (*n* = 67 stations/year) and 400-m buffer areas around each point to investigate the effects of habitat preference, fire impacts, and weather variations on bobwhite abundance. Using logistic regression, we determined that bobwhite in south-central Florida prefer open canopy, dry/mesic habitats in prairie and flatwoods over pine plantations and wet areas. Investigated by ANOVA, bobwhite abundance was highest when at least 40% of a buffer area was burned. Using only burns which occurred on at least 40% of a buffer area, higher bobwhite abundance occurred in buffers which received a dormant or growing season burn within the previous year. Two years post-burn, bobwhite abundance significantly decreased for both burn seasons. Burning in less optimal habitats (e.g., those dominated by dense canopy) did not affect bobwhite populations. Correlation analysis revealed significant negative correlations between bobwhite abundance and April PMDI, May PMDI, and November rain. Bobwhite abundance had significant positive correlations with October PMDI and July rain days. By knowing how local habitat, fire, and weather can impact early breeding season bobwhite abundance, managers may help their population flourish.

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Introduction

In the Southeast, the northern bobwhite (*Colinus virginianus*) populations have been declining for decades (Brennan 1991, Capel et al. 1995, Peterson et al. 2002, Brennan and Kuvlesky 2005, Stewart 2005). Changes in land use, reduction in the use of fire, and reduction of usable space and habitat have been attributed to its decline (Roseberry et al. 1979, Brennan 1991, Guthery 1997, Brennan et al. 1998, Brennan and Kuvlesky 2005, Stewart 2005). A better understanding of which habitats and management actions, such as fire, can promote productive bobwhite populations is important, as well as knowing how local weather may impact a population.

Throughout their range, bobwhites depend on early successional habitats in high productivity sites to late successional habitats in sites of low productivity for successful reproduction and survival (Spears et al. 1993, Guthery 1997). Generally, where there is an open canopy (if any), a sparse woody mid-story, and a diverse groundcover layer, bobwhites may be abundant (Landers and Mueller 1986, DeVos and Mueller 1993, Cram et al. 2002, Stewart 2005). As canopy cover increases in woodlands, bobwhite abundance declines (Lee and Brennan 1994, Cram et al. 2002). Without periodic disturbance, such as fire, microhabitat characteristics become unsuitable for bobwhites during the breeding season (Landers and Mueller 1986, Stewart 2005).

In the Southeast, fire has occurred for many centuries, historically during the early lightning season (Komarek 1964, Christensen 1981, Abrahamson and Hartnett 1990); thus, bobwhites have evolved with this natural disturbance. Bobwhites may benefit from fire by it reducing litter and woody plant invasion and increasing insect abundance and plant forage (Murray and Frye 1964, Hurst 1972, Moore 1972, Landers 1981, Landers and Mueller 1986, Lewis and

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Harshbarger 1986, Brennan et al. 1998, Hermann et al. 1998). On the other hand, fire may reduce nest sites and escape cover and consume nests and chicks (Dimmick 1972, Landers 1981, Robbins and Myers 1992, Lyon et al. 2000*a*,*b*). When fire is excluded from these fire-adapted plant communities, bobwhite populations may decrease over time (Engstrom et al. 1984).

Season of fire can have differing effects (Landers 1981, Robbins and Myers 1992, Hermann et al. 1998). Fires conducted during the winter may reduce woody plant cover for only a few months but may actually increase number of stems by sprouting (Waldrop et al. 1987, Robbins and Myers 1992). Spring and early summer fires may more effectively reduce woody plant cover and abundance and increase bare ground, especially with annual burns (Waldrop et al. 1987, Robbins and Myers 1992, Brennan et al. 1998, Hermann et al. 1998).

Weather has been shown to significantly influence bobwhite abundance by directly or indirectly affecting survival and productivity (Speake and Haugen 1960, Jackson 1962, Stanford 1972, Bridges et al. 2001, Perez et al. 2002, Hernandez et al. 2005). Excessive rains may cause flooding which can drown adults and chicks and kill or reduce vegetation for forage or cover (Frye 1948, Rosene 1969, Landers and Mueller 1986). Droughts can reduce productivity by reducing hatching rates, nesting rates, percentage of hens nesting, cover, and forage (Speake and Haugen 1960, Jackson 1962, Stanford 1972, Landers and Mueller 1986, Hernandez et al. 2005). In the Southeast, wet summers can yield greater bobwhite reproductive output, whereas dry (especially hot) summers can yield lower reproductive output (Murray 1959, Reid and Goodrum 1960, Speake and Haugen 1960). On poorly drained, flat landscapes, very wet summers or hurricanes have had a negative impact on bobwhite populations by drowning nests, chicks, and adults (Frye 1948).

Few studies have investigated northern bobwhites in south-central Florida for habitat, fire, and weather influences on bobwhite breeding abundance. In an effort to better understand which habitats may be optimal and what effects fire and weather may have on bobwhite breeding abundance, data from thirteen years of breeding season call-counts were used to determine any influence they had on bobwhite breeding abundance.

Study Area

The study area was located on Avon Park Air Force Range (APAFR, 42,430 ha, 27° 37′ N, 81° 16′ W), Highlands and Polk counties, which is in south-central Florida, USA. APAFR is managed for multiple uses including military activities, timber resources, cattle grazing, natural areas, endangered species, and recreation uses, including hunting. The main plant communities in the study area include pine flatwoods, wet and dry prairies, and pine plantations, with some swamps, marshes, hammocks, scrub, and improved pastures. An endemic flatwoods community occurs on the installation called cutthroat grass (*Panicum abscissum*) flatwoods, which is dominated by the dense, coarse cutthroat grass (Bridges and Orzell 1999). The climate is characterized as humid subtropical, with mild, dry winters and hot, wet summers (Chen and Gerber 1990). The temperatures range from a monthly mean January temperature of 16°C to a monthly mean August temperature of 28°C. Most of the mean yearly rainfall of 127 cm falls from June to September (72 cm, 57%).

Burning has never ceased on the installation, but the season in which it is has burned has shifted from natural regimes (S. L. Orzell, APAFR, unpublished data). Ordnance fires can occur on the ranges at any time of the year. In south-central Florida, the natural season for fire occurrence was in the late spring to early summer, during the time period when there is usually an ongoing drought and lightning storms start occurring (Komarek 1964, Snyder 1991, Beckage et al. 2003, Slocum et al. 2003, W. J. Platt, Louisiana State University, unpublished data). The managers have been shifting some prescribed burning back to this time period over the last decade. During the study period most of the burns were during January (30%) and February (21%), followed by May (12%) and March (11%).

Methods

Call Counts

Since 1993, annual male whistle counts have been conducted for 7-9 weeks from April to June on seven permanent routes, which had 11-12 listening-stations each spaced ca. 0.8 km apart, for a total of 83 stations. The routes were distributed in a fairly even manner across the installation with no regard for habitat. The counts started around sunrise and continued for about 2 hours past sunrise until a given route was completed. The number of "bobwhite" calls and number of bobwhite calling for 8 minutes per station were recorded. Each route was repeated weekly during the time period with the order of stations reversed each time.

Since peak call rates coincide with peak breeding initiation activity and thus detection rates increase (Hansen and Guthery 2001), the four highest replications for a given route in bobwhite number were used for determining average bobwhite per station per year. In most years, the replications used were mostly in May with some weeks in early June and late April.

Listening Station Attributes

All stations were fixed with a global positioning system and a layer in ARCGIS created. In ARCGIS, we created 400-m buffers around each station, in order to obtain habitat and burn histories. Four hundred meters is within the range of the assumed audible distance of the "bobwhite" call for the human ear (Hansen and Guthery 2001). We discarded stations that overlapped more than 5% within the 400-m buffer from the analysis due to the possibility of non-independence of station data. We discarded 4 other stations because they bordered the property, so their management history was unknown. This left a total of 67 stations for analysis.

Habitat

Within each buffer, we determined the proportion of each habitat type based on a plant community GIS coverage created by Edwin Bridges (Table 1). Some habitats were further broken down by wet and dry/mesic classes and closed (moderate to dense closure) and open (none to sparse closure) canopy classes (Table 1). Based upon the dominant habitats (≥20% of the buffer area) and canopy closure of the optimal habitat (as determined from the analysis), we classified each station into five habitat groups. The five habitat groups were *OpOpt*, dominated by open canopy dry/mesic flatwoods, prairie, and/or cutthroat only (n = 17); *OptPl*, dominated by plantations and open canopy dry/mesic flatwoods, prairie, and/or cutthroat (wet habitat may be present, n = 18); *OptWet*, dominated by wet habitats and open canopy dry/mesic flatwoods, prairie, and/or cutthroat (n = 11); *ClOpt*, dominated by closed canopy dry/mesic flatwoods, prairie, and/or cutthroat only (n = 9); *Other*, dominated by habitats other than dry/mesic flatwoods, prairie, and/or cutthroat (n = 12). Mean bobwhite per habitat group per year were calculated for habitat group analysis. All means are given with ±1 SE.

Fire

Within each buffer, we determined the season of burn, proportion of area burned, and length of time between burns for the sample period. We categorized burn types into *dormant season burns* (DSB, from October of previous year to March of current year) and *growing season burns* (GSB, from previous year's April through September). Because of when the call counts were conducted, GSB effects were not assessed for almost a year after they happened because the burn may have occurred during or after the call count survey period. During the time of the study, most GSB occurred in May (39%), followed by June (26%) and April (21%). Therefore, we analyzed DSB and GSB separately.

We categorized stations by the proportion of area burned each year into the following categories: 0%, 10% (1-19%), 30% (20-39%), 50% (40-59%), and 80% (60-100%). To avoid confounding effects between seasons, 0% burns only represent incidents where neither a DSB nor GSB occurred. Due to sample sizes, the 10% and 30% categories and 50% and 80%

Table 1: Individual Wald P-values, coefficient sign, and percent of each habitat represented in the buffer areas with low abundance (< 2 bobwhite on average per station,n = 45) and high abundance ($\geq$ 2 bobwhite on average per station, n = 22) for variables used to determine optimal habitat logistic regression models at Avon Park Air Force Range, Florida, 1993-2005.

Habitat	Wald P-value	Coeff. sign	% Habitat Abundance Low	% Habitat Abundance High
Cutthroat	0.095	+	2.2	8.3
Dry/Mesic cutthroat	0.084	+	0.5	7.9
Open canopy dry/mesic cutthroat	0.109	+	0.5	6.7
Closed canopy dry/mesic cutthroat	0.980	+	0.0	1.1
Wet cutthroat	0.809	-	2.0	1.6
Flatwoods	0.262	-	45.6	37.5
Open canopy flatwoods	0.660	+	29.1	31.8
Closed canopy flatwoods	0.033	-	16.5	5.7
Dry/Mesic flatwoods	0.977	-	33.9	33.7
Open canopy dry/mesic flatwoods	0.133	+	21.0	29.7
Closed canopy dry/mesic flatwoods	0.058	-	12.9	4.0
Wet flatwoods	0.016	-	11.7	3.8
Open canopy wet flatwoods	0.052	-	8.1	3.2
Closed canopy wet flatwoods	0.065	-	3.6	0.5
Hammocks	0.370	-	1.4	0.2
Marsh and swamps	0.423	-	12.9	10.6
Improved pasture	0.415	-	4.8	1.3
Pine plantations	0.002	-	25.3	5.5
Open canopy pine plantations	0.547	+	0.6	1.2
Prairies	0.002	+	5.3	29.1
Open canopy prairies	0.004	+	4.6	27.5
Closed canopy prairies	0.499	+	0.8	1.5
Dry/Mesic prairies	0.004	+	2.1	25.9
Open canopy dry/mesic prairies	0.010	+	1.4	24.8
Closed canopy dry/mesic prairies	0.583	+	0.7	1.3
Wet prairies	0.990	+	3.2	3.3
Open canopy wet prairies	0.890	-	3.2	3.0
Closed canopy wet prairies	0.355	+	0.1	0.3
Roads and disturbed areas	0.016	+	4.5	11.4
Scrub	0.514	+	2.0	3.2
Wet areas	0.011	-	34.1	18.7
Open canopy wet areas	0.175	-	21.2	15.9
Closed canopy wet areas	0.006	-	12.9	2.8
Open canopy areas	0.000	+	52.9	88.1

categories were pooled when fire influences for each habitat group were examined.

Based on the results of this analysis, we investigated time since burn when at least 40% of the buffer area was burned. Time since burn was broken down into two to four classes, depending on the sample size of each class. For DSB, classes were $<$ *0.5 year, 1.5 years, 2.5 years, and 3.5 plus years* since the burn event. For GSB, classes were $<$ *1 year, 2 years, and 3 plus years* since the burn event. For burns in each habitat group, we reduced DSB classes by one, while we reduced growing season classes by one only for habitat group *OptWet*. We pooled habitat groups *ClOpt* and *Other* for this analysis, creating the habitat group *NoOpt*. Mean bobwhite per station per burn season and class per year were determined and repeated for each habitat group. All means are given with $\pm$1 SE.

Weather

We used raw precipitation (rain), number of days with $>$2.5 mm rain (rain days), and Palmer Modified Drought Index (PMDI) to determine weather effects on breeding season bobwhite abundance overall and after DSB and GSB. Palmer's Drought Severity Index takes into consideration precipitation, temperature, evapotranspiration index, runoff, soil recharge, and average regional weather conditions to measure departures from normal regional moisture supply, with the PMDI representing better real-time conditions and transitional periods (Heddinghaus and Sabol 1991). We determined raw precipitation and rain days from on-site weather stations. We obtained PMDI from NOAA's National Climatic Data Center for region 4 (south-central) in Florida. For overall abundance and abundance after a DSB, we calculated monthly, seasonal sums, and total yearly sums from previous year's April to current year's March. For abundance after a GSB, we used the previous year's October (before the burn) to the year's September after a GSB.

Data Analyses

We determined optimal habitat by forward stepwise logistic regression using Systat 7.0 (SPSS Inc. 1997). Used as the dependent variable, the stations were classified into two classes based on the mean number of bobwhite per station over all years: with less than two present (low abundance, n = 45) or with $\geq$ two present (high abundance, n = 22). We used the proportions of habitats within the buffers as independent variables. Broad habitat classes were used first, and then subclasses that are more distinct were used including different canopy closures within subclasses (Table 1). An alpha level of 0.15 was used for inclusion in model and 0.20 for removal from each model (Hosmer and Lemeshow 1989, 108). These values were used to avoid leaving out significant habitats as can happen in stepwise regression, especially if significance levels are too stringent. We determined each model's goodness of fit by using Hosmer-Lemeshow statistic (C, higher values mean higher significance of model) and percent correct. We also assessed each habitat class individually with the Wald statistic p-value and coefficient sign.

We analyzed habitat group and burn analysis by ANOVA with year as a main effect to account for yearly fluctuations. Bobwhite abundance was square-root transformed to meet assumptions of ANOVA. If there was a significant effect ($P < 0.05$), multiple range tests were conducted using least significant differences.

Weather variables were analyzed with correlation analysis using Pearson product-moment correlation coefficient. Some variables were log-transformed to meet the assumptions of normality. If transformations were not effective, spearman rank correlation was used (wet season rain days, dry season rain, and September rain days). Significance level was set at 0.10 for this analysis.

Results

During the 13 years of call counts, a total of 54242 calls and 5733 bobwhite were recorded ($\bar{x}$ = 14.7 $\pm$ 0.37 and $\bar{x}$ = 1.6 $\pm$ 0.03 per station, respectively). The highest abundance occurred in 2002 ($\bar{x}$ = 2.2 $\pm$ 0.25), followed by 1996 ($\bar{x}$ = 2.0 $\pm$ 0.17) and 2005 ($\bar{x}$ = 1.8 $\pm$ 0.16). The lowest abundance occurred in 1998 ($\bar{x}$ = 1.2 $\pm$ 0.12) and 1999 ($\bar{x}$ = 1.2 $\pm$ 0.11), followed by 2004 ($\bar{x}$ = 1.4 $\pm$ 0.14). The mean peak of calling rate occurred on Julian day 133 $\pm$ 0.5 (13 May), with the 2002 having the earliest mean calling peak ($\bar{x}$ = 122 $\pm$ 2.1, 2 May) and 2003 having the latest mean calling peak ($\bar{x}$ = 145 $\pm$ 1.7, 25 May).

Table 2: Optimal habitat model parameters, coefficients, odds ratios, Hosmer-Lemeshow statistic (C) and percent total correct as determined by logistic regression at Avon Park Air Force Range, Florida.

Model	Parameter[a]	Coeff. (SE)	Odds Ratio (95% CI)	C	Total Correct
1	Intercept	-4.00 (1.184)		0.221	73.1%
	CT	0.07 (0.025)	1.07 (1.123 - 1.019)		
	FL	0.04 (0.017)	1.04 (1.072 - 1.003)		
	PR	0.10 (0.027)	1.10 (1.160 - 1.043)		
2	Intercept	-2.81 (1.242)		0.339	84.2%
	OP PR	0.15 (0.052)	1.12 (1.292 - 1.054)		
	CCWA	-0.36 (0.172)	0.70 (0.977 - 0.500)		
	CT	0.14 (0.055)	1.15 (1.286 - 1.036)		
	OP FL	0.04 (0.022)	1.04 (1.089 - 1.001)		
3	Intercept	-5.52 (1.550)		0.370	81.8%
	DM CT	0.24 (0.102)	1.28 (1.559 - 1.044)		
	DM FL	0.07 (0.024)	1.07 (1.121 - 1.021)		
	DM PR	0.15 (0.043)	1.16 (1.264 - 1.068)		
4	Intercept	-5.73 (1.453)		0.563	85.7%
	OP DM CT	0.17 (0.090)	1.19 (1.419 - 1.001)		
	OP DM PR	0.22 (0.069)	1.25 (1.431 - 1.093)		
	OP DM FL	0.10 (0.028)	1.10 (1.166 - 1.044)		

[a] CT= Cutthroat, FL=Flatwoods, PR=Prairie, OP=Open Canopy, CCWA=Closed Canopy Wet Areas, DM= Dry-Mesic

Habitat

All of the optimal habitat models included flatwoods, cutthroat, and prairies (Table 2). Closed canopy flatwoods, closed canopy dry/mesic flatwoods, closed and open canopy wet flatwoods, wet areas, closed canopy wet areas, and pine plantations were not preferred habitat (Table 1). The most optimal habitat included open canopy dry/mesic cutthroat, open canopy dry/mesic prairies, and open canopy dry/mesic flatwoods. All models were significant, but model 4 yielded the best total correct (86%) based on the actual values versus expected values and a Hosmer-Lemeshow statistic of 0.563. Over 78% of the high stations and 89% of the low stations were correctly predicted by the model.

More bobwhite abundance significantly occurred in the *OpOpt* group ($\bar{x}$ = 2.4 $\pm$ 0.14) than the other habitat groups during the breeding season ($F_{4,48}$ = 78.38, $P < 0.001$). Wet areas (*OptWet*) were preferred to pine plantations (*OptPl*) as a codominant habitat type ($\bar{x}$ = 1.7 $\pm$ 0.11 and $\bar{x}$ = 1.4 $\pm$ 0.08, respectively). The least amount of bobwhite occurred at stations which had less than 20% of optimal habitat present with either closed canopy dry/mesic habitats or other habitats ($\bar{x}$ = 1.0 $\pm$ 0.07 and $\bar{x}$ = 1.0 $\pm$ 0.07, respectively).

Fire

Proportion Burned - More bobwhite abundance occurred when at least 40% of the buffer area was DSB or GSB ($F_{4,46}$ = 7.56, $P < 0.001$; $F_{4,43}$ = 6.17, $P <$ 0.001, respectively; Table 3). For DSB, almost twice as many bobwhite were found at stations which had 60%+ of their buffers burned than stations which received no burns. The GSB impact was greatest when 40 to 59% of the buffer area burned.

Table 3: Mean bobwhite per station with dormant and growing season burns by percent buffer area burned and time since burn at Avon Park Air Force Range, Florida, 1993-2005.

	Dormant season burn			Growing season burn		
	#	SE	n[a]	#	SE	*n*
% buffer area burned, midpoints						
0	1.1C[b]	0.10	349	1.1BC	0.10	349
10	1.2C	0.11	86	0.9C	0.12	92
30	1.5BC	0.20	88	0.9C	0.14	83
50	1.8AB	0.19	104	1.7A	0.17	55
80	2.2A	0.32	71	1.4AB	0.22	30
P	< 0.001			< 0.001		
Years since burn						
< 1[c]	1.9A	0.22	175	1.7A	0.16	85
1-2	1.6A	0.13	161	1.5A	0.30	54
2-3	1.1B	0.15	101	0.9B	0.19	103
3+	0.7B	0.14	175			
P	< 0.001			0.026		

[a] number of occurrences in each category

[b] column means followed by the same letter or without letters were not different, $P > 0.05$ (LSD), for % buffer area burned and years since burn, respectively

[c] dormant season burns are closer to midpoint in years, while growing season burns are closer to upper value. Interval 2-3 for growing season burns represents all years beyond 2 years since burn. Burns occurred when at least 40% of buffer area was burned

When investigating burn effects within each habitat group, only *OpOpt* and *OptPl* had significantly higher bobwhite abundance when greater than 1% and 40% of a buffer area had a DSB, respectively ($F_{2,24}$ = 13.26, $P < 0.001$; $F_{2,23}$ = 6.22, P = 0.007, respectively; Table 4). *OptWet* had almost twice as many bobwhite at stations which were burned greater than 40% than at stations which were not burned, though it was not significant ($F_{2,17}$ = 3.26, P = 0.063). Only the *OptWet* habitat group had significantly more bobwhite abundance when at least 40% of the buffer area had a GSB ($F_{2,16}$ = 4.19, P = 0.034; Table 5).

Time Since Burn - Considering only time since burn for burns which had at least 40% of their buffer burned, bobwhite abundance increased within one year of a DSB or GSB by as much as 171% and 89%, respectively, then significantly decreased after 2 or more years post burn ($F_{3,36}$ = 11.10, $P < 0.001$; $F_{2,23}$ = 4.30, P = 0.026, respectively; Table 3). Higher bobwhite abundance followed DSB than GSB, though not a significant amount (P = 0.337).

After a DSB occurred, only *OpOpt* and *OptWet* habitat groups significantly increased in bobwhite abundance (65% and 250%, respectively), which significantly decreased after 1.5 years post burn ($F_{2,21}$ = 4.69, P = 0.020; $F_{2,18}$ = 9.69, P = 0.001, respectively; Table 4). After a GSB occurred, only *OpOpt* habitat group significantly increased in bobwhite abundance (156%), which significantly decreased after 2 years post burn ($F_{2,16}$ = 6.36, P = 0.009; Table 5).

Weather

Of the seasonal and yearly weather variables, only wet season rain days was significantly corre-

Table 4: Mean bobwhite per station after dormant season burns by percent buffer area burned and time since burn for each habitat group at Avon Park Air Force Range, Florida, 1993-2005.

	Habitat group[a]											
	OpOpt			*OptPl*			*OptWet*			*NoOpt*		
	#	SE	n[b]	#	SE	n	#	SE	n	#	SE	n
% buffer area burned, midpoints												
0	1.9B[b]	0.12	91	1.0B	0.15	81	1.1	0.19	58	0.8	0.11	119
20	2.6A	0.22	48	0.8B	0.16	58	1.5	0.35	16	0.9	0.14	52
70	2.8A	0.26	59	1.7A	0.31	38	2.1	0.35	37	1.1	0.27	41
P	< 0.001			0.007			0.063			0.352		
Years since burn[c]												
< 0.5	2.8A	0.26	59	1.7	0.31	38	2.1A	0.35	37	1.1	0.27	41
1.5	2.4A	0.28	42	1.4	0.21	44	1.7A	0.32	29	1.1	0.15	46
2.5+	1.7B	0.17	61	0.9	0.13	66	0.6B	0.19	46	0.6	0.09	103
P	0.02			0.054			0.001			0.097		

[a] OpOpt = optimal habitat dominated only, OptPl = optimal habitat with pine plantations dominated, OptWet = optimal habitat with wet habitats dominated, NoOpt = other, no optimal habitat dominated

[b] number of occurrences in each category

[c] column means followed by the same letter or without letters were not different, $P > 0.05$ (LSD), for % buffer area burned and years since burn, respectively

[d] burns occurred when at least 40% of buffer area was burned

lated (r_s = 0.50, P = 0.082; Table 6). Bobwhite abundance was negatively correlated with April and May PMDI and November rain (r = -0.54, P = 0.055, r = -0.60, P = 0.030, and r = -0.61, P = 0.025, respectively; Figure 1a). Bobwhite abundance was positively correlated with October PMDI and July rain days (r = 0.53, P = 0.061 and r = 0.60, P = 0.030, respectively; Figure 1a).

Bobwhite abundance after DSB was negatively correlated with April and November rain (r = -0.69, P = 0.009 and r = -0.67, P = 0.013, respectively; Figure 1b). Also, bobwhite abundance after DSB was negatively correlated with January, February, winter, and dry season rain days (r = -0.52, P = 0.066, r = -0.59, P = 0.035, r = -0.60, P = 0.032, and r = -0.62, P = 0.024, respectively; Table 7 and Figure 1b).

Bobwhite abundance after GSB was negatively correlated with October, November, December, and Fall PMDI preceding that growing season (r = -0.48, P = 0.099, r = -0.52, P = 0.067, r = -0.50, P = 0.079, and r = -0.52, P = 0.069, respectively; Figure 1c). Also, bobwhite abundance after GSB was negatively correlated with fall rain and December rain days preceding that growing season (r = -0.53, P = 0.061 and r = -0.60, P = 0.030, respectively; Table 7 and Figure 1c). Contrary to normal weather patterns for the region, positive correlations occurred between bobwhite abundance and April rain and January rain days preceding that growing season (r = 0.70, P = 0.008 and r = 0.49, P = 0.087, respectively; Figure 1c).

Discussion

Habitat

Being ground dwelling and nesting birds, bobwhite preferred dry/mesic habitats, especially open

Table 5: Mean bobwhite per station after growing season burns by percent buffer area burned and time since burn for each habitat group at Avon Park Air Force Range, Florida, 1993-2005.

	Habitat group[a]											
	OpOpt			*OptPl*			*OptWet*			*NoOpt*		
	#	SE	n[b]	#	SE	n	#	SE	n	#	SE	n
% buffer area burned, midpoints												
0	1.9	0.12	91	1	0.15	81	1.1B[c]	0.19	58	0.8AB	0.11	119
20	1.9	0.35	26	1.1	0.08	53	0.9B	0.16	16	0.6B	0.1	70
70	2.3	0.16	24	1.4	0.23	24	1.8A	0.31	37	1.1A	0.19	21
P	0.416			0.204			0.034			0.041		
Years since burn[d]												
< 1	2.3A	0.16	24	1.4	0.23	24	1.8	0.31	16	1.1	0.19	21
2	2.5A	0.51	12	1.2	0.23	19	1.6	0.35	18	0.7	0.17	15
3+	0.9B	0.2	18	1	0.43	27				0.8	0.19	48
P	0.009			0.646			0.719			0.478		

[a] OpOpt = optimal habitat dominated only, OptPl = optimal habitat with pine plantations dominated, OptWet = optimal habitat with wet habitats dominated, NoOpt = other, no optimal habitat dominated

[b] number of occurrences in each category

[c] column means followed by the same letter or without letters were not different, $P > 0.05$ (LSD), for % buffer area burned and years since burn, respectively

[d] burns occurred when at least 40% of buffer area was burned

canopy habitats. During the beginning and middle part of the breeding season, drier habitats were not usually flooded by sheet flow; thus, nests were safer from flooding. Open canopy habitats contained fewer perches for avian predators such as hawks and usually had more groundcover vegetation for forage and cover. These habitats also had the necessary microhabitat requirements for the breeding season (i.e., nesting sites with escape and forb cover, bare ground, and food resources nearby), especially if fire was periodically used. Much of the vegetation was heterogeneous across the landscape, with scattered saw palmetto clumps, a diversity of grasses, sedges, and forbs, and scattered low-growing shrub patches. Cattle and other animal trails and localized lower areas created bare ground as well as general scattered bare ground areas. Unlike bobwhites adjusting to the agricultural fields further north, bobwhites in south-central Florida have evolved with vast open habitat that has only recently been fragmented.

As others have shown (DeVos and Mueller 1993, Kitts 2004), pine plantations and closed canopy forests were not preferred habitats because they had a dense canopy, plentiful perches for hawks, less herbaceous vegetation, and much less bare soil. In Mississippi, Lee and Brennan (1994) showed a reduction in the bobwhite population as the forests with >50% canopy cover became more abundant over 38 years in their study area. Using logistic regression and landsat imagery, Schairer et al. (1999) found a negative association between bobwhite abundance and patch size of deciduous forest in Virginia. Provencher et al. (2002) found higher bobwhite abundance after hardwood midstory re-

Table 6: Correlations between number of mean bobwhite per station and annual (Apr-Mar) and seasonal Modified Palmer Drought Severity Index (PMDI), rain, and number of rain days at Avon Park Air Force Range, Florida, 1993-2005.

	PMDI		Rain		Rain days[a]	
Season	*r*	*P*	*r*	*P*	*r*	*P*
Annual	-0.12	0.702	-0.03	0.925	0.23	0.457
Spring	-0.06	0.841	-0.21	0.498	0.02	0.941
Summer	-0.09	0.765	0.30	0.325	0.42	0.143
Fall	0.42	0.153	0.14	0.655	0.24	0.421
Winter	-0.12	0.702	-0.21	0.487	-0.26	0.385
Wet (Jun-Sep)	0.07	0.828	0.41	0.164	0.50	0.082
Dry (Oct-May)	0.01	0.966	0.16	0.603	-0.22	0.470

[a] Rain days = every day that at least 0.25 cm fell

duction treatments over no treatment in northwest Florida sandhills. Cram et al. (2002) had a significant bobwhite abundance response to thinning pine-hardwood stands in Arkansas. Therefore, if the closed canopy were reduced below some level, bobwhite would utilize the area.

Bobwhite showed a higher preference for wet areas in conjunction with dry/mesic habitats than for plantations in conjunction with dry/mesic habitats because some of these wet areas habitats had little or no canopy, were dry during the early breeding season, and had their main food source in south-central Florida, slough grass (*Scleria reticulata*). Slough grass, an annual sedge, was frequently found in wet areas and in disturbed mesic areas. During the study period, many of the hunting season crops had slough grass present as a main component. During the winter, Yoho and Dimmick (1972) and Dixon et al. (1996) had some of their coveys preferentially use wet areas.

Fire

Despite the vegetation having less than 6 months (frequently less than 3 months) to recover after a DSB, bobwhite abundance was elevated in these burned areas the year of the burn as well as the following year. Bobwhite abundance increased more after large acreage fires than small acreage fires. In south Florida, Moore (1972) advocated the use of fire and burning about a third to a half of an area yearly in south Florida pinelands, which supports our findings. In Alabama, Speake (1994) reported increases in fall bobwhite abundance after DSB, particularly with frequent fires. In red-cocked woodpecker (*Picoides borealis*) restoration stands subjected to thinning and fire, Cram et al. (2002) found higher bobwhite abundance after 1 year post burn as compared to unburned and unthinned stands but even higher abundance after 2 years post burn. In south-central Florida, the vegetation can recover quickly from fire and many plant species flower more profusely or only after fire (Myers and Boettcher 1987, Abrahamson and Hartnett 1990, Maliakal et al. 2000, Myers 2000). Increased slough grass seed heads have been found after burns (Frye 1954, Moore 1972). The fires reduced litter and the woody cover for awhile and consumed old saw palmetto fronds, making traveling easier under this frequently used escape and loafing cover and nest sites (Moore 1972). Without fire, saw palmetto and litter cover would increase with time, which would reduce herbaceous and bare ground over time (Maliakal et al. 2000).

An endangered, ground-nesting songbird found

Table 7: Correlations between number of mean bobwhite per station for stations that were burned and annual (Apr-Mar for dormant and Oct-Sept for growing) and seasonal Modified Palmer Drought Severity Index (PMDI), rain, and number of rain days at Avon Park Air Force Range, Florida, 1993-2005.

	Dormant season burns						Growing season burns					
	PMDI		Rain		Rain days[a]		PMDI		Rain		Rain days	
Season	*r*	*P*	*r*	*P*	*r*	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Annual	-0.31	0.299	-0.28	0.348	-0.14	0.646	-0.30	0.316	-0.03	0.935	0.02	0.957
Spring	-0.25	0.415	-0.24	0.425	-0.33	0.273	-0.05	0.859	0.19	0.533	0.25	0.401
Summer	-0.11	0.714	0.01	0.972	0.18	0.566	-0.17	0.569	0.10	0.745	-0.12	0.707
Fall	0.15	0.620	0.09	0.777	0.01	0.982	-0.52	0.069	-0.53	0.061	-0.09	0.761
Winter	-0.42	0.151	-0.47	0.105	-0.60	0.032	-0.36	0.226	-0.10	0.740	0.11	0.726
Wet (Jun-Sep)	-0.02	0.949	0.18	0.565	0.24	0.437	-0.11	0.720	0.16	0.595	0.08	0.789
Dry (Oct-May)	-0.27	0.378	0.04	0.890	-0.62	0.024	-0.29	0.329	-0.30	0.310	0.18	0.556

[a] Rain days = every day that at least 0.25 cm fell

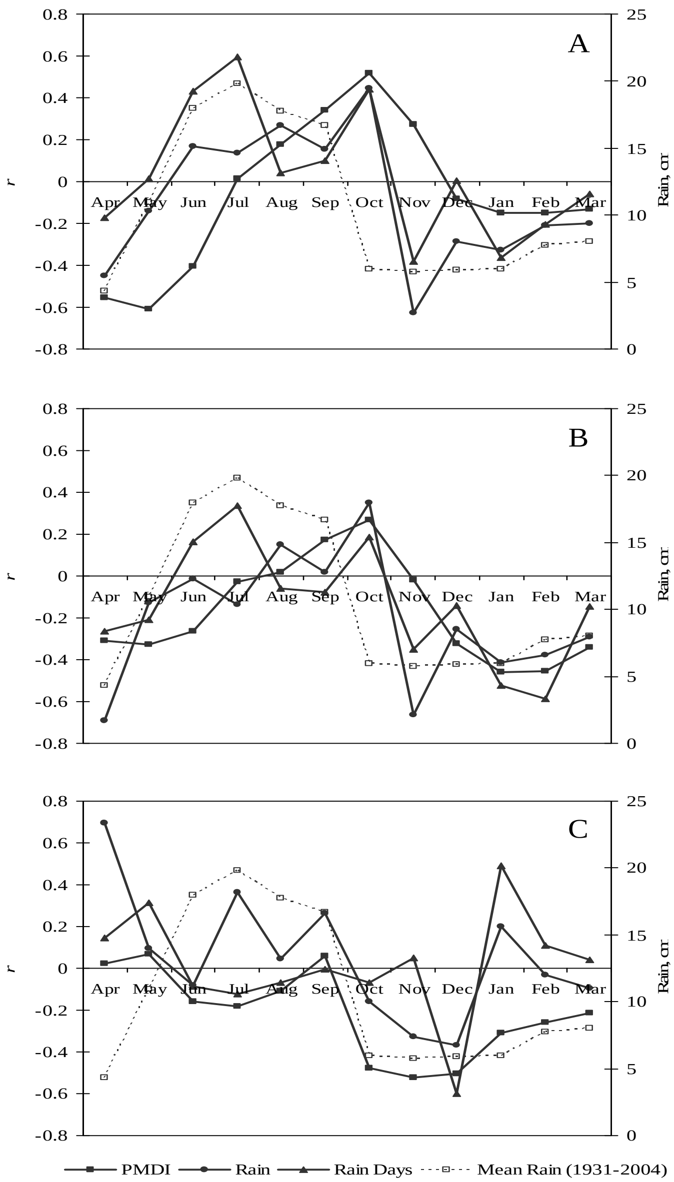

Figure 1: Correlations between number of mean bobwhite per station and monthly Modified Palmer Drought Severity Index (PMDI), rain, and number of rain days at Avon Park Air Force Range, Florida, 1993-2005. A.) Overall abundance. B.) Bobwhite abundance after a dormant season burn bobwhite abundance. C.) Bobwhite abundance after a growing season burn.

in Florida dry prairies, the Florida grasshopper sparrow (*Ammodramus savannarum floridanus*), has also been shown to be positively affected by frequent DSB (Walsh et al. 1995, Delany et al. 2002). Walsh et al. (1995) found that sparrows selected areas recently burned and avoided areas >2 years post burn. Investigating density and reproduction in the sparrows, Delany et al. (2002) reported significantly higher reproductive success at the population level with fire, which reduced with time, but they found no density differences with time since burn. Thus, other ground-nesting birds in dry prairies show similar responses to fire as bobwhite do.

Unfortunately, the GSB burns were not evaluated within a few months of their occurrence because they were mostly conducted during or shortly after each year's call-count. If we had conducted a fall count, differences between GSB with DSB could have been assessed more accurately. Even so, bobwhite abundance did increase within a year of a GSB and did not significantly decline until after 2 years post burn. If the burn was conducted during the drought period in April and May (as most of our burns were), more vegetation would have been consumed with a GSB than a DSB, leaving fewer nesting sites and less escape cover. As with a DSB, vegetation quickly recovers after a GSB, especially once the summer rains start, but shrubs may be more negatively impacted by a GSB. Shriver et al. (1999) found Florida grasshopper sparrows using summer burned areas within a week of their burns and being reproductively active into September. Many of the local plant species flower only or flower more profusely after a GSB, with these mostly being the fall-blooming grasses, sedges, and composites (Abrahamson 1984, Seamon et al. 1989, Robbins and Myers 1992, Streng et al. 1993, Main and Barry 2002). Also, arthropods may increase after burning (Hurst 1972, DeVos and Mueller 1993, Hermann et al. 1998). Therefore, bobwhite abundance almost a year after a GSB may be a reflection of improved forage the preceding summer, fall, and winter before the census.

The main impact after an early GSB would be a reduction of the breeding season due to nest site reduction and increased nest predation, with more nests later in the season than in the early part of the season (Simpson 1972). This is probably why bobwhite abundance peaked when 40 to 59% of a buffer was burned, as there would be areas left unburned. Stations that had optimal habitats and wet areas dominating had a significant increase in bobwhite abundance when greater than 40% of the buffer area was burned, probably due to some areas being too wet to burn and leaving more unburned patches. Weather may ameliorate negative effects of GSB.

Weather

Unlike studies in more arid climates, typical weather patterns were more conducive to bobwhite abundance than deviations from the norm. In the more humid regions of Texas, Bridges et al. (2001) found no correlations between bobwhite abundance and weather. Despite a dry season here, increased wet conditions during the dry season did not have a positive influence on bobwhite breeding abundance.

We did find a positive correlation between bobwhite abundance and July and wet season rain days, but we did not identify an effect due to the amount of rain or PMDI. Though other southeastern weather studies have shown a positive association with a wet or typical summer rainfall and bobwhite abundance or reproduction (Murray 1959, Reid and Goodrum 1960, Speake and Haugen 1960), it seemed more important to have consistent rain rather than large amounts of rain in south-central Florida. Less rain days in July might stress the bobwhite when ambient temperatures are already very high so that more do not survive the harsh summer, especially the young. Increasing rain days might increase the amount of forage on herbaceous plants and insects. Frye (1948) contended that extremely wet summers might actually drown chicks and adults, especially with major flooding events like hurricanes. We found no negative correlations with summer rain, but our study area is generally better drained than that of Frye (1948). He also found higher bobwhite abundance after wet a May, which is contrary to our results. Weather's influence on bobwhite abundance after fire followed the same overall weather trend, except for a positive correlation between bobwhite abundance and April rain and January rain days after a GSB. Fires after a dry fall and winter could result in more fine fuels available for consumption, more vegetation and fuels being consumed and greater of an impact on the resulting vegetation, more wet areas burning that would normally be too wet to burn, and opening up more space (Slocum et al. 2003, Thaxton and Platt 2006). Wet of conditions for DSB would produce very patchy burns and a reduction of effectiveness in increasing usable space if the area was overgrown. With a wet April and more rain days in January, a GSB would probably be more spotty and not burn across the landscape as well (Slocum et al. 2003). Also, the vegetation would probably recover more quickly, increasing usable space more rapidly than in dry years and possibly increasing successful reproduction.

Management Implications

By knowing which habitats in a given area are optimal for bobwhite abundance, managers can better manage for bobwhites. In south-central Florida, optimal habitat was open canopy dry/mesic habitats, especially dry prairie. Reducing canopy coverage and burning increased useable space in these habitats. A mosaic of optimal habitats with marginal or unsuitable habitats is better than no optimal habitat present within the management area. In south-central Florida, bobwhite respond favorably to fire, especially DSB when optimal habitats were present. After 2 years post burn, bobwhite abundance declines. To keep the diverse ground cover intact and viable, the woody cover reduced, and the open ground, frequent fire is needed in these habitats (Moore 1972, Lewis and Harshbarger 1986, Hermann et al. 1998). A burn cycle of 2-4 years would be best in south-central Florida in optimal habitats. Fire effects on bobwhite abundance can interact. A dry winter and dry season produces a better outcome for bobwhite abundance when a DSB is conducted, probably due to more fuel being consumed. Vegetation and insects may colonize quicker after a wet April when a GSB is conducted. As with DSB, GSB benefit bobwhite abundance more after a dry fall and winter. Other interactions of management activities (such as grazing and hunting) with weather should be investigated further to see if management may ameliorate weather impacts on abundance. Also, linking actual reproduction measures and movement studies to these findings would be useful.

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