National Quail Symposium Proceedings

Volume 6 Article 24

2009

Population Response of Northern Bobwhite to Field Border Management Practices in Mississippi

Mark D. Smith
Missisippi State University

L. Wes Burger Jr.
Mississippi State University

Population Response of Northern Bobwhite to Field Border Management Practices in Mississippi

Mark D. Smith[1,2], **L. Wes Burger, Jr.**

Department of Wildlife and Fisheries, Mississippi State University, Box 9690, Mississippi State, MS 39762, USA

Empirical relationships of the intensity and spatial extent of field border management required to elicit measurable population responses of northern bobwhite are needed. We established 90.5km of herbaceous field borders (6.1 m wide) along row crop field edges on one half of each of 3 - 800-ha agricultural landscapes in northeast Mississippi. Mean percentage of row crop fields established in field borders was 6.0%. During 2000-2002, we measured breeding season abundance and fall density on all 3 sites and survival of radiomarked bobwhite on 2 of the 3 sites. We used space-use models of bobwhite habitat composition and configuration to estimate changes in habitat suitability resulting from field border implementation. Breeding season survival did not differ between bordered (S = 37.2, SE = 0.06) and non-bordered (S = 42.7, SE = 0.09; χ^2_1 = 0.001, P = 0.97) sites. Moreover, bordered and non-bordered sites did not differ significantly with respect to breeding season call counts (bordered = 1.0, SE = 0.18; non-bordered = 0.8, SE = 0.27; $F_{1,10}$ = 0.44, P = 0.22) and fall density (bordered = 0.2 birds/ac, SE = 0.07; non-bordered = 0.1 birds/ac, SE = 0.05; $F_{1,10}$ = 2.18, P = 0.17). However, field borders increased the amount of usable space on average up to 13.1% on bordered landscapes. The relatively low percentage of field borders established on our sites was not sufficient to elicit measurable population responses of bobwhite. We recommend at least 5-10% of a study area be placed in field border habitats to enhance local bobwhite populations.

Citation: Smith MD, Burger LW Jr. 2009. Population response of northern bobwhite to field border management practices in Mississippi. Pages 220 - 231 in Cederbaum SB, Faircloth BC, Terhune TM, Thompson JJ, Carroll JP, eds. Gamebird 2006: Quail VI and Perdix XII. 31 May - 4 June 2006. Warnell School of Forestry and Natural Resources, Athens, GA, USA.

Key words: abundance, *Colinus virginianus*, habitat modeling, Mississippi, northern bobwhite, space use, suitability

Introduction

Northern bobwhite (*Colinus virginianus*; hereafter bobwhite) are one of the most intensively studied game-birds in North America; resulting in a wealth of published literature on bobwhite ecology. Despite this wealth of accumulated knowledge, bobwhite populations continue to decline over most of their historic distribution (Church et al. 1993, Sauer et al. 2003). Habitat loss/degradation due to agricultural intensification, conversion of native grasslands to exotic forage grasses, advanced natural succession, intensive grazing, summer mowing, intensive silvicultural practices, and suppression of natural disturbance regimes (fire) have been identified as probable causes for this continued decline (Stoddard 1931, Exum et al. 1982, Roseberry and Klimstra 1984, Brennan 1991, Hunter et al. 2001). Only recently has there been a coordinated range-wide effort to restore bobwhite populations. In 2002, the Southeast Quail Study Group technical committee, as requested by the Directors of the Southeastern Association of Fish and Wildlife Agencies, developed a range-wide bobwhite habitat restoration and population recovery plan.

The Northern Bobwhite Conservation Initiative (NBCI; Dimmick et al. 2002) is a habitat-based conservation plan designed to restore bobwhite populations to levels observed in 1980. One of the primary objectives of NBCI is to increase the amount and enhance the quality of agricultural lands for nesting, brood rearing, and roosting by bobwhites (Dimmick et al. 2002).

Most (81%) of the 2.8 million coveys needed to reach NBCI population goals are predicted to be produced on 8.4 million ha of farmlands within

[1]**Correspondence**: mds0007@auburn.edu
[2]**Current Address**: School of Forestry and Wildlife Sciences, 3301 Forestry and Wildlife Sciences Building, Auburn University, AL 36849-5418.

the planning region (Dimmick et al. 2002). Creation and maintenance of native grass and forb communities is the primary management practice through which agricultural lands would presumptively be enhanced. Practices encouraged under the USDA National Conservation Buffer Initiative such as field borders, filter strips, and riparian buffers, offer unprecedented opportunities to enhance bobwhite habitat at a scale commensurate with NBCI goals.

Field borders, defined as intentionally managed herbaceous plant communities along crop field edges to provide environmental and wildlife habitat benefits, are one type of conservation buffer practice. Field borders are often used in addition to existing field edge habitats such as fence rows and drainage ditches to reduce soil erosion (Dillaha et al. 1989), increase herbicide and nutrient retention (Webster and Shaw 1996), or to provide wildlife habitat (Davison 1941, Bryan and Best 1991, Puckett et al. 1995, Palmer et al. 2005). Whereas field borders are advocated as a priority in NBCI, the ability of this site-specific management practice to elicit measurable (using currently available indices and census techniques) population responses at local (farm), state, or regional scales throughout the NBCI coverage area is less well understood. Empirical relationships of the intensity and spatial extent of field border management required to elicit measurable population responses of bobwhite are needed. Only Palmer et al. (2005) and Puckett et al. (2000) have examined effects of field border and filter strip habitats, respectively, on bobwhite survival, reproduction, and abundance in the Upper and Lower Coastal Plains of North Carolina.

More than a decade ago, Roseberry (1993) suggested a shift in bobwhite research from emphasis on site and practice-specific research to consideration of the spatial arrangement and extent of habitat management. Likewise, Capel et al. (1993) suggested future research should focus on determining minimal and optimal sizes of habitat management units. However, only Guthery (1997, 1999) has attempted to formalize hypotheses about the quantity and spatial arrangement of suitable habitat as driving mechanisms behind bobwhite population response at local scales. Few experimental studies have addressed this issue. If field borders are to be implemented at a nation-wide scale to increase or maintain bobwhite populations within agricultural landscapes, as encouraged by NBCI and multiple government sponsored programs, empirical relationships regarding intensity and spatial extent of field border practices required to elicit measurable population responses of bobwhite must be addressed. Our objectives were to measure bobwhite population response, survival, and changes in the amount of usable space (Guthery 1997) relative to field border establishment in agricultural landscapes in northeast Mississippi.

Study Area

Our study was conducted on 3 privately owned farms (BRYAN, 3,172 ha; CHANCE, 3,123 ha; MAST, 2,185 ha) in Clay and Lowndes counties, Mississippi. Located within the Black Prairie physiographic region of northeast Mississippi, all sites had a history of agriculture use with most sites actively producing crops for more than 50 years. Primary agricultural practices were row crop (soybean [*Glycine max*], corn [*Zea mays*]), forage, and livestock production. Sites were selected based on similarities in cropping practices, landscape composition (approximately 60-80% row crop), soil associations, and landowner cooperation to maximize homogeneity among and within sites. Most grasslands on each site consisted of perennial, exotic cool (tall fesuce [*Festuca arundinacea*]) and warm season (Bermuda grass [*Cynodon dactylon*], Bahia grass [*Paspalum notatum*]) forage grasses. However, some small remnant and re-introduced stands of native warm-season grasses (big bluestem [*Andropogon gerardii*], little bluestem [*Schizachyrium scoparium*], broomsedge [*Andropodgon* sp.]) were scattered throughout each site. Most linear features (e.g., fencerows, drainage ditches) contained tall fescue and Johnson grass (*Sorghum halapense*). Periodically disturbed areas consisted of early successional grasses and forbs (paspalums

[*Paspalum* sp.], panic grass [*Panicum* sp.], giant ragweed [*Ambrosia trifida*], sumpweed [*Iva annua*], Johnson grass, golden rod (*Solidago* sp.) and partridge pea (*Chamaecrista fasciculata*). Wooded areas were predominantly oak (*Quercus* sp.), green ash (*Fraxinus pennsylvanica*), maple (*Acer* sp.) hickory (*Carya* sp.), sugarberry (*Celtis laevegata*) and eastern red cedar (*Juniperus virginiana*).

During early spring 2000, field borders (6.1 m wide) were established along agriculture field edges (fence rows, drainage ditches, access roads, and contour filter strips) on one half of each site. The field border treatment was assigned randomly to approximately each half of each study site (BRYAN, 1,731 ha; CHANCE 1,471 ha; MAST 1046 ha). For row crop fields receiving field borders, mean field size was 26.9 ha (range = 2.9-146.9; Table 1) and mean percentage of the crop field converted to field borders was 6.0% (range = 0.5-15.3; Table 1). Due to differences in crop field size and configuration among sites, the BRYAN site had a greater percentage of crop field converted to field borders (8.8%) than the CHANCE (4.1%) and MAST (3.0%) sites. We defined our effective site size by buffering all cropping units which received field borders by 800 m (2 x radius of a circular range equivalent in size to the mean home range of resident radiomarked bobwhites). Overall, field borders (54.3 ha) composed between 0.8-1.3% of the total land area of bordered sections of each farm. Row crop field mean shape index was similar among sites (Table 1). Shape index was calculated as the patch perimeter divided by the minimum perimeter possible for a maximally compact patch of the corresponding patch area (McGarigal et al. 2002).

Producers were paid an initial $247.10/ha sign-up bonus with a $123.55/ha/year rental rate paid at the end of each growing season for land planted to field borders. Furthermore, producers were required not to mow, herbicide, or disk field borders during the three years of study. Use of field borders as "turn rows" during harvesting was permitted because this activity occurred generally after the nesting season for most birds, usually involved only one or 2 edges of a field, and facilitated producer participation in the study. Field borders were seeded initially in 2000 with a Kobe lespedeza (*Lespedeza striata*) and partridge pea mix at rates of 11.2 kg/ha and of 3.4 kg/ha, respectively. Following drought conditions during the 2000 growing season which resulted in poor plant growth, field borders were re-seeded in late spring 2001. However, despite these 2 attempts to establish a desired plant community, most field borders re-seeded naturally from seed present within the seed bank (i.e., fallow community). Common species were morningglory (*Ipomea* sp.), crab grass (*Digitaria ciliaris*), Johnson grass, hemp sesbania (*Sesbania exaltata*), nutsedge (*Cyperus esculentes*), and ragweed (*Ambrosia* sp.).

Methods

Survival

Wild bobwhites were captured from January-April each year from 2000-2002 with baited walk-in funnel traps (Stoddard 1931) or by night netting (Truitt and Dailey 2000) on the BRYAN and CHANCE sites. We also captured additional bobwhites from June-July of each year using call-back traps and by night-netting. Captured bobwhite were sexed, aged (adult/sub-adult), weighed, banded with a #7 aluminum leg band, and fitted with a 5-6 g pendant style radio transmitter (American Wildlife Enterprises, Tallahassee, Florida, USA), and then released at the capture site. Radio transmitters operated on 148.000-151.000 MHz bands and were equipped with a 12-hr motion sensitive mortality switch. Capture, handling, tagging, and radiomarking procedures were consistent with the Mississippi State University Institutional Animal Care and Use Committee guidelines (IACUC permit no. #99-212).

We used a programmable scanning receiver (R4000; Advanced Telemetry Systems, Inc., Isanti, MN) with a 3-element Yagi antennae to locate radiomarked birds. Wide-ranging birds were located using fixed wing aircraft. Radiomarked birds were located $\geq$5 times/week during the breeding season (15 April-15 September) by homing to $\leq$40 m and triangulating from positions referenced geographically

with a Trimble Geo-Explorer II hand-held global positioning system (GPS) unit. When a mortality signal was detected, we located the transmitter and determined fate of the radiomarked bird using evidence at the recovery site (bird remains, scat, tracks, whitewash) and transmitter damage (Dumke and Pils 1973).

We used Cox's partial likelihood regression (Cox 1975) in PROC PHREG (Allison 1995) in SAS (SAS Institute, Inc. 2002) to estimate survival and test hypotheses of no difference in proportional hazard among genders, ages, years, and treatment effect (bordered/non-bordered). Because of small sample sizes on the CHANCE site, we pooled radiomarked bird failure times with those of the BRYAN site. Radiomarked birds which moved $\geq$2 km from the sites prior to the breeding season were excluded from analyses. Birds which moved off the site during the breeding season were right censored on the last date they were found on the site. Likewise, birds for which transmitter failure was suspected were censored on the last date a transmitter signal was recorded. Breeding season survival was based on a 154-day interval (15 April-15 September) beginning with covey breakup and initiation of reproduction (Burger et al. 1995*b*) except for the non-bordered section of the CHANCE site in 2000. All radiomarked birds (n = 4; 3 female, 1 male) captured during the winter trapping session on this area died by early May before additional birds could be captured and radiomarked. Therefore, we only report survival estimates for the period of 23 May-15 September for the non-bordered sections of the BRYAN and CHANCE sites for 2000 only. This survival estimate does not reflect survival for the entire breeding interval (15 April - 15 September). We assumed gender and age classes were sampled randomly, individual survival times were independent, the censoring mechanism was random, and capturing, handling, and radiomarking did not affect survival (Pollock et al. 1989). Results of all tests were considered significant at α = 0.05.

Population response

We estimated annual fall density and relative covey abundance of bobwhites using the fall covey-call technique (Seiler et al. 2002, Wellendorf et al. 2004). We defined our sampling frame by overlaying a grid composed of 500-m x 500-m cells on each site to identify the pool of potential sampling cells within the ownership boundaries. For each site, we then selected randomly 3 cells from each of the bordered and non-bordered sections. Cell selections were re-randomized each year. Covey counts were conducted during late October-early November 2000-2002 (Wellendorf et al. 2002, 2004).

We placed one observer at midpoints along each side of a sampling cell $>$0.5 hours before sunrise (CST) to monitor morning covey calls until 0.25 hours after sunrise. Observers recorded time, azimuth, duration, and number of covey calls per calling event for coveys within and outside the cell. We then triangulated covey locations based on observer azimuths plotted on 1:10,000 scale GIS land cover/land use maps in relation to time of calling activity to determine number of coveys within the sampling cell. Because of likely differences among observers' abilities (hearing acuity, experience, and attentiveness) to detect covey calls, we used only covey detections for which $>$2 observers recorded a calling event at approximately the same time and location for fall density estimation. However, when estimating relative covey abundance (coveys heard/observer/morning), we used all covey detections recorded per observer regardless of the number of other observers who may have recorded the same calling event and covey location (within and outside of the sampling cell). This approach requires several assumptions because multiple observers may have detected the same calling event. However, we believe this approach to be a valid index of relative covey abundance because cells were distributed randomly and because effort (observers/cell) and intensity (# of cells/farm section) remained constant throughout the study. For a detailed description of density, calling rate, and variance estimation procedures see Smith (2001, 2004).

Table 1: Number, percentage of field border per field, size (ha), and shape index of fields receiving field borders at BRYAN, CHANCE, and MAST sites in Clay and Lowndes counties, MS, 2000-2002.

		% Field Border		Field Size		Shape Index	
Site	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
BRYAN	16	8.8	0.89	19.6	5.6	1.6	0.12
CHANCE	18	4.1	0.61	18.8	3.3	2.2	0.25
MAST	3	3.0	0.90	114.8	20.1	1.9	0.59
Overall	37	6.0	0.63	26.9	5.4	1.8	0.15

We used breeding season call counts (Bennitt 1951) to index annual bobwhite breeding density. Stations were arranged in grid fashion with a 800-m spacing between stations. All stations were geo-referenced and the same set of stations was used throughout the study. Call counts were conducted in mid-June between 0545-0900 hrs (CST) with average wind speeds <15mph. We recorded number of calling males heard during a 5-minute listening period at 102 stations (55 bordered, 47 non-bordered). Counts were conducted twice at each station during a 4-day interval each year.

For fall and breeding season relative abundance measures, we used a repeated measures ANOVA in a randomized complete block design in PROC MIXED (SAS Institute, Inc. 2002) to test the null hypothesis that abundance measures did not differ between bordered and non-bordered sites during the 3 years of study. Because subtle differences in landscape context and farming practices existed among the sites, we used site as a random block effect whereas year was the repeated time effect. The annual population measure at the half-site was used as the response variable. We modeled within-subject covariance (i.e., the repeated year effect) using the autoregressive (order 1) covariance structure. Results of all tests were considered significant at α = 0.05.

Habitat Modeling

We created a Geographic Information System (GIS) coverage for each site by digitizing land cover/land use polygons from 1:12,000 geo-referenced Digital Orthophoto Quarter Quadrangle (DOQQ) imagery. We used a hand held Global Positioning Systems (GPS) unit or IKONOS multi-spectral imagery acquired during the study for updating coverages. We subjectively grouped land cover/land use classes into habitat classes based on management regimes and/or similarities in vegetation characteristics. Pasture/hay fields, CRP fields, cover strips, and filter strips (GRASS) were grouped together due to similarity in structural characteristics, species composition, and/or lack of periodic disturbance. Wood lots, wooded fence rows and ditches, and road right of ways containing woody vegetation were grouped as WOODY. Row crops (ROWCROP) included soybeans, corn, or food plots. Roads, buildings, and water were classified as "ODD" areas. Field borders were classified as early succession habitats (SUCC). We created 2 GIS habitat coverages for the bordered sections of each site; one coverage before field borders were established and one coverage after field borders were established. We then converted these vector-based coverages to grid coverages (10m cell size) for analyses. To measure the impact of field borders on bobwhite habitat suitability, we used a logistic regression-based

Table 2: Breeding season (15 April-15 September) survival of radiomarked northern bobwhite at field border management sites in Clay and Lowndes counties, MS, 2000-2002.

	Border			No Border			Overall		
Year	n	S[a]	SE[b]	n	S[a]	SE[b]	n	S[a]	SE[b]
2000	37	34.3	0.10	16	75.0[c]	0.13	53	43.3	0.09
2001	37	35.6	0.09	34	32.1	0.09	71	33.1	0.07
2002	21	41	0.12	19	54.6	0.16	40	50.6	0.09
Pooled	95	37.2	0.06	69	42.7	0.09	164	40.8	0.05

[a]Interval survival
[b]Standard error of survival
[c]Survival from 23 May - 15 September

space-use model constructed from differences in the composition and structure of habitat patches within the home ranges of 285 radio-marked bobwhite and those of random ranges in the same landscape context as this study (Smith 2004). This model contained habitat metrics describing the relative dominance of woody patches (woody_lpi), percentage of early succession habitat (succ_pland), and total perimeter-to-area ratio of all patches (paramn). See McGarigal et al. (2002) for a description of metric formulae. We used the posterior probabilities generated from this logistic regression model to measure and spatially map bobwhite habitat suitability for the bordered sections of each site (HSI; Brennan et al. 1986). HSI was computed as:

$$\frac{e^{(-1.4916-0.0529(woody\_lpi)+0.0456(suc\_pland)+0.0011(paramn))}}{1+e^{(-1.4916-0.0529(woody\_lpi)+0.0456(suc\_pland)+0.0011(paramn))}}$$

We used the moving window process with a 400-m search radius in FRAGSTATS (McGarigal et al. 2002) to calculate respective model metrics for each grid cell in the land cover grid. We used a 400-m search radius because this distance produced an area equivalent in size to the median home range of bobwhites in this study. The value of the habitat metric generated within this 400-meter window was assigned to the center grid cell within the window. This process was repeated for each grid cell within the land cover grid, resulting in one habitat metric grid for each habitat metric contained within a model. We then used these habitat metric grids to computed respective HSI grids (posterior classification probabilities) using map algebra functions in ARCINFO GRID. We classified HSI values into 4 categories representing excellent (1.0-0.9), good (0.9-0.75), fair (0.75-0.5), and unsuitable (<0.5) habitat and report percentage change in each HSI category before and after border establishment for each site. More specific details on habitat model development are reported in Smith (2004).

Results

Survival

During 2000-2002, we radiomarked 209 bobwhite. However, only 168 birds were alive during the breeding season (15 April-15 September). Of these, 98 birds were right censored due to survival past the end of the breeding season (n = 49), movement from the site or loss of signal (n = 44), and transmitter failure or accidental researcher induced mortality (n = 5). Primary sources of mortality included avian (n = 6), mammalian (n = 20), unknown predator (n = 41), and unknown cause of death (n

= 3). Unknown mortalities were events in which an intact bird was found but no identifiable source of mortality could be identified. All intact birds were decomposed to an extent to preclude necropsy.

Breeding season survival did not differ by sex (MALE = 42.8, SE = 0.06, FEMALE = 31.3, SE = 0.08; χ^2_1 = 0.409, P = 0.52), age (ADULT = 30.7, SE = 0.09, SUB-ADULT = 41.0, SE = 0.05; χ^2_1 = 0.443, P = 0.44), or among years (2000 = 43.7, SE = 0.09, 2001 = 33.1, SE = 0.07, 2002 = 50.6, SE = 0.09; χ^2_1 = 0.428, P = 0.51). Furthermore, breeding season survival did not differ between bordered (S = 37.2, SE = 0.06) and non-bordered (S = 42.7, SE = 0.09; χ^2_1 = 1.707, P = 0.191; Table 2) sites. Overall breeding season survival was 40.8% (SE = 0.05; Table 2).

Population response

Fall density (birds/acre) did not differ between bordered ($\bar{\chi}$ = 0.18, SE = 0.067) and non-bordered ($\bar{\chi}$ = 0.11, SE = 0.049) sites ($F_{1,10}$ = 2.18, P = 0.17; Table 3). Likewise, number of coveys detected/observer/morning did not differ between bordered ($\bar{\chi}$ = 0.71, SE = 0.228) and non-bordered ($\bar{\chi}$ = 0.46, SE = 0.149) sites ($F_{1,10}$ = 3.34, P = 0.10; Table 3). Mean number of calling males/station during the breeding season did not differ between bordered ($\bar{\chi}$ = 0.98, SE = 0.181) and non-bordered ($\bar{\chi}$ = 0.80, SE = 0.269) sites ($F_{1,10}$ = 0.44, P = 0.22; Table 3).

Habitat Modeling

Overall landscape suitability was greater after field border establishment for the BRYAN (HSI_{before} = 0.32; HSI_{after} = 0.36), CHANCE (HSI_{before} = 0.23; HSI_{after} = 0.28), and MAST (HSI_{before} = 0.38; HSI_{after} = 0.49) sites. Assuming HSI $>$ 0.50 represents suitable habitat, habitat suitability increased by 7.6% on the BRYAN, 7.8% on the CHANCE, and 23.9% on the MAST sites (Table 4). However, relative effect size [(Bordered number of pixels with HSI $>$ 0.5 - Non-bordered number of pixels with HSI $>$ 0.5 for non-bordered) / (Non-bordered number of pixels with HSI $>$ 0.5)] differed among the study sites. Relative effect of field border establishment was greatest for the MAST site (79.6%), intermediate for the CHANCE site (66.7%), and lowest for the BRYAN site (33.9%). Field borders did not affect the amount excellent (HSI = 1.0-0.90) habitat on the CHANCE and MAST sites and only slightly (0.3%) increased the amount of excellent habitat on the BRYAN site.

Discussion

Survival is a critical component governing bobwhite population growth. Bobwhites in our study experienced similar survival to those reported in other studies within agricultural landscapes (33.2% Burger et al. 1995*a*), but lesser survival than on intensively managed areas (43.8%, 46.9%, 50.9%, respectively; Burger et al. 1998, Smith 2001, Taylor et al. 2000). Adult (30.7%) and sub-adult (41.0%) survival of radiomarked bobwhite in our study were similar to those reported in Puckett et al. (1995) (adult = 28%, sub-adult = 41%). Management techniques (e.g., burning, disking) recommended by Stoddard (1931), Rosene (1969) and others are practiced today to elicit positive population responses. Presumptively, these responses stem from increases in population vital rates (survival, reproduction) or rates of immigration. However, identifying and understanding the specific fitness benefits of field border management practices has been more difficult. Although the point estimates of survival for bordered areas suggest that bobwhite inhabiting field border areas may have experienced greater survival during the 2001 breeding season, this difference was not sufficient to elicit a measurable response in abundance during Fall 2001.

The NBCI is predicated on the assumption that nesting and brood-rearing habitat is lacking in agricultural landscapes and addition of native warm-season grass and forb communities will provide this essential resource (Dimmick et al. 2002). The presumption is that population response will occur through increased reproductive effort and/or success associated with expanded breeding habitat. Puckett et al. (2000) and Palmer et al. (2005) attributed population responses observed in their studies to enhanced reproductive success. The modest population response we observed clearly did

Table 3: Overall mean response of fall bird density (birds/acre), coveys detected/observer, and breeding season call counts for field border management sites in Clay, Lowndes, and Noxubee counties, MS, 1999-2002.

	Border		No Border		
	$\bar{x}$	SE	$\bar{x}$	SE	P-value
Fall Density	0.18	0.067	0.11	0.049	0.171
Coveys Heard	0.71	0.228	0.46	0.149	0.097
Call Count	0.98	0.181	0.80	0.269	0.219

not occur through substantively enhanced survival, thus increased reproductive effort or success was the likely mechanism for response. Although we collected information regarding reproductive performance, insufficient numbers of nests were available to obtain reliable estimates of reproductive success, thus precluding definitive statements regarding the role of reproduction in our results.

Bobwhite exhibit substantial reproductive ability to respond dramatically to favorable habitat conditions. Puckett et al. (2000) reported 59.1% more calling males/stations on one of 2 sites where filter strips were established. Greater abundance was recorded on both sites for breeding season flush count (430%) and catch-per-effort (89.3%) indices. Similarly, Palmer et al. (2005) observed on average 36.1% more bobwhite coveys on sites with field borders and predator removal than non-bordered sites across 3 years of study. Field borders in Palmer et al. (2005) comprised between 9-13% of the tillable land across all study sites. We observed similar, although not significant, relative effect sizes in fall density (65.8%), coveys heard/observer/morning (55.7%), and breeding season call counts (23.3%) indices to those reported in Puckett et al. (2000) and Palmer et al. (2005). Our observed effect sizes with a smaller amount of tillable land converted to field border habitats (6.0%) suggest that field borders may enhance bobwhite abundance, but given the magnitude of variation of the estimates and relatively small number of replicate landscapes in our study, these differences were not detectable statistically.

Field borders in our study were of comparable width (6.1 m) to the filter strips (6.9 m) in Puckett et al. (2000) and field borders (3.0-5.0 m) in Palmer et al. (2005). However, field borders in Puckett et al. (2000) comprised 4.9-9.4% of the landscape and approximately 5.6% of the Wilson county site. Field borders in our study comprised only 0.8-1.3% of the landscape of bordered sites. Because study area boundaries of the above studies were defined by land ownership without regard to the species under study, quantifying the percentage of field border habitats depends on the balance of other habitats within the study area. We defined our effective site size by buffering all cropping units which received field borders by 800 m (2x mean home range size of resident radiomarked bobwhites) which may differ from methods used in Puckett et al. (2000) for delineating study area boundaries, thus influencing percentage of land area in field borders. Based upon percentage of land area in field borders and field border width, the study area in Puckett et al. (2000) was more complex (i.e., greater edge density of field borders/ha) than sites in our study. Similarly, the size of fields receiving field borders in our study (26.9 ha) was much greater than those in Wilson (1.8 ha) and Hyde and Terrell (8 ha) counties in Palmer et al.

Table 4: Change in habitat suitability index values resulting from field border establishment on treatment sites in Clay, Lowndes, and Noxubee counties, MS, 1999-2002.

	BRYAN		CHANCE		MAST	
	Border	No Border	Border	No Border	Border	No Border
HSI	% [a]	%	%	%	%	%
1.000.90	0.6	0.3	0.0	0.0	0.0	0.0
0.900.75	9.5	4.6	8.5	3.7	21.9	8.4
0.750.50	19.9	17.5	11.0	8.0	32.0	21.6
<0.50	70.0	77.6	80.5	88.3	46.1	70.0

[a] Percentage of study area

(2005). In the context of Puckett et al. (2000) and Palmer et al. (2005), our results suggest that the percentage of the land base established in field borders, and presumably usable space, may play a greater role in eliciting population responses of bobwhite than field border width.

Although field borders have been demonstrated to elicit population responses in other studies (Puckett et al. 2000, Palmer et al. 2005), we observed only qualitative, not statistical, differences in abundance when field borders comprise between 0.8-1.3% of the land area of bordered sections of each site. Therefore, given our results in the context of those reported in Puckett et al. (1995, 2000) and Palmer et al. (2005), we suggest that at least 5-10% of a site be placed in field border habitats to elicit measurable responses from bobwhite populations.

On average, field borders increased the amount of suitable habitat for bobwhites by 13.1% across all sites with a mean relative effect size of 60.1%. However, overall mean landscape suitability remained relatively low (HSI = 0.23-0.49). This was due primarily to the relatively poor habitat that remained over the balance of the study sites. Change in habitat suitability was most pronounced on the MAST site which had substantially greater field size, thus less percentage in field borders than the BRYAN or CHANCE sites. This site was typical of most large scale production systems which emphasize field consolidation. Establishment of field borders within these systems will have a greater net effect on whole-farm habitat suitability for bobwhites. Field borders were not able to alter the amount of area deemed excellent (HSI = 1.0-0.90) on 2 of 3 sites; suggesting that field borders alone will not significantly provide optimum habitat across an entire farm. Insofar as a 0.8-1.3% change in land use resulted in a 7.6-23.9% increase in the amount of suitable bobwhite habitat, additional management (i.e., prescribed fire, herbicide renovation, etc.) of surrounding habitats will be necessary to further elevate whole-farm habitat suitability.

Resource professionals are being held under greater scrutiny and accountability for resources (time, money, etc.) expended on wildlife conservation. The NBCI plan estimated that changes in land management on 33.1 million ha of farm, forest, and range land would be necessary to achieve population goals; however, primary land use would be affected on only 6.2% of this area. Given that 5-10% of a farm must be converted to field border practices to elicit a measurable bobwhite response, additional management of surrounding habitats may be required to further elevate and maintain bobwhite

populations above pre-management levels (Palmer et al. 2005). Field border management practices encouraged by NBCI and the USDA National Conservation Buffer Initiative can be used to enhance bobwhite populations. However, the amount of field borders established will likely govern their ability to evoke measurable changes in population parameters or abundance. USDA conservation practices, such as the recently announced CP-33 (Bobwhite Buffers) practice, may enhance bobwhite habitat in agricultural landscapes with minimal changes in primary land use only if sufficient acreage is established as field border habitat. Using a focal area approach to target delivery of conservation practices such as CP33 may help to increase the proportion of the local landscape impacted above thresholds required to elicit measurable bobwhite population responses.

Acknowledgments

This study was funded by the Mississippi State University-Remote Sensing Technologies Center; the USDA-Natural Resource Conservation Service-Wildlife Habitat Management and Watershed Science Institutes; the Mississippi Department of Wildlife, Fisheries, and Parks; Southern Region Sustainable Agriculture Research and Education Program; Quail Unlimited, Monsanto; and the Forest and Wildlife Research Center, Mississippi State University. This manuscript is publication number WF233-0507 of the Forest and Wildlife Research Center, Mississippi State University.

References

Allison, P. D. 1995. Survival analysis using the SAS system: A practical guide. SAS Institute Incorporated, Cary, NC, USA.

Bennitt, R. 1951. Some aspects of Missouri quail and quail hunting. 1938-1948. Technical Bulletin 2:1–51, Missouri Conservation Commission.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555.

Brennan, L. A., W. M. Block, and R. J. Gutiérrez. 1986. The use of multivariate statistics for developing habitat suitability index models. Pages 177–189 *in* J. Verner, M. L. Morrison, and C. J. Ralph, editors. Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates. University of Wisconsin, Madison, WI, USA.

Bryan, G. G., and L. B. Best. 1991. Bird abundance and species richness in grassed waterways in Iowa rowcrop fields. American Midland Naturalist 126:90–102.

Burger, L. W., Jr., T. V. Dailey, E. W. Kurzejeski, and M. R. Ryan. 1995*a*. Seasonal and annual survival and cause specific mortality of northern bobwhite in Missouri. Journal of Wildlife Management 59:401–410.

Burger, L. W., Jr., M. R. Ryan, T. V. Dailey, and E. W. Kurzejeski. 1995*b*. Reproductive strategies, success, and mating systems of northern bobwhite in Missouri. Journal of Wildlife Management 59:417–426.

Burger, L. W., Jr., D. C. Sisson, H. L. Stribling, and D. W. Speake. 1998. Northern bobwhite survival and cause specific mortality on an intensively managed plantation in Georgia. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 52:174–190.

Capel, S., J. A. Crawford, R. J. Robel, L. W. Burger, Jr., and N. W. Sotherton. 1993. Strategic plan for quail management and research in the United States: Issues and strategies-agricultural practices and pesticides. Pages 172–173 *in* K. Church and T. Dailey, editors. Quail III: National Quail Symposium. Kansas Department of Wildlife and Parks, Pratt, KS, USA.

Church, K. E., J. R. Sauer, and S. Droege. 1993. Population trends of quails in North America. Pages 44–54 *in* K. E. Church and T. V. Dailey, editors. Quail III: National Quail Symposium. Kansas Department of Wildlife and Parks, Pratt, KS, USA.

Cox, D. R. 1975. Partial likelihood. Biometrika 2:269–276.

Davison, V. E. 1941. Wildlife borders-an innovation in farm management. Journal of Wildlife Management 5:390–394.

Dillaha, T. A., R. B. Reneau, S. Mostaghini, and D. Lee. 1989. Vegetative filter strips for agricultural non-point source pollution control. Pages 513–519 *in* Transactions of the American Society of Agricultural Engineers, volume 32.

Dimmick, R. W., M. J. Gudlin, and D. F. McKenzie. 2002. The northern bobwhite conservation initiative. Miscellaneous publication, Southeastern Association of Fish and Wildlife Agencies, SC, USA.

Dumke, R. T., and C. M. Pils. 1973. Mortality of radio-tagged pheasants on the Waterloo Wildlife Area. Technical Bulletin 72, Wisconsin Department of Natural Resources, WI USA.

Exum, J. H., R. W. Dimmick, and B. L. Dearden. 1982. Land use and bobwhite populations in an agricultural system in west Tennessee. Pages 6–12 *in* F. Schitoskey, E. C. Schitoskey, and L. G. Talent, editors. Proceedings of the Second National Bobwhite Quail Symposium. Arts and Sciences Research, Oklahoma State University, Stillwater, OK, USA.

Guthery, F. S. 1997. A philosophy of habitat management for northern bobwhites. Journal of Wildlife Management 61:291–301.

Guthery, F. S. 1999. Slack in the configuration of habitat patches for northern bobwhites. Journal of Wildlife Management 63:245–250.

Hunter, W. C., D. A. Buehler, R. A. Canterbury, J. L. Confer, and P. B. Hamel. 2001. Conservation of disturbance-dependent birds in eastern North America. Wildlife Society Bulletin 29:440–455.

McGarigal, K., S. A. Cushman, M. C. Neel, and E. Ene. 2002. FRAGSTATS: Spatial pattern analysis program for categorical maps, version 3.3.

Palmer, W. E., S. D. Wellendorf, J. R. Gillis, and P. T. Bromley. 2005. Effect of field borders and nest-predator reduction on abundance of northern bobwhites. Wildlife Society Bulletin 33:1398–1405.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: The staggered entry design. Journal of Wildlife Management 53:7–15.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, Jr., and T. L. Sharpe. 1995. Bobwhite nesting ecology and modern agriculture: A management experiment. Proceedings of the Annual Conference of Southeastern Fish and Wildlife Agencies 49:505–515.

Puckett, K. M., W. E. Palmer, P. T. Bromley, J. R. Anderson, Jr., and T. L. Sharpe. 2000. Effects of filter strips on habitat use and home range of northern bobwhites on Alligator River National Wildlife Refuge. Pages 26–31 *in* L. Brennan, W. Palmer, L. W. Burger, Jr., and T. Pruden, editors. Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL, USA.

Roseberry, J. L. 1993. Bobwhite and the "new" biology. Pages 16—20 *in* K. Church and T. Dailey, editors. Quail III: National Quail Symposium. Kansas Department of Wildlife and Parks, Pratt, KS, USA.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, IL, USA.

Rosene, W. 1969. The bobwhite quail: Its life and management. Rutgers University Press, New Brunswick, NJ, USA.

SAS Institute, Inc. 2002. SAS procedures guide, version 8.2. SAS Institute, Inc., Cary, NC, USA.

Sauer, J. R., J. E. Hines, and J. Fallon. 2003. The North American Breeding Bird Survey: Results and analysis 1966-2001. Version 2002.1, USGS Patuxent Wildlife Research Center, Laurel, MD, USA.

Seiler, T. P., R. D. Drobney, and T. V. Dailey. 2002. Use of weather variables for predicting fall covey calling rates of northern bobwhites. Proceedings of the National Quail Symposium 5:91–98.

Smith, M. D. 2001. Response of northern bobwhite to intensive habitat development on a prairie site in Mississippi. Ph.D. thesis, Mississippi State University, Mississippi State, MS, USA.

Smith, M. D. 2004. Wildlife habitat benefits of field border management practices in Mississippi. Ph.D. thesis, Mississippi State University, MS, USA.

Stoddard, H. L. 1931. The bobwhite quail: Its habits, preservation, and increase. Charles Scribner's Sons, New York, NY, USA.

Taylor, J. D., II, L. W. Burger, Jr., S. W. Manley, and L. A. Brennan. 2000. Seasonal survival and cause–specific mortality of northern bobwhite in Mississippi. Pages 103–107 *in* L. Brennan, W. Palmer, L. W. Burger, Jr., and T. Pruden, editors. Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL, USA.

Truitt, V. L., and T. V. Dailey. 2000. Efficiency of bait trapping and night lighting for capturing northern bobwhites in Missouri. Page 207 *in* L. Brennan, W. Palmer, L. W. Burger, Jr., and T. Pruden, editors. Quail IV: Proceedings of the Fourth National Quail Symposium. Tall Timbers Research Station, Tallahassee, FL, USA.

Webster, E. P., and D. R. Shaw. 1996. Impact of vegetative filter strips on herbicide loss in runoff from soybean (*Glycine max*). Weed Science 44:662–671.

Wellendorf, S. D., W. E. Palmer, and P. T. Bromley. 2002. Factors influencing early morning covey calling in northern bobwhites. Proceedings of the National Quail Symposium 5:217.

Wellendorf, S. D., W. E. Palmer, and P. T. Bromley. 2004. Estimating call rates of northern bobwhite coveys and censusing population. Journal of Wildlife Management 68:672–682.