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FIG. 1. Location of study sites in North Carolina, USA.

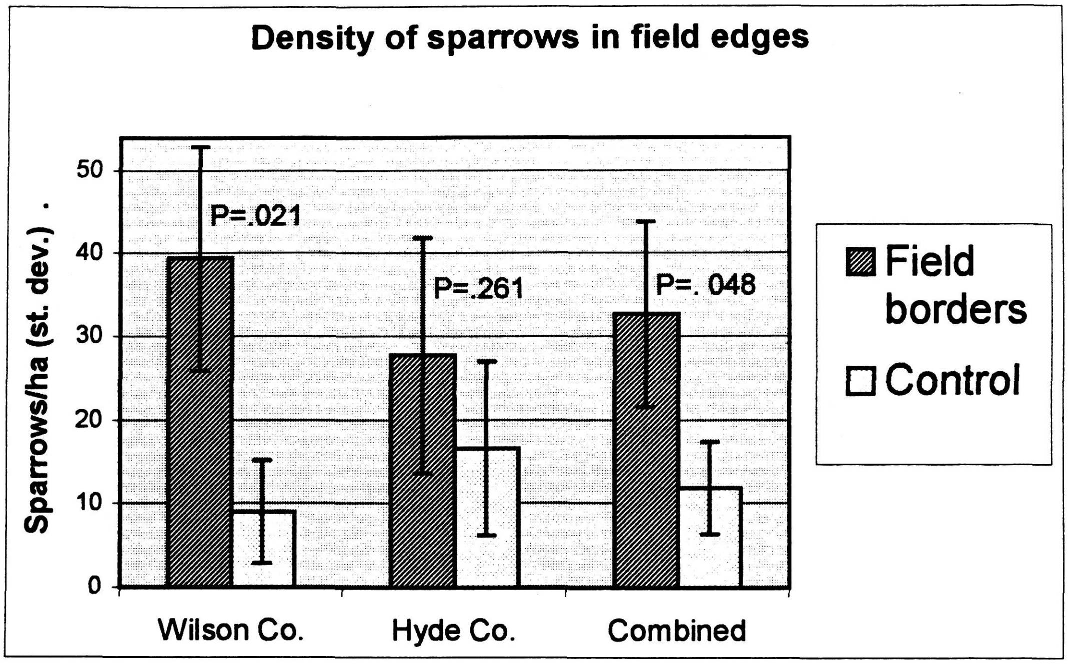

FIG. 2. Overwintering sparrow densities in farm field edges, Wilson and Hyde Counties, NC. *P* values refer to comparisons between field border and control edges within a given county.

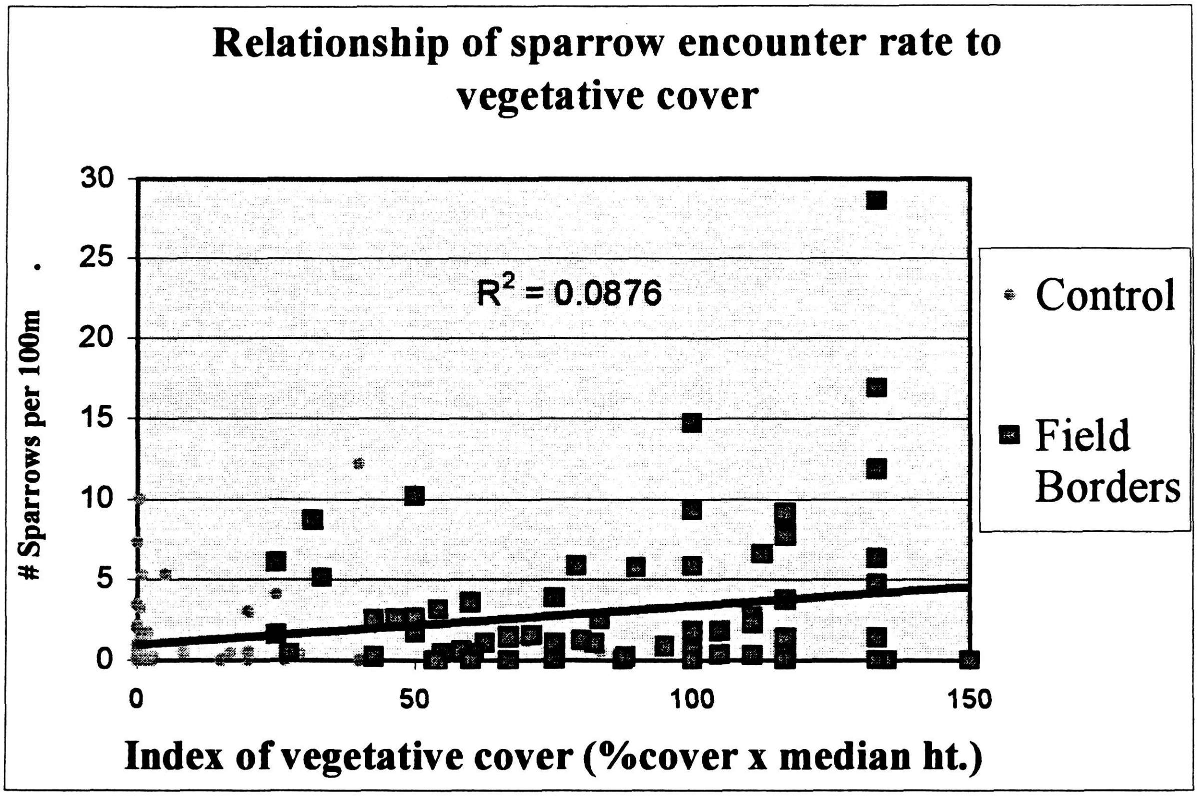

FIG. 3. Relationship of winter sparrow density in field edges to vegetative cover. The index of vegetative cover was calculated by multiplying the % cover of standing vegetation >15 cm by the median height in meters. This graph shows a weak, positive relationship between vegetative cover and sparrow density and also indicates the increasing variance in density with increasing cover.

Table 1. Densities of overwintering sparrows on farm fields with and without field borders. Comparisions of sparrow densities between field interiors and field edges should be made with caution since different methodologies were used to arrive at each density estimate.

	Density, birds/ha		*P* (FB vs
	Field Borders	Control	control)
Sparrows in field interior			
(95% Confidence Interval)			
1997 and 1998 Combined[A]	8.90 (5.6, 14.1)	3.93 (2.2, 7.2)	.043
Sparrows in field edge			
(st.err., # transects)			
1997	32.54 (26.1, 38)	4.13 (4.8, 34)	
1998	32.84 (25.8, 35)	23.50 (24.5, 31)	
Combined	32.70 (13.1, 72)	11.80 (6.8, 66)	.048

[A] Sample sizes were too low to generate accurate density estimates for each year individually.

Table 2. Relative proportions of birds found on farm fields during line transect surveys in Wilson and Hyde County, NC, in February of 1997 and 1998.

Species or Group	Proportion of birds detected
Sparrows[1]	38%
American Robin	23%
Killdeer	17%
Eastern Meadowlark	9%
Mourning Dove	7%
Blackbirds[2]	2%
Common Snipe	1%
Other[3]	3%

[1] -Predominantly Savannah Sparrow and Dark-eyed Junco
[2] –Red-winged Blackbird, Common Grackle, European Starling, Brown-headed Cowbird
[3] - American Crow, Eastern Bluebird, Northern Cardinal, Northern Flicker, Yellow-bellied Sapsucker, American Goldfinch, Canada Goose, American Kestral, Mallard, Northern Harrier, Northern Mockingbird, Eastern Towhee

Table 3. Vegetative structure measurements for field edges. Values are mean (SE).

Study area	% Cover[A]	Median height[B] in m
Hyde Co., NC		
Field borders	74.5 (2.85)	0.90 (0.05)
Control	4.1 (1.48)	0.18 (0.05)
Wilson Co., NC		
Field borders	92.3 (2.14)	1.12 (0.04)
Control	15.2 (3.40)	0.48 (0.08)

[A] Visual estimate of the percentage of the 10 m strip of field edge that contained standing vegetation over 15 cm.
[B] Visual estimate of median height of standing vegetation.

The effects of habitat improvement and predator removal on breeding farmland birds across two farming landscapes.

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Abstract Modern grain farms offer little cover or nesting substrate for birds adapted to early successional habitats. On farm landscapes, birds nest in small patches of available habitat where they may be especially vulnerable to nest predation. We tested the hypotheses that the addition of field border systems of early successional vegetation and the removal of mid-sized mammalian nest predators would increase the abundance, diversity, and reproductive success of farmland birds. This experiment was replicated on three study sites representing two farming landscapes in the North Carolina coastal plain. Field borders were established in the spring of 1996 and predator management was conducted from January to June, 1997 and 1998. Avian abundance and diversity were measured via point count surveys in the summers of 1996 – 1998 and reproductive success was assessed by monitoring nests in the summer of 1997. Bird detections differed between counties and years. We detected a trend toward greater abundance of field sparrows (*Spizella pusilla*) and northern bobwhites (*Colinus virginianus*) and a lower abundance of indigo buntings (*Passerina cyanea*) and brown-headed cowbirds (*Molothrus ater*) on farms with field borders. Upper coastal plain farms with field borders had greater bird nesting density, particularly for field sparrows and common yellowthroats (*Geothlypis trichas*), and greater nesting bird diversity. On lower coastal plain farms, field borders had no effect on nesting density. Field borders, predator management, and the combination of the two did not affect nesting success. Nesting success for field sparrows was low (daily survival rate = 0.863) indicating that field borders may be acting as population sinks for these birds.

Key words: *Colinus virginianus*, blue grosbeak, common yellowthroat, farm landscapes, field borders, filter strips, *Geothlypis trichas, Guiraca caerulea,* indigo bunting, nest success, northern bobwhite quail, *Passerina cyanea,* point counts, predation, predator removal, *Spizella pusilla*

Management of grain farms has changed dramatically in the past century. Economic pressures and advances in farm equipment have led farmers to make fields and farmed openings larger (Warner 1994), thereby reducing edge habitats. Advances in machinery, herbicides, and transgenic crops have enabled farmers to effectively control most non-crop vegetation in and around fields. These trends in agriculture have led to a dramatic alteration of the quantity and quality of wildlife habitat on farms and may have contributed to population declines of many farmland birds (Warner 1994, LeGrand 1996).

The economic and social interest (Morris 1998) in reversing the decline (Church et al. 1993) of northern bobwhites (*Colinus virginianus*, hereafter quail) has been a catalyst for habitat management. The United States Department of Agriculture has provided funding for farmland habitat improvements, including field borders. Field borders (referred to as filter strips in Puckett et al. 1995) are 5-10 meter wide strips of uncultivated, grassy and weedy vegetation around the edges of fields. Field border systems may be a viable management strategy because they are economically compatible with modern agricultural practices (Morris 1998).

This habitat management may provide opportunities to increase passerine populations as well and may provide water quality and soil conservation benefits. The fallow habitat provided by field borders may be critical for farmland birds to breed, forage, and avoid predators, particularly in the spring when there is little cover available in the crops or mowed field edges (Puckett et al. 1995). The importance of field edge habitat for farmland wildlife in general and birds in particular has been recognized for many years (Davison 1941, Dambach 1945) and has been investigated in Britain and the midwestern United States (e.g. Rands and Sotherton 1987, Best et al. 1995), but it has not been extensively studied in the southeastern US.

When suitable nesting habitat is limited, bird nests that are concentrated in remaining habitats, such as field borders, may be particularly vulnerable to predation (Greenwood et al. 1985, Camp and Best 1994, Pasitschniak-Arts and Messier 1995, Puckett et al. 1995). Mid-sized mammalian predator population levels may be higher today than in recent decades (Miller and Leopold 1992, Reynolds and Tapper 1996), possibly due to reductions in fur trapping (e.g. Lipe et al 1990, Hamilton and Vangilder 1992), changes in rural landscapes (Hurst et al. 1996), or the elimination of top predators (Johnson and Sargeant 1977, Cowardin et al. 1983). Red foxes (*Vulpes vulpes*), gray foxes (*Urocyon cinereoargenteus*), raccoons (*Procyon lotor*), opossums (*Didelphis virginianus*) and striped skunks (*Mephitis mephitis*) may all be significant predators on ground nesting birds in the southeastern US (Fies and Puckett, *in press*). Local reduction of these nest predator populations in conjunction with habitat improvements may improve reproductive success of quail and other birds (Côté and Sutherland 1997).

This study was initiated to test the efficacy of field borders and mammalian nest predator management in increasing farmland bird abundance, diversity and reproductive success. Since management results will likely differ across different farming landscapes, this research was conducted in two regions of eastern North Carolina with different farm landscape configurations.

Study sites

Field work was done on 3 study sites in the North Carolina coastal plain (Fig. 1). Each study site was divided into four, 120-300 hectare farms. Each farm contained similar crops (except where noted) and amount of wood edge and were located at least 1.7 km apart. Field borders were established around all fields on 2 of these farms, while the other 2 were farmed as normal. Red and gray foxes, raccoons, opossums, and feral cats (*Felis sylvestris*) and dogs (*Canis familiaris*) were removed from one field border farm and one control farm (NCSU IACUC #97-004) creating a 2x2 factorial experimental design (Fig. 2).

The Wilson County farms, located in the upper coastal plain, averaged 250 ha and contained irregularly shaped fields averaging less than 2.5 ha. Tilled fields comprised 43% of the farms and were intermixed with a mosaic of timber stands of various ages and house sites.

Field borders were established on field edges beside drainage ditches, roadsides and woodlines. The fields contained soybeans, corn, cotton, wheat and tobacco.

The farms in Hyde and Tyrrell Counties, located in the lower coastal plain, averaged 167 ha and consisted of flat, uniformly rectangular fields of 8 ha. The fields, arrayed in contiguous openings of over 200 ha, were separated only by drainage ditches or dirt roads. The farmed openings were bordered on one or two sides by a woodlot and tilled fields comprised 68% of each farm. These farms were located on drained wetlands with organic soils and were typical of large "ditch to ditch" commercial agriculture of the lower coastal plain. Field borders were established along ditches. The fields contained corn, soybeans and wheat. Within a given year, crops were not identical between field border and control farms (Table 1).

Field borders were established in the spring of 1996 in Wilson and Hyde Counties and in the spring of 1997 in Tyrrell County by allowing native vegetation to colonize the field edges. Woody vegetation was controlled in field borders using a selective herbicide application (Warson et al. *in press*) in the fall of 1997. The field borders comprised 13.4% of the tilled land in Wilson County and 9.8% of the tilled land in Hyde and Tyrrell Counties. On the control farms, crops were planted to the outside edge of the field and all non-crop vegetation in field edges was mowed in early winter of each year.

Field borders in Wilson County were dominated (average > 5% cover) by goldenrods (*Solidago* sp.), giant cane (*Arundinaria giganteum*), blackberry (*Rubus argutus*) and fescue (*Fescue* sp.). Field borders in Hyde County consisted primarily of lespedezas (*Lespedeza* sp.), wax myrtle (*Myrica cerifera*), and dog fennel (*Eupatorium capillifolium*). Field borders in Tyrrell County consisted primarily of goldenrods, giant cane, dog fennel, and lespedezas. Control edges in Wilson County were dominated by crabgrass (*Digiteria* sp.), fescue, and goldenrods. Control edges in Hyde County consisted primarily of giant cane, goldenrods, dog fennel and smartweed (*Polygonum lapathefolium*). Tyrrell County control edges were dominated by smartweed.

Predators were removed from January – June, 1997 and 1998, by two technicians in each county. Technicians trapped for 17 days in a 30 day cycle using soft-catch leghold and box traps. Cats and dogs were returned to the owners or taken to an animal shelter. In Wilson County in 1997, a total of 100 animals were removed in 3,297 trap-nights (Table 2).

Methods

Point counts

Point counts were conducted to obtain a comparative index of avian abundance and diversity. This index did not provide accurate estimates of actual population density, but measured a relatively constant, though unknown, proportion of the total population (Bull, 1981). Fourteen farmland birds were initially chosen as indicator species. We chose species representing several feeding and nesting guilds that are commonly associated with North Carolina farms and that may benefit directly or indirectly from field borders and predator removals. Concentrating on a subset of species facilitated training the summer field technicians for bird identification. Horned lark (*Eremophila alpestris*), grasshopper sparrow (*Ammodramus savannarum*), song sparrow (*Melospiza melodia*), eastern kingbird (*Tyrannus tyrannus*) and eastern wood-pewee (*Contopus virens*) were later eliminated from analysis, leaving 9 indicator species (Table 3). Horned lark, grasshopper sparrow and song sparrow were eliminated because they did not occur in large numbers and were not evenly distributed across study sites. Eastern kingbird and eastern wood-pewee were eliminated because they did not use farm fields extensively and did not use field borders as perching and foraging sites, as anticipated.

Point counts were conducted 3 times (May, June and July) in 1996, 1997, and 1998 in Wilson and Hyde Counties and in 1997 and 1998 in Tyrrell County. At each "point", every indicator bird and the presence of all other species to an unlimited distance were recorded over a 7 minute period (Freemark and Rogers 1995). Points were arrayed to census the farms with the maximum number of independent points and were spaced >250 m apart in Wilson County and >350 m apart in Hyde and Tyrrell Counties to ensure independence. Surveys started 15 minutes before sunrise and were completed before 10 am. All 4 farms within a given county were surveyed under similar weather conditions by simultaneously using 4 observers. We did not survey if wind was >25 km per hour or if there was any precipitation. Observers were assigned to alternating treatments on subsequent surveys to help mitigate observer biases.

Vegetation measurements

In order to quantify habitat differences between field border and control farms, we measured vegetative structure and composition in field edges. Vegetative structure and density were measured using a modified vegetation profile board (Nudds 1977). A pole, 2 m high and 8 cm in diameter, was placed upright in the vegetation while an observer took measurements from 2.5 m away, perpendicular to the field edge. The observer estimated the percentage of the pole obscured at 0-0.25 m, 0.25-0.5 m, 0.5-1.0 m, 1.0-1.5 m, and 1.5-2 m. An index of vegetation volume was then calculated by averaging the values for these 5 height intervals.

Vegetative composition was measured using a modified Daubenmire grid (Daubenmire 1959). A 0.5 m x 0.5 m grid was held 1 meter above the ground and the absolute cover of vegetation within the grid was visually estimated. Percent cover of bare ground, leaf litter, grasses (including rushes and sedges), forbs (all broad-leafed, non-woody vegetation, including vines), and woody vegetation was estimated. We also recorded the percent cover of dominant plants (defined as any plant comprising >30% of at least 3 field edges) and important wildlife food plants. All plants were identified to genus. Crop plants were not recorded. Each category was measured independent of all others, thus the totals could sum to >100% when vegetation was multi-layered.

An index of potential food plants for seed and berry eating birds was obtained by averaging the coverages for crab grasses, panicums (*Panicum* sp.), ragweed (*Ambrosia artemisiaefolia*), smartweed, lambsquarter (*Chenopodium album*), docks (*Rumex* sp.), lespedezas, pokeweed (*Phytolacca americana*), and blackberry (based on Judd 1901, Martin et al. 1951, Pulliam and Enders 1971, and pers. obs.). We created an index of potential nesting substrates based on the plants in which we found most nests and from Puckett et al. (1995). These plants included broomsedge (*Andropogon virginicus*), giant cane, fleabanes (*Erigeron* sp.), goldenrods, greenbriar (*Smilax* sp.), and all woody vegetation. While these indices by no means encompass all potential food and nesting plants, they do allow useful comparisons.

In each year 30 field edges per farm were randomly selected and 3-5 subsamples were taken per field edge, depending on field length. The first subsample was placed randomly and subsequent subsamples were taken every 30m (in Wilson County) or 50m (in Hyde and Tyrrell Counties) along the field edge.

The vegetative composition and structure in field edges varied with distance from the drainage ditch or woodline. Therefore, vegetation measurements were stratified by distance from ditch or woodline. The outside edge of the field was defined as the center of a drainage ditch or the woods edge. Measurements were taken at 0, 1, and 2.5 m from the outside edge.

Nest searching and monitoring

Reproductive success was estimated by monitoring the outcome of nests following the guidelines of Martin and Geupel (1993). We used behavioral cues and systematic searching to find nests. For systematic searches, we parted all vegetation in field edges and crops with a stick. For behavioral searches we attempted to flush birds from the nest or elicit defensive alarm calls by walking along field edges. We also looked for birds carrying nesting material and food, and attempted to follow these birds back to nest sites. We abandoned searches for nests after 10 minutes of defensive alarm calls to minimize observer disturbance. We recorded evidence of nesting effort in instances where we encountered fledglings or nesting behavior but did not find a nest. In order to obtain a measure of search effort, we recorded the amount of time spent in behavioral searches and the area of crop field and linear distance of field edge systematically searched.

Once a nest was found it was marked with blue flagging tape on 3 sides, 5m away from the nest. Active nests (defined as nests with $\geq$ 1 egg or chick) were visited every 3-4 days until the nest fledged $\geq$1 young or failed. Successful fledging was determined by looking for scats in the nest or on the ground, one side of the nest matted down from chicks perching on the edge, or the presence of fledglings nearby (e.g. Payne 1992).

Statistical analysis

For point count analysis of the effects of crops and environmental conditions on bird counts, we treated each "point" as a sample. For evaluation of the effects of field borders on bird abundance, each "point" was considered a subsample and each farm considered the sample unit. Only the habitat enhancement treatment was analyzed because it is unlikely that the removal of mid-sized mammalian predators will affect counts of singing birds (Côté and Sutherland 1997). Wilson County was not included in analysis of effect of crop types because points surveyed fields with more than one crop. For analyses, recently tilled fields were categorized as bare, and unplanted fields with >5 months vegetative growth were categorized as fallow.

Comparisons between treatments, counties and years were made using PROC GLM in SAS (SAS Institute 1990). In the year before field borders were established (1996 for Wilson and Hyde and 1997 for Tyrrell County), the habitat on field border farms was not different from the controls. We treated these point counts as baseline data to test the assumption that all farms were similar prior to the application of our treatments. Since there were significant 3 way interactions between treatment, year, and county for the post-treatment years, counties and years were analyzed separately.

Only nests found during systematic searches were used for nest density comparisons because area searched allowed for more reliable standardization of effort than did the time spent in behavioral searches. Nest densities were compared using a chi-squared test (Zar 1996). Daily survival rates were computed using the Mayfield method (Mayfield 1961, 1975) and compared using a 2 sample z test for proportions (Zar 1996). Due to small sample sizes, all open cup nests were pooled for some analyses.

Vegetation subsamples were averaged before analysis. Comparisons of vegetative structure and composition between counties and treatment areas were made using PROC GLM in SAS (SAS Institute 1990). We tested for correlations between vegetation measurements using

PROC CORR in SAS (SAS Institute 1990). The measurements of vegetation volume, height, and cover of growth forms were all highly correlated ($R^2 > 0.50$, $P < 0.001$) and thus are somewhat redundant. However, we feel that each category is biologically relevant, and have included all in our summary of vegetation measurements. Measures of percent cover of the various plant genera were not highly correlated with each other ($R^2 < 0.07$).

Results

Bird Abundance and Diversity

In the baseline year we detected more ($P < 0.03$) common yellowthroats (*Geothlypis trichas*) on farms chosen to have field borders in subsequent years compared to those selected as controls in Hyde County (Table 4). In Tyrrell County, we detected significantly fewer ($P < 0.04$) indigo buntings (*Passerina cyanea*), eastern meadowlarks (*Sturnella magna*), and indicator individuals and species on field border farms in the baseline year (Table 5). In Wilson County, we detected no significant differences ($P > 0.22$) in abundance or diversity of indicator species between field border and control farms (Table 6). This indicates that our baseline bird detection rates were similar in Wilson and Hyde Counties, but that post-treatment comparisons in Tyrrell County must be made with caution.

In 1997 and 1998 in Hyde County, we detected no differences ($P > 0.10$) in abundance of any of the indicator species between field border and control farms and no difference ($P > 0.24$) in indicator species diversity or overall species diversity (Table 4). If we adjust for the baseline level of common yellowthroats then we find fewer ($P < 0.03$) yellowthroats on field border farms in 1997.

In 1997 in Wilson County, we detected significantly more ($P < 0.04$) field sparrows (*Spizella pusilla*) and common yellowthroats ($P = 0.002$), and fewer indigo buntings ($P < 0.03$) and brown-headed cowbirds (*Molothrus ater*, $P = 0.003$) on farms with field borders. We detected no significant differences ($P > 0.10$) between field border and control farms in Wilson County in 1998 (Table 6).

In Tyrrell County in 1998 we detected fewer indigo buntings ($P = 0.03$) and more quail ($P < 0.03$) on farms with field borders (Table 5). If we adjust for the baseline differences, we find no difference in indigo buntings ($P = 0.99$), and significantly more quail ($P < 0.03$), eastern meadowlarks ($P < 0.01$), and indicator individuals ($P < 0.01$) and species ($P < 0.01$) per point on farms with field borders.

Across all farms in Wilson County, we detected fewer indigo buntings ($P < 0.05$), eastern meadowlarks ($P < 0.01$) and abundance ($P = 0.01$) and diversity ($P < 0.03$) of indicator birds in 1998 than in 1997. There were no differences ($P > 0.17$) in birds detected across all farms in Hyde County between the two post-treatment years.

Across all treatments we detected a greater ($P < 0.04$) abundance of indigo buntings, brown-headed cowbirds, field sparrows, chipping sparrows, indicator individuals and species and overall number of species in Wilson County compared to Hyde and Tyrrell Counties in both years. We detected a lower ($P < 0.03$) abundance of eastern meadowlarks and quail in Wilson County compared to Hyde and Tyrrell Counties. We detected no difference ($P > 0.18$) in the abundance of common yellowthroats between counties. Tyrrell County had a greater ($P < 0.01$) number of eastern meadowlarks and fewer ($P = 0.03$) blue grosbeaks than Hyde County. Otherwise, Hyde and Tyrrell County did not differ ($P > 0.10$) in bird detections.

Wind, cloud cover, noise, temperature, and time of day did not significantly ($P > 0.05$) affect the total number of individuals or species detected per point. Crop type did affect counts of some birds. In Hyde and Tyrrell Counties, indigo buntings appeared to prefer wheat to soybeans, eastern meadowlarks preferred wheat and fallow fields to soybeans, bare fields and corn, and common yellowthroats preferred corn and wheat to soybean, bare and fallow fields. These results are confounded by the fact that different crop types are present at different times of the year (e.g. soybeans are often planted after wheat is harvested). Blue grosbeaks and quail did not show preferences for any crop type.

Vegetation

In both years and across all counties, field borders had greater ($P < 0.03$) vegetation volume, height and forbs and less bare ground than control edges. Field borders in Wilson and Hyde Counties also contained more ($P < 0.01$) woody vegetation than their corresponding controls. Within each county, field borders had a greater ($P = 0.02$) index of nesting substrate than control edges. In Hyde and Tyrrell counties, field borders had a greater ($P < 0.03$) index of potential food plants than controls. (Table 7)

Vegetation measurements differed between counties, edge types, and distance from outside edge of field. Measurements of growth forms did not differ ($P > 0.05$) between years in Hyde County. Vegetation volume and height, coverage of grasses, forbs and woody vegetation, and the indices of nesting cover and food all were lower ($P < 0.02$) in Wilson County field borders and control edges in 1998 compared to 1997.

Within the drainage ditch, field borders and control edges were taller ($P < 0.01$) and contained more ($P = 0.01$) vegetation volume, forbs, and woody vegetation compared to vegetation growing outside the ditch. One meter away from the drainage ditch or woods edge, the border was dominated by grasses and forbs. Cover of all vegetation types was lowest ($P < 0.001$) on the outside edge of field borders, closest to the crops.

Wilson and Tyrrell County field borders were taller ($P < 0.01$), and had more ($P < 0.01$) vegetation volume, grasses and forbs than Hyde County. Wilson and Hyde County field borders had more ($P < 0.01$) woody vegetation than Tyrrell County. Wilson County field borders were wider and had a greater index of nesting substrates ($P < 0.02$) than either Hyde or Tyrrell Counties.

Wilson County control edges were taller ($P < 0.01$) and wider with more grasses ($P < 0.01$), forbs ($P < 0.01$) and woody ($P < 0.01$) vegetation than Hyde and Tyrrell County control edges. In Wilson County the farmers often left a meter or two of space between the crops and the outside edge of control fields that grew fallow vegetation by mid-summer, whereas in Hyde and Tyrrell Counties the farmers planted their crops to the very edge of the field.

In Wilson County vegetation measurements differed with edge type. For measures of height, vegetation volume, and cover of forbs and woody vegetation, field-field edges were greater ($P < 0.02$) than field-woods edges which were greater ($P < 0.01$) than field-road edges. Field-road edges contained more ($P < 0.01$) grasses and bare ground than field-field or field-woods edges. Field-field and field-road edges often contained a drainage ditch while field-woods edges often did not. Field-road edges were mowed regularly between the road and the drainage ditch by the state Department of Transportation. More fallow habitat was available at field-field edges since edge habitat from two fields was juxtaposed. There were no road or woods edges in Hyde and Tyrrell Counties.

Nesting density and success

In Wilson County we found 138 nests of 9 different species (Table 8) in 142 hours of behavioral observation and 47.5 km of field edge, and 51.5 ha of crop searched. Of these, 51 nests of 8 species were active for a total of 418.2 exposure days (Table 9).

Only 5 nests of 3 species (Table 8) were found in Hyde County in 48 hours of behavioral observation and 33.5 km of field edge, and 56.0 ha of crop searched. Two of these nests were active, for a total of 26.0 exposure days. In Hyde County we encountered 10 incidences of nesting activity without finding a nest and 4 groups of fledglings of 6 species.

Most (145/159, 91%) nests were found in linear field edges with the rest found in "odd" areas such as woodpiles or fallow patches. No nests were found in soybean, corn, cotton, tobacco or wheat crops. We concentrated our searches on elevated, open cup nests and thus cannot draw conclusions about the distribution of ground nests, such as eastern meadowlark and quail. In 1997 and 1998 we found 8 quail nests in field borders in Wilson and Tyrrell Counties and none on control farms. We found only 1 meadowlark nest in a grassy strip on a control farm in Wilson County.

Due to the low number of nests found in Hyde County, only nests from Wilson County were used for nesting density and survival rate analysis. We found a greater ($P < 0.02$) density of nests in field borders (2.29 nests/km) than control edges (1.33 nests/km) via systematic searching. The nesting density in field borders was greater ($P < 0.02$) before June 30 (1.51 vs. 0.54 nests/km) but did not differ ($P > 0.40$) for nests found after June 30 (2.92 vs. 2.27 nests/km). Additionally, we encountered 17 incidences of nesting activity without finding a nest and 20 groups of fledglings of 9 species on field border farms and 9 incidences of nesting activity without finding a nest and 7 groups of fledglings of 6 species on control farms.

The daily survival rate for eggs (0.923) did not differ ($P > 0.90$) from the rate for chicks (0.925) thus all exposure days were combined for most analyses. The daily survival rate for all open cup nests combined was 0.924 (n = 407 exposure days). The daily survival rate for nests in field borders (0.898) did not differ ($P = 0.34$, n = 350.2 exposure days) from nests in control edges (0.927, Table 10). If our estimates of daily survival rates are accurate, it would have required a total of 1,464 exposure days to differentiate these estimates at the alpha = 0.05 level. The daily survival rate for nests on predator removal farms (0.926) did not differ ($P = 0.64$) from nests found on non-removal farms (0.914) for any individual species or for all nests combined (n = 418.2 exposure days, Table 10). It would have required a total of 7,390 exposure days to differentiate these estimates at the alpha = 0.05 level. Predator removals appeared to have a non-significant ($P = 0.21$), positive effect on chick survival rate of blue grosbeaks (0.978 vs. 0.895, n = 54.5 exposure days). It would have required 79 total blue grosbeak chick exposure days to differentiate these estimates at the alpha = 0.05 level.

Blue grosbeaks fledged at least 1 chick in 6 of 12 active nests and had a daily survival rate of 0.958 . Indigo buntings fledged 3 of 9 nests with a daily survival rate of 0.958. Field sparrows fledged 1 of 16 nests with a daily survival rate of 0.863 (Table 9). Common yellowthroats fledged 1 of 7 nests but had too few exposure days to calculate an accurate Mayfield estimate (Hensler and Nichols 1981).

Nests appeared to be initiated on field border farms earlier than control farms and nests continued to be initiated later in the year on control farms (Fig. 3). Daily survival rates increased ($P < 0.03$) on all treatment areas from 0.884 before June 1 to 0.945 after June 1. The daily survival rate for chicks was slightly lower than for eggs before June 1 (0.862 vs. 0.899) but was slightly greater after June 1 (0.959 vs. 0.937).

edges. Changes in abundance of indicator species in this study were correlated with changes in vegetation. Vegetation did not differ between years in Hyde County and there were no significant changes in bird numbers between years. In Wilson County both bird abundance and vegetation coverage were lower in 1998. These differences are not adequately explained by observer differences between years. It is apparent that the maturation of vegetation in field borders will not be identical across all areas. The reduction in vegetative cover may have been due in part to a drier summer in 1998.

Quail were more abundant on farms with field borders. This result is consistent with the findings of Puckett et al. (1995) who demonstrated greater quail breeding densities on lower coastal plain farms with field borders in Dare County, NC.

Field edge habitat appears to be very important for providing nesting opportunities for birds with elevated cup nests (Shalaway 1985, Bryan and Best 1994, Camp and Best 1994). The presence of early successional fallow vegetation around fields increases the density and diversity of bird nests on farms. Row crops are not attractive nesting cover for open cup nesting birds. Patterson and Best (1996) found no elevated cup nests in row crop fields in Iowa. Basore et al. (1986) found very low densities of elevated cup nests in both conventional and reduced tillage corn and soybean fields, and found much higher densities in fallow strip habitats. Non-crop habitats allow more bird species to breed on large farms than would with crops alone.

Indigo buntings and blue grosbeaks did not appear to increase their numbers or nesting density with the addition of field borders, despite the fact that field borders contained more of the nesting substrates that they preferred (Marcus, *unpublished data*). This surprising result was not adequately explained by any of the factors we measured. Indigo buntings and blue grosbeaks concentrated their nests in woody vegetation within drainage ditches. This habitat became available on control farms in Wilson County by mid-summer and these birds nested extensively in control edges in mid to late summer.

Common yellowthroats and field sparrows appeared to be attracted to and concentrated nests in field borders in Wilson County in 1997. In field borders, these birds nested in the grass and forb habitat away from the drainage ditch in addition to using the woody vegetation in the ditch. This grass and forb habitat was highly reduced or absent in control edges. The nests of both of these species suffered heavy predation. If our estimates of nesting success are accurate, then it is likely that their reproductive rate is below replacement (Best 1978, Farnsworth 1998) despite the fact that these species can renest rapidly and many times throughout the summer (Hofslund 1959, Best 1978). If birds are lured away from more productive habitats to nest in field borders, then field borders would be acting as ecological traps (Gates and Gysel 1978). However, if these birds are habitat limited and become non-breeding floaters in the absence of suitable habitat, then field borders will contribute to overall reproduction by providing additional nesting opportunities.

It is unclear why indigo buntings and blue grosbeaks suffered less depredation than field sparrows and common yellowthroats. Field sparrows and common yellowthroats placed their nests lower in vegetation and closer to the interface of crop field and fallow edge. We observed predator tracks concentrated at this interface and in the bottom of ditches.

Field borders increased early season nesting densities, but this benefit was mitigated by low early season nesting success. Puckett et al. (1995) found a similar result for quail. For quail on large "ditch to ditch" farms, nesting was limited to field borders early in the season. Nesting success was low before mid-July and increased later in the season when more nesting habitat became available.

Nesting success appears to be low across many agricultural landscapes, and depredation has been reported to be the major cause of nest loss (Basore et al. 1986, Bryan and Best 1994, Camp and Best 1994, Puckett et al. 1995). Our daily survival rate (DSR) estimate (0.924) was similar to estimates for passerines (mostly red-winged blackbirds, *Agelaius phoeniceus*) in grassed waterways (DSR = .9019, Bryan and Best 1994) and roadsides (DSR = 0.9471, Camp and Best 1994) in agricultural landscapes in the midwest. Basore et al. (1986) observed 33/166 (20%) nests of all species (mostly red-winged blackbirds) were successful in strip cover habitats surrounded by corn and soybean fields in Iowa. Our estimate of field sparrow nesting success (Mayfield nest success = 6%) is similar to the rate of 10% found by Best (1978) in Illinois shrub-grassland.

Nest losses in agricultural landscapes may be higher than in other habitats. Suarez et al. (1997) found that predation rates for indigo buntings in agricultural field edges (daily predation rate = 0.098) was higher than in tree fall gap, stream bed, or old field edges (daily predation rate = 0.021 – 0.066). Farmland may provide easy travel corridors and abundant prey for predators.

Most nest failures were due to depredation, even on predator removal areas. In a review of 20 predator removal studies, Côté and Sutherland (1997) found that removal areas had higher hatching success (for mostly galliformes and ducks), on average, than 75% of control areas. The proportions of predator populations removed and immigration rates in our study are unknown. It is also unclear how the removal of mid-sized mammalian predators affected depredation rates of other nest predators. Potential nest predators included American crows (*Corvus brachyrhynchos*), blue jays (*Cyanocitta cristata*), black rat snakes (*Elaphe obseleta*), cotton rats (*Sigmadon hispidis*) and other rodents. We could not determine which predators were responsible for depredation solely from the condition of the nest (Fies and Puckett, *in press*).

Best (1978) suggested that snakes (primarily blue racers, *Coluber constrictor*) were the primary predators of field sparrow nests in grassland, shrub-grassland and shrub-woodland habitats in Iowa. Using remote video cameras, Thompson et al. (*in press*) found that black rat snakes were the primary predators on field sparrow and indigo bunting nests in old fields in Missouri. The role of snakes in passerine nest depredation bears further study. Patterson and Best (1996) determined that mammals accounted for 88% of predation events on red-winged blackbird nests.

Our observed overall nest parasitism rate (3/53 nests, 6%) appears to be lower than most reported in the midwest for indigo buntings, blue grosbeaks and field sparrows (24%- Peck and James 1987, 20%- Payne 1992, 32%- Hicks 1934). However, Best (1978) found a similar parasitism rate (10% of 147 nests) for field sparrows in Illinois. Carey et al. (1994) reported only 1 of 371 field sparrow nests parasitized in Pennsylvania. The trend we observed of greater abundance of brown-headed cowbirds on farms without field border systems appears to be driven by one control farm in Wilson County that contained a small beef cattle operation.

Field borders did not appear to affect bird abundance, diversity, or nesting density in Hyde County. This may be attributed in part to differences in vegetation within the field borders, as evidenced by the fact that field borders in Hyde County contained fewer suitable nesting substrates than Wilson County. It is possible that as the field borders mature, more birds will use them. During a brief survey of 2.5 km of Hyde County field borders in the summer of 1998 we found 4 birds nests of 2 species, more than in all of 1997. However, nesting densities still appeared to be much lower than for Wilson County.

A second explanation for the differences between counties is that field borders may not be effective without suitable nearby habitats. It is possible that 5m wide field borders are inadequate to support open cup nesting birds in the Hyde County farming landscape. We rarely saw open cup nesting birds using the field interiors. Common yellowthroats were the only passerine found with regularity in field borders on the lower coastal plain farms in summer. Cup nesting birds tended to be located at the periphery of the farms along the woodlines and canals which had thicker and more permanent vegetation. The interiors of the study areas were far from woodlots and fallow fields and much of the farm remains inaccessible to birds requiring these habitat features as part of their territory. While field borders did appear to increase the abundance and diversity of indicator species in Tyrrell County, this result is potentially confounded with differences between farms in crops and surrounding landscape.

Management implications

Field border systems appear to be only part of successful habitat management for farmland wildlife. The matrix habitat around the field borders seems to be a critical determinant of their value for birds (Bryan and Best 1994). Wilson County field borders were located close to timber stands, clear cuts, and other field borders and received greater use by nesting birds than field borders in Hyde County. Even within Wilson County, field borders that were interspersed amongst small, irregularly shaped fields and close to woodlots had higher nesting densities than field borders isolated in the middle of larger fields. Additional considerations in managing wildlife populations on farms would include management history, field size, crop selection, pesticide application, tillage practice, presence of windrows and fallow areas, timber management, density of human development, and attitude and resources of the landowner. Field border systems may be an important part of whole farm management, but they do not appear to be sufficient by themselves to increase breeding populations of farmland birds, with the possible exception of bobwhite quail.

Potential sources of error

One of the critical assumptions for our comparisons is that the farms within a given county were similar in all respects except for our treatments. While area and amount of woods edge was similar between farms within each county, several differences between farms existed at a number of spatial scales. The crops were not identical on all farms in Hyde and Tyrrell Counties in all years, and timber management and surrounding land use also differed between some farms.

The relationship of birds detected during point counts to population size is unclear. Point count surveys detected mostly singing males. Indigo buntings sing at consistent rates regardless of mating status (Carey and Nolan Jr. 1979) while field sparrows will reduce their singing rates when mated (Carey et al. 1994). For birds that reduced singing rates when mated, point counts likely underestimated population indices in better reproductive habitat.

Comparisons of point counts between farms must be made with caution since the effective detection radius likely differed between farms. In Hyde and Tyrrell Counties, the terrain was very flat there were no timber stands or other structures to impede sound, thus birds could be heard at greater distances than in Wilson County. Despite the fact that a greater area was surveyed per point in Hyde and Tyrrell Counties, we consistently measured lower bird abundance on these farms.

We must interpret the Mayfield estimates for nesting success with caution. Hensler and Nichols (1981) suggested that a minimum of 20 nests be used when making comparisons of daily survival rates. We did not have more than 20 active nests for any species. Combining species improved sample size but may yield misleading information because survival rates and locations of nests differed between species.

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