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THE EFFECTS OF PREDATION AND HABITAT IMPROVEMENT ON FARMLAND BIRDS

by

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ABSTRACT

MARCUS, JEFFREY FRANKLIN. The effects of predation and habitat improvement on farmland birds. (Under the direction of Peter T. Bromley.)

Modern grain farms offer little nesting substrate or winter cover 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 borders of early successional vegetation and the removal of mid-sized mammalian nest predators would increase the wintering density and summer abundance, diversity, and reproductive success of farmland birds. This experiment was replicated in three counties 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. Wintering bird densities on fields with and without field borders were assessed using strip transect and line transect methods in February of 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. In late winter, most (93%) birds detected in field edges were sparrows (song [*Melospiza melodia*], swamp [*Melospiza georgiana*], field [*Spizella pusilla*], chipping [*Spizella passerina*], white-throated [*Zonotrichia albicollis*], and savannah [*Passerculus sandwichensis*] sparrows and dark-eyed juncos [*Junco hyemalis*]). Field borders harbored a greater ($P = 0.048$) winter density of sparrows (32.7 sparrows/ha) than corresponding mowed edges (11.8 sparrows/ha). The interiors of fields with a field border beside them held a greater ($P = 0.043$) winter density of sparrows than fields without a field border (8.90 sparrows/ha vs. 3.93 sparrows/ha). Breeding season bird detections differed between counties and years. We detected a trend toward greater abundance of field sparrows 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. In the 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 population sinks for these birds. Establishing field borders may increase overwintering sparrow populations but are likely not sufficient to improve reproductive success of passerines on farms in the southeastern US coastal plain. While predation was the major cause of nest failure, removal of mid-sized mammalian predators did not increase nesting success.

BIOGRAPHY

Jeff was born in raised in Newton, Massachusetts the son of Drs. Leonard and Eugenia Marcus. Along with his sister, Helena, his interest in the outdoors was sparked by early childhood hiking trips with his father to look for snakes. In high school, Jeff took a six week wilderness expedition trip with Wilderness Ventures to the Pacific Northwest that exposed him to some of the heated controversies over natural resources conservation. Jeff would later take a wilderness leadership training course in Alaska and work for Wilderness Ventures as a trip director for three summers.

Deciding that education was the best way to make a difference in the world, Jeff majored in Psychology, focusing on childhood development, at the University of Rochester in Rochester, NY. After graduation Jeff worked for a year managing a gymnastics gym in Boston. After this, he wanted to get back on track with an education career, but realized that he would need more experience with natural resources management to become a more effective teacher.

Jeff volunteered through the Student Conservation Association in Big Bend National Park, Texas leading nature hikes and helping with resource management projects. He then was accepted to an Americorps position to work with the park's wildlife specialist monitoring endangered species populations and surveying natural springs in the park. It was in Big Bend where he met his future wife, Ellen.

Jeff accepted a graduate position at North Carolina State University under Dr. Peter Bromley because he wished to learn more about wildlife management in intensively utilized environments. Assigned the task of evaluating the impacts of farm field border habitat improvements on non-game wildlife, Jeff spent over three years learning about both wildlife and farming.

Jeff wishes to pursue a career that combines wildlife research, management, and education. After graduation, he and his wife plan to work overseas for a year and to then seek employment as land steward of a nature preserve.

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I would like to thank Pete Bromley for taking a chance on me when I applied to graduate school and for providing a seemingly inexhaustible supply of guidance, challenges, advice, barbecued game, and friendship. Bill Palmer helped introduce me to how to think like a scientist and provided invaluable guidance in learning research techniques and customs of southern living. Ken Pollock, Jaime Collazo, and Richard Lancia were faithful committee members and always provided assistance when asked. John Anderson and Clyde Sorensen both played large roles in implementing this project. Brian Warson and Marc Puckett helped blaze a research path for me to follow. Shane Wellendorf, Walter Lane, Randy Outward and Jim Gillis were always at hand to provide tons of help, or a good laugh.

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We would have been stuck trying to study birds in our backyard if not for the generous contributions of our cooperating farmers. Glenn and Barbara Smith were committed to helping this project succeed. They took me under their wing, taught me about farming, and showed true kindness, hospitality, and interest in my work. Thank you Glenn and Barbara. Wilson Doughtery often took time out of his busy day to talk with me about the farm, the project, and the damn wolves. Other cooperating farmers and landowners include Rodney and Neil Glass, Alan Balance, Mitch Corbin, Dave Bischoff, Jeff Burgweger, Sonny Scott, Jim Nethercutt, Tony Crotser, Jimmy Garnett, Kenny and Danny Bervard, Tommy Bernard, Damon Moyer, Marvin Langley, Jim Vincent, Tommy Beamon, Tim Shelton, Bill Bridger, Dave Baughman and John Hancock Insurance Company. Connie Jernigan helped educate me on farming and quail hunting.

Help with statistical analyses was provided by Ken Pollock, Jaime Collazo, Marcia Gumpertz, Jim Gilliam, Sandy Donoughy, Russell Alpizar, Terry Smith, Mike Mitchell and Mike Holliman. For help with plant identification I thank John Stuckey and Todd Lasseigne.

The North Carolina Wildlife Resources Commission (NCWRC) was an integral partner in this project. Particularly involved were Mark Jones, Terry Sharpe, Denny Baumbarger, Perry Sumner, and Carl Betsill. The Virginia Department of Game and Inland Fisheries (VDGIF) was another important partner. Pat Keyser, Mark Puckett, and Mike Fies all were extremely helpful and were key players on the team. Additional critical input was provided by Steve Capel, Hank Henry, Greg Jennings, Matt Flint and Dennis Hosack. I would also like to recognize the help of Annette Gibbs, Don Temple and all of the Lake Matamuskeet National Wildlife refuge staff.

My parents, sister, and bubby all helped give me the foundation to achieve whatever I wanted and inspired me to take the world by storm. Most of all I want to thank my wife Ellen who provides more love and caring than any guy deserves.

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INTRODUCTION

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 United States Department of Agriculture has responded to this conservation challenge by providing funding for farmland habitat improvement practices, 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. The fallow habitat provided by field borders may be critical for farmland birds to breed, forage, escape predators, and gain protection from the elements. The value 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 may be concentrated in remaining habitats, such as field borders, and they may be particularly vulnerable to predation (Camp and Best 1994, Greenwood et al. 1995, Pasitschniak-Arts and Messier 1995, Puckett et al. 1995).

Local reduction of mid-sized mammalian nest predator populations in conjunction with habitat improvements may help improve avian reproductive success (Côté and Sutherland 1997).

A team of researchers from North Carolina State University, North Carolina Wildlife Resources Commission and the Virginia Department of Game and Inland Fisheries decided to test the efficacy of field borders, predator removals, and other conservation practices on modern grain farms. Puckett et al. (1995) demonstrated that field borders have the potential to provide early season nesting cover for quail, and Morris (1998) established that field borders may be an economically viable management strategy. Warson et al. (*in press*) tested the efficacy of a selective herbicide application for managing woody growth in early successional habitat. Palmer (1995) demonstrated that insecticides do not kill quail directly but insects may be limiting on agricultural fields for foraging quail chicks. Continuing research is investigating the effects of no-till agriculture on quail chick foraging, and the effects of field borders and predator removals on water quality, pest and beneficial insects, weeds, fall recruitment of quail, reproductive success and summer and winter abundance of passerines, and activity rates of predators.

This thesis deals with the responses of birds to field borders and predator removals across two farming landscapes in eastern North Carolina. It is arranged in stand-alone chapters that address bird population responses at two critical times of the year: late winter and breeding season. Chapter one deals with the abundance of wintering sparrows and will be submitted to the Wilson Bulletin for publication. Chapter two deals with abundance and nesting success of birds in the breeding season and will be submitted to the Wildlife Society Bulletin for publication.

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THE EFFECTS OF FARM FIELD BORDERS ON OVERWINTERING SPARROW DENSITIES

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ABSTRACT.-- Wintering sparrows that utilize farm fields may benefit from strips of uncultivated, grassy and weedy vegetation, called field borders, around the edges of fields. Field borders were established on 2 farms in the North Carolina coastal plain in Wilson and Hyde Counties in the spring of 1996. In February of 1997 and 1998, bird numbers on fields with and without field borders were surveyed using strip transect and line transect methods. Most (93%) birds detected in field edges were sparrows, including Song (*Melospiza melodia*), Swamp (*Melospiza georgiana*), Field (*Spizella pusilla*), Chipping (*Spizella passerina*), White-throated (*Zonotrichia albicollis*), and Savannah (*Passerculus sandwichensis*) Sparrows and Dark-eyed Juncos (*Junco hyemalis*). Field borders harbored a greater ($P = 0.048$) density of sparrows (32.7 sparrows/ha) than corresponding mowed edges (11.8 sparrows/ha). The interiors of fields with a field border beside them held a greater ($P = 0.043$) density of sparrows than fields without a field border (8.90 sparrows/ha vs. 3.93 sparrows/ha). These results suggest that establishing field border systems may be an effective way to increase densities of overwintering sparrows on farms in the southeastern US coastal plain.

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 value of field edge habitat for farmland wildlife in general and birds in particular has been investigated in Britain and the midwestern United States (e.g. Parish et al. 1995, Best et al. 1995), but has not been extensively studied in the southeastern US.

The recent decline in populations of Song (*Melospiza melodia*), Field (*Spizella pusilla*), and Savannah (*Passerculus sandwichensis*) Sparrows has generated concern among biologists (LeGrand 1996). These sparrows rely on an interspersion of habitats in various seral stages (Bent 1968). Early successional habitats may be the most limiting habitat type on modern farms.

Sparrow populations may benefit from 5-10 meter wide strips of uncultivated, grassy and weedy vegetation, called field borders, around the edges of fields. The cost of this management strategy for producers is minimal because field edges are less productive than field interiors (Morris 1998) and several United States Department of Agriculture natural resource programs provide funds to subsidize the implementation of field borders.

The fallow habitat provided by field borders may be critical for overwintering sparrows to forage, avoid predators, and gain protection from the elements. Studies have implicated both food and habitat as resources potentially limiting the winter densities of sparrows (Pulliam and Enders 1971, Davis 1973, Lima 1990, Watts 1990). Field borders may help provide some of these critical resources and may increase the usable habitat space on farmland for overwintering sparrows. The objectives of this study were to determine which birds use field borders in late winter and to test the hypothesis that field borders increase the density of sparrows using farm fields.

STUDY SITES AND METHODS

Study Sites.- Field work was done on two study sites in the North Carolina coastal plain (Fig. 1). Each study site was divided into four, 120 - 300 ha farms. Field borders were established around all fields on two of these farms, while the other two were farmed as normal. The farms contained similar crops (except where noted) and amount of wood edge and were located at least 1.7 km apart.

The Wilson County farms, located in the upper coastal plain, averaged 250 ha and contained irregularly shaped row crop fields averaging less than 2.5 ha. Fields were intermixed with a mosaic of house sites and timber stands of various ages and comprised 43% of each farm. Field borders were established on field edges beside drainage ditches, roadsides and woodlines. The fields used in this study contained residue of corn, soybeans, and tobacco.

The farms in Hyde County, located in the lower coastal plain, averaged 167 ha and consisted of uniform rectangular fields of 8 ha. The fields, arrayed in contiguous openings of over 200 hectares, were separated only by drainage ditches or dirt roads. The farmed openings were bordered on one or two sides by a timber stand 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. Fields contained residue of corn or soybeans and the field border farms were planted to winter wheat in 1998.

Field borders were established in both counties in the spring of 1996 by allowing native vegetation to colonize the field edges. The field borders comprised 13.4% of the tilled land in Wilson County and 9.8% of the tilled land in Hyde County. The edges of control fields consisted of narrow (<2m) strips of annual vegetation that were mowed in early winter of each year. Throughout this paper we will use the term “field borders” to refer to the habitat enhancement strips, “mowed edges” to refer to the corresponding area of mowed vegetation and crop residue on control fields, and “field edge” to refer to the margin of a field with or without a field border.

Field borders in Wilson County consisted primarily of dead stalks of dog fennel (*Eupatorium capillifolium*) and broomsedge (*Andropogon virginicus*), dormant blackberry (*Rubus argutus*) and giant cane (*Arundinaria giganteum*), and dead saplings of sweetgum (*Liquidambar styraciflua*) and red maple (*Acer rubrum*). Field borders in Hyde County consisted primarily of dead stalks of dog fennel and fall panicum (*Panicum* sp.), dormant blackberry and giant cane, and saplings of wax myrtle (*Myrica cerifera*).

Bird surveys.--Bird densities were measured using line transect and strip transect methods (Lancia et al. 1994). Since the probabilities of detecting a bird on an open field and in the brushy cover of field edges were unequal, fields and field edges were surveyed separately.

Field edges were surveyed with a strip transect method. Each strip was 10 m wide, corresponding to the maximum width of the field borders. On control farms, the corresponding 10 m of crop residue and mowed vegetation was surveyed. The observer walked along the field edge and counted all birds within the 10 m strip. Since it was possible for birds to escape detection in field borders, the probability of detecting a bird was estimated by having a second individual walk through the middle of the field border immediately after the observer finished the transect and flush all remaining birds in the strip by shouting and beating the vegetation. We assumed that the second individual flushed all birds remaining in the strip. The detection probability was calculated by dividing the number of birds counted by the observer by the total number of birds detected (Lancia et al. 1994). The probability of detecting a bird in a mowed edge was assumed to be 1.

When flushed, sparrows tended to fly along the field edge and land in the vegetation further down the border. The location of these birds was noted and a sparrow subsequently flushed from this location was not counted a second time.

It was difficult to identify sparrows to species during surveys while maintaining an accurate count of the number present. Relative species composition of sparrows in field edges was estimated by identifying birds while walking between the random survey points. Approximately 4.5 total hours was spent identifying 149 birds in field borders and approximately 1.5 hours was spent identifying 22 birds in mowed edges. In order to avoid the bias of overcounting species that are readily identified from a distance (such as the Dark-eyed Junco [*Junco hyemalis*]), only observations of perched or standing sparrows made through binoculars were included.

Field interiors were surveyed by walking transect lines through the middles of fields and estimating the perpendicular distance from the transect line to each individual or flock of birds. Sparrows could easily hide in the crop residue and the probability of detecting a sparrow decreased as a function of distance from the survey line. Therefore, these observations were treated as line transect surveys, and sparrow densities were estimated by fitting a detection function to the data to estimate densities (Buckland et al. 1993).

Fields were stratified by crop residue type and selected randomly. Field edges were selected randomly within fields. Transects were located at least 150 m apart to ensure independence. Surveys were conducted in February each year between sunrise and 11am, on mornings with no precipitation, and wind <15 mph. We surveyed both field border and control farms on the same days and we alternated which treatment was surveyed first.

Transect lengths were measured with a range finder or by pacing. Distances to bird observations were estimated visually. To avoid observer bias in estimates of distance and flock size, a single observer conducted all surveys.

We conducted 66 strip transects totaling 21.6 km on field borders and 72 strip transects totaling 22.1 km on mowed edges. We conducted 110 line transects totaling 18.6 km on fields with field borders and 106 transects totaling 16.5 km on control fields.

Vegetation- Vegetative structure of field edges was measured at the time of the bird surveys by visually estimating the % cover and median height of standing vegetation. The % cover was defined as the percentage of the 10 m strip that contained standing vegetation over 15 cm. An index to vegetative structure was calculated by multiplying % cover by median height (in meters).

A more detailed analysis of the composition and structure of vegetation in field edges was conducted in the summer of 1997. Vegetative structure was 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.

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), and woody vegetation were estimated. Each category was measured independent of all others, thus the totals could sum to >100% when vegetation was multi-layered..

In addition, we recorded the % cover of plants whose seeds were potentially eaten by sparrows. Potential food plants included crab grasses (*Digiteria* sp.), panicums (*Panicum* sp.), ragweed (*Ambrosia artemisiaefolia*), smartweed (*Polygonum lapathefolium*), lambsquarter (*Chenopodium album*), docks (*Rumex* sp.), lespedezas (*Lespedeza* sp.), and blackberry (*Rubus argutus*) (based on Judd 1901, Pulliam and Enders 1971, and pers. obs.).

Data analysis.--Since all transects were not of equal length, each strip transect was weighted by transect length. A weighted sparrow encounter rate was calculated as

$$\hat{E} = \frac{\sum L_i \hat{E}_i}{\sum L_i} \tag{1}$$

where $\hat{E}$ is the encounter rate, $\hat{E}_i = (c_i / L_i)$, c_i is the count of birds on each individual transect, and L_i is the length of each transect. The variance of this estimate is

$$Var(\hat{E}) = \frac{\sum L_i^2 \hat{\sigma}^2}{(\sum L_i)^2} \tag{2}$$

where

$$\hat{\sigma}^2 = \frac{\sum L_i (\hat{E}_i - \bar{E})^2}{n-1} \tag{3}$$

and n is the number of transects. The encounter rate of sparrows in field borders was adjusted for detectability by dividing by the detection probability (β). The variance of this adjusted estimate is

$$Var(\hat{E}^*) = (\hat{E}^*)^2 \left(\frac{Var(\hat{E})}{\hat{E}^2} + \frac{Var(\hat{\beta})}{\hat{\beta}^2} \right) \tag{4}$$

where $\hat{E}^*$ is the adjusted encounter rate and $Var(\hat{\beta})$ is a binomial variance. These equations were derived with the assistance of Ken Pollock, Department of Statistics, North Carolina State University. Estimated encounter rates were compared using a Z test. We considered P values less than 0.05 to be significant. The encounter rates were converted into densities by dividing $\hat{E}$ and its associated standard deviation by the transect width.

Sparrow densities on fields were estimated using program DISTANCE (Laake et al. 1993). Five percent of the data was truncated to improve performance of the model since observations far from the transect line contribute little to density estimates. The program selected the best detection function fit using the minimum Akaike's Information Criterion and was permitted to include up to two parameters in the model.

Comparisons of vegetative composition between counties and treatments were made using PROC GLM in SAS. Possible correlations between sparrow observations and weather, wind, temperature, and time of day were tested using PROC CORR in SAS (SAS Institute 1990).

RESULTS

Most (93%) birds detected in field edges were sparrows. Wilson County field edges contained 6 different sparrow species. Of 127 sparrows positively identified in Wilson County, 50% were Dark-eyed Juncos, 24% were Song Sparrows, 15% were White-throated Sparrows (*Zonotrichia albicollis*), 6% were Savannah Sparrows, 3% were Field Sparrows, and 1% were Chipping Sparrows (*Spizella passerina*). Hyde County field edges contained 3 different sparrow species. Of 44 sparrows positively identified, 50% were Song Sparrows, 36% were Savannah Sparrows, and 14% were Swamp Sparrows (*Melospiza georgiana*). Seven species of sparrows were identified in field borders and 4 species were found in mowed edges. The species detected only in field borders and not in mowed edges were Field, Chipping, and White-throated Sparrows. Field borders contained a greater proportion of Dark-eyed Juncos and a smaller proportion of Savannah Sparrows compared to mowed edges.

Encounter rates of sparrows in field edges did not differ ($P > 0.10$) between years (Table 1) on any farm so data were pooled for analysis. Since density estimates derived from small sample sizes using program DISTANCE are poor (Laake et al. 1993), data on sparrows in field interiors were pooled for both years.

The probability of detecting a sparrow in a field border was 0.71 (SE = 0.081, n = 31 transects). Overall, field borders contained 32.7 sparrows/ha (SE = 13.1), a greater (P = 0.048) density than in mowed edges which held 11.8 sparrows/ha (SE = 6.8, Table 1). This difference was greater in Wilson County where field borders contained 4 times as many (P = 0.021) sparrows as mowed edges (Fig. 2). In Hyde County, field borders did not harbor significantly more ($P = 0.26$) sparrows than mowed edges (Fig. 2). There was no difference ($P > 0.25$) in sparrow densities in field edges, with and without a field border, between Wilson and Hyde Counties.

Crop fields contained a greater variety of birds than field edges. Sparrows comprised about 38% of the birds detected on fields (Table 2). Most of the sparrows positively identified on fields were Savannah Sparrows and Dark-eyed Juncos. There was a greater (P = 0.043) density of sparrows on fields with field borders (8.90/ha, SE = 2.13) than control fields (3.93/ha, SE = 1.22) (Table 1). There was a non-significantly ($P = 0.093$) greater density of sparrows on fields in Wilson County (11.47/ha, SE = 4.20) than in Hyde County (4.31/ha, SE = 0.68) and mean flock size of sparrows in Wilson County was larger (5.50 sparrows/cluster, SE = 1.24 vs. 1.49 sparrows/cluster, SE = 0.12, $P < 0.002$). Observed cluster size of sparrows on control fields (4.22 sparrows/cluster, SE = 0.38) was larger ($P = 0.048$) than on fields with field borders (2.06 sparrows/cluster, SE = 1.02). There was no difference ($P > 0.10$) in sparrow densities between untilled corn residue, untilled soybean residue, and tilled tobacco fields. There were no significant ($P > 0.05$) correlations between sparrow densities and weather, wind, temperature, or time of day.

Vegetative cover and height did not differ on any of the farms between years ($P > 0.12$) with the exception of Hyde County field borders which had greater mean cover in 1997 (85% vs. 61%, $P < 0.001$). In both years, edges with field borders had greater ($P < 0.001$) vegetative cover and height during bird surveys than mowed edges (Table 3). Sparrow densities were weakly correlated with vegetative structure ($R^2 = 0.088$, $P < 0.0005$, Fig. 3).

In the summer of 1997, field borders were taller, wider, and had greater vertical structure than mowed edges ($P < 0.0001$) in both counties. Field borders contained less bare ground and more leaf litter, forbs, and woody plants ($P < 0.04$). There was no difference in the cover of grasses ($P > 0.10$). For both field borders and mowed edges, Wilson County had greater ($P < 0.04$) cover of potential food plants than Hyde County. In Hyde County, field borders contained twice as much cover of potential food plants as mowed edges ($P = 0.013$), while there was no difference ($P = 0.28$) in cover of potential food plants between field borders and mowed edges in Wilson County. Both field borders and mowed edges in Wilson County were taller and wider with greater vertical structure than the corresponding field edges in Hyde County ($P < 0.003$).

DISCUSSION

Greater densities of overwintering sparrows were found on farms with field borders. Fields with field borders may potentially provide more food, escape cover, and thermal protection for sparrows than fields without field borders. Several studies have suggested that sparrows prefer to forage near cover to reduce the risk of avian predation (Schneider 1984, Lima 1990, Watts 1990). Potential avian predators on our study sites included Northern Harriers (*Circus cyaneus*), Cooper's Hawks (*Accipiter cooperi*), Sharp-shinned Hawks (*Accipiter striatus*), American Kestrels (*Falco sparverius*) and Red-tailed Hawks (*Buteo jamaicensis*) in both counties. In addition, Peregrine Falcons (*Falco peregrinis*) and Merlins (*Falco cyaneus*) occurred in Hyde County (Marcus, pers. obs.). Lima (1990) found that White-crowned Sparrows (*Zonotrichia leucophrys*) would not forage without cover present, even when abundant food was available, and he surmised that this was due to predation risk. We observed that sparrows foraging in a field often would fly to the cover of a field border, wood pile, or adjacent timber stand when disturbed. Since the effects of escape cover may be limited by distance (Watts 1991), the presence of field borders in the middle of large farmed openings may make more of the farm landscape available to sparrows and support higher densities.

Potential food abundance did not help explain observed differences in sparrow densities. While we observed sparrows foraging in field borders, observed densities of birds did not correlate well with our measures of potential food plants. In Wilson County, field borders held a greater density of sparrows than mowed edges but did not have more potential food plants. In Hyde County, field borders did not have significantly greater densities of sparrows than mowed edges, even though they contained significantly more potential food plants. This suggests that food may not be the most critical resource sought by sparrows in field borders.

Sparrows may derive energetic benefits from foraging in or near field borders. Field border vegetation helps block the wind and sparrows foraging within or near a border may incur less energy loss from thermoregulation. Grubb and Greenwald (1982) noted that in cold temperatures, House Sparrows (*Passer domesticus*) foraged in sheltered areas, even when this incurred a higher risk of predation. However, we did not find any direct evidence to support this idea, since weather conditions and temperature did not appear to affect sparrow distributions. While higher sparrow densities were correlated with increased vegetative structure, the relationship was weak. Thick, brushy borders sometimes held no birds while mowed edges with scanty cover often held a surprising number of sparrows.

The greater average flock size found in Wilson County over Hyde County may be explained in part by the fact that there was an overall greater abundance of potential food plants there. Grzybowski (1983) observed that sparrow group size increased with increasing seed density. However, the smaller mean flock size in Hyde County may also be due to the fact that this study site contained a higher proportion of Savannah Sparrows which tend to be more solitary birds.

The greater mean flock size on fields without field borders may have been a response to increased perceived predation risk (Barnard 1980). The sparrows may also have been concentrated because less area meeting their foraging habitat requirements was available on fields with mowed edges.

We conclude that the addition of field borders may help increase densities of wintering sparrows on farm fields in eastern North Carolina, including some species of conservation concern. However, we can only surmise that field borders offer advantages in energetics, survivorship and reduced predation. Since field borders can be an economically viable management strategy on some agricultural lands (Morris 1998), they hold promise for improving wintering abundance of sparrows on modern farms.

Potential sources of error--A critical assumption for estimating sparrow densities on fields is that the probability of seeing a sparrow decreases as a function of the perpendicular distance from the transect line. This assumption appears to be supported by our observations. We also assume that all distances were measured accurately and all flocks were counted accurately. While there likely was some measurement error, particularly with larger flocks and birds detected at greater distances, any errors would counterbalance in the paired comparisons since the same observer made all of the measurements.

We assume that sparrow flocks were randomly distributed on fields. If sparrows prefer to forage near field edges (Pulliam and Mills 1977, Lima 1990, Watts 1991) then we may have undercounted sparrows in fields because transects were placed through the middle of fields and sparrow detectability was lowest toward the edges.

The density estimates in field edges may be considered minimum estimates since birds were counted conservatively to avoid counting birds twice. Any violation of the assumption that all birds were flushed by the second observer would yield a low density estimate. The assumption that all birds were seen in the mowed edges was likely not violated because of the lack of vegetation in these field edges. For the few mowed edges that did contain a substantial amount of cover, a field assistant was used in the manner described in the methods to ensure that all birds were counted.

We assume that all farms within a county were similar in all respects except our field border treatment. In reality, there were some differences in timber management and land use surrounding the farms. Additionally, the fact that field border farms in Hyde County in 1998 were planted to winter wheat, while the control farms were not, potentially confounds the effects of field borders in Hyde County for that year.

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