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Fig. 1. Locations of study sites in North Carolina, USA.

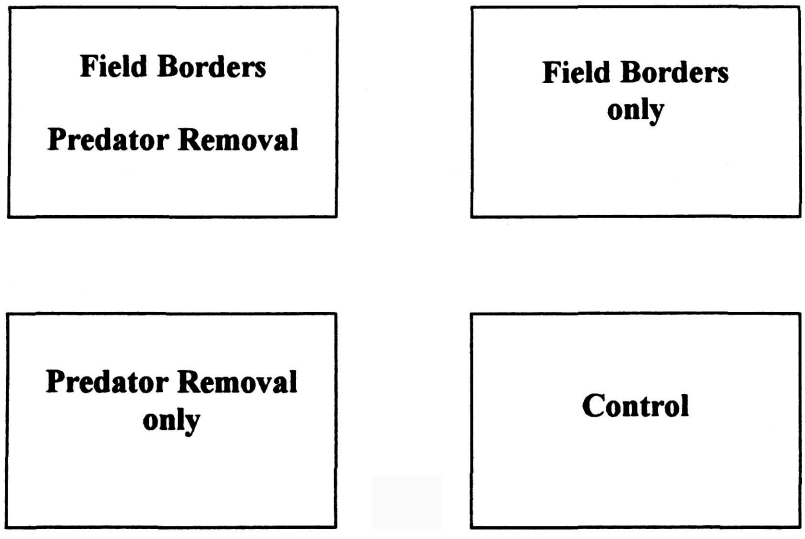

Fig. 2. Experimental design for the four farms within each county. Farms were 120 - 300 ha., consisted of tilled fields, timber stands and house sites, and were located at least 1.7 km apart.

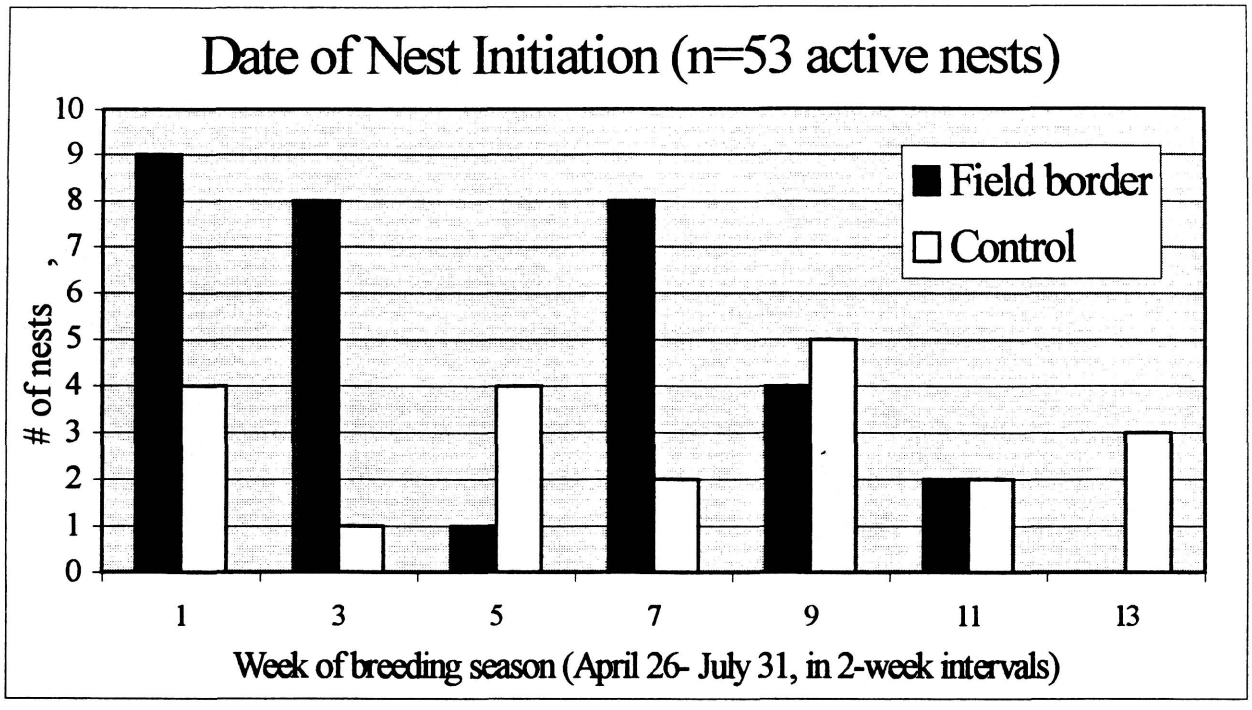

Fig. 3. Date of nest initiation for active nests found in Wilson Co., NC in 1997 for farms with and without field border habitat improvements.

Table 1. Distributions of crops in Hyde and Tyrrell Counties, NC.

Treatment	HYDE Co.			TYRRELL Co.	
	1996	1997	1998	1997	1998
Field Borders	C, S	S	W, S	C, S	W, S
Control	C, W, S	C, S, G	S, C, B	C, W, S	C, W, S

Key to crops: W = Wheat (planted previous winter, harvested in June)
S = Soybeans (planted in June, harvested in fall)
C = Corn (planted in May, harvested in fall)
G = Cabbage (planted in spring, harvested in June)
B = Stringbeans (planted in spring, harvested in June)

Table 2. Mammalian nest predators removed from farms in Wilson County, NC, January-June, 1997.

Species	Wilson Co. removal area		**Total**
	w/ field borders	w/out field borders	
Procyon lotor	11	6	**17**
Didelphis virginianus	22	34	**56**
Vulpes vulpes	2	0	**2**
Urocyon cinereoargenteus	10	6	**16**
Felis sylvestris	2	3	**5**
Canis familiaris	2	2	**4**
Total	**49**	**51**	**100**

Table 3. List of indicator species. These are farmland birds hypothesized to be affected either directly or indirectly by field borders.

Bobwhite Quail *Colinus virginianus*	Field Sparrow *Spizella pusilla*
Eastern Bluebird *Sialia sialis*	Chipping Sparrow *Spizella passerina*
Common Yellowthroat *Geothlypis trichas*	Eastern Meadowlark *Sturnella magna*
Indigo Bunting *Passerina cyanea*	Brown-headed Cowbird *Molothrus ater*
Blue Grosbeak *Guiraca caerulea*	

Table 4. Number of birds detected per seven minute, unlimited distance point count in Hyde County, NC. Field borders were initiated in 1996, and were not fully established until 1997, therefore the 1996 data serve as a pre-treatment, baseline survey. Values are mean number of birds detected per point (SE). Post-treatment results have not been adjusted for differences in baseline detections. Superscript letters indicate statistically significant ($P < 0.05$) differences between field border and control farms within a given year.

Hyde Co., NC	1996- pre-treatment		1997		1998	
	F.B.[1]	Ctl.[2]	F.B.	Ctl.	F.B.	Ctl.
Indigo Bunting *Passerina cyanea*	0.45 (1.09)	1.56 (0.71)	0.11 (0.23)	0.61 (0.23)	0.30 (0.25)	0.47 (0.23)
Blue Grosbeak *Guiraca caerulea*	0.65 (0.45)	1.04 (0.30)	0.47 (0.24)	0.33 (0.24)	0.78 (0.26)	0.63 (0.24)
Common Yellowthroat *Geothlypis trichas*	1.77[A] (0.28)	0.74[A] (0.18)	0.44 (0.34)	1.00 (0.34)	1.16 (0.36)	0.75 (0.33)
Field Sparrow *Spizella pusilla*	0	0	0	0	0	0
Chipping Sparrow *Spizella passerina*	0	0	0	0	0	0
Eastern Bluebird *Sialia sialis*	0.06 (0.22)	0	0	0	0	0
E. Meadowlark *Sturnella magna*	1.25 (0.31)	0.78 (0.20)	0.69 (0.16)	0.45 (0.17)	0.40 (0.18)	0.43 (0.16)
Northern Bobwhite *Colinus virginianus*	0.72 (0.96)	1.67 (0.63)	2.20 (0.37)	1.75 (0.38)	1.50 (0.40)	1.31 (0.37)
Brown-headed Cowbird *Molothrus ater*	0	0.15 (0.14)	0.07 (0.11)	0.01 (0.11)	0.21 (0.11)	0.20 (0.10)
# Individuals[3]	4.75 (1.82)	6.11 (1.20)	3.65 (0.87)	3.68 (0.87)	4.53 (0.94)	3.92 (0.86)
# Indicator species[4]	2.60 (0.60)	3.17 (0.40)	2.13 (0.32)	2.45 (0.32)	2.79 (0.34)	2.64 (0.31)

[1] Farms with field border habitat improvement
[2] Control farms
[3] Total number of indicator bird individuals detected per point
[4] Number of indicator bird species detected per point
[A] $P = 0.012$

Table 5. Number of birds detected per seven minute, unlimited distance point count in Tyrrell County, NC. Field borders were initiated in 1997, and were not fully established until 1998, therefore the 1997 data serve as a pre-treatment, baseline survey. Values are mean number of birds detected per point (SE). Post-treatment results have not been adjusted for differences in baseline detections. Superscript letters indicate statistically significant differences between field border and control farms within a given year.

Tyrrell Co., NC	1997- pre-treatment		1998	
	F.B.[1]	Ctl.[2]	F.B.	Ctl.
Indigo Bunting *Passerina cyanea*	0.14[A] (0.21)	0.75[A] (0.24)	0.24[B] (0.21)	0.85[B] (0.25)
Blue Grosbeak *Guiraca caerulea*	0.07 (0.17)	0.44 (0.19)	0.53 (0.19)	0.46 (0.17)
Common Yellowthroat *Geothlypis trichas*	1.01 (0.30)	0.82 (0.34)	0.34 (0.30)	0.39 (0.35)
Field Sparrow *Spizella pusilla*	0	0	0	0
Chipping Sparrow *Spizella passerina*	0	0	0	0
Eastern Bluebird *Sialia sialis*	0	0	0	0
E. Meadowlark *Sturnella magna*	0.93[C] (0.36)	2.63[C] (0.40)	1.69 (0.35)	0.94 (0.41)
Northern Bobwhite *Colinus virginianus*	1.70 (0.45)	1.41 (0.50)	2.48[D] (0.44)	1.15[D] (0.51)
Brown-headed Cowbird *Molothrus ater*	0.13 (0.05)	0.16 (0.06)	0	0
# Individuals[3]	3.98[E] (0.61)	6.19[E] (0.69)	5.25[F] (0.60)	3.81[F] (0.70)
# Indicator species[4]	2.38[G] (0.19)	2.94[G] (0.22)	2.82 (0.19)	2.43 (0.22)

[1] Farms with field border habitat enhancements
[2] Control farms
[3] Total number of indicator bird individuals detected per point
[4] Number of indicator bird species detected per point
[A] $P = 0.036$
[B] $P = 0.032$
[C] $P = 0.002$
[D] $P = 0.026$
[E] $P = 0.010$
[F] $P = 0.067$
[G] $P = 0.029$

Table 6. Number of birds detected per seven minute, unlimited distance point count in Wilson County, NC. Field borders were initiated in 1996, and were not fully established until 1997, therefore the 1996 data serve as a pre-treatment, baseline survey. Values are mean number of birds detected per point (SE). Superscript letters indicate statistically significant ($P < 0.05$) differences between field border and control farms within a given year.

Wilson Co., NC	1996- pre-treatment		1997		1998	
	F.B.[1]	Ctl.[2]	F.B.	Ctl.	F.B.	Ctl.
Indigo Bunting *Passerina cyanea*	1.55 (0.59)	1.60 (0.52)	1.52[A] (0.18)	2.03[A] (0.16)	1.22 (0.18)	1.33 (0.20)
Blue Grosbeak *Guiraca caerulea*	0.01 (0.24)	0.24 (0.21)	0.80 (0.19)	0.56 (0.17)	0.52 (0.19)	0.53 (0.21)
Common Yellowthroat *Geothlypis trichas*	0.61 (0.15)	0.69 (0.13)	1.46[B] (0.26)	0.41[B] (0.23)	0.80 (0.26)	0.63 (0.30)
Field Sparrow *Spizella pusilla*	1.00 (0.21)	1.28 (0.18)	1.26[C] (0.19)	0.78[C] (0.17)	1.02 (0.19)	0.82 (0.21)
Chipping Sparrow *Spizella passerina*	0.62 (0.12)	0.58 (0.10)	0.33 (0.11)	0.55 (0.10)	0.30 (0.11)	0.36 (0.12)
Eastern Bluebird *Sialia sialis*	0.28 (0.12)	0.20 (0.10)	0.39 (0.13)	0.12 (0.11)	0.33 (0.13)	0.28 (0.15)
E. Meadowlark *Sturnella magna*	0.37 (0.17)	0.50 (0.15)	0.37 (0.13)	0.52 (0.11)	0	0
Northern Bobwhite *Colinus virginianus*	0.59 (0.52)	1.00 (0.46)	1.36 (0.29)	1.16 (0.26)	0.84 (0.29)	0.26 (0.33)
Brown-headed Cowbird *Molothrus ater*	0	0.06 (0.10)	0.08[D] (0.08)	0.39[D] (0.07)	0.14 (0.08)	0.17 (0.09)
# Individuals[3]	5.00 (0.99)	6.15 (0.87)	7.58 (0.68)	6.50 (0.61)	5.14 (0.68)	4.31 (0.78)
# Indicator species[4]	3.26 (0.33)	3.65 (0.29)	4.18 (0.25)	3.61 (0.22)	3.29 (0.25)	3.01 (0.28)

[1] Farms with field border habitat enhancements
[2] Control farms
[3] Total number of indicator bird individuals detected per point
[4] Number of indicator bird species detected per point
[A] $P = 0.022$
[B] $P = 0.002$
[C] $P = 0.035$
[D] $P = 0.003$

Table 7. Vegetation measurements for field borders and control edges. Vegetation volume was measured with a modified vegetation profile board and growth forms were measured with a modified Daubenmire grid (see text for detailed description). Values are average % cover (SE) unless otherwise noted. Values with the same superscript letter within a given row are not statistically different ($P > 0.05$). Measurements were taken in Wilson and Hyde Counties, NC in 1997 and 1998 and in Tyrrell County, NC in 1998 only.

Vegetation	FIELD BORDERS			CONTROL EDGES		
Measurement	Wilson Co.	Hyde Co.	Tyrrell Co.	Wilson Co.	Hyde Co.	Tyrrell Co.
Height[1]	93.6 (2.0)^{A}	72.8 (4.0)^{B}	87.9 (3.4)^{A}	48.5 (1.9)^{C}	28.0 (3.0)^{D}	16.2 (3.2)^{E}
Volume[2]	36.4 (0.8)^{A}	26.0 (1.6)^{B}	34.2 (1.4)^{A}	16.7 (0.8)^{C}	8.7 (1.3)^{D}	3.7 (1.3)^{E}
Bare ground[3]	8.9 (1.5)^{D}	13.8 (2.9)^{D}	11.1 (2.5)^{D}	25.3 (1.4)^{C}	57.0 (2.2)^{A}	34.0 (2.4)^{B}
Grasses[4]	36.9 (1.4)^{A}	20.0 (2.7)^{C}	27.3 (2.3)^{B}	37.2 (1.3)^{A}	17.4 (2.0)^{C}	16.1 (2.2)^{C}
Forbs[5]	43.3 (1.3)^{A}	33.2 (2.6)^{B}	42.3 (2.3)^{A}	31.2 (1.3)^{B}	24.4 (2.0)^{C}	13.3 (2.1)^{D}
Woody	15.3 (0.8)^{A}	13.3 (1.6)^{A}	0.1 (1.4)^{C}	7.6 (0.8)^{B}	0.9 (1.2)^{C}	1.2 (1.3)^{C}
Food[6]	2.1 (0.2)^{A}	2.1 (0.3)^{A}	1.7 (0.3)^{A}	2.0 (0.2)^{A}	1.3 (0.2)^{B}	0.7 (0.3)^{C}
Nesting[7]	7.7 (0.3)^{A}	2.5 (0.6)^{C}	4.1 (0.5)^{B}	3.3 (0.3)^{B}	1.0 (0.4)^{D}	0.0 (0.5)^{E}

[1] Average height in centimeters.

[2] Average of estimates of vertical cover 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.

[3] Percent cover of bare ground accessible to a sparrow.

[4] Includes grasses, sedges and rushes.

[5] All broad-leafed, non-woody plants, including vines.

[6] Average of coverages for crab grasses (*Digiteria* sp.), panicums *(Panicum* sp.), ragweed (*Ambrosia artemisiaefolia*), smartweed (*Polygonum lapathefolium*), lambsquarter (*Chenopodium album*), docks (*Rumex* sp.), lespedezas (*Lespedeza* sp.), pokeweed (*Phytolacca americana*), and blackberry (*Rubus argutus*).

[7] Average of coverages for broomsedge (*Andropogon virginicus*), giant cane (*Arundinaria giganteum*), fleabanes (*Erigeron* sp.), goldenrods (*Solidago* sp.), greenbriar (*Smilax* sp.), and all woody vegetation.

Table 8. Number of nests found in 1997 in Wilson and Hyde Counties, NC in field border and control farms.

County	Treat-ment[1]	Field Sparrow	Blue Grosbeak	Indigo Bunting	Common Yellowthroat	N. Mocking-bird	Other[2]	Total
Wilson	**FB**	27	7	13	14	4	22	87
	Ctl	11	18	12	4	1	5	51
	Total	38	25	25	18	5	27	138
Hyde	**FB**	0	0	0	1	0	1	2
	Ctl	0	0	1	2	0	0	3
	Total	0	0	1	3	0	1	5

[1] FB = farms with field border habitat enhancement
Ctl = farms without field border systems

[2] Wilson Co. field borders: 2 northern bobwhite, 2 yellow-breasted chat, 2 brown thrasher, 1 eastern towhee, 1 Carolina wren and 14 unknown nests
Wilson Co. control: 1 eastern meadowlark and 4 unknown nests
Hyde Co. field borders: 1 northern bobwhite

Table 9. Exposure days and daily survival rates of open cup nests found in Wilson County, NC, across all treatments.

Species	Exposure days	Daily survival rate (95% CI)	Mayfield Nest Success[1]
Blue Grosbeak	118.25	0.958 (0.92, 0.99)	0.406 (21)
Field Sparrow	109.45	0.863 (0.80, 0.93)	0.056 (19.5)
Indigo Bunting	95.25	0.958 (0.92, 1.00)	0.389 (22)
Northern Mockingbird	42.0	0.976 (0.93, 1.00)	0.551 (24.5)
Other cup nests[2]	42.05	NA	NA
Combined	407.0	0.924 (0.90, 0.95)	0.176 (22)

[1] Daily survival rate raised to average number of days from start of egg laying to fledging. Number of days indicated in parentheses.

[2] Includes 7 common yellowthroat, 1 brown thrasher, 1 yellow-breasted chat, and 1 unknown nest.

Table 10. Comparisons of daily survival rates for field border and predator removal treatments, Wilson County, 1997. All open cup nests have been combined. For field border comparison, only nests found in field edges are included.

Treatment	Exposure Days	Daily Survival Rate	*P* value
Field Borders	186.0	0.898	0.342
Control	164.2	0.927	
Predator Removal	244.0	0.926	0.644
Non-removal	174.2	0.914	

DISCUSSION

A wide variety of open field, forest, and "edge" bird species use field edge habitat for nesting, foraging, and escape cover. Improving field edge habitat with field border systems on moderate-sized farms appears to increase the abundance of sparrows in winter and quail and field sparrows in the breeding season. However, many other factors seem to affect whether birds will use field edge habitat, with or without a field border. These factors may include, and are likely not limited to, crop type, tillage practice, herbicide and pesticide application, field size, proximity of woodlots, vegetative composition of field edge, distributions of birds at many spatial scales including regional and national, prey abundance, competitive and predatory interactions, temperature, time of day, season, precipitation, and yearly cycles. Due to this wide range of confounding factors, it is apparent that in many cases field border systems alone will not significantly affect populations of birds on farmland. However, they do appear to have the potential to increase wintering population of sparrows and nesting density and diversity of some species, given the proper surrounding habitat.

Nest losses on farmland due to predation appear to be high. Nesting success of passerines was not improved by the removal of mid-sized mammalian nest predators in Wilson County in 1997. We cannot draw definitive conclusions about the efficacy of this management practice based on only 51 nests monitored in one county in one year.

Management implications- Field borders appear to offer some promise for conservation of farmland birds. However, they do not appear to be sufficient by themselves to support the

reproduction of many species. It appears that maximum benefits will be derived from field borders when they are part of an integrated habitat management plan on farms that may include managed timber stands in a variety of successional stages, conservation tillage, small fields, fence rows and windbreaks, ponds and streams, a variety of crops, reduced herbicide and pesticide application and periodically idling fields.

Future research- Ongoing research is addressing the effects of field border systems and predator removals on fall densities of quail, water quality, pest and beneficial insects, weeds, and activity rates of the entire predator community. Much remains to be studied about the biological and economic efficacy of predator removal and the ecological impacts of this management practice. Little is known currently about the response of target and non-target predator populations over time and space. The response is likely to differ across different landscapes and predator communities. Questions about the ethics and public acceptance of this management practice should also be addressed before predator removal is encouraged on a large scale. Future research should address which predators are responsible for songbird nest losses and how to mitigate some of these losses if trapping mammalian predators is not effective.

Future research may investigate the role of field border systems in providing habitat for other species besides birds and their role in animal movements across landscapes. We should also study field borders in the context of surrounding habitat to learn more about how different farm and forest habitats interact and complement each other. The value of narrow strips of habitat such as field borders compared to blocks of early successional habitat should be investigated to properly guide the allocation of conservation funding and management efforts.

Additional studies of blue grosbeak nesting success should be conducted since there is a dearth of published information on reproductive success for this species. Additional research could attempt to ascertain why blue grosbeaks and indigo buntings did not respond favorably to field borders and why they suffered lower predation than field sparrows and common yellowthroats.

We still know little about how field borders affect selection of breeding territories. To resolve the question of whether field borders may be acting at ecological traps, research should address how birds make decisions about where to nest at both large and small spatial scales. Basic demographic questions need to be answered about these populations such as measuring seasonal fecundity, whether these birds are habitat limited, and identifying the population "sources" if farm fields indeed act as population "sinks".

To ascertain the full benefits of field borders for wintering sparrows, studies should be conducted on wintering sparrow energetics, movements, and survival in field borders. Further research may also address how field borders affect the winter distributions of birds that forage on open fields such as eastern meadowlark, mourning dove (*Zenaida macroura*), killdeer (*Charadrius vociferus*), and American robin (*Turdus migratorius*).

Finally, further work needs to be done to investigate how to benefit nesting birds and other wildlife in the intensively farmed "agribusiness" landscapes of the lower coastal plain. This region contains some of the highest remaining densities of quail in North Carolina along with lower human population densities than the piedmont, and thus is a wise place to concentrate management efforts. However, this farming landscape does not appear to be hospitable to breeding populations of many songbirds. Since it is likely that we will see a trend in the future toward more large, commercial farms with larger fields and little edge habitat, we need to find

conservation practices that are biologically successful in this farming landscape and are financially, logistically, and socially compatible with modern farming.