An investigation of factors that may affect nest success in CRP lands and other grassland habitats in an agricultural landscape
by Mark R Clawson

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
In 1993-94, I investigated factors influencing nest success of grassland birds and characterized avian communities in various habitats in an agricultural landscape near Three Forks, Montana. I used artificial nests to study relationships between nest success and various spatial, temporal, and vegetation variables in 3 grassland habitats: (1) Conservation Reserve Program (CRP) fields; (2) other non-native grass patches; and (3) native vegetation patches. I conducted point-counts in 4 land-use classes: (1) CRP fields; (2) fallow fields; (3) crop fields; and (4) native vegetation (rangeland). I detected a clear association between vegetation characteristics and survival rate of artificial nests. Univariate and multivariate data analyses indicated that taller, thicker cover surrounding nest sites reduced the likelihood of predation. Similarly, nests initiated later in the season, when vegetation volume was greater, survived at higher rates than nests initiated earlier. These relationships held when vegetative variables were analyzed among as well as within grassland types. Multivariate analyses indicated only weak relationships beween nest success and spatial variables (e.g., patch size). Nest success was higher and vegetative structure was greater in CRP fields than in other grassland types. CRP fields attracted a relatively diverse assemblage of breeding birds, which included several grassland species of concern. Thus, it appears that CRP lands provide attractive habitat for numerous species of grassland birds and may be acting as important population sources.

AN INVESTIGATION OF FACTORS THAT MAY AFFECT NEST SUCCESS IN CRP LANDS AND OTHER GRASSLAND HABITATS IN AN AGRICULTURAL LANDSCAPE

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APPROVAL

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Mark R. Clawson

This thesis has been read by each member of the thesis committee and been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

In 1993-94, I investigated factors influencing nest success of grassland birds and characterized avian communities in various habitats in an agricultural landscape near Three Forks, Montana. I used artificial nests to study relationships between nest success and various spatial, temporal, and vegetation variables in 3 grassland habitats: (1) Conservation Reserve Program (CRP) fields; (2) other non-native grass patches; and (3) native vegetation patches. I conducted point-counts in 4 land-use classes: (1) CRP fields; (2) fallow fields; (3) crop fields; and (4) native vegetation (rangeland). I detected a clear association between vegetation characteristics and survival rate of artificial nests. Univariate and multivariate data analyses indicated that taller, thicker cover surrounding nest sites reduced the likelihood of predation. Similarly, nests initiated later in the season, when vegetation volume was greater, survived at higher rates than nests initiated earlier. These relationships held when vegetative variables were analyzed among as well as within grassland types. Multivariate analyses indicated only weak relationships beween nest success and spatial variables (e.g., patch size). Nest success was higher and vegetative structure was greater in CRP fields than in other grassland types. CRP fields attracted a relatively diverse assemblage of breeding birds, which included several grassland species of concern. Thus, it appears that CRP lands provide attractive habitat for numerous species of grassland birds and may be acting as important population sources.

INTRODUCTION

Background and Statement of Problem

Widespread declines in avian populations have been reported recently (Robbins et al. 1989, Askins et al 1990, Hagan and Johnston 1992, Faaborg et al. 1992). The reasons for declining populations are not clear, but loss, fragmentation, and degradation of breeding habitat appear to be major factors in these declines (Dobkin 1992, Finch 1991).

Some of the greatest reductions in avian populations have occurred in grasslands (Paige 1990, Robbins et al. 1992, Knopf 1994). In the past several decades many grassland species have experienced steep, consistent, and widespread declines (e.g., Brewer's sparrow, Cassin's sparrow, clay-colored sparrow, mountain plover, and long-billed curlew) (see Appendix for scientific names). Other species have experienced regional declines (e.g., lark bunting, grasshopper sparrow, savannah sparrow, Henslow's sparrow , dickcissel, eastern meadowlark, vesper sparrow, and Bairds sparrow) (Robbins et al. 1992, Rodenhouse et al. 1992, Knopf 1994). No other habitats in North America have as great a proportion of their species in decline (Paige 1990, Knopf 1994).

Grasslands have been altered as much as any ecosystem in the U. S. (Bock et al. 1992, Knopf 1994). The midwest grassland has experienced the most severe impacts: virtually all of the original tallgrass prairie (Illinois and Iowa) has been converted to cereal grain production (87%) or tame-grass hayfields and pasture land (13%). Further west, losses have been substantial but not complete, and remnants occur as fragments. Approximately 41% of the mixed-grass prairie (Kansas, Nebraska, North Dakota, South Dakota and Oklahoma), and 30% of the shortgrass prairie and eastern inter-mountain shrubsteppe (Montana, Wyoming and Colorado) are currently under small-grain or tame-grass cultivation (Knopf 1994).

Habitat losses have primarily been caused by 2 major agricultural practices: cultivation of row crops and tame grasses, and draining of wetlands (Finch 1991, Dobkin 1992, Knopf 1994). The amount of land devoted to row crop agriculture throughout the west has greatly increased through time due to the advent of large-scale irrigation, consolidation of farms, and emphasis on one or a few commodities per farm (Rodenhouse et al 1992). Wetland drainage, as part of cultivation practices, has had major impacts on the phytogeography of grasslands locally (Dahl 1990). Wetland loss exceeds 85% in the tallgrass prairie, 56% in the mixed-grass prairie, and 40% in the shortgrass prairie (Knopf 1994). Additionally, nearly 3% of the Great Plains is now forested by shelterbelts planted to reduce wind erosion (Baer 1987).

Much of the mixed- and shortgrass prairies, and inter-mountain shrubsteppe remains uncultivated. In these grasslands, habitat alteration, rather than habitat loss, has had the greatest impact (Bock et al. 1992, Reynolds et al. 1994). Domestic grazers (e.g., cattle and sheep) have replaced native grazers [e.g.,bison (Bison bison) and prairie dogs (Cynomys ludovicianus)] across the Great Plains. As a consequence, landscapes grazed with varying intensity by native species are now fenced and intensively grazed throughout (Dobkin 1992, Knopf 1994). Shrubsteppe ecosystems did not evolve with large ungulate herds, and their grasses were evolutionary unprepared for domestic grazers (Mack and Thompson 1982). Intense livestock grazing and active fire suppression, which strongly altered grassland disturbance patterns, have reduced vegetation diversity and facilitated loss of native grasses and forbs, spread of shrubs into grasslands, and invasion of exotic plants (Bock et al. 1992, Knopf 1994).

The rate of degradation and loss of native grasslands has slowed recently. The introduction of the Conservation Reserve Program (CRP), initiated in 1985, has prompted the reseeding of grasses and grass/legume mixes into nearly 4 million ha throughout the northern plains and almost 1.25 million ha in Montana alone(Johnson and Schwartz 1993). The reseeded area represented nearly 6% of the cropland in the shortgrass prairie states (Knopf 1994).

Because of the vast area affected, the CRP has enormous potential to provide nesting and brood-rearing habitat for grassland birds. In preliminary surveys in eastern Montana, North Dakota, South Dakota, and western Minnesota, Johnson and Schwartz (1993) found higher densities of many breeding grassland-birds (e.g., lark bunting, grasshopper sparrow, western meadowlark, eastern meadowlark, savannah sparrow, clay-colored sparrow, bobolink, dickcissel, and Baird's sparrow) in CRP fields than in cropland. Thus, it appears that numerous species have gained habitat through the CRP. However, the extent to which the CRP is helping slow, or even reverse, declines in grassland bird populations remains largely unknown. This is unfortunate given the amount of land and resources involved in the CRP.

Justification and Objectives

Further study of the suitability and effectiveness of CRP lands to restore avian populations is needed. Although CRP fields appear to attract greater densities of grassland birds than the cropland they replaced, abundance alone does not adequately measure population viability (Van Horne 1983, Pulliam 1988, Ratti and Reese 1988). Reproduction sufficient to offset mortality is essential to population stability. Thus, habitat-specific estimates of recruitment are needed to determine whether various habitats function as population sources or sinks.

Nest predation and parasitism are widely regarded as the primary factors responsible for depressing nest success and thus, recruitment. After evaluating the importance of the two factors, Martin (1992) identified nest predation as the most important cause of reproductive failure. Prior studies have reported greater predation pressure and lower nest success in small habitat patches and near habitat edges, in both forests and grasslands (see review article by Paton 1994). Vegetative structure has also been shown to affect nest success (e.g., Schrank 1972, Bowman and Harris 1980, Redmond et al. 1982, Sugden and Beyersbergen 1987, Crabtree et al. 1989, DeLong et al. 1995). However, study results relating nest success to vegetative structure have been inconsistent, and the importance of concealing cover remains unclear.

To fully evaluate the potential of the CRP, we need to: (1) estimate nest success, a strong correlate of recruitment, in CRP fields and other grassland habitats (e.g., roadsides, waterways, odd areas), and (2) understand relationships between nest success and spatial and structural characteristics of various habitats. CRP fields and other idle areas occur as patches of grassland-habitat within agricultural landscapes. These patches vary greatly in size and shape. Also, various plant communities (native to completely introduced) and mowing regimes (annually to none) have resulted in vegetative structures that vary dramatically from patch to patch. Thus, there is ample reason to suspect that nest success and recruitment vary greatly among available grassland habitats.

Therefore, I implemented this study to examine nest success versus spatial and structural characteristics in CRP and other grassland habitats in an agricultural landscape in southwest Montana. Because of the logistical difficulties of working with actual nests, I used artificial nests, which allow comparisons of relative nest success among various habitat scenarios. Furthermore, I conducted extensive point-counts in 4 major habitats (crop-fields, fallow-fields, CRP-fields, and rangeland) to characterize the avian communities associated with various habitats.

STUDY AREA

The 80-km^2 study area was in south Broadwater County and northwest Gallatin County of southwestern Montana. The area extended from 12 km south to 18 km north of the town of Three-Forks. The terrain was undulating, and the elevation of the area ranged from 1,220 to 1,460 m above sea level. The light-colored, shallow soils were calcareous, unleached, and alkaline, with accumulations of silicate clay. Temperatures ranged from a low monthly average of -5.6 C in January to a high of 18.9 C for July. Of 41 cm of average annual precipitation, two-thirds occurred in May and June. Soils were typically depleted of plant-available water for most of the summer.

The landscape was classified as shrubsteppe, dominated by the Agropyron spicatum/Agropyron smithii and Artemisia tridentata/Agropyron spicatum habitat types (Mueggler and Stewart 1980). The A. spicatum/A. smithii habitat type was dominated by grasses and low shrubs including bluebunch wheatgrass (A. spicatum), western wheatgrass (A. smithii), prairie Junegrass (Koleria cristata), needle-and-thread (Stipa comata), Sandbergh's bluegrass (Poa sandbergii), fringed sagewort (Artemisia frigida), snakeweed (Gutierrezia sarothrae), and a variety of forbs. This habitat type typically occupied relatively productive sites; that is, sites at lower elevations, with gentle topography and deep soils. The Artemisia tridentata/Agropyron spicatum habitat type was dominated by low shrubs and grasses, including sagebrush (Artemisia tridentata ssp.), fringed sagewort, snakeweed, bluebunch wheatgrass, prairie Junegrass, Sandbergh's bluegrass, needle-and-thread, blue grama (Bouteloua gracilis) and a variety of forbs. This habitat type typically occupied slightly less productive sites with steeper slopes and shallow, rocky soils (Mueggler and Stewart 1980).

Virtually all tillable land had been converted to small-grain production, primarily spring and winter wheat. Historically, cultivated land was primarily *Agropyron spicatum* /*Agropyron smithii* habitat type. Grainfield size varied from 8 to 500 ha. Grazed rangeland, mostly sites with higher elevation (above 1,350 m.) and more rugged topography, surrounded the cropland, and was primarily *Artemisia tridentata*/*Agropyron spicatum* habitat type. Within the mosaic of crop fields, grassland habitat occurred primarily as 3 types: CRP fields, linear strips and small patches of non-native grasses (e.g., roadsides), and patches (typically <16 ha) of native vegetation. Patches of native vegetation occurred as hillsides, ridge tops, and other slopes too steep to plow and were generally surrounded by cultivated ground. CRP fields were grass and grass-legume mixes composed primarily of wheatgrasses (*Agropyron* spp.) and alfalfa (*Medicago sativa*). Roadsides, waterways, fencelines and other odd areas were dominated by non-native grasses including smooth brome (*Bromus inermis*), cheatgrass (*B. tectorum*), Kentucky bluegrass (*Poa pratensis*), western wheatgrass and crested wheatgrass (*A. cristatum*). Native vegetation was primarily *Artemisia tridentata*/ *Agropyron spicatum* habitat type.

Potential mammalian nest predators observed on the study area included coyote (*Canis latrans*), red fox (*Vulpes vulpes*), badger (*Taxidea taxus*), long-tailed weasel (*Mustela frenata*), striped skunk (*Mephitis mephitis*) and Richardson's ground squirrel (*Spermophilus richardsonii*). Avian nest predators included common raven (*Corvus corax*) and black-billed magpie (*Pica pica*).

METHODS

Field Procedures

Nest Success

Studying nest success of birds in the field is difficult because nest studies are typically expensive and time consuming (Klett and Johnson 1982). Furthermore, it is difficult to meet requirements of experimental design needed to adequately test many hypotheses (Balser et al. 1968, Willebrand and Marcstrom 1988). Consequently, many researchers have used artificial nests to study factors affecting nest success. The ability to select nest location of artificial nests allows greater flexibility in assessing the influence of specific variables on nest success and permits controlled experiments with large sample sizes. Therefore, I used artificial nests to estimate nest success.

Artificial nests were vegetation-lined scrapes (5-8 cm in diameter and 2-3 cm deep) that contained 2 Japanese quail (Coturnix japonica) eggs. I placed nests along transects in grassland patches of varying composition and sizes (e.g., field borders, fence lines, roadsides, watercourses, CRP fields, and odd areas). Based on the average minimum dimension of each patch (i.e., width), I placed each patch into 1 of the following categories: $\leq$20 m (linear strips), 50 to 100 m (0.25 to 2 ha), 150 to 400 m (4 to 24 ha), and >600 m (>36 ha). I did not place nests in crop- or fallow fields because nest losses from agricultural field operations would have precluded accurate assessment of relationships between nest predation and spatial and structural variables.

Paton (1994) suggested that previous research focused on distances that were too far from edges and had nests too widely spaced to detect threshold values for "edge effects". Therefore, I placed nests along transects at as many of the following distances from a patch edge as were available within half of a given patch's minimum dimension: ≤ 5 m, 15 m, 25 m, 50 m, 75 m, 100 m, and 200 m. I established only 1 transect per patch, except in linear strips such as roadsides. In linear strips, transects were placed ≥200 m apart to ensure transect independence. Each transect was established parallel to the minimum dimension of a patch. Except for linear-strip transects, I started each transect along the length of the patch at a random distance from a patch corner. To ensure that each nest was at its designated distance from the nearest edge, the distance from a patch's corner to the transect's starting point was at least as long as the transect's length.

To assess nest success over time, I placed nests in 3 trials: June 1993, May 1994, and June 1994. Within each trial, all nests were initiated within a 5-day period, and nest-initiation dates were recorded. I subsequently monitored nest fates at 7-day intervals for three weeks. Thus, the exposure period was 21 days for each nest. I considered a nest failed if ≥1 egg was missing or damaged.

I wore latex gloves and rubber boots during nest placement and monitoring to minimize human scent at nest sites and along transects. To reduce the likelihood of attracting predators to nests, I placed nests 10 m away from, and perpendicular to, transect lines. I placed small flags on wire stakes along transect lines to mark nest locations. Each nest was placed within 25 cm of designated locations at the position with the greatest vegetative concealment.

I quantified the vegetative structure and composition associated with each nest using the methods of Hays and Farmer (1990). At each nest site, I measured visual obstruction in the 4 cardinal directions (Robel et al. 1970) and average height of herbaceous cover, percent canopy cover, proportion of herbaceous cover in grass, percent bare-ground, and percent litter-covered ground within a 0.85 m-diameter frame centered on the nest. I also recorded grassland type: (1) CRP land, (2) other non-native grasses, and (3) native vegetation. I measured nest-site vegetation after each nest's 21-day exposure period and completed all vegetation measurements within a one-week time period.

Avian Community Composition

To characterize and evaluate differences in avian community composition in various habitats and thus, put nest-success findings in perspective, I conducted extensive point counts from mid-May through June in 4 major land-use types in the area: CRP land, grain fields, fallow fields, and native vegetation (i.e., rangeland). To characterize the avian community in native vegetation I did not conduct point counts in the patches of native vegetation in which I placed artificial nests because they were typically too small to avoid potentially confounding effects of adjoining habitat. However, rangeland and smaller patches of native vegetation had very similar vegetation structure and species composition. Point counts were not conducted in patches of non-native grasses because these patches were also not large enough to accurately identify bird use.

Using fixed-radius point counts (Hutto et al. 1986, Ralph et al. 1992), I recorded all birds detected during a 5-minute count $\leq$125 m of a point center. Singing males were recorded separately from birds observed only visually. Point counts began at sunrise and continued for approximately four hours. Point counts were not conducted during inclement weather or strong winds (Ralph et al. 1992). I conducted counts along secondary roads and trails within the study area. Sample points were systematically located following location of a random starting point. Points were $\geq$400 m apart, >200 m from adjacent habitats, and sampled only once. Because many fields in the study area were large (>64 ha), the occurrence of multiple sample points in a field was common. Points in each land-use type were combined for analyses.

Data Analysis

Univariate Analyses

I used chi-square analysis to determine if nest survival in a patch was independent of patch-size, distance-from-an-edge or nest-initiation date. If results of a chi-square test were significant, I conducted weighted least-squares contrasts to determine which explanatory variable categories differed (Grizzle et al. 1969). I used MANOVA to compare vegetative characteristics among grassland habitats. If results of MANOVA were significant, I used Tukey HSD tests (Statsoft Inc. 1994) to conduct between-habitat comparisons. To test for differences in vegetative characteristics between nests that survived and nests that failed, I used Hotelling's T^2 test for an overall multivariate test, followed by t-tests for individual variables (Manly 1986:39-42). This was done for data from individual habitats as well as from pooled habitats. Significance for all tests was set at 0.10 to balance Type I and Type II statistical errors (Steel and Torrie 1980: 88-89).

Multivariate Analyses

I used best subsets logistic regression (Hosmer and Lemeshow 1989) to estimate relationships between nest survival and vegetational, spatial, and temporal variables. An explanatory variable was a candidate for a model if univariate analysis indicated that survival differed between different levels of the variable ($\underline{P} \leq 0.25$, Hosmer and Lemeshow 1989:82-87). I conducted four multivariate analyses, one that included all nests, and three that included nests stratified by grassland type. This allowed me to examine variables independently of potential confounding factors (e.g., disproportionate represention of various grassland types in patch size categories). Best-fit models were chosen based on the Mallow's Cp statistic and the adjusted $\underline{R}^2$ value for each model. Analyses were conducted using the Basic Statistics, ANOVA/MANOVA and Non-parametrics modules of program STATISTICA (StatSoft Inc. 1994) and PROC CATMOD in SAS (SAS Institute, Inc 1989).

Point-count Analyses

Point-count data were analyzed to estimate relative abundance, average species richness, cumulative species richness, and ecological species diversity (a transformation of Shannon's Index) (Nur et al. 1995) for each of the 4 land-use classes. Separate data analyses were conducted from birds detected aurally (singing males) and from birds detected either aurally or visually (all detections).

RESULTS

I established 268 transects, and initiated 741 nests in 3 trials: 247 nests in June 1993, 287 nests in May 1994, and 207 nests in June 1994 (Table 1). Transects were established in 3 grassland types and 4 patch-size categories. I monitored all nests for 21 days and determined their fates. Vegetational, spatial, and temporal variables were measured and recorded for each nest. Overall nest survival was 52.6%.

Univariate Analyses

Nest Success versus Grassland Type

Both nest survival and vegetation variables differed among grassland types ($\underline{P} < 0.10$) (Table 2). In pairwise comparisons of grassland types, survival rate, visual obstruction and vegetation height were highest in CRP fields and lowest in native vegetation. Percent canopy-cover and percent litter cover were greatest in non-native grass patches, and lowest in native vegetation. Percent bare-ground was highest in native vegetation, and lowest in non-native grass patches.

Nest Success versus Vegetation Variables

When data from all grassland types were pooled, estimates of 5 vegetation variables differed ($\underline{P} <0.10$) between failed and successful nest sites (Table 3). Visual obstruction, vegetation height, and percent canopy-cover were higher, and proportion of vegetation in grass, and percent bare-ground were lower at successful nest sites than at depredated nest sites.

Table 1. Numbers of transects and artificial nests used to study relationships between nest survival and habitat variables in 3 grassland habitats in an agricultural landscape near Three-Forks, Montana, 1993-94.

		Numbers of nests at each distance to nearest habitat edge (m)							
Patch size[a]	Number of Transects	≤5	15	25	50	75	100	200	Total
linear	155	155							155
0.25-2 ha	30	30	18	30	19				97
4-24 ha	28	28	20	28	28	20	16	4	144
> 36 ha	55	55	35	55	55	35	55	55	345
Total	268	268	73	113	102	55	71	59	741

[a] Patches were categorized based on their average minimum dimension (i.e., width), in the following categories: ≤ 20 m (linear), 50 to 100 m (0.25 to 2 ha), 150 to 400 m (4 to 24 ha), and >600 m (>36 ha). Linear strips were long, narrow habitat patches (e.g., roadsides or fencelines). Four linear strip transects were in native vegetation, and 151 were in non-native grasses. Twenty small patches were in native vegetation, 8 were Conservation Reserve Program (CRP) fields, and 2 were in other non-native grasses. Sixteen medium patches were in native vegetation, and 12 were CRP fields. Fifty-three large patches were CRP fields, and 2 were in native vegetation.

Table 2. Comparisons of vegetative characteristics and survival rates of artificial nests in 3 grassland habitats in an agricultural landscape near Three-Forks, Montana, 1993-94.

	Grassland Habitat[a]					
	CRP (n=432)		NNG (n=156)		Native (n=153)	
Variable[b]	mean	SE	mean	SE	mean	SE
Visual obstruction	2.4 A[c]	0.1	1.8 B	0.1	1.1 C	0.1
Vegetation height	5.1 A	0.1	4.2 B	0.1	3.1 C	0.1
% canopy cover	39.3 B	0.9	44.3 A	1.4	32.4 C	1.4
Percentage grass	70.5 B	1.4	90.0 A	1.1	69.3 B	0.9
% bare ground	39.3 B	1.2	26.2 C	1.6	52.0 A	1.7
% litter cover	22.6 B	0.8	31.4 A	1.4	16.2 C	1.1
Nest survival (%)	62.7 A	2.3	53.2 B	4.0	23.5 C	3.5

[a] Grassland habitats are: (1) CRP - lands enrolled in the Conservation Reserve Program, which were in grass and grass-legume mixes, primarily wheatgrasses and alfalfa; (2) NNG - idle patches of non-native grasses, dominated by smooth brome, cheatgrass, Kentucky bluegrass, western wheatgrass and crested wheatgrass; and (3) Native - habitat patches dominated by native vegetation, primarily Artemisia tridentata/ Agropyron spicatum habitat type (Mueggler and Stewart 1980).

[b] Visual obstruction was measured in the 4 cardinal directions (Robel et al. 1970). Other vegetative characteristics were measured on 0.85 m-diameter circular plots centered on nest sites. Vegetation height was the average vegetation height within a plot, in decimeters. Percent canopy-cover was the percentage of a plot obscured by vegetation when viewed from above. Percent grass was the percentage of herbaceous vegetation on a plot that was grass. Percent bare-ground was the percentage of a plot with exposed soil. Percent litter-cover was the percentage of a plot that was covered with vegetation litter.

[c] Mean values within a row sharing the same capital letter are not significantly different from one another ($\underline{P}$ <0.10). Vegetation variable means were compared using MANOVA (Wilks' Lamda $\underline{P}$ <0.001) followed by Tukey HSD tests (Statsoft Inc. 1994). Survival rates were compared using a chi-square test ($\underline{P}$ <0.001) followed by least squares contrasts (Grizzle et al. 1969).

Table 3. Comparisons of vegetative characteristics of sites where artificial nests were successful and depredated in 3 grassland habitats in an agricultural landscape near Three-Forks, Montana, 1993-94.

	Depredated nests			Successful nests			
Variable[a]	n	Mean	SE	n	Mean	SE	P
All Nests							<0.001[b]
Visual obstruction	345	1.5	0.1	396	2.5	0.1	<0.001
Vegetation height	345	3.9	0.1	396	5.0	0.1	<0.001
% canopy cover	345	34.0	0.9	396	43.2	0.9	<0.001
Percentage grass	345	78.4	1.3	396	70.9	1.5	0.002
% bare ground	345	44.0	1.4	396	35.0	1.2	<0.001
% litter cover	345	22.5	0.9	396	23.9	0.8	0.244
Nests in CRP							<0.001[b]
Visual obstruction	161	1.9	0.1	271	2.7	0.1	<0.001
Vegetation height	161	4.6	0.1	271	5.3	0.1	<0.001
% canopy cover	161	34.4	1.5	271	42.0	1.1	<0.001
Percentage grass	161	78.6	2.1	271	66.0	1.8	<0.001
% bare ground	161	43.3	1.8	271	37.1	1.4	0.007
% litter cover	161	22.1	1.3	271	22.8	1.0	0.798
Nests in NNG							<0.001
Visual obstruction	74	1.5	0.1	82	2.1	0.1	0.001
Vegetation height	74	3.8	0.2	82	4.6	0.2	<0.001
% canopy cover	74	39.2	1.7	82	48.9	2.1	<0.001
Percentage grass	74	90.1	1.7	82	89.9	1.6	0.935
% bare ground	74	27.4	2.1	82	25.1	2.5	0.486
% litter cover	74	34.8	1.9	82	28.5	2.0	0.042
Nests in NV							<0.001[b]
Visual obstruction	117	1.0	0.1	36	1.6	0.1	<0.001
Vegetation height	117	2.9	0.1	36	3.6	0.2	0.007
% canopy cover	117	30.2	1.4	36	39.1	3.0	0.004
Percentage grass	117	70.6	2.3	36	65.4	4.3	0.270
% bare ground	117	55.4	1.9	36	41.7	3.8	<0.001
% litter cover	117	14.8	1.2	36	20.4	2.2	0.021

Table 3. Continued.

[a] Visual obstruction was measured in the 4 cardinal directions (Robel et al. 1970). Other vegetative characteristics were measured on a 0.85 m-diameter circular plots centered on nest sites. Vegetation height was the average vegetation height within a plot, in decimeters. Percent canopy-cover was the percentage of a plot obscured by vegetation when viewed from above. Percent grass was the percentage of herbaceous vegetation on a plot that was grass. Percent bare-ground was the percentage of a plot with exposed soil. Percent litter-cover was the percentage of a plot that was covered with vegetation litter. CRP is land enrolled in the Conservation Reserve Program, which is in grass and grass-legume mixes, primarily wheatgrasses and alfalfa; NNG is habitat patches of non-native grasses, dominated by smooth brome, cheatgrass, Kentucky bluegrass, western wheatgrass and crested wheatgrass; and NV is habitat patches dominated by native vegetation, primarily Artemisia tridentata/ Agropyron spicatum habitat type (Mueggler and Stewart 1980).

[b] Multivariate comparisons were made using Hotelling's T^2 tests ($\underline{P} < 0.001$) followed by t-tests for individual variables when results of a multivariate test was significant (Manly 1994:39-42).

Within all 3 grassland types, visual obstruction, vegetation height, and percent canopy-cover were greater at survived nest sites.

All 3 measures of vegetation structure were interrelated. Visual obstruction was highly correlated with vegetation height (r = 0.505, P < 0.001, n = 741) and percent canopy-cover (r = 0.503, P < 0.001, n =741). Vegetation height was only moderately correlated with percent canopy-cover (r = 0.090, P = 0.004, n = 741). Additionally, in CRP fields, visual obstruction was inversely correlated with the proportion of vegetation in grass (r = -0.550, P < 0.001, n = 432).

Nest Success versus Spatial and Temporal Variables

When nests in all grassland types were pooled, nest success was greater in June than May (P <0.001), in the largest fields (P <0.001), and at the farthest distances from field edges (P = 0.042)(Table 4). However, effects of distance-from-edge and patch-size were confounded by disproportionate representation of vegetation types in patch-size categories (Table 1). In CRP fields, nest success was highest in large patches and lowest in small patches (P <0.001). In native vegetation, nest success did not differ with patch size (P = 0.929). Within grassland types, nest success did not differ with distance edge (P = 0.694 in CRP fields and P = 0.579 in native vegetation). There were insufficient sample sizes in patches of non-native grasses to test for differences in distance-to-edge and patch-size categories

Table 4. Survival rates of artificial nests in relation to spatial and temporal variables in 3 grassland habitats in an agricultural landscape near Three-Forks, Montana, 1993-94.

Variable	n	Nest survival(%)	P
Nest-initiation date[a]			
June 1993	247	56.7 A[d]	<0.001
May 1994	287	44.3 B	
June 1994	207	62.8 A	
Patch size			
linear strips[b]	155	52.2 B	<0.001
0.25-2 ha	30	30.4 C	
4-24 ha	28	34.0 C	
> 36 ha	55	66.6 A	
Distance from an edge[c]			
≤ 5 m	155	52.2 B	0.042
5 m	113	46.9 B	
15 m	73	46.6 B	
25 m	113	47.7 B	
50 m	102	54.0 B	
75 m	55	54.5 B	
100 m	71	57.8 B	
200 m	59	69.5 A	

[a] Time period in which 21-day nest exposure periods began.

[b] Linear strips were long, narrow habitat patches <25 m wide (e.g., roadsides or fencelines).

[c] Categorical distances that nests were placed away from, and perpendicular to, the abrupt edge of a habitat patch (e.g., roadside or cropfield). Nests ≤ 5 m from an edge were those placed in linear strips. All other distance-to-edge categories refer to nests placed within patches of greater minimum dimension (>50 m).

[d] Values within a column for a particular variable sharing the same capital letter are not significantly different from one another (P >0.10). Survival rates were compared using chi-square tests followed by least-squares contrasts if the chi-square statistic was significant (Grizzle et al. 1969).

Table 5. Best-subsets logistic regression models of habitat variables that affect nest survival within and among grassland habitats in an agricultural landscape near Three-Forks, Montana, 1993-94.

Grassland Type[a]	Best-subsets Model[b]	Cp[c]	Adj R^2
CRP	1.56 VO - 0.35 PG + 0.58 VH	4.28	0.34
NNG	0.79 VO + 0.08 ID + 0.07 CC	2.45	0.34
Native	6.09 VO + 0.06 ID + 1.17 CC + 1.59 VH	6.37	0.45
All	2.35 VO + 0.02 ID + 0.41 CC	3.72	0.38

[a] Vegetation types are: (1) CRP - land enrolled in the Conservation Reserve Program, which is in grass and grass-legume mixes, primarily wheatgrasses and alfalfa; (2) NNG - habitat patches of non-native grasses, dominated by smooth brome, cheatgrass, Kentucky bluegrass, western wheatgrass and crested wheatgrass; and (3) Native - habitat patches dominated by native vegetation, primarily Artemisia tridentata/ Agropyron spicatum habitat type (Mueggler and Stewart 1980).

[b] Variables in the models are: VO - visual obstruction, VH - vegetation height, ID - nest-initiation date, CC - percent canopy cover, and PG - percentage of herbaceous vegetation in grass.

[c] Mallows Cp statistic.

Multivariate Analyses

I conducted best subsets logistic regression analyses to better evaluate the effects of variables on nest success, both within and among vegetation types. In all analyses, 3 or 4-variable models containing vegetation structure and nest-initiation date, but not spatial variables, were the most parsimonius and least biased (Table 5). Of ten variables evaluated with univariate screening tests ($\underline{P} < 0.25$), nine (distance-from-an-edge, patch-size, nest-initiation date, vegetation height, visual obstruction, percent canopy-cover, proportion of vegetation in grass, percent bare-ground, and percent litter-cover) were allowed entry into one or more regression analyses.

In the analysis of data pooled from all habitats, a 3-variable model containing visual obstruction, percent canopy cover, and nest-initiation date provided the best fit (Mallows' Cp = 3.72, and adjusted $R^2 = 0.38$). Regression analyses within grassland types yielded similar results. Best fits were provided by 3 or 4-variable models. For CRP patches, a 3-variable model including visual obstruction, vegetation height, and proportion of vegetation in grass was selected (Mallows' Cp = 4.28, and adjusted $R^2 = 0.34$). For other non-native grass patches, a 3-variable model including visual obstruction, percent canopy-cover, and nest-initiation date provided the best fit (Mallows' Cp = 2.45, and adjusted $R^2 = 0.34$). For native vegetation patches, a 4-variable model including visual obstruction, percent canopy cover, nest initiation date, and vegetation height was selected (Mallows' Cp = 6.37, and adjusted $R^2 = 0.45$).

When variables from best-subset models were evaluated individually with regression, each explained a significant amount of variation in nest success. However, in all analyses, visual obstruction explained the most variation: 32.8%

in the pooled nest analysis, 28.7% in CRP, 18.4% in other non-native grasses, and 20.1% in native vegetation. No other variable explained >13.6% of the variation in nest survival in any analysis.

Point Count Analyses

Avian community complexity and composition varied among different land uses. Species richness and diversity were two to three-times greater in CRP fields and rangeland (native vegetation) than in crop or fallow fields (Table 6). Bird abundance was greatest in fallow fields (all detections) and in rangeland (singing males only), and least in crop fields. Species richness was greater in CRP fields and rangeland than in fallow fields and crop fields.

Three species were common to all 4 land uses (Tables 7-10): western meadowlark, horned lark and vesper sparrow (see Table 11 in the Appendix for scientific names). These same three were the only species I observed displaying breeding behavior in crop and fallow fields. Five species were unique to CRP fields (savannah sparrow, grasshopper sparrow, northern harrier, short-eared owl, and mallard) and seven to rangeland (Brewer's sparrow, sage thrasher, mourning dove, mountain bluebird, brown-headed cowbird, black-billed magpie, and common raven). I observed 8 species (savannah sparrow, grasshopper sparrow, vesper sparrow, western meadowlark, horned lark, long-billed curlew, northern harrier, and mallard) displaying breeding behavior in CRP fields and 7 (Brewer's sparrow, sage thrasher, mourning dove, vesper sparrow, western meadowlark, horned lark, and Brewer's blackbird) in rangeland.

Table 6. Characteristics of avian communities determined from 125-m radius point-counts, using visual and aural detections in four land use classes in an agricultural landscape near Three-Forks, Montana, 1994.

All Detections

Land use class[a]	n	Avg. number individuals/pt.[b] mean	SE	Species richness/pt. mean	SE	Cumulative spp. richness	Ecol. species diversity (N1)[c]
CRP-field	50	3.1 B[d]	0.2	1.9 A	0.1	11	4.3
Fallow-field	51	4.5 A	0.4	1.4 B	0.1	5	1.7
Crop-field	50	2.9 B	0.4	1.0 B	0.1	6	1.8
Rangeland	51	3.7 AB	0.3	2.2 A	0.2	13	6.1

Singing Males Only

Land use class[a]	n	Avg. number individuals/pt.[b] mean	SE	Species richness/pt. mean	SE	Cumulative spp. richness	Ecol. species diversity (N1)[c]
CRP field	50	2.7 AB	0.2	1.8 A	0.1	5	3.4
Fallow field	51	2.5 B	0.2	1.2 B	0.1	3	1.5
Crop field	50	1.9 C	0.2	0.9 B	0.1	3	1.3
Rangeland	51	3.1 A	0.2	2.0 A	0.1	7	4.7

[a] CRP fields were fields enrolled in the Conservation Reserve Program, and seeded into grass or grass/legume mixes; fallow fields were fields left in residual wheat stubble between years of biannual crop production; crop-fields were fields seeded into spring- or winter-wheat; and rangeland was grazed land, in native vegetation , primarily of the Artemisia tridentata/Agropyron spicatum habitat type (Mueggler and Stewart 1980).

[b] Birds detected within 5 minutes of observation.

[c] Calculated from a transformation of Shannon's Index (Nur et al. 1995).

[d] Mean values within a column sharing the same capital letter are not significantly different from one another (P <0.10). Average number of individuals/point and species richness/point means were compared using MANOVA (Wilks' Lamda P <0.01) followed by Tukey HSD tests (Statsoft Inc. 1994).

Table 7. Frequency of occurrence and relative abundance of avian species detected with 125 m-radius point counts (n=50) in Conservation Reserve Program (CRP) fields[a] in an agricultural landscape near Three-Forks, Montana, 1994.

All Detections (Species Total = 11)

Species[b]	Frequency of Occurrence[c]	Relative Abundance[d] Mean	Relative Abundance[d] SE
Western meadowlark	0.32	0.42	0.09
Horned lark	0.06	0.06	0.03
Vesper sparrow	0.74	1.52	0.17
Savannah sparrow	0.54	0.76	0.12
Grasshopper sparrow	0.10	0.14	0.07
European starling	0.02	0.12	0.12
Gray partridge	0.02	0.02	0.02
Mallard[e]	0.02	0.02	0.02
Northern harrier[e]	0.02	0.02	0.02
Short-eared owl	0.02	0.02	0.02
Long-billed curlew[e]	0.02	0.02	0.02

Singing Males Only (Species Total = 5)

Species[b]	Frequency of Occurrence[c]	Relative Abundance[d] Mean	Relative Abundance[d] SE
Western meadowlark	0.24	0.26	0.07
Horned lark	0.06	0.06	0.03
Vesper sparrow	0.66	1.34	0.15
Savannah sparrow	0.54	0.76	0.12
Grasshopper sparrow	0.10	0.14	0.07

[a] CRP fields were seeded into grass or grass/legume mixes.

[b] See Table 7 for scientific names.

[c] Frequency of occurrence is the proportion of points in which a species was detected.

[d] Relative abundance is the number of detections per point.

[e] Species that had an active nest and/or exhibited territorial behavior (exclusive of singing males) within a sample point.

Table 8. Frequency of occurrence and relative abundance of avian species detected with 125 m-radius point counts (n=51) in fallow-fields[a] in an agricultural landscape near Three-Forks, Montana, 1994.

All Detections (Species Total = 5)

Species[b]	Frequency of Occurrence[c]	Relative Abundance[d] Mean	Relative Abundance[d] SE
Western meadowlark	0.10	0.16	0.07
Horned lark	0.94	3.96	0.39
Vesper sparrow	0.24	0.35	0.10
Long-billed curlew	0.06	0.06	0.03
Killdeer	0.02	0.02	0.02

Singing Males Only (Species Total = 3)

Species[b]	Frequency of Occurrence[c]	Relative Abundance[d] Mean	Relative Abundance[d] SE
Western meadowlark	0.10	0.10	0.04
Horned lark	0.94	2.24	0.13
Vesper sparrow	0.18	0.22	0.08

[a] Fallow fields were fields left in residual wheat stubble between years of biannual crop production.

[b] See Table 7 for scientific names.

[c] Frequency of occurrence is the proportion of points in which a species was detected.

[d] Relative abundance is the number of detections per point.

Table 9. Frequency of occurrence and relative abundance of avian species detected with 125 m-radius point counts (n=50) in crop-fields[a] in an agricultural landscape near Three-Forks, Montana, 1994.

	All Detections (Species Total = 6)		
	Frequency of	Relative Abundance[d]	
Species[b]	Occurrence[c]	Mean	SE
Western meadowlark	0.18	0.28	0.11
Horned lark	0.74	2.42	0.32
Vesper sparrow	0.04	0.08	0.06
Brewer's blackbird	0.02	0.02	0.06
European starling	0.02	0.06	0.02
Long-billed curlew	0.02	0.02	0.02

	Singing Males Only (Species Total = 3)		
	Frequency of	Relative Abundance[d]	
Species[b]	Occurrence[c]	Mean	SE
Western meadowlark	0.14	0.14	0.05
Horned lark	0.74	1.68	0.17
Vesper sparrow	0.02	0.02	0.02

[a] Crop-fields were fields seeded into spring- or winter-wheat.

[b] See Table 7 for scientific names.

[c] Frequency of occurrence is the proportion of points in which a species was detected.

[d] Relative abundance is the number of detections per point.

Table 10. Frequency of occurrence and relative abundance of avian species detected with 125m-radius point counts (n=51) in native vegetation (rangeland)[a] in an agricultural landscape near Three-Forks, Montana, 1994.

All Detections (Species Total = 13)

Species[b]	Frequency of Occurrence[c]	Relative Abundance[d] Mean	SE
Western meadowlark	0.35	0.47	0.10
Horned lark	0.33	0.76	0.20
Vesper sparrow	0.57	0.98	0.16
Brewer's sparrow	0.57	0.96	0.16
Sage thrasher	0.10	0.12	0.05
Mourning dove	0.06	0.08	0.05
Mountain bluebird	0.02	0.04	0.04
Brewer's blackbird	0.02	0.02	0.02
Brown-headed cowbird	0.06	0.10	0.06
Black-billed magpie	0.04	0.02	0.02
Common raven	0.02	0.02	0.02
Long-billed curlew	0.02	0.02	0.02
Gray partridge	0.04	0.08	0.05

Singing Males Only (Species Total = 7)

Species[b]	Frequency of Occurrence[c]	Relative Abundance[d] Mean	SE
Western meadowlark	0.35	0.47	0.10
Horned lark	0.33	0.65	0.15
Vesper sparrow	0.57	0.90	0.14
Brewer's sparrow	0.57	0.84	0.12
Sage thrasher	0.10	0.12	0.05
Brewer's blackbird	0.02	0.02	0.02
Mourning dove	0.04	0.04	0.02

[a] Native vegetation (rangeland) was grazed land, primarily of the Artemisia tridentata/ Agropyron spicatum habitat type (Mueggler and Stewart 1980).

[b] See Table 7 for scientific names.

[c] Frequency of occurrence is the proportion of points in which a species was detected.

[d] Relative abundance is the number of detections per point.

DISCUSSION

Nest Success

Nest Success versus Grassland Type

Nest success was highest in CRP fields and lowest in native vegetation. Similarly, all 3 measures of vegetation structure were highest in CRP fields and lowest in native vegetation. Thus, nest success appears to be related primarily to vegetation structure. The disparity in vegetation structure between CRP fields and native vegetation patches may, in part, be related to structural differences inherent in the vegetation species occupying respective habitats, as well as to relative productivity of sites where each habitat typically occurred. Results from within all grassland types demonstrated little relationship between spatial variables and nest survival. Previous research has also reported different nest success rates in various grassland habitats (e.g., Klett et al. 1988, Mankin and Warner 1992, Greenwood et al. 1995). However, I am unaware of any investigation of causative factors for observed differences. I suspect that in my study, vegetation structure was primarily responsible for the differences in nest success among the various grassland types.

Nest Success versus Vegetation Structure

Nest success was consistently higher in areas with taller, thicker vegetation, both within and among vegetation types. Visual obstruction explained the greatest amount of variation in survival rate in all analyses. Other structure related variables (e.g. percent canopy cover and vegetation height) explained much less of the variation but were also significant predictors of nest success. My results are similar to those of previous studies involving both artificial and natural nests. Mankin and Warner (1992) demonstrated that predation of artificial nests was inversely correlated with vegetation concealment and cover density at nest sites. DeLong et al. (1995) reported that greater amounts of both tall ($\geq$15 cm) grass cover and medium-height (40-80 cm) shrub cover were associated with lower predation rates on artificial nests. Similarly, Gregg et al. (1994) found that successful sage grouse nests had a higher percentage of tall (>18 cm) grass cover in the surrounding area than did depredated nests.

The reasons for better nest success in grasslands with thicker vegetation have been suggested by several authors. Dwernychuk and Boag (1972) and Jones and Hungerford (1972) suggested that the visibility of eggs was a key factor in predation by avian predators. Similarly, Sugden and Beyersbergen (1987) reported that tall, dense cover acted as a behavioral deterrent, as well as a physical barrier to American crows (Corvus brachyrhynchos) hunting on foot. Schrank (1972), Bowman and Harris (1980), and Crabtree et al. (1989) found that nest predation by mammalian predators decreased with increased lateral cover density, and vegetation height. Thus, it appears that heavy cover may reduce nest predation by reducing nest visibility, restricting predator movements, and increasing predator foraging costs.

One other vegetation variable, proportion of vegetation in grass, was inversely related to and was a significant predictor of nest success in CRP fields. Alfalfa was typically the only forb seeded into CRP fields in my study area and accounted for the most of the non-grass proportion of vegetation. The presence of alfalfa in the vicinity of a nest site may have lowered the probability of nest predation. The reasons for this (aside from alfalfa increasing foliage density, a measurement that should have been captured in visual obstruction, percent canopy cover and/or vegetation height) are unclear. It may be the complex branching pattern of alfalfa provides greater concealment for nests and eggs than does the simpler branching patterns typical of grasses. Alfalfa may also be more difficult to move through than grass, and thereby reduces mammalian predators nest-finding abilities.

Nest Success versus Spatial Variation

Spatial variables (patch size and distance to edge) appeared to be poor predictors of nest success in all grassland types. Univariate data analyses of patch-size effects on nest survival were equivocal because results from various grassland types differed (nest survival rates did not differ with patch size in native vegetation patches but did in CRP fields). However, multivariate data analyses demonstrated only a very weak relationship between patch size and nest survival within or among grassland types. Similarly, in both univariate and multivariate data analyses, distance to edge was very weakly linked to nest survival within grassland types. I suggest cautious interpretation of my data, however, because I placed multiple nests on individual transects. Nests on a given transect were separated by 10 to 100m. It has been hypothesized that nest density (or nest proximity) influences survival probability (e.g., Tinbergen et al. 1967, O'Reilly and Hannon 1989). Thus, it is difficult to draw conclusions on the relationship between nest survival and distance to edge because of the confounding of potential edge effects and nest proximity effects.

In sharp contrast to other grassland studies, I found little relationship between nest success and distance to edge. However, comparisons of "edge effect" among grassland studies is problematic. Differences in study designs (e.g., multiple nests on a transect versus random nest locations) and variation in the nature of the ecotones that constitute edge in each study area make comparisons difficult. Edge in my study area was the abrupt departure from roadsides or cropfields to grassland. Burger et al. (1994), and Johnson and Temple (1990) conducted nest-success studies in areas where edge was the interface between grassland and woody cover and grassland and forest edge respectively. In the latter study areas, woody cover was a likely source of non-grassland predators and thus, added to the diversity of predators searching the edge zone. Also, woody cover likely provided escape-cover and travel corridors for mammalian predators, and numerous elevated perch sites for avian predators, thereby concentrating predator activity along edges. For example, Fritzell (1978) found prairie raccoons (Procyon lotor) used shelterbelts for travel lanes, and Jones and Hungerford (1972) reported higher predation rates on artificial nests <33 m from black-billed magpie (Pica pica) perch sites than nests farther away. Indeed, Burger et al. (1994) found that artificial nests <60 m from woody cover had predation rates 3 times greater than nests >60 m away and Johnson and Temple (1990) reported that passerine nests <45 m from a forest edge had lower reproductive success than those nests farther away. My results may differ in part, because edge ecotones in my study area provided little cover for mammalian predators and few perch sites for avian predators.

Results of studies of the importance of patch size to nest success also vary. Burger et al. (1994) reported greater predation on artificial nests in prairie fragments <15 ha than in fragments >15 ha. Johnson and Temple (1990) found that predation rates on nests of 5 species of grassland passerines were higher in prairie patches <32 ha than in patches >130 ha. Nelson and Duebbert (1974) reported that waterfowl nest success was higher in blocks of upland cover >32 ha than in blocks ≤16 ha. However, in many studies (in forest as well as grassland), statistical tests were performed primarily to identify relationships between nest success and patch size. Few attempts have been made to quantify the relationship or evaluate the potential confounding effects of patch size and other variables (e.g., vegetation structure). Although I found a significant difference in nest success among patch sizes in CRP fields, regression analysis revealed that patch size explained very little of the variation (adj $R^2 = 0.03$) in nest-survival rate. Thus, patch size appeared to have little effect on nest survival. Only one other grassland bird study that I am aware of (Burger et al. 1994) used regression analysis to determine the magnitude of the relationship between patch size and nest success in tallgrass prairie in Missouri. In that study, natural log transformation of tract size regressed against arcsine-transformed predation rate yielded an $R^2 = 0.76$. Future study of patch size effects and comparisons of study results might benefit from more in-depth and standardized methods of data analysis.

Nest Success versus Temporal Variation

Nest success rate increased as the nesting season progressed. Nest-initiation date was a significant predictor of nest survival in all grassland types but CRP. Previous waterfowl studies reported higher nest success rates for nests initiated later in the season for both artificial and natural nests (Gottfried and Thompson 1978, Sugden and Beyersbergen 1986, Greenwood et al. 1995). Higher survival rates may have been a function of increased vegetation volume through the growing season, prey switching by nest predators, or a combination of these and other factors. In CRP fields, greater amounts of over-winter residual cover existed and may have provided adequate concealment to allow higher nest success rates for early-season nests.

Results of artificial nest studies should be intepreted with caution. It has been hypothesized that artificial nest predation is biased in favor of sight-oriented predators (i.e., birds), and against predators that rely more heavily on olfactory cues (i.e., mammals) compared to natural nests (Sugden and Beyersbergen 1986, Storass 1988, Willebrand and Marcstrom 1988). Thus, artificial nest predation may not hold a consistent relationship with natural nest predation under all circumstances (Butler 1996). Therefore, artificial nest studies may be more valuable as guides in designing studies of predation on natural nests, rather than bases for mangement decisions. However, in many instances (exclusive perhaps of waterfowl and some upland gamebirds) artificial nest studies may provide the best, and in some cases the only, nest success information available

Avian Communities

CRP lands had a relatively diverse bird community compared to surrounding lands, and provided nesting habitat for nearly 3 times as many species as the crop and fallow fields they have replaced. Although comparable to native vegetation (rangeland) in species abundance and richness, CRP lands supported a somewhat different avian community. A likely reason for this may be that the vegetation composition and structure in CRP lands and native vegetation also differed. This has important implications about the potential of the CRP to restore populations of some grassland species, given that CRP fields may little resemble lost native habitat.

CRP lands lacked the shrub component of the native shrubsteppe habitats and contained mostly exotic rather than native grasses and forbs. Structurally, CRP fields more closely resembled a short- or mixed-grass prairie and probably had greater appeal as nesting habitat to species related more to prairie than to shrubsteppe. Indeed, one grassland endemic (long-billed curlew) and three secondary grassland species (grasshopper sparrow, savannah sparrow, and northern harrier) displayed breeding behavior and/or had active nests only in CRP fields. Although more than 50 species of neotropical migratory birds may breed in various parts of the shrubsteppe region, a typical shrubsteppe community has only 2-7 regular breeding species (Bock et al. 1992). The most common shrubsteppe birds are horned lark, sage thrasher, Brewer's sparrow, sage sparrow, vesper sparrow,and western meadowlark. In my study, 3 of these (horned lark, vesper sparrow,and western meadowlark) occurred in CRP fields, whereas 5 (horned lark, sage thrasher, Brewer's sparrow, vesper sparrow,and western meadowlark) occurred in native vegetation. Although CRP lands did not appear to contain the full complement of shrubsteppe bird species, they did provide breeding habitat for some shrubsteppe species. Furthermore, CRP lands provided preferred and higher quality nesting habitat for numerous species, including several species of concern (e.g., long-billed curlew, northern harrier and grasshopper sparrow), than did crop- or fallow fields.

Indeed, broad regional information on effects of CRP lands on wildlife populations has suggested substantial benefit to many avian species. For example, Kantrud et al. (1993) found that CRP fields in North Dakota were utilized by most upland waterfowl. Allen (1993) and Berner (1994) reported increased populations of upland gamebirds associated with CRP lands throughout the Midwest and Northern Plains. Johnson and Schwartz (1993) recorded greater densities of 16 species in CRP fields than in cropfields. Breeding Bird Survey data indicate that some grassland passerine populations (e.g., lark bunting and grasshopper sparrow) have increased coincident with the CRP (Reynolds et al. 1994). Although studies indicate that numerous avian species are correlated with CRP lands, insufficient focus has been placed on CRP-field effects on populations. More species- (or at least guild-) specific study of life-requisite responses to CRP lands over broad geographical areas is needed to fully evaluate the programs effectiveness towards restoring avian populations.

CONCLUSIONS AND RECOMMENDATIONS

My results indicate that a nest's survival is influenced more by the structure of surrounding vegetation than by a nest's location (e.g., proximity to an edge or patch size). It would seem appropriate, therefore, to recommend seeding mixtures that provide dense vegetation for patches of planted cover (e.g., CRP lands). Promotion of habitat characteristics that negatively affect predator nest-searching behavior and provide suitable nesting cover should be the goal of grassland plantings. For example, seeding mixes that include alfalfa or similar forbs (e.g., yellow sweet-clover) may provide thicker cover than grass-only mixes. Seeding mixes that provide optimal vegetation structure and cover probably differ from site to site because predator abundance and community composition vary greatly both locally and regionally. Knowledge of the predator community in a given area is important to appropriate habitat recommendations. For example, overhead nest concealment may be most important when nest predators are primarily avian (Jones and Hungerford 1972, Dwernychuk and Boag 1972, Clark and Nudds 1991), whereas lateral cover has greater influence on mammalian predators (Schranck 1972, Bowman and Harris 1980, Crabtree et al. 1989).

However, cover recommendation alone is certainly insufficient to address the needs of all grassland birds. That is, it fails to take into account site specific requirements of individual or groups of species. Specific nest and/or foraging site requirements vary from species to species. At one extreme is a group (e.g., savannah sparrow, Baird's sparrow, long-billed curlew, northern harrier, short-eared owl) that depends on heavy litter and grass canopy. At the other extreme are species that respond well to short, sparse vegetation (e.g., horned lark, killdeer, McCown's longspur, burrowing owl). In between is a group that appears to require intermediate levels of ground cover (e.g., vesper sparrow, western meadowlark, lark bunting, grasshopper sparrow, upland plover).

Currently, millions of hectares of CRP grasslands exist in Montana and other western states. Most are dominated by exotic rather than native grasses, and lack the diversity of plant species and structural complexity of native grasslands (Gerard 1995). Furthermore, program regulations prevent manipulation of vegetation (e.g., burning, disking, mowing, grazing) that might better mimic the historical patterns of disturbance that created mosaics of vegetation structure and diversity across the landscape. Thus, the appeal of CRP lands to a broad array of avian species is probably limited. Although CRP grasslands appear to be more valuable to many bird species than the croplands they have replaced (e.g., Allen 1993, Johnson and Schwartz 1994, Reynolds et al. 1994, this study), potential benefits from appropriate changes in conservation practices might be enormous. Future management of CRP (or similar program lands) should be oriented towards seed mixes that maximize structural diversity and include species composition that more closely resemble those of native vegetation. Additionally, practices that incorporate moderate livestock grazing, haying, prescribed burning, or other management options to create a mosaic of habitats may make set aside lands more valuable to a wider variety of species. Future research should focus on avian population dynamics in existing CRP fields and other remaining grassland habitats to better evaluate their roles as source or sink habitats.

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APPENDIX

Table 11. Common and scientific names of avian species listed in text and tables.

Common name	Scientific name
Baird's Sparrow	Ammodramus bairdii
Bobolink	Dolichonys oryzivorus
Black-billed Magpie	Pica pica
Brewer's Blackbird	Euphagus cyanocephalus
Brewer's Sparrow	Spizella breweri
Brown-headed Cowbird	Molothrus ater
Cassin's Sparrow	Aimophila cassinii
Clay-colored Sparrow	Spizella pallida
Common Raven	Corvus corax
Dickcissel	Spiza americana
Eastern Meadowlark	Sturnella magna
European Starling	Sturnus vulgaris
Grasshopper Sparrow	Ammodramus savannarum
Gray Partridge	Perdix perdix
Henslow's Sparrow	Ammodramus henslowii
Horned Lark	Ermophila alpestris
Killdeer	Charadrius vociferus
Lark Bunting	Calmospiza melanocorys
Long-billed Curlew	Numenius americanus
Mallard	Anas platyrhynchos
Mountain Bluebird	Sialia currucoides
Mountain Plover	Charadrius montanus
Mourning Dove	Zenaida macroura
Northern Harrier	Circus cyaneus
Sage Thrasher	Oreoscoptes montanus
Savannah Sparrow	Passerculus sandwichensis
Short-eared Owl	Asio flammeus
Vesper Sparrow	Pooecetes gramineus
Western Meadowlark	Sturnella neglecta