

SUCCESS OF ARTIFICIAL NESTS IN CRP FIELDS, NATIVE VEGETATION, AND FIELD BORDERS IN SOUTHWESTERN MONTANA

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Abstract.—In 1993–1994, we used artificial nests to study relationships between nest success and various spatial, temporal, and vegetation variables in three grassland types: Conservation Reserve Program (CRP) fields, field borders and watercourses, and native vegetation. Nest success was higher and vegetation was structurally more complex in CRP fields than in other grassland types. Nest success was 63% in CRP fields but only 24% in native vegetation. Results of univariate and multivariate analyses indicated that nests surrounded by taller, thicker cover were more likely to survive than nests with less concealing vegetation. Nests initiated later in the season, when vegetation volume was greater, survived at higher rates than nests initiated earlier. Spatial variables were not strongly related to nest success. Field size was directly related to nest success in CRP fields but not in other grassland types. However, field size was not included in the most parsimonious, multivariate model of factors related to nest success in CRP fields. Similarly, proximity to field borders was not related to nest success in any grassland type. Our results suggest that CRP fields, which cover a large area in the Northern Great Plains and attract a greater diversity of grassland birds than the cropfields they replaced, provide secure nesting cover for ground-nesting species.

EXITO DE NIDOS ARTIFICIALES EN CAMPOS DEL PRC, EN VEGETACIÓN NATIVA, Y EN CAMPOS DE BORDE EN EL SUROESTE DE MONTANA.

Sinopsis.—Utilizamos nidos artificiales entre 1993 y 1994 para estudiar las relaciones entre éxito del nido y ciertas variables espaciales, temporales y vegetacionales en tres tipos de pastizales: terrenos del Programa de Reservas de Conservación (PRC), bordes de campo y rutas acuáticas, y vegetación nativa. El éxito de nidos fué mayor y la estructura vegetacional fué más compleja en los terrenos del PRC que en otros tipos de pastizal. El éxito de anidaje fué de 63% en terrenos del PRC pero solo de 24% en la vegetación nativa. Los resultados de análisis univariados y multivariados indican que nidos rodeados de mayor cobertura que sea más densa tenían mayor probabilidad de sobrevivir que nidos con vegetación menos encubridora. Los nidos iniciados tarde en la temporada, cuando el volumen de la vegetación es mayor, tuvieron mayores tasas de supervivencia que nidos iniciados antes. Las variables espaciales no se relacionaron fuertemente con el éxito de nido. Se halló que el tamaño del terreno está directamente relacionado con el éxito de nidos en terrenos del PRC, pero no en otros tipos de pastizales. Sin embargo, el tamaño del terreno no se incluyó en el modelo multivariado más parsimonioso de factores relacionados con el éxito de nidos en terrenos del PRC. De igual manera, la proximidad a bordes de campo no se relacionó con éxito de nido en ningún terreno del PRC. Nuestros resultados sugieren que terrenos del PRC, que cubren una gran área en las Grandes Planicies de Norte América y atraen mayor diversidad de aves de pastizales que los cosechos que reemplazaron, proveen una cubierta de anidaje segura para especies que anidan en el suelo.

During the past several decades, populations of bird species associated with grasslands of the Great Plains have declined more than any other group of birds (Knopf 1994, Paige 1990). Loss and/or alteration of grassland breeding habitat are hypothesized to be at least partially responsible for population declines. The Conservation Reserve Program (CRP) of the

1985 Food Security Act converted approximately four million ha of croplands to a variety of grass and grass/legume cover types throughout states in the northern plains and may benefit populations of many grassland birds (Johnson and Schwartz 1993). Impacts of the CRP on avian communities typically have been evaluated by comparing breeding densities of passerines in CRP fields and other cover types (Igl and Johnson 1995, Johnson and Igl 1995, Johnson and Schwartz 1993, King and Savidge 1995) or by applying Habitat Suitability Index models (Hays et al. 1989). Such studies characterize species use of CRP fields but do not determine whether CRP fields provide secure nesting cover and function as population source areas (Van Horne 1983).

Therefore, we examined nest success in CRP fields and other grassland habitats in an agricultural landscape in southwestern Montana. We also investigated relationships between nest success and vegetative structure, spatial attributes of habitat, and nest-initiation date. Because of the logistical difficulties of working with actual nests, we used artificial nests, which allowed comparisons of relative nest success among various habitats (Yahner 1996).

STUDY AREA

The 80-km² study area extended from 12 km south to 18 km north of Three-Forks, Montana in Broadwater and Gallatin Counties (45°53'N, 111°33'W). Terrain was undulating, and elevation ranged from 1220–1460 m. Temperature and precipitation patterns were similar to long-term averages during the study. Temperatures ranged from a low monthly average of -6 C in January to a high of 19 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 agricultural landscape potentially supported *Agropyron spicatum*/*Agropyron smithii* and *Artemisia tridentata*/*Agropyron spicatum* habitat types (Mueggler and Stewart 1980). Virtually all lands that could support *A. spicatum*/*A. smithii* habitat, which typically occurred at lower elevations on relatively productive sites with gentle topography and deep soils, were in spring and winter wheat or CRP. Patches of *A. tridentata*/*A. spicatum* habitat typically occupied slightly less productive sites with steeper slopes and shallow rocky soils were not used for agriculture, and were typically surrounded by croplands. Thus, grassland habitat occurred in CRP fields, linear strips of non-native grasses (roadsides, waterways, or fence lines), or remnant patches of native vegetation (typically <16 ha). CRP fields were established 6–8 years before the study and had grass and grass-legume mixes composed primarily of wheatgrasses (*Agropyron* spp.) and alfalfa (*Medicago sativa*). Linear strips were dominated by non-native grasses including smooth brome (*Bromus inermis*), cheatgrass (*B. tectorum*), Kentucky bluegrass (*Poa pratensis*), western wheatgrass (*A. smithii*), and crested wheatgrass (*A. cristatum*). Native vegetation was primarily the *A. tridentata*/*A. spicatum* habitat type. Potential egg 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*), Richardson's ground squirrel (*Spermophilus richardsonii*), Common Raven (*Corvus corax*), and Black-billed Magpie (*Pica pica*). Because CRP fields, linear strips, and native vegetation were adjacent to one another and because predators were often seen in or near habitat boundaries, we could not delineate habitat-specific predator communities.

METHODS

Nest success.—We used artificial nests to estimate nest success because of the difficulty and expense of working with real nests and to better meet demands of experimental designs needed to test hypotheses of interest adequately (Balsler et al. 1968, Willebrand and Marcstrom 1988). We acknowledge that there are concerns about using artificial nests (e.g., Haskell 1995, Roper 1992, Sugden and Beyersbergen 1986). However, we believe that artificial nests are valuable exploratory tools and note that artificial nests are believed by many to provide useful data and are commonly used (e.g., Burger et al. 1994, Major and Kendal 1996, Yahner 1996). We do, however, agree with Major and Kendal (1996) that real nests should be used to further explore hypotheses developed from studies of artificial nests when possible.

We placed artificial nests in three types of grassland patches: CRP fields, linear strips, and native vegetation. We did not place nests in cropfields because nest losses from agricultural field operations precluded assessment of relationships between nest predation and spatial and structural variables. Each artificial nest was a vegetation-lined scrape containing two Japanese quail (*Coturnix japonica*) eggs.

We placed nests along transects at as many of the following distances from a patch edge as were available within one half of each patch's minimum width: ≤ 5 , 15, 25, 50, 75, 100, and 200 m. We established one transect in each CRP or native-vegetation patch. In linear strips, we placed transects ≥ 200 m apart to establish transect independence. We started each transect at a random point along the long dimension of the patch and placed each transect parallel to the patch's minimum dimension. To ensure that each nest was at its designated distance from the nearest edge, the distance from any patch corner to the transect starting point was at least as long as the transect's length.

We placed nests in three trials: 1–4 Jun. 1993, 5–12 May 1994, and 8–17 Jun. 1994. We monitored each nest every 7 d for 21 d and considered a nest unsuccessful if ≥ 1 egg was missing or damaged. We wore latex gloves and rubber boots during nest work to minimize human scent. We placed nests 10 m away from, and perpendicular to, transect lines and marked nest locations along transect lines with small wired flags. Each nest was placed within 25 cm of its designated location at the position with the greatest vegetative concealment.

Twenty-one days after a nest was initiated, we quantified vegetative characteristics of the nest site. We measured visual obstruction of vegetation

using Robel et al.'s (1970) method. We used Hays and Farmer's (1990) methods to obtain ocular estimates of average height of herbaceous cover (measured to the nearest 5 cm using a vertical measuring stick placed next to the nest), percent canopy cover (measured by looking down on the plot), percentage of herbaceous layer in grass, and percentage of bare versus litter-covered ground on a 0.57-m² circular plot centered on the nest site. We used the following categories when measuring percentage data: 5, 20, 40, 60, 80, and 95%. We hypothesized that sites with taller, thicker vegetation; greater amounts of grass in the herbaceous layer; and less bare ground provided greater concealment of nests and contained numerous potential nest sites, which reduced predator searching efficiency.

Data analysis.—We compared nest success and vegetation characteristics among grassland types using chi-square analysis and MANOVA, respectively. If results of chi-square analysis were significant, we used weighted least-squares contrasts to determine which grassland types had different nest-success rates (Grizzle et al. 1969). If results of MANOVA were significant, we used Tukey Honest-Significant-Difference tests to conduct between-habitat comparisons of vegetation characteristics. To test for differences in vegetative characteristics associated with successful and unsuccessful nests, we used Hotelling's T^2 test and subsequent *t*-tests on individual variables (Manly 1994:39–42). We used chi-square analyses to determine if nest fate was independent of patch size, distance to the nearest patch edge, or nest-initiation date in each grassland type. If results were statistically significant, we used weighted least-squares contrasts to determine which categories of an explanatory variable had different nest-success rates (Grizzle et al. 1969).

We used stepwise logistic regression (Hosmer and Lemeshow 1989) to estimate multivariate relationships between nest success and spatial, temporal, and vegetation-structure variables. An explanatory variable was a candidate in a model if univariate analysis indicated that nest success differed between different levels of the variable ($P \leq 0.25$, Hosmer and Lemeshow 1989:82–87). We conducted four multivariate analyses (one for each grassland type and one overall analysis) and chose the best models based on likelihood-ratio tests (Hosmer and Lemeshow 1989:106–112). Fit of each chosen model was evaluated with the Hosmer-Lemeshow test (Hosmer and Lemeshow 1989:140–145). Significance for all tests was set at 0.05.

RESULTS

We established 268 transects and monitored fates of 741 nests: 155 transects and 155 nests were in linear strips, 30 transects and 97 nests were in patches 50–100-m wide (22 native-vegetation fields and 8 CRP fields), 28 transects and 144 nests were in patches 150–400-m wide (16 native-vegetation fields and 12 CRP fields), and 55 transects and 345 nests were in patches >600-m wide (2 native-vegetation fields and 53 CRP fields). Nest success averaged 52.6% overall but varied temporally and spatially.

TABLE 1. Comparisons of nest success and vegetation characteristics for artificial nests in three grassland types in an agricultural landscape near Three-Forks, Montana.

Variable ^b	Grassland type ^a					
	CRP (<i>n</i> = 432)		Linear strip (<i>n</i> = 156)		Native (<i>n</i> = 153)	
	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE
Nest success	63.9 A ^c	2.3	52.6 B	4.0	24.8 C	3.5
Vegetation height (dm)	5.1 A	0.1	4.2 B	0.1	3.1 C	0.1
Visual obstruction (dm)	2.4 A	0.1	1.8 B	0.1	1.1 C	0.1
Percent canopy cover	39.3 B	0.9	44.3 A	1.4	32.4 C	1.4
Percent grass	70.5 B	1.4	90.0 A	1.2	69.3 B	2.0
Percent bare ground	39.3 B	1.2	26.2 C	1.7	52.0 A	1.8
Percent litter cover	22.6 B	0.8	31.4 A	1.4	16.2 C	1.1

^a Grassland types were: lands enrolled in the Conservation Reserve Program (CRP); fence-lines and roadsides (linear strip); and native vegetation.

^b The following vegetation characteristics were measured on 0.57-m² plots centered on nests: visual obstruction (a measure of the height and density of vegetation [Robel et al. 1970]); percent canopy cover (proportion of a plot covered by vegetation when viewed from above); percent grass (percentage of herbaceous vegetation comprised of grass); and percent bare ground and litter cover (the amount of soil that was exposed or covered with litter, respectively).

^c Within a row, mean values sharing the same capital letter are not significantly different from one another ($P > 0.10$). Nest success rates were compared using a chi-square test ($P < 0.001$) followed by least-squares contrasts (Grizzle et al. 1969).

Vegetation variable means were compared using MANOVA (Wilks' Lambda $P < 0.001$) followed by Tukey HSD tests (Statsoft Inc. 1994).

Nest success versus vegetation characteristics.—Nest success and vegetation characteristics differed among grassland types ($P < 0.001$) (Table 1). Pairwise comparisons indicated that nest success, vegetative visual obstruction, and vegetation height were highest in CRP fields and lowest in native vegetation.

Within each grassland type, vegetative visual obstruction, vegetation height, and percent canopy cover were greater ($P < 0.007$) at successful nests than at failed nests (Table 2). In CRP fields, the percentage of the herbaceous layer comprised of grass, which was inversely related ($r = -0.55$, $P < 0.001$, $n = 432$) with vegetative visual obstruction, was lower ($P < 0.001$) at successful nests. Visual obstruction was also correlated with vegetation height ($r = 0.51$, $P < 0.001$, $n = 741$) and percent canopy cover ($r = 0.50$, $P < 0.001$, $n = 741$). Vegetation height was significantly but weakly correlated with percent canopy cover ($r = 0.09$, $P = 0.004$, $n = 741$).

Nest success versus spatial and temporal variables.—In CRP fields, nest success was not independent of patch size ($P < 0.001$). Nest success in large CRP fields (>36 ha) averaged 67% ($n = 356$), which was greater than success in fields that were 5–25 ha ($P = 0.02$, $\bar{x} = 55\%$, $n = 51$) or <2 ha ($P < 0.001$, $\bar{x} = 30\%$, $n = 25$). Nest success in CRP fields that were 5–25 ha was not different ($P = 0.08$) from success in smaller fields.

TABLE 2. Comparisons of vegetation characteristics associated with successful and depredated artificial nests in three grassland types in an agricultural landscape in southwestern Montana.

Vegetation characteristic ^b	Grassland type ^a														
	CRP				Linear strip				Native vegetation						
	S (n = 276)	D (n = 156)	P		S (n = 82)	D (n = 74)	P		S (n = 38)	D (n = 115)	P				
\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE	\bar{x}	SE		
Vegetation height (dm)	5.3	0.1	4.6	0.1	<0.001 ^c	4.6	0.2	3.8	0.2	0.001	3.6	0.2	2.9	0.1	0.007
Visual obstruction	2.7	0.1	1.9	0.1	<0.001	2.1	0.1	1.5	0.1	0.001	1.6	0.1	1.0	0.1	<0.001
Percent canopy cover	42.0	1.1	34.4	1.5	<0.001	48.9	2.1	39.2	1.7	<0.001	39.1	3.0	30.2	1.4	0.004
Percent grass	66.0	1.8	78.6	2.1	<0.001	89.9	1.6	90.1	1.7	0.935	65.4	4.3	70.6	2.3	0.270
Percent bare ground	37.1	1.4	43.3	1.8	0.007	25.1	2.5	27.2	2.1	0.486	41.7	3.8	55.4	1.9	<0.001
Percent litter cover	22.8	1.0	22.1	1.3	0.798	28.5	2.0	34.9	1.9	0.042	20.4	2.2	14.8	1.2	0.021

^a Lands enrolled in the Conservation Reserve Program (CRP); fencelines and roadsides (linear strip); and native vegetation. Sample sites for successful (S) and depredated nests (D) are provided parenthetically for each grassland type.

^b The following vegetation characteristics were measured on 0.57-m² plots centered on nests: visual obstruction (a measure of the height and density of vegetation [Robel et al. 1970]); percent canopy cover (proportion of a plot covered by vegetation when viewed from above); percent grass (percentage of herbaceous vegetation comprised of grass); and percent bare ground and litter cover (the amount of soil that was exposed or covered with litter, respectively).

^c Multivariate comparisons were made using Hotelling's T² tests ($P < 0.001$ for each grassland type) followed by *t*-tests for individual variables (Manly 1994:39-42).

TABLE 3. Logistic-regression models of variables related to nest success in three grassland types in an agricultural landscape near Three-Forks, Montana.

Grassland type ^a	Logit of logistic-regression model ^b	Goodness-of-fit			Betas = 0
		H-L χ^2	df	P^c	P^c
CRP	1.93 - 0.85 VVO - 0.02 NID	14.17	8	0.08	0.0001
Linear strip	2.92 - 0.04 PCC - 0.06 NID	8.90	8	0.34	0.0001
Native veg.	3.73 - 1.26 VVO - 0.04 NID	7.43	8	0.49	0.0001
All	2.89 - 0.91 VVO - 0.01 PCC - 0.03 NID	11.28	8	0.19	0.0001

^a Lands enrolled in the Conservation Reserve Program (CRP); linear strips (fencelines and roadsides); native vegetation, and all grassland types combined.

^b The probability of a nest *failing* within 21 days of initiation equals $e^{-\text{logit}} / (1 + e^{-\text{logit}})$. Variables considered in regression analyses were: vegetative visual obstruction (VVO), vegetation height, percent canopy cover (PCC), percentage of herbaceous vegetation comprised of grass, percent bare ground, percent litter cover, nest-initiation date (NID), field size, and distance from the nest to the nearest field edge.

^c Goodness of fit was assessed using the Hosmer-Lemeshow chi-square test (H-L χ^2), and the global null hypothesis that regression coefficients were zero was tested with a likelihood-ratio test (Hosmer and Lemeshow 1989).

In native vegetation, nest success did not vary with patch size ($P = 0.93$). Nest success did not vary with distance to the nearest field edge in CRP fields ($P = 0.69$) or in native vegetation ($P = 0.58$). However, nest success did vary ($P < 0.001$) with time of year. Nest success for nests initiated in May 1994 ($\bar{x} = 44\%$, $n = 287$) was lower ($P < 0.004$) than success for nests initiated in June 1993 ($\bar{x} = 57\%$, $n = 247$) or 1994 ($\bar{x} = 63\%$, $n = 207$), which had similar ($P = 0.18$) success.

Multivariate analyses of variables related to nest success.—Results of multiple logistic regression supported results of univariate tests. Logistic regression analyses (one analysis per habitat and one overall analysis) indicated that nest success was related to vegetation structure and nest-initiation date but not to spatial variables. In each grassland type and for pooled data, the final model contained variables with regression coefficients different from zero ($P < 0.0001$) and adequately fit the data ($P > 0.08$) (Table 3). For nests in CRP fields and native vegetation, models containing vegetative visual obstruction and nest-initiation date were most parsimonious. For nests in linear strips, a two-variable model including percent canopy cover and nest-initiation date provided the best fit. For data pooled among all habitat types, the most parsimonious model consisted of vegetative visual obstruction, percent canopy cover, and nest-initiation date.

DISCUSSION

Nest success versus grassland type.—Of three grassland types studied, we found the highest nest success (67%) in CRP fields. Furthermore, CRP fields supported a more diverse bird community than the croplands and fallow fields they replaced (Clawson 1996). Thus, the large habitat base

created by the CRP (26,000 ha in the two counties where we collected data) appears to benefit ground-nesting grassland birds in southwestern Montana. Nest success may have been higher in CRP fields because predators were less dense, spent less time, or were less efficient in CRP fields than in other habitats. Also, composition of predator communities may have differed among habitat types and been more favorable to ground-nesting birds in CRP fields (e.g., Sovada et al. 1995). We were unable to determine the mechanisms underlying higher nest success in CRP fields, however, because we could not identify habitat-specific predator communities or collect data on predator behavior.

Nest success in native vegetation was relatively low, which raises concerns for species breeding exclusively in native grassland/shrubsteppe. These concerns seem especially relevant to species nesting in small remnant patches of native habitat such as those examined in our study. Brewer's Sparrows (*Spizella breweri*) and Sage Thrashers (*Oreoscoptes montanus*), which typically nest in or under *Artemisia* shrubs (Dobkin 1992), were only found in native vegetation on our study area (Clawson 1996). Thus, the benefits of CRP fields, which lack a shrub component, do not apply to the full complement of shrubsteppe species. Furthermore, the needs of grassland species that primarily use areas with sparse cover (e.g., Mountain Plovers [*Charadrius montanus*] and Horned Larks [*Eremophila alpestris*]) may also not be met by CRP fields.

Few other studies have compared success of artificial or natural nests in CRP fields with nest success in other habitats. Most studies have dealt with upland nesting ducks or galliforms, reported high nest success in CRP fields, and concluded that the CRP positively influenced populations (e.g., Berthelsen et al. 1990, Kantrud 1993, Reynolds et al. 1994). Granfors et al. (1996) found no differences in nest success for Eastern Meadowlarks (*S. magna*) nesting in CRP fields versus rangeland but cautioned that they had small sample sizes and low test power.

Nest success versus vegetation structure.—Our results indicated a strong relationship between vegetation structure and nest success. Comparisons among grassland types indicated that CRP fields had vegetation with more complex structure and higher nest success than other grassland types. Similarly, within each grassland type, successful nest sites had vegetation with more complex structure than failed nest sites. Multivariate analyses also indicated that height and density of vegetation was positively related to nest success in each habitat type. Thus, both within and among grassland types, nest success was consistently higher in areas with taller, thicker vegetation.

Although nest success is not universally higher at sites with more concealing vegetation (e.g., Dwernychuk and Boag 1972, Krasowski and Nudds 1986), our results are similar to those of many previous studies that evaluated the relationship between survival of artificial and/or natural nests and vegetative structure in grasslands. Several studies of passerines (Gottfried and Thompson 1978, Mankin and Warner 1992, Roseberry and Klimstra 1970) and numerous studies of ducks and galliformes

(e.g., Duebbert 1969, Gregg et al. 1994, Sugden and Beyersbergen 1987) have demonstrated that nest success in grasslands is higher at sites with greater vegetative concealment.

Thicker vegetation has been hypothesized to improve nest success by reducing nest visibility, restricting predator movements, and increasing predator foraging costs. Dwernychuk and Boag (1972) and Jones and Hungerford (1972) suggested that egg visibility greatly influences risk of egg loss to avian predators. Similarly, Sugden and Beyersbergen (1987) reported that tall, dense cover acted as a behavioral deterrent and a physical barrier to American Crows (*Corvus brachyrhynchos*) hunting on foot. Bowman and Harris (1980) and Crabtree et al. (1989) reported that mammalian predators found a smaller proportion of nests in areas with more complex vegetative structure and hypothesized that dense cover reduced foraging efficiency of mammalian predators.

Nest success versus spatial variables.—Nest success in a CRP field was positively related to field size. However, multivariate analyses revealed that CRP-field size explained little of the variation in nest success once effects of vegetative structure were taken into account. Similarly, field size was not related to nest success in native vegetation. Thus, our data indicate that field size was not a major factor influencing predation rates on nests. We also found little relationship between nest success and distance to the nearest field edge, which further indicates the lack of importance of spatial variables to nest fate on our area.

Our results contrast findings of previous grassland studies of passerine nests. Johnson and Temple (1990) studied five species of grassland passerines and reported lower nest success in smaller prairie fragments (<32 ha) than in large patches (>130 ha). Similarly, Burger et al. (1994) reported lower survival of artificial nests in smaller prairie fragments (<15 ha) than in large fragments. However, Johnson and Temple (1990) and Burger et al. (1994) worked in areas where grasslands abutted woody/forest cover, which was likely a source of additional predators. Thus, in previous studies, the diversity and/or density of predators searching edges may have been higher. Also, woody cover likely provided travel corridors for mammalian predators and elevated perch sites for avian predators, which may have concentrated predator activity along edges. In contrast, ecotones on our study area were linear features (e.g., roadside against CRP field or CRP field against cropfield) that were unlikely to concentrate predators.

Nest success versus temporal variation.—Nest success increased as the breeding season progressed. Much of the increase was likely due to reduced predator efficiency as plants produced new material during the growth season. However, we suspect that initiation date, which was a significant predictor of nest success in all habitats even after vegetative structure was accounted for, was also related to other factors that influenced nest success, e.g., prey-switching by predators (Crabtree and Wolfe 1988). Numerous studies of ducks have also reported higher survival rates for artificial and/or natural nests initiated later in the season (e.g., Gottfried

and Thompson 1978, Greenwood et al. 1995, Sugden and Beyersbergen 1986).

Research implications.—Given the low nest success that we recorded in native vegetation, it seems important to determine if nest success in these habitats is adequate to sustain populations of native species. Data are especially needed for larger patches of native habitat in a less fragmented landscape. Also, although artificial nests provide useful data and are commonly used (e.g., Burger et al. 1994, Major and Kendal 1996, Yahner 1996) there are concerns regarding their use (e.g., Sugden and Beyersbergen 1986, Roper 1992, Haskell 1995). Therefore, results of artificial nest studies should be interpreted with caution. If possible, studies of real nests should be designed to evaluate hypotheses developed from studies of artificial nests (Major and Kendal 1996).

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LITERATURE CITED

- BALSER, D. S., H. H. DILL, AND H. K. NELSON. 1968. Effect of predator reduction on waterfowl nesting success. *J. Wildl. Manage.* 32:669–682.
- BERTHELSEN, P. S., L. M. SMITH, AND R. R. GEORGE. 1990. Ring-necked pheasant nesting ecology and production on CRP lands in the Texas Southern High Plains. *Trans. N. Am. Wildl. Nat. Resour. Conf.* 55:46–56.
- BOWMAN, G. B., AND L. D. HARRIS. 1980. Effect of spatial heterogeneity on ground-nest depredation. *J. Wildl. Manage.* 44:806–813.
- BURGER, L. D., L. W. BURGER, JR., AND J. FAABORG. 1994. Effects of prairie fragmentation on predation on artificial nests. *J. Wildl. Manage.* 58:249–253.
- CLAWSON, M. R. 1996. An investigation of factors that may affect nest success in CRP lands and other grassland habitats in an agricultural landscape. M.Sc. thesis, Montana State Univ., Bozeman, Montana.
- CRABTREE, R. L., L. S. BROOME, AND M. L. WOLFE. 1989. Effects of habitat characteristics on gadwall nest predation and rest-site selection. *J. Wildl. Manage.* 53:129–137.
- , AND M. L. WOLFE. 1988. Effects of alternate prey on skunk predation on waterfowl nests. *Wildl. Soc. Bull.* 16:163–169.
- DOBKIN, D. S. 1992. Neotropical migrant landbirds in the Northern Rockies and Great Plains. U.S. For. Serv., North. Reg., Publ. No. R1, Missoula, Montana.
- DUEBBERT, H. F. 1969. High nest density and hatching success of ducks on South Dakota CAP land. *Trans. N. Am. Wildl. Nat. Resour. Conf.* 34:218–228.
- DWERNYCHUK, L. W., AND D. A. BOAG. 1972. How vegetative cover protects duck nests from egg eating birds. *J. Wildl. Manage.* 36:955–958.
- GOTTFRIED, B. M., AND F. C. THOMPSON. 1978. Experimental analysis of nest predation in an old field habitat. *Auk* 95:304–312.
- GRANFORS, D. A., K. E. CHURCH, AND L. M. SMITH. 1996. Eastern Meadowlarks nesting in rangelands and Conservation Reserve Program fields in Kansas. *J. Field Ornithol.* 67:222–235.
- GREENWOOD, R. J., A. B. SARGEANT, D. H. JOHNSON, L. M. COWARDIN, AND T. L. SHAFFER. 1995. Factors associated with duck nest success in the prairie pothole region of Canada. *Wildl. Monogr.* 128:1–57.
- GREGG, M. A., J. A. CRAWFORD, M. S. DRUT, AND A. K. DELONG. 1994. Vegetational cover and predation of sage grouse nests in Oregon. *J. Wildl. Manage.* 58:162–166.

- GRIZZLE, J. E., C. F. STARMER, AND G. G. KOCH. 1969. Analysis of categorical data by linear models. *Biometrika* 52:298-504.
- HASKELL, D. G. 1995. Forest fragmentation and nest-predation: are experiments with Japanese Quail eggs misleading? *Auk* 112:767-770.
- HAYS, R. L., AND A. H. FARMER. 1990. Effects of the CRP on wildlife habitat: emergency haying in the midwest and pine plantings in the southeast. *Trans. N. Am. Wildl. Nat. Resour. Conf.* 55:30-39.
- , R. P. WEBB, AND A. H. FARMER. 1989. Effects of the Conservation Reserve Program on wildlife habitat: result of the 1988 monitoring. *Trans. N. Am. Wildl. Resour. Conf.* 54:365-376.
- HOSMER, JR., D. W., AND S. LEMESHOW. 1989. *Applied logistic regression*. John Wiley and Sons, New York, New York. 244 pp.
- IGL, L. D., AND D. H. JOHNSON. 1995. Dramatic increase of LeConte's sparrow in Conservation Reserve Program fields in the Northern Great Plains. *Prairie Nat.* 27:89-94.
- JOHNSON, D. H., AND L. D. IGL. 1995. Contributions of the Conservation Reserve Program to populations of breeding birds in North Dakota. *Wilson Bull.* 107:709-718.
- , AND M. D. SCHWARTZ. 1993. The Conservation Reserve Program and grassland birds. *Cons. Biol.* 7:934-937.
- JOHNSON, R. G., AND S. A. TEMPLE. 1990. Nest predation and brood parasitism of tallgrass prairie birds. *J. Wildl. Manage.* 54:106-111.
- JONES, R. E., AND K. E. HUNGERFORD. 1972. Evaluation of nesting cover as protection from magpie predation. *J. Wildl. Manage.* 36:727-732.
- KANTRUD, H. A. 1993. Duck nest success on Conservation Reserve Program land in the Prairie Pothole region. *J. Soil Water Conserv.* 48:238-242.
- KING, J. W., AND J. A. SAVIDGE. 1995. Effects of the Conservation Reserve Program on wildlife in southeast Nebraska. *Wildl. Soc. Bull.* 23:377-385.
- KNOFF, F. L. 1994. Avian assemblages on altered grasslands. Pp. 247-257, in J. R. Jehl, Jr., and N. K. Johnson, eds. *Stud. Avian Biol.* No. 15. Cooper Ornithol. Soc., Sacramento, California.
- KRASOWSKI, T. P., AND T. D. NUDDS. 1986. Microhabitat structure of nest sites and nesting success of diving ducks. *J. Wildl. Manage.* 50:203-208.
- MAJOR, R. E., AND C. E. KENDAL. 1996. The contribution of artificial nest experiments to understanding avian reproductive success: a review of methods and conclusions. *Ibis* 138:298-307.
- MANKIN, P. C., AND R. E. WARNER. 1992. Vulnerability of ground nests to predation on an agricultural habitat island in east-central Illinois. *Am. Midl. Nat.* 128:281-291.
- MANLY, B. F. 1994. *Multivariate statistical methods, a primer*. Chapman and Hall, New York, New York. 215 pp.
- MUEGLER, W. F., AND W. L. STEWART. 1980. Grassland and shrubland habitat types of western Montana. U.S. For. Serv., Gen. Tech. Rep. INT-66, Intermt. For. and Range Exp. Stn., Ogden, Utah. 154 pp.
- PAIGE, L. C. 1990. Population trends of songbirds in western North America. M.Sc. thesis, Univ. Montana, Missoula, Montana.
- REYNOLDS, R. E., T. L. SHAFFER, J. R. SAUER, AND B. G. PETERJOHN. 1994. Conservation Reserve Program: benefit for grassland birds in the Northern Plains. *Trans. N. Am. Wildl. Nat. Resour. Conf.* 59:328-336.
- ROBEL, R. J., J. N. BRIGGS, A. D. DAYTON, AND L. C. HURLBERT. 1970. Relationships between visual measurements and weight of grassland vegetation. *J. Range Manage.* 23:295-297.
- ROPER, J. J. 1992. Nest predation experiments with quail eggs: too much to swallow? *Oikos* 65:528-530.
- ROSEBERRY, J. L., AND W. D. KLIMSTRA. 1970. The nesting ecology and reproductive performance of the Eastern Meadowlark. *Wilson Bull.* 82:243-267.
- SOVADA, M. A., A. B. SARGEANT, AND J. W. GRIER. 1995. Differential effects of coyotes and red foxes on duck nest success. *J. Wildl. Manage.* 59:1-9.
- STATSOFT, INC. 1994. *STATISTICA for Windows (Volume 1): general conventions and statistics I* Statsoft, Inc. Tulsa, Oklahoma.

- SUGDEN, L. G., AND G. W. BEYERSBERGEN. 1986. Effect of density and concealment on American crow predation of simulated duck nests. *J. Wildl. Manage.* 50:9–14.
- , AND ———. 1987. Effect of nesting cover density on American crow predation of simulated duck nests. *J. Wildl. Manage.* 51:481–485.
- VAN HORNE, B. 1983. Density as a misleading indicator of habitat quality. *J. Wildl. Manage.* 47:893–901.
- WILLEBRAND, T., AND V. MARCSTROM. 1988. On the danger of using dummy nests to study predation. *Auk* 105:378–379.
- YAHNER, R. H. 1996. Forest fragmentation, artificial nest studies, and predator abundance. *Cons. Biol.* 10:672–673.

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