GRASSLAND BIRDS NESTING IN HAYLANDS OF SOUTHERN SASKATCHEWAN: LANDSCAPE INFLUENCES AND CONSERVATION PRIORITIES

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Abstract: To determine the benefits to grassland birds of converting cropland to hayland in southern Saskatchewan, Canada, we quantified the relative nest abundance and success of grassland nesting birds in haylands and the influence landscape variables have on these parameters. We found nests of 26 species of grassland nesting birds, primarily waterfowl and vesper sparrow (*Pooecetes gramineus*). With the exception of the northern pintail (*Anas acuta*), few nesting attempts were recorded for species of high priority in the Prairie Pothole Bird Conservation Region. Mayfield nest success for all waterfowl (20 and 13% in 1999 and 2000, respectively) was high relative to previously reported nest success estimates in other habitat types—especially spring-seeded cropland—and was near levels thought to be required to sustain populations (15–20%). Vesper sparrow nest success (39 and 33% in 1999 and 2000, respectively) also was high relative to that reported in other studies. Haying destroyed few nests as wet weather delayed operations in 1999 and 2000. More nests may be destroyed by haying in other years as approximately 25% of nests in this study were still active on the long-term average haying date for southern Saskatchewan. Among models we developed to explain waterfowl relative nest abundance, amount of cropland in the surrounding landscape and field area were the most informative. Evidence that a specific set of landscape variables was important to models of waterfowl nest success was equivocal. Landscape variables did not explain variation in vesper sparrow relative nest abundance or nest success. Within our study area, conversion of cropland to hayland appears to provide significant benefits to a variety of grassland species, including some species of high conservation priority (e.g., northern pintail). Grassland species of conservation concern nested less frequently in hayland than in native grassland.

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Historically, the Prairie Pothole Region (PPR) of North America was a mosaic of wetlands and grassland that under natural disturbance regimes of grazing, drought, and fire provided nesting and foraging habitats for a variety of specialized avian species. Conversion of native prairie to cropland and draining of wetlands have severely degraded this habitat; thus, many grassland-dependent bird species are now high conservation priorities in the Prairie Potholes Bird Conservation Region (Knopf 1994, Dunn et al. 1999, Carter et al. 2000, Partners in Flight Species Assessment Database http://www.rmbo.org/pif/pifdb.html). Re-creation of native prairie currently costs more per unit area to establish than tame seeded grasses, thus limiting its application as a tool for restoring cropland to grassland communities (E. Soulodre, personal communication). Conversion of cropland to hayland (seeded to grass or grass/legume mixtures that are harvested annually) or seeded pasture (grass or grass/legume mixtures that are grazed annually) also may provide quality nesting habitat for grassland birds. Although converted cropland is known to attract grassland birds, the species composition, relative use for nesting, and reproductive success of birds using haylands remain largely unknown in the northern portion of the PPR.

The Conservation Reserve Program (CRP) in the United States has converted large areas of cropland to idle grass/legume cover (13,767,656 ha active as of 31 March 2003, CRP Monthly Active Contract Database http://www.fsa.usda.gov/crpstorpt/03approved/r1sumyr/R1sumyr2.htm), likely benefiting a variety of wildlife species (Johnson and Schwartz 1993*a*, *b*; Johnson and Igl 1995; Best et al. 1997). In Canada, cropland conversion programs have differed from CRP in that producers annually hay or graze the converted land. From 1989 to 1992, Agriculture and Agri-food Canada's Permanent Cover Program (PCP) converted 445,148 ha of private cropland in Prairie Canada to hayland and pasture, resulting in apparent benefits to grassland birds (Davis and

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Duncan 1999, McMaster and Davis 2001). Several conservation organizations in Saskatchewan currently employ cropland conversion as a conservation tool, and interest in cropland conversion programs in prairie Canada is anticipated to remain strong among producers while global grain prices remain low.

Although responses of grassland birds to patch size may vary regionally (Johnson and Igl 2001), studies of grassland bird abundance and nest success (Herkert 1994, Vickery et al. 1994, Helzer and Jelinski 1999, Winter and Faaborg 1999, Winter et al. 2000) recommend creation of large habitat patches with minimal edge for increasing abundance and reproductive success. The landscape structure surrounding a patch may also influence abundance and productivity of grassland birds, but has seldom been tested (Clark and Nudds 1991, Sovada et al. 2000). Within the prairie region, Greenwood et al. (1995) found waterfowl nest success in all habitats combined was negatively related to the percentage of cropland in the landscape, which suggests that cropland conversion programs targeted at landscapes with significant areas of existing grassland should result in higher breeding success. Nest success of waterfowl in CRP increased with percentage of perennial cover in the surrounding landscape (Reynolds et al. 2001). Management of both patch and landscape metrics may increase benefits of wildlife habitat programs (Ball 1996).

Although cropland conversion programs often have multiple objectives (e.g., soil and water conservation, carbon sequestration, rural economic development), our evaluation focused exclusively on the value of these programs for breeding grassland birds. To explore the influence of patch and landscape structure on breeding birds, we documented the species composition, relative nest abundance, and nest success of grassland birds in haylands.

STUDY AREA AND METHODS

Our study area encompassed a portion of the Missouri Coteau: a glacial moraine of rolling hills characterized by knob and kettle topography extending from South Dakota northwest through North Dakota and Saskatchewan. In Saskatchewan, the Coteau (Fig. 1) covers 2.4 million hectares acres of Mixed Grassland Ecoregion (Ecological Stratification Working Group 1995), and although dominated by cropland (56%), 30% of the region is native prairie, 5% hayland and seeded pasture, 7% wetlands, and 2% other lands (Saskatchewan Watershed Authority [SWA], unpublished data). The distribution of the area of grassland patches (not considering roads) in the Coteau is skewed toward small patches, with only 386 patches being larger than 64 ha ($\bar{x}$ = 21.3 ha, SD = 1186.24, n = 33106; Saskatchewan Watershed Authority, unpublished analysis of South Digital Landcover Landsat TM data). We selected the Missouri Coteau because it supports a wide variety of grassland avifauna in high densities and has been targeted for habitat preservation and restoration by conservation organizations.

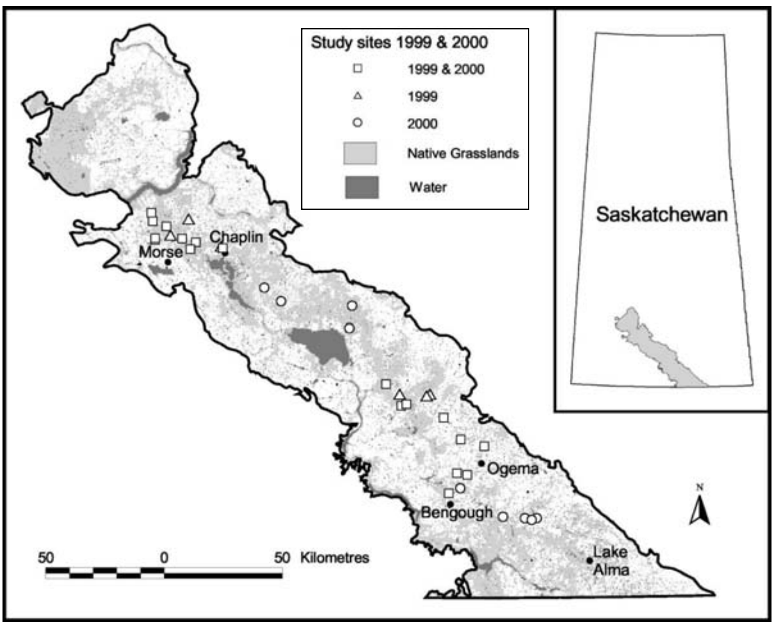

Fig. 1. Distribution of 34 hayland study fields in the Missouri Coteau region of southern Saskatchewan, Canada, 1999–2000. Six fields were sampled in 1999 only, 10 fields were sampled in 2000 only, and 18 fields were sampled in both years.

Potential study fields within the Missouri Coteau were identified using Agriculture and Agri-Food Canada database of PCP locations, South Digital Landcover database, which consisted of 24 habitat classes including haylands, and opportunistically while travelling throughout the area. For inclusion in the study, haylands were required to have (1) semipermanent or permanent freshwater wetlands (Stewart and Kantrud 1971) on or adjacent to the field; (2) been established at least 4 years previous to the study; (3) been hayed the previous year; and (4) landowners willing to permit research on their property. The resulting sample of candidate fields was too small to allow randomized selection of fields. Nonrandom selection of fields prevented inference to other existing haylands in the study area (Thompson et al. 2000), but the spatial distribution of study fields allowed inference regarding the quality of future haylands in the area. We sampled a total of 34 hay fields during the course of our study (Fig. 1). Six fields were sampled in 1999 only, 10 fields were sampled in 2000 only, and 18 fields were sampled in both years. This sampling design was a tradeoff enabling larger sample sizes while retaining the ability to describe inter-annual variation. Haylands ranged from 16 to 61 ha in size, and averaged 41 ha. All haylands were seeded with alfalfa (*Medicago* spp.) in some combination with tame grasses, typically crested wheatgrass (*Agropryon cristatum*), smooth brome (*Bromus inermis*), or Russian wild rye (*Elymus junceus*). Frequently haylands were adjacent to several types of landcover, such as native and tame pasture, or cropland.

We searched haylands for waterfowl and shorebird nests 3 times between late April and mid-June using All-Terrain Vehicle cable-chain drags (hereafter "ATV search") following standard procedures (Higgins et al. 1969, Gloutney et al. 1993). Within 30 of the 34 haylands, a 400 × 400 m plot (in 100 × 100 m grids) was randomly located (possible at 85% of haylands) on each study field and marked with surveyor pin flags. Because there was a relatively small range of hayland area in this study, maintaining constant plot area despite variation in hayland area likely reduced only slightly the probability of locating nests of rare species in large fields. Within these plots, staff pulled 25 m weighted nylon ropes, with tin cans attached, through the vegetation to locate nests of all species including songbirds (hereafter rope search). Two rope searches were conducted in late May and mid- to late June of 1999, and 4 times between 9 May and 27 June of 2000. Wet weather and expectations of an earlier haying date reduced the number of rope searches in 1999. In each year, the entire hayland was searched for nests during the first ATV search, whereas the second and third ATV searches were conducted in the area of the hayland outside the rope search plot (1 field was searched only by rope search). As fields had been hayed the previous summer, early in the spring residual vegetation consisted of cut grass stems and dead alfalfa regrowth (dependent on late-summer moisture conditions) from the previous year, with considerable bare ground. From mid-May to early July, vegetation grew rapidly, reaching heights up to 1.2 m that may produce yields in excess of 3,000 kg/ha (SWA, unpublished data).

We monitored waterfowl, shorebird, raptor, and grouse nests at 7-day intervals (Klett et al. 1986), while songbird nests were monitored every 3-4 days. Nests that were abandoned due to investigator disturbance, fully or partially destroyed by investigators, or could not be relocated, were excluded from calculations of nest success. Because we did not estimate detection probability, we cannot estimate nest density directly. We calculated relative nest abundance (nests/ha) as an index of the actual nest density. In doing so we assume nest detection probabilities were constant among hayfields. We calculated Mayfield nest success with modification by Johnson (1979) for species with sample sizes ($n > 27$, waterfowl and vesper sparrow) that permitted calculation of reasonably narrow confidence intervals.

In addition, we conducted songbird abundance surveys in June of both years within the 400 × 400 m plots using 3 parallel 100 m fixed-width transects (Ralph et al. 1993) separated by 2, 50 m strips. Abundance surveys provided frequency of occurrence data and indicated breeding pair estimates.

We examined whether the difference in frequency of rope searches between years (more frequent in 2000 than 1999) and fields (4 fields were searched using ATVs only) biased estimates of waterfowl relative nest abundance. We found removal of waterfowl nests located with rope searches resulted in only a small decrease in relative nest abundance estimates for all waterfowl species combined (1999: 16% reduction in estimated relative nest abundance, 2000: 8% reduction in estimated relative nest abundance), and therefore we pooled data for waterfowl nests located by both techniques.

Because we were interested in whether the habitat composition of the surrounding landscape affected use and reproductive success in haylands (e.g., Greenwood et al. 1995, Reynolds et al. 2001), we quantified habitat composition within a 4 km by 4 km block (hereafter referred to as the "landscape buffer") centered on the quarter section containing our study field. We used classified Landsat-TM imagery and ground-truthed landcover classification for each landscape buffer in both years. Habitats classified included cropland (summerfallow and seeded cropland), seeded hayland (seeded grassland used for hay), seeded pasture (seeded grassland used for pasture), native pasture (native vegetation used for pasture), shrubland (mainly low perennial woody shrubs; e.g., snowberry [*Symphoricarpos* sp.]), trees (deciduous hardwoods), wetland (wetland vegetation), open water, and other (e.g., exposed mud, saline flats). Consistent with previous research (e.g., Reynolds et al. 2001), we agglomerated habitat types into 3 classes for analyses: cropland (summerfallow and seeded cropland), grassland (hayland, tame pasture, native pasture, and shrub), and wetland (waterbody, marsh, exposed mud, and saline flats). Landscape buffers overlapped for 5 pairs and 1 trio of study fields (range 16% to 64% overlap). Despite overlap, we treated each landscape buffer as an independent datum in subsequent analyses. Study fields occurred in landscapes ranging from cropland to grassland-dominated (0–95% cropland).

We used Spatial Analyst (Environmental Systems Research Institute 1996) and Patch Analyst Extensions (Elkie et al. 1999) in Arcview 3.1 to generate metrics describing habitat composition and configuration within landscape buffers. Most metrics were highly correlated, so we excluded from analysis all but grass patch shape index (SHAPE: perimeter divided by the square root of area of the study field and any contiguous grassland), the area of the study field (AREA: excluding any contiguous grassland), and the total area of cropland (CROP) and wetland habitats (WET) in the landscape buffer. For calculation of SHAPE we initially considered the study field and any adjacent grassland habitat, regardless of roads, to be a single habitat patch. In subsequent analyses we recalculated SHAPE assuming roads, trails and railways divide habitat into patches. Cart tracks (a parallel pair of tire tracks with grass in between) were assumed not to divide habitat into patches. Considering roads as patch boundaries may alter the value of SHAPE, but does not alter AREA, CROP, or WET. For analyses considering roads, we also included, as an explanatory variable, the total length of road within the landscape buffer.

We used PROC MIXED with the maximum likelihood option (SAS 1996) to analyze the influence of SHAPE, AREA, CROP, and WET on untransformed relative nest abundance (nests/ha), and Mayfield success (weighted by exposure days) over 2 years. We included study field and year as random effects in our models to account for annual variation in fields assessed in both years. Landscape variables were also included as random effects as metrics changed between years at a few fields. Road effects were considered subsequent to initial analyses without roads.

We used Akaike's Information Criterion (Akaike 1973) with the adjustment for small samples (AIC_c), and AIC weights to choose the most parsimonious models providing reasonable fit to the data (Burnham and Anderson 1998; Anderson et al. 2000, 2001). All combinations of landscape variables were considered as well as a y-intercept model. We considered the model with the lowest AIC_c value to be best. Differences between the AIC_c value for the best model and values from other models (ΔAIC_c) were used to evaluate the relative plausibility of competing models. We considered inclusion of the y-intercept model among the best models to indicate that landscape variables were uninformative. We considered all models within 2 AIC_c values of the best model (Burnham and Anderson 1998:63) to develop our primary inference. We used AIC weights as the relative weight of evidence supporting each model (Burnham and Anderson 1998:124). Parameter estimates were generated by averaging over models within 4 AIC_c units of the best model (± unconditional standard error) if they did not include zero (Burnham and Anderson 1998). Sum of model weights for a parameter was calculated using all model weights containing the parameter as a variable. We examined influence statistics to detect outliers in the dataset, and deleted outliers. To assess variation explained by models, we calculated likelihood-based coefficients of determination (R^2; Agresti 1990:110) for global models. Means are reported with ±1 SE.

RESULTS

During 1999–2000, we located 1420 nests of 26 species in haylands in southern Saskatchewan. Waterfowl and vesper sparrow nests dominated the sample (69.8 and 19.0% of all nests, respectively, Table 1). Relative nest abundance varied among waterfowl species and average waterfowl relative nest abundance was 0.446 (±0.049) and 0.524 (±0.075) nests/ha in 1999 and 2000, respectively (Table 2). Of the 5 common nesting water-

Table 1. Number of nests found and conservation priority rank score (for Prairie Potholes Bird Conservation Region #11 [from Partners in Flight Species Assessment Database http://www.rmbo.org/pif/pifdb.html]) for each of 27 species found nesting in hayland in southern Saskatchewan, Canada, 1999–2000. Higher priority ranks indicate species of higher conservation priority. Relative ranks are among only species listed here.

Species	Nests	Priority rank score	Relative rank
Gadwall (*Anas strepera*)	272	16	4
American wigeon (*A. americana*)	30	18	6
Mallard (*A. platyrhynchos*)	181	17	5
Blue-winged teal (*A. discors*)	198	17	5
Northern shoveler (*A. clypeata*)	160	16	4
Northern pintail (*A. acuta*)	136	20	8
Green-winged teal (*A. crecca*)	2	13	2
Lesser scaup (*Aythya affinis*)	11	19	7
Sharp-tailed grouse (*Tympanuchus phasianellus*)	11	22	9
Northern harrier (*Circus cyaneus*)	2	22	9
Short-eared owl (*Asio flammeus*)	1	22	9
Willet (*Catoptrophorus semipalmatus*)	4	24	11
Upland sandpiper (*Bartramia longicauda*)	17	23	10
Marbled godwit (*Limosa fedoa*)	6	26	13
Wilson's phalarope (*Phalaropus tricolor*)	12	25	12
Mourning dove (*Zenaida macroura*)	3	11	1
Horned lark (*Eremophila alpestris*)	5	13	2
Clay-colored sparrow (*Spizella pallida*)	10	20	8
Vesper sparrow (*Pooecetes gramineus*)	269	16	4
Savannah sparrow (*Passerculus sandwichensis*)	43	13	2
Baird's sparrow (*Ammodramus bairdii*)	3	29	14
Le Conte's sparrow (*A. leconteii*)	1	24	11
Chestnut-collared longspur (*Calcarius ornatus*)	10	24	11
Bobolink (*Dolichonyx oryzivorus*)	1	20	8
Western meadowlark (*Sturnella neglecta*)	19	18	6
Red-winged blackbird (*Agelaius phoeniceus*)	2	14	3

fowl species, gadwall was the most numerous waterfowl species using hayland and northern pintail the least numerous. Vesper sparrow relative nest abundance was 0.299 (±0.047) and 0.432 (±0.052) nests in 1999 and 2000, respectively (Table 2).

Waterfowl nest success varied among species and between years and averaged 20% (95% CI: 16–25%) and 13% (95% CI: 10–16%) in 1999 and 2000, respectively (Table 3). Vesper sparrow nest success was similar in both incubation and nestling periods and nest success at fledging averaged 39% (95% CI: 27–56%) and 33% (95% CI: 24–50%) in 1999 and 2000, respectively (Table 3). Wet weather delayed haying sufficiently in both years that nest loss to haying equipment was minimal.

Table 2. Variation in relative nest abundance (nests/ha) of common species nesting in haylands of the Missouri Coteau region of Saskatchewan, Canada, 1999–2000. Presented are only species for which more than 50 nests per year were located. Means and SE are calculated from relative nest abundance estimates for each field, while *n* represents number of total number of nests.

Species	1999			2000		
	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Gadwall	108	0.116	0.018	164	0.158	0.033
Mallard	76	0.076	0.013	105	0.093	0.016
Blue-winged teal	86	0.091	0.015	112	0.099	0.013
Northern shoveler	70	0.073	0.010	90	0.084	0.013
Northern pintail	60	0.063	0.012	76	0.072	0.019
Waterfowl combined	424	0.446	0.049	565	0.524	0.075
Vesper sparrow	110	0.299	0.047	159	0.432	0.052

Table 3. Mayfield nest success (%) estimates (95% CI) for waterfowl and vesper sparrows nesting in haylands of the Missouri Coteau region of Saskatchewan, Canada, 1999–2000.

Species	1999		2000	
	n	Nest success	n	Nest success
Gadwall	91	16 (10–26)	153	14 (9–20)
American wigeon	16	7 (2–30)	12	9 (2–44)
Mallard	57	12 (6–23)	90	13 (8–22)
Blue-winged teal	72	37 (26–52)	101	20 (14–30)
Northern shoveler	62	30 (20–46)	82	9 (5–17)
Northern pintail	51	15 (7–29)	66	10 (5–18)
Waterfowl combined	355	20 (16–25)	507	13 (10–16)
Vesper sparrow – incubation	88	61 (51–73)	132	61 (50–73)
Vesper sparrow – nestling	70	64 (53–77)	107	58 (49–69)
Vesper sparrow – overall	103	39 (27–56)	143	33 (24–50)

Landscape variables affected the relative nest abundance of waterfowl in haylands. Our global model explained a reasonable amount of variation in relative waterfowl nest abundance (R^2 = 0.58). The low Akaike weight of the best model describing waterfowl relative nest abundance indicates only moderate support for this model relative to others (Table 4). AREA and CROP were consistently included in the best models (sum of model weights equaled 0.83 and 0.84, respectively). After having accounted for field-level effects on waterfowl relative nest abundance (covariance estimate = 0.001237), we also found considerable annual variation in relative nest abundance in those fields assessed in both years (covariance estimate = 0.001762). Model-averaged (ΔAIC $\leq$ 4) parameter estimates for those

Table 4. Best 2 (ΔAIC ≤ 2) of 16 combined waterfowl relative nest abundance models in haylands of the Missouri Coteau region of Saskatchewan, Canada, 1999–2000. Rankings were based on Akaike's Information Criterion (AIC) values.

Models[a]	K[b]	AIC_c[c]	ΔAIC_c	Weight
AREA + CROP	5	–94.6	0.0	0.3499
AREA + CROP + WET	6	–93.8	0.8	0.2384

[a] AREA refers to the area of the study site; CROP and WET refer to the amount of cropland and wetland, respectively, in the surrounding landscape.
[b] Number of model parameters including all independent variables, the dependent variable, the intercept and Φ^2.
[c] Akaike's Information Criterion corrected for small samples.

variables identified in the most parsimonious model indicated waterfowl relative nest abundance decreased as study field size increased (AREA: = –0.0069, SE = 0.0038), but increased with the amount of cropland in the landscape buffer (CROP:= 0.00026, SE = 0.00013). The average parameter estimates for the best model predict relative nest abundance to decrease by 0.031 to 0.107 nests per ha for every 10 ha increase in AREA, and increase by 0.001 to 0.004 nests per ha for every 10 ha increase in CROP. Including roads as patch borders and distance of roads reduced the amount of variation explained by the global model (R^2 = 0.50), and increased the uncertainty of model selection (weight of best model = 0.2208). AREA and CROP were still consistently included in the best models (sum of model weights equaled 0.77 and 0.77, respectively).

Inclusion of the y-intercept among the best models indicates landscape variables explained little variation in vesper sparrow relative nest abundance (Table 5; global model R^2 = 0.13). WET and AREA had the highest sum of model weights (0.44 and 0.52, respectively). After having accounted for the field-level effects on vesper sparrow relative nest abundance (covariance estimate = 0.02688), we also found considerable annual variation in relative nest abundance in those fields assessed in both years (covariance estimate = 0.02073). Including roads as patch borders and distance of roads altered the amount of variation explained by the global model only slightly (R^2 = 0.16). Uncertainty in model selection increased (weight of best model = 0.1323), and AREA was consistently included in the best models (sum of model weights equaled 0.43).

Landscape metrics explained little variation in waterfowl nest success (R^2 = 0.09). There was high uncertainty in model selection and therefore little difference between models in explaining variation in estimates of waterfowl nest success (Table 6). Field-level and year effects on waterfowl nest success were negligible (covariance estimate = 0.0 and 0.0, respectively). Support for the best model decreased slightly when roads were considered as patch borders (weight of the best model = 0.2169), and the increase in variation explained by the global model was slight (R^2 = 0.14).

Although the global model explained a moderate amount of variation in vesper sparrow nest success (R^2 = 0.28), the best models did not perform better than the y-intercept model (Table 7). The low Akaike weight of the best model predicting vesper sparrow nest success (0.2550) indicates uncertainty in model selection (Table 7). WET had the highest sum of model weights (0.7918). Field-level effects on vesper sparrow nest success (covariance estimate = 0.0337) were much greater than year effects (covariance estimate = 0.0061). Consideration of roads resulted in little change in the amount of variation explained by the global model (R^2 = 0.31), and decreased support for the best model relative to others (weight of the best model = 0.1663).

Table 5. Best 4 (ΔAIC ≤ 2) of 16 vesper sparrow relative nest abundance models in haylands of the Missouri Coteau region of Saskatchewan, Canada, 1999–2000. Rankings were based on Akaike's Information Criterion (AIC) values.

Models[a]	K[b]	AIC_c[c]	ΔAIC_c	Weight
AREA	4	–1.6	0.0	0.1968
Y-INTERCEPT	3	–1.4	0.2	—
WET	4	–1.0	0.6	0.1458
AREA + WET	5	–0.6	1.0	0.1198

[a] Y-INTERCEPT refers to the null model containing no landscape variables; AREA refers to the area of the study site; WET refer to the amount of wetland in the surrounding landscape.
[b] Number of model parameters including all independent variables, the dependent variable, the intercept and Φ^2.
[c] Akaike's Information Criterion corrected for small samples.

Table 6. Best 4 (ΔAIC ≤ 2) of 16 combined waterfowl nest success models in haylands of the Missouri Coteau region of Saskatchewan, 1999–2000. Rankings were based on Akaike's Information Criterion (AIC) values.

Models[a]	K[b]	AIC_c[c]	ΔAIC_c	Weight
AREA + SHAPE + CROP	6	–29.75	0.0	0.1850
AREA + SHAPE	5	–29.70	0.05	0.1805
SHAPE	4	–29.66	0.1	0.1765
SHAPE + WET	5	–28.2	1.5	0.0853

[a] AREA refers to the area of the study site; CROP and WET refer to the amount of cropland and wetland, respectively, in the surrounding landscape; SHAPE refers to the shape index of the patch.
[b] Number of model parameters including all independent variables, the dependent variable, the intercept and Φ^2.
[c] Akaike's Information Criterion corrected for small samples.

DISCUSSION

Waterfowl comprised a significant portion of our nest sample, largely because we constrained selection of our sample fields to those associated with semi-permanent or permanent wetlands. Waterfowl are known to use hayland for nesting primarily due to relatively dense vegetation provided through much of the nesting season (e.g., Klett et al. 1988, Greenwood et al. 1995). Gadwall, a late-nesting species that prefers taller vegetation, was especially prevalent in our sample. Northern pintail also made considerable use of hayland. Relative to other habitats in the PPR, hayland generally ranks moderate to high in preference by nesting waterfowl (e.g., Reynolds et al. 2001). Compared to evaluations of other land-uses in Saskatchewan, our estimate of relative nest abundance for all waterfowl species combined was approximately twice that of rotational grazing systems that combined tame and native pastures (Ignatiuk and Duncan 2001; J. Ignatiuk, personal communication) but was half that of waterfowl nests found in idle planted nesting cover (McKinnon and Duncan 1999). This pattern is consistent with the notion that relative amount of residual vegetation available to conceal nesting ducks is a major factor determining relative nest abundance in each of these habitats (e.g., Kirsch et al. 1978). Assuming constant wetland conditions, haylands likely attract fewer waterfowl than does idle vegetation since the previous year's hay operation removes much of the residual vegetation that attracts nesting ducks early in the spring (Martz 1967, Oetting and Cassel 1971, Renner et al. 1995).

Vesper sparrows dominated the sample of songbird nests, while other taxa, such as shorebirds, raptors, and grouse, comprised only a small proportion of the overall nest sample. This abundance of vesper sparrows in our study is not unexpected because prior to mid-June (when vegetation becomes tall and dense) our hayfields were composed of clumps of short vegetation interspersed with considerable bare ground that is attractive to vesper sparrows (Jones and Cornely 2002). Vesper sparrows also are frequently detected in hayfields during song surveys (McMaster and Davis 2001, but see Prescott et al. 1995). Although shorebirds, raptors, and grouse nested at low densities in this study, conversion of cropland to hayland likely provides additional breeding habitat for these species because many avoid nesting in cropland (e.g., marbled godwit, Gratto-Trevor 2000; Wilson's phalarope, http://www.npwrc.usgs.gov/resource/literatr/grasbird/ambi/ambi.htm).

Table 7. Best 2 (ΔAIC $\leq$ 2) of 16 vesper sparrow nest success models in haylands of the Missouri Coteau region of Saskatchewan, Canada, 1999–2000. Rankings were based on Akaike's Information Criterion (AIC) values.

Models[a]	K[b]	AIC_c[c]	ΔAIC_c	Weight
Y-INTERCEPT	3	4.0	0.0	—
WET	4	6.0	2.0	0.2550

[a] Y-INTERCEPT refers to the null model without landscape variables; WET refers to the amount of wetland in the surrounding landscape.

[b] Number of model parameters including all independent variables, the dependent variable, the intercept and Φ^2.

[c] Akaike's Information Criterion corrected for small samples.

Previous research has demonstrated the ecological impact on grassland birds of grassland loss to cropland in the PPR (e.g., Knopf 1994). Much of this impact results from loss and fragmentation of breeding and foraging habitat (Rodenhouse et al. 1993, Herkert 1994), and potential increases in predation in remaining habitat (U.S. Department of the Interior Grassland Bird Working Group 1996). Cropland itself is a potential ecological trap for birds that use it as nesting habitat (e.g., Milonski 1958, Best 1986). Conversion of cropland to hayland is 1 method currently used by conservation organizations for returning grassland habitat to the PPR. This activity is not without some risk to grassland birds during haying operations (Martz 1967, Bollinger et al. 1990, Frawley and Best 1991, Dale et al. 1997). Our results confirm that haylands are used for nesting by many species of grassland birds although relatively few may be present at high densities.

Of waterfowl species that nested regularly in haylands, the northern pintail currently is of highest management concern due to relatively low continental populations (Table 1; Miller and Duncan 1999, Podruzny et al. 2002). Because upland-nesting shorebirds often nest at low densities, the relatively high total number of nests (39) located for 4 high-priority (Partners in Flight scores >23) shorebird species suggests haylands may provide valuable habitat for these species. However, of 11 songbird species with Partners in Flight scores >20, whose range distributions and habitat preferences were seemingly appropriate for nesting in haylands of the Missouri Coteau, only 5 species nested in haylands (clay-colored sparrow, Baird's sparrow, Le Conte's sparrow, chestnut-collared longspur and bobolink), all with 10 nests or less. The relative nest abundance of clay-colored sparrow, chestnut-collared longspur and Baird's sparrow in our study was lower than in native pasture (Davis and Sealy 2000; SWA, unpublished data).

Best et al.'s (1997) study of CRP fields in the midwestern United States demonstrated benefits for several high-priority grassland species for that region, although only 11 of 33 species contributed >1% to the total nest count. McMaster and Davis (2001) concluded that although a number of high priority species occur in tame forage (see also Davis et al. 1999), factors such as nest success must also be determined to evaluate habitat quality (Van Horne 1983, Vickery et al. 1992). Low relative nest abundance of Baird's sparrows in haylands is unlikely to be an artifact of inability to locate nests, given the success of rope searches in other habitats in the same region (e.g., Davis and Sealy 1998; SWA, unpublished data).

Nest success of all waterfowl combined in this study (20% in 1999 and 13% in 2000) is similar to that reported by Greenwood et al. (1995; 18%), but higher than that reported by Klett et al. (1988; 6%). Estimates of nest success in this study are also similar to those in planted nesting cover (19%, Johnson et al. 1987; 13%, Klett et al. 1988; 15%, McKinnon and Duncan 1999) and CRP (~14%, Reynolds et al. 2001). Northern pintail nest success in this study (15% in 1999, 10% in 2000) was slightly lower than the estimate of Greenwood et al. (1995; 17% for pintails in hayland over all years), but similar to that of Guyn and Clark (2000) in native pasture (18%, 6%, and 11% over 3 years). Further, our waterfowl nest success estimates are generally within the range necessary to sustain waterfowl populations (15–20%, Cowardin et al. 1985; Klett et al. 1988) and are well above estimates of duck nest success in cropland (2%, Greenwood et al. 1995; 7%, Klett et al. 1988). Our estimate of vesper sparrow nest success in haylands (39% in 1999 and 33% in 2000) was relatively high compared to that of vesper sparrows breeding in cropland where nests are vulnerable to tillage operations (Rodenhouse and Best 1983, 13%), and to that of other grassland songbird species breeding in native pasture in a more fragmented landscape (Davis and Sealy 2000, 7–30% for 8 species).

In our study, the impact of haying operations on songbird and waterfowl nest success was minimal due to weather-delayed hay cutting. The long-term average cutting date for Saskatchewan is 7 July (M. Tremblay, personal communication); however, the median hay cut date on our fields was 18 July (range: 2 Jul–5 Aug) and 17 July (range: 30 Jun–3 Aug) in 1999 and 2000, respectively. In both years, 25–30% of waterfowl and vesper sparrow nesting attempts were vulnerable to destruction if haying had occurred on 7 July. Other studies have demonstrated the detrimental impact of haying on reproductive success of birds (Labisky 1957, Cowardin et al. 1985, Bollinger et al. 1990, Frawley and Best 1991, Dale et al. 1997; but see DeSmet and Conrad 1991, Renner et al. 1995).

Within the range of landscape composition encountered in our study, waterfowl relative nest abundance increased with the proportion of cropland in the landscape buffer, and decreased as the area of hayland increased. Vesper sparrow relative nest abundance was not influenced by landscape metrics. The relationship between waterfowl relative nest abundance and proportion of cropland is consistent with observations that waterfowl may concentrate in any available nesting habitat in landscapes where nesting habitat is scarce (Dahl et al. 1999). As a result of concentrating in available habitat, however, waterfowl are expected to suffer poor nest success due to increased vulnerability to predators (Cowardin et al. 1985, Klett et al. 1988, Clark and Nudds 1991, Greenwood et al. 1995; but see Ignatiuk and Duncan 2001). Therefore previous research has indicated that the impact of predators may be minimized by creating habitat with low edge to area ratios (Braun et al. 1978, Krasowski and Nudds 1986, Klett et al. 1988) in regions dominated by grasslands (Greenwood et al. 1995, Reynolds et al. 2001). In our study, however, patch and landscape metrics at the 4 km × 4 km scale explained little variation in waterfowl and vesper sparrow nest success, and there was only weak support for the best model relative to others. Including roads as patch borders did not reduce the uncertainty of model selection. Sovada et al. (2000) found weak evidence that nest success was related to patch size, but their study included much larger patches (maximum 2,342 ha) than this study. Differences between the results of this study and those of Greenwood et al. (1995) and Reynolds et al. (2001) could be due to differences among habitats, geographic regions, or environmental conditions. Indeed, Winter et al. (http://www.npwrc.usgs.gov/resource/2002/bca2001/bca2001.htm) concluded that in tallgrass prairie, variation in nesting density and success among years prevented determination of consistent relationships with patch size and landscape. Further information on temporal and spatial variation in composition and density of predator communities among habitats would contribute to knowledge of the importance of landscape-level characteristics to grassland birds (Sovada et al. 2000).

MANAGEMENT IMPLICATIONS

Our results indicate that cropland converted to hayland provides attractive nesting habitat for a suite of grassland species, most of which are of low conservation priority in the PPR, with the notable exception of the northern pintail. Higher priority songbirds (e.g., Baird's sparrow) nested less frequently in hayland than in native pasture, or not at all (e.g., Sprague's pipit). Although nest success of northern pintail in haylands is likely to be higher than in spring-seeded crop stubble, nest success is still low. Comparative data on pintail productivity among a broad suite of available habitats is required to fully understand the relative benefit of haylands. Vulnerability of nests to haying indicates delayed hay cut agreements or use of flushing bars should be negotiated with private landowners who convert cropland to hayland. The greatest benefits of cropland conversion to haylands are likely to be derived by waterfowl; therefore, waterfowl managers should continue to target conversion programs in areas of high-quality wetlands. However, for the range of patches and landscapes we examined, and the species that commonly occurred in haylands, our results indicate patches need not be large located in landscapes dominated by grassland to ensure higher nesting success. Conservation of native grassland in a mosaic of heavily to lightly grazed areas likely remains the best way to meet habitat requirements of the entire grassland bird community. The greatest contribution that conversion of cropland to hayland may make toward conservation of high-priority grassland bird species may be in providing landowners with additional forage for their livestock, thereby reducing or deferring grazing pressure on native pasture and improving range condition.

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