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Management and Conservation Article

Waterfowl Nesting in Fall-Seeded and Spring-Seeded Cropland in Saskatchewan

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ABSTRACT Waterfowl nesting in annual croplands has remained a little-known aspect of waterfowl nesting ecology because of the inability of many studies to systematically search this habitat through the nesting season. Where searches have been conducted, they are generally restricted to the period prior to seeding, and many nests found are destroyed by the seeding operation. Consequently, fall-seeded crops have been promoted as an alternative cropping practice that could increase nest survival of waterfowl nesting in croplands. During 1996–1999, we conducted 3–4 complete nest searches on 4,274 ha of cropland, including spring-seeded wheat and barley, winter wheat, and fall rye in southern Saskatchewan, Canada. Using suites of predictive models, we tested hypotheses regarding relative nest abundance and nest survival among crop types and tested the influence of several landscape-scale covariates on these metrics. Apparent nest densities were higher in fall-seeded crops (winter wheat: 0.39 nests/ha, fall rye: 0.25 nests/ha) than in spring-seeded crops (0.03 nests/ha), and nest density in spring-seeded croplands increased with percent cropland and percent wetland habitat in the surrounding landscape. Nest survival was higher in winter wheat (38%) than in either fall rye (18%) or spring-seeded crops (12%), and nest survival in spring-seeded crops increased with relative nest initiation date. Nest survival was unaffected by surrounding landscape characteristics but tended to be higher in years of average wetness. Based on our findings, winter wheat and fall rye have the potential to provide productive nesting habitat for ≥7 species of upland nesting ducks and fall-seeded crops are a conservation tool well suited to highly cropped landscapes. (JOURNAL OF WILDLIFE MANAGEMENT 72(8):1790–1797; 2008)

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KEY WORDS agriculture, cropland, dabbling ducks, fall rye, nest density, nest success, Prairie Pothole Region, Saskatchewan, waterfowl, winter wheat.

Use of croplands for nesting by waterfowl has been well documented (Goelitz 1918, Earl 1950, Milonski 1958, Higgins 1977, Lokemoen and Beiser 1997). However, quantifying waterfowl use of croplands for nesting has been problematic because of the perceived potential for crop damage by the searching process. Hence, nest searches in cropland are typically limited in timing or frequency relative to other habitats (e.g., Klett et al. 1988, Greenwood et al. 1995) and therefore use and nest survival estimates are less well known. Examination of mallard (*Anas platyrhynchos*) nest site selection via telemetry across 27 sites in the parklands of Prairie Canada indicated that, on average, about 2.6% of all mallard nests were initiated in cropland (range: 0–6.9%; J. H. Devries, Ducks Unlimited Canada, unpublished data). Similar results were reported for mallards in North Dakota, USA (Cowardin et al. 1985). Northern pintails (*Anas acuta*) typically use croplands for nesting at much higher rates than mallards (Austin and Miller 1995, Greenwood et al. 1995), and blue-winged teal (*Anas discors*) preference for nesting in croplands is similar to that of mallards (Klett et al. 1988). However, with respect to waterfowl use and nest success, croplands remain the least known habitat in the Prairie Pothole Region (PPR) due to a lack of data from systematically searched croplands.

Nests initiated in cropland, especially early nests, face risks of destruction by seeding, tillage, and spraying operations in addition to predation. Milonski (1958), Duebbert and Kantrud (1974), Higgins (1977), and Cowan (1982) have suggested that these agricultural operations tend to limit waterfowl production in croplands and, where reported, nest survival is generally low in this habitat (Cowardin et al. 1985, Klett et al. 1988, Greenwood et al. 1995, Richkus 2002). Use of croplands for nesting, coupled with low nest survival, is of concern because >85% of upland habitats in some important waterfowl breeding areas are annually cultivated (Sugden and Beyersbergen 1984), and area of annually seeded cropland continues to increase in Prairie Canada (Statistics Canada 2006).

One strategy to reduce agricultural destruction of waterfowl nests in croplands is the use of fall-seeded crops (Macaulay 1981). These crops (e.g., winter wheat and fall rye) are seeded in the fall and remain relatively undisturbed through the duck nesting season of the following year. To assess potential benefits of fall-seeded cereal crops on waterfowl production, reliable knowledge of waterfowl use and breeding success in these habitats versus conventional croplands is required. Hence, our objectives were to 1) estimate relative nest abundance among fall-seeded and spring-seeded cereal crops, 2) estimate relative nest survival among crop types, and 3) examine the influence of expected

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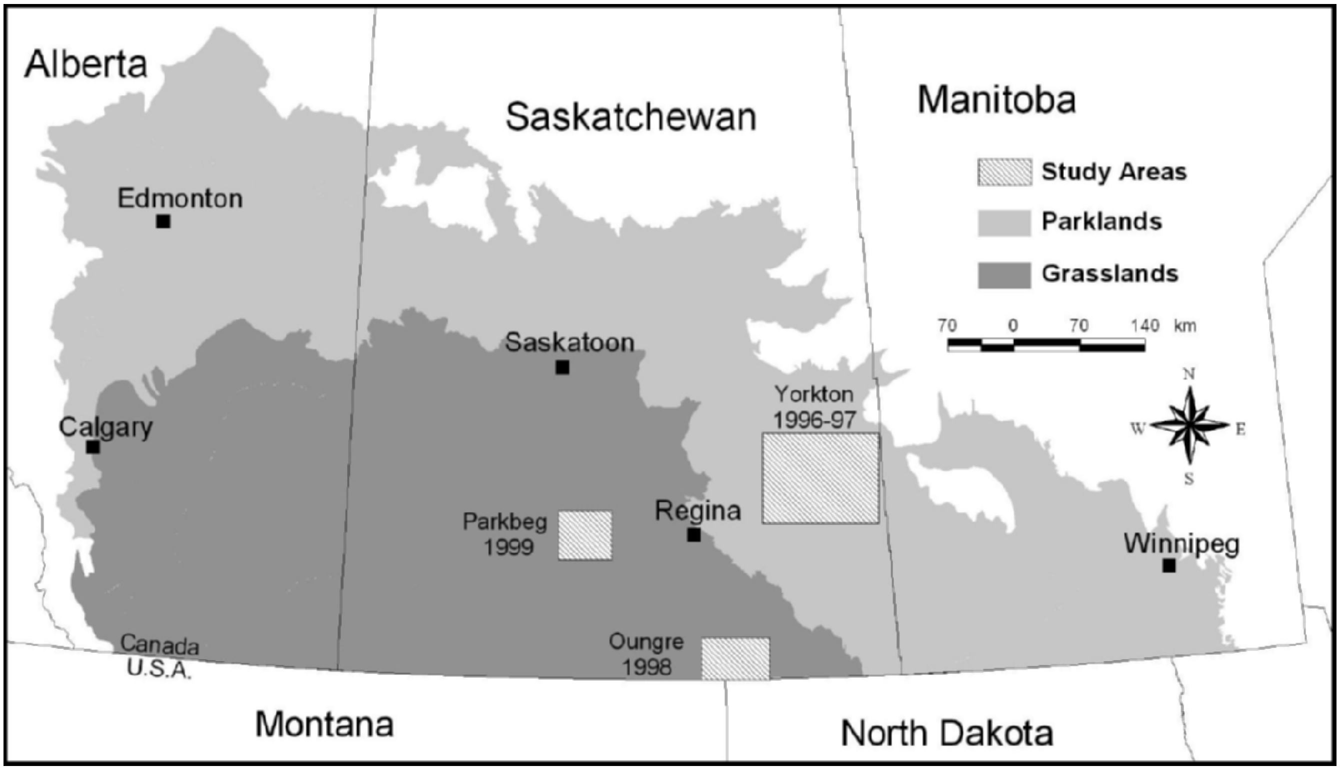

Figure 1. Location of general study areas (hatched squares) used to examine waterfowl nest density and nest success in croplands in the Parkland and Grassland ecoregions of southern Saskatchewan, Canada, 1996–1999. Study fields in 1996 and 1997 were all within the Yorkton study area, and we subsequently moved study areas each year.

sources of landscape-level variability on both nest density and success.

STUDY AREA

We chose study areas within the Parkland and Grassland ecoregions of Saskatchewan, Canada, in areas where Ducks Unlimited Canada (DUC) was offering incentive payments for grain producers (hereafter, producers) to try winter wheat as a cereal crop alternative. These areas were within landscapes where estimated long-term average breeding duck density was >12 pairs/km^2 (J. H. Devries, unpublished data).

Study areas were located near Yorkton, Saskatchewan, in 1996 and 1997, near Oungre, Saskatchewan, in 1998, and near Parkbeg, Saskatchewan, in 1999 (Fig. 1). These areas were highly altered by agricultural land uses, including croplands for cereal, pulse and oilseed production, and haylands and pasture (tame and native grasses and treed pasture) for cattle forage. Areas not in agricultural production included wetlands, road and railway rights-of-way, fence lines, and remnant small patches of idle grass, shrubs, and trees.

METHODS

In June, July, and August of 1995–1998 (i.e., summer and fall prior to yr of study), we canvassed producers in the targeted landscapes regarding their interest in participating in a research project involving waterfowl use of DUC's Fall Cereal Crop Habitat Program. Producers participating in the research agreed to allow a DUC contractor to plant fall cereals on their land and allow nest-searching activities both on these fields and an approximately equal acreage of their spring-seeded crop (spring-seeded crop was not included in 1996). As incentives for participation, DUC covered seed and seeding costs and we offered producers compensation in the event of >5% crop damage from nest searches. Although winter wheat was the preferred option by DUC, we gave producers the option to plant fall rye because of cold-hardiness and disease concerns with winter wheat. At the Oungre study site, we seeded only fall rye for this reason (Table 1).

The exact location of fall cereal crops within the study area was constrained by the willingness of producers to be involved in the study and by crop rotation considerations of individual producers. Once the producer's spring seeding plans had been finalized, we randomly selected spring-seeded fields from those the producer had available that met the area requirement. We considered only spring-seeded wheat and barley fields for comparison given their dominance on the Canadian prairie landscape and similar growth form to fall cereals. We sowed fall-seeded fields, with a few exceptions, into standing stubble (no-till). Spring-seeded fields were a combination of minimum-till (cultivated once prior to seeding) and no-till, as is the common practice over much of the Canadian PPR. We examined 471 ha of winter wheat, 1,928 ha of fall rye, and 1,875 ha of spring-seeded crops during this study (Table 1). To heuristically track crop growth among crop types over

Table 1. Areas (ha) we searched for waterfowl nests by crop type at study sites in southern Saskatchewan, Canada, 1996–1999.

Study site and yr	Crop type		
	Winter wheat	Fall rye	Spring-seeded
Yorkton 1996	124	326	0
Yorkton 1997	184	135	311
Oungre 1998	0	838	769
Parkbeg 1999	163	629	795
Total	471	1,928	1,875

time, we visually assessed study fields weekly and categorized them by Zadoks et al. (1974) growth stage.

We conducted nest searches using an all-terrain vehicle rope drag similar to the cable-chain drag described by Higgins et al. (1977). We used a doubled 50-m-long, 2.5-cm-diameter manila or nylon rope, rather than a cable-chain configuration, to minimize potential damage to growing crops.

Beginning in the last week of April in each year, we conducted 3 or 4 nest searches at 3-week intervals. We generally completed nest searches by the last week of June. We conducted searches between 0730 hours and 1330 hours (Gloutney et al. 1993) and postponed them during moderate to heavy rainfall. For all nests, we recorded crop type, date we found the nest, number of eggs, and incubation stage (Weller 1956). We defined a nest as ≥ 1 egg tended by a female (Klett et al. 1986). We visited all nests every 6–8 days until we determined nest fate (Klett et al. 1986). We classed nests as successful if ≥ 1 egg hatched. To assign the date a nest was initiated, we assumed a laying interval of 1 egg per day and that partial nest depredation had not occurred before we located a nest unless there was evidence to the contrary (i.e., presence of broken eggshells). We included nests that were abandoned due to investigator disturbance, fully or partially destroyed by investigators, or could not be relocated, in estimates of relative nest abundance, but we excluded them from nest survival calculations. We marked nests for relocation by placing a flag 4 m north of the nest and recorded nest sites, as accurately as possible, on available air photos of study plots. To avoid bias in nest survival, we advised equipment operators involved in farming operations not to try to avoid marked nests. Nest searching protocols were approved under Canadian Wildlife Service Scientific Permits (no. WS-S29, CWS98-S017, and CWS99-S013).

We estimated various landscape-scale characteristics for use in our analysis that, based on previous work (e.g., Greenwood et al. 1995, Dahl et al. 1999), may have influenced our response variables of nest abundance and survival. We used Spatial Analyst in Arcview 3.2 to query the Saskatchewan South Digital Landcover Landsat-Thematic Mapper database (circa 1994) for estimates of the percent wetland habitat (PCTWET) and cropland (PCTCROP) within a 2-km radius of the centroid of each study field. Because this landcover database was primarily designed to detect croplands, we viewed percent wetland as an index to availability of wetland habitat rather than an absolute measure. Further, to account for annual variability (e.g., Greenwood et al. 1995), we generated a geographically specific estimate of the annual wetness of the area around study fields (PONDINDEX) relative to the long-term (1970–2000) average from United States Fish and Wildlife Service May Breeding Waterfowl Survey pond counts at the survey segment level (Benning 1976). We first estimated segment-year specific median absolute deviations (PROC STDIZE; SAS Institute 2005) in pond counts for all segments surrounding our study sites. Annual wetness for each field was the inverse distance weighted deviation of the nearest 3 survey segment centroids for the specific year of study.

We examined how field and landscape characteristics affected relative waterfowl nest abundance and how nest, field, and landscape characteristics affected nest success by considering a series of a priori models. Each model set included an intercept-only (null) model. All other models included the influence of crop type (CROPTYPE) as a categorical explanatory variable; crop type categories were spring-seeded (SS), fall rye (FR), and winter wheat (WW). We limited a priori models to those including an additional 2 factors, simple interactions, single variable quadratics, and combinations thereof. We included quadratic variables for all continuous covariates to allow for nonlinearity in effects. We developed and contrasted 34 models examining relative nest abundance and 38 models examining nest survival.

All models examining relative nest abundance included field area (AREA) to account for the probability of finding more nests in larger fields. We included annual wetness, percent crop, and percent wetland as continuous covariates in alternative nest abundance models. We assumed nest detection probability with our methods was unrelated to the covariates of interest. We used generalized linear models (PROC GENMOD; SAS Institute 2005) to examine the impact of covariates on relative nest abundance. We modeled number of nests found per field as a negative binomial variable with a log link function. The negative binomial model explicitly estimates a dispersion parameter to accommodate unaccounted spatial covariance and other possible sources of overdispersion (White and Bennetts 1996).

Models examining nest survival included species (SPEC) as a 5-category variable (mallard, gadwall [*Anas strepera*], blue-winged teal, northern shoveler [*Anas clypeata*], and northern pintail) and relative nest initiation date (IDATE; standardized to $\bar{x} = 0$ and SD $= 1$ by yr). We included field area, annual wetness, percent cropland, and percent wetland as continuous covariates in alternative nest survival models. We used code developed for PROC NLMIXED (SAS Institute 2005) to explore the influence of covariates on nest survival probability (Emery et al. 2005). Our response variable was the interval-specific fate for a nest and we characterized nest fate and length in days for up to 2 risk intervals: 1) from date of nest discovery, the period for which the nest was known to remain viable, and 2) the period during which the nest was known to fail. We used a

Table 2. Species composition of waterfowl nests found by crop type at study sites in southern Saskatchewan, Canada, 1996–1999.

Species	Crop type		
	Winter wheat	Fall rye	Spring-seeded
Mallard	44	184	17
Northern pintail	14	132	31
Blue-winged teal	74	59	15
Northern shoveler	23	55	3
Gadwall	14	37	3
Green-winged teal	2	0	0
Lesser scaup	2	0	0
Total	173	467	69

logistic link function for modeling the logit of daily survival rate (DSR) as a transformably linear function of covariates (Dinsmore et al. 2002). We calculated Mayfield nest success rates from DSR by assuming a 34-day exposure period (i.e., average age of clutch at hatch for the 5 most common dabbling duck species; Klett et al. 1986).

We used Akaike's Information Criterion (AIC; Burnham and Anderson 2002) with the adjustment for small sample size (AIC_c) to compare among nest abundance models and with an overdispersion adjustment (QAIC) to compare among nest survival models. We present and rank models within 2 AIC units of the best ranked model (Burnham and Anderson 2002). Among ranked models, we considered a model to be a competitor for drawing inference if parameters in the top model were not simply a subset of those in the competing model (Burnham and Anderson 2002). We used AIC weights (w_i) as a measure of evidence for a particular model being the best model. We report means and effect estimates ±1 standard error.

RESULTS

We searched 114 crop fields and found 709 nests of 7 duck species (Table 2). Mallards, northern pintails, and blue-winged teal were the most numerous nesters, comprising 36%, 23%, and 21% of nests in fall crops versus 25%, 45%, and 22% of nests in spring-seeded crops, respectively. We found green-winged teal (*Anas crecca*) and lesser scaup (*Aythya affinis*) nests in winter wheat but not in fall rye or spring-seeded crops (Table 2). Median nest initiation dates in our study were 15 May (range: 11 Apr–7 Jul) in spring-seeded, 23 May (range: 10 Apr–27 Jun) in fall rye, and 9 June (range: 20 Apr–3 Jul) in winter wheat.

Our study sites were generally wetter than average (annual wetness: $\bar{x} = 0.32 \pm 0.12$; range: −1.3 to 4.4); annual wetness values averaged 1.3, 1.4, −1.2, and 0.7 during each year of 1996–1999, respectively. Landscapes surrounding study fields were primarily cropland (% cropland: $\bar{x} = 60.1 \pm 1.9$; range: 14–89) with interspersed wetlands (% wetland: $\bar{x} = 6.5 \pm 0.5$; range: 0–20).

The best approximating model evaluating nest abundance received high relative model weight ($w_i = 0.46$) and included field area, crop type, and percent wetland and percent cropland each interacting with crop type (Table 3). As expected, field area was an important predictor of nest abundance ($\hat{\beta} = 0.968 \pm 0.146$) and the coefficient (approx. 1) suggested nest density scaled directly with field size. At mean percent cropland and wetland values, this model predicted highest apparent nest density in winter wheat ($\bar{x} = 0.39$ nests/ha, 95% CI: 0.15–0.99), moderate density in fall rye ($\bar{x} = 0.25$ nests/ha, 95% CI: 0.08–0.75), and lowest density in spring crops ($\bar{x} = 0.03$ nests/ha, 95% CI: 0.01–0.09). Per unit area, this model provided evidence that nest numbers in spring-seeded crops increased with increasing percent cropland (Fig. 2a; $\hat{\beta} = 0.024 \pm 0.009$) and percent wetland (Fig. 2b; $\hat{\beta} = 0.111 \pm 0.034$) in the surrounding landscape, but we did not observe these effects in winter wheat (Fig. 2a, b; $\hat{\beta}_{\mathrm{WW \times PCTCROP}} = 0.011 \pm 0.010$; $\hat{\beta}_{\mathrm{WW \times PCTWET}} = -0.025 \pm 0.036$) or fall rye (Fig. 2a, b; $\hat{\beta}_{\mathrm{FR \times PCTCROP}} = -0.009 \pm 0.006$; $\hat{\beta}_{\mathrm{FR \times PCTWET}} = 0.034 \pm 0.025$).

The competing model excluded crop type by percent cropland interaction but included a marginal quadratic effect of percent wetland ($\hat{\beta} = -0.006 \pm 0.003$). This model received considerably less support ($w_i = 0.23$).

The top ranked model examining variation in nest survival included effects of crop type, initiation date, and their interaction (Table 4). At mean initiation date, estimated daily survival rate for nests is highest in winter wheat (DSR = 0.972 ± 0.004), moderate in fall rye (DSR = 0.951 ± 0.003), and lowest in spring-seeded crop (DSR = 0.939 ± 0.010). These DSRs equate to 38.1%, 18.1%, and 11.8% Mayfield nest success in winter wheat, fall rye, and spring-seeded crop, respectively. Daily nest survival increased with initiation date in spring-seeded crop ($\hat{\beta} = 0.497 \pm 0.131$) but remained relatively constant throughout the season in winter wheat ($\hat{\beta} = -0.058 \pm 0.146$) and fall rye ($\hat{\beta} = -0.047 \pm 0.068$; Fig. 3).

The competing model was about half as likely and

Table 3. The 2 best approximating models (i.e., within 2 Akaike's Information Criterion corrected for small sample size [AIC_c] units of the top ranked model), the primary main effects (field area, crop type) model, and the null model from the a priori analysis examining number of waterfowl nests discovered as a function of various field and landscape-scale variables at study sites in southern Saskatchewan, Canada, 1996–1999.

Model[a]	AIC_c	ΔAIC_c	Parameters[b]	Model wt (w_i)
NA(AREA + CROPTYPE × PCTWET + CROPTYPE × PCTCROP)	−1,931.29	0.00	11	0.464
NA(AREA + CROPTYPE × PCTWET + $PCTWET^2$)	−1,929.88	1.41	9	0.230
NA(AREA + CROPTYPE)	−1,924.05	7.24	5	0.012
Null	−1,838.68	92.60	2	0

[a] Models including interaction or quadratic terms include all main effects.

[b] We included an intercept and dispersion estimate in the parameter total for all models.

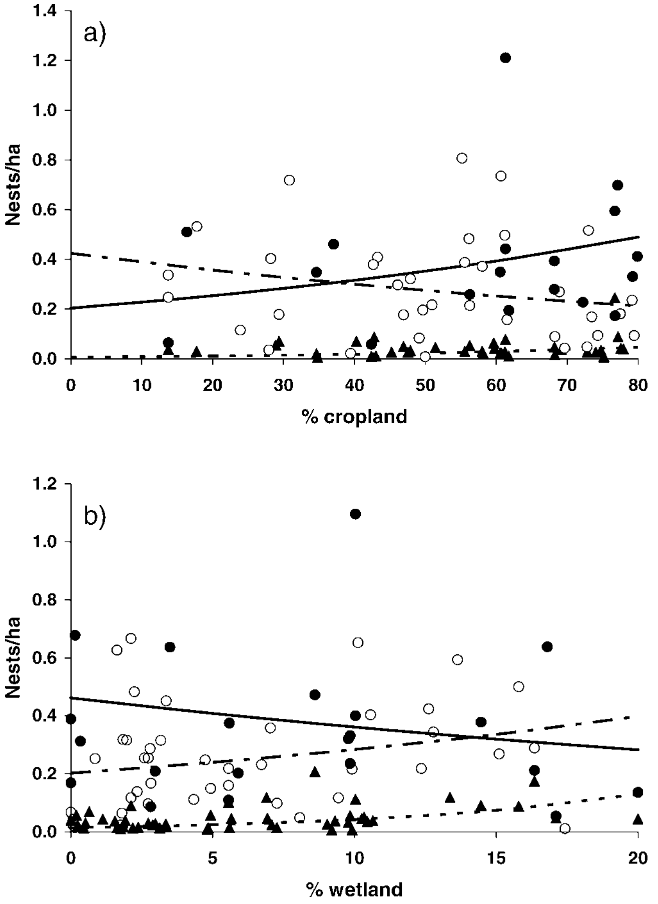

Figure 2. Response of apparent waterfowl nest density by crop type to the percentage of the surrounding landscape composed of (a) cropland and (b) wetland as indicated by the best approximating model in our analysis. Model-based predictions and field-level estimates for spring-seeded cropland (dashed lines, closed triangles), winter wheat (solid line, solid circles), and fall rye (dash-dot line, open circles) have been adjusted to average percent wetland in part a, average percent cropland in part b, and a field size of 1 ha in both. Beta estimates differed from zero only for spring-seeded cropland in both. We measured surrounding landscape composition within a 2-km radius of the centroid of each study field in southern Saskatchewan, Canada, 1996–1999.

included a similar crop type effect and indicated a negative curvilinear response of daily nest survival to annual wetness ($\hat{\beta}_{\mathrm{PONDINDEX}} = 0.122 \pm 0.060$; $\hat{\beta}_{\mathrm{PONDINDEX}^2} = -0.084 \pm 0.028$), such that survival was lower at the extremes of annual wetness and high in the central range.

DISCUSSION

We were able to conduct multiple nest searches throughout the nesting season in croplands and hence gather new information regarding waterfowl use and productivity in spring- and fall-seeded croplands. At least 7 species used croplands for nesting, with mallards, northern pintails, and blue-winged teal predominating.

Fall-seeded crops, especially winter wheat, were attractive to nesting waterfowl. Our estimates of apparent nest density are 6 times higher than previously reported for this crop type and ≤39 times higher than previously reported for spring-seeded cropland (Table 5). We suspect this is due in part to our greater searching effort in growing grain than previous studies. Mallards and pintails were generally the only species we found nesting in crop stubble prior to seeding. Toward late May, crop growth was well advanced, with fall rye in the booting to heading growth stage (Zadoks scale 39–55, approx. 50–70 cm tall; Zadoks et al. 1974) and winter wheat in the tillering to stem elongation growth stage (Zadoks scale 25–39, approx. 30–50 cm tall). Spring-seeded wheat or barley fields were generally in the 0–4 leaf stage of seedling development (Zadoks scale 9–14, approx. 5–15 cm tall) at this point. Our estimates of apparent nest density are conservative given the flushing efficiency of nest drags (Higgins et al. 1977), potential absence of females from nests at the time of nest searching (Gloutney et al. 1993), and inability to find nests initiated and destroyed between search periods.

Apparent nest density was 8–13 times greater in fall-seeded cropland versus spring-seeded cropland (Table 5). However, we recognize that nest survival can affect apparent nest density estimates (Miller and Johnson 1978). Taking nest survival into account (i.e., dividing total nests found by DSR raised to the average nest age at first discovery; Arnold et al. 2007), our estimates of initiated nests/ha for winter wheat, fall rye, and spring-seeded cropland would be 0.51, 0.41, and 0.07, respectively. Comparable estimates for annually tilled cropland and untilled uplands from Higgins (1977) are 0.06 initiated nests/ha and 0.54 initiated nests/ha, respectively (based on Higgins 1977, table 4 and using Green's [1989] correction for apparent nest success and Miller and Johnson's [1978] nest density correction). Hence, fall crops approach untilled uplands in provision of attractive nest sites.

Table 4. The 3 best approximating models (i.e., within 2 Akaike's Information Criterion corrected for overdispersion [QAIC] units of the top ranked model), the primary main effect (crop type) model, and the null model from the a priori analysis examining waterfowl nest survival as a function of various nest, field, and landscape-scale variables at study sites in southern Saskatchewan, Canada, 1996–1999.

Model[a]	QAIC	ΔQAIC	Parameters[b]	Model wt (w_i)
NS(CROPTYPE × IDATE)	784.95	0.00	7	0.190
NS(CROPTYPE + PONDINDEX^2)	786.54	1.59	6	0.086
NS(CROPTYPE × IDATE + IDATE^2)[c]	786.57	1.62	8	0.085
NS(CROPTYPE)	787.16	2.21	4	0.063
Null	793.05	8.10	2	0.003

[a] Models including interaction or quadratic terms include all main effects.

[b] We included an intercept and $\hat{c}$ in the parameter total for all models.

[c] Not a competing model because it is a more complex version of higher ranked model.

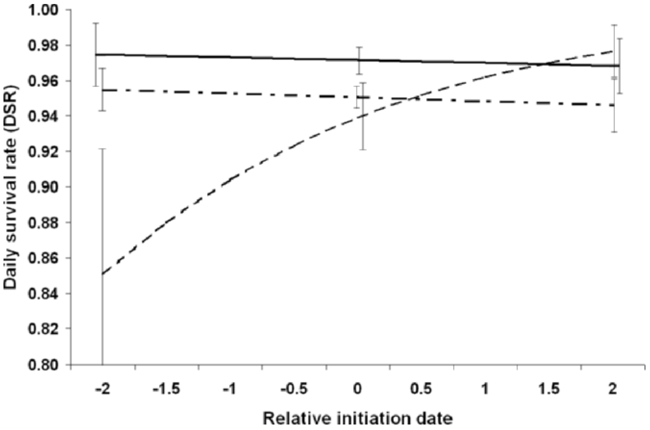

Figure 3. Trends in daily nest survival rate with standardized initiation date for waterfowl nests in winter wheat (solid line), fall rye (dash-dot line), and spring-seeded (dashed line) croplands in southern Saskatchewan, Canada, 1996–1999. Confidence limits (95%) are provided for relative initiation dates −2, 0, and 2.

Table 5. Published and unpublished estimates of waterfowl apparent nest density and Mayfield nest success (NS) in cropland habitat where it was systematically searched.

Study and crop type	Estimated nest density (nests/ha)	Estimated % Mayfield[a] NS	Nest sample size
Higgins 1977			
Standing stubble	0.037	5[b]	27
Mulched stubble	0.016	3[b]	34
Growing grain	0.011	20[b]	20
Summerfallow	0.012	2[b]	12
All types	0.017	5[b]	93
Cowan 1982			
No-till spring-seeded	0.147	38[b,c]	20
Conventional spring-seeded	0.010	0	2
Duebbert and Kantrud 1987			
No-till winter wheat	0.065	27	151
Fisher 1993			
No-till spring-seeded	0.016	13	13
This study			
No-till winter wheat	0.390	38	150
Fall rye	0.250	18	420
No or min.-till spring-seeded	0.030	12	58

[a] Johnson (1979).

[b] Estimated Mayfield NS (Green 1989) based on reported apparent nest success rate.

[c] Farm operators were instructed to actively avoid nests in the field and covered nests after females flushed.

We observed that apparent nest density in spring-seeded cropland was influenced by surrounding landscape composition. Apparent nest density in spring-seeded cropland increased with the amount of cropland and wetland in the surrounding landscape, which was counterintuitive because as we would expect nest density to increase in covers with greater concealment (e.g., winter wheat) as overall cropland increases (i.e., limiting available nest habitat for most species; e.g., Dahl et al. 1999). A nest density response to amount of cropland in the landscape may be an artifact of the observational nature of our study. Given the location of our study sites in the latter 2 years, we found many more pintail nests (a species that readily nests in spring-seeded croplands) and one of these sites had some of the highest proportions of cropland in the surrounding landscape. Increased use of spring-seeded cropland with wetland habitat may simply be a response to the dependence of waterfowl on wetland habitat, although we did not observe a similar pattern in fall-seeded crops.

Our nest survival rates in croplands were high relative to most previously reported estimates (e.g., Higgins 1977, Klett et al. 1988, Greenwood et al. 1995). Only Duebbert and Kantrud (1987) provide previous data on winter wheat, and our estimates support their finding that nest survival in this crop type is higher than most habitats examined in the PPR.

Although lower nest survival in spring-seeded crops is expected due to nest destruction associated with the seeding operation, 78% of destroyed nests in spring-seeded cropland were a result of depredation. If we remove nests destroyed during seeding ($n = 9$), estimated nest survival would increase from 12% to 18%. Previously reported estimates of nest survival for spring-seeded cropland are generally low but variable and often limited by sample size (Table 5; Klett et al. 1988). We suspect our inclusion of nests in growing grain, and hence later in the nesting season than many previous studies, may be the reason our estimates for spring-seeded cropland are generally higher than most previously reported. The combination of nest destruction by seeding early in the season and increased concealment in growing grain as the season progresses likely drives the seasonal pattern in nest survival that we observed in spring-seeded cropland. A similar pattern in nest survival in spring-seeded croplands was observed by Emery et al. (2005). Applying our nest survival estimates to estimated initiated nest densities as calculated above indicates that winter wheat and fall rye could hatch 0.194 nests/ha and 0.074 nests/ha, respectively, relative to 0.008 hatched nests/ha in spring-seeded cropland.

Waterfowl hatching early in the season typically have survival and growth advantages over later hatched individuals and are more likely to recruit into the breeding population (Dzus and Clark 1998, Blums and Clark 2004). Unlike most habitats in the PPR where nest survival increases throughout the season (Greenwood et al. 1995, Emery et al. 2005), nest survival in fall-seeded croplands is consistently high through the nesting season and hence may provide early nesting species (e.g., pintail, mallard) a recruitment advantage.

Vulnerability to disease, one of the primary barriers to growing winter wheat in the PPR, has been overcome with new varieties, and management systems have been developed to improve overwinter survival of winter wheat varieties. Overcoming the remaining barriers (e.g., spring-seeding tradition, price relative to spring wheat, information extension) is the challenge ahead. Fall rye continues to be limited by lack of available markets for this grain. As of 2006, approximately 0.2 million ha of fall rye and 0.3 million ha of winter wheat were grown in Prairie Canada out of approximately 29.2 million ha of cropped land (Statistics Canada 2006). About 7.4 million ha of spring-seeded wheat were grown in Prairie Canada in 2006, and it is estimated that approximately 30% of this acreage could be converted to a winter variety given current crop rotations (J. Davidson, Winter Cereals Canada, personal communication).

MANAGEMENT IMPLICATIONS

Fall-seeded crops provide an opportunity for the provision of safe nesting habitat on private land in landscapes that attract high waterfowl populations but are predominantly cropland. Promotion of fall-seeded cropland is a strategy that could benefit the northern pintail, a species currently suspected of poor recruitment due to cropland nesting in combination with increasing cropping intensity in the PPR (Krapu 1977, Miller and Duncan 1999, Podruzny et al. 2002). Although efforts to increase winter wheat by encouraging variety development (e.g., Ducks Unlimited Canada's funding of the Winter Wheat Breeding Program at the University of Saskatchewan) have been successful in facilitating expansion of this crop, a similar effort to expand fall rye would require removal of market barriers. Given reasonable value to nesting waterfowl (especially early nesters), efforts to promote fall rye as an alternative to spring-seeded crops are warranted where winter wheat may not be an option.

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