

Assessing Predation of Artificial Nests: Does Patch Size Matter?

Alex J. Solem^{1*} and Travis J. Runia¹

Abstract - Populations of Ring-necked Pheasants and other upland nesting game birds have responded positively to the establishment of undisturbed nesting habitat. Federal programs such as the Conservation Reserve Program (CRP) are a source of this habitat; however, the average patch size of this conservation practice has declined in recent years. Pheasant and waterfowl populations are sensitive to nest survival, which can be influenced by habitat patch size, patch shape and distance to edge, and juxtaposition. We used artificial nests to investigate if survival in CRP fields was influenced by nest-site characteristics, CRP patch size, and surrounding landscape-level characteristics. We were particularly interested in whether nest predation rates differed between patches approximating the average size of general sign-up CRP (32 ha; large patches) and continuous sign-up CRP (8 ha; small patches) in South Dakota. Nest survival increased with an increase in percent grassland cover types within 2,000 m from nests in small patches but decreased for nests in large patches. A greater distance to the edge of the field provided higher nest survival, thus portions of large fields provided enhanced nest survival compared to small fields. Nest survival increased with an increase in average litter depth at the nest and as percent of developed area increased within 2,000 m of the nest. Wildlife managers should continue to manage and advocate for large patches of undisturbed nesting cover to reduce predation risk while establishing additional nesting cover near small patches.

Introduction

Habitat is the foundation of sustainable, long-term populations of many wildlife species. Populations of *Phasianus colchicus* L. (Ring-necked Pheasant; hereafter Pheasant) and other upland nesting game birds have responded positively to the establishment of undisturbed upland habitat provided by cropland conversion programs such as the Conservation Reserve Program (CRP; Kantrud 1993, Reynolds et al. 2001, Taylor et al. 2018). The undisturbed blocks of grassland provided by CRP-like habitat are attractive nesting and brood-rearing habitat (Best et al. 1997; Clark et al. 1999; Matthews et al. 2012a, 2012b; Reynolds et al. 2001; Riley 1995; Pauly et al. 2018; Taylor et al. 2018) but are limited in their distribution and area (Hellerstein 2017). Sensitivity analyses have shown nesting survival is a major driver of Pheasant and waterfowl populations (Clark et al. 2008, Cowardin and Johnson 1979, Johnson et al. 1987, Klett et al. 1988). Since the inception of the CRP in 1985, programmatic changes have trended enrollment towards smaller patches in lieu of larger, full field conversions (Hellerstein 2017, Taylor et al. 2018). This trend could have implications for upland nesting birds because size, shape, and juxtaposition of habitat patches can influence predation risk and subsequent nest survival.

Nest depredation is the main cause of reproductive failure in most upland nesting birds (Martin 1993, Sargeant et al. 1993, Walker et al. 2013). Nest survival rates are often influenced by habitat configuration surrounding nests (Clark et al. 1999) and larger patches of nesting habitat generally yield higher nest survival than small patches (Andr n 1995:225–255, Clark and Bogenschutz 1999, Koford et al. 2016, Riley and Schulz 2001,

¹South Dakota Department of Game, Fish, and Parks, 895 3rd Street SW, Huron, SD, 57350, USA.

*Corresponding author: Alex.Solem@state.sd.us.

Sovada et al. 2000). However, this relationship may not always hold true with small, isolated patches of habitat yielding higher overall nest survival rates than that of larger patches of habitat (Clark et al. 1999). In some cases, the configuration, shape, and overall core area of the patches are more important predictors of nest success than size (Clark et al. 1999, Koford et al. 2016). This reduction in predation rate may be attributed to the abundance and behavior of predators (Stephens and Krebs 1986) or a lower overall number of nests (Clark et al. 1999, Kuehl and Clark 2002). Generally, the addition of grassland habitats surrounding nests increases overall nest survival (Clark and Bogenschutz 1999) but the diversity of the landscape in which this habitat is situated adds complexity to the influence of grassland abundance on nest survival (Riley 1995). Assessing patch size influence in the context of the surrounding landscape is an important aspect of optimizing nest survival.

Habitat fragmentation and resulting habitat loss of nesting patches have important implications for grassland bird populations (Horn et al. 2005, Neimuth et al. 2007, Taylor et al. 1978, Warner et al. 1984, Wimberly et al. 2018). Increased habitat fragmentation generally reduces the size of patches of habitat and increases the edge density relative to the patch size, ultimately reducing the distance to edge for that nest (Andrén 1995). Increased predation rates can occur on nests located closer to patch edges (Batáry and Báldi 2004). Land use changes and habitat fragmentation force wildlife managers to develop ever changing recommendations to existing and impending habitat practices.

Wildlife managers are faced with the challenge of producing viable wildlife populations on less overall undisturbed habitat with shrinking habitat patch sizes. To maximize the production of wildlife populations, wildlife managers must help identify the optimal undisturbed patch size of nesting cover and the landscape configuration. This information can help maximize wildlife production and identify the agro-economic trade-offs associated with the retirement of marginal cropland acres into perennial grassland, such as CRP. Therefore, the objective of our study was to investigate if nest survival in CRP fields was influenced by nest-site characteristics, patch size, and surrounding landscape-level characteristics. We were particularly interested in whether nest predation risk differed between patches approximating the average size of general sign-up CRP (32 ha) and continuous sign-up CRP (8 ha) (USDA 2017) for South Dakota.

Methods

Study Area

We conducted our study on parcels of CRP grassland during the primary nesting season (May–July) within Beadle and Sanborn counties, South Dakota, USA (Fig. 1). Study sites were situated in a variety of sandy, silty and loam soil types, interspersed with temporary, seasonal and semi-permanent wetlands, and were contained in a mosaic of native rangelands, other undisturbed grassland/CRP fields, *Medicago sativa* L. (Alfalfa), tame grassland cut for hay, and crop fields including *Zea mays* L. (Corn), *Glycine max* (L.) Merr. (Soybean), *Triticum aestivum* L. (Spring and Winter Wheat), and *Sorghum bicolor* (L.) Moench (Sorghum). Historical average annual precipitation ranged from 55.8 to 60.9 cm and the average annual temperature ranged from 7.7 to 8.3° C (NOAA 2019).

Our study sites consisted of 10 CRP patches in 2018 and 9 CRP patches in 2019. Sites varied in the number of years they have been enrolled in CRP and since perennial cover was initially established (2–15 years). Initial seedings included native and introduced warm and cool season grasses and a variety of native and introduced forbs. The variability in field age

and original seeding resulted in a variety of different vegetative species and successional stages. However, nest success has been found to be similar among native- and tame-seeded CRP fields (Sherfy et al. 2018). The vegetation was dominated by native vegetation including *Andropogon gerardii* Vitman (Big Bluestem), *Panicum virgatum* L. (Switchgrass), and *Schizachyrium scoparium* (Mi-chx.) Nash (Little Bluestem), introduced vegetation including *Poa pratensis* L. (Kentucky Bluegrass), *Thinopyrum intermedium* (Host) Barkworth and D.R Dewey (Intermediate Wheatgrass), and *Bromus inermis* Leyss. (Smooth Brome), and a variety of forbs.

Study Site Selection and Land Use Mapping

We initially categorized CRP fields as small patches ranging in size from 6.8 to 9.3 ha and as large patches ranging in size from 30.9 to 33.4 ha from a subset of CRP enrollments provided by the Farm Service Agency (FSA). Patch size was ultimately defined by the boundary delineated by the FSA at the time of CRP enrollment or re-enrollment for that field. We then implemented focal statistics in ArcMap (ESRI, Redlands, CA, USA) to determine the amount of grassland and CRP grassland practices within 2,000 m of each field boundary. A grassland cover category was developed by combining the grassland/herbaceous and pasture/hay classes of the National Land Cover Database 2011 (NASS CDL 2011). We stratified patches by % grassland categories (high [$>60\%$], medium [$30\text{--}60\%$], low [$<30\%$]) and % CRP categories (high [$>15\%$], medium [$10\text{--}15\%$], low [$<10\%$] CRP landscapes) within 2,000 m of each field boundary. We then preliminarily selected small

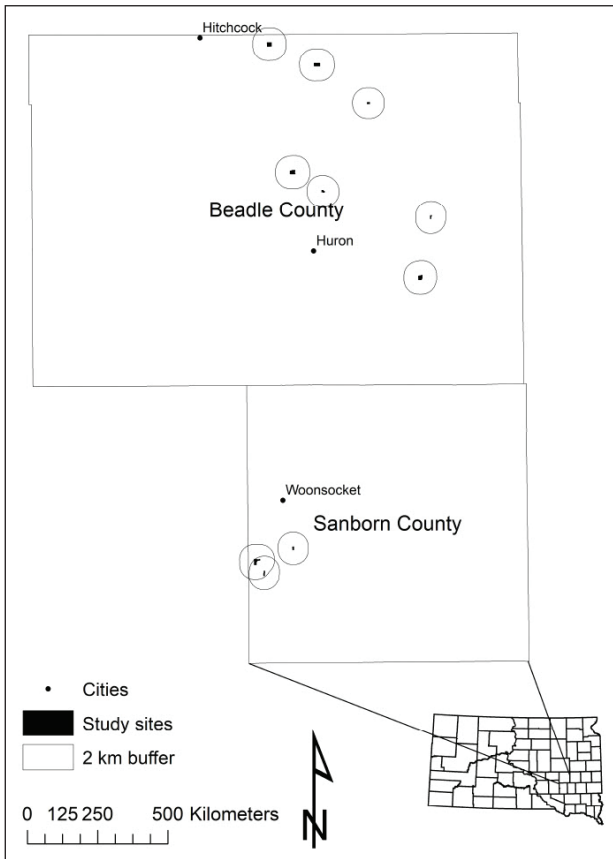


Figure 1. Study sites and a 2,000 m buffer for evaluating survival of artificial nests in Beadle and Sanborn counties, South Dakota, USA, 2018–2019.

($n = 5$) and large ($n = 5$) patch size sites as our study sites to represent a combination of these CRP and grassland categories (Table 1).

After study sites were selected, we manually digitized the land use within 2,000 m of each field boundary using ArcMap. We used the most recent National Agricultural Imagery Program aerial imagery for the digitizing process with a 0.5-ha minimum mapping unit. We annually conducted ground surveys within digitized area, recorded any additional land use changes, and corrected land uses that were digitized incorrectly. Land use was classified as cropland, undisturbed grassland, grassland, Alfalfa, small grains (Spring and Winter wheat), right-of-way, woody habitat, open water, and developed (Table 2). Study sites were not adjacent to other CRP grassland practices; however, in some instances they were adjacent to other grassland practices, such as pastures. This change in habitat type was interpreted as edge because there was a discrete change in habitat type or vegetative structure and was easily discerned from one another (Wiens 1976). In 2019, above-average precipitation prevented some crop fields from being planted. However, we continued to classify them as cropland because of the limited residual/actively growing vegetation in these fields.

We calculated landscape covariates using our digitized layer within a 2,000-m window from the location of each nest using FRAGSTATS V4.2.1 (Table 1; McGarigal et al. 2002) and used the values associated with these nests for modeling. We chose this scale because it is biologically relevant to a Pheasant’s home range and life cycle (Clark et al. 1999, Riley et al. 1998, Simonsen and Fontaine 2016) and primary nest predator home ranges, including *Procyon lotor* L. (Raccoon), *Mephitis mephitis* Schreber (Striped Skunk) (Klug et al. 2009, Phillips et al. 2003). This scale also offered a large enough area to measure potential landscape level

Table 1. Candidate patch size, % grass and % Conservation Reserve Program (CRP) land surrounding CRP sites chosen to evaluate survival of artificial nests in Beadle and Sanborn counties, South Dakota, USA, 2018–2019.

Patch size ^a	% grass ^b	% CRP ^c
Large	Medium	Low
Large	Medium	Low
Large	Medium	Low
Large	Medium	High
Large	High	Medium
Small	Medium	Medium
Small	Low	Medium
Small	High	Medium
Small	High	High
Small	Medium	Medium

^a Patch size: Large ~ 32 ha; Small ~8 ha.

^b % grass: % grassland/herbaceous + % pasture/hay classes of the National Land Cover Database 2011 (NASS CDL 2011).

^c %CRP: % Conservation Reserve Program grassland practices (CRP; from the Farm Service Agency - 2018).

effects and could serve as a direct comparison to previous artificial nest research (Simonsen and Fontaine 2016). We did not calculate landscape specific covariates for small grains (Spring and Winter Wheat) or Alfalfa because they rarely occurred in our analysis area.

Nest Location and Placement

We were primarily interested in nest survival rates within two CRP patch sizes, as well as the nest-site characteristics and the landscape surrounding them. Artificial nests can be used as a surrogate for determining nest survival rates when the use of real nests or marked birds is economically and logistically infeasible (Moore and Robinson 2004). Artificial nests allow researchers a practical means to measure effects of treatments, and investigate how landscape and patch level attributes, and nest predator behavior influence nest survival rates (Fontaine et al. 2007, Simonsen and Fontaine 2016).

Caution should be used when interpreting results using artificial nests because survival rates do not always translate equally to real nests (Reitsma 1992, Butler and Rotella 1998, Major and

Table 2. Landscape and nest site covariates used to evaluate survival of artificial nests in Beadle and Sanborn counties, South Dakota, USA, 2018–2019.

Variable Name	Variable Type	Scale	Description
LITTERDEPTH	Continuous	Nest site	Average depth of residual matter parallel with the ground 1, 3, and 5 m in each cardinal direction from the nest bowl.
ROBEL	Continuous	Nest site	Average of 4 VOR ^a at the nest bowl from each cardinal direction.
ALIVEHEIGHT	Continuous	Nest site	Average maximum height of growing vegetation 1, 3, and 5 m in each cardinal direction from the nest bowl.
DEADHEIGHT	Continuous	Nest site	Average maximum height of residual vegetation 1, 3, and 5 m in each cardinal direction from the nest bowl.
AVG_CONCEALMENT	Continuous	Nest site	Average % of nest visible from overhead, and each cardinal direction 1 m from the nest bowl.
DEVELOPED	Continuous	Landscape	% farmsteads + building sites + associated infrastructure + adjacent woody vegetation.
GRASS	Continuous	Landscape	% pastures + hayfields.
TREE	Continuous	Landscape	% woody habitat, independent from developed areas.
IDLEGRASS	Continuous	Landscape	% Conservation Reserve Program (CRP; from FSA ^b - 2018) + grassland left undisturbed year to year.
ALLGRASS	Continuous	Landscape	% idle grassland + pastures + hayfields.
CRP	Continuous	Landscape	% Conservation Reserve Program (CRP).
DISTEDGE	Continuous	Landscape	Distance to the edge of the patch the nest was placed in from the nest site (m).
PATCHSIZE	Categorical	Landscape	Size of the field the nest is in (large or small).

^a Visual obstruction reading (Robel et al. 1970).

^b Farm Service Agency.

Kendal 1996, Zanette 2002, Moore and Robinson 2004), partly due to hen selection processes at a small scale that can obscure environmental hazards that affect nest survival (Fontaine et al. 2007). Other factors, such as differences in the type of egg used (Major and Kendal 1996), nest predator communities, the lack of scent from an incubating hen (Willebrand and Marcström 1988), and the spatial and seasonal patterns of predation (Zanette 2002) may also affect these rates and must be taken into consideration when interpreting results from artificial nest studies. However, artificial nests ensure adequate sample sizes and experimental design protocols are met (Butler and Rotella 1998). Because of this, artificial nests allow researchers the ability to mitigate potential biases associated with traditional nesting studies and assess true environmental risks on a landscape (Fontaine et al. 2007). Therefore, we elected to use artificial nests in lieu of marked hens to determine the direct effects of landscape configuration and eliminate female nest-site selection behavior.

We conducted 21-day trials in mid-May and mid-June each year to coincide with Pheasant nesting chronology in South Dakota (Leif 1996). Nests were comprised of 4 brown *Gallus domesticus* L. (Domestic Chicken) eggs and concealed within a nest bowl with vegetation substrate from the patch. Each artificial nest was placed with the intention of replicating a Pheasant nest in shape, size, and nest bowl substrate to increase experimental validity and eliminate bias of predator communities within these patches (Major and Kendal 1996, Moore and Robinson 2004, Riley and Schulz 2001, Simonsen and Fontaine 2016).

The same person created nests throughout the duration of the study to ensure consistency. Scent masking methods were not utilized due to their lack of effect on nest survival rates (Donalxy and Henke 2001). Nests were discretely marked by placing 2 contrasting neon colored zip ties around the vegetation 1 m north of the nest bowl. We deployed nests at a standard density (1 nest/0.81 ha) because nest predation rates can be affected by nest density (Göransson et al. 1975, Niemuth and Boyce 1995). In small patches, we utilized the entire patch for nest placement while maintaining appropriate nest density. In large patches, we randomly generated an ~8-ha sampling plot for each trial to maintain nest density between our two patch sizes without having more nests in larger patches. We then randomly generated nest locations within these boundaries in ArcMap. If a random location occurred within a wetland basin or on bare ground, we moved the nest to the nearest adjacent upland habitat.

In 2018, 5 of our 10 patches had been partially hayed the prior year. If haying occurred on a patch, it did not change our definition of patch size and we only placed nests in the non-hayed areas for the first trial in 2018. By the start of the second nesting trial in 2018, new vegetation growth resulted in vegetation structure that could be used for nesting, so the entire patch was used for potential nest sites.

During nest placement, we estimated visibility from above and from 1 m in each cardinal direction (Table 2). We monitored nests every 1 to 5 days. Nests were considered unsuccessful if ≥ 1 egg was missing, damaged or destroyed. If a nest failed during the 21-day exposure period, the remaining eggs or eggshell fragments were removed from the nest bowl. Any nest surviving the 21-day exposure period was removed prior to the next trial. To ensure the nest bowls were properly marked after a depredation event for future vegetation sampling, a pin flag was inserted flush with the ground in the original nest bowl.

Vegetation Sampling

We sampled vegetation at nests at the conclusion of each trial to eliminate bias associated with sampling immediately after nest fate (McConnell et al. 2017). We measured vegetative structure and cover adapted from the BBIRD Field Protocol (Martin et al. 1997, Simonsen and Fontaine 2016). We established 4 distinct sampling quadrants by extending a 5-m rope from

the nest in each cardinal direction. We recorded 4 visual obstruction readings at each nest and used the average of these readings for analysis (Table 2; Robel et al. 1970). We recorded the maximum height of the growing and residual vegetation at each nest and at 1, 3, and 5 m in each cardinal direction and used the average value for analysis (Table 2). We recorded depth of residual matter (litter depth) parallel with the ground at 1, 3, and 5 m in each cardinal direction from each nest and used the average of these values for analysis (Table 2).

Statistical Analyses

We used a modified logistic exposure model to estimate daily nest survival rate (DSR) which allowed for varying time between nest checks (Shaffer 2004). We investigated potential influences of the non-biological covariate SITE as a random effect to determine if there was lack of statistical independence between nests from multiple visits to these sites (`glmer()` function of the R package `lme4` [Bates et al. 2015]). However, our random effects models failed to converge, indicating no variation among SITE ($\sigma^2 = 0$). Therefore, we removed SITE as a random effect and developed temporal, nest-site, and landscape-level models using the `gml()` function of the R package `stats` (R Core Team 2020).

We modeled DSR as a function of covariates in successive stages (Table 2). At each stage, an information-theoretic model selection approach was used to identify the most parsimonious model (Arnold 2010, Burnham and Anderson 2002). We first modeled DSR as a function of the temporal variables TRIAL and YEAR associated with each nest. We used our most parsimonious model as a base to form the model set to evaluate nest site covariates (Table 2), then a set of identified *a priori* landscape-level models only utilizing variables we deemed biologically significant to nesting game birds (Table 2).

We inspected our model sets for uninformative variables by identifying nested models where the addition of one parameter only improved model fit by trivial amounts of deviance (Arnold 2010). We avoided modeling combinations of landscape level covariates with collinearity (i.e., $|r| > 0.70$, Green 1979). We report DSR model predictions and 85% confidence limits for the most parsimonious model while holding all other continuous variables at their mean. All statistical analyses were completed in R version 4.0.2 (R Core Team 2020).

Results

We were unable to gain access to 1 small patch in 2019. Therefore, we sampled in 10 patches in 2018 and 9 patches in 2019. In 2018, we placed 92 nests in the first trial and 100 in the second trial. In 2019, we placed 89 nests in both the first and second trials. The fates of 369 nests were used in analyses and we documented 109 predation events for an overall DSR of 0.984 (95% CI: 0.980–0.986). Nests varied in the percent surrounding grassland cover types (% undisturbed grassland + % pasture + % hayfields) from 18–62% within 2,000 m of the nest sites.

YEAR was the only informative temporal variable (Table 3; Table 4) and LITTERDEPTH was the only informative nest site variable (Table 3; Table 4). The top-ranked model from the final model set was most parsimonious and included the variables YEAR, LITTERDEPTH, ALLGRASS, PATCHSIZE, DEVELOPED, DISTEDGE, and an interaction between ALLGRASS and PATCHSIZE (Table 3; Table 4). We had 2 additional models within 2 Δ AICc of our top model. Our third ranked model differed from the top model by the addition of one uninformative variable (CRP). Our second ranked model was identical to the top ranked model except for the exclusion of DISTEDGE. Because the model with DISTEDGE ranked higher while still being penalized for an additional parameter, we accepted the top-ranked model as the best model. Overall, DSR was negatively related to PATCHSIZE, however, the interaction term

Table 3. Selection table for logistic exposure models estimating survival of artificial nests within a 2,000 m scale in Beadle and Sanborn counties, South Dakota, USA, 2018–2019. Only models within 4 AICc units of the top model are presented for the landscape modeling at 2,000 m. K is the number of parameters. Models are ranked by Akaike's Information Criterion adjusted for small sample size (AICc). $\Delta AICc$ is the difference in AICc score relative to the highest-ranked model and ω_i is the Akaike weight indicating the relative support of the model.

Model-selection Process and Covariates		K	AICc	$\Delta AICc$	ω_i
<u>Temporal</u>					
YEAR		1	808.3	0.0	0.6
YEAR + TRIAL		2	809.4	1.1	0.4
NULL		1	828.3	20.1	0.0
TRIAL		2	829.5	21.3	0.0
<u>Nest-site</u>					
YEAR* + LITTERDEPTH		2	808.0	0.0	0.7
YEAR + LITTERDEPTH + ROBEL		3	809.9	2.0	0.3
YEAR + ALIVEHEIGHT		2	814.3	6.4	0.0
YEAR + AVERAGECONCEALMENT		2	814.9	6.9	0.0
YEAR + DEADHEIGHT		2	816.6	8.6	0.0
YEAR + ROBEL		2	816.9	9.0	0.0
<u>Landscape</u>					
YEAR + LITTERDEPTH + ALLGRASS*PATCHSIZE + DEVELOPED + DISTEDGE		7	790.8	0.0	0.3
YEAR + LITTERDEPTH + ALLGRASS*PATCHSIZE + DEVELOPED		6	791.6	0.8	0.2
YEAR + LITTERDEPTH + ALLGRASS*PATCHSIZE + DEVELOPED + DISTEDGE + CRP		8	792.6	1.8	0.1
YEAR + LITTERDEPTH + ALLGRASS*PATCHSIZE + DISTEDGE		6	792.9	2.2	0.1
YEAR + LITTERDEPTH + ALLGRASS*PATCHSIZE + DEVELOPED + CRP		7	793.5	2.7	0.1
YEAR + LITTERDEPTH + ALLGRASS + DISTEDGE + CRP		5	793.8	3.0	0.1
YEAR + LITTERDEPTH + ALLGRASS + DISTEDGE		4	794.0	3.2	0.1
YEAR + LITTERDEPTH + ALLGRASS*PATCHSIZE		5	794.0	3.3	0.0
YEAR + LITTERDEPTH + ALLGRASS*PATCHSIZE + DISTEDGE + CRP		7	794.4	3.6	0.0

Table 4. Model parameters, beta estimates (β), and standard errors (SE) from the top ranked model estimating survival for artificial nests in Beadle and Sanborn counties, South Dakota, USA, 2018–2019.

Model Parameter	Estimate	SE
(Intercept)	3.701	0.603
YEAR	0.093	0.220
LITTERDEPTH	0.110	0.040
ALLGRASS	-0.023	0.018
PATCHSIZE	-2.902	1.040
DEVELOPED	0.426	0.213
DISTEDGE	0.004	0.002

(ALLGRASS*PATCHSIZE) revealed that DSR in small fields was positively influenced by ALLGRASS surrounding nests, while a negative association was observed for nests located in large fields (Fig. 2). DSR increased with increases in DISTEDGE, DEVELOPED and LITTERDEPTH (Fig. 2).

Discussion

Our study design allowed a unique opportunity to test effects of landscape configurations, as well as patch size, on nest success, giving wildlife managers

insight into the true landscape hazards that may influence nest survival rates. Our results indicated DSR was largely influenced by landscape effects in relation to patch size, as well as specific habitat features of the nest site. Previous studies have found similar results with landscape effects on nest success with multiple grassland nesting species (Chalfoun et al. 2002, Clark and Bogenschutz 1999, Clark et al. 1999, Reynolds et al. 2001, Stephens et al. 2003); however, the scale at which the landscape effects are significant has been highly variable. Scale-dependent mechanisms based on hen nest site selection (Clark et al. 1999), specifics with nest predator species and their diversity on the landscape (Chalfoun et al. 2002, Klug et al. 2009, Stephens et al. 2003), and the amount of fragmentation in relation to the landscape studied (Andrén 1995, Donovan et al. 1997) all play a role in determining landscape effects on nest survival.

Generally, research has indicated that smaller, isolated patches of nesting habitat result in higher predation risk (Clark and Bogenschutz 1999, Gates and Hale 1975, Sovada et al. 2000, Stephens et al. 2003), although this effect can be landscape-dependent (Clark et al. 1999). Contrary to our results, we expected smaller patches to have lower nest survival rates. Other nesting studies have found similar results with smaller patch sizes; however, it is speculated that this is a result of lower use of smaller habitat patches by predators and nesting hens (Clark et al. 1999, Horn et al. 1999). Even though smaller patches might yield higher nest survival, this benefit may be outweighed by the lack of use by hens for nesting (Clark et al. 1999). Our large patch fields were representative of the size of general CRP enrollments in South Dakota, but larger fields do occur and may provide even higher nest survival. Clark et al. (1999) suggested ≥ 15 ha fields as a minimum management goal for Pheasant nesting habitat, but they observed their highest nest success in patches 4 times that size.

Our results reflect the importance of the percent grassland on the landscape and its relationship to nest survival (Clark and Bogenschutz 1999, Clark et al. 1999, Greenwood et al. 1987, Horn et al. 2005, Simonsen and Fontaine 2016). It was not our objective to identify the apparent nest predators of these artificial nests; however, anecdotal sign near failed nests indicated evidence of mammalian nest predation in all but one instance. Common mammalian nest predators in South Dakota include Raccoon, Striped Skunk, *Didelphis virginiana* Kerr (Virginia Opossum), and *Taxidea taxus* Schreber (American Badger) (Docken 2011, Flake et al. 2012). Nest predators, such as Raccoon, have a relatively low use of upland habitats suggesting any increase in the percent of uplands within their home range could decrease their overall nest predation (Fritzell 1978). However, the patch size relationship we experienced was inversely related to ALLGRASS at 2,000 m for large patches compared to small patches.

We suspected DSR would be lower for smaller patches but anticipated an increase in DSR for both patch sizes as ALLGRASS increased on the landscape. Generally, the addition of surrounding grassland on the landscape improves game bird nest survival (Clark and Bogenschutz 1999), but the magnitude of the effect can depend on the presence or absence of other landscape components that affect predator communities (Riley and Schulz 2001). We witnessed a substantial overall increase in DSR as the percent of grassland increased for our small patches, suggesting the addition of more nesting habitat around these patches might have decreased the foraging efficacy of nest predators (Phillips et al. 2003, Simonsen and Fontaine 2016, Stephens et al. 2003).

Any additional habitat added around CRP fields would offer its own source of habitat for nest predators, possibly resulting in a positive influence in their population dynamics. Additionally, it is possible this variation in DSR by patch size could be attributed to dif-

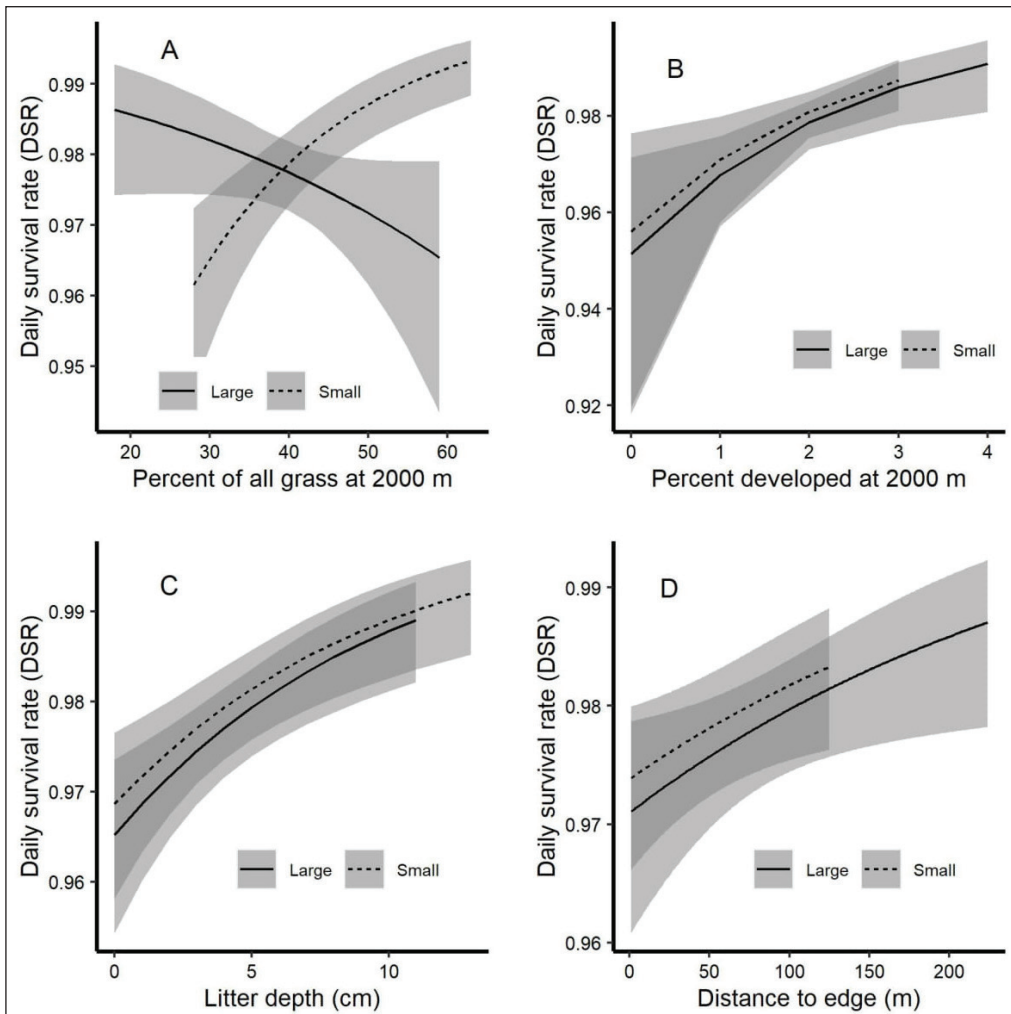


Figure 2. Daily survival rate and 85% confidence intervals (grey band) as a function of A: percent of landscape in all grassland cover types, B: percent of landscape in developed cover types, C: average litter depth around the nest, and D: distance to patch edge for artificial nests in Beadle and Sanborn counties, South Dakota, USA, 2018. All percent of landscape variables were at the 2,000 m scale from the nest.

ferences in the nest predator communities, the nature of said predators, or the diversity of the landscape surrounding patches offering predator habitat sources or influencing foraging patterns (Klug et al. 2009, Stephens et al. 2003, Tewksbury et al. 2006).

Management techniques such as increasing the percent of grassland within a landscape to mitigate loss from nest predation may not always reduce rates of predation. Instead, it could create a shift in the nest predator communities resulting in different levels of susceptibility to nest predation (Benson et al. 2010, Thompson and Ribic 2012). We suggest investigating the make-up of the predator community around these patches and determining how they are influenced by the landscape around habitat patches. This information may yield additional insight into recommendations for certain habitat practices that help mitigate nest predation and increase overall nest survival.

Distance to edge provides a simplified view of how nest survival processes can work regarding the landscape around it. The interior of our patches provided lower nest predation rates than those located close to the patch edge, much like other nesting studies (Andrén 1995, Clark et al. 1999, Phillips et al. 2003). Our findings are consistent with others noting highest nest success within the interior portions of large patches (Clark et al. 1999). Greater distance to edge values occur within the interior portions of large fields compared to any area of a small field (Fig. 3). These results suggest that areas of ‘blocky’ nesting cover could offer superior nest survival compared to areas with a higher perimeter to area ratio. This is especially important for species such as Pheasants, which select for interior portions of fields for nesting (Clark et al. 1999).

Batáry and Báldi (2004) found similar results showing increased predation rates near habitat edges. However, they suggested these findings may not completely translate to artificial nests because edge effects were not significantly different during typical incubation periods but were significant during shorter exposure periods. Our nest success estimate of 56.9% (95%CI = 49.31–61.05%) was comparable to Pheasant nests (Clark et al. 1999; 39.8–53.8%, Matthews et al. 2012a; 28–47%, Pauly et al. 2018; 51%) but higher than other artificial Pheasant nest studies (Simonsen and Fontaine 2016; 41.6%). Our typical exposure period was 21 days which is comparable to the incubation period of a Pheasant, but shorter than a total exposure period of 35 days which includes the egg laying process, and accounts for the average clutch size and the incubation period combined. Distance to edge may not always yield an overall increase in nest predation (McKee et al. 1998) and may be more related to overall landscape fragmentation (Andrén 1995:225–255). Our results indicate the edge effect is not the sole mechanism driving nest success but provides some explanation in conjunction with other landscape features surrounding the patches.

It was not our main objective to determine if DEVELOPED was a main driver of nest success and subsequently had little variation in the amount of this land use type among fields (Range = 0.12–3.53). However, Burr et al. (2017) found nest success for *Tympanuchus phasianellus* L. (Sharp-tailed Grouse) in North Dakota to be 1.95 times higher in areas with greater natural gas development intensity compared to minimal intensity areas; however predator densities were also lower. Because we did not survey the nest predator community around our study patches, we are not aware of the nest predator densities associated with these developed areas.

Many of the areas we classified DEVELOPED were occupied farmsteads with adjacent woody habitat and adjacent building sites that had daily anthropogenic activity. Species such as Raccoons, which thrive in human-modified landscapes (Stancyk 1982), may have been deterred from indirect disturbance occurring around these sites. In addition, these developed areas may have offered alternative food sources for predators. Fritzell (1978) found

developed habitat cover types used by Raccoons decreased as wetland availability increased through the spring, suggesting the use of developed cover types were used when traditional food availability was low. Considering the unseasonably wet conditions we experienced during our nesting trials, it is possible common nest predators shifted their use to wetlands given their availability on the landscape and were no longer associated with these developed areas around our sites, inadvertently driving nest survival higher within their vicinity.

In addition to patch size and landscape effects on nest predation, we found that nest-site conditions, such as LITTERDEPTH, can also aid in mitigating nest predation. Local habitat features and subsequent nest-site characteristics can widely vary from region to region and between fields of similar vegetative structure, which can influence predation rates (Sutter and Ritchison 2005, Winter et al. 2005). Vegetation density can have positive effects on nest survival rates (Sutter and Ritchison 2005, Vander Lee et al. 1999); however, differences in predator communities and interactions with vegetative characteristics in these areas complicate the interpretation of these findings (Martin 1995).

Increased litter depth, often associated with taller and more dense vegetation, results in higher nest survival rates (Sutter and Ritchison 2005). Vegetative characteristics such as litter depth may offer more overall sensory nest concealment (DeLong et al. 1995, Duebber 1969, Duebber and Lokemoen 1976) and provide less efficient foraging opportunities for primary nest predators due to their opportunistic nature (Sugden and Beyersbergen 1986). However, this benefit could be offset by decreased chick mobility, less efficient prey capture, and lack of sufficient insect abundance, ultimately lowering

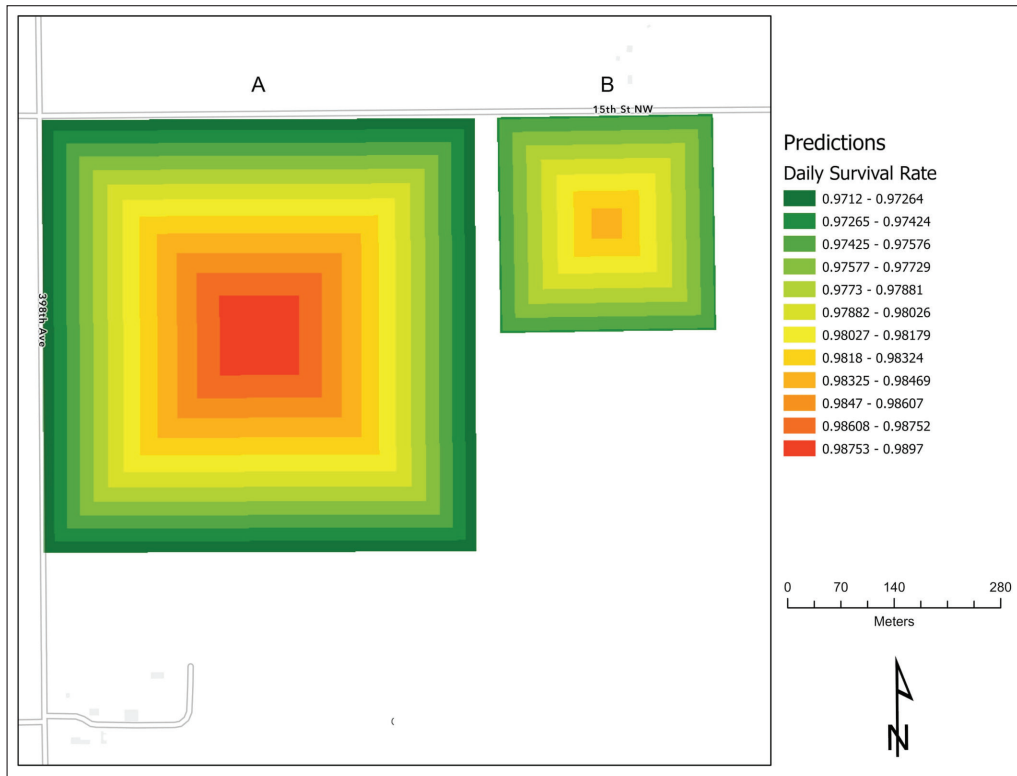


Figure 3. Estimated daily survival rates of artificial nests in a large (A; 32 ha) and small field (B; 8 ha) from research in Beadle and Sanborn counties, South Dakota, USA, 2018. All continuous covariates were held at their observed mean except for distance to edge.

overall chick survival (Doxon 2005, Matthews et al. 2012b). Overall vegetative structure of nesting cover and the number of years between management activities should be considered for the overall health of the grassland system (Matthews et al. 2012a). Offering areas of bare ground as travel corridors for chick movement is a critical factor in brood survival (Doxon and Carroll 2007).

Our study occurred in an area of relatively high Pheasant density in the heart of their primary range in South Dakota. Our patch sizes of CRP enrollments might not reflect those in other states even though the general trend of smaller CRP enrollments is currently observed nationwide (Hellerstein 2017). It is possible that nest survival may be impacted differently depending on each state's CRP enrollment sizes. Even though our study sites were stratified to include fields in what we classified as low, medium, and high grassland landscapes, other areas of the Pheasant range may only contain landscapes where their primary range would fall under our low grassland category. These results generally suggest an increase in grassland will increase overall nest success but might not translate to other areas of the nation where Pheasant habitat is less than optimal.

Management Implications

Habitat patches of differing size and juxtaposition on the landscape are not created equally in offering what wildlife managers consider quality nesting habitat. Conservation programs such as the CRP are commonly designed to address specific resource concerns such as soil erosion, water quality and wildlife habitat. Although small and linear enrollments could effectively address soil erosion or water quality concerns, the benefit to upland nesting birds would be higher if the enrolled lands were consolidated into larger blocks. Managers and policy makers should be aware of the trade-off between small, targeted enrollments and the need for large fields for upland nesting birds.

Habitat management techniques on these nesting patches should not focus on one aspect of the vegetative cover. Managing for residual litter depth in nesting cover may have increased benefits for nesting gamebirds, but these benefits could inadvertently be offset by affecting other population parameters important to upland nesting birds. Rather, managers should continue to focus on promoting vegetative structure that benefits all population parameters of upland nesting game birds.

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