Research Article

Mid-Contract Management of Conservation Reserve Program Grasslands provides Benefits for Ring-Necked Pheasant Nest and Brood Survival

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ABSTRACT Conservation Reserve Program (CRP) fields may provide good habitat for nesting and brood-rearing ring-necked pheasants (*Phasianus colchicus*) during early stages of succession. But, the success of hens in early successional CRP, relative to late successional CRP and other grassland habitats, has yet to be evaluated. The reproductive period is especially critical for populations of pheasants, and CRP's benefits to hens and chicks may decrease as fields age because of loss of vegetative diversity, decrease in vegetation density, and accumulation of residual litter. During 2005–2006, we evaluated spatial and temporal variation in nest and brood survival for radio-marked hen pheasants in areas of northeastern Nebraska where portions of CRP fields had been recently disced and interseeded (DICRP) with legumes. Nests in DICRP tended to have a higher daily survival rate (0.984; 95% CI: 0.957–0.994) than nests in grasslands (including CRP) that were unmanaged (0.951; 95% CI: 0.941–0.972). The probability of 23-day nest success was 0.696 (95% CI: 0.631–0.762) for DICRP and 0.314 (95% CI: 0.240–0.389) for unmanaged grasslands. Daily brood survival rates varied by habitat type, brood age, and date of hatch. The probability of a brood surviving to day 21 was 0.710 (95% CI: 0.610–0.856). Brood survival rates increased with time spent in DICRP and as the brood aged. Survival decreased as broods spent more time in cropland and peaked seasonally with broods that hatched on 15 June. Brood survival probability, to 21 days, would be reduced to 0.36 (95% CI: 0.100–0.701) if broods in our sample had not used DICRP. We combined nest and brood survival in a productivity model that suggested 2,000 hens, in a landscape with no DICRP, would produce 1,826 chicks, whereas the same hens in a landscape of 100% DICRP would produce 5,398 chicks. Production of first-year roosters more than doubled when hens nested in DICRP. Without DICRP, population growth rates of pheasant populations usually declined; with DICRP, populations stabilized with at annual survival rates of 0.3 or greater. The positive response of nest and brood survival to discing and interseeding CRP provides further evidence that CRP fields must be managed to optimize wildlife benefits. © 2012 The Wildlife Society.

KEY WORDS Conservation Reserve Program, grassland habitat, *Phasianus colchicus*, radio-telemetry, ring-necked pheasant, survival.

The decline in populations of ring-necked pheasants (*Phasianus colchicus*) throughout the Midwest has been linked to low nest and brood survival rates, as well as low hen survival (Warner et al. 1984, Etter et al. 1988, Schmitz and Clark 1999, Warner et al. 1999). Low nest and brood survival may result from loss of quality nesting and brood rearing habitat (Warner et al. 1987, 1999), along with other factors including climate and hatch date (Riley et al. 1998).

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Pheasant mortality increases as hens shift from using protective winter cover to searching for suitable nest sites (Hill and Robertson 1988). Hen survival may be enhanced by having winter cover near abundant, high-quality nesting cover, the latter of which is being lost through current farming practices (Schmitz and Clark 1999).

A primary goal of the Conservation Reserve Program (CRP) is to enhance wildlife habitat. Given the billions of dollars ($1.8 billion in fiscal year 2006; U.S. Department of Agriculture 2006) spent to fund CRP, habitat provisions and guidelines should maximize the use of these federal funds for reaching wildlife population goals. Evidence suggests that CRP is not reaching its potential to provide optimal wildlife habitat, including habitat for ring-necked pheasants, because

of the lack of vegetative and structural diversity in CRP fields (Rodgers 1999).

Early research suggested that the CRP increased the amount of suitable nesting and brood rearing cover in many of the Great Plains states (Dahlgren 1988). Riley (1995) demonstrated an increase in pheasant numbers in relation to an increase in CRP grasslands, but benefits in most states were short lived. The CRP was less beneficial to wildlife than anticipated (Church and Taylor 1999, Rodgers 1999), because of effects of field age on plant succession and lack of active habitat management in fields under CRP contracts (King and Savidge 1995, Ryan et al. 1998, Rodgers 1999). In the early stages of succession, CRP provides dense nesting cover and high diversity vegetation. Early successional vegetation includes forbs, which tend to be associated with high invertebrate abundance, the primary food source for pheasant chicks (Hill 1985). Also, bare ground provided by early successional grass stands offers movement corridors used for young pheasants to capture prey and avoid predators (Doxon and Carroll 2007). Without active habitat management during the contract period, CRP fields often become dense, monotypic grass stands.

The Nebraska Game and Parks Commission (NGPC) has actively supported discing and interseeding legumes in late successional, monotypic CRP fields since 2002; NGPC's goal was to increase the pheasant abundance by disturbing the later serial stages of CRP grasslands to provide early successional habitats (generally ≤4 years after disturbance). Negus et al. (2010) and Matthews et al. (2012) demonstrated that discing and interseeding monotypic CRP fields increased vegetation density, preferred by nesting hens. Similarly, this type of management has been shown to increase forb and legume cover, along with bare ground (Greenfield et al. 2002, 2003; Leathers 2003). As vegetation diversity increased post-management, Leathers (2003) found an increase in arthropod abundance. Both nesting and brooding hens preferred disced and interseeded CRP

(DICRP) to unmanaged CRP fields as a result of an increase in forb and legume content (Matthews et al. 2012).

Pheasant productivity can vary within the breeding season and may be affected by weather. Extreme temperatures and precipitation events are thought to negatively affect nest and brood survival (Riley et al. 1998, Schmitz and Clark 1999). Riley et al. (1998) also found that chicks hatched later in the year had lesser body mass and experienced lower survival than those hatched earlier in the breeding season. Although management cannot control weather-related factors, such factors must be accounted for when assessing habitat effects in production.

The purpose of our study was to determine the impact discing and interseeding CRP fields have on radio-tagged pheasant productivity in eastern Nebraska. Our objectives were to 1) monitor nests of radio-marked hens to estimate survival rates, 2) monitor broods of radio-marked hens to estimate survival rates, and 3) develop a productivity model to assess local effects on pheasant productivity. We assessed variation in nest and brood survival in relation to macroscale, field- or patch-level variables as well as vegetative composition and structure, weather, and temporal variables.

STUDY AREA

We conducted our study in Stanton County, Nebraska during 2005 and 2006. The 83-km² study area was located in the tallgrass prairie ecoregion in Stanton County (Fig. 1). The landscape was dominated by agriculture (35.7%) and CRP fields (37.2%). Other landscape features included pastures and other grasslands (19.9%), wetlands (0.5%), woodlands (4.7%), and farmsteads and roads (2.0%). Agriculture cropland included corn, soybean, and alfalfa. However, approximately 2,200 ha of the study area was composed of cropland that had been enrolled in CRP >10 years prior to the beginning of our study (CP-1: 52%, CP-2: 46%, filter strips: 2%). Fields initially were planted with a mixture of native (CP-2) and nonnative grasses (CP-1) or grass-forb
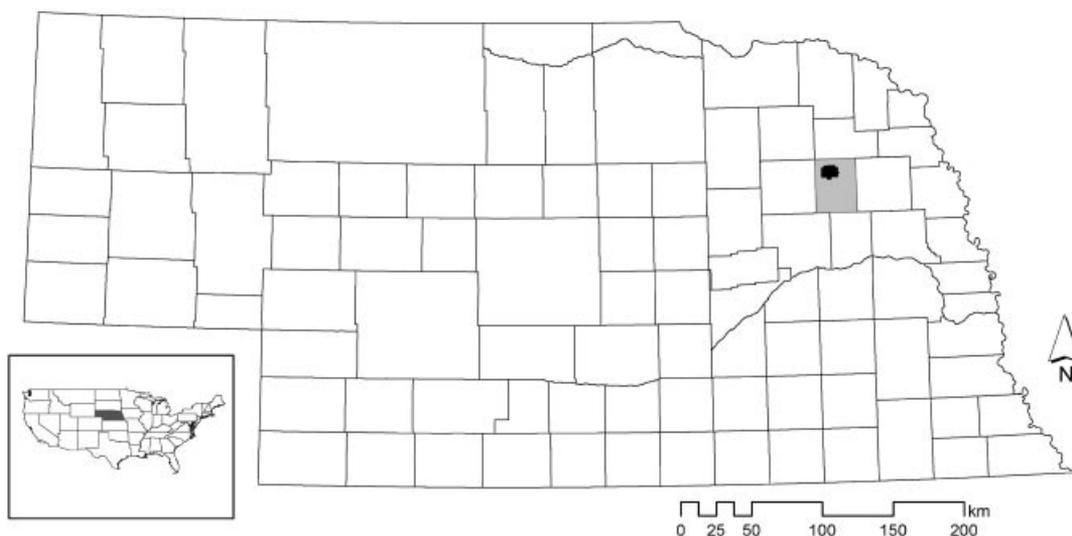

Figure 1. Map of location of 83-km² study area (dark shaded) in Stanton County (light shaded), Nebraska, USA where we assessed nest and brood survival of ring-necked pheasants, 2005–2006.

mixtures. Prior to 2002, no management had occurred in the fields since establishment. Preliminary observations revealed fields generally were monocultures of smooth brome (*Bromus inermus*; CP-1) or switchgrass (*Panicum virgatum*; CP-2); legume and other forb components were scarce or nonexistent (S. Taylor, Nebraska Game and Parks Commission, unpublished data).

From 2002 to 2005, portions of 36 CRP fields were disced and interseeded. Each managed portion (range: 16–240 ha) was disced 2 to 3 times with a tractor-pulled tandem disc designed for sod breakup to a depth of 7.6–10.2 cm. All discing depths and seeding rates were performed in accordance with USDA guidelines (Natural Resource Conservation Service [NRCS] 2002). Discing was followed by interseeding with a seed mixture (Best Legume Mix 1/CRP Upgrade Mix, Nebraska Pheasant and Quail Forever, Elba, NE) containing alfalfa (*Medicago sativa*), red clover (*Trifolium pratens*), and yellow sweet clover (*Melilotus officinalis*) using a no-till drill. Legumes were seeded at a rate of 6.75 kg/ha (3.38 kg of alfalfa, 1.69 kg of red clover, and 1.69 kg of yellow sweet clover). All discing and interseeding dates complied with United States Department of Agriculture guidelines (NRCS 2002).

No more than a third ($\bar{x} = 8$ ha) of each field was disced and interseeded each year. In rare occasions, a field received a second treatment, but most treated fields only received 1 treatment during the life of our study. Management sites were selected based on topography and landowner preference. Fields that had been mowed in the previous year were disced and interseeded because of the reduction of residual litter and ease of discing. By May 2004, approximately 850 ha of the CRP fields were interseeded in the study area. The interseeded area represented 27.8% of the CRP field area and 10.5% of the study area.

METHODS

Radio-Telemetry

We captured pheasant hens using baited funnel-entrance box traps (Wilbur 1967) and night-lighting techniques (Labisky 1956). We captured hen pheasants in 12 fields within the study area and in 1 field outside the area. We selected trapping and night-lighting sites based on evidence of high pheasant abundance, but we also attempted to distribute captures throughout the study area. We fitted each hen with a necklace-type radio transmitter weighing 18 g (Model #A3960; Advanced Telemetry Systems, Inc., Isanti, MN) and immediately released marked hens. Our animal capture and handling protocols were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee (Protocol #05-0-2007).

We used vehicle-mounted, null-peak antenna-receivers with an electronic compass (Gilsdorf et al. 2008) to estimate the location of each hen with triangulation 5–10 times/week from 1 February to 1 August of each year. We located hens between 0700 and 2000 hours, and we randomly ordered hens to avoid temporal bias. We took at least 3 bearings to estimate each location within a 5- to 15-minute period to minimize movement bias. We took additional bearings until the error polygon produced was <1,500 m^2 (approx. 22-m radius). We processed all Universal Transverse Mercator (UTM) coordinates and error polygons in the field with an on-board computer using Location Of A Signal (LOAS) software (version 4.0, Ecological Software Solutions, Urnäsch, Switzerland). We located missing hens by systematic ground searches and aerial telemetry.

Nest and Brood Monitoring

We determined the location of each nest 2–5 days after incubation initiation, as determined by sequential hen locations in the same area. While the hen was on the nest, we determined the general location (precision < 5 m) of the nest using a hand held antenna-receiver. We placed flagging 5 m to the north and south of the nest to mark the general location of the nest (Guiliano and Daves 2002). We attempted to minimize flushing hens from nests during our initial visit, as disturbance has the potential to decrease nest success (Evans and Wolfe 1967). We obtained the exact location of the nest using a hand-held Global Positioning System unit and recorded the number of eggs in the nest while the hen was away from the nest. We used the radio-marked hen's behavior to provide information on the fate of the nest. For successful nests, we recorded the number of hatched eggs as determined by the presence of detached shell membranes. We considered nests successful if ≥1 egg hatched. We used daily telemetry observations to locate hens with broods for 21 days after hatch. At days 10 and 21, post-hatch, we flushed hens with broods from nocturnal roost sites to determine if each hen still had a brood. We considered a brood successful if ≥1 chick survived to 21 days.

Habitat and Vegetation Sampling

We determined macro-scale, field- or patch-level composition by creating a year-specific, vector-based Geographic Information System (GIS; ArcGIS 9.0, ESRI, Redlands, CA) landcover layer; we modified original polygons established by Hammond (1982). We used aerial photographs and ground-truthing to determine landcover classes for 2005, and we modified the layer for 2006 using ground-truthed observations to determine changes in crop rotation and other adjustments. The NGPC continued to initiate discing and interseeding of CRP fields in our study area through 2005, and we incorporated those changes in our landcover layer. Our landcover layer included the following classifications: 1) warm-season CRP (switchgrass, big bluestem [*Andropogon gerardi*], little bluestem [*Schizachyrium scoparium*], Indiangrass [*Sorghastrum nutans*], sideoats grama [*Bouteloua curtipendula*]), 2) warm-season, disced, and interseeded CRP (DICRP), 3) cool-season CRP (predominantly smooth brome), 4) cool-season DICRP, 5) other grasslands (grazed and hayed pastures, roadsides, ditches, terraces), and 6) other landcover types (any landcover not included above).

We used coordinates of nest and brood locations to assign landcover classifications. We recorded micro-habitat information at each nest site and at every third recorded brood location including overlapping percent canopy cover of grasses, forbs, woody vegetation, and bare ground to the

nearest 5% using a 1-m diameter sampling ring (adapted from Daubenmire 1959). We also estimated vegetative density by using visual obstruction readings (VOR) to the nearest 0.25 dm at the nest site (Robel et al. 1970).

Survival Analysis

Nest survival.—We expected nest survival to vary according to landcover classification, vegetation composition and structure, and weather, as well as temporally. We combined individual covariates to construct a set of 16 a priori models. We used a null model with no covariates (constant survival through time and space) for comparison. We compared the null model to models composed of all biologically reasonable combinations of the following groups of covariates: 1) landcover type (DICRP + unmanaged grasslands), 2) vegetation composition (% cover) and structure (grass + forb + VOR), 3) a quadratic function (day + day^2) of date in breeding season during the nest monitoring interval (day: deviation from the median initiation of incubation [27 May]), and 4) weather (average daily temperature + average daily precipitation during the nest monitoring interval). We did not distinguish between unmanaged CRP and other non-CRP grasslands, as their structure and composition appeared similar. We used unmanaged CRP as our baseline categorical landcover type variable in the model structure. We estimated date of nest initiation for calculating Julian day of initiation by using location data and hen movement patterns. We right-censored nests that we believed were abandoned because of our monitoring.

We used the logistic-exposure method to estimate daily survival of pheasant nests and evaluate time and site-specific factors that may affect survival (Shaffer 2004). We structured our models using logistic-exposure (Shaffer 2004) using Program R and the logexp package (Post van der Burg 2005).

Brood survival.—We had similar expectations for causes of variation in brood survival. Thus, we compared the null model (i.e., constant survival) to models composed of biological reasonable combinations of the following groups of covariates: 1) landcover (proportion of locations during each monitoring interval in each landcover type: DICRP, CRP, other grassland, cropland), 2) time (a quadratic function [day + day^2] of days past the season's first hatch), and 3) weather (average daily temperature and average daily precipitation during the monitoring interval). We used unmanaged CRP as the baseline categorical variable in the landcover model structure.

We also used the logistic-exposure method (Shaffer 2004) to estimate daily pheasant brood survival, because our observations of brood survival were limited to 2 flushing occasions, at 10 and 21 days after hatch. We encountered numerical difficulties with convergence using the standard methods (Post van der Burg 2005) because some categories had no observations of death; all broods survived during the 10- to 21-day period. Consequently, we estimated survival using the logistic-exposure structure in a Bayesian–Markov–Chain–Monte Carlo (MCMC) framework using WinBUGS (Version 1.4.2) and R2WinBUGS package (R package version 2.1–8) in R. For each MCMC run, we used 3 replicate chains of 100,000 iterations, each initialized by sampling a starting value (uninformed priors) for each parameter from a normal distribution with a mean of 0 and a standard deviation of 0.2. We discarded (i.e., burn-in) the first 50,000 samples to minimize bias associated with the initial parameters. We thinned the chains of simulation by keeping every 150th simulation to account for any possible autocorrelation between parameters.

We performed model selection using an information-theoretic approach to evaluate a priori models for both nest and brood survival. We ranked each model from most to least support given the data using Akaike's Information Criterion corrected for small sample size (AIC$_c$; Burnham and Anderson 2002). We used effective sample size (n = total number of days samples survived + number of intervals that ended in failure) for the calculation of AIC$_c$ (Rotella et al. 2004). To select the best model from the nest and brood model sets, we first selected the top models that had a combined model weight (ω_i) of $\geq$90% (Burnham and Anderson 2002). We selected the highest-ranked model from that set, if the highest-ranked model was the most parsimonious of the set (Richards 2008). When the highest-ranked model was not the most parsimonious, we used conditional model averaging over the 90% confidence set to predict the covariates and associated standard errors (Burnham and Anderson 2002).

We estimated daily nest and brood survival rates as a function of the explanatory variables using either the model averaged predictions or the top predictive model. To describe effects of continuous factors on nest and brood survival, we varied the continuous variable of interest within the observed range while holding all other variables at their mean. We calculated probability of nest (23-day incubation) and brood (21-day period) success as the product of the daily survival for each day in their respective period (Shaffer and Thompson 2007). We estimated 95% confidence intervals for period survival rates using the delta method (Powell 2007). We used weather data from Norfolk Karl Stefan Airport weather station in Norfolk, Nebraska, approximately 16 km west from the center of the study area for both nest and brood survival weather data.

Productivity and Population Growth

We used program R to modify the stochastic, dynamic, individual-based productivity model described in Powell et al. (1999) to simulate dynamics of pheasants. We used nest and brood survival rates obtained from our concurrent analysis, and we used an adult daily survival rate of 0.996 (SE = 0.0002; T. Matthews, University of Nebraska-Lincoln, unpublished data) from hens in our study. We held all vegetation, weather, and temporal variables at their means to produce the daily nest survival rate and brood survival rate used in each scenario. We simulated 3 scenarios to assess potential impacts of landscape changes on pheasant productivity: 1) no DICRP on landscape (no hens nested or reared broods in DICRP), 2) landscape with moderate amounts of DICRP (50% of hens nested and reared broods in DICRP), and 3) landscape with abundant DICRP (100%

of hens nested and reared broods in DICRP). We simulated each scenario as a landscape with 2,000 hens; we performed 200 simulations of each scenario. The model outputs were the mean and standard deviation of the number of chicks produced per hen (alive on 15 Aug) during a breeding season (Powell et al. 1999). We also calculated the mean number of males/females produced per hen, assuming a 50:50 sex ratio, using the delta method (Powell 2007) to construct our confidence intervals.

We predicted discrete population growth (λ) as a function of annual adult survival (S^A), 7-month juvenile survival (S^J; 15 Aug to 15 Mar), and recruitment (β, the number of females produced per female during the breeding season): $\lambda = S^A + \beta S^J$. We used the output from our productivity model as the estimate of β. Because we had no annual survival estimates for adults or juveniles at our study site, we predicted λ under a range of survival rates: 0.20–0.50. Snyder (1985) reported an annual survival rate of 0.517 (95% CI = 0.284–0.820) in Colorado, which justified the top end of our range of annual survival. We also used the variance reported by Snyder as the variance for survival in our model. Our model assumed that winter survival was equal for adults and juveniles.

We followed the methods of Powell et al. (2000), and we performed 200 stochastic simulations of annual population growth. During each iteration of the model, we used random number generators, based on appropriate distributions (Powell et al. 2000), to select rates for each demographic parameter in the model. We constrained rates within possible ranges for each parameter, as a function of our estimates and variance for each estimate. The model provided a prediction of λ for each survival rate scenario, accompanied by a 95% confidence interval (Powell et al. 2000).

RESULTS

We captured and monitored 110 hens (2005: 54, 2006: 56). Our sample size declined because of mortalities before 15 May, the peak of the nesting period (Matthews 2009; 2005: 16 mortalities, 3 censored; 2006: 22 mortalities, 0 censored). We located and monitored 73 nests (2005: 34, 2006: 39) in the 4 landcover classes (DICRP: 34, CRP: 33, other grasslands: 5, other: 1). The median incubation start date for first nest attempts pooled over both years was 11 May, and 10 June for second attempts. The median hatch date was 16 June with an average of 11.3 (SE = 3.4) eggs/nest. The proportion of hens attempting a second nest was 0.39, and the proportion of hens making third nest attempts was 0.02. Broods surviving to day 21 had an average of 4.8 (SE = 2.1) chicks per brood. Twenty-seven of 73 nests (37%) hatched successfully; 17 broods had at least 1 chick 21 days post-hatch. Two hens died before their broods reached day 10 in 2005, and the broods were presumed dead. Ten of 27 hens with broods had the majority of their locations in DICRP, more than any other landcover type (CRP: majority of use by 7 hens, other grassland: 5 hens, row crop: 5 hens).

Nest Survival
More than 1 model merited consideration during our model comparisons (top model: $\omega_i = 0.26$), so we model-averaged covariate estimates across 9 models that cumulatively accounted for $\geq 90\%$ of the ωAIC (Tables 1 and 2). The effects of landcover on daily nest survival were found in 8 of the top 9 models (cumulative $\omega_i = 0.86$). Nests found in unmanaged grasslands tended to have a lower rate of daily survival (0.951, 95% CI: 0.941–0.972) compared to those in DICRP (0.984, 95% CI: 0.957–0.994). The probability of 23-day nest success (using mean values for day and

Table 1. Comparison of competing logistic-exposure models for ring-necked pheasant daily nest survival in northeast Nebraska, 2005–2006. Models are ranked by AIC_c, Akaike's Information Criterion adjusted for small sample size; K is the number of parameters, ΔAIC_c is the difference of each model's AIC_c value from that of the highest ranked model (row 1), and ω_i is the Akaike weight (sum of all weights = 1.00). We considered 16 models and the top 9 models represent the 90% confidence set according to their ω_i.

Model	K	AIC_c	ΔAIC_c	ω_i
Landcover[a] + Vegetation[b]	5	247.55	0.00	0.26
Landcover + Vegetation + Day[c]	7	248.95	1.39	0.13
Landcover	2	249.23	1.68	0.12
Landcover + Vegetation + Day + Weather[d]	9	249.44	1.89	0.10
Landcover + Vegetation + Weather	7	249.89	2.34	0.08
Landcover + Day	4	249.99	2.44	0.08
Landcover + Day + Weather	6	251.07	3.52	0.05
Vegetation	4	251.35	3.80	0.04
Landcover + Weather	4	251.43	3.88	0.04
Constant	1	251.43	3.88	0.04
Vegetation + Weather	6	252.86	5.31	0.02
Weather	3	253.30	5.74	0.01
Day	3	253.67	6.11	0.01
Vegetation + Day	6	254.10	6.55	0.01
Vegetation + Day + Weather	8	255.01	7.45	0.01
Day + Weather	5	255.38	7.83	0.01

[a] Landcover model: disced and interseeded Conservation Reserve Program grasslands + unmanaged grassland.
[b] Vegetation model: % grass + % forb + vertical obstruction reading.
[c] Day model: day + day^2.
[d] Weather model: daily precipitation + daily temperature.

Table 2. Model averaged coefficient (β) estimates and 95% confidence intervals (CI) for habitat, vegetation structure and composition, day of nest incubation (day), daily temperature, and daily precipitation effects on survival of nests of ring-necked pheasant hens in northeast Nebraska, 2005–2006. We derived coefficients from the 90% confidence set.

Parameter	β estimate	95% CI
Intercept	3.31	$2.06 < \beta < 4.56$
Landcover[a]		
DICRP	1.18	$0.004 < \beta < 2.35$
Grass cover	−1.00	$-2.51 < \beta < 0.51$
Forb cover	−0.61	$-2.51 < \beta < 1.29$
Visual obstruction	0.03	$-0.21 < \beta < 0.27$
Day	0.01	$-0.01 < \beta < 0.03$
Day^2	0.00	$-0.002 < \beta < 0.0008$
Temperature	−0.010	$-0.05 < \beta < 0.03$
Precipitation	0.17	$-0.75 < \beta < 1.09$

[a] DICRP: Disced, interseeded Conservation Reserve Program grasslands. Unmanaged grassland was used as baseline in model ($\beta = 0.0$).

Table 4. Posterior coefficient (β) estimates and 95% Bayesian credibility intervals (BCI) for landcover, brood age, and Julian hatch date (day) on survival of broods of ring-necked pheasant hens in northeast Nebraska, 2005–2006.

Parameter	β estimate	95% BCI
Intercept	3.63	$1.87 < \beta < 5.39$
Landcover[a]		
Disced and interseeded CRP	3.76	$0.79 < \beta < 6.72$
Other grassland	1.15	$-1.93 < \beta < 4.23$
Crop	−2.72	$-5.43 < \beta < -0.01$
Brood age[b]		
11–21 days	3.39	$0.88 < \beta < 5.9$
Day	0.005	$-0.05 < \beta < 0.06$
Day^2	−0.005	$-0.009 < \beta < -0.0005$

[a] Percent time spent in each landcover type, unmanaged Conservation Reserve Program grassland used as baseline in model ($\beta = 0.0$).
[b] Brood age from 1 to 10 days used as baseline in model ($\beta = 0.0$).

precipitation) was 0.696 (95% CI: 0.631–0.762) for DICRP and 0.314 (95% CI: 0.240–0.389) for unmanaged grasslands. Vegetation structure and composition also was included in the top model and was present in 4 of the top 5 models; but, the model averaged confidence intervals for each parameter included zero (Table 2).

Brood Survival

We found a high correlation between hatch date and temperature ($r = 0.77$). Thus, we removed temperature from any model in which hatch date was included. Variation in brood survival was best explained by 2 models that both included landcover and hatch date components. The second best model also included weather variables (Table 3). These models accounted for $\geq 90\%$ of the ω_i; therefore we used the top, most parsimonious model, which indicated that brood survival was a function of landcover and hatch date (Table 3). Brood survival increased as the brood spent a greater proportion of its time in DICRP and less time in unmanaged CRP (Table 4, Fig. 2a). Brood survival decreased as time in

crop fields increased (Table 4, Fig. 2b). Daily survival of broods declined as the hatch date deviated from 15 June (Table 4, Fig. 3). The probability (using mean value for day and the mean landcover use information across broods) of a brood surviving to day 21 was 0.710 (95% CI: 0.610–0.856). If the landcover use information for all broods was modified by replacing DICRP with unmanaged CRP, survival would be reduced to 0.36 (95% CL: 0.100–0.701).

Productivity and Population Growth

Our first scenario, no DICRP on the landscape, achieved a mean of 1,826 (SE = 92.9) chicks surviving through 15 August from 2,000 hens; 913 roosters were produced by 2,000 hens under this scenario (Fig. 4). The second scenario, with 50% of hens nesting and raising broods in DICRP, resulted in productivity of 4,632 (SE = 151.6) chicks and 2,316 roosters. Last, when 100% of hens nested and raised broods in DICRP, productivity increased to 5,398 (SE = 155.0) chicks, of which 2,699 were roosters.

Our model predicted declining populations ($\lambda < 1.0$) under all scenarios of no DICRP, except under the highest survival scenario ($S^A = 0.50$; Fig. 5). Populations with survival of 0.30 or greater were predicted to remain stable or increase substantially (Fig. 5).

DISCUSSION

Our data suggest that nesting hens could double their probability of nest success (69% vs. 31%) by selecting nest sites in DICRP areas. Also, our simulation model predicted that productivity, a function of nest success and brood success, and population growth rates were dramatically greater when the simulated landscape contained $\geq 50\%$ DICRP. Our nest success rate in unmanaged grasslands (31%) was similar to rates from Illinois reported by Warner et al. (1987) but below the benchmark stated in Clark et al. (2008) of 42% nest success, which they suggested is needed to maintain a stable population under average conditions. Certainly, sub-optimal nest success in unmanaged, low diversity grasslands could be partially responsible for the recent decline in pheasant numbers throughout most of the Great Plains states, even after
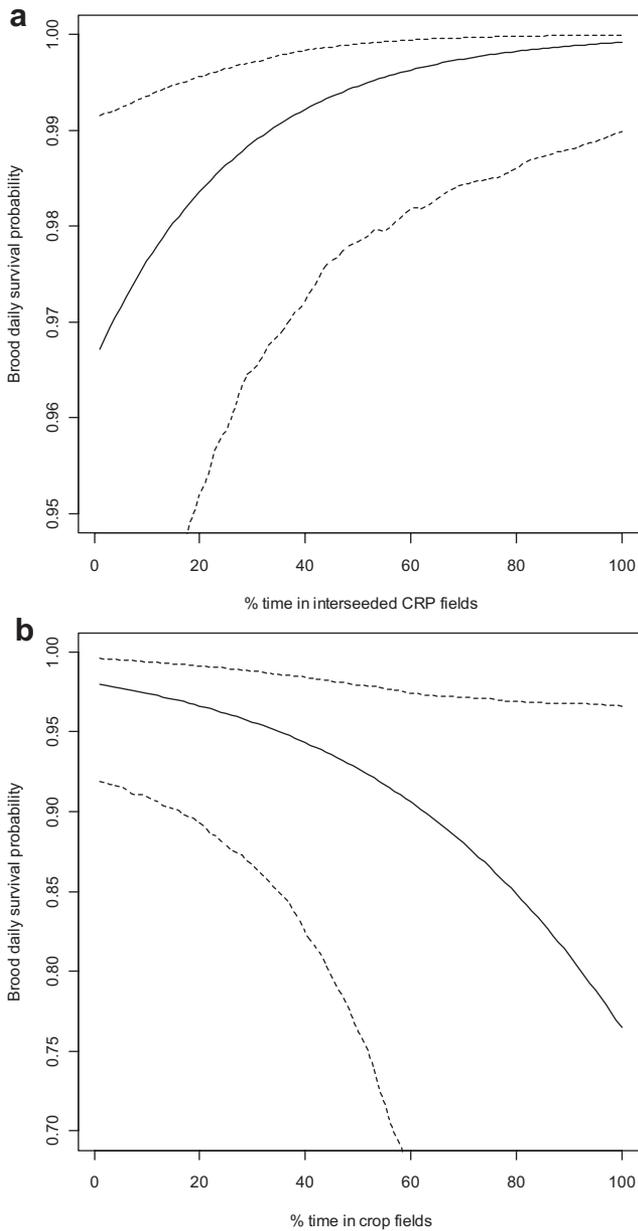
Table 3. Comparison of competing logistic-exposure models for daily survival of broods of ring-necked pheasants in northeastern Nebraska, 2005–2006. Models are ranked by AIC$_c$, Akaike's Information Criterion adjusted for small sample size; K is the number of parameters, ΔAIC$_c$ is the difference of each model's AIC$_c$ value from that of the highest ranked model (row 1), and ω_i is the Akaike weight (sum of all weights = 1.00). We considered 8 models; the top 2 models represent the 90% confidence set according to their ω_i.

Models	K	AIC$_c$	ΔAIC$_c$	ω_i
Landcover[a] + Day[b]	7	33.11	0.00	0.88
Landcover + Day + Weather[c]	9	37.44	4.33	0.10
Day	4	42.07	8.96	0.01
Landcover	4	44.07	10.96	0.00
Day + Weather	6	44.39	11.27	0.00
Landcover + Weather	6	48.90	15.78	0.00
Constant	1	53.34	20.23	0.00
Weather	3	58.20	25.09	0.00

[a] Landcover model: disced and interseeded Conservation Reserve Program (CRP) grassland + unmanaged CRP + other grassland + crop.
[b] Day model: brood age + hatch date + hatch date^2.
[c] Weather model: daily precipitation + daily temperature.

a

b

Figure 2. Daily survival (95% credibility interval: dotted line) of ring-necked pheasant broods in northeast Nebraska, 2005–2006, as a function of (a) time spent in disced and interseeded Conservation Reserve Program fields and (b) as a function of time spent in crop fields with all other variables held constant and brood age set at 1–10 days.

Figure 3. The non-linear effect of day in the breeding season on daily survival probability (95% CI: dotted line) of ring-necked pheasant broods in northeast Nebraska, 2005–2006.

opportunity. First-year roosters make up a large proportion of the hunter bag; in Utah, age ratios in hunter bags ranged from 4 to 11 juveniles per adult (Stokes 1968). Our data support investments to manage CRP for population growth of pheasants, but our productivity model also provides

the introduction of CRP (Rodgers 1999). Higher nest success may not always correspond to greater rates of productivity (Powell et al. 1999), but Hill and Robertson (1988) reported that with simulated data a 50% increase over an average nest success rate had a significant effect on autumn pheasant numbers. Our data suggest an increase of >100%, which should have profound population effects (Fig. 5). We suggest that programs that apply mid-contract management to potential breeding habitat within a landscape could benefit local pheasant populations through increased nest survival, even if brood survival is unaffected by management of CRP.

Pheasant management usually has 2 concurrent goals: 1) population stability or increase, and 2) maximizing hunter
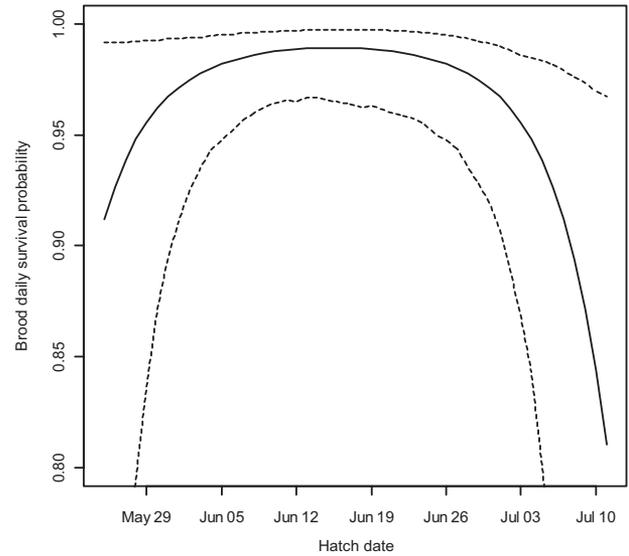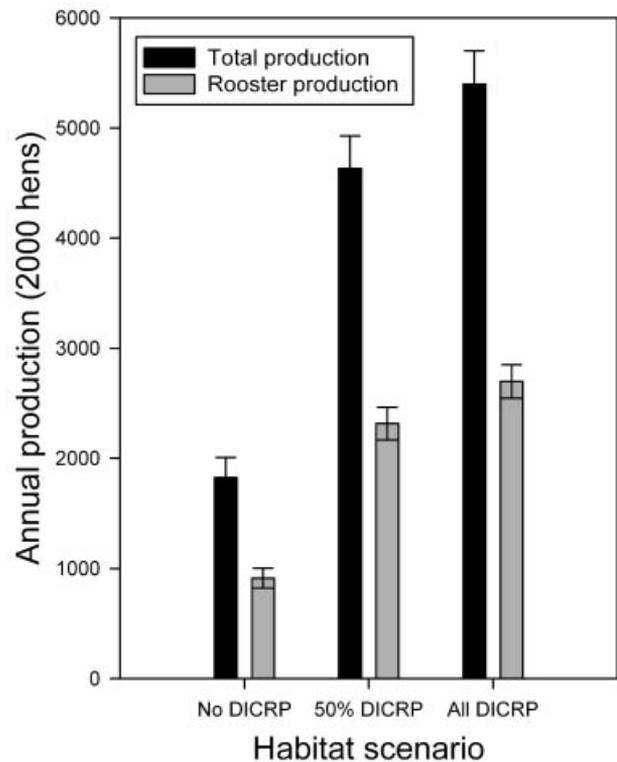

Figure 4. Annual productivity, as predicted by a model of total offspring and males (roosters) from 2,000 hens in 3 landscape scenarios: 1) no hens nesting in disked and interseeded Conservation Reserve Program grasslands (DICRP), 2) 50% of hens nesting in DICRP, or 3) all hens nesting in DICRP. Model inputs were based on ring-necked pheasant hens nesting in northeast Nebraska, 2005–2006.
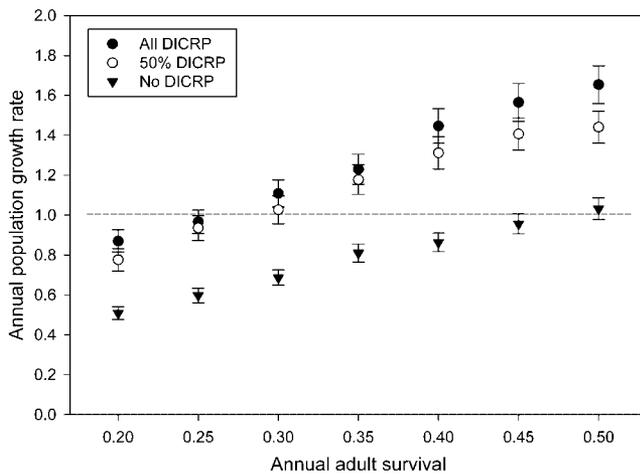
Figure 5. Predicted annual population growth rate (λ) of ring-necked pheasant hens using a range of survival rates and productivity data from northeast Nebraska, 2005–2006. Productivity was modeled under 3 scenarios: 1) no hens nesting in disked and interseeded Conservation Reserve Program grasslands (DICRP), 2) 50% of hens nesting in DICRP, or 3) all hens nesting in DICRP. The dashed line represents λ = 1.0, a stable population.

evidence that managers could double the availability of first-year roosters through CRP management (Fig. 4). County-level surveys of pheasants provide additional support and validation of our demographic estimates and model predictions of increased productivity (Matthews et al. 2012).

Why do hens in DICRP have greater nest success? We suggest 2 possible mechanisms: 1) vegetation structure effects on predators, and 2) greater insect availability as food for hens. Our data do not directly support the first hypothesis, as we did not find that vegetation structure (VOR) at the nest bowl caused variation in nest survival (Tables 1 and 2). We did find that hens selected nest sites with high levels of vegetation density (Matthews et al. 2012). In addition, DICRP fields had greater vegetation density and structural heterogeneity than monotypic grasslands found in unmanaged CRP and pasture fields (Matthews et al. 2012). Also, structural heterogeneity in the habitat patch surrounding the nest can influence nest success more than the vegetation at the nest (Schranck 1972, Bowman and Harris 1980, Mankin and Warner 1992). Providing large patches with structural heterogeneity around ground nests can decrease the foraging efficiency of nest predators (Bowman and Harris 1980). An increase in heterogeneity at the patch level can increase the search time of nest predators and subsequently decrease the number of clutches found. An increase in the vegetative density in a field also might act as a physical barrier and deter nest predators (Duebbert 1969, Schranck 1972, Schmitz and Clark 1999). Although we did not find a measurable increase in nest survival related to vegetation structure or composition at the nest site, our habitat selection analyses show that pheasants selected nest sites with greater percent forb cover and visual obstruction reading than random sites in the same field, regardless of landcover type (Matthews et al. 2012).

With regard to the second hypothesis, Martin et al. (2000) and Rastogi et al. (2006) found that increased food avail-

ability resulted in shorter foraging bouts for nesting female songbirds, which resulted in lower rates of nest predation. We would expect pheasant nest survival to be affected by similar pressures, although Hoodless et al. (1999) were unable to show effects of supplemental feeding on nest success. But, food availability in desired insect orders was greater on DICRP plots than other plots on our study site (L. Negus, NGPC, unpublished data). We did not measure hen foraging behavior, but we did find that hens moved less throughout the landscape when they were in DICRP (Matthews et al. 2012). Thus, if nesting hens fed primarily on insects, we could logically expect greater insect abundance in DICRP to cause the lower rates of nest mortality we observed.

Brood age, hatch date, percent time spent in DICRP fields, and percent time spent in crop fields were influential predictors of brood survival (Table 3). An increase in daily brood survival as the brood ages has been well-documented (Hill 1985, Riley et al. 1998). An increase in daily brood survival that begins at about 10 days of age may be attributed to an increase in the chicks' ability to thermoregulate (Gdowska et al. 1993) and their increased ability to avoid predators through short flights (Cramp and Simmons 1980).

We may be the first to show a non-linear trend in brood survival during the breeding season with lower survival early in the season for ring-necked pheasants (Fig. 3). Grant et al. (2005) suggested that temporal effects may have been missed in previous studies because of the prevalence of linear modeling approaches. The change in brood survival during the breeding season may be related to temperature and insect abundance. Pheasant broods hatching early in the breeding season may experience less-than-optimal environmental temperatures, retarding cold resistance and increasing mortality (Ryser and Morrison 1954). Hill (1985) found that pheasant chicks reduce the amount of time feeding in cold, wet conditions, and those conditions led to malnutrition, poor growth and ultimately mortality. Broods hatching later in the season may be exposed to higher environmental temperatures, inducing heat stress and water loss, and higher temperatures have been attributed to low production in other galliforms (Flanders-Wanner et al. 2004). Broods hatching early or late in the breeding season also might experience lesser insect abundance because of the colder or warmer environmental temperatures (Riley et al. 1998). The decline in brood survival late in the breeding season of pheasants reaffirms the need of pheasant hens to have a successful first nest (Riley et al. 1998). This is reaffirmed in our study, as pheasants seemed to nest at the optimum time to achieve the peak survival of broods (Matthews 2009). This may require land managers to carefully plan the timing of habitat management, such as prescribed burning, grazing, discing, and haying. Our data suggest that mid-season nests should be considered especially valuable to seasonal pheasant productivity.

Brood survival increased on our study area as hens and broods spent more time in DICRP fields, and this trend was especially dramatic for broods that were ≤10 days old (Fig. 2a). Although our a priori hypotheses to explain variation in brood survival did not include vegetation composition

and structure, the increased brood survival in DICRP fields may be caused by the influx of legumes and annual forbs and an increase in bare ground associated with these types of fields (Matthews et al. 2012). Unmanaged CRP fields and pasture may provide adequate overhead cover for pheasant chicks but the vegetation may lack sufficient insect abundance. Abundance of insect orders used as primary sources of food by broods (*Coleoptera*, *Hemiptera*, *Hymenoptera*, and *Lepidoptera*; T. Matthews, unpublished data) was 2.6 times greater in DICRP fields than in unmanaged CRP fields (L. Negus, unpublished data). Hill (1985) found variation in insect abundance to explain 75% of the variation in brood survival. Forbs and other legumes produced in these habitats also may have forage value for brooding hens, including seeds and blossoms, reducing the need to forage in open cropland and the associated risks to predation. Croplands in Nebraska provide little, if any, insect prey for pheasant chicks because of pesticide use; in addition, field edges may create travel lanes for predators, decreasing survival. As hens with broods spend more time in crop fields, chicks may grow more slowly and gain flight and thermoregulation abilities at slower rates.

Unmanaged CRP grasslands also exhibit high vegetation stem density and high amounts of litter accumulation, both of which can decrease chick mobility (Doxon 2005). A decrease in mobility can hinder chicks in prey capture and predator avoidance. Discing CRP fields decreases litter and perennial grass densities and increases bare ground, which creates travel corridors needed for chick movement. Doxon and Carroll (2007) hypothesized that the amount of bare ground, rather than insect abundance, may be most the most critical factor for brood survival.

MANAGEMENT IMPLICATIONS

Our data suggest that the United States Department of Agriculture's requirement of mid-contract management of new CRP contracts should benefit pheasant populations in the Midwest. Approximately 10% of our study area was disturbed by management; we suggest that mid-contract management would be most effective when discing and interseeding are applied to similarly large portions of the landscape. A landscape-level approach to pheasant habitat management enhances nest and brood survival by creating a heterogeneous landscape, at both the macro- and micro-habitat levels. Such heterogeneity may cause the greatest effects on pheasant populations (Clark et al. 2008). Landscape-level efforts are labor intensive, as they require assistance and consultation with many landowners. Such efforts also take time and efficient planning; for example, fields disced in our study had been mowed in the previous year to increase the effective depth of discing. Future CRP-related policy decisions should reflect a synthesis of costs and natural resource benefits accrued by CRP with and without mid-contract management. Our study suggests that agencies can expect substantial benefits to local populations of pheasants after landscape-level efforts to disturb late successional CRP grasslands.

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