

University of Nebraska - Lincoln

DigitalCommons@University of Nebraska - Lincoln

Papers in Natural Resources

Natural Resources, School of

2011

Nest survival of Long-billed Curlew in Nebraska

Cory J. Gregory

Iowa State University, cgregory@iastate.edu

Stephen J. Dinsmore

Iowa State University, cootjr@iastate.edu

Larkin A. Powell

University of Nebraska-Lincoln, lpowell3@unl.edu

Joel G. Jorgensen

Nebraska Game and Parks Commission, joel.jorgensen@nebraska.gov

Follow this and additional works at: <https://digitalcommons.unl.edu/natrespapers>



Part of the [Natural Resources and Conservation Commons](#)

Gregory, Cory J.; Dinsmore, Stephen J.; Powell, Larkin A.; and Jorgensen, Joel G., "Nest survival of Long-billed Curlew in Nebraska" (2011). *Papers in Natural Resources*. 350.

<https://digitalcommons.unl.edu/natrespapers/350>

This Article is brought to you for free and open access by the Natural Resources, School of at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Papers in Natural Resources by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

Nest survival of Long-billed Curlew in Nebraska

Cory J. Gregory¹, Stephen J. Dinsmore¹*, Larkin A. Powell² & Joel G. Jorgensen³

¹Department of Natural Resource Ecology and Management, Iowa State University, 339 Science Hall II, Ames, IA 50011, USA

²School of Natural Resources, University of Nebraska, 3310 Holdrege Street, 419 Hardin Hall, Lincoln, NE 68583, USA

³Nebraska Game and Parks Commission, 2200 N. 33rd Street, Lincoln, NE 68503, USA

*Corresponding author: cootjr@iastate.edu

Gregory, C.J., Dinsmore, S.J., Powell, L.A. & Jorgensen, J.G. 2011. Nest survival of Long-billed Curlew in Nebraska. *Wader Study Group Bull.* 118(2): 109–113.

Keywords: Long-billed Curlew, nest survival, Program MARK, Nebraska, *Numenius americanus*

Long-billed Curlew *Numenius americanus* is an imperiled shorebird of western North America. Populations have declined dramatically in the last 150 years from the conversion of prairie to agriculture and it is now listed as a “Tier I at-risk” species in Nebraska. We undertook a 3-year project (2008–2010) to study the nest survival of Long-billed Curlews in Nebraska. We measured vegetation characteristics at each nest site (n = 14 nests) on two different spatial scales and used program MARK to model nest survival as a function of multiple covariates. Apparent nest survival was 29% (n = 4 successful nests) and our model-based estimate of nest survival was 33% (95% CL: 24%, 93%). This estimate is similar to other estimates of curlew nest survival in Nevada (31%) and South Dakota (15% to 39%). Visual obstruction reading height ($\beta_{\text{o.vor}} = -4.17$, 95% CL: -7.58 , -0.77) and forb cover at the nest ($\beta_{\text{forb}} = -12.49$, 95% CL: -26.14 , 1.17) negatively affected survival. Bare ground cover positively affected nest survival ($\beta_{\text{bare}} = 3.28$, 95% CL: -1.03 , 7.59), but we found no evidence that nest age, grass cover, or litter depth affected nest survival. These findings suggest that Long-billed Curlews in Nebraska have a relatively low nest survival rate, but it is within the expected range for the species. Furthermore, nest survival is affected negatively by tall vegetation and forb cover at and near the nest.

INTRODUCTION

Conservation of threatened and declining species often relies on a thorough understanding of nest-site selection and subsequent nest survival. The type of habitat used by nesting birds may affect predation rates (Lima 2009, Martin & Briskie 2009). This link between nest-site habitat and nest survival is especially important when studying ground-nesting species. The surroundings of a nest placed on the ground potentially have a direct effect on nest and bird concealment and ultimately nest success (Singh *et al.* 2010). Without an understanding of these habitat and nest-site characteristics, management actions may not be suitable for conservation of the target species.

The Long-billed Curlew *Numenius americanus* is a large and distinctive shorebird of western North America and one of only nine grassland birds considered endemic to the North American Great Plains (Dugger & Dugger 2002). It is listed as a bird of conservation concern in five U.S. Fish and Wildlife regions (Fellows & Jones 2009). The Long-billed Curlew is listed as “highly imperiled” by the United States Shorebird Conservation Plan (USSCP; Brown *et al.* 2000, Fellows *et al.* 2001). Current declines are attributed to breeding habitat loss (Dugger & Dugger 2002). Because habitat loss continues (Fellows & Jones 2009), understanding relationships of curlew nest survival and habitat is important.

Historically, the Long-billed Curlew bred in prairies throughout the Great Plains east to Indiana, Michigan, and probably even Ohio (Bent 1929). This range reduction during the last 150 years is thought to be associated with farming practices that eliminated the grasslands used by breeding

curlews (Bent 1927, Yocum 1956). In Nebraska, the species’ breeding range is centered primarily in the Sandhills and shortgrass prairies of the north-central and north-western parts of the state. The Long-billed Curlew is socially monogamous and many return to the breeding grounds in spring already paired (Allen 1980, Forsythe 1970). For unpaired birds, courtship begins upon arrival and both paired and unpaired males quickly establish territories (Allen 1980, Pampush & Anthony 1993). Nest construction begins within one week after pairing and many nests are initiated by early April (Dugger & Dugger 2002, Jenni *et al.* 1981). Nests consist of a shallow depression (Dugger & Dugger 2002) lined with various materials such as pebbles, livestock droppings, grass, stems, twigs, and seeds (Jenni *et al.* 1981). Unlike other grassland shorebird species which conceal their nests in thick vegetation, the curlew nests are often placed in sparse areas with short vegetation (Allen 1980, Jenni *et al.* 1981). This tendency is thought to assist the adult in detecting approaching predators (Pampush & Anthony 1993). The typical clutch size is four eggs (range 2–5) and both parents share incubation duties for the 28-day (range 27–31 days) incubation period (Dugger & Dugger 2002). Curlew chicks hatch synchronously, most within a 4–6 hour period, and leave the nest within 4–5 hrs (Allen 1980, Jenni *et al.* 1981).

Past studies of Long-billed Curlew breeding biology have been conducted in many western states including Idaho, Nevada, Oregon, South Dakota, Utah, Washington, and Wyoming. Clarke (2006) found that nest success in grazed landscapes of western South Dakota was 39% in 2005 and 15% in 2006. She estimated the constant daily survival rate for nests during 2005 and 2006 as 0.94 (Clarke 2006). The

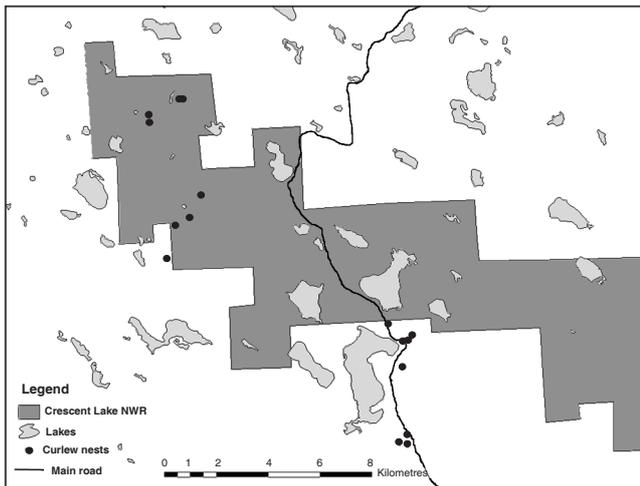


Fig. 1. The study site at Crescent Lake National Wildlife Refuge, Garden County, Nebraska and Long-billed Curlew nest locations for 2008–2010.

study found that daily nest survival rates were positively related to average visual obstruction readings (VOR) taken at nest sites and negatively related to the bison density in grazed pastures. Hartman & Oring (2009) monitored Long-billed Curlew nests in northeastern Nevada hay fields from 2003 to 2006. They found that mean nest success was 31% but with considerable inter-annual variation. Research focused on the breeding ecology of the Long-billed Curlew is scarce for Nebraska; only one published study on this species has been conducted in the state. Bicak (1977) studied the behavioral aspects of curlews at Crescent Lake National Wildlife Refuge (CLNWR) but did not focus on nest survival or habitat assessments.

We studied the nest survival of Long-billed Curlews in western Nebraska and used program MARK (White & Burnham 1999) to model nest survival as a function of multiple covariates as described by Dinsmore *et al.* (2002). Nest-site vegetation can affect nest success in some birds (Crabtree *et al.* 1989), so we modeled nest success as a function of seven vegetation variables (VOR, height of tallest vegetation, litter depth, forb cover, litter cover, grass cover, and bare ground) as well as nest age and within-season variation. We expected to find that nests had increased survival when placed in vegetation with high VOR measurements and in areas of greater forb cover as found by Clarke (2006).

METHODS

Study area

We studied curlews at Crescent Lake National Wildlife Refuge, Garden County, Nebraska during spring and summer, 2008–2010. This is an 18,615-ha refuge of grass-covered and exposed sand dunes, meadows, and shallow lakes situated in the eastern panhandle of Nebraska (Fig. 1). With the numerous shallow alkali lakes and meadows, this area was known to contain a substantial breeding population of curlews (Sharpe *et al.* 2001). Nearby private land is similarly comprised of lakes, grasslands, and grazed meadows. The topography of this landscape ranges from choppy and bare sand dunes to low and flat wet meadows. Cattle-grazing is the dominant land-use in the Sandhills (Miller 1998).

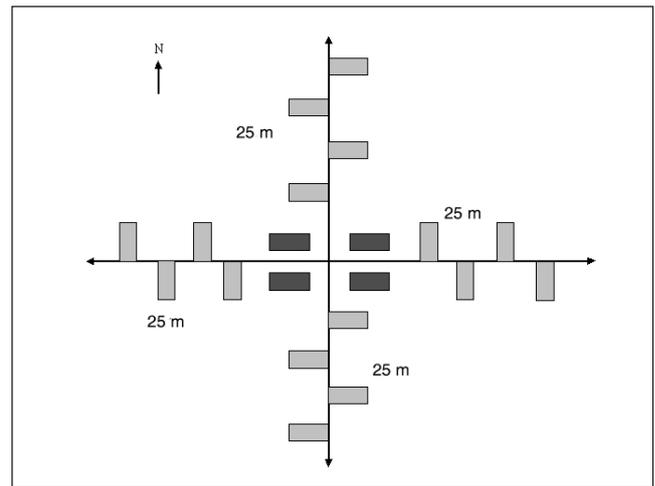


Fig. 2. The layout of Daubenmire frames and visual obstruction readings (VOR) relative to Long-billed Curlew nest locations (in center). Darker shades represent the "inner" scale of measurements and lighter shades represent the "outer" scale of measurements.

Nest searching and monitoring

We searched for nests using rope dragging and observations of adults. Once a nest was located and marked with flagging and Global Positioning System (GPS) coordinates, eggs were floated to determine development of the embryo and estimate a hatch date (Liebezeit *et al.* 2007).

We monitored each nest every 2–3 days, except that we checked nests daily within five days of the predicted hatch date. Evidence of depredation included missing eggs, large eggshell fragments or yolk from broken eggs, or disturbed nest cup contents. A nest was categorized as abandoned if no adults were present or defending the nest on multiple consecutive visits. Dusty, sun-bleached, cold, or unattended eggs were additional signs of abandonment. A nest was successful if at least one egg hatched.

We took a series of vegetation measurements at two different scales at 14 nests to assess the habitat composition in these areas. Grassland vegetation in western Nebraska can be categorized into grasses, litter, forbs, succulents, woody plants, and bare ground. We used a 100 cm × 50 cm Daubenmire frame placed around each nest site to measure vertical ground cover density and percent cover of the aforementioned vegetation groups (Daubenmire 1959). In addition to four centered frame readings directly around the nest, 16 additional frame readings were taken along 25 m transects in all four cardinal directions from the nest (Fig. 2). At the center of each Daubenmire frame, we also measured the visual obstruction reading (VOR) using a Robel pole (Robel *et al.* 1970). Vegetation was sampled at nest sites at four sample locations, each 0.5 m from the nest in the four cardinal directions. We did not sample vegetation at the exact nest location due to skewed vegetative readings caused by the open nest cup. Litter depth (cm) and the tallest piece of vegetation (dm) were measured at three locations within each Daubenmire frame and were later averaged for use as covariates. We standardized measurements by measuring vegetation within one week after the nest was predicted to hatch regardless of actual nest fate. Nest vegetation was measured between 2 June and 7 July (36-day range).

We used program MARK to build nest survival models as

a function of multiple covariates. They included a constant nest survival model (\cdot), also known as the Mayfield approach (Mayfield 1975), which assumes survival is constant through time. We also included date in season as linear (T) and quadratic (TT) survival models to investigate seasonal variation in nest survival. We created the covariate “nest age” by coding the age of each nest when found by using egg flotation data. We also used the covariates of VOR (mean of four samples within 2 m of nests) and outer VOR (mean of 16 samples within 2–25 m of nests), litter depth (cm), height of the tallest piece of vegetation (dm), forb cover (%), litter cover (%), grass cover (%), and bare ground (%). Finally, we built three additive models combining effects found in the top three models: outer VOR + T, outer VOR + age, outer VOR + TT. We followed the guidelines of Burnham & Anderson (2002) for making model inferences. Models were ranked by Akaike’s Information Criterion, corrected for small sample size (AIC_c); the model with the lowest AIC_c value was considered best and all models within 2.0 AIC_c units of that model were considered competitive. We present effects as “strong” when the 95% CL does not overlap zero and “weak” when it barely overlaps zero but with a strongly off-centered 95% CL range. We present estimates of apparent nest success for comparison to earlier estimates for the curlew. We then derive a model-based estimate to minimize the bias associated with apparent nest success (Mayfield 1975). To get this estimate, we used our best nest survival model, started a nest on the mean nest initiation date (11 May), and calculated the probability that a nest would survive the entire incubation period (28 days; Dugger & Dugger 2002) from that date. This extrapolation was straightforward because our best model was very simplistic and used only a constant daily survival rate.

RESULTS

We monitored and measured vegetation at 14 nests ($n = 12$ active, $n = 2$ depredated prior to discovery) between 25 April and 18 June during the 3-year study (2008–2010). All nests were found using the observation technique; no nests were found by rope dragging. The mean nest initiation date for all nests was 11 May. Apparent nest survival, defined as the percentage of nests producing one or more chicks, was 29% ($n = 4$ successful nests). Our model-based estimate of nest survival was 33% (95% CL: 24%, 93%). The average VOR at nest sites ranged from 0.05 dm to 0.68 dm, the average litter depth ranged from 0 cm to 2.27 cm, and the tallest piece of vegetation within the frames ranged from 5 cm to 75 cm.

We considered 21 models in our nest survival analysis, three of which had ΔAIC_c values < 2.0 (Table 1). The best model indicates there is strong evidence for a negative effect of large-scale VOR on nest survival ($\beta_{\text{outer vor}} = -4.17$, $SE = 1.74$, 95% CL: $-7.58, -0.77$). On a smaller scale, the effect of VOR at the nest site suggests a weak but negative influence on nest survival ($\beta_{\text{vor}} = -3.57$, $SE = 1.95$, 95% CL: $-7.40, 0.26$). We acknowledge that these scales may be correlated and present the latter to illustrate that the effect appears to be independent of scale. The forb model showed weak evidence for a negative influence of forb cover on nest survival ($\beta_{\text{forb}} = -12.49$, $SE = 6.97$, 95% CL: $-26.14, 1.17$) whereas the bare ground model showed a weak, positive influence of bare ground on survival ($\beta_{\text{bare}} = 3.28$, $SE = 2.20$, 95% CL: $-1.03, 7.59$). Two of the competitive models were additive: a linear seasonal trend + outer VOR model ($\Delta AIC_c = 0.55$) and age + outer VOR ($\Delta AIC_c = 1.53$).

None of the time trend models were competitive as stand-alone models. The linear trend model (T) had a ΔAIC_c of 3.31

and showed a slight trend towards poorer survival as the nesting season progressed ($\beta_T = -0.05$, $SE = 0.03$, 95% CL: $-0.12, 0.01$). The constant survival model (\cdot) was not competitive ($\Delta AIC_c = 3.68$). Lastly, the linear nest age model (age) was also not competitive ($\Delta AIC_c = 4.08$) but still showed a weak trend towards poorer survival with increasing nest age ($\beta_{\text{age}} = -0.04$, $SE = 0.03$, 95% CL: $-0.09, 0.02$). Models that included the effects of grass cover, litter cover, vegetation depth, height of the tallest vegetation, and the quadratic trend model (TT) were not competitive ($\Delta AIC_c > 2.0$) and we concluded that they had little or no influence on nest survival in this study.

DISCUSSION

Quantifying demographic parameters is useful in understanding the life stages that may be driving population trends. Demographic rates are more useful if researchers can uncover relationships between those rates and habitat characteristics. Our study sought to provide an estimate of the nest survival

Table 1. Model selection results for Long-billed Curlew nest survival in western Nebraska, 2008–2010. Models are ordered by Akaike’s Information Criterion, corrected for small sample size (AIC_c). K is the number of parameters and ΔAIC_c is the AIC_c difference from the top model. $S_{(\cdot)}$ represents a model with a constant daily survival rate, $S_{(T)}$ represents a model with a linear time trend, $S_{(TT)}$ represents a model with a quadratic time trend, and $S_{(\text{age})}$ represents a model with an age effect. $S_{(\text{height})}$ represents a model using maximum vegetation height, $S_{(\text{depth})}$ represents a model using litter depth, and $S_{(\text{vor})}$ represents a model using visual obstruction readings. $S_{(\text{bare})}$ represents a model using percent bare ground, $S_{(\text{grass})}$ represents a model using percent grass cover, $S_{(\text{forb})}$ represents a model using percent forb cover, and $S_{(\text{litter})}$ represents a model using percent litter cover. Models with $(_{o,})$ represent covariates from the outer 16 frames and a lack of $(_{i,})$ represent covariates from the inner 4 frames.

Model	ΔAIC_c^a	w_i	K	Deviance
$S_{(o.vor)}$	0.00	0.22	2	35.80
$S_{(T + o.vor)}$	0.55	0.16	3	34.28
$S_{(\text{age} + o.vor)}$	1.53	0.10	3	35.26
$S_{(vor)}$	2.17	0.07	2	37.98
$S_{(TT + o.vor)}$	2.24	0.07	4	33.87
$S_{(\text{forb})}$	2.31	0.07	2	38.12
$S_{(T)}$	3.31	0.04	2	39.11
$S_{(o.litter)}$	3.33	0.04	2	39.13
$S_{(\cdot)}$	3.68	0.03	1	41.53
$S_{(\text{bare})}$	3.73	0.03	2	39.53
$S_{(o.depth)}$	3.90	0.03	2	39.71
$S_{(\text{age})}$	4.08	0.03	2	39.88
$S_{(o.forb)}$	4.40	0.02	2	40.21
$S_{(o.height)}$	4.41	0.02	2	40.21
$S_{(\text{grass})}$	4.76	0.02	2	40.56
$S_{(\text{litter})}$	5.02	0.02	2	40.82
$S_{(TT)}$	5.28	0.02	3	39.01
$S_{(\text{depth})}$	5.49	0.01	2	41.29
$S_{(o.grass)}$	5.52	0.01	2	41.33
$S_{(o.bare)}$	5.63	0.01	2	41.43
$S_{(\text{height})}$	5.72	0.01	2	41.52

^a The AIC_c value of the best model is 39.88.

of the Long-billed Curlew in Nebraska, and then use that information to provide insight into the overall nest success on a larger scale. Below, we discuss some aspects of a modeling approach to estimate curlew nest survival and how Nebraska's nest survival rates compare regionally and nationally.

There are five assumptions that must be met for nest survival models to be unbiased (Dinsmore *et al.* 2002). They are: 1. nests are correctly aged when they are discovered, 2. nest fates are correctly determined, 3. nest discovery and subsequent nest checks do not influence survival, 4. nest fates are independent, and 5. homogeneity of daily nest-survival rates. We believe our study of curlew nest survival meets these criteria. First, determining the age of nests is possible using egg-flotation, a widely-used technique among ornithologists (Liebezeit *et al.* 2007, Westerskov 1950). Secondly, nest fates were fairly straightforward to assign because we checked the nests often and floated eggs multiple times to ensure an accurate hatch-date. Finding a nest with no eggs well before that date proves depredation. Ensuring that nest discovery and subsequent nest visits did not influence survival is very difficult to measure. We cannot eliminate the possibility that mammalian nest depredations may have occurred due to researcher visits although we took precautions to avoid leaving scents at nest sites. For example, we never kneeled, sat, or placed gear on the ground near nests and we did all our banding of curlews >25 m away from nest sites. Likewise, we cannot fully eliminate the possibility that the two abandoned nests were abandoned due to researcher visits. However, we found and monitored other nests in which abandonment was not an issue and we believe this was an unlikely cause of nest failure. Nest fates were almost certainly independent due to the large territory size of curlews and the great distances between nests (>2 km).

Curlew nest site selection occurs early in the growing season (March–April) and we did not find the majority of curlew nests at nest initiation. We assumed that vegetation growth at nest sites throughout the nesting season was unavoidable. To address this issue, we standardized our vegetation measurements to within one week after the nest was predicted to hatch. In doing this, we minimized the effect of different vegetation height due to seasonality. It is possible that nest sites were grazed during nesting but given the relatively low stocking rate of the Sandhills, we do not believe this played a major role in our results.

Estimates of curlew nest survival have been reported from Idaho, Oregon, South Dakota, Utah, and Wyoming but never from Nebraska, which contains a substantial portion of the continental breeding range (Fellows & Jones 2009). The mean hatching success estimate of 29% is one of the lowest among studies of Long-billed Curlews. Only two other studies have published lower rates; a study in Utah estimated apparent nest success of 20% ($n = 10$ nests; Paton & Dalton 1994) and a study in South Dakota estimated nest success of 15% ($n = 48$; Clarke 2006). Other studies found nest success rates between 35% and 69% (Dugger & Dugger 2002). However, Hartman & Oring (2009) estimated nest success of 31% with a substantial sample ($n = 215$) in Nevada. Mean nest success of other *Numenius* species ranged between 54% and 86% for Whimbrel nests in Manitoba ($n = 65$; Skeel 1983) and 37% ($n = 20$; Marks *et al.* 2002) in a study of Bristle-thighed Curlews in Alaska.

The results in program MARK yielded three competitive models, which suggests that more than one factor is affecting curlew nest survival in Nebraska. All of the competitive models included large-scale VOR suggesting importance of this vegetative characteristic on nest survival. For example,

the analyses suggest that more dense vegetation of outer patch levels negatively affects nest survival whereas bare ground positively affects nest survival. Likewise, the analyses suggest that nests placed in areas with less forb cover had greater survival. Although these findings are not in accordance with the findings of Clarke (2006), they confirm what other studies state about curlews using areas with short vegetation and their tendency to use barren areas (Allen 1980, Dugger & Dugger 2002). This tendency is thought to provide nesting curlews with better visibility and therefore predator avoidance (Pampush & Anthony 1993). Redmond & Jenni (1986) hypothesized that lush vegetation may protect small mammals from avian predators and that the diet of these predators would then shift to include curlew chicks. If this is the case, this might persuade curlews to nest in areas away from thick vegetation. The different conclusions may also be due to predominant vegetation types at the study site. The Clarke (2006) study was located in grazed grasslands of South Dakota. The typical plant community, VOR measurements, and predator scheme may be different there compared to the more barren Nebraska Sandhills.

A potential source of bias in this study was the small sample of nests. We intentionally kept models simple to avoid over-fitting, although the many competitive models suggest that these data may have been too sparse for even some of these models. There are three primary reasons for the small sample of nests. First, late season blizzards in 2008 and an unusually wet year in 2010 hampered search efforts and were suspected to reduce nest survival. Secondly, wet conditions in 2010 may have facilitated taller vegetation than normal and created more suitable wet meadow habitats elsewhere resulting in fewer nesting pairs in our study area. Lastly, Long-billed Curlews have large breeding territories and rope-dragging by foot was inefficient. Rope-dragging using ATVs was not permitted in much of the study area and we would suggest future studies use areas that allow ATVs to maximize coverage. Collectively, this limited our chances for finding many curlew nests.

Our study provides the first estimates of nest survival for Long-billed Curlews in Nebraska and these estimates are both statistically acceptable and within the known range found in other curlew studies. They can be used as a baseline estimate for further study but additional studies with larger samples may improve the accuracy. We confirm that nesting curlews used grasslands with short vegetation, more bare ground, and less forb cover. This habitat scheme was historically more widespread when bison *Bison bison* grazed the prairies and regular fire regimes created patches of shorter vegetation within the tallgrass prairie (Risser *et al.* 1981). Changes in the last century, such as reducing the frequency of naturally occurring fires and converting grazed prairies into cropland, have diminished much of this habitat (Oring 2006, Pampush & Anthony 1993). Our study area, both on private and federal land, was grazed to a variable extent but we did not have a sufficient sample of nests to evaluate the effect(s) of grazing intensity. However, other studies indicate care should be taken when managing grazing pressure; Clarke (2006) found up to 75% of curlew nest failure due to trampling in South Dakota. Her study recommends reducing livestock density to less than 33 cattle/km² and 220 bison/km² in pastures during the peak of curlew incubation/hatching (10 April to 25 June). However, the stocking rates in the Sandhills tend to be much lower than those areas and Kempema (2007) found only 3% of grassland bird nests (9 of 287 nests) were trampled by cattle in the Sandhills. A widely used method of maintaining variable habitat characteristics is patch-burn grazing (Fuhlendorf *et al.* 2006).

Studies have shown that patch-burn grazing is a suitable method of managing for a suite of grassland songbird species, and on a large scale (>10 km) and in the correct context, this may provide the needed habitat for the entire life-cycle of curlews. Rotational grazing treatments have also been shown to host greater densities of some grassland bird species, e.g. Grasshopper Sparrow *Ammodramus savannarum*, and these systems may be more appropriate to use in dry areas of high fire risk (Kempema 2007).

Our study provides a critical baseline understanding of the factors that affect breeding Long-billed Curlews in Nebraska. The range reduction of curlews during the last 150 years has been attributed to a loss of habitat and this threat still remains today in the Sandhills (Schneider *et al.* 2005). To ensure that Nebraska continues to host a sizeable portion of the curlews' range, future studies are needed to better estimate adult survival thus providing information for population growth models and ultimately population trends. The Sandhills are biologically unique and remain an important stronghold for the curlew and other declining grassland species. We are optimistic that land-use managers will use these data to make informed decisions regarding grazing pressures, burning regimes, and grassland preservation for this emblematic prairie species.

ACKNOWLEDGEMENTS

We thank the staff at Crescent Lake National Wildlife Refuge for logistical support, the nearby private landowners (B. Bailey, J. Haskell, and E. Deitlein) for allowing access to their lands, and the Sandhills Task Force. Funding was provided by the Nebraska State Wildlife Grant Program and the Nebraska Wildlife Conservation Fund with additional assistance from the U.S. Fish and Wildlife Region 6 office. LAP's contributions to this research was supported by Hatch Act funds through the University of Nebraska Agricultural Research Division, Lincoln, Nebraska. Field assistance was provided by M. Reed, V. Tran, and A. Casey. We are grateful to Mark Colwell for his review of a draft of our paper.

REFERENCES

- Allen, J.N. 1980. The ecology and behavior of the Long-billed Curlew in southeastern Washington. *Wildlife Monographs* 73: 1–67.
- Bent, A.C. 1929. *Life histories of North American shorebirds. Part 2*. U.S. National Museum Bulletin No. 146.
- Bicak, T.K. 1977. *Some eco-ethological aspects of a breeding population of Long-billed Curlews (Numenius americanus) in Nebraska*. M.S. Thesis, University of Nebraska, Omaha, NE.
- Brown, S., Hickey, C., Harrington, B. & Gill, R. 2000. *The U.S. Shorebird Conservation Plan, 2nd ed.* Manomet Center for Conservation Sciences, Manomet, MA.
- Burnham, K.P. & Anderson, D.R. 2002. *Model selection and multimodel inference: a practical information-theoretic approach*. 2nd ed. Springer-Verlag, New York, NY.
- Clarke, J.N. 2006. Reproductive ecology of Long-billed Curlews breeding in grazed landscapes of western South Dakota. M.S. Thesis, South Dakota State University, Brookings, SD.
- Crabtree, R.L., Broome, L.S. & Wolfe, M.L. 1989. Effects of habitat characteristics on Gadwall nest predation and nest-site selection. *J. Wildlife Man.* 53: 129–137.
- Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. *Northwest Science* 33: 43–64.
- Dinsmore, S.J., White, G.C. & Knopf, F.L. 2002. Advanced techniques for modeling avian nest survival. *Ecology* 83: 3,476–3,588.
- Dugger, B.D. & Dugger, K.M. 2002. Long-billed Curlew (*Numenius americanus*). In: *The Birds of North America*, No. 628 (A. Poole & F. Gill, eds). The Birds of North America, Inc., Philadelphia, PA.
- Fellows, S.D. & Jones, S.L. 2009. *Status assessment and conservation action plan for the Long-billed Curlew (Numenius americanus)*. U.S. Department of Interior, Fish and Wildlife Service, Biological Technical Publication, FWS/BTP-R6012-2009, Washington, D.C.
- Fellows, S., Stone, K., Jones, S., Damude, N. & Brown, S. 2001. Central Plains/Playa Lakes regional shorebird conservation plan, version 1.0. www.fws.gov/shorebirdplan/RegionalShorebird/downloads/CPPLR.doc (accessed 15 November 2010).
- Forsythe, D.M. 1970. Vocalizations of the Long-billed Curlew. *Condor* 72: 213–224.
- Fuhlendorf, S.D., Harrell, W.C., Engle, D.M., Hamilton, R.G., Davis, C.A. & Leslie, D.M. Jr. 2006. Should heterogeneity be the basis for conservation? Grassland bird response to fire and grazing. *Ecol Appl.* 16: 1706–1716.
- Hartman, C.A. & Oring, L.W. 2009. Reproductive success of Long-billed Curlews (*Numenius americanus*) in northeastern Nevada hay fields. *Auk* 126: 420–430.
- Jenni, D.A., Redmond, R.L. & Bicak, T.K. 1981. *Behavioral Ecology and Habitat Relationships of Long-billed Curlew in Western Idaho*. Department of the Interior, Bureau of Land Management Boise District, Boise, ID.
- Kempema, S.L.F. 2007. *The influence of grazing systems on grassland bird density, productivity, and species richness on private rangeland in the Nebraska Sandhills*. M.S. Thesis, University of Nebraska, Lincoln, NE.
- Liebezeit, J.R., Smith, P.A., Lanctot, R.B., Schekkerman, H., Tulp, I., Kendall, S.J., Tracy, D.M., Rodrigues, R.J., Meltofte, H., Robinson, J.A., Gratto-Trevor, C., McCaffery, B.J., Morse, J. & Zack, S.W. 2007. Assessing the development of shorebird eggs using the flotation method: species-specific and generalized regression models. *Condor* 109: 32–47.
- Lima, S.L. 2009. Predators and the breeding bird: behavioral and reproductive flexibility under the risk of predation. *Biol. Reviews* 84: 845–513.
- Marks, J.S., Tibbitts, T.L., Gill, R.E. & McCaffery, B.J. 2002. Bristle-thighed Curlew (*Numenius tahitiensis*). *The Birds of North America Online* (A. Poole, ed.). Cornell Lab of Ornithology, Ithaca. *Birds of North America Online*: bna.birds.cornell.edu/bna/species/705doi:10.2173/bna.705 (accessed 22 January 2011).
- Martin, T.E. & Briskie, J.V. 2009. Predation on dependent offspring: a review of the consequences for mean expression and phenotypic plasticity in avian life history traits. The year in evolutionary biology 2009. *Annals New York Acad. Sciences* 1168: 201–217.
- Mayfield, H.F. 1975. Suggestions for calculating nest success. *Wilson Bull.* 87: 456–466.
- Miller, S. 1998. *Land Development and Use: An Atlas of the Sand Hills*. Conservation and survey division, University of Nebraska, Lincoln, Nebraska, USA.
- Oring, L.W. 2006. Long-billed Curlew symposium. *Wader Study Group Bull.* 109: 30.
- Pampush, G.J. & Anthony, R.G. 1993. Nest success, habitat utilization and nest-site selection of Long-billed Curlews in the Columbia Basin, Oregon. *Condor* 95: 957–967.
- Paton, P.W.C. & Dalton, J. 1994. Breeding ecology of Long-billed Curlews at Great Salt Lake, Utah. *Great Basin Nat.* 54: 79–85.
- Redmond, R.L. & Jenni, D.A. 1986. Population ecology of the Long-billed Curlew (*N. americanus*) in W. Idaho. *Auk* 103: 755–767.
- Risser, P.G., Birney, E.C., Blocker, H.D., May, S.W., Parton, W.J. & Wiens, J.A. 1981. *The True Prairie Ecosystem*. US/IBP Synthesis Series, No. 16, Hutchinson Ross Publishing Co., Stroudsburg, PA. 557 pp.
- Robel, R.J., Briggs, J.N., Dayton, A.D. & Hulbert, L.C. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. *J. Range Man.* 23: 295–297.
- Schneider, R., Humpert, M., Stoner, K. & Steinauer, G. 2005. *The Nebraska Natural Legacy Project: a Comprehensive Wildlife Conservation Strategy*. Nebraska Game and Parks Commission, Lincoln, NE.
- Sharpe, R.S., Silcock, W.R. & Jorgensen, J.G. 2001. *The Birds of Nebraska: their Distribution and Temporal Occurrence*. University of Nebraska Press, Lincoln, Nebraska. 520 pp.
- Singh, A., Hines, T.C., Percival, H.F. & Oli, M.K. 2010. Does nest-site selection influence bobwhite nesting success in south Florida? *Wildlife Research* 37: 489–496.
- Skeel, M.A. 1983. Nesting success, density, philopatry, and nest-site selection of the Whimbrel (*Numenius phaeopus*) in different habitats. *Canadian J. Zool.* 61: 218–225.
- Westerskov, K. 1950. Methods for determining the age of game bird eggs. *Journal of Wildlife Management* 14: 56–67.
- White, G.C. & Burnham, K.P. 1999. Program MARK: Survival estimation from populations of marked animals. *Bird Study* 46 Supplement, 120–138.
- Yocum, C.F. 1956. Re-establishment of breeding populations of Long-billed Curlews in Washington. *Wilson Bull.* 68: 228–231.