Killdeer *Charadrius vociferus* breeding abundance and habitat use in the Eastern Rainwater Basin, Nebraska

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The Killdeer *Charadrius vociferous* is a common shorebird that breeds throughout much of North America. The most recent estimate of the total population of Killdeer is 1 million individuals, but this estimate is supported by few quantitative studies. We used distance sampling to survey Killdeer in the agricultural ecosystem of the Eastern Rainwater Basin, Nebraska. Our results show that as many as 100,000 Killdeer may breed in the Eastern Rainwater Basin. The region we surveyed covers a very small portion of the Killdeer's overall breeding range, suggesting that the Killdeer population is likely >1 million birds. We also evaluated habitat use in the heavily modified Eastern Rainwater Basin. Our results show that Killdeer primarily occupy row crop agricultural fields and prefer fields planted to soybeans the previous growing season over those that had been planted to corn in the previous season. Our results highlight the need to further assess Killdeer population size and trends throughout the species' range, and also evaluate localized and range-wide threats to the species' long-term survival while the species is common.

INTRODUCTION

The Killdeer *Charadrius vociferous* is the most widespread and common breeding shorebird in temperate North America (Jackson & Jackson 2000). Despite the fact that it is ubiquitous and familiar, it is poorly studied. In particular, there are few quantitative estimates of Killdeer numbers or information on population trends over the species' range (Jackson & Jackson 2000, Morrison *et al.* 2006). Recent efforts to provide population estimates for North American shorebirds produced preliminary estimates for Killdeer as low as 100,000 (Morrison *et al.* 2001). This initial figure was recently revised to 1 million (Morrison *et al.* 2006). Confidence in this new figure is low, however, reflecting the dearth of information available to make this assessment (Brown *et al.* 2001).

The Killdeer is one of five plover species that breed in temperate North America and it is the only member of this group that is not a species of significant conservation concern. Indeed, the other four species, Snowy Plover *Ch. alexandrinus*, Wilson's Plover *Ch. wilsonia*, Piping Plover *Ch. melodus*, and Mountain Plover *Ch. montanus*, are all listed as a species of "high concern" or "highly imperiled" by the United States Shorebird Conservation Plan (USSCP; Brown *et al.* 2001). Piping and Snowy Plover are also either federally and/or state listed as threatened or endangered in all or portions of their respective ranges (Brown *et al.* 2001). Mountain Plover was a recent candidate species for federal listing (Federal Register, vol. 66, no. 174, p. 55,083). While the Killdeer remains common, evidence from the Breeding Bird Survey (BBS) suggests it has experienced declines over portions of its range (Sazenbacher & Haig 2001). It is considered a species of "moderate concern" by the USSCP (Brown et al 2001). Given the uncertainties about total population size and the trend over time in populations, additional information is needed to properly assess Killdeer population size and trends and to ensure that the species remains common and widespread.

The Rainwater Basin, Nebraska, is a clearly delineated landscape defined by numerous imbedded playa wetlands (LaGrange 2005) and is classified as a "Landscape of Hemispheric Importance" by the Western Hemisphere Shorebird Reserve Network (Fig. 1). Recent work has emphasized the importance of this landscape to migratory shorebirds (Brennan 2006, Jorgensen 2004) and migratory shorebird's relationship with agricultural habitats (Jorgensen 2007, Jorgensen *et al.* 2007). Little attention has been given to Killdeer, the most common breeding shorebird in the region. The Rainwater Basin is an intensely agricultural landscape and Killdeer often nest in agricultural habitats (Jorgensen 2004). This raises concerns because accidental tillage of Mountain Plover nests in fallow agricultural fields in the western Great Plains has been identified as a possible source of declines in that species (Knopf & Rupert 1996, Shackford *et al.* 1999). Birds breeding in agricultural fields may also be exposed to high concentrations of agricultural chemicals (Mineau & Whiteside 2006).

During 2004 and 2005, we conducted shorebird surveys in the Eastern Rainwater Basin focusing on upland, agricultural habitats. We used distance sampling to determine Killdeer density and abundance in the Eastern Rainwater Basin. We also determined which habitats were used by Killdeer. We used these results to evaluate the potential importance of this geographic region and specific land uses for breeding Killdeer and compare the numbers we obtained to current global population estimates.

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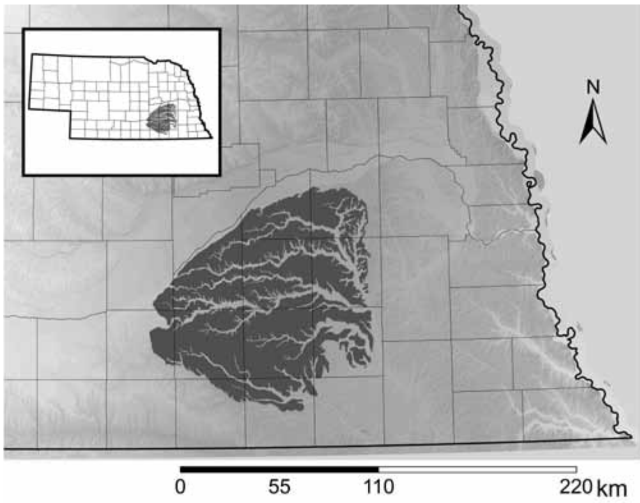

Fig. 1. Location and extent of the Eastern Rainwater Basin, Nebraska, USA (dark grey).

METHODS

Observations of Killdeer were recorded as part of a study on the migratory stopover of Buff-breasted Sandpipers and we apply the same methods to determine the densities of Killdeer (Jorgensen *et al.* 2008). We conducted surveys in the Eastern Rainwater Basin in 2004 and 2005 using distance sampling at point transects (Buckland *et al.* 2001, 2004). The study area was defined by identifying specific loess soil types (Kuzila 1994, Kuzila & Lewis 1993) of a Soil Survey Geographic Data (SSURGO; NRCS 2005) layer in a Geographic Information System. This process produced a study area of 849,028 ha. Within the study area, we placed point transects on county roads using a 4.62 km grid (i.e. 3 miles; Jorgensen *et al.* 2007, 2008). Point transects were not located off roads because of logistical limitations (Jorgensen *et al.* 2008).

Point transects were visited four or five times during May when Killdeer breeding is well underway. Killdeer arrive in the Eastern Rainwater Basin in early March (Jorgensen 2004). Pair formation and nesting occurs in the following weeks. Birds are incubating eggs by early to mid-April in the Rainwater Basin (pers. obs.), Nebraska (Pickwell 1925) and similar latitudes (Jackson & Jackson 2000). We spent 5 minutes at point transects and recorded distances to all Killdeer using a laser rangefinder. We surveyed in the mornings beginning a half hour before sunrise until 11h00, and during late afternoon, commencing at 16h00 and continuing until sunset in 2004. In 2005, surveys were conducted continuously during daylight hours. Surveys were not conducted during extreme rainfall or when winds were >40 km per hour. To eliminate problems with observer bias, JGJ conducted all surveys.

Killdeer are often observed individually, however, we recorded detections as "clusters" (Buckland *et al.* 2001). Clusters occur when the detection of one individual is dependent on the known location of another individual. When a cluster was encountered, we recorded the distance from the point transect to the center of the cluster and the number of birds in it.

We used Program Distance 5.1 (Thomas *et al.* 2006) to analyze data. We pooled data from the two years to increase precision of parameter estimates. We truncated 10% of observations furthest from the point of observation to limit error from outliers (Buckland *et al.* 2001). We fit data to the six model suggested by Buckland *et al.* (2001). The top model was selected using the lowest Akaike's Information Criterion (AIC) value and non-significant *P*-values from Cramér-von-Mises, Kolmogorov-Smirnov, and χ^2 goodness-of-fit tests.

Overall numbers of Killdeer breeding in the Eastern Rainwater Basin were predicted by multiplying mean density estimate by the size of the study area. Our surveys were conducted from roads and because this may introduce a bias into estimates, we produced additional predictions that only consider the area adjacent to roads following methods outlined in Jorgensen *et al.* (2008). Areas adjacent to roads were calculated by placing a 350 m buffer around roads and by using the effective radii, the distance where detection and non-detection is equal, estimated by Program Distance.

Habitat (i.e. land use) was recorded by quadrant around each point prior to each 5 minute survey following methods used in Jorgensen *et al.* (2007). Quadrants were defined by referencing public roads that traverse north–south and east–west and form a grid. When points were located at an intersection, quadrant boundaries were explicitly defined by roads. When points were located away from intersections, quadrants were delineated using a perpendicular line from the road. Row crop agricultural fields are the primary land use in the Eastern Rainwater Basin and fields are typically >65 ha. Most observations were made at distances <500 m, therefore each quadrant was generally designated under one type of land use. The survey was conducted at a time when the previous season's crop residue was still present in fields and when field preparation and planting was in progress. We used a multifactorial regression model to determine whether crop residue was preferred more than expected based on availability. Corn and soybeans are the dominant crops grown in this region and we considered three common field conditions encountered: 1) fields with soybean residue, 2) fields with corn residue with no vertical structure, and 3) fields with cut corn stalks with erect base >15 cm remaining. Crop type and year were predictor variables and presence/absence was the response variable. A small number of observations during the initial survey period, when methodology was being refined, were excluded from this final analysis.

RESULTS

The majority of Killdeer observations were in agricultural fields. We recorded a total of 432 Killdeer detections during the two years of surveys. Data best fit hazard rate model with both cosine and simple polynomial expansions. Mean density estimate from the selected model was 0.12 birds/ha (95% C.I., 0.09, 0.16) (Tables 1 & 2). Goodness-of-fit tests were non-significant. Using mean density and overall size of the study area (849,028 ha), we produced predictions of 101,883 (±14,433) Killdeer in the Eastern Rainwater Basin during May. Using the 350 m buffer (643,009 ha) our prediction was 77,161 (±10,931) Killdeer and when we used a buffer based on the Effective Radii of 83.60 m the prediction was 22,033 (±3,121) Killdeer.

We classified habitat type in 8,065 quadrants around survey points. Corn or soybean fields accounted for 82.3 % of all quadrants. Buildings were found in 4.9% of quadrants and 2.1% were classified as alfalfa hayfields. No other habitat type occupied more than 2% of quadrants (e.g. wheat fields, cool-season pasture, wetlands, cattle feed lots). The majority (98%) of quadrants occupied by Killdeer were private agricultural lands, including >91% of all observations in corn and soybean fields. Less than 2% of observations were from public conservation lands. We further subdivided row crop fields

Table 1. Models of Killdeer density in the Rainwater Basin, Nebraska, USA, in 2004–05. Models are ordered by Akaike's information criterion (AIC). Log (*L*) is the log-likelihood, K is the number of parameters, Δ AIC is the difference in AIC from the top model.

Model + series expansion[a]	K	Log (*L*)	Δ AIC[b]	Density birds/ha	Density UCL[c]	Density LCL[d]	CV[e]
Hazard rate + simple polynomial	2	–2028.94	0.00	0.12	0.16	0.09	0.14
Hazard rate + cosine	2	–2028.94	0.00	0.12	0.16	0.09	0.14
Uniform + cosine	5	–2025.99	0.10	0.15	0.20	0.14	0.14
Half normal + cosine	2	–2031.99	5.61	0.12	0.14	0.10	0.10
Uniform + simple polynomial	3	–2038.40	20.93	0.08	0.10	0.08	0.08
Half normal + hermite polynomial	1	–2043.69	27.5	0.08	0.09	0.07	0.75

[a] Model and series expansion recommended by Buckland *et al.* (2001).
[b] The AIC values of the top models in this analysis were 4061.87.
[c] Upper 95% confidence limit.
[d] Lower 95% confidence limit.
[e] Coefficient of variation.

into fields with the previous year's soybean stubble, fields with the previous year's corn stubble standing less than 15 cm high, and fields with the previous year's corn stubble standing more than 15 cm high. Killdeer were significantly associated with certain field habitats (Fig. 2; likelihood ratio $\chi^2 = 31.6$, df = 2, $P < 0.0001$). In particular, they were 1.6 times more likely to occur in fields with soybean stubble (likelihood ratio $\chi^2 = 23.8$, $P < 0.0001$) than in fields with short corn stubble. However, they were not significantly more likely to occur in quadrants with corn stalks >15 cm (likelihood ratio $\chi^2 = 2.8$, $P = 0.09$). Killdeer occupied more quadrants in 2004 than in 2005 (likelihood ratio $\chi^2 = 7.9$, df = 1, $P = 0.005$) and there was no significant interaction between year and habitat (likelihood ratio $\chi^2 = 3.4$, df = 2, $P = 0.18$).

DISCUSSION

Our results indicate that over 100,000 Killdeer may breed in Eastern Rainwater Basin, primarily in agricultural fields. This estimate is derived from road-based surveys and assumes that density of Killdeer is similar in areas near the center of sections where we did not sample. If we limit our inferences about density to areas adjacent to roads we produce estimates ranging from 22,000 to 77,000 Killdeer plus an unknown number in the portions of sections more distant from roads. Killdeer also showed differential use between agricultural habitats, preferring fields that were planted to soybeans the previous growing season.

While our estimates include an unknown proportion of unpaired individuals and, potentially, migrants, the presence of as many as 100,000 breeding Killdeer in such a small portion of the species range reinforces Morrison *et al.* (2006) suggestion that the species estimate of 1 million individuals may be too low. To our knowledge, these are the first estimates of Killdeer density for Nebraska and one of the few estimates of breeding Killdeer anywhere in the species' range (Jackson & Jackson 2000, Morrison *et al.* 2006). Thus, we do not know if these densities are representative of Killdeer densities in other areas of the Great Plains though BBS data suggest similar densities throughout much of the Great Plains and Midwestern United States (Sauer *et al.* 2005).

Most Killdeer we observed were in corn and soybean fields. Across the eastern Great Plains and Midwest (Nebraska, North Dakota, South Dakota, Minnesota, Iowa, Wisconsin, Illinois, Indiana, Ohio) where the majority of corn and soybeans in the U.S. are grown (National Agricultural Statistics Service 2007) and where BBS surveys find high densities of Killdeer comparable to those in the Rainwater Basin (Sauer *et al.* 2005), 44.9 million hectares were planted to corn and soybeans in 2004 and 44.2 million hectares were planted in 2005 (National Agricultural Statistics Service 2007). If Killdeer densities in corn and soybean fields in these nine states are similar to those we found in the Rainwater Basin then agricultural fields may be a primary habitat for Killdeer in the core of its range. This result emphasizes the need to

Table 2. Killdeer density in the Rainwater Basin, Nebraska, USA, and associated parameter estimates (±SE) for 2004–05. Estimates were calculated using the top model from Program Distance using Akaike's information criterion.

Parameter	Parameter estimate
Density (birds per ha)	0.12(±0.02)
Mean cluster size (number of birds)	1.09(±0.02)
Detection probability	0.17
Effective radii (m)	83.60
Maximum detection distance (m)	600
Maximum detection distance after truncation (m)	204

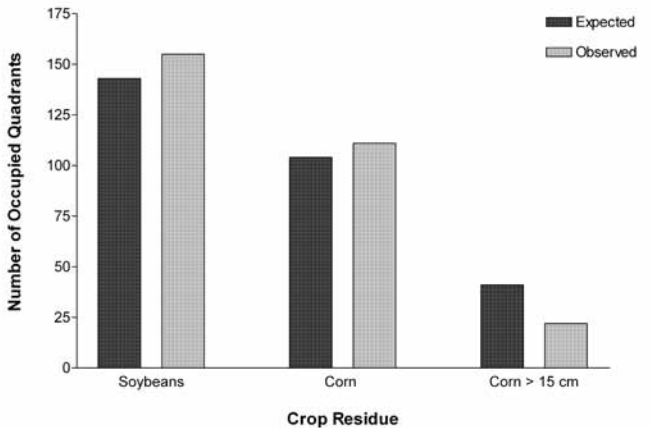

Fig. 2. Killdeer habitat use compared to expected use with respect to habitat availability in the Eastern Rainwater Basin, Nebraska, USA. Three habitat types are fields with 1) soybean residue, 2) corn residue with no vertical structure, and 3) field with erect corn stalks >15 cm. The expected number of occupied quadrants (white bars) and observed number of occupied quadrants (black bars). Killdeer were significantly more likely to occur in fields with soybean residue than field with corn residue (likelihood ratio $\chi^2 = 23.8$, $P < 0.0001$). Killdeer were not significantly more likely to occur in quadrants with corn stalks >15 cm (likelihood ratio $\chi^2 = 2.8$, $P = 0.09$).

better understand variation in abundance of Killdeer and the importance of crop fields as breeding habitat.

While these numbers on their own appear impressive, they do not by themselves indicate whether Killdeer are secure in the long term. Regardless of actual population size, Sazenbacher & Haig (2001) showed that Killdeer have declined regionally over the period of the Breeding Bird Survey, 1967–2005. BBS results suggest that Killdeer have slightly increased in Nebraska since 1967 (Sauer *et al.* 2005). These results, however, also suggest that this increase occurred before 1980 and that numbers have actually declined after that year. This result may indicate that a large portion of the Killdeer population is nesting in agricultural fields where they may be subject to a variety of stressors including direct disturbance from agricultural practices, exposure to high levels of agricultural chemicals, and inadequate food resources.

Evaluation of possible risks to Killdeer populations associated with nesting in active agricultural fields emerges as a priority from our results. Such an evaluation may also provide insights about stressor affecting other species of conservation concern. For example, both Killdeer and Mountain Plover commonly nest in agricultural fields. Incidental tillage of Mountain Plover nests in agricultural fields has been identified as a potential source of sharp Mountain Plover declines in Colorado and nearby states (Dreitz 2005, Knopf & Rupert 1996). Concerns about negative impacts of agricultural practices on Killdeer nests have been largely non-existent, which suggests one of several possible explanations, including: 1) incidental nest tillage is not a significant factor in population regulation of either species, 2) incidental nest tillage is causing similar population declines in Killdeer that have not been detected, or 3) specific agricultural practices in the Mountain Plovers limited range acutely affects that species while similar or different agricultural practices do not have similar effects on Killdeer. Regardless of the explanation, identifying the effects of agricultural practices on the common species would aid in understanding the impacts to at-risk species and hopefully also prevent declines in common species.

Our results provide a snapshot of the status of a significant population Killdeer breeding in conjunction with agriculture and suggest that the current global population is likely to be greater than a million birds. Without additional information about densities elsewhere in the species range we suggest that the most precise current estimate of population size would be simply >1 million. Of more concern is the presence of such a large number of breeding birds in a potentially hazardous habitat, coupled with previous observations of range-wide population declines (Sauer *et al.* 2005, Sazenbacher & Haig 2001). A better understanding of the breeding success of Killdeer in different habitats coupled with monitoring of population trends is called for to ensure this common species remains common.

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