Nest fate and vegetation characteristics for Snowy Plover and Killdeer in Colorado, USA

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We quantified vegetation characteristics at nest sites of Snowy Plovers (*Charadrius alexandrinus*) and Killdeers (*C. vociferus*) in south-eastern Colorado during 1995 to assess interspecific differences in nesting habitat and determine whether habitat characteristics influenced nest fate. Killdeers nested in areas with significantly more grass, litter, and vegetation within 10 cm of the ground than Snowy Plovers. We found no significant differences between any of the coverage or structural habitat characteristics and successful or failed nests of Snowy Plovers and Killdeers. Small–scale management of nesting habitat of shorebirds should be undertaken only if reproductive success varies among habitat types.

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INTRODUCTION

Habitat degradation has been implicated as a principal cause of population decline for federally–listed shorebirds such as the Piping Plover (*Charadrius melodus)* and Snowy Plover (*C. alexandrinus*) (USFWS 1994, Page *et al.* 1995). To reverse this trend, habitat management on the breeding grounds has been recommended to maximize nesting success and survival of endangered shorebirds (Prindiville, Gaines & Ryan 1988, USFWS 1994, Koenen *et al.* 1996). Habitat management may include several techniques that are not mutually exclusive, including, creation of nesting habitat, modification of substrate, restoration of damaged sites, or control of vegetation by chemical methods or grazing. By no means are the issues of habitat degradation and habitat management limited to shorebirds. For example, several species of ground–nesting grassland birds face similar threats of habitat degradation on the breeding grounds; loss of prairie habitat and reduced complexity of grasslands due to uniform grazing pressure and disturbance (Knopf 1996). Given that one–third of prairie bird species in North America are declining at statistically significant rates (Knopf 1996), habitats will likely be managed in the future to increase nesting success.

However, before one can manage for increased productivity, it must be demonstrated that successful nests occur in vegetation with different characteristics than unsuccessful nests for the species of concern. Vegetation density of nesting habitat has often been implicated as an important influence on the ability of predators to destroy nests (for review, see Martin 1992). For example, vegetation structure could affect nesting success by reducing the detectability of the incubating adult by predators (Bergerud & Gratson 1988) or lead to differential rates of nest predation (Pampush and Anthony 1993). Regardless of the mechanism, if reproductive success does not vary in disparate nesting habitat, then attempts to modify the existing habitat to increase reproductive success is likely to be ineffective. To date, studies examining the relationship between nest fate and habitat characteristics for shorebirds have documented a significant relationship for Snowy Plovers (Page *et al.* 1985), a temporally variable relationship for Piping Plovers (Prindiville, Gaines & Ryan 1988), or no relationship for Wilson's Phalarope (*Phalaropus tricolor*; Colwell 1992).

Our objectives were to (1) quantify interspecific differences in nesting habitat between Snowy Plovers and Killdeers (*C. vociferus*); and (2) determine whether successful nests occur in vegetation with different characteristics than unsuccessful nests.

STUDY AREA AND METHODS

Approximately 25,000 playa lakes are scattered throughout south-eastern Colorado and adjoining areas of Kansas, Oklahoma, Texas, and New Mexico (Bolen *et al.* 1989). Playa lakes are ephemeral wetlands (i.e., frequent drying and flooding cycles) characterized by Randall Clay soils in the playa interior that grade into more porous soils in adjacent uplands (Davis and Smith 1998). Our study sites encompassed several impounded and natural playa lakes in Kiowa and Prowers counties, and John Martin Reservoir in Bent County, Colorado. Snowy Plovers and Killdeers are ground–nesting shorebirds that incubate 2–4 eggs for ~26–27 d (Warriner *et al.* 1986, Powers 1978). Both species frequently initiated nests along lakeshores (open sand beaches or alkaline flats) surrounding impounded and natural playa lakes. We searched all habitat types (i.e., open to densely vegetated) repeatedly for nests.

Common vegetation at reservoirs and altered playa lakes included grasses (*Bouteloua gracilis*, *B. hirsuta*, *Buchloe dactyloides*, *Aristida longiseta*, *Hordeum jubatum*) and forbs (*Plantago patagonica*, *Oenothera albicaulis*, *Sphaeralcea coccinea*, *Zinnia acerosa*, *Conyza canadensis*, *Helianthus annuus*, *Dalea candida*, *Psoralea tenuiflora*, *Chamaesyce glyptosperma*, *Reverchonia arenaria*, *Heliotropium convolvulaceum*, *Chenopodium glaucum*). Common vegetation at natural playa lakes included grasses (*Distichlis spicata*), forbs (*Kochia americana*, *K. scoparia*, *Salsola iberica*, *Sesuvium verrucosum*), and shrubs (*Suaeda torreyana*).

We recorded habitat characteristics at nest sites of Snowy Plovers and Killdeers between 30 June–6 August, 1995 and 19 April–7 August, 1995, respectively, as part of a study evaluating the effectiveness of predator exclosures for nesting plovers in Colorado (Mabee and Estelle 2000). Because exclosures were ineffectual [i.e., we did not find a significant difference in the daily survival rate between protected (0.977; SE = 0.009; n = 14) or unprotected (0.973; SE = 0.011; n = 14) Snowy Plover nests (Z = 0.20; P = 0.42)] and they were allocated randomly with respect to habitat, we assumed that nest success was independent of the presence of a predator exclosure and used both types of nests in the habitat analyses. We did not protect Killdeer nests with predator exclosures during 1995.

Habitat measurements

We sampled habitat features at two scales using a square quadrat (0.25 m^2); the nest micro–site (one quadrat centered over the nest) and within a 5–m radius of the nest (five quadrats placed randomly within a 5–m radius of the nest). We selected these scales because they characterized habitat features of nest sites and the general plant community surrounding a nest, respectively. Together, these local scales encompassed the general habitat available for nesting plovers. A larger scale of measurement would have incorporated additional habitat types that would not have been representative of plover nesting areas (e.g., dense forbs at the junction of lakeshores and upland prairie). Within each quadrat, we measured coverage by visually estimating the percent of grass, sedge, forb, shrub, and litter to the nearest 10% interval. All observers practiced visual estimation of coverage to minimize interobserver variability. We measured structural attributes of vegetation by passing a 4.8 mm diameter rod vertically through the vegetation at four standardized locations within the quadrat. At each point we counted the number of times each plant life form contacted the rod within each 10 cm interval up to 1 m. We collected habitat measurements at the nest micro–site only when we initially found a nest (to minimize disturbance) and at both scales when a nest became inactive.

Habitat derived variables

We selected and derived several variables describing horizontal and vertical structure and horizontal heterogeneity following researchers studying habitat relationships with ground–nesting passerines and shorebirds (Wiens 1974, Rotenberry and Wiens 1980, Colwell and Oring 1990). These variables were useful for investigating the relationship between nest success and habitat features because they characterized salient habitat features around playa lakes in our study area. We indexed horizontal structure by calculating the average number of contacts within the first 10 cm interval (HIT10). We measured vertical structure by calculating the average total number of contacts over the entire rod (TOTHITS), and the average maximum 10 cm interval at which vegetation contacted the rod (MAXHGT). We assessed horizontal heterogeneity of vegetation by calculating the coefficient of variation of HIT10 (CVHIT10) and MAXHGT (CVMAXHGT). Because we distributed our sampling points over horizontal space, the between–point variation in these variables measured horizontal heterogeneity (Rotenberry and Wiens 1980).

Nests selected for habitat analyses

We floated eggs from all Snowy Plover (n = 31) and Killdeer (n = 49) clutches in tap water to estimate the age of a clutch (Hill 1985, Alberico 1995, Sandercock 1998) and to determine which nests were early in incubation (i.e., a maximum of 7 d old). We used this subset of Snowy Plover (n = 23) and Killdeer (n = 33) nests to determine if there were interspecific differences in habitat when birds initiated a nest. We also collected habitat data on inactive nests (either hatched or failed) to determine if nest success ($\geq$ 1 egg hatch per clutch) was independent of habitat features for each species. We included nests that were either successful or failed due to predation or abandonment (Snowy Plover; n = 27, Killdeer; n = 25).

Statistical analyses.—We calculated a Spearman correlation coefficient for all possible pairs of variables (SAS 1990) and decided *a priori* to remove one member of any pair of intercorrelated variables that had an r_s value of ≥ 0.85 at either the nest or 5–m scale. The degree of correlation among retained variables ranged between $r_s = 0.20–0.79$. To insure adequate samples, we omitted coverage categories that occurred at <15% of nests. Removal of redundant or minor variables reduces the number of comparisons and increases the power of detecting differences when making multiple comparisons (Rice 1989).

Because most variables were not normally distributed, we used the nonparametric Mann–Whitney *U*–test to test for differences between initial habitats, and between nest fate and individual habitat variables (SAS 1990). We used the midpoints of the coverage and MAXHGT intervals in the analyses (e.g., an interval of 1–10% = 5%, 11–20% = 15%, etc.) and rounded the values to the nearest 5% (coverage) and 5 cm (MAXHGT) in the tables. We calculated mean values of habitat variables from the five quadrats used in the 5–m scale to compare to the value obtained at the nest microsite. We used the nonparametric, sequential Bonferroni test to control the experiment-wise error rate at alpha = 0.10 for all individual comparisons (Rice 1989) of Snowy Plover and Killdeer nest sites. We selected this alpha level *a priori* due to

Table 1. Vegetation characteristics of nest sites of Snowy Plovers and Killdeers in Colorado, 1995. Habitat variables denote median (range). P values indicate significance of individual Mann–Whitney *U*–tests.

Habitat variable	Snowy Plover (*n* = 23)	Killdeer (*n* = 33)	Z (*P*)
Coverage (%)			
Grass	0 (—[a])	0 (0–85)	-3.8 (<0.01)*
Forb	5 (0–85)	5 (0–85)	0.8 (0.43)
Litter	5 (—[a])	5 (0–95)	-3.5 (<0.01)*
Structural			
HIT10[b]	0 (0–2.8)	1.3 (0–3.3)	-4.0 (<0.01)*
Heterogeneity (CV)			
CVHIT10	0 (0–200)	61 (0–200)	-1.6 (0.11)

[a] Indicates no range of values.
[b] HIT10 equals average number of vegetation contacts within 10 cm of the ground.
* Significant (*P* £ 0.10) when experimentwise error rate was controlled at alpha = 0.10 by the sequential Bonferroni test

Table 2. Vegetation characteristics of nest sites of Snowy Plovers in Colorado, 1995. Habitat variables denote median (range). P values indicate significance of individual Mann–Whitney *U*–tests.

Habitat variable	Nest site Successful *n* = 14	Failed *n* = 13	Z (*P*)	5 m radius Successful *n* = 14	Failed *n* = 13	Z (*P*)
Coverage (%)						
Forb	5 (0–25)	5 (0–75)	0.9 (0.37)	5 (0–25)	0 (0–20)	0 (0.98)
Shrub	—[a]	—[a]	—[a]	0 (—[b])	0 (0–5)	-1.5 (0.13)
Litter	5 (—[b])	5 (—[b])	0 (0.99)	5 (0–5)	5 (0–5)	-0.4 (0.70)
Structural						
HIT10[c]	0.1 (0–1)	0.3 (0–3.3)	0 (0.99)	0.1 (0–1.2)	0.1 (0–0.95)	-1.2 (0.24)
Heterogeneity						
CVHIT10[d]	64 (0–200)	92 (0–200)	0.2 (0.85)	309 (0–447)	255 (0–447)	-1.2 (0.22)

[a] Missing values were not calculated because of low frequency of occurrence.
[b] Indicates no range of values.
[c] HIT10 equals average number of vegetation contacts within 10 cm of the ground.
[d] CVHIT10 equals coefficient of variation of HIT10.

Table 3. Vegetation characteristics of nest sites of Killdeers in Colorado, 1995. Habitat variables denote median (range). P values indicate significance of individual Mann–Whitney *U*–tests.

Habitat variable	Nest site Successful $n=9$	Failed $n=16$	$Z(P)$	5 m radius Successful $n=9$	Failed $n=16$	$Z(P)$
Coverage (%)						
Grass	5 (0–65)	5 (0–55)	1.6 (0.10)	10 (0–65)	5 (0–50)	1.2 (0.23)
Forb	5 (0–15)	5 (0–25)	-0.9 (0.36)	5 (5–15)	5 (0–45)	0.3 (0.80)
Shrub	—[a]	—[a]	—[a]	0 (0–15)	0 (0–15)	1.2 (0.22)
Litter	5 (5–25)	5 (5–55)	0.21 (0.83)	5 (5–15)	5 (5–15)	0.8 (0.45)
Structural						
HIT10[b]	2 (0–5)	1.4 (0.3–3.5)	0.8 (0.41)	1.8 (0.8–4.8)	1.3 (0.1–4.6)	1.3 (0.19)
MAXHGT[c]	5 (0–10)	5 (0–10)	0 (0.98)	5 (1–15)	5 (1–10)	0.7 (0.51)
Heterogeneity[d]						
CVHIT10	71 (0–155)	82 (29–200)	-0.9 (0.38)	93 (56–309)	112 (37–308)	-0.7 (0.48)
CVMAXHGT	0 (0–115)	84 (0–200)	-1.7 (0.10)	84 (34–215)	97 (34–308)	-1.0 (0.33)

[a] Missing values were not calculated because of low frequency of occurrence.
[b] HIT10 equals average number of vegetation contacts within 10 cm of the ground.
[c] MAXHGT equals average maximum height of vegetation in cm.
[d] Heterogeneity expressed as coefficient of variation.

concern of low expected sample sizes and to reduce the risk of a type II error. We presented median, minimum, and maximum values for all habitat variables in the tables because data were not normally distributed.

RESULTS

Interspecific habitat analysis.—At the nest micro–site scale, Snowy Plovers initiated nests in areas characterized by significantly lesser amounts of grass, litter, and vegetation within 10 cm of the ground than Killdeers, whereas there were no significant differences in the amount of forbs surrounding nests of these species (Table 1). Snowy Plover nest sites contained no grass, variable amounts of forbs, and sparse litter, whereas Killdeers nested in areas with highly variable amounts of grass, forbs, and litter (ranging from 0–95%). There were no significant differences in the horizontal heterogeneity of vegetation between Snowy Plover and Killdeer nests (Table 1).

Analysis of nest fate by habitat attributes.—There were no significant relationships between nest fate and any of the coverage or structural habitat variables at either the nest or 5–m scale for Snowy Plovers (Table 2) or Killdeers (Table 3) after we controlled the experimentwise error rate. Measures of horizontal heterogeneity at both scales did not differ significantly between successful and failed nests for Snowy Plovers (Table 2) or Killdeers (Table 3). Median and range of coverage, structural, and heterogeneity variables were similar for successful and failed nests of Snowy Plovers (Table 2) and Killdeers (Table 3).

DISCUSSION

Documenting variation in nesting habitat within and between species is important when attempting to manage or create nesting habitat for a particular species. In several geographic locations Snowy Plovers have been characterized as nesting in open areas, often on alkaline flats surrounding lakes (Page *et al.* 1995). Results from this study were consistent with this general description, as newly–initiated Snowy Plover nests were located around playa lakes in open areas with limited litter and sparse vegetation. Killdeers nest in a wide variety of open and vegetated habitats throughout the U.S. (Nol & Lambert 1984, Colwell & Oring 1990). In Colorado, Killdeers appear to be flexible in their nesting locations as they nest along gravel roadsides, throughout the shortgrass prairie, and around playa lakes.

Nest success of Snowy Plovers and Killdeers was independent of habitat attributes that we measured and their degree of horizontal heterogeneity (patchiness) at both the nest–site and 5–m scales. Most Snowy Plover and Killdeer nests during 1995 failed due to predation by unknown predators, deer mice (*Peromyscus maniculatus*), and bullsnakes (*Pituophis melanoleucus*) or coachwhips (*Masticophis flagellum*) (Mabee and Estelle 2000). The absence of a discernable relationship between nest success and habitat features in our study may have been due to several factors, including, the occurrence of these predators in a wide variety of habitat types, the method of locating prey (e.g., olfactory vs. visual cues), or the small sample sizes in our study.

Previous studies examining the relationship between nest fate and habitat characteristics for shorebirds have shown mixed results. Page *et al.* (1985) established that Snowy Plover clutches had higher nest success when located under objects or in the open compared to nests beside objects. Prindiville Gaines and Ryan (1988) found Piping Plovers had higher nest success in areas with little vegetative cover during one year and in areas with highly clumped vegetation during the following year. Colwell (1992) reported nest success of Wilson's Phalaropes was not correlated with vegetation attributes. Koenen *et al.* (1996) used artificial nests to simulate Snowy Plover and Least Tern (*Sterna antillarum*) nests. They documented that nests near vegetation had higher losses to canid predators but lower losses to flooding during one year, whereas this relationship was absent during another year. Dissimilarities in the results among these studies may be attributed to different predators in each location and unique behavioral responses of each shorebird species to various predators.

We recommend that future studies should identify the predator community surrounding plover nest sites to predict if vegetation features surrounding nest sites would influence predation rates. If so, then studies could focus on appropriate scales around a nest site and measure vegetation characteristics to identify whether nest fate is related to vegetation attributes at those scales. This information is essential for managers to decide whether vegetation should be managed in nesting areas and at what scale, particularly for threatened and endangered species. If nest success varies significantly among habitat types, then one should determine whether habitat features influence nest success indirectly (e.g., by attracting predators to nesting habitat) or directly (e.g., by altering the nest microclimate). If predation is the dominant cause of nest failure, it is essential to understand the method(s) predators use to locate nests and how birds respond to predators in order to understand the importance of vegetation attributes around nest sites. An experimental approach may be necessary to identify the mechanism(s) explaining the relationship between habitat attributes and nest success, and ultimately, to evaluate whether habitat management will increase reproductive success of shorebirds.

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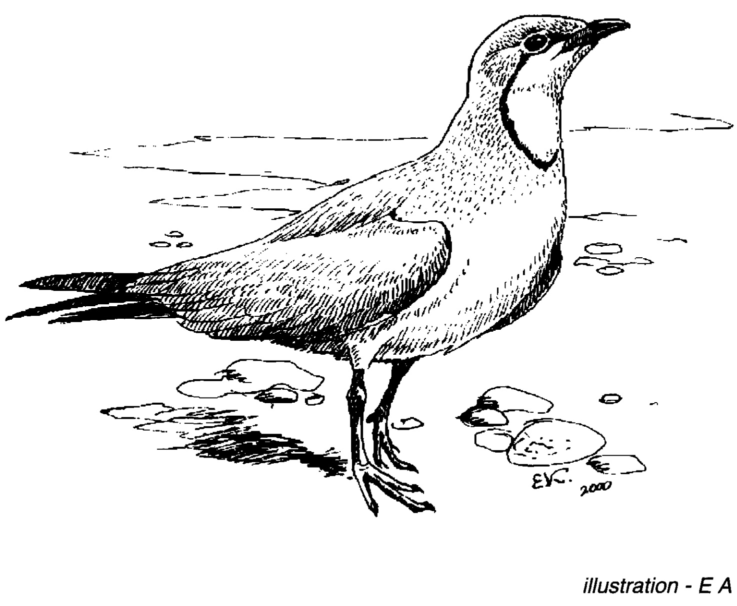

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