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ABSTRACT—We monitored nest success of mountain plovers (*Charadrius montanus*) relative to distance from the nearest anthropogenic edges, such as fence lines, roads, and perimeters of crop fields, in 2003 and 2004. We located and observed 163 mountain plover nests in eastern Colorado (USA). At least one egg hatched in 81 of 163 nests. Successful nests occurred at a mean distance of 93.94 m $\pm$ 8.87 *SE,* whereas unsuccessful nests were located 84.39 m $\pm$ 8.95 *SE* from the nearest edge. Based on our model selection criteria (AIC$_c$), nests farther from edges were not necessarily more successful than those closer to edges. The logistic regression coefficient for edge effects (0.13 $\pm$ 0.12 *SE*) suggests that nests farther from edges are more successful. However, the standard error for the edge coefficient was large and the 95% confidence interval (-0.08, 0.35) encompassed zero, suggesting nest success was independent of distance from an anthropomorphic edge. We conclude that phenomena determining nest success of mountain plovers cannot be attributed to the single factor of anthropogenic edges in this fragmented landscape.

RESUMEN—Observamos el éxito de nidificación del chorlo llanero (*Charadrius montanus*) con relación a la distancia de los bordes antropogénicos tales como cercas, caminos, y límites de campos sembrados en 2003 y 2004. Localizamos y observamos 163 nidos del chorlo en el este de Colorado (USA). Por lo menos un huevo eclosionó en 81 de 163 nidos. Los nidos exitosos ocurrieron a una distancia media de 93.94 m $\pm$ 8.87 *EE,* mientras que los nidos fracasados fueron localizados a 84.39 m $\pm$ 8.95 *EE* del borde más cercano. Basado en nuestros criterios de selección de modelos (AIC$_c$), los nidos más lejos de los bordes no fueron necesariamente más exitosos que los más cercanos a los bordes. El coeficiente de regresión logístico para efectos de borde (0.13 $\pm$ 0.12 *EE*) sugiere que los nidos más lejos de bordes son más exitosos. Sin embargo, el error estándar para el coeficiente de borde fue grande y el intervalo de confianza del 95% (-0.08, 0.35) incluyó el cero, sugiriendo que el éxito del nido fue independiente de la distancia al borde antropogénico. Concluimos que los fenómenos que determinan el éxito de nidificación del chorlo no pueden ser atribuidos sólo al factor antropogénico de los bordes en este paisaje fragmentado.

Fragmented landscapes contribute to the decline of many avian species across a wide range of habitats (Knopf, 1994; Rappole and McDonald, 1994; Warner, 1994; Askins, 1995; Peterjohn and Sauer, 1999; Murphy, 2003). These declines, especially of grassland birds, have led to various studies of the impact of fragmentation on nest success, especially relative to predation rates on eggs and nestlings near habitat edges (''edge effects''). Some of those studies have found increased predation near edges (Burger et al., 1994; Paton, 1994; Yosef, 1994; Keyser, 2002), whereas other studies have in-

consistent findings or no significant impact by predation on nest survival in relation to distance from the habitat edge (Vickery et al., 1992; Keyser et. al., 1998; Howard et. al., 2001; Woodward et al., 2001). These conflicting results probably reflect differing experimental designs (Paton, 1994) and differing vegetative landscapes among studies.

Most research on the impact of edge effects on avian nest success has focused on habitat types such as fragmented forests, with some research in midgrass to tallgrass prairie systems; few studies have examined this relationship in

a shortgrass prairie landscape (Howard et al., 2001). The vegetative structure along habitat edges in the shortgrass prairie is different from edges in forest ecosystems and midgrass and tallgrass prairies. Because of the short stature of vegetation in the shortgrass prairie, edges are less conspicuous and are seasonally inconsistent, as driven by climate patterns. Changes in the vegetative structure often are caused by anthropogenic features, such as grazing rotations, burning regimes, roads, and interfacing crop fields and Conservation Reserve Program lands. Mountain plovers (*Charadrius montanus*), in particular, are strongly associated with these subtle changes in vegetation structure that might have a direct impact on their nest survival.

The mountain plover is a native species of the shortgrass prairie whose breeding range is primarily in Colorado, Montana, New Mexico, and Wyoming (Graul and Webster, 1976; Knopf, 1996). The continental population of the mountain plover has declined by as much as 63% since the mid 1960s (Knopf, 1994, 1996), which has generated much interest in the reproductive success of this species. Mountain plovers nest in areas with sparse vegetation with ≥30% bare ground (Knopf and Miller, 1994; Knopf and Rupert, 1999). Mountain plovers, like many other grassland birds (Yosef, 1994; Howard et. al., 2001), can often be observed nesting on or near anthropogenic edges across rangeland and crop-field habitats within the native shortgrass prairie biome. By understanding the impact of anthropogenic edge effects on the nesting success of the mountain plover, the development of future management practices can be focused on the habitat needs of the mountain plover. The objective of our study was to evaluate the impact of anthropogenic edges, such as crop-field perimeters, on mountain plover nesting success.

METHODS—From approximately mid April to mid July in 2003 and 2004, we located mountain plover nests on crop fields and rangelands in Cheyenne, El Paso, Kiowa, Lincoln, Pueblo, and Weld counties, Colorado. The study sites occurred on both private and public lands comprised primarily of rangeland fragmented by various types of crop fields. A total of 68 crop fields were searched during our study period. Over 62% (42 of 68) of the crop fields consisted of dryland wheat interspersed with fallow strips. The remaining 38% (26 of 68) of crop fields were either dryland wheat or fallow strips. The rangeland habitat was primarily native shortgrass prairie dominated by blue grama (*Bouteloua gracilis*), buffalo grass (*Buchloe dactyloides*), and other xeric grasses.

Once nests were located, distances to the nearest anthropogenic edge were measured using laser range finders (Bushnell Laser Rangefinder Model 500, Bushnell Performance Optics, Overland Park, Kansas). Anthropogenic edges consisted of crop-field perimeters; paved or highly maintained gravel roads; or major changes in vegetation structure and height due to manipulative management practices, such as burning regimes or domestic animal grazing. Nest success was determined by observing hatching or examining the contents of the nest for tiny fragments of eggshell resulting from the pipping process (Mabee, 1997). We used logistic regression to test for the effect of distance to edge on mountain plover nest success. We developed a candidate set of 5 a priori models. Model S was a time-independent model; nest success was held constant. Model S_{EDGE} allowed for the effect of distance to nearest edge. Because the distance to an edge might be a result of the type of habitat (rangeland or crop field) in which a plover nests, we developed Model $S_{EDGE+HABITAT}$. Dreitz (2005, unpubl. report, Colorado Natural Heritage Program, Colorado State University, Fort Collins) suggested that habitat does not influence nest success of mountain plovers. Considering that the study by Dreitz (2005) encompassed a larger temporal and spatial extent in eastern Colorado than this study, we did not test for the influence of habitat (Model $S_{HABITAT}$) on nest success. Model $S_{YEAR+EDGE}$ determined if the impact of edges on nest success had an additive yearly effect. Finally, we developed Model $S_{YEAR+EDGE+HABITAT}$ to examine additive effects of habitat types and years with edge effects on nest success were the best approximation of our data.

Model selection criterion was based on Akaike's Information Criterion (AIC) (Akaike, 1973) corrected for small sample size (AIC$_c$; Hurvich and Tsai, 1989; Burnham and Anderson, 2002). The goal of model selection is to identify a biologically meaningful model that explains much of the observed variability by including enough parameters to avoid substantial bias, but not so many parameters that precision is lost (Burnham and Anderson, 2002). We used 2 additional measures to provide insight into the amount of uncertainty in model selection. The first measure is the difference in AIC$_c$ between the best approximating model and all other models (Lebreton et al., 1992; Burnham and Anderson, 2002), termed ΔAIC$_c$. The second measure calibrates models to provide relative plausibility by normalizing each model on the basis of its ΔAIC$_c$ value, termed model weight (Anderson and Burnham, 1999; Burnham and Anderson, 2002).
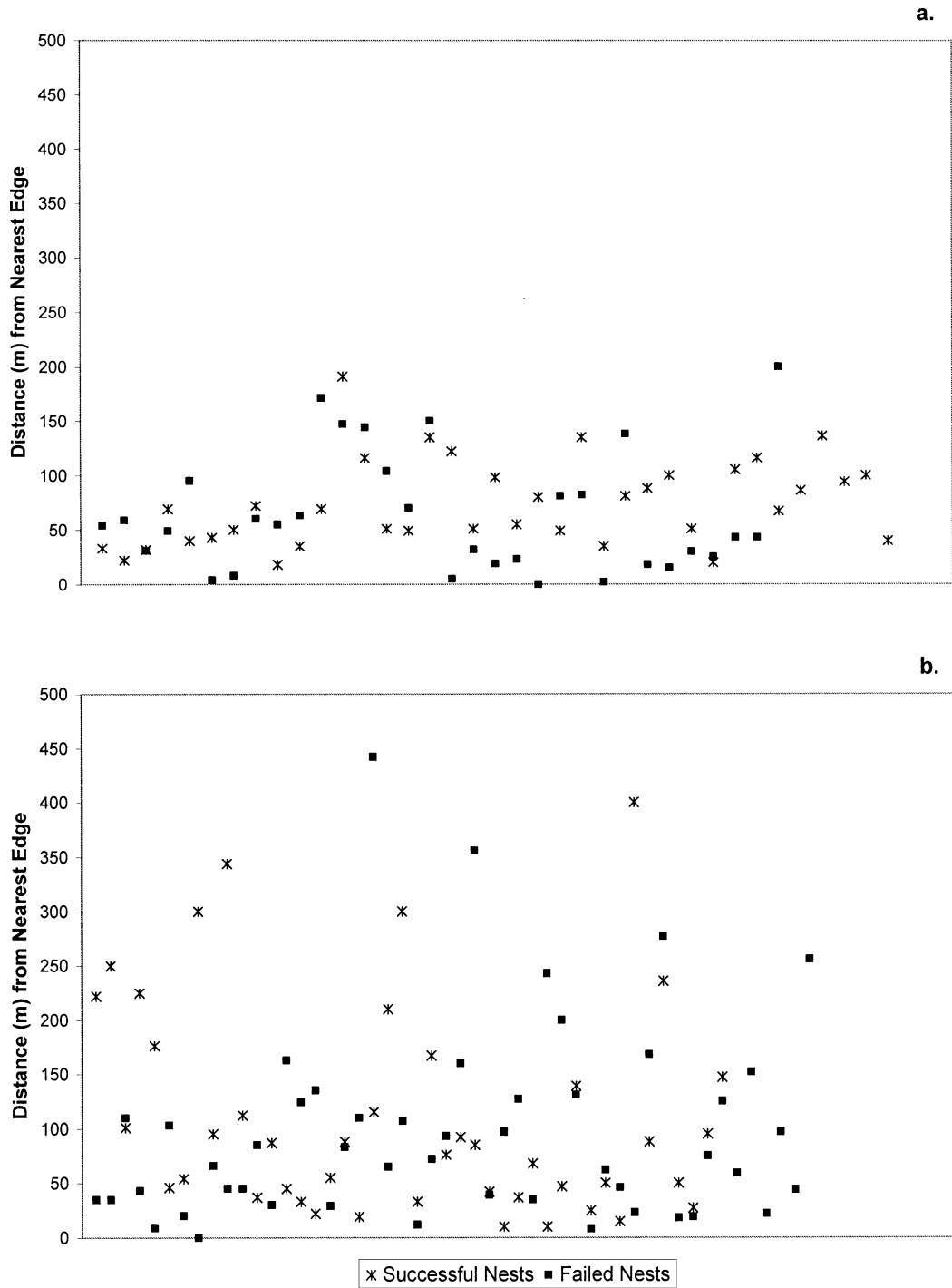
a.

b.

x Successful Nests ■ Failed Nests

FIG. 1—Nest success of mountain plovers (*Charadrius montanus*) relative to distance from nearest edge in crop-field (a) vs. rangeland (b) landscapes in eastern Colorado.

TABLE 1—Logistic regression models examining the impacts of anthropogenic edges on mountain plover (*Charadrius montanus*) nesting success. Models are listed in ascending order by lowest Akaike's Information Criteria (AIC_c) value and ΔAIC_c.

Model	AIC_c	ΔAIC_c	Model weight	Number of parameters	Deviance
S	411.796	0.00	0.349	1	409.794
$S_{EDGE+HABITAT}$	412.193	0.40	0.286	3	406.179
S_{EDGE}	413.272	1.48	0.167	2	409.265
$S_{YEAR+EDGE+HABITAT}$	413.926	2.13	0.120	4	405.903
$S_{YEAR+EDGE}$	414.809	3.01	0.077	3	408.795

RESULTS—In 2003 and 2004, we located 163 mountain plover nests on rangeland and crop-field habitats. Of the 68 crop fields we searched for mountain plover nests, most (97%) fields contained at least one nest. Of the 163 nests in the study, 81 (50%) hatched successfully and the other 82 nests (50%) failed due to predation (87%) or abandonment (13%). Nests ranged from 0 to 442 m from the nearest anthropogenic edge. For both habitats, the successful nests were a mean distance from an anthropogenic edge of 93.94 m ± 8.87 *SE,* and failed nests were 84.39 m ± 8.95 *SE* from the nearest anthropogenic edge. Nests that were successful in crop fields (54%) were a mean distance of 73.89 m ± 6.31 *SE* from the nearest edge, and successful nests found on rangeland (47%) had a mean distance of 110.80 m ± 9.88 *SE* from the nearest edge (Fig. 1). Failed nests on crop fields had a mean distance from the nearest edge of 63.13 m ± 7.38 *SE,* and failed nests on rangeland a mean distance of 98.00 m ± 9.52 *SE* from the nearest edge (Fig. 1).

Based on our model selection criterion, the most parsimonious model that best explained the data was the model that contained no effects, *S* (Table 1). This model was followed by model $S_{EDGE+HABITAT}$, which included the effect of distance from an edge. The logistic regression coefficient for the effect of distance from the nearest edge was 0.13 ± 0.12 *SE,* which suggested that nests farther from edges might be more successful. However, the standard error for the edge coefficient was large and the 95% confidence interval (−0.08, 0.35) encompassed zero and was not symmetrical around zero, suggesting the effect was minimal. The remaining models we developed did not im-prove our ability to assess edge effects on mountain plover nest success.

DISCUSSION—The results of our study suggested that anthropogenic edges in fragmented landscapes had minimal or no effect on the nest success of mountain plovers in the short-grass prairie biome of Colorado. Our findings indicated that nests that were farther away from edges were as successful as those closer to edges. The nest success relative to the distance from the nearest edge was similar between rangeland and crop-field habitats, and year-to-year differences were insignificant. The results of this study seem to be consistent with other studies that reported no impact of edge effects on nest survival (Vickery et al., 1992; Keyser et al., 1998; Rivers et al., 2003), including a study in shortgrass prairie landscape (Howard et al., 2001).

The influence of anthropogenic edges might not directly impact the nest success of mountain plovers, but rather might indirectly influence other factors contributing to nest failure. These factors include the quantity of available habitat for nesting and the concentration of predators into these areas. Mountain plovers prefer landscapes that provide them with high visibility (with short vegetative heights and ≥30% exposed bare ground) for nest construction (Knopf and Miller, 1994; Knopf and Rupert, 1999). The fragmentation of these preferred landscapes reduces the quantity of nesting habitat.

Nest predation was the main cause of failure in our study. The predators of the short-grass prairie that most impact mountain plover nests include coyote (*Canis latrans*), swift fox (*Vulpes velox*), badger (*Taxidea taxus*), and thir-

teen-lined ground squirrel (*Spermophilus tride-cemlineatus*) (Knopf, 1996). Although predators often concentrate their foraging activities and movements along habitat edges in other biomes (Yahner and Wright, 1985), these predators of shortgrass prairie apparently do not hunt along anthropogenic edges selectively.

We conclude that anthropogenic edges have minimal or no effect on the nest success of mountain plovers in shortgrass prairie landscapes. The shortgrass prairie, like many other grassland ecosystems, has become highly fragmented over the past century. The preservation of these grassland ecosystems is not only important to the breeding ecology of the mountain plover, but to all grassland bird species that have experienced dramatic population declines. Unlike some grassland avian species, the plover readily nests in crop fields, and our finding that nest success of the plover was independent of distance to an anthropogenic edge might make the mountain plover a unique avian species of this landscape. The significance of other factors, such as landscape heterogeneity and patch size, on mountain plover nest success remain to be examined.

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