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EFFECTS OF RECREATIONAL TRAILS ON WINTERING DIURNAL RAPTORS ALONG RIPARIAN CORRIDORS IN A COLORADO GRASSLAND

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ABSTRACT.—Different types of human activity may influence raptors in various ways, potentially affecting their abundance, distribution, habitat use and productivity. We studied the effects of recreational trails on wintering raptor populations in grasslands of eastern Boulder County, Colorado, from December 1995–March 1996. We conducted strip transects to survey raptor populations at six study sites. All sites consisted of short and/or tallgrass prairie, and all contained a riparian corridor. Three sites contained recreational trails running adjacent to the riparian corridor (trail), while three sites contained no trails (control). Species richness, abundance and perch use were compared between control and trail sites. Species richness was consistently greater in control sites. Abundance of total raptors observed was greater in control sites. Abundance of Bald Eagles (*Haliaeetus leucocephalus*) was greater in control sites, while abundance of Red-tailed Hawks (*Buteo jamaicensis*) was similar for control and trail sites. Perching distances from riparian corridors were greater in trail sites than in control sites. In addition, raptors perched along riparian corridors more frequently in control sites. Results of this study suggest that recreational trails may have affected habitat selection of some raptor species in this grassland ecosystem.

KEY WORDS: *raptors; human activity; recreational trails; perch use; riparian corridors; grasslands.*

Corredores ribereños en un pastizal de Colorado

RESUMEN.—Diferentes tipos de actividad humana pueden influenciar a las aves rapaces de varias maneras; potencialmente afectando su abundancia, distribución, uso de habitat, y productividad. Estudiamos los efectos de los senderos recreativos en las poblaciones de aves rapaces del este del Condado de Boulder, Colorado desde Diciembre 1995–Marzo 1996. Efectuamos transectos lineares para documentar las poblaciones de aves rapaces en seis áreas de estudio. Los sitios de estudio fueron en pastizales cortos y/o altos que contenían un corredor ribereño (sendero), mientras que tres sitios no contenían ningún sendero (control). La riqueza de especies, abundancia, utilización de perchas fueron comparadas entre el control y los sitios con senderos. La riqueza de especies fue consistentemente mayor en los sitios de control. La abundancia total de aves rapaces observadas fue mayor en los sitios de control. La abundancia de águilas calvas (*Haliaeetus leucocephalus*) fue mayor en los sitios de control, mientras que la abundancia de *Buteo jamaicensis* fué similar para ambos sitios. La distancia entre perchas de los corredores ribereños fue mayor en los sitios con senderos que en los sitios de control. Adicionalmente, las aves rapaces utilizaron con mas frecuencia las perchas a lo largo de los corredores ribereños en los sitios de control. Los resultados de este estudio sugieren que los senderos recreativos pudieron haber afectado la selección de habitat de algunas especies de aves rapaces en este ecosistema de pastizales.

[Traducción de César Márquez]

Raptor abundance and distribution can be affected by many factors, including prey availability (Howard and Wolfe 1976, Preston and Beane 1996, Gietzen et al. 1997, Plumpton and Andersen 1998), vegetation (Wakeley 1978), and the availability of perch sites (Stahlecker 1978, Jones 1989, Janes 1994, Widen 1994). While open space areas and green belts provide potential habitats for grassland raptors in urban environments (Cringan and Horak 1989), such areas are also characterized by a variety of human activities. These human activities may affect raptor habitat use and may influence raptor abundance.

Certain effects of human activity on raptor pop-

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ulations have been extensively studied, yet with equivocal results. For example, Stalmaster and Newman (1978) found that Bald Eagles (*Haliaeetus leucocephalus*) avoid areas of high human activity. Smallwood et al. (1996) also observed many species of raptors avoiding human settlements. However, other research suggests that human activity may not affect raptor distribution and productivity (Mathisen 1968, Grier 1969, Preston and Beane 1996). Human activity may affect raptors in different ways, and some types of human activity may affect raptors more than others (Preston and Beane 1996). For instance, Fraser et al. (1985) found that nesting success of Bald Eagles was not affected by human activity; however, eagles did choose nest sites far from human development. Both Skagen (1980) and Holmes et al. (1993) found that raptors were more sensitive to humans approaching on foot than to humans approaching in vehicles.

We studied the potential effects of recreational trails on wintering grassland raptor populations in Boulder County, Colorado, during the winter of 1995–96. We compared species richness, abundance, and perch use along riparian corridors in areas with trails adjacent to corridors and areas without trails. We also compared distances between raptor perches and riparian corridors in areas with and without trails along corridors.

STUDY AREA AND METHODS

We studied raptors in the grasslands of east Boulder County, Colorado (40°00′N, 105°20′W) from December 1995 until March 1996. We chose six study sites of similar habitat on the City of Boulder Open Space property. All study sites contained riparian corridors, with adjacent vegetation consisting of short and/or tallgrass prairie. Previous research in this region showed a high correlation of raptor abundance to perch sites (Jones 1989). We chose sites containing riparian corridors with numerous potential perches to control for perch availability. All sites also contained many perches outside the riparian area, at a wide range of distances from the corridor (0–440 m). Three sites included recreational trails running adjacent to the riparian corridor (trail sites), within 15 m of the corridor at all locations. Three sites had no trails (control sites). Recreational trails were 2–3 m in width and composed of gravel. Throughout the study period, trails were used frequently each day by hikers and/or bicyclists, but were closed to vehicle use. Study site size was determined by open space boundaries, and was estimated using 7.5 min U.S. Geological Survey topographic quadrangle maps. Overall, trail sites included 72 ha ($\bar{x}$ = 23.9 ± 6.1, ±SE) of grassland and riparian habitat, and control sites included 54 ha ($\bar{x}$ = 18.0 ± 5.1). Predominant vegetation along riparian areas included cottonwoods (*Populus sargenti*), willows (*Salix* spp.) and Russian olives (*Elaeagnus angustifolia*).

Potential prey items for raptors included lagomorphs (*Sylvilagus* spp. and *Lepus* spp.), black-tailed prairie dogs (*Cynomys ludovicianus*), and other small rodents (e.g., *Microtus ochrogaster*). None of the sites contained prairie dog colonies, but colonies were potentially within the home ranges of raptors seen on each of our study sites. We estimated the distance from the center of each site to the edge of the closest prairie dog colony, based on 1997 Boulder County Open Space digitized maps. The average distance to prairie dog colonies for control sites (2.3 ± 0.6 km) and trail sites (1.9 ± 0.3 km) did not differ statistically (two-tailed, two sample *t*-test; $t = 0.61$, df = 4, $P = 0.58$).

We conducted strip transects to survey raptor populations twice a week at each site from 0700–1130 H (MST). Each transect was 350 m long, parallel to the riparian corridor, at distances of 5–30 m from each corridor. Transect width was delineated based on public land boundaries, ranging from 315–450 m. For each survey, a single observer walked slowly along the transect for 15 min, recording the species and number of raptors observed within the study site, the type of perch used by perching raptors, and mapping perches used by raptors. Perch distances (i.e., distance from the perch used to the edge of the riparian corridor) were later measured when raptors were not present. We rotated the order of sites surveyed each day to control for survey time differences. We did not conduct surveys during inclement weather (e.g., snowstorms) because inclement weather could affect the detectability of raptors and there was probably less recreational activity during inclement weather. We conducted a total of 77 surveys, ranging from 10–15 for each site. We conducted 41 surveys at trail sites and 36 surveys at control sites.

We sampled vegetation along the riparian corridors and in surrounding grassland vegetation at each site. To sample riparian corridors, we walked one 300 m transect running along the grassland/riparian edge at each site, recording the species and diameter breast height (dbh) of the closest tree in each cardinal direction at 50 m intervals ($N = 24$ for each site). For sampling grassland characteristics at each site, we walked four 300 m transects running parallel to each riparian corridor at distances of 50, 100, 150, and 200 m from the edge of the corridor. Every 50 m we recorded the coarse defining characteristic of the vegetation (shortgrass prairie, tallgrass prairie, broad-leaf shrub, tree, bare ground) and visually estimated the percent ground vegetation cover within a 1 m^2 radius aluminum ring placed on the ground ($N = 24$ for each site).

Riparian corridors provided a high, uniform density of potential perches at each of the six sites. We quantified surrounding perch density (i.e., not including the riparian perch density) for each site by counting the total number of natural perches (i.e., trees, shrubs and snags) ≥2 m in height (Janes 1985) at each study site, and dividing this total by the area of the site (in ha). We did not include perch types other than trees and shrubs (e.g., utility poles), because we only observed raptors using trees and shrubs for perching in our study sites.

To directly compare surveys conducted in study sites of differing size, we analyzed the abundance of raptors as the number of raptors observed per km^2 surveyed, and

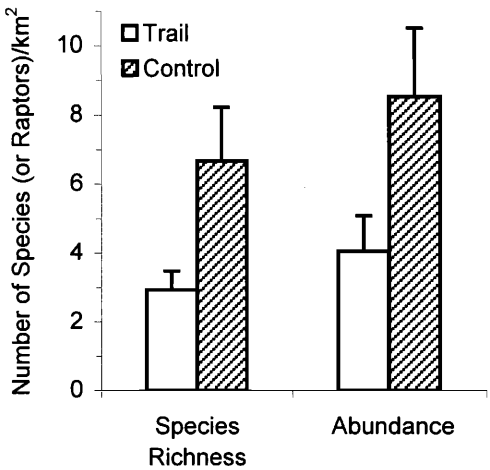

Figure 1. The total abundance and species richness ($\bar{x} \pm$ SE) of all raptors observed, December 1995–March 1996. Abundance is defined as the number of raptors observed per km² surveyed. Species richness is defined as the number of species observed per km² surveyed.

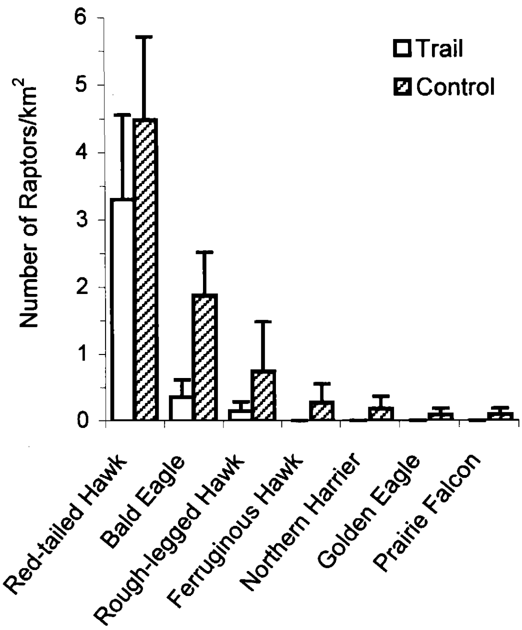

Figure 2. Abundance indices ($\bar{x} \pm$ SE) of each species observed at trail and control sites, December 1995–March 1996. Abundance is defined as the number of raptors observed per km² surveyed.

species richness as the number of species observed per km² surveyed. Both species richness and abundance indices were analyzed using two-way analysis of variance (ANOVA) with a repeated measures design, using transect type (trail or control) as one factor and sampling date as the repeated measure. Using sampling date as a repeated measure allowed us to investigate any potential temporal differences in abundance and species richness within the sampling period. We used the procedure, PROC MIXED on SAS statistical software, to run the repeated measure ANOVA analyses, because this procedure can accomodate unbalanced repeated measure designs (SAS 1997).

The data collected for perching distances from riparian corridors were not normally distributed and therefore were analyzed using a Kruskal-Wallis nonparametric test (with Chi-square approximation, SAS 1989). We investigated potential temporal differences in perching distance from corridors by regressing the response variable, perching distance, on sampling date (PROC GLM, SAS 1989). The frequency of use of riparian areas for perching was analyzed using a χ^2 contingency table, with transect type (trail or control) as one criterion, and number of perching events on and off riparian areas as a second criterion.

We analyzed dbh, percent ground cover, and perch availability for trail and control sites using one way ANOVAs. Species composition of the riparian canopy was analyzed using a χ^2 goodness-of-fit test against the null expectation of equal numbers of trees in trail and control sites. For all analyses, we chose $\alpha = 0.05$. Arithemetic means ±SE are reported.

RESULTS

Species Composition. Seven species of raptors were observed during our study, including (in decreasing frequency of observation): Red-tailed Hawks (*Buteo jamaicensis*), Bald Eagles, Rough-legged Hawks (*Buteo lagopus*), Ferruginous Hawks (*Buteo regalis*), Northern Harriers (*Circus cyaneus*), Golden Eagles (*Aquila chrysaetos*) and Prairie Falcons (*Falco mexicanus*). Seven species were observed in control sites, while only three were observed in trail sites. We observed a consistent pattern of greater species richness in control sites (ANOVA: $F = 12.67$, df = 1, $P < 0.001$) (Fig. 1).

Raptor Abundance. Abundance indices for total raptors were greater at control sites (ANOVA: $F = 9.70$, df = 1, $P = 0.003$) (Fig. 1). Abundance indices for Red-tailed Hawks were similar for control and trail sites (ANOVA: $F = 1.52$, df = 1, $P = 0.224$) (Fig. 2). Bald Eagle abundance indices were greater in control sites (ANOVA: $F = 6.25$, df = 1, $P = 0.016$). We pooled all other species of raptors, due to small sample size. Abundance indices for these raptors were greater in control sites (ANOVA: $F = 7.29$, df = 1, $P = 0.010$). For all abundance and species richness analyses, sampling date as the repeated measure was not significant ($P \geq 0.15$), and there were no statistically significant interactions among the two factors ($P \geq 0.3$), suggesting

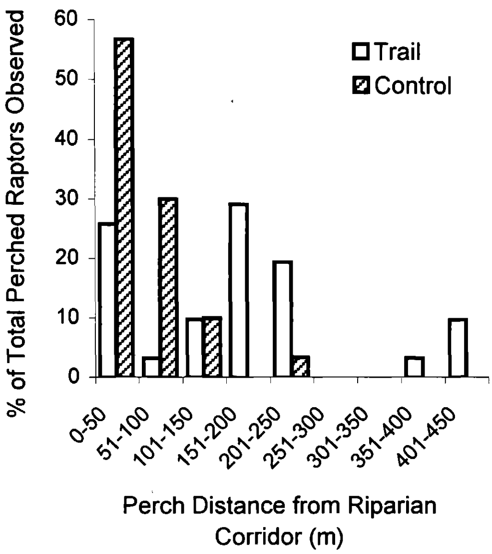

Figure 3. The distribution of raptor perching distances from riparian corridors in trail and control sites, December 1995–March 1996. Perch distance was measured from the perch used to the riparian corridor (m).

both the abundance and species richness of raptors did not change temporally during the sampling period.

Perch Use. During the study period, 60.2% ($N = 56$) of all raptors were observed perching. In all observations, raptors used deciduous trees and snags for perching, even though fence posts, power lines and utility poles were present at the study sites. The distribution of perching distances from riparian corridors was different in control and experimental sites (Fig. 3), where the mean perch distance from riparian corridors was significantly greater in trail sites (155.9 ± 28.0 m) than in control sites (42.3 ± 9.8 m) (Kruskal-Wallis: $\chi^2 = 18.97$, df = 1, $P < 0.001$). In addition, raptors perched along riparian corridors significantly more often in control sites (54.8%, $N = 17$) than in trail sites (24.0%, $N = 6$) ($\chi^2 = 5.61$, df = 1, $P = 0.018$). Raptors perching on riparian corridors were often flushed by the observer conducting the transect, due to the proximity of the walking transect to the riparian area. However, this occurred in both trail and control sites, and did not appear to change overall habitat use by raptors. Throughout the study period, there was no evidence for a temporal change in perching distances from riparian corridors in control ($F = 0.12$, df = 1, 27, $P = 0.74$) and trail sites ($F = 0.62$, df = 1, 24, $P = 0.44$).

Table 1. Habitat characteristics ($\bar{x}$ ± SE) for trail and control sites, Boulder County, CO, December 1995–March 1996. For riparian canopy composition, each species is reported as the percent occurrence sampled at control and trail sites ($N = 72$). Percent ground cover is the percent sampled within 1 m^2 radius points at control and trail sites ($N = 72$).

SITE CHARACTERISTICS	TRAIL	CONTROL
Riparian canopy:		
Populus sargenti	45.8 ± 9.6	37.5 ± 16.7
Salix spp.	26.4 ± 8.4	33.3 ± 7.2
Elaeagnus angustifolia[a]	6.3 ± 3.7	23.6 ± 12.1
Dbh (cm)	26.4 ± 4.3	25.5 ± 1.8
Grass cover (%)	81.4 ± 8.7	83.9 ± 0.7
Bare ground (%)	14.4 ± 7.4	15.7 ± 0.6
Shrub cover (%)[a]	4.2 ± 1.5	0.4 ± 0.2
Perches/ha	1.7 ± 0.3	2.7 ± 0.8

[a] $P < 0.05$.

Habitat Sampling. Three species of trees, *Populus sargenti, Salix* spp., and *Elaeagnus angustifolia* comprised 84.4% ($N = 123$) of all trees sampled along riparian corridors at all sites (Table 1). *P. sargenti* did not differ in the percent sampled between control and trail sites ($\chi^2 = 0.60$, df = 1, $P = 0.438$), nor did the total number of *Salix* spp. ($\chi^2 = 0.86$, df = 1, $P = 0.354$). However, the percent sampled of *E. angustifolia* was greater in control sites, due to the riparian canopy of one site being predominately comprised of this species ($\chi^2 = 4.02$, df = 1, $P = 0.045$). The dbh of trees sampled along each riparian corridor did not differ between control and trail sites (ANOVA: $F = 0.08$, df = 1, $P = 0.777$).

The surrounding vegetation at five of the sites consisted primarily of grazed shortgrass prairie. One trail site consisted primarily of tallgrass prairie. The percent of ground cover sampled was predominately either grass, bare ground (no cover), or broad-leaf shrubs. Grass cover did not differ between control and trail sites (ANOVA: $F = 0.42$, df = 1, $P = 0.520$), nor did the percent of bare ground (ANOVA: $F = 0.13$, df = 1, $P = 0.723$). Shrub cover was greater at trail sites than at control sites (ANOVA: $F = 5.51$, df = 1, $P = 0.020$). However, shrub cover comprised <5% of all ground cover sampled (Table 1). The surrounding perch densities were similar between control and trail sites (ANOVA: $F = 1.59$, df = 1, $P = 0.276$).

DISCUSSION

Human activity associated with recreational trails in our study area may have affected wintering raptor populations, in terms of species richness, abundance and perch use. Species richness was consistently greater in control areas, with few raptors other than Red-tailed Hawks being observed at trail sites. The abundance of total raptors was more than three times greater in areas without trails, and those raptors observed in areas containing trails perched farther from riparian corridors. Habitat characteristics at trail and control sites were generally similar in both riparian canopy composition and dbh, and in the surrounding grassland habitat. Perch density was also similar in control and trail sites. A predominant difference in trail and control sites was the presence or absence of a recreational trail. Prior research has indicated that humans approaching on foot may affect raptors more than vehicle disturbance (Holmes et al. 1993), but no research to date has correlated the potential effects of recreational trails on raptor distribution and abundance.

The potential effects of recreational trails on raptors may be species-specific. Abundance of Bald Eagles was greater at control areas. Bald Eagles avoiding areas of human activity has been documented (Stalmaster and Newman 1978, Fraser et al. 1985), but we are unaware of any previous studies documenting recreational trail effects on Bald Eagles. Abundance of Red-tailed Hawks did not differ between control or trail sites. This was the only species of raptor commonly observed in trail areas. Red-tailed Hawks are generalist raptors, both in diet (Errington 1933, Hansen and Flake 1995) and in distribution (Brown and Amadon 1968). Knight and Kawashima (1993) observed Red-tailed Hawks exploiting power lines more often than expected, while Minor et al. (1993) found no significant differences in density and productivity of Red-tailed Hawks in urban and nonurban environments. In Boulder County, both wintering and breeding distributions of Red-tailed Hawks have not been sensitive to landscape urbanization (Berry et al. 1998). These studies suggest that Red-tailed Hawks have adapted to human development and associated activity. Our study suggests that Red-tailed Hawks tolerate human activity along recreational trails. Although our sample size was small for species of raptors other than Red-tailed Hawks and Bald Eagles, overall these species were more abundant in areas with no recreational trails.

Perch use in control and trail sites varied greatly in our study, where the mean perch distance of raptors from riparian corridors was greater in trail sites. Although the overall density of perches outside of the riparian areas was similar between control and trail sites, we did not quantify raptor perching distance in relation to the distribution of potential perches from corridors. Nevertheless, raptors did use riparian corridors for perching more in control areas than in trail areas. Other research also indicates that riparian areas are used frequently by raptors, both for wintering habitat (Lingle 1989, Smallwood et al. 1996) and for nesting (Hansen and Flake 1995). Our study suggests both that riparian corridors are important areas for wintering raptors and that trails may displace raptor perch use away from riparian habitat.

One potential reason for differences in raptor abundance between trail and control sites could be from the increased shrub cover on trail sites. An increase in shrub cover could affect hunting strategies of raptors and could conceal prey, making prey less vulnerable (Craighead and Craighead 1956, Wakeley 1978). However, because shrub cover comprised <5% of all ground vegetation sampled, it is unlikely that this variable would control for the large differences of raptor abundance we observed.

The distribution of prey items may affect raptor distribution (Plumpton and Andersen 1998). We did not quantify prey availability at our sites. Prairie dog colonies, which are an important prey base for Bald Eagles, Red-tailed Hawks, and Ferruginous Hawks (Jones 1989), were not present at any of our sites. Distances to the closest prairie dog town were similar for both control and trail sites. Because distances were similar among sites, we believe that prey availability for these larger raptors did not confound our results. If these species were concentrating hunting efforts on prairie dogs, then foraging activities may have been infrequent in our sites. Smaller rodents, such as voles (e.g., *Microtus ochrogaster*), are important prey items for Rough-legged Hawks and Northern Harriers. Although vegetation was generally similar for control and trail sites, we cannot ascertain if vole populations were different among sites.

Because of large home ranges and movement ability of wintering raptors, effects of human activity and urbanization on wintering raptors should be viewed with a landscape context (Berry et al. 1998). In areas of human activity, other factors affecting wintering raptors in the landscape could be mitigated, such as enhancing foraging opportunities (Preston and Beane 1996) or increasing perch availability (Widen 1994).

Buffer zones have been suggested as a means to reduce conflicts between human activities and raptor populations (Stalmaster and Newman 1979, Knight and Skagen 1988, Holmes et al. 1993). Although prior research has documented potential buffer zones for wintering raptors (Holmes et al. 1993), future research should focus on determining appropriate buffer zones from recreational trails and other specific types of human activity during the nonbreeding season. The type of activity should be considered because different effects could potentially occur from different types of activity (Preston and Beane 1996). By integrating perch availability (e.g., Marion and Ryder 1975), habitat type, prey abundance, and types of human activity, suitable indices for predicting optimal raptor environments and also appropriate buffer zones may be determined.

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