RESPONSES OF RAVEN AND RED-TAILED HAWK POPULATIONS TO LINEAR RIGHT-OF-WAYS

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Abstract: Linear right-of-ways are ubiquitous in the United States and may alter vertebrate populations, yet they remain little studied. We examined the relationship between these areas and common raven (*Corvus corax*) and red-tailed hawk (*Buteo jamaicensis*) populations in the Mojave Desert of California by flying helicopter transects along paved highways, transmission powerlines, and control areas (i.e., no highways nor powerlines within 3.2 km). Ravens were equally ($P > 0.10$) common along highway and powerline transects, but were more ($P < 0.02$) abundant along these transects than along controls. Raven nests were more ($P < 0.0001$) abundant along powerlines than along either highways or controls. Red-tailed hawks and their nests were more ($P < 0.0001$) abundant along powerlines than along either highway or control transects. Neither species used potential nest or perch sites in proportion to their availability. Ravens used power poles as nest sites more ($P < 0.001$) than expected based on availability, but not ($P > 0.10$) as perch sites. Red-tailed hawks used power poles for both nesting and perching more ($P < 0.001$) than expected based on availability. Our data suggest that ravens are more abundant along highways because of automobile-generated carrion, whereas both ravens and red-tailed hawks are more common along powerlines because of the presence of superior perch and nest sites. We recommend that land managers evaluate possible changes in vertebrate populations and community-level interactions when assessing the effects of future linear right-of-way projects.

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There are >5 million km of highways in the conterminous United States, which collectively occupy almost 9.5 million ha of land (Asplundh Environ. Serv. 1978). Likewise, there are >0.5 million km of powerlines in the United States that occur on almost 2.1 million ha of land. Although diverse in form and function, such linear right-of-ways share some features in common. Both are relatively 1-dimensional, having great length relative to width or height. Additionally, both are commonly associated with human activity, either through direct use or maintenance. Although these energy and transportation conveyance systems are commonplace in many areas of the world, their impacts on vertebrate populations are poorly understood. Thus, we studied common ravens and red-tailed hawks (hereafter called red-tail) in the Mojave Desert of California to determine if their populations were related to specific types of right-of-ways (i.e., highways and powerlines). We also examined their patterns of perch- and nest-site use relative to these right-of-ways.

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STUDY AREA

The study area encompassed approximately 45,000 km² of the Mojave Desert, San Bernadino County, California (Fig. 1). Elevations ranged from 90 to 2,400 m above sea level; most of the desert is above 600 m in elevation. Mountain ranges are common and run north–south. The climate is seasonally severe, being hot (>37 C) in summer and cold (8–18 C) in winter. Average rainfall varies between 25 and 114 mm annually with the greatest amount of precipitation occurring from December through March.

The boundaries of the Mojave Desert closely parallel the distributional limits of the Joshua tree (*Yucca brevifolia*) (Jaeger 1957). The major floral communities consist of alkali sinks, creosote bush (*Larrea divaricata*) scrub, shadscale (*Atriplex brevifolia*) scrub, Joshua tree woodland, and pinyon (*Pinus* spp.)-juniper (*Juniperus* spp.) woodland (Munz and Keck 1959).

METHODS

We designed our study to minimize the confounding influences of towns, landfills, and other human-associated factors that might be related to either raven or red-tail numbers. Transects were established along transmission powerlines, paved highways, and in areas with neither pow-

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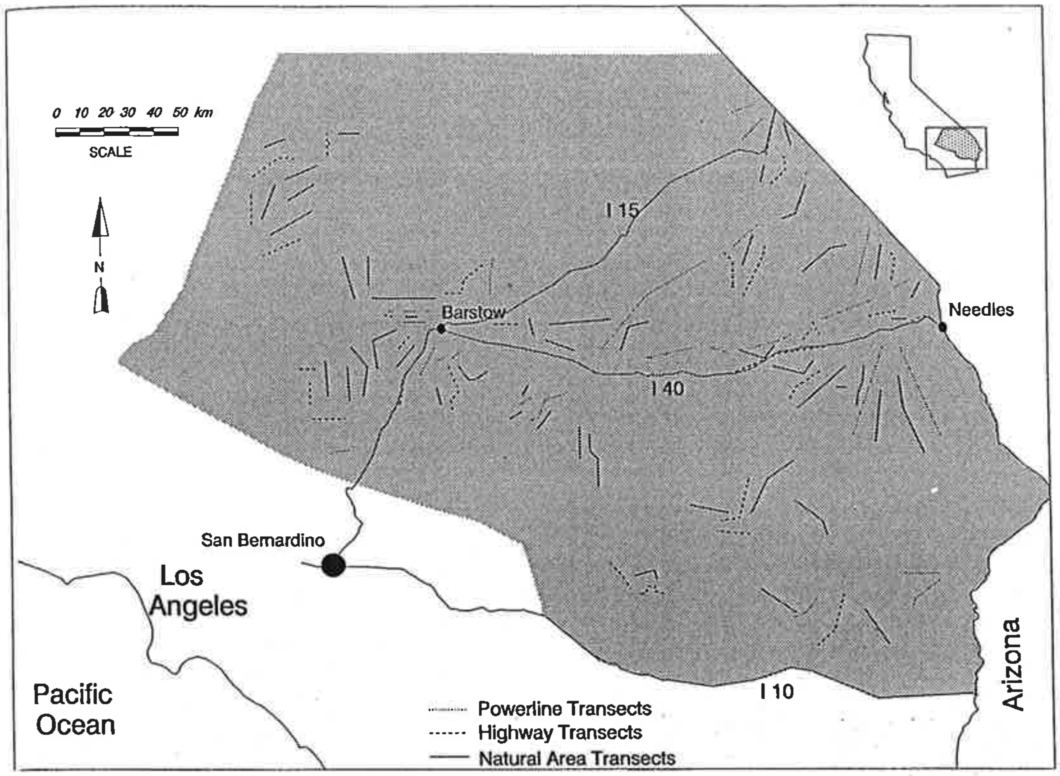

Fig. 1. Study area (shaded) showing powerline, highway, and natural-area transects, Mojave Desert, California, 1989.

erlines nor highways <3.2 km from any point of the transect center (hereafter called controls). Powerline and highway transects also were >3.2 km away from other highways or powerlines. We chose transects so they occurred throughout the study area and >3.2 km from any urban center (because ravens congregate in urban areas [R. L. Knight, unpubl. data]). We chose 3.2 km because it was the maximum distance whereby we were able to obtain adequate numbers of transects to survey and because it minimized duplication of raven and red-tail counts based on our knowledge of their home range size (R. L. Knight, unpubl. data; Johnsgard 1990:242). Controls were chosen to best duplicate the habitat and elevation characteristics of powerline and highway transects.

Ravens and red-tails were surveyed along transects from a Bell Jet Ranger helicopter, between 0620 and 1930 hours, from 14 May to 1 June 1989. Helicopters are useful in surveying animals that occur singly or in small groups and that can be observed easily from the air (e.g., Johnson et al. 1989). The helicopter was flown along the center of the transect at approximately 40 kmph (range = 35–45 kmph) and approximately 65 m (range = 55–75 m) above the ground while 2 observers, other than the pilot, surveyed an area 400 m on either side of the cockpit. Each observer scanned a 90° arc away from, but including, the center of the transect. This allowed the observers to detect the bird's behavior (e.g., perching, flying) in advance of the approaching helicopter.

We recorded the number and behavior (i.e., perched, flying, feeding, or nesting) of ravens and red-tails seen on each survey, as well as the location of each sighting (on U.S. Geol. Surv. maps). If a bird was perched, the type of structure (i.e., natural or artificial) also was recorded. Upon completion of a transect, it was reflown and we recorded the number and type of potential perch and nest sites within 400 m of the transect center. Potential perch and nest sites were listed as either natural (trees, cliffs), or artificial (transmission tower, telephone pole, sign, highway overpass, other). A potential perch site was defined as any structure (natural or artificial) >3 m in height. This height limitation precluded fence posts from consideration, how-

Table 1. Numbers of common ravens and red-tailed hawks seen along 3 transect types, Mojave Desert, California, May–June 1989.

No./100 km	Species	Control $\bar{x}$	Control SD	Powerline $\bar{x}$	Powerline SD	Highway $\bar{x}$	Highway SD
Sightings[a]	Raven	3.9	7.8	10.6	20.3	13.3	21.6
	Red-tail	0.8	2.4	13.6	13.1	1.3	3.4
Birds	Raven	6.6	18.1	73.5	228.9	36.5	92.4
	Red-tail	0.8	2.4	14.5	13.1	1.3	3.4
Nests	Raven	0.1	0.4	4.2	7.4	1.7	5.7
	Red-tail	0.1	0.7	6.7	8.6	0.0	0.0

[a] A sighting may contain more than a single bird.

ever, we never saw ravens or red-tails utilizing these structures. Potential nest sites were defined as natural structures: trees >5 m in height, or cliffs >5 m in height with >1 ledge with a horizontal surface area of >0.3 m^2; and artificial structures: any unoccupied human-built structure >5 m in height with >1 ledge with a horizontal surface area of >0.3 m^2, or telephone poles or power poles with cross structures that could support a horizontally placed stick >30 cm. All powerline towers met the criteria for nest sites. Nest-site criteria were derived from our unpublished information of raven and red-tail nests and other sources (Bent 1961, 1964; Knight and Call 1980).

Because our variables were not normally distributed (PROC UNIVARIATE; SAS Inst. Inc. 1987), we examined relationships between bird numbers and transect types using the Kruskal-Wallis test (Chi-square approximation) (PROC NPAR). Patterns of use of nest and perch sites were analyzed with goodness-of-fit tests using the proportions of available nest and perch sites to generate the expected values.

RESULTS

Sightings by Transect Type

We surveyed 97 transects, totaling 1,684.8 km; 462.5 km were surveyed along transmission powerlines (n = 24), 404 km along paved highways (n = 28), and 818.3 km along controls (n = 45) (Fig. 1). The mean (±SD) and range of transect lengths (km) along powerlines, highways, and controls were 19.3 (16.1), 3.4–67.1; 14.4 (10.5), 3.7–50; and 18.2 (8.6), 5.6–36.5; respectively.

Although raven sightings were equally numerous between powerlines and highways, ravens were more numerous in these areas than in controls (Kruskal-Wallis, $\chi^2 = 7.4$, $P < 0.02$; Table 1). Raven nests, however, were more abundant along powerlines than along either highways or controls (Kruskal-Wallis, $\chi^2 = 19.8$, $P < 0.0001$). Any discrepancy between the number of raven sightings (≥1 bird) and the actual number of ravens (Table 1) was due to several sightings where many ravens were seen in a single group; this did not occur for red-tails.

Red-tail sightings were more common along powerlines than either highways or controls (Kruskal-Wallis, $\chi^2 = 39.0$, $P < 0.0001$; Table 1). Likewise, red-tail nests were more common along powerlines than along highways or controls (Kruskal-Wallis, $\chi^2 = 48.8$, $P < 0.0001$).

Utilization Patterns of Perch and Nest Sites

Ravens and red-tails did not utilize potential nest or perch sites in proportion to their availability (Fig. 2). For all transects combined, ravens and red-tails used power poles as nesting sites more than expected based on availability, and used trees, cliffs, and telephone poles less than expected based on availability (goodness-of-fit tests: ravens—$\chi^2 = 17.8$, 1 df, $P < 0.001$; red-tails—$\chi^2 = 27.1$, 1 df, $P < 0.001$). Ravens did not perch on power poles more than expected ($\chi^2 = 2.3$, 1 df, $P > 0.10$); however, the converse was true for red-tails ($\chi^2 = 193.5$, 1 df, $P < 0.001$).

DISCUSSION

Sightings by Transect Type

The foraging ecology of each species most likely explains why ravens were more numerous along highways and powerlines than along controls, and red-tails were more numerous along powerlines than along either of the other transect types. Ravens are facultative scavengers (Knight and Call 1980), whereas red-tails hunt live prey (Brown and Amadon 1968; but see

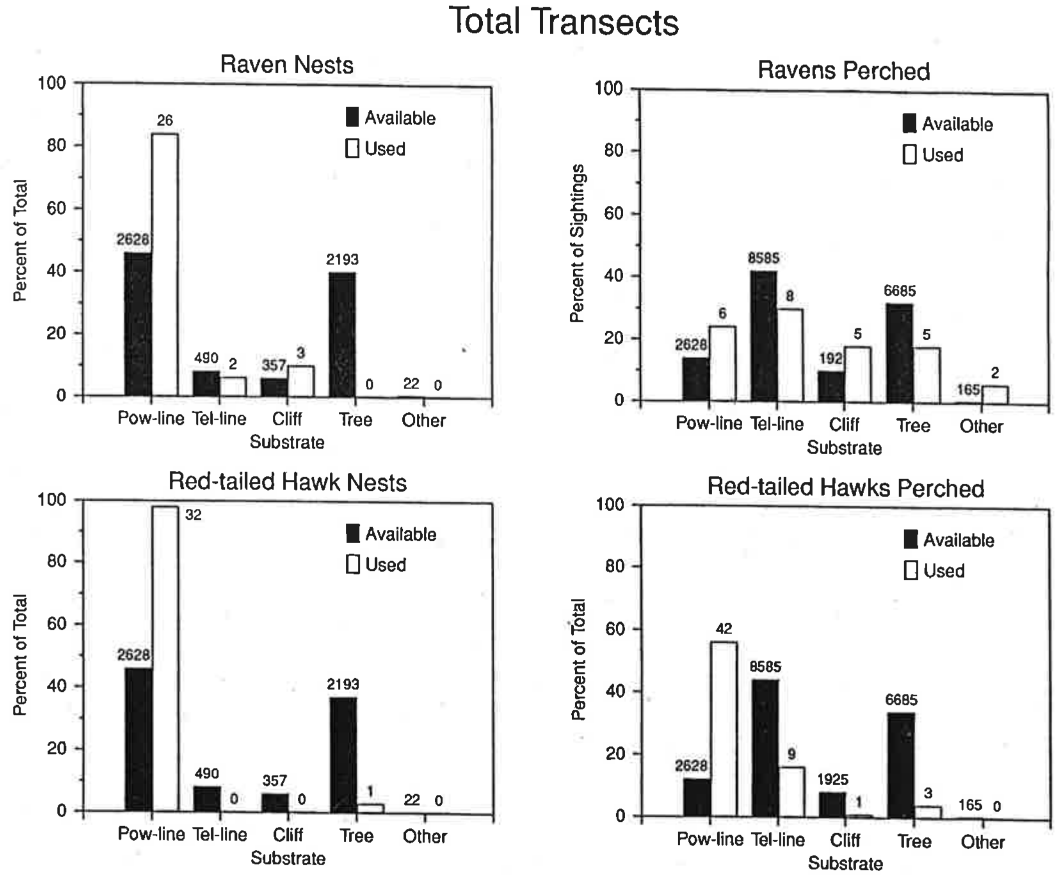

Fig. 2. Frequency distributions of common raven and red-tailed hawk nesting and perching on available nest and perch sites for all transects combined, Mojave Desert, California, 1989. Numbers above bars represent numbers of perch or nest sites available, or the number of sites used as perches or nests by ravens or red-tailed hawks.

Stalmaster [1980]). Thus, carrion is a frequent component of raven diets (Nelson 1934, Harlow et al. 1975, Marquiss and Booth 1986, Engel and Young 1989). Automobiles are responsible for millions of road-killed wildlife daily (see Leedy [1975] and Leedy et al. [1975]), and provide a ready food-source for scavengers. Although undocumented, we suspect carrion in much of the American West may be more abundant along highways than away from highways. If so, ravens, but not red-tails, may be more numerous along highways because of a continually renewable supply of carrion provided by vehicles. Others also have noted increased raven numbers or nesting success near highways and have attributed the differences to scavenging on road-killed wildlife (Austin 1971, Conner and Adkisson 1976, Hooper 1977).

We suspect that ravens and red-tails were more abundant along powerline transects than along controls because powerlines provide suitable perch, roost, and nest sites (Olendorff et al. 1981, Williams and Colson 1989, Engel et al. 1992). Stahlecker (1979) studied raptor populations before and after construction of a transmission line and noted that raptors were more abundant following completion of the powerline.

We do not believe that the relative scarcity of nests and perched birds of either species along control areas was due to observational bias. Because of the speed and height of the helicopter above ground, the experience of the 2 observers and pilot, and the relatively small number of available perching and nesting sites to check, we feel that few birds or nests were missed.

Utilization Patterns of Perch and Nest Sites

Our findings that powerline towers were used by perching red-tails more than expected, particularly relative to trees and telephone poles, agree with those of Stahlecker (1975, 1979), who found that although transmission towers comprised 1.5% of the available perches in a grassland area in Colorado, 81% of the raptors seen during surveys utilized them as perches. Likewise, Craig (1978) noted that almost 78% of all raptors perched along a 187-km survey route in Idaho were on power poles or wires. In the Mojave Desert, tall powerline towers may provide birds with a wider range of vision, easier takeoff, and greater attack speed when hunting prey on the ground, than shorter perch sites such as trees or telephone poles.

Both ravens and red-tails nested on powerline towers more than expected. Nelson and Nelson (1976) suggested that powerline towers were better nest sites for raptors than cliff sites with southern exposure, because of the shading provided by the beams and braces on powerline towers. Likewise, nests on towers supposedly experience greater cooling in hot environments due to the increased openness around the nest (Williams and Colson 1989). In addition, the beams and latticework of powerline towers provide secure nest-site anchors against extreme winds (cf. Gilmer and Wiehe 1977).

MANAGEMENT IMPLICATIONS

Linear right-of-ways (e.g., highways, transmission powerlines) have noticeably altered western landscapes in North America. Our data suggest that the response of wildlife to a right-of-way depends on the species involved as well as the type of right-of-way. Roads benefit ravens in that they provide increased amounts of food; whereas powerlines provide suitable perch and nest sites for ravens and red-tails. If linear right-of-ways result in increased predator populations, or concentrate the activities of predators, land managers should monitor possible population decreases in sensitive prey species like the desert tortoise (*Gopherus agassizii*).

The U.S. Fish and Wildlife Service and the Canadian Wildlife Service annually estimate population trends of migratory North American birds with the use of the Breeding Bird Survey (BBS) (Robbins and Van Velzen 1967). Birds are surveyed along roads and the survey consists of 50 3-minute stops 0.8 km apart. These surveys provide information, both locally and on a continental scale, on population changes of North American birds, and enable these agencies to detect population trends of species (Robbins et al. 1986). Because our work indicates that some bird populations are unnaturally high along highways, the BBS may reflect population trends that are not representative of that species in areas away from highways.

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NESTING BY RAPTORS AND COMMON RAVENS ON ELECTRICAL TRANSMISSION LINE TOWERS

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Abstract: Raptors and common ravens (*Corvus corax*) (hereafter called ravens) began nesting on towers along a 596-km segment of a 500-kV transmission line in southern Idaho and Oregon within 1 year of its construction. We began monitoring these nesting populations in 1981 to assess the effectiveness of artificial structures in attracting nesting raptors and to provide guidelines for enhancing raptor nesting opportunities on transmission lines. Within 10 years, 133 pairs of raptors and ravens were nesting along the 500-kV line. Rapid colonization of towers along the line probably was due to lack of other nesting substrate in the transmission line corridor, and the proximity of existing nesting populations in the nearby Snake River Canyon. Transmission towers provided both new and alternative nesting substrates. Raptors and ravens used all types of towers on the line but preferred (all $P < 0.05$) tower types and sections of towers where steel latticework was relatively dense. They tended to nest on the same or adjacent towers each year even though a low percentage of nests remained intact after the breeding season. Destruction of nests by wind was the most common cause of nest failure on transmission towers. Artificial platforms protected nests from wind damage, and hawks and eagles showed a preference for platforms. Overall nesting success of pairs on transmission towers was similar to or higher than that of pairs nesting on other substrates. Utility companies can enhance raptor nesting opportunities and minimize conflicts with power transmission by providing stable nesting substrate that is not directly above insulators. Nest site modifications either during or after line construction can attract nesting raptors and improve their nesting success.

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Electrical power lines have affected birds of prey adversely and beneficially (Olendorff et al. 1980, 1981; Nelson 1982). One apparent benefit of power-transmission line towers is that they provide nesting substrate for birds of prey. Raptors and corvids nest on transmission line towers throughout western North America (Gilmer and Wiehe 1977, Stahlecker and Griese 1979, Lee 1980, Nelson 1982, Sierra Pacific et al. 1988, Roppe et al. 1989) and in other parts of the