Nesting by Raptors and Common Ravens on Electrical Transmission Line Towers
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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 world (Dean 1975, Ledger et al. 1987). However, no study has demonstrated whether raptor nesting density and productivity are enhanced by transmission lines. As more power lines are built in western North America (Enabnit and Anderson 1991), resource managers and utility companies need to ensure that line routes and tower designs are compatible with transmission of power and enhancement of raptor nesting habitat.

Construction of a 500-kV transmission line across southern Idaho and Oregon by Pacific Power and Light (PP&L) in 1980–81 provided an opportunity to investigate the biology of raptors and ravens nesting along a new transmission line. Thus, we documented the number of raptor and raven nests on transmission line towers from 1981 to 1989; identified factors influencing nest abundance and distribution along the line; determined if the total number of pairs nesting in the region increased due to the line or if pairs had simply moved to towers from natural substrate nests; identified preferred nesting locations on transmission line towers; ascertained productivity of nesting pairs; and determined if nesting success of pairs on towers differed from pairs nesting on other substrates in the study area.

Special thanks go to S. E. Wilder and M. E. Mulrooney of PP&L, who assisted with all phases of the study. We also are indebted to L. S. Young, M. G. Garrett, K. A. Engel, A. J. Brody, J. A. Putera, J. D. Doremus, M. V. Ichisaka, W. G. Kell, and D. L. Aleshire for assistance with data collection and logistical support. A. L. Haak and D. M. Ramirez provided assistance with data tabulation. We thank M. W. Nelson whose interest, foresight, and dedication laid the groundwork for this investigation. We also thank our many pilots, especially S. T. Sandmeyer, J. L. Judge, R. L. Day, and the late L. E. Haney, whose skill made successful completion of surveys possible. J. M. Marzluff, R. R. Olendorff, A. M. A. Holthuijzen, and M. R. Fuller provided helpful comments on draft manuscripts.

STUDY AREA

We studied the portion of the Malin to Midpoint 500-kV transmission line that runs 596 km from Midpoint Substation, Jerome County, Idaho, to Summer Lake Substation, Lake County, Oregon (Fig. 1). In Idaho, the line follows the relatively flat, deep-soiled Snake River plain. At the Oregon border, the Snake River heads north, but the line continues west into more rolling topography. Along much of the Idaho stretch, dense populations of raptors and ravens nest in the Snake River Birds of Prey Area and adjacent stretches of the Snake River Canyon (U.S. Dep. Inter. 1979; Fig. 1). The transmission line crosses the Snake River 4 times in Idaho and parallels it at distances of 0.5 to 7 km in some stretches and up to 40 km in others.

Construction of the transmission line began early in 1980 and was completed late in 1981. The free-standing steel-lattice towers are 25–47 m high, and most are spaced about 300–400 m apart. Six different tower types occur on the line (4 are shown in Fig. 2). Types B and C (not shown) have the same general configuration as Types A and E, but each has different steel widths and latticework densities. During line construction, PP&L, in cooperation with the Bureau of Land Management (BLM), installed 37 artificial nesting platforms (Nelson and Nelson 1976, Nelson 1982) on non-random towers. By 1986, PP&L personnel had placed sticks in all platforms to attract nesting raptors, and sticks were wired in place on some platforms.

We conducted surveys in 3 study areas. Investigations focused on the eastern portion of the transmission line that paralleled the Snake River Canyon. This eastern survey area extended from Midpoint substation to Givens Hot Springs, Idaho, and included the first 213 km of the line (Fig. 1). We studied this portion of the line more intensively because it was closer to our headquarters in Boise, Idaho; raptor and raven nesting densities both on and near the power line corridor were relatively high; and we had complete aerial photo coverage for habitat analyses. The western survey area was mainly in Oregon and included the remaining 383 km of the transmission line. To compare nesting success rates, we surveyed raptors in a third canyon survey area, extending along the Snake River and its major tributaries from Hagerman, Idaho to Givens Hot Springs, Idaho. Background data on nesting populations were available from the canyon study area where raptors have been studied intensively since the early 1970's (Beecham and Kochert 1975; U.S. Dep. Inter. 1979; BLM, unpubl. data).

METHODS

In 1981 and 1982, M. W. Nelson and PP&L employees began checking artificial nesting platforms on transmission line towers for occupancy. Additional information was obtained in 1982 during PP&L line patrols. Aerial surveys

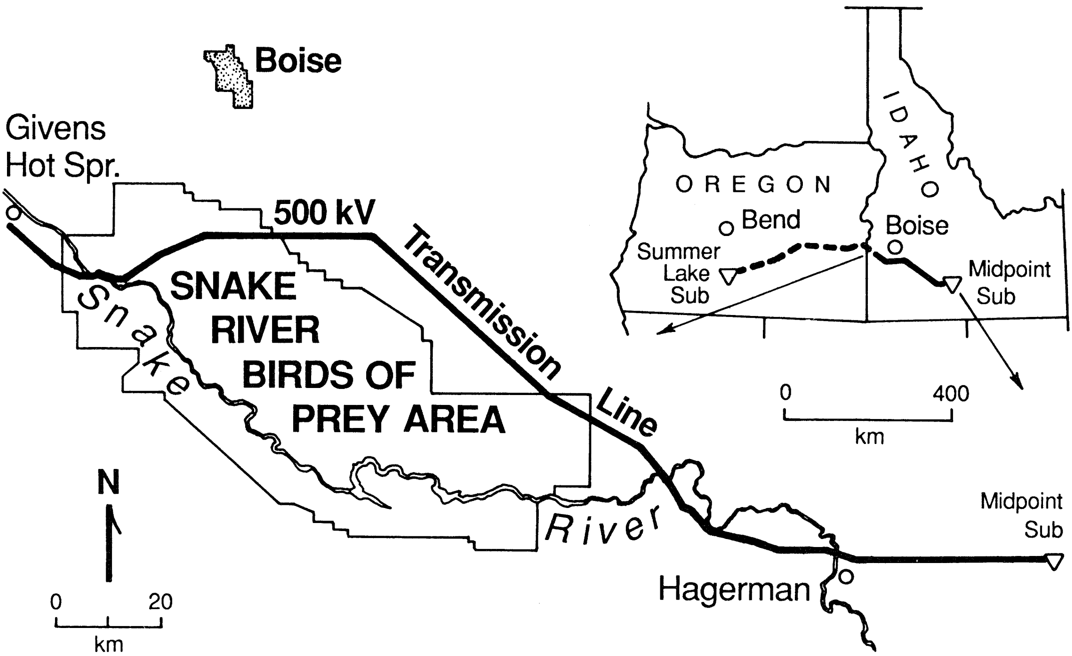

Fig. 1. Portion of the Pacific Power and Light 500-kV transmission line studied in Oregon and Idaho, 1981–89. The more intensively studied eastern study area is blackened on the 2-state map and enlarged.

of the line began in 1983 with a combination of helicopter and fixed-wing surveys in March and June. From 1984 to 1989, the eastern survey area was checked 4 times each nesting season from a helicopter, and the western area was checked twice each year.

Helicopters were flown at speeds of 70–95 km/hour. We usually hovered ≥20 m from nests from 5–25 seconds to view nest contents. Approximately one-third of the nests were photographed from the helicopter, and 39% were subsequently observed from the ground. In 1984, additional information on raven productivity was obtained when crews entered nests to band young as part of another study (Young and Engel 1988). We recorded the presence and condition of nests on transmission line towers during a 28 October 1986 helicopter survey to evaluate nest persistence after the nesting season.

Nesting success of pairs in the Snake River Canyon was ascertained from ground and aerial surveys during other research activities (see Steenhof and Kochert [1982]). In comparative analyses, we excluded pairs nesting on natural substrate if we found them after incubation because conspicuous successful breeders found later in the nesting season can inflate estimates of nesting success (Steenhof and Kochert 1982).

We defined nesting areas as confined localities within the home range of a pair of mated birds where ≥1 nest occurred and where ≤1 pair of a given species ever bred in a single year (Newton and Marquiss 1982, Steenhof 1987). Along the transmission line a nesting area typically included 1–3 towers. We considered nesting areas to be occupied by nesting pairs if a breeding attempt was confirmed (see below), or if paired adults were observed consistently near a nest. Pairs were considered "breeding" if they laid ≥1 egg; this was confirmed by observing eggs, young, or an incubating adult. We considered a breeding attempt successful if young reached 80% of the average age when most young normally leave the nest (Steenhof 1987). Ages of nestlings were determined by comparison with photographs of known-age chicks (Moritsch 1983, 1985; BLM, unpubl. data).

During helicopter surveys, we described topography within a tower-span radius of all towers used for nesting and 98 randomly selected towers as either flat, rolling, canyon/cliff, or valley floor. We classified land use within this 300- to 400-m radius as agricultural if 50% or more of the area was farmed, range or forested if <10% was farmed, and mixed if between 10% and 50% was farmed.

We also assessed topographic characteristics, cultural features, and land use from topographic

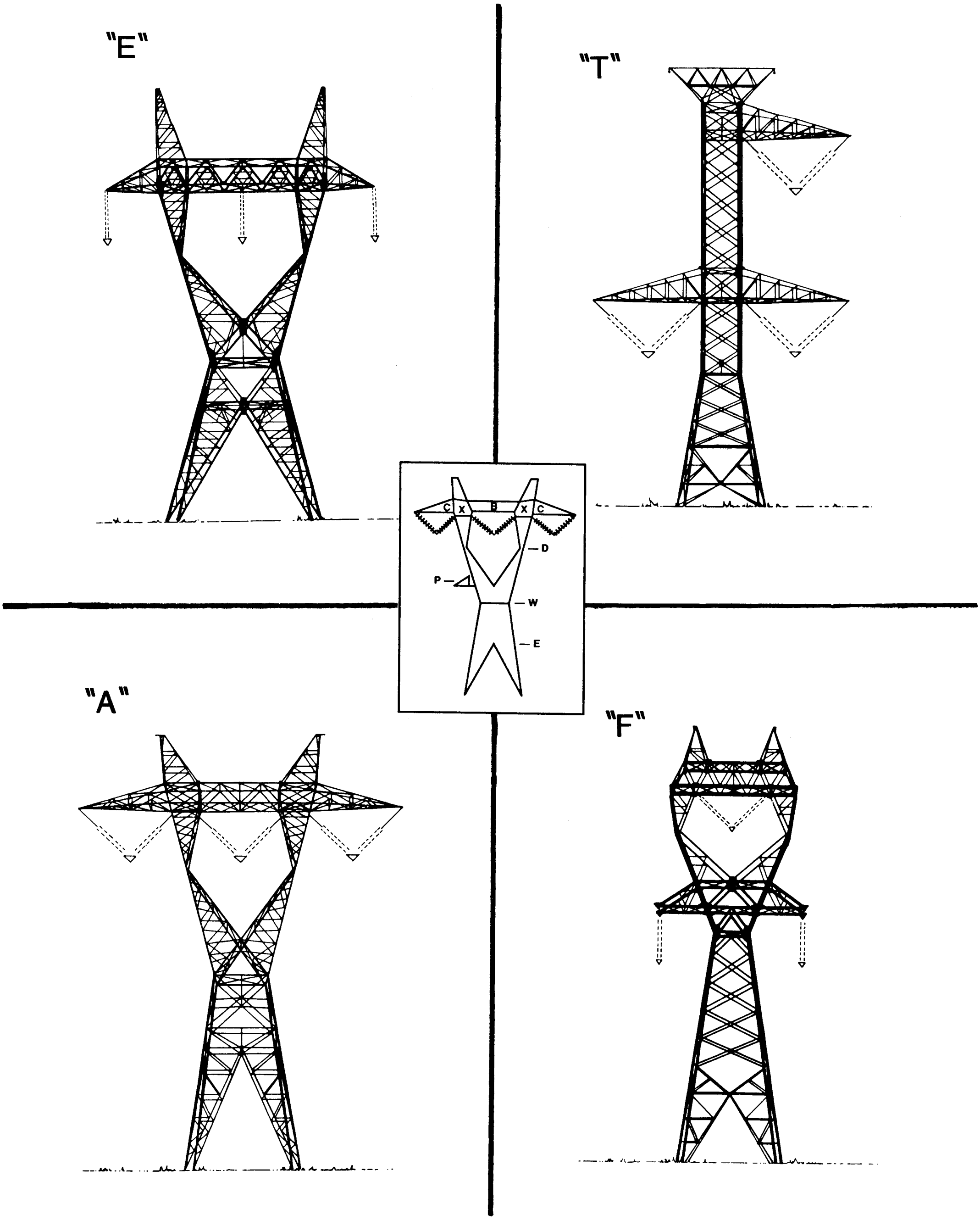

Fig. 2. Tower types used by raptors and ravens for nesting in Oregon and Idaho, 1983–89. Tower types "B" and "C" (not shown) were similar in shape to "A" and "E" towers, but latticework density differed. Inset shows tower section designations.

maps, aerial photos, and PP&L plan and profile maps of the eastern study area. We calculated amounts of shrub, grass, and agricultural land within a 1-km radius of each nest where a breeding attempt occurred in 1985 and at 73 randomly selected towers not used for nesting in 1985. Topographic variation around each tower was calculated as the difference in elevation be-

Table 1. Number of raptor and common raven nesting pairs on the Pacific Power & Light 500-kV transmission line, Oregon and Idaho, 1981–89.

	1981	1982	1983	1984	1985	1986	1987	1988	1989
Golden eagle	1	2	5	4	4	4	7	8	8
Ferruginous hawk	1	3	9	7	6	8	9	12	11
Red-tailed hawk	0	2	2	13	20	28	33	27	33
Common raven	1	9	39	55	58	73	81	80	81
Great horned owl	0	0	0	0	0	0	1	1	0
Total	3	16	55	79	88	113	131	128	133

tween the lowest and highest points within a 1-km radius of the tower. We also assessed the presence and number of roads, cliffs, buildings, and smaller power lines in the same radius, and we calculated distance from the tower to the nearest road. The maintenance road following the transmission line was excluded from the analysis.

To assess possible differences between nesting towers and randomly selected towers we used t-tests for continuous variables using the System for Statistics (SYSTAT) software package (Wilkinson 1988) and contingency tables (log-likelihood G-tests) for categorical variables using StatXact software (Cytel 1989). (Use of brand names does not imply endorsement by the federal government.) We also used log-likelihood G-tests to test for differences in tower availability and use, side of tower preference, nest persistence, and nesting success rates. Nesting success was compared among substrates using 1-df log-likelihood tests. Contrasts for each species included tower platforms versus nests on other parts of the tower; all tower nests versus nests on natural substrate; and tower nests versus nests on other artificial structures. We used analysis of covariance (SYSTAT) to test for differences in densities and colonization rate on the eastern versus western portion of the line; we tested for homogeneity of slopes by evaluating interaction effects (area•year) in a regression model where number of pairs/km = constant + year + area + area•year. All tests were evaluated at $P < 0.05$.

RESULTS

Colonization and Nesting Densities

Raptors and ravens started nesting on transmission line towers within 1 year after construction. Number of raptor and raven pairs nesting on towers increased from 3 in 1981 to 133 in 1989 (Table 1). Number of pairs increased each year, except 1988. Each year, ravens were the most abundant of 5 species nesting on the transmission towers (Table 1).

Transmission line towers provided both new and alternative nesting substrate for raptors and ravens. In 1982, golden eagles (*Aquila chrysaetos*) in the Little Canyon Creek nesting area shifted from existing natural substrate nests and began nesting on a transmission tower, 400 m from traditional nests on a cliff. Since 1982, eagles at Little Canyon Creek have nested on the tower twice and the cliff 4 times. Another eagle pair established a new nesting area in 1983 when they began nesting on a tower at the northern periphery of a home range (Dunstan et al. 1978) used by an eagle pair that nests in the canyon. The area used by the new pair had been thoroughly surveyed in previous years; 2 eagle nesting areas within 4 km of the newly established tower nest were occupied during the study period. At least 5 other eagle pairs started nesting on transmission towers where no other nesting substrate occurred within 3 km and where no eagles nested prior to line construction.

In 1989, we recorded 0.22 nesting pairs/km or 8 nesting pairs for every 100 towers. Each year nesting densities of all species combined were higher ($t = 2.62$ for area effect; $P = 0.02$; analysis of covariance) in the eastern survey area, where the line parallels the Snake River Canyon, than in the western study area (Fig. 3). Colonization occurred earlier and increased more rapidly on the eastern portion of the line (slopes differed [$t = -2.88$ for interaction effect; $P = 0.01$]; analysis of covariance). The number of nesting pairs per km of line also varied within the eastern survey area. From 1984 to 1989, we observed 0.29–0.45 pairs/km in a 109-km stretch within or just north of the Snake River Birds of Prey Area (Fig. 1) compared with only 0.16–0.27 pairs/km in the rest of the eastern survey

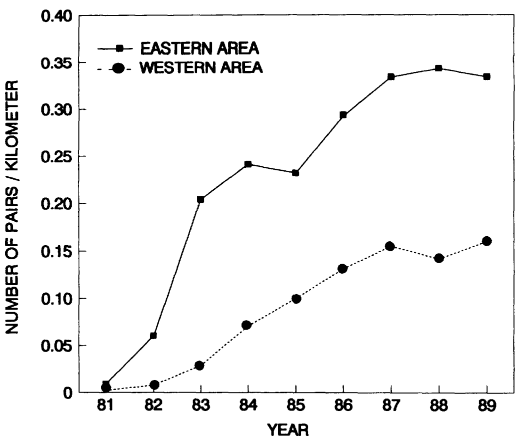

Fig. 3. Number of raptor and raven pairs nesting per km of transmission line along 2 stretches of the PP&L 500-kV transmission line in Oregon and Idaho, 1981–89. Numbers of pairs and the rate of increase were higher in the eastern survey area (analysis of covariance: $t = 5.84$, $P < 0.001$ for year effects; $t = 2.62$, $P = 0.02$ for area effects; $t = -2.88$, $P = 0.01$ for area•year interaction effects).

area. During those same years, a 10-km stretch of line inside the Birds of Prey Area contained ≥0.7 nesting pairs/km, more than 3 times the average density for the line.

At least 2 golden eagles nesting on transmission line towers had hatched in the canyon. In 1989, one of the golden eagles incubating on a tower nest was a wing-marked bird that had been banded as a nestling in the Snake River Canyon in 1980 (BLM, unpubl. data). During a separate study in 1991, an eagle nesting on a tower was trapped by Greenfalk Consultants; the eagle had been banded as a nestling 15 years earlier in a cliff nest within the canyon, 42 km away.

Raptors and ravens sometimes occupied nests on adjacent towers. Red-tailed hawks (*Buteo jamaicensis*) nested within 350 m of occupied raven nests, and ferruginous hawks (*Buteo regalis*) nested within 100 m of occupied raven nests. Occupied raven nests were as close as 300 m, but minimum distances between conspecific raptors always exceeded 600 m.

Nest Site Selection

Between 1986 and 1989, raptors and ravens nested on all tower types on the line, but each year the frequency with which tower types were used differed (log-likelihood ratio tests, 5 df, all $P < 0.05$) from the frequency with which tower types were available. Tower types E and T were used more than expected on the basis of their availability, and types A and B were used less than expected (Fig. 4). Although "A" towers (Fig. 2) were the most commonly used towers, they were by far the most common tower type available (79% of all towers). Each year only 6–7% of "A" towers were used for nesting, and 17% of pairs on "A" towers nested on platforms and not the tower latticework. In contrast, raptors and ravens nested on 30–48% of available "E" towers and 8–33% of "T" towers each year. Tower types "B" and "C," which are similar to "A" had relatively low use, and only one of the 8 "F" towers was used (first by ravens and then by great horned owls [*Bubo virginianus*] in the subsequent year).

Seventy-nine percent of nesting attempts from 1984 to 1989 were in the cross-arm ("x") of the tower bridge (Fig. 2; Table 2) where steel latticework is relatively dense. Small metal plates or gussets on "B," "C," and "E" towers provided stable nesting substrate in the x-section. Nests also were built on the edge of the tower bridge ("c"), the middle of the bridge ("b"), the tower waist ("w"), the tower body ("d"), and the artificial platforms ("p"; Fig. 2; Table 2). Use of tower section was related to tower type and the relative density of latticework. All nests on the bridge's edge were on "E" towers; "E" towers have about 2.4 times the horizontal steel in this area than "A" towers. Nests in the tower body were most common on "B" and "C" towers, which have relatively more latticework in lower portions of the tower. Most waist nests were on "B" towers.

Red-tailed hawks used more tower sections for nesting than the other 3 diurnal species, and ravens appeared to be the least versatile, nesting in the x-section in 401 of 408 nesting attempts. Birds showed no ($G_1 = 2.07$; $P = 0.17$) distinct preference for side of tower. Of non-platform nests, 255 were on the north, and 303 were on the south side of towers.

Seventy-two percent of golden eagle and 48% of ferruginous hawk breeding attempts were on the specially designed artificial platforms. A preference for platforms by hawks and eagles was apparent because only 2% of towers on the line contained platforms. By 1989, 19 of the 37 platforms had been used at least once. A tower with a platform 400 m from traditional cliff nests attracted the Little Canyon Creek golden eagle pair, but a tower without a platform was never used by the Glenns Ferry golden eagle pair, which nested only 175 m from the tower.

Land use immediately surrounding nesting

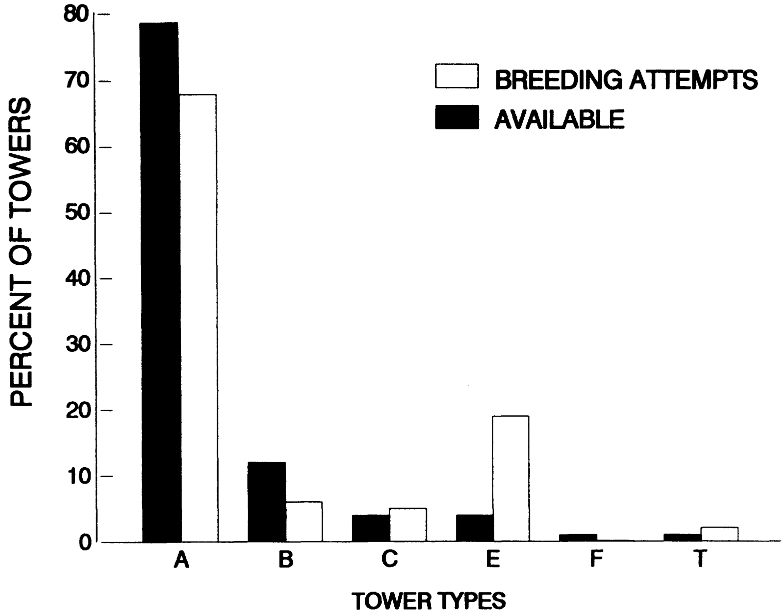

Fig. 4. Availability of tower types on the PP&L 500-kV transmission line and percent of raptor and raven breeding attempts by tower type in Oregon and Idaho, 1986–89. Each year the frequency with which tower types were used differed (log-likelihood ratio tests, 5 df, all $P < 0.05$) from the frequency with which tower types were available.

towers differed (G_1 = 17.86; $P < 0.001$) from that around unused randomly selected towers. Most towers used for nesting were surrounded by rangeland (94%), whereas many unused towers (22%) were bordered by agriculture or forested habitat. Topography within 0.5 km of all towers used for nesting during the study period did not differ (G_3 = 3.29; P = 0.35) from randomly selected unused towers. Within the eastern study area, 12 towers used by nesting raptors in 1985 had fewer ($t = -2.27$; P = 0.03) km of road within a 1-km radius than did 73 random towers. They also had fewer ($t = -3.41$; $P <$ 0.01) km of distribution power lines in the same radius. Raven nests (n = 39), on the other hand, were closer ($t = -2.42$; P = 0.02) to roads than were random towers. Other habitat characteristics we measured provided little insight into factors influencing nest tower selection in 1985. Within the eastern study area, randomly selected towers did not differ (t-tests and G_1-tests; all $P > 0.05$) from 1985 nesting towers in amounts of agriculture, shrubs, or grassland; the amount of habitat interspersion or topographic variation; or the presence of cliffs, buildings, or farmland within a 1-km radius of towers.

Nesting Success and Productivity

Each year from 1983 to 1989, between 76% and 85% of breeding pairs in the eastern study area produced young that reached fledging age. Nesting success of pairs that laid eggs in the eastern study area averaged 65% for golden eagles, 83% for ferruginous hawks, 74% for red-tailed hawks, and 86% for ravens (Table 3). Average number of young fledged per pair per year ranged from 0.79 for golden eagles to 3.16 for ravens (Table 3). Based on fledging rates in the eastern study area, an estimated 51 golden eagles, 128 ferruginous hawks, 250 red-tailed hawks, and 1,350 ravens fledged from nests along the entire transmission line between 1984 and 1989.

Not all golden eagles associated with nests on towers laid eggs every year. Eagle pairs at 5 nesting areas remained in the vicinity of a nest but did not lay eggs in ≥1 year. One nonbreeding ferruginous hawk pair also was recorded.

Wind caused at least 10 nest failures during our study. Fourteen percent of all recorded nest failures on towers were due to nests being blown from towers, and all species except great horned owls experienced nest failures due to wind. All nests destroyed by wind had been built in the x-section of towers. Ravens nesting on transmission towers experienced additional hazards: in 1984, at least 3 young ravens became trapped in the lower tower lattice and subsequently died. Apparently these birds attempted to land on a diagonal stanchion and slid down, catching their

Table 2. Raptor and common raven breeding attempts by tower section on the Pacific Power & Light 500-kV transmission line, Oregon and Idaho, 1984–89.[a]

Species	n	Tower section used (%)[b] c	x	b	d	p	w
Common raven	408	0	98	0	1	0	1
Ferruginous hawk	52	8	42	2	0	48	0
Golden eagle	29	0	28	0	0	72	0
Red-tailed hawk	142	7	47	5	4	21	15

[a] Summaries do not include "T" and "F" towers.
[b] See Figure 2 and text for tower section designations.

feet in the angular joint between the vertical and diagonal stanchions.

Ferruginous hawks nesting on transmission towers had higher ($G_1 = 9.58$; $P = 0.002$) success rates than those nesting on cliffs and other natural substrates (Fig. 5). However, rates were similar ($G_1 = 0.03$; $P = 0.87$) to those on other non-natural substrates (artificial platforms and smaller utility poles). In contrast, the frequency of successful raven nests was similar ($G_1 = 0.07$; $P = 0.79$) on cliffs and on transmission towers, but ravens on the 500-kV towers had higher ($G_1 = 5.71$; $P = 0.017$) nesting success rates than those that nested on smaller power poles in the study areas (Fig. 5). Neither red-tailed hawk nor golden eagle nesting success differed (all $P > 0.05$) among nesting substrates in the study areas (Fig. 5).

Within the eastern study area, red-tailed hawk nesting success was similar ($G_1 = 1.78$; $P = 0.18$) on platforms and on other parts of towers (Table 4). Golden eagle pairs that nested on platforms had higher ($G_1 = 10.16$; $P = 0.001$) nesting success rates than in other tower sections, and ferruginous hawk pairs tended to be more successful ($G_1 = 3.52$; $P = 0.06$) on platforms (Table 4). Eagles nested successfully on steel platforms installed when the line was built (Fig. 2) and also on a plywood platform installed to fortify an existing nest in the x-section, but all eagle nesting attempts in towers without platforms failed. Eagles at Mile 119 nested unsuccessfully in the x-section in both 1983 and 1984; a 6-week-old nestling died in 1984 when the x-section nest was blown from the tower by strong winds. PP&L personnel subsequently installed a plywood platform in the x-section, and eagles nested successfully on the platform in 1986, 1987, and 1989.

Nest Site Fidelity and Nest Persistence

During the 9-year study, raptors and ravens used 274 of 1,608 available towers. Each year from 1985 to 1989, most pairs (82.4%) nested within 2 towers of where a nesting attempt had occurred in earlier years. Most of these (66.9% of all attempts) nested on the same tower where an earlier attempt had occurred, and many (60%) nested in the same section on the tower. By 1989, at least 43 towers had been used for 5 years or more by the same species.

A helicopter survey in October 1986 indicated that about half of the nests on towers remained intact 4 months after the breeding season. Sixty-one of 114 nests used in 1986 (54%) were in moderate or good condition in October, whereas 53 (46%) were completely gone or in disrepair. Two factors, species and tower section, were associated with nest persistence. Successful nests had the same ($G_1 = 0.26$; $P = 0.78$)

Table 3. Nesting success and productivity of raptors and common ravens[a] along the eastern portion of the 500-kV transmission line in Idaho 1983–89.

	Breeding pairs successful						Young/successful attempt						No. young fledged/pair[c]		
	GE		FH		RA		GE		FH		RA				
	%	n[b]	%	n	%	n	No.	n	No.	n	No.	n	GE	FH	RA
1983	33	3	100	1	92	13	1.00	1			2.67	3	0.33		2.46
1984	50	4	100	6	89	35	1.00	2	3.00	5	3.80	20	0.50	3.00	3.38
1985	100	2	67	6	89	37	1.50	2	3.00	3	3.42	12	0.75	2.01	3.04
1986	67	3	75	8	88	41	2.00	2	2.00	5	3.50	20	1.00	1.50	3.08
1987	100	4	89	9	81	48	1.50	4	3.67	6	4.00	17	1.50	3.27	3.24
1988	67	3	82	11	88	50	1.00	2	3.00	8	3.61	18	0.40	2.26	3.17
1989	50	4	91	11	79	48	2.00	2	2.63	8	3.86	14	1.00	2.39	3.05
Average	65	23	83	52	86	272	1.47	15	2.89	35	3.67	104	0.79	2.30	3.16

[a] Golden eagle = GE, ferruginous hawk = FH, common raven = RA.
[b] Sample sizes.
[c] Includes nonbreeding pairs.

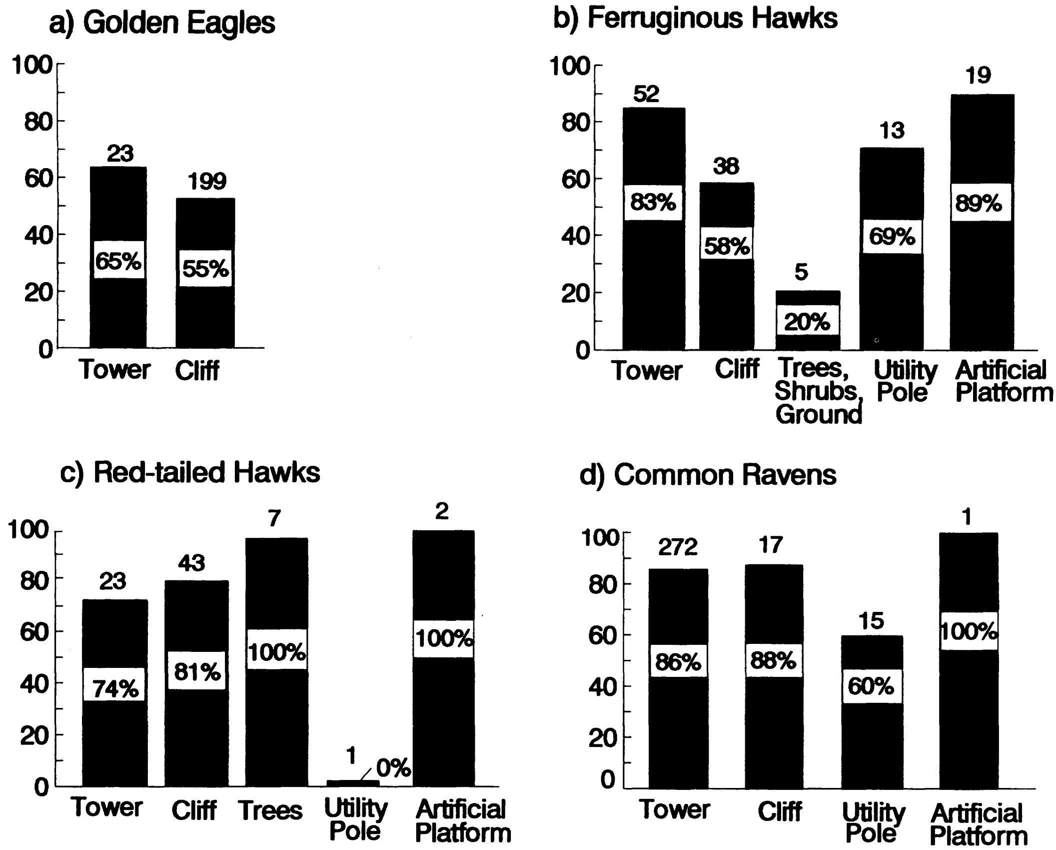

Fig. 5. Nesting success of raptors and ravens by substrate type in southwestern Idaho, 1983–89. Ferruginous hawk nesting success on transmission towers was higher (G_1 = 9.58; P = 0.002) than on cliffs and other natural substrates, but success was similar (G_1 = 0.03; P = 0.87) to that on other artificial substrates. Raven nesting success was higher (G_1 = 5.71; P = 0.017) along the 500-kV line than along smaller power lines, but was similar (G_1 = 0.07; P = 0.79) on cliffs and transmission towers. Neither red-tailed hawk nor golden eagle nesting success differed (all $P > 0.05$) among nesting substrates in the study areas.

rate of loss/deterioration as unsuccessful nests. All nests in artificial platforms were in good or moderate condition, but only 52% of nests in the x-section remained intact. Nests below the bridge suffered the highest loss rate: 67% of nests in the waist and tower body sections were completely gone by October.

Golden eagle and ferruginous hawk nests had the highest persistence rate (100% and 62% in good or moderate condition for the 2 species, respectively). This finding is no doubt related to use of artificial platforms by these 2 species. In general, buteo nests were highly unstable. All 3 ferruginous hawk nests not in platforms had disappeared by October. Only 7 of 25 (28%) red-tailed hawk nests not in platforms were in good to moderate condition by October. Overall, 64% of all red-tailed hawk nests and 43% of raven nests had disappeared or were in serious disrepair 4 months after the breeding season.

DISCUSSION

Olendorff and Stoddart (1974) suggested that artificial nesting structures could be used to increase breeding populations of open-country raptors. The 500-kV transmission line we studied clearly provided raptors and ravens an opportunity to nest in areas where nest sites were previously unavailable. The disproportionately high use of towers in rangeland habitats without other power lines suggests that nesting populations may have been limited by a lack of nesting substrate. The increase in numbers of pairs nesting along the line has not been at the expense of nesting populations in nearby areas because during our study, nesting densities of golden eagles, red-tailed hawks, ferruginous hawks, and common ravens in the Snake River Canyon were as high as or higher than pre-1982 levels (BLM, unpubl. data). The line is likely responsible for increased numbers of breeding raptors and ra-

Table 4. Raptor nesting success on platform and non-platform sections of towers in the eastern portion of the Pacific Power and Light 500-kV transmission line, Idaho, 1983–89.

	Platform		Non-platform		
	%	n^a	%	n	Significance[b]
Golden eagle	79[c]	19	0	4	$G = 10.16$ $P = 0.001$
Red-tailed hawk	60	10	85	13	$G = 1.78$ $P = 0.18$
Ferruginous hawk	92	26	73	26	$G = 3.52$ $P = 0.06$

[a] No. of nesting attempts.
[b] Based on 1-df log-likelihood G-tests.
[c] Includes data from 1986–89 at tower 119/3, where PP&L personnel constructed a plywood platform in the lattice.

vens in the portions of southern Idaho and Oregon that we surveyed.

Densities of nesting raptors and ravens along this 500-kV transmission line were as high as, or higher than, on any power transmission line previously studied (Gilmer and Wiehe 1977, Lee 1980, Sierra Pacific et al. 1988). At least 2 factors appear responsible for the high numbers. First, much of the line was built in areas where no natural nesting substrate existed within 1–5 km. However, the transmission line was usually within 30 km of the Snake River Canyon. The fact that colonization of the transmission line towers occurred earlier and more rapidly near the canyon suggests that canyon-nesting populations were a principal source of birds nesting on towers.

Raptor and raven nesting success on towers was similar to, or higher than, that on surrounding natural substrates. In some cases, transmission line towers provided more secure nesting substrate than natural nesting sites. Towers along power lines offer nesting raptors and ravens protection from mammalian predators and range fires. Ferruginous hawks are the species most likely to benefit because they typically nest at low heights (MacLaren 1986). Most ferruginous hawk nests on natural substrate in the study area were accessible to mammalian predators (BLM, unpubl. data), and accessible nests both in our study area and in Kansas (Roth and Marzluff 1989) failed more often than inaccessible nests. Transmission towers also may offer nesting raptors protection from heat. Winds may keep nests in exposed transmission towers cooler than nests in more sheltered canyon sites. In addition, tower nests are at least partially shaded during most of the day (BLM, unpubl. data). In contrast, a significant portion of raptor nests in the Snake River Canyon receive no shade during the hottest part of the day (BLM, unpubl. data). Thermal stress is a leading cause of golden eagle nestling mortality in the Snake River Canyon (Beecham and Kochert 1975; BLM, unpubl. data), and red-tailed hawk and ferruginous hawk nestlings also succumb to extreme heat (BLM, unpubl. data). During our study, no nestling raptors or ravens on transmission towers were known to have died from heat stress. The biggest risk of nesting on towers appears to be destruction of nests by wind (see Gilmer and Wiehe [1977]). Entanglement in tower stanchions may be another hazard.

MANAGEMENT IMPLICATIONS

Industry officials have been concerned that contamination from nests may cause power outages (Sierra Pacific et al. 1988). However, raptor and raven nests along the 500-kV line did not interfere with power transmission because only 3% of nests were directly above insulator strings. The probability of nesting material and/or fecal matter contaminating insulators was low. Because raptors and ravens prefer to build nests on sections of the towers with dense steel latticework, power companies could minimize conflicts between nesting raptors and power transmission by designing or modifying towers so that insulators are not directly below dense latticework. Where this is not feasible, artificial platforms or tower modifications could safely attract raptors and ravens to tower sections away from insulators. Each year most raptors and ravens returned to nest in the same general area if not the same tower. Modifying only those towers known to be used by nesting raptors and ravens would be more practical than removing nests. Our data on nest persistence and the rate of nest re-building indicate that removing nests will not deter raptors and ravens from nesting on towers.

Artificial platforms and tower fortifications also can benefit raptors by enhancing their nesting success. Even the 500-kV towers' latticework was not dense enough to support large, bulky eagle nests during high winds. Nest-site enhancements (e.g., steel platforms, additional latticework, and/or plywood fortification) can be effective both during line construction and also after raptors have begun nesting on transmission towers. Our data on nesting success did not indicate that electromagnetic field effects had depressed raptor and raven productivity, but more study is needed to determine if long-term effects exist.

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