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Original Article

Managing Nesting by Chihuahuan Ravens on H-Frame Electric Transmission Structures

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ABSTRACT Electric utility structures occur widely in natural and human-dominated landscapes and are often used by birds for nesting. Nests can cause power outages, fires, and electrocution of birds and their young, particularly if nests occur directly above energized equipment and incorporate metal wire. Chihuahuan raven (*Corvus cryptoleucus*) nests often contain metal wire and occur over energized equipment. To explore a proactive risk mitigation strategy we deployed novel nest diverters on 51 structures supporting a 230 kV H-frame transmission line in Kiowa and Bent Counties, Colorado, USA, and compared nesting on these structures with nesting on 66 structures without nest diverters on the same line. Chihuahuan ravens placed nest material on 7% of treated structures and 43% of untreated structures and nested on 0% of treated structures and 34% of untreated structures. Chihuahuan ravens were less likely to attempt to nest on, or actually nest on, structures treated with nest diverters. Future research should evaluate nest diverters over larger spatial and temporal scales and compare prey populations in areas where ravens are excluded to prey populations in areas where ravens persist. © 2012 The Wildlife Society.

KEY WORDS Chihuahuan raven, corvid, *Corvus cryptoleucus*, nest deterrent, nest diverter, power line, raptor.

Utility structures supporting phone, fiber optic, and electric power lines have become a ubiquitous part of natural and human-dominated landscapes. These structures have been widely implicated in incidents of avian electrocution (Harness and Wilson 2001, Dwyer and Mannan 2007, Lehman et al. 2007), electric shock injury (Dwyer 2004, 2006), and collision (Harness et al. 2003, Heck 2007). Subsequent population-level effects have been postulated for species in the United States (Dawson 1988), Europe (Real et al. 2001, Sergio et al. 2004, Lopez-Lopez et al. 2011), and Africa (Boschoff et al. 2011, Jenkins et al. 2011).

Avian power-line interactions are not universally negative, however, particularly because utility structures are widely used for nesting. Bald eagles (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), and golden eagles (*Aquila chrysaetos*) routinely nest on utility structures (Buehler 2000, Poole et al. 2002, and Kochert et al. 2002, respectively), and often use utility structures where anthropogenic landscape changes have reduced or eliminated natural substrates. In Serbia, saker falcons (*Falco cherrug*, an internationally vulnerable species; Birdlife International 2011) nest almost exclusively on power structures (Puzović 2008). These structures are subsequently believed to facilitate the species' persistence in the region. Other species nesting on utility structures include martial eagles (*Polemaetus bellicosus*; Dean 1975), kestrels (*F. tinnunculus*; Krueger 1998), and hobbys (*F. subbuteo*; Puzović 2008) in Europe, upland buzzards (*Buteo hemilasius*; Ellis et al. 2009) in Asia, and ferruginous hawks (*B. regalis*; Gilmer and Wiehe 1977), Swainson's hawks (*B. swainsoni*; James 1992), and prairie falcons (*F. mexicanus*; Roppe et al. 1989) in North America.

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Though raptors are perhaps most widely recognized for their use of utility structures, species in the family Corvidae also commonly nest on utility structures. For example, black-billed magpies (*Pica hudsonia*) nest on utility structures in North America, Europe, and Asia (Trost 1999, Puzović 2008, and Wang et al. 2008, respectively). Common ravens (*Corvus corax*) nest on utility structures in Europe (Puzović 2008) and North America (Brubaker et al. 2003, Lammers and Collopy 2007). Hooded crows (*C. corone*) nest on utility structures in Europe (Puzović 2008), and Chihuahuan ravens (*Corvus cryptoleucus*) nest on utility structures in North America (Bednarz and Raitt 2002).

In North America, utility companies can typically allow the nests of raptors and corvids to persist during breeding seasons unless a specific nest poses an immediate threat to human or avian health or safety (reviewed in Avian Power Line Interaction Committee [APLIC] 2006). To minimize the risk of power outages, fires, avian mortality resulting from electrocution, and unauthorized take of avian species, nests often are carefully managed during nonbreeding seasons. Nest management can include trimming nest materials, insulating conductors, moving nests to alternate structures, and removing unoccupied nests (Hobbs and Ledger 1986, APLIC 2006). Management actions typically are case specific and depend on the nesting species, the type of structure supporting the nest, the location of a nest on the structure, and the materials comprising the nest (APLIC 2006).

Tri-State Generation and Transmission Association, Inc. (Tri-State) owns and operates a 230 kV transmission line supported by H-frame wood structures. Each year Chihuahuan ravens construct nests directly above the center energized wire (hereafter, center phase). Tri-State annually allows nests to persist during the summer breeding season and then removes nests after young have fledged. This prevents large nests from developing over multiple seasons, facilitates removal of metal wire before nests begin to collapse after use, and allows maintenance personnel to remove avian excrement from insulators before the function of the insulators is compromised. However, this strategy requires annual expenditures for cleaning and removing nests from structures and allows annual development of potentially hazardous situations.

Though Chihuahuan ravens breed widely throughout the lowland arid and semiarid areas of the southwestern United States and northern Mexico, they remain the least studied corvid in North America (Bednarz and Raitt 2002). Most research has focused on breeding areas within the species' historic range, and though the presence of utility structures in largely treeless landscapes is believed to have facilitated range expansion (Kristan and Boarman 2007) very little research has explored the biological consequences of changes to avian communities in recently colonized areas. Chihuahuan ravens commonly nest on anthropogenic structures, often in areas that contain no other tall structures nearby (Bednarz and Raitt 2002).

Chihuahuan ravens can nest colonially where nest sites are scarce or where mobbing may deter predators (Bednarz and Raitt 2002). Chihuahuan ravens occupy dry lowland habitat and build nests 30–60 cm in diameter (Brandt 1940, Bednarz and Raitt 2002), and they usually incorporate wire strands in nesting materials (Brandt 1940, Ligon 1961). When metal wire occurs in a nest directly over energized equipment, the likelihood of that wire contacting energized equipment and leading to a fire, outage, or electrocution can be high. During nonbreeding seasons, Chihuahuan ravens can form groups of >100 individuals (Andrews and Righter 1992), which typically depart breeding habitat and wander nearby (Bednarz and Raitt 2002). The species is considered an agricultural pest, particularly in groups, and consequently has been a common recipient of human persecution through shooting, trapping, poisoning, and nest removal (Bednarz and Raitt 2002).

Management of corvids has been suggested to advance conservation goals for numerous sensitive or endangered species including least terns (*Sternula antillarum*; U.S. Fish and Wildlife Service [USFWS] 1985), greater sage-grouse (*Centrocercus urophasianus*; Coates et al. 2008), and marbled murrelets (*Brachyramphus marmoratus*; Peery and Henry 2010). A device that minimizes nesting on anthropogenic structures may offer an effective management tool in treeless landscapes. To facilitate safer nesting and perhaps offer a new management strategy, we designed a nest diverter to be deployed over the center phase and center-phase fitting of H-frame transmission structures (Figs. 1 and 2). The nest diverter was intended to dissuade Chihuahuan ravens from nesting above the center phase while not deterring their nesting elsewhere on the structure and not deterring perching by any species. We predicted that fewer nests would occur on structures with nest diverters and that those nests that did occur would not be placed over the center phase. We also predicted that there would be no difference in perching by wintering raptors on structures with or without nest diverters.

STUDY AREA

Our study area occurred within the Western Great Plains of North America in Kiowa and Bent Counties of Southeast Colorado, USA. The landscape was xeric and flat. The soil was sandy, pebbly, and minimally compacted (Chronic and Williams 2002). The plant community was composed primarily of short-grass prairie (Andrews and Righter 1992), and the study area was used primarily to support cattle production and row crops. Tall sagebrush (*Artemisia tridentata*) occurred in low densities in and around the study area and provided much of the rigid material incorporated by Chihuahuan ravens into nests.

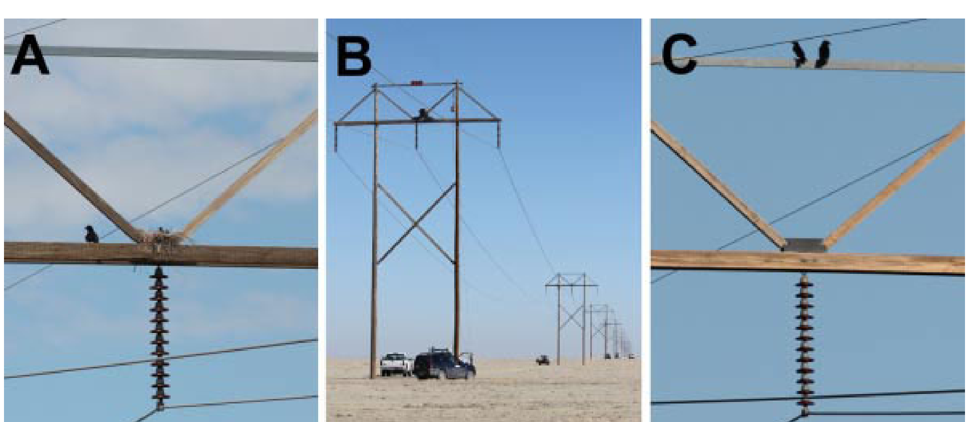

Figure 1. (A) Chihuahuan raven nest on 230-kV H-frame transmission structure. (B) Deployment of nest diverters. (C) Preclusion of nesting. Data collected 22 February 2011 through 29 July 2011, in Kiowa and Bent Counties of Southeast Colorado, USA.

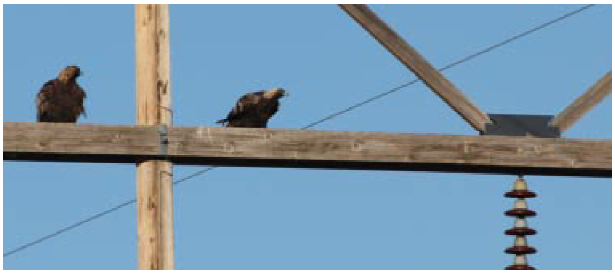

Figure 2. Close view of nest diverter deployed on 230-kV H-frame transmission structure. Golden eagles indicate scale. Data collected 22 February 2011 through 29 July 2011, in Kiowa and Bent Counties of Southeast Colorado, USA.

METHODS

Our study was conducted on a 230-kV line supported by H-frame structures (Fig. 1). Tri-State recorded the occurrence of Chihuahuan raven nests on this line during surveys in February 2004, May 2005, February 2006, December 2008, January 2010, and November 2010. During nonbreeding seasons following each survey, Tri-State removed all nests documented on the transmission line. Most nests occurred on a 29-km line segment, where 64% of the structures supported a nest or partial nest during at least one survey (Dwyer 2011). Our study included this 29-km segment together with a 1.5-km segment on each end of the 29-km segment; thus, we studied a segment length of 32 km. We divided the 32-km study span into approximately 1.45-km segments and randomly assigned all of the structures within each segment to be treated with nest diverters or to be untreated. We secured a nest diverter to the center-phase fitting of each treated structure. Each nest diverter was 56 cm long, 45 cm wide, 20 cm tall, constructed of ultraviolet-resistant rigid polyvinyl chloride, and cost US$ 55.00 (Power Line Sentry, LLC, Fort Collins, CO). The diverters were developed specifically for a study on this line and were not previously tested. We monitored 117 H-frame structures during this study, including 51 structures treated with nest diverters. Chihuahuan ravens typically nest no closer than 300 m to one another (Bednarz and Raitt 2002). We deployed nest diverters in 1.45-km segments so that multiple breeding pairs nesting near one another would be challenged to find a way to nest on a diverter, move to an alternate location on a structure with a nest diverter, or move to a segment of the line without nest diverters. Random assignment of nest diverters to individual structures would not have challenged the birds as rigorously because the Chihuahuan ravens would likely have been able to move within their existing breeding areas to a structure without a nest diverter, thus minimizing the challenge to the birds, and, subsequently, to the nest diverters.

Chihuahuan ravens begin to occupy breeding habitat in March and lay eggs primarily in April and May (Bednarz and Raitt 2002, Burton and Mueller 2006). Tri-State deployed nest diverters 21–22 February 2011, and we searched for nests throughout the line segment during deployment. We then visited the line once every other week in March and April 2011 and once each month in May through July 2011. Visits began at 0600 hours local time and concluded when we had driven the entire study segment twice. The study segment was accessible from either end and we alternated beginning visits from each end.

During each visit we examined each structure to verify that nest diverters remained in place on structures and to check for Chihuahuan raven nests, partial nests, and nesting materials. We also recorded all raptors observed on any structure within the study segment. Recording all raptors allowed us to evaluate whether nest diverters might affect the area's protected raptor community. We used Zeiss 10 × 40 binoculars (Jena, Germany), and a Nikon Prostaff 20–60× variable-zoom spotting scope (Tokyo, Japan) to view all birds perched on or adjacent to structures and used Wheeler and Clark (1995) and Brinkley (2007) to identify birds to species.

Most studies of the nesting biology of Chihuahuan ravens have focused on nests on natural substrates (Bednarz and Raitt 2002, Burton and Mueller 2006, D'Auria and Caccamise 2007) and excluded nests on human-made structures. For comparison to those studies, we used an Opti-Logic 400XTA laser range finder (Tullahoma, TN) to identify nest height for each of the Chihuahuan raven nests we identified. We also measured cross-arm heights for all structures in the study segment to facilitate comparison between actual nest heights and potential nest heights. Most studies of Chihuahuan raven nesting have used mirror poles to quantify nest contents as a measure of productivity (Bednarz and Raitt 2002). The nests in this study were within 1 m of a noninsulated 230-kV energized transmission line. This precluded the use of a mirror pole due to safety concerns, so we did not evaluate productivity.

Structures were assigned to treatments in segments; therefore, segments (not structures) were our sampling unit (e.g., Hurlbert 1984). To accommodate this study design in our analysis, we identified the proportion of structures in each treatment segment that were positive for a variable of interest (i.e., nest materials, complete nests, etc.). We then used a 2-tailed Fisher's exact test to evaluate differences in the proportions of structures used as perch sites by raptors, used as perch sites by Chihuahuan ravens, and used as nest substrates by Chihuahuan ravens. All tests were conducted in Program JMP (SAS Institute, Cary, NC).

RESULTS

Tri-State crews installed nest diverters on treated structures on 21 and 22 February 2011. We monitored treated structures in 10 line segments and compared them with untreated structures in 12 line segments. From west to east, the arrangement of treatments along the line was U,T,U,T,U,T,U,U,T,U,U,T,T,U,T,U,U,T,T,U,T,U where T indicates a treated segment and U indicates an untreated segment. All nest diverters remained in place for the duration of the study. We visited the line study segment on 22 February, 3 March, 10 March, 24 March, 21 April, 26 May, 23 June, and 29 July, 2011. We observed raptors perched on studied structures during each visit from 22 February through 24 March. We observed Chihuahuan

Table 1. Use of H-frame transmission structures for perching and nesting by raptors and Chihuahuan ravens. Treated structures were fitted with a nest diverter over the center phase. Data collected 22 February 2011 through 29 July 2011, in Kiowa and Bent Counties of Southeast Colorado, USA.

	Structure status			
Variable	Treated %[a] (*n*)	Untreated %[a] (*n*)	F^b	*P*-value
Raptor observed perching	43.0 (22)	42.7 (28)	0.001	0.980
Raven perching before nesting	24.0 (12)	41.1 (26)	2.021	0.171
Raven perching during nesting	26.0 (13)	51.7 (33)	3.474	0.077
Nest material present	11.7 (7)	67.9 (43)	30.060	<0.001
Partial or complete nest present	4.0 (2)	38.1 (24)	13.478	0.002
Complete nest present	0.0 (0)	33.7 (21)	14.251	0.001

[a] % Indicates the average percentage of events from each segment.
[b] df = 21 for all tests from 10 treated segments and 12 untreated segments.

ravens perched on studied structures during each visit from 3 March through 29 July. We observed Chihuahuan raven nest materials on studied structures from 24 March through the conclusion of the study and Chihuahuan ravens incubating at completed nests from 26 May through 23 June.

Chihuahuan ravens were the only species that attempted to construct nests on monitored structures. We observed 21 complete nests, 19 of which included metal wire. All structures without a nest diverter and with nest materials had those materials exclusively on the cross-arm directly above the center phase. Structures with nest diverters were less likely to support nest materials, partial nests, or complete nests (Table 1) but not less likely to be perched upon by either raptors or ravens. Nests were more likely to be located on untreated structures immediately adjacent to treated line segments ($\chi^2 = 8.05$, $P = 0.005$; Table 2) than on untreated structures separated from treated line segments by at least one other untreated structure. Four structures with nest diverters supported nest materials. Two of these structures had a single grass stem wedged beneath the nest diverter. One of these structures had 5 grass stems wrapped around the static wire where it attached to the pole and pile of nest materials scattered on the ground beneath the static wire (the static wire linked the top of each structure to each adjacent structure and was not energized). One treated structure had a partial nest straddling the static wire where it attached to the pole.

Average cross-arm height was 19.8 m (95% CI = ±0.3 m) for structures with nest diverters and 19.5 m (95% CI = ±0.3 m) for structures without nest diverters. There was no difference in cross-arm height for structures with verses without nest diverters ($F_{21} = 1.471$, $P = 0.285$). The average height for partial or completed nests was 19.7 m (95% CI = 19.4–20.1 m, range = 19.5–20.1 m).

Table 2. Occurrence of nests of Chihuahuan ravens on untreated transmission structures in proximity to treated structures. Treated structures were fitted with a nest diverter over the center phase. Data collected 22 February through 29 July 2011, in Kiowa and Bent Counties of Southeast Colorado, USA.

	Treated structure adjacent		
Nest present	Yes	No	Sum
Yes	9	12	21
No	7	38	45
Sum	16	50	66

We observed Swainson's hawks, rough-legged hawks (*Buteo lagopus*), ferruginous hawks, golden eagles, American kestrels (*Falco sparverius*), merlins (*F. columbarius*), and prairie falcons perched on studied structures. There was no difference in raptor propensity to perch on structures with or without diverters. When raptors perched on structures, they consistently perched on pole tops or cross-arms. Only American kestrels were observed perched on wires and then only on static wires. Chihuahuan ravens did not differ in their propensity to perch on structures either prior to, or after initiation of, incubation. When Chihuahuan ravens perched on structures, they used cross-arms, braces, pole tops, and static wires.

DISCUSSION

We effectively excluded Chihuahuan ravens from nesting on structures where we deployed a nest diverter, thus completely eliminating nesting-related concerns regarding power outages, fires, and avian electrocutions. To our knowledge, this is the first study to demonstrate that corvids can be excluded from nesting on a preferred substrate without lethal control. Our results may encourage electric transmission companies that have concerns about raptors or ravens nesting over the center phase on H-frame structures to deploy the nest diverters described herein. However, because we only monitored nest diverters in relatively small treatment segments along a single transmission line over one breeding season, additional research is warranted to demonstrate the true effectiveness of nest diverters. The durability and longevity of the nest diverters also warrants careful evaluation beyond the 100% retention rate documented during the 6 months of this study. If costs, effectiveness, and durability are found to meet standards required by electric utilities, then the nest diverters described herein should be deployed on every H-frame transmission structure where nesting by Chihuahuan ravens potentially jeopardizes the reliability of the electric transmission system or the safety of the nesting birds.

Though we found no difference in perching on treated verses untreated structures, Chihuahuan ravens almost certainly spent more time on untreated structures after nesting began, given that incubation would have occurred exclusively on untreated structures. Although we did observe Chihuahuan ravens on untreated structures during the nesting period, the lack of difference in use is likely either 1) an artifact of our monthly sampling schedule, or

2) a consequence of incubating Chihuahuan ravens observing our approach and departing the nest before we recorded their occurrence.

The results reported herein suggest the potential for an experiment with far broader implications to expand our understanding of predator–prey dynamics. Future research should apply nest diverters over much larger segments to exclude Chihuahuan ravens from nesting over larger habitat patches. If Chihuahuan ravens substantially affect prey populations, then surveys of avian populations in treated verses untreated line segments should show differences in the richness, equitability, and productivity of avian communities. Because the raptor species we observed largely migrated out of the study area during the Chihuahuan ravens' nesting season, the study area investigated herein offers a particularly suitable location for such a study. Quantification of habitat along the transmission line should be undertaken as part of such a study to help identify the reason that Chihuahuan ravens focused nesting so precisely on the study segment.

On natural substrates Chihuahuan ravens typically nest between 2.5 m $\pm$ 0.73 m above ground level (Burton and Mueller 2006) and 3–5 m above ground level (D'Auria and Caccamise 2007). In this study, Chihuahuan ravens nested 19.7 m above ground level. Future research also should investigate and compare other potential differences in the nesting ecology of Chihuahuan ravens nesting on natural versus anthropogenic substrates.

MANAGEMENT IMPLICATIONS

Substantial numerical and geographic expansion of Corvidae populations in response to anthropogenic changes in habitat have led to concerns that predation by corvids on the nests and juveniles of species of concern may have substantial consequences for prey populations and community structure (Jerzak 2001, Marzluff and Neatherlin 2006). Management of corvids has subsequently been suggested to advance conservation goals (Oles 2007) for numerous sensitive or endangered species including, least terns (USFWS 1985), marbled murrelets (Peery and Henry 2010), and snowy plovers (*Charadrius alexandrinus*; USFWS 2007). In treeless areas, greater sage-grouse (a species preyed upon by common ravens; Coates et al. 2008) and Gunnison sage-grouse (*Centrocercus minimus*) are species of special concern (Colorado Division of Wildlife 2010, Utah Department of Natural Resources 2011). Our results may encourage managers concerned with the impact of corvids on sensitive species, particularly in treeless areas, to explore the conservation implications of nonlethal prevention of nesting by corvids.

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