Efficacy of a mitigation method to reduce raptor electrocution at an electricity distribution line in Mongolia

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SUMMARY

We conducted a trial of a mitigation technique aimed at reducing avian electrocution rates at a 15kV electricity distribution line in the Mongolian steppe. Electrocution resulted from birds contacting live conductor cables either when perched at the top of the grounded steel-reinforced concrete pole or when perched on the steel crossarm. Mitigation focused on line poles and involved creating a barrier between the live conductors and perch sites at randomly selected poles. This involved attaching the pin insulator at the top of the pole with a new mount so that it was repositioned centrally to discourage birds from perching on top of the pole, while additional unconnected pin insulators were affixed adjacent to those supporting the conductor cables on the crossarm to provide a barrier to birds touching the live cables. Electrocution rates were significantly lower at mitigated poles compared to control poles, with an average reduction of 85%. This mitigation technique is relatively inexpensive to implement (approximately US$12/pole for materials), with no additional maintenance requirement and a life expectancy similar to that of the base pole design. While not eliminating electrocution risk, this mitigation technique may be useful in circumstances where the cost of implementation and sustained maintenance largely determines whether or not any form of mitigation is undertaken.

BACKGROUND

Avian electrocution on power lines is a major cause of mortality for birds of prey in central Asia (Dixon *et al*. 2013), India (Harness *et al*. 2013), Africa (Boshoff *et al*. 2011, Angelov *et al.* 2012), Europe (Prinsen *et al*. 2011) and North America (APLIC 2006). There is a significant electrocution problem in Mongolia, with 15 kV distribution lines being particularly dangerous for birds of prey, especially where lines are located in open steppe habitat with a high density of rodent prey (Dixon *et al*. 2017). Avian electrocution in Mongolia is caused by the dangerous design of power pole infrastructure, consisting of grounded steel-reinforced concrete poles with steel crossarms and brackets supporting upright pin insulators (Dixon *et al*. 2017). A bird that simultaneously touches a conductor cable while perched on the pole top or crossarm will be electrocuted.

In Europe and North America steps have been taken to improve the safety of distribution lines and technical guidance has been produced identifying a range of potential mitigation strategies (e.g. APLIC 2006, Prinsen *et al*. 2012). Power pole mitigation can be targeted at bird behaviour, by reducing perching frequency using deterrents (e.g. Slater & Smith 2010) or manipulating the availability of perch sites using deflectors or alternative perches (e.g. Ferrer & Hiraldo 1991). Alternatively, mitigation can be targeted at the pole hardware, to insulate conductors or grounded pole components (e.g. Dwyer & Mannan 2007).

Electrocution at electricity distribution lines is an avoidable cause of anthropogenic avian mortality that kills thousands of raptors each year in Mongolia. The problem has been known for at least a decade (Harness *et al*. 2008), yet effective mitigation has not been deployed at most power lines in the country, due to limited awareness of mitigation methods among power company engineers, and financial constraints (Dixon 2016). The scale of the electrocution problem in Mongolia has the potential to have population level impacts on some species; there is thus an urgent need for effective, cost-efficient mitigation or remediation measures to be adopted widely by companies responsible for electricity distribution lines. We present results of a trial to assess the efficacy of a simple, relatively inexpensive mitigation method.

ACTION

We conducted an experimental trial of a novel mitigation method at a single 15 kV 3-phase electricity distribution line with a known history of avian electrocution: previous surveys of the line recorded large numbers of electrocuted birds (Table 1). The line comprised 480 poles that traversed 54 km of flat and undulating steppe habitat between the district centres of Bayan Ovoo (46.284° N, 100.451° E) and Galuut (46.700° N, 100.145° E) in Bayankhongor Province, Mongolia. The line comprised line (tangent) poles (N = 453) with anchor (dead-end) poles (N = 27) located at deviation points where the line changed direction and at intervals of approximately 1.5 km along straight spans. Poles of each type were of similar design, consisting of reinforced concrete poles with steel crossarms and steel vertical brackets to support upright pin insulators on line poles, and jumper wires over the crossarms of anchor poles. Of the line poles, 27 were fitted with two double-connected pin insulators: i.e. both pin insulators were connected to each of the phase conductor cables for additional safety near settlements at each end of the line. The remainder of the line poles had single pin

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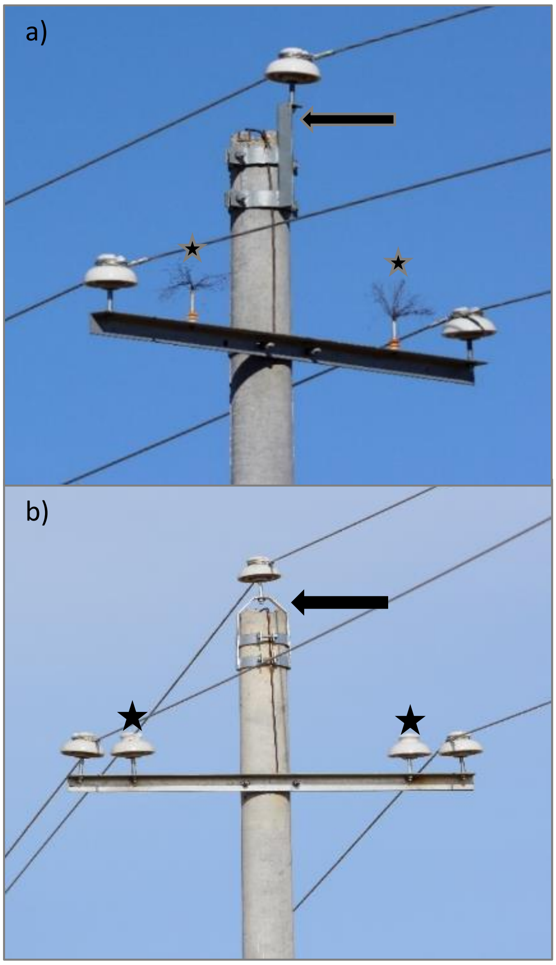

Figure 1. a) Control line pole with side-mounted single pin insulator at the top of the pole (indicated by arrow), and single pin insulators with pre-existing 'insulated brush' perch deflectors (indicated by stars) on the crossarm. b) Mitigated line pole, with centrally mounted pin insulator (arrow) at the top of the pole and additional unconnected pin insulators (stars) on the crossarm.

insulators connected to each of the phase conductor cables. The conductor cable was side-tied to the pin insulator neck, and so attached on the pole side of the insulators on the crossarm (Figure 1).

Prior to our study, the power company (Bayankhongor Erchim ED Company, Central Energy System) had fitted each pole with a pair of insulated wire-brush perch deflectors (Figure 1a) situated on the crossarm either side of the pole, typically midway between the pole and the pin insulator carrying the live conductor cable. In addition, the crossarms of a small number of line poles had also been previously fitted with rotating-mirrorperch deterrents (N = 15). The 15 lines poles with rotating-mirror perch deterrents and 27 poles with double connected pin insulators were excluded from our experimental study, along with the 27 anchor poles.

On 21-27 September 2016, we removed the brush deflectors and installed new 'barrier mitigation' at randomly selected line poles (N = 248) to compare with 'control' poles fitted with pre-existing insulated wire-brush perch deflectors (N = 163). Mitigation at the top of the pole for the phase 1 conductor involved replacing the existing side-fixed vertical steel pin insulator bracket with an arched-shaped bracket that held the pin insulator centrally over the top of the pole. The diameter of the pin insulator skirt was 185 mm and the external diameter of the concrete pole top was 190 mm (Figure 1b). Mitigation on the crossarm for the conductors at phases 2 and 3 involved adding another unconnected ceramic pin insulator adjacent to the connected pin insulators at either end of the crossarm, to introduce an insulated barrier between birds perched on the crossarm and the live conductor cables (Figure 1b). The materials used for this mitigation, two ceramic upright pin insulators and a steel arch-shaped insulator mount for each pole, cost approximately US$12 per pole; for a new line this configuration would result in an additional cost of approximately US$7.50 per pole.

We conducted daily surveys for 35 days post-mitigation (27 September to 31 October 2016), plus single visit follow-up surveys in the following spring (3 May 2017), autumn (5 November 2017) and summer (18-19 June 2018). We searched the ground within a radius of 20 m around the base of each pole and recorded the presence of avian remains. We quantified the efficacy of mitigation by comparing the observed electrocution rate at mitigated poles and unmitigated control poles.

Table 1. Number of birds of each species electrocuted at the Bayan Ovoo–Galuut 15 kV line recorded during single-visit line surveys over four consecutive years (3 October 2013, 12 August 2014, 20 August 2015 and 20 September 2016).

Species	2013	2014	2015	2016	Total
Black kite *Milvus migrans*	5	6	-	1	12
Black vulture *Aegyphus monachus*	1	-	-	-	1
Steppe eagle *Aquila nipalensis*	3	-	1	-	4
Common buzzard *Buteo buteo*	-	-	-	1	1
Upland buzzard *Buteo hemilasius*	12	4	3	6	25
Long-legged buzzard *Buteo rufinus*	-	-	1	-	1
Common kestrel *Falco tinnunculus*	-	1	3	2	6
Saker falcon *Falco cherrug*	31	48	86	39	204
Common raven *Corvus corax*	1	4	1	3	9
Total	**53**	**63**	**95**	**52**	**263**

CONSEQUENCES

During daily line surveys in September-October 2017, we recorded 35 newly electrocuted raptors at the mitigated and control line poles over 35 days (Table 2). One electric shock victim, an upland buzzard, was found stunned but alive. Single-visit line surveys in May 2017, November 2017 and June 2018 recorded a further 23, 44 and 21 electrocution victims respectively (Table 2).

We found that 106 electrocutions occurred at 71 different control poles, compared to just 17 electrocutions at 13 different mitigated poles; a significant difference in the number of poles with electrocution victims (Fischer's exact test, $p < 0.0001$; electrocutions at 5.2% of mitigated poles compared to 43.6% of control poles). The observed reduction in electrocution rate at

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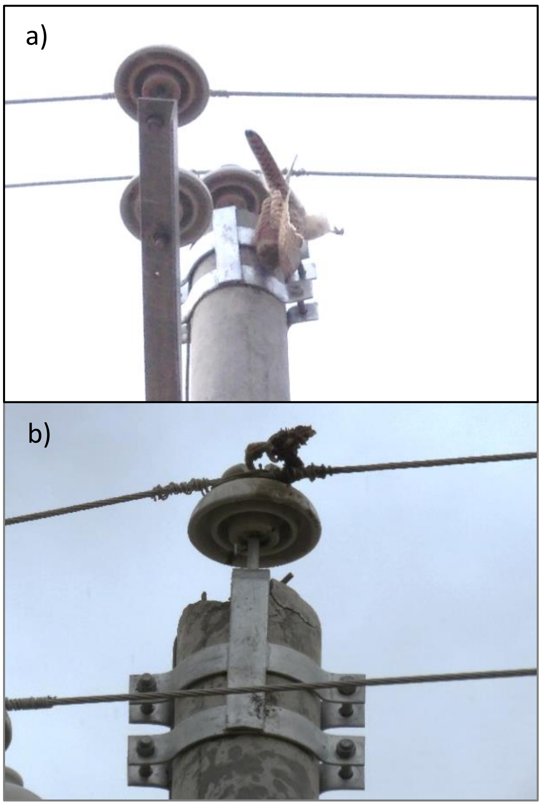

Figure 2. Evidence of raptors electrocuted at the top of mitigated poles: a) common kestrel electrocuted when perched on the bolt-bracket for the arch-shaped pin insulator mount. b) golden eagle talon still attached to phase cable after electrocution when perched on the pin insulator while carrying a large prey item (eagle carcass with steppe polecat prey found below pole).

mitigated poles compared to control poles ranged from 74% to 97% over the four different surveys (Table 2), with a mean reduction of 85% (95% confidence limits: 75-95%) and a total reduction of 88% (Table 2).

DISCUSSION

Our mitigation method significantly reduced the rate of raptor electrocutions but did not eliminate them. When positioned centrally at the top of the pole, the skirt of the pin-insulator was a physical barrier preventing any bird from perching on the pole top. The arch-shaped mounts used to position the pin centrally were designed to be fitted parallel with the phase conductor cable, with the attachment bolt brackets positioned perpendicular to the line. However, the power company engineers faced difficulty when fitting the arch mount at most poles due to the presence of an external lightning conductor, resulting in the bolt brackets being placed directly under the lightning conductor cable; the distance between the top of the bracket and the conductor cable was 38 cm. As a result, a common kestrel was electrocuted at the top of one pole after touching the live conductor cable when perching on the bolted bracket (Figure 2a). Similarly, a golden eagle was electrocuted when perched on the pin insulator at the top of a pole because it held a steppe polecat *Mustela eversmanii* in its talons; the prey hanging down presumably contacted the metal insulator mount or pole top resulting in electrocution (Figure 2b). It was not possible to determine whether the other birds killed at mitigated poles were killed at the top of the pole or at the crossarm. Smaller species, such common kestrel and little owl, may have been able to perch between the unconnected and connected pin insulators on the crossarm, while a single unconnected ceramic pin insulator may have been inadequate to deflect larger birds of prey far enough away from the conductor cables to entirely eliminate the risk of simultaneously contacting the cable and crossarm, particularly when taking off or landing.

It would be possible to modify the arch mount for the top of the pole by increasing the distance from the bolt brackets to the conductor cable; a distance of 50 cm is likely to be sufficient to prevent electrocution for species as large as a saker falcon (APLIC 2006); it is unlikely that larger species would perch on the bolt brackets. In addition, increasing the diameter of the arch mount would ease fitting during installation and enable the brackets to be positioned perpendicular to the line, further

Table 2. Number of raptors found electrocuted at mitigated (M; n = 248) and control (C; n = 163) poles during four power-line surveys. Totals expressed as the number of carcasses recorded per pole. The percentage difference shows the difference in the number of observed electrocution level at mitigated poles compared to the expected level based on electrocution rate at control poles.

Species	Sep/Oct 2016		May 2017		Nov 2017		Jun 2018		Total	
	M	C	M	C	M	C	M	C	M	C
Black kite *Milvus migrans*	-	1	-	2	-	1	-	-	0	4
Golden eagle *Aquila chrysaetos*	-	1	1	-	-	1	2	-	3	2
Steppe eagle *Aquila nipalensis*	-	1	-	-	-	3	-	-	0	4
Common buzzard *Buteo buteo*	-	1	-	-	-	-	-	-	0	1
Upland buzzard *Buteo hemilasius*	2	7	-	-	-	11	-	2	2	20
Northern goshawk *Accipiter gentilis*	-	1	-	-	-	-	-	-	0	1
Common kestrel *Falco tinnunculus*	3	5	-	-	-	-	-	-	3	5
Saker falcon *Falco cherrug*	1	11	-	15	2	26	3	14	6	66
Little owl *Athene noctua*	1	-	-	-	-	-	-	-	1	0
Common raven *Corvus corax*	-	-	2	3	-	-	-	-	2	3
Total	7	28	3	20	2	42	5	16	17	106
Carcasses/pole	0.03	0.17	0.01	0.12	0.01	0.26	0.02	0.10	0.07	0.65
Observed versus expected.	7 *v.* 43		3 *v.* 30		2 *v.* 64		5 *v.* 24		17 *v.* 161	
% difference	-80%		-89%		-97%		-74%		-88%	

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reducing the risk of a perching bird contacting the conductor cable.

The repositioning of the pin insulator to a central position at the top of the pole can be considered a form of remediation (i.e. permanently altering the base configuration of the pole hardware), while the placement of unconnected pin insulators on the crossarm is a form of mitigation (i.e. fitting an additional component to the base configuration of the pole hardware). In this case, the additional pin insulator mitigation does not require any additional maintenance and has an expected lifespan similar to that of the base design.

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