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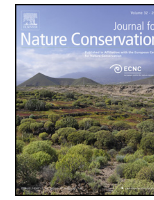


# Avian electrocution rates associated with density of active small mammal holes and power-pole mitigation: Implications for the conservation of Threatened raptors in Mongolia

Andrew Dixon[a,*], Md Lutfor Rahman[a], Batbayar Galtbalt[b], Amarkhuu Gunga[b], Batkhuu Sugarsaikhan[c], Nyambayar Batbayar[b]

[a] International Wildlife Consultants Ltd., PO Box 19, Carmarthen, SA33 5YL, UK
[b] Wildlife Science and Conservation Center, B-802 Union Building, Sukhbaatar District, Ulaanbaatar 14210, Mongolia
[c] Eastern Energy Company, Baruun-Urt, Sukhbaatar, Mongolia

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A B S T R A C T

Avian electrocution at power lines is a well-documented phenomenon, yet factors influencing the frequency of electrocution events and the efficacy of mitigation techniques remain relatively under-reported. During May-July, we surveyed a 56 km long 15 kV electricity distribution line running across open steppe in Mongolia recording electrocuted birds of prey under the power poles. We recorded high rates of electrocution of several Threatened raptor species, particularly the Endangered Saker Falcon *Falco cherrug*, which was killed at a monthly rate of 1.6 birds per 10 km during the period of our study. Electrocution frequency at line poles was associated with density of small mammal holes and the deployment of mitigation measures. It is likely that local prey abundance influences the frequency of birds of prey perching on power poles, which is consequently reflected in electrocution rate. We evaluated the efficacy of mitigation measures and found that the use of perch deflector spikes on the crossarms of line poles reduced electrocution rates when 3 or 4 spikes were deployed. Perch deflectors probably worked by reducing the opportunity for birds to perch adjacent to pin insulators rather than by reducing the frequency of birds perching on the crossarm *per se*. At anchor poles, reconfiguration of jump wires at two phases, so they passed under the crossarm rather than over, significantly reduced electrocution rates. These mitigation measures potentially represent a relatively inexpensive method to reduce the frequency of raptor electrocution events in regions where cost is a key factor for power line managers in determining whether or not any form of mitigation is used.



## 1. Introduction

Electrocution of birds of prey at low and medium voltage electricity distribution lines is a widespread global phenomenon that potentially has significant conservation implications (González, Bustamante, & Hiraldo, 1992; López-López, Ferrer, Madero, Casado, & McGrady, 2011; Sorenson, Burnett, & Davis, 2000). Mitigation methods to reduce risks of electrocution fall into three main categories: (i) isolation, by increasing separation between conductors, (ii) insulation, either of the live conductors (including burial below ground; Navrud, Ready, Magnussen, & Bergland, 2008) or the grounded components of the pole hardware and (iii) perch discouragers and deflectors to reduce the likelihood of a bird perching in position on a power pole where there is a high risk of electrocution (APLIC, 2006; Prinsen, Smallie, Boere, & Píres, 2011b). Isolation and insulation of conductors is relatively expensive compared to the deployment of perch deflectors and discouragers at dangerous poles. However, there are relatively few studies that assess the efficacy of different management measures to reduce the incidence of electrocutions (e.g., Bevanger, 1994; Guil et al., 2011; Janss & Ferrer, 1999; Negro & Ferrer, 1995), although perch deflectors have been shown to be effective at reducing predator perching rates on power poles (Dwyer & Dolоughan, 2014; Lammers & Collopy, 2007).

Electrocution rates at power lines can vary in relation to the raptor community, land cover and topography, prey availability and pole configuration (e.g., Ferrer, Delariva, & Castroviejo, 1991; Guil et al., 2011; Harness and Wilson, 2001; Janss and Ferrer, 2001). With

* Corresponding author. Present address: 22 Bronant, Talgarth, Brecon, LD3 0HF, UK.
*E-mail address:* adixonwales@gmail.com (A. Dixon).

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regard to the latter, a prevalent design for line poles on 10–15 kV distribution lines in Mongolia consists of grounded steel-reinforced concrete poles with metal crossarms and upright pin insulators to support the live phases. Electrocution can occur when birds perch on top of the pole or on the crossarm and touch an adjacent conductor, and every pole has the potential to electrocute birds of prey (Dixon, Maming, Gunga, Purev-Ochir, & Batbayar, 2013). At intervals of *ca*. 1.5 km and at deviation points along these lines there are anchor poles, where each phase of the conductors is connected via a jumper wire to a pair of pivoting chain insulators. The jumper wires can either pass above the hardware supporting the insulators or below it. Anchor poles have been shown to pose a significant electrocution risk to birds, particularly in relation to the configuration of the jumper wires (Dixon et al., 2013; Dwyer, Harness, & Donohue, 2013; Harness, Juvvadi, & Dwyer, 2013).

A positive relationship between electrocution rates of raptors and prey abundance has been documented among power lines (Guil et al., 2011, 2015), while open landscapes can result in greater use of poles and pylons as perching sites (Lehman, Kennedy, & Savidge, 2007). Consequently, high quality foraging areas in open landscapes can attract more individuals with an increased probability of electrocution from the higher likelihood of perching on power line infrastructure. In Mongolia, dangerous electricity distribution lines cross huge expanses of open steppe connecting settlements and industrial sites to the transmission network (Tserennyam, 2013). Every pole presents an electrocution risk and high prey densities can occur unpredictably around any distribution line so remediation needs to be carried out on a very large scale, which has significant cost implications.

The grounded concrete poles used for many electricity distribution lines in Mongolia are known to kill substantial numbers of birds of prey (Dixon et al., 2013; Dixon, 2016), thus there is a need to identify efficient and cost effective mitigation measures that can be implemented to address the problem of raptor electrocution. In this study, we recorded avian electrocution rates taking into account carcass removal by scavengers, and used this data to investigate the potential influence of (i) mitigation in form of pre-existing perch deflectors fitted to line poles and experimentally reconfigured jumper wires on anchor poles, and (ii) prey availability on raptor electrocution rates.

## 2. Material and methods

### 2.1. Study site

We undertook our study along a 56 km, 3-phase, 15 kV distribution line traversing open, undulating steppe landscape at an elevation of *ca*. 1250 m a.s.l between the district centres of Uulbayan and Monkhkhaan in Sukhbaatar Province, Mongolia (46.491N 112.347E to 46.967N 112.053E). The regional climate is characterised by cold winters (typically below freezing from October to April) and short summers (frost-free period from June to August). Most precipitation falls during July and August. The landscape and vegetation cover around the line was relatively homogenous along its whole length, characterised by short, sparse grasses growing in sandy soil, enabling clear visibility of any carcasses lying on the ground below power poles. The area has no formal protected status and the landscape in the immediate vicinity of the power line had few potential nesting sites for the resident breeding species.

All poles were constructed of reinforced concrete and the surveyed line comprised 493 line poles and 35 anchor poles. All anchor poles had jumper wires passing over the pole top at the central 1st phase. Of these, 13 had jumper wires passing over the crossarm on the 2nd and 3rd phases (termed 3-over anchor poles) and 22 had jump-wires passing under the crossarm on the 2nd and 3rd phases (termed 1-over anchor poles; Fig. 1). In March 2012, we reconfigured all the 3-over anchor poles so that the jump wires on the 2nd and 3rd phases passed under the crossarm i.e., they were converted to 1-over anchor poles.

Line poles had an upright pin insulator affixed to a vertical section of angled steel at the top of the concrete pole (1st phase), with a single horizontal crossarm of angled steel with one (or two near villages at each end of the line; N = 29) upright pin-insulators bolted to each end to carry the 2nd and 3rd conducting phases. Over the whole line 218 (41%) line poles were equipped with 1–4 perch-deflector spikes. These spikes had been fixed to the crossarms by the power line company previously in an attempt to reduce electrocution risk for raptors. However, the initial installation was haphazard, such that some crossarms had two centrally-positioned spikes that did not prevent birds perching adjacent to the pin insulators at the ends of the crossarms, whereas other crossarms were equipped with four-spikes, where the two outermost spikes could potentially function to deflect birds from perching adjacent to the pin-insulators (Fig. 2). Furthermore, over time a number of spikes had broken-off, so that we recorded 17 with one deflector, 64 with two, 25 with three and 112 poles with four perch deflectors.

### 2.2. Data collection

We made an initial line survey on 08 March 2012 prior to reconfiguring jump wires at 3-over anchor poles on 15 March 2012. Thereafter, we conducted six line surveys from 11 May to 20 July 2012 at 10–15-day intervals; we removed all carcasses found on 11 May and recorded these in our overall total (Table 1). We recorded 'observed electrocution' rates over 51 days from 11 May to 01 July and 'observed carcass removal' rates over 37 days from the second survey visit to 01 July. On 07 July the majority of carcasses were removed from the line by another team of surveyors unaware that we were working on this line, thus we were not able to use the information from our final survey visit on 20 July in our mortality and removal rate calculations, though we did include any new carcasses in our overall totals. In addition to raptors (Accipitriformes and Falconiformes) we have also included two crow species (Corvidae) in our analysis i.e., Red-billed Chough *Pyrrhocorax pyrrhocorax* and Common Raven *Corvus corax*.

To find electrocuted birds we drove along the power line and searched for carcasses within an area of 10 m around each pole; vegetation along the line was sparse and any dead raptors were clearly visible on the ground. We recorded each carcass found, the type and individual identification number of the pole and the number of perch deflector spikes present on the crossarm. On successive line surveys we recorded whether or not a carcass found on a previous visit was still present. During the line survey on 04/05 June, we recorded the number of active small mammal holes within a 20 m radius of alternate poles (1257 $m^2$; N = 191 poles) to record spatial variation in small mammal availability along the line. Active small mammal holes were identified from droppings or tracks at the entrance and searches were conducted by two people. The main small mammal species identified using the holes were Daurian Pika *Ochotona dauurica*, Mongolian Gerbil *Meriones unguiculatus* and Brandt's Vole *Lasiopodomys brandti*. However, we were not able to determine how many species, nor the number of individuals, that were using each burrow entrance.

### 2.3. Statistical analysis

We calculated daily removal rate by recording the number of days exposure ($E_s$) for each carcass between successive survey visits ($s$), with a period of 10, 12 and 15 days exposure for carcasses first found on the 1st, 2nd and 3rd survey visits respectively. If a