Short Communication

A new power transmission line causes significant mortality in the largest remaining population of Critically Endangered Bengal floricans *Houbaropsis bengalensis* in Cambodia

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Paper submitted 28 April 2022, revised manuscript accepted 21 November 2022.

Over the last decade Cambodia has witnessed a rapid expansion of its power transmission line network. This has been driven by rapid economic development and increasing energy demands for manufacturing and residential areas. Power transmission and distribution lines have been found to kill birds in all countries where their impacts have been studied (e.g., Jenkins *et al*., 2010). For instance, in the United States, it has been estimated that between 8 million and 57 million birds are killed by power lines annually (Loss *et al*., 2014). Typically, birds are killed not by electrocution, but because they fly into the wires at high speed, causing trauma and broken bones (Loss *et al*., 2014). Bird species differ in their susceptibility to collisions with power lines in predictable ways. The risk of collisions is higher for species whose eyes are aligned such that they have a narrow field of view when looking forwards, because they cannot see the power lines when they are flying directly towards them until they are very close to the lines (Martin & Shaw, 2010). The risk of collision is higher in fast-flying birds with heavy bodies because they cannot manoeuvre easily to avoid the lines, which is a particular problem if they do not see the power line until they are very close (Bevanger, 1998). Bustards, a family of 26 Eastern Hemisphere bird species, possess a combination of physical characteristics that makes them the most vulnerable group to power line collisions (Martin & Shaw, 2010). Elevated mortality due to collisions with power lines has caused population level declines in some bustard species (Shaw *et al*., 2017).

Bustards are represented in Cambodia by one species, the Bengal florican *Houbaropsis bengalensis* (Goes, 2013). This species is Critically Endangered, with a global population of less than 500 individuals (BirdLife International, 2022). The global population of the Southeast Asian subspecies *H. b. blandini* is now restricted to the Tonle Sap floodplain, where displaying males have declined from 416 (95% CI: 333–502) in 2007 to 216 (95% CI: 156–275) in 2012 and 104 (95% CI: 89–117) in 2018 (Gray *et al*., 2009; Packman *et al*., 2013; Mahood *et al*., 2019). These declines have been caused by the almost complete conversion of grassland in the Tonle Sap floodplain to irrigated dry-season rice (Mahood *et al*., 2020), an agricultural land-use that is incompatible with the breeding ecology of Bengal floricans (Ibbett *et al*., 2019), and to a lesser extent small-scale hunting. Since 2018, Bengal floricans are thought to breed only in four sites in the Tonle Sap Floodplain, with the Stoung-Chikreang sector of the Northern Tonle Sap Protected Landscape (NTSPL) accounting for half

CITATION: Mahood, S.P., Sum P., Hong C., Son V., Gnuen, G., Ly R. & Tizard, R. (2022) A new power transmission line causes significant mortality in the largest remaining population of Critically Endangered Bengal floricans *Houbaropsis bengalensis* in Cambodia. *Cambodian Journal of Natural History*, **2022**, 84–89.

of all remaining birds, and the only stable population (Mahood *et al*., 2019).

In 2019, a new threat to Cambodia's Bengal floricans emerged in the form of a 350 km power transmission line that was constructed from Kampong Cham to Battambang, along the northern edge of the Tonle Sap floodplain. A five-kilometre stretch of the power line runs through the northeast part of the Stoung-Chikreang sector of the NTSPL, which was completed in June 2019. Before the power line was constructed, it was predicted that this would likely cause elevated Bengal florican mortality, as well as mortality of other bird species (Mahood *et al*., 2016). These predictions were based on satellite telemetry data from 15 Bengal floricans that were satellite-tagged by the University of East Anglia in 2010 (Packman, 2011). These data showed that almost all of Cambodia's Bengal floricans must migrate over the power line twice each year when they move from their breeding to their non-breeding grounds, whilst those in the Stoung-Chikreang sector of the NTSPL were likely to cross it more frequently and would therefore be at greatest risk (Mahood *et al*., 2016).

To determine whether the power line causes Bengal florican mortality, we conducted weekly searches for carcasses underneath the stretch of the line that passes through the Stoung-Chikreang sector of the NTSPL. These began as soon as the power line was installed (June 2019) and have continued to the time of writing. The surveys are conducted by a team of four or five community members who have worked for the Wildlife Conservation Society Bengal florican project for many years and are familiar with the bird species of the area. Survey methodology follows standard protocols for assessing mortality of birds associated with power lines (e.g., Burnside *et al*., 2015). During each survey, the team arrange themselves approximately 15 m apart in a row under the power line at 13°00′50.8″N, 104°28′41.9″E and slowly walk for 4.5 km to 13°00′47.2″N, 104°28′54.6″E. During the survey they look carefully at the ground to search for bird carcasses.

The following data were recorded for each survey: site name, observer name, time start, time end and date of survey. These data are recorded whether or not any carcasses are found on the survey. For each carcass found, the following data were recorded: date, time found, name of finder, GPS location, location name, English name of species (where known), Khmer name of species, estimated cause of death, and distance from the carcass to the power line. A new survey sheet is used for each survey irrespective of whether any carcasses are found. All carcasses found were photographed so that species identifications could be verified. Carcasses found were not removed but based on photographs of these it is not thought that any carcasses remained from one week to the next. A total of 111 power line surveys were undertaken between 23 June 2019 and 22 February 2022. These were typically conducted weekly, but no surveys were undertaken in March 2020 due to constraints caused by COVID-19 precautions, and no surveys were conducted from late October to mid-December 2020 because the survey area was under deep water.

A total of 140 bird carcasses constituting at least 30 species were recorded during the surveys (Annex 1). This should be considered a minimum estimate of the number of birds killed by the power line since it was installed. Of significant concern, mortalities included six Bengal floricans (Table 1). Carcasses of two globally Near Threatened species were also recorded comprising seven spot-billed pelicans *Pelecanus philippensis* and four painted storks *Mycteria leucocephala*. The most commonly recorded species included birds that are common in the local area, and species that are scarcer but more susceptible to power line collisions. It was not possible to definitively identify all species killed by the power transmission line, specifically accurate identification of all small birds of the order Passeriformes was not possible, so many of these

Table 1 Bengal florican carcasses recorded during surveys conducted between June 2019 and February 2022.

Date	Sex	Location Name	Coordinates
19 September 2019	F	Tom Neab Kork Touch	13°00'36.1"N, 104°29'50.8"E
5 February 2020	M	Tom Neab Kon Thnal	13°00'50.0"N, 104°29'03.7"E
12 August 2020	M	Tom Neab Kork Touch	13°00'23.4"N, 104°30'12.7"E
12 August 2020	M	Tom Neab Kork Touch	13°00'23.2"N, 104°30'12.2"E
2 March 2021	F	Tom Neab Kon Thnal	13°00'39.0"N, 104°29'21.8"E
25 August 2021	M	Tom Neab Kork	13°00'23.6"N, 104°30'12.9"E

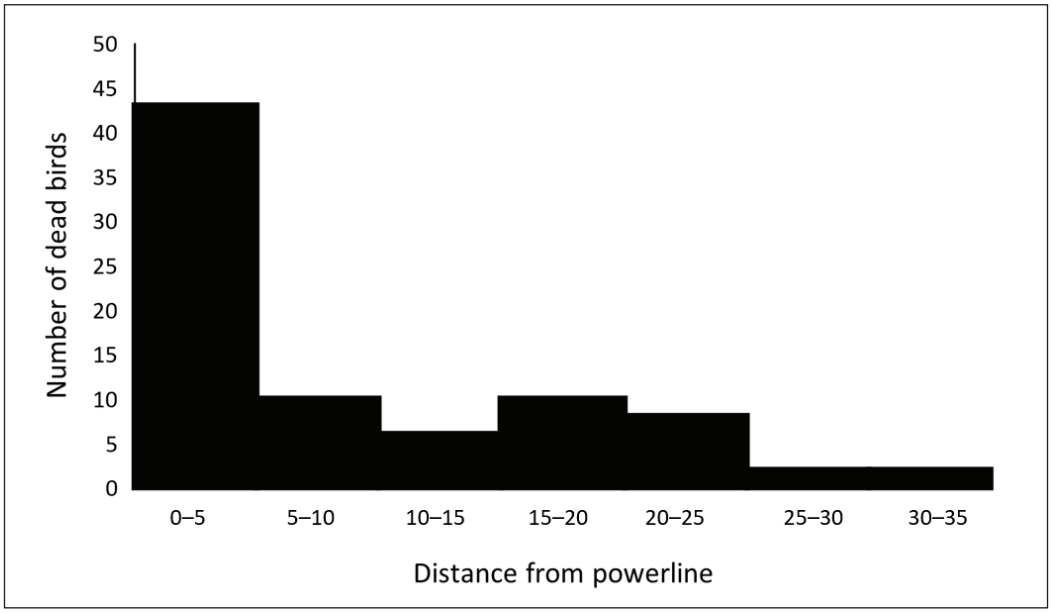

Fig. 1 Histogram showing distance (metres) of bird carcasses relative to the power line. Only species of a mass greater than 500g are included.

were recorded as Passerine sp. It is possible that some carcasses of birds that were killed by the power line were scavenged by free-ranging domestic dogs before the survey team conducted the weekly surveys. In addition, the survey team may not have found all the carcasses that were present at the time of the surveys.

It may be postulated that finding a bird carcass under a power line does not itself mean that the bird was killed by the power line. We tested this assumption by analysing the distance that carcasses were found from the power line. More birds were found closer to the power line than further from it, indicating a strong positive influence of the power line on the distribution of bird carcasses in the landscape (Fig. 1). However, owing to our search method we were unable to account for crippling bias, whereby estimates of power line mortalities are under-estimated because birds collide with a power line and continue flying in an injured state, dying tens or hundreds of meters from it. Estimates of crippling mortality vary by species, location and type of power line, but can be up to 80% (Rioux *et al*., 2013).

Despite being one of the rarest species in the study area, six Bengal floricans collided with the power transmission line and were killed. Of these, two were females and four were males (Table 1). All were adult (aged from photographs). Excluding "Passerine sp.", which covers many unidentified small bird species, Bengal floricans were the 7th most abundant bird species in our power line casualty statistics. Many other species that are far more abundant in the study area than Bengal floricans, such as herons and egrets, suffered less mortality, or no mortality at all. This finding is consistent with other studies that have found that bustards are particularly vulnerable to collisions with power lines (e.g., Uddin *et al*., 2021; Shaw *et al*., 2017). The study area is in the most important part of Cambodia for Bengal floricans. Within this area, the power line cuts through a protected area of grassland that supports 44 (95% CI: 25–63) male Bengal floricans (and an unknown number of females), which equal 42% of Cambodia's Bengal florican population (Mahood *et al*., 2019). The additional loss of six adult Bengal floricans from this population over less than three years is unlikely to be trivial. Bengal floricans reproduce slowly, laying one (or occasionally two) eggs each year (Collar, 2019), so they cannot sustain high levels of adult mortality. Cambodia's Bengal florican population is already undergoing a rapid decline (55% over the 2012–2018 period, prior to power line construction), which even the level of mortality recorded during our survey is likely to worsen.

All of the detected power line mortalities of Bengal floricans occurred in February–March or August–September. Outside of these periods, Bengal floricans are either holding display territories and nesting to the south of the power line (March–August) or on the non-breeding grounds located north of the power line (October–January). The lack of detected mortality during the breeding season is surprising, because the power line

is extremely close to a known lek. We did not quantify the impacts of the power line on Bengal florican mortality outside of the study area. However, since all Bengal floricans are likely to cross the power line during their migration periods, it is plausible that additional Bengal florican mortalities occurred elsewhere along the line.

There was very limited mitigation of impacts to birds during development of the Kampong Cham to Battambang power transmission line. The most effective mitigation option would have been to re-route the power line in areas where it would otherwise closely approach the sites where Bengal floricans breed (such as the study area). Bird flight deflectors, disks or spirals that make it easier for the birds to see the power line, could have been fitted to the wires prior to erection of the power line to reduce the number of birds that would be killed (Barrientos *et al*., 2011). However, they were only attached to the pylons, which are of little threat to flying birds, not to the wires. Because birds typically collide with the earth wire, bird flight deflectors are usually attached only to this wire. It is low cost and technically simple to do this prior to installation of power lines. It is still possible to attach bird flight deflectors to a power line after construction is completed, but this is considerably costlier and logistically difficult. These mitigation measures are standard in many countries in areas where power lines cross areas used by globally threatened species that are susceptible to power line mortalities, such as bustards. Although they reduce mortality of most bird species, long-term data sets and a recent meta-analysis concluded that bird flight deflectors do not reduce mortality of bustards (Shaw *et al*., 2021; Silva *et al*., 2022). Future construction of power lines should ideally be avoided completely in areas with populations of Bengal floricans. Where it is unavoidable that power lines pass close to areas that support Bengal floricans, there is a need to improve habitat management and reduce hunting to offset residual power line mortality, in addition to fitting bird flight deflectors to reduce mortalities of other species.

Acknowledgements

This study was conducted as part of a wider program of work on Bengal florican conservation in the Tonle Sap Landscape under a Memorandum of Understanding between the Ministry of Environment, Cambodia, and Wildlife Conservation Society. Our work was funded by grants from Margaret A. Cargill Philanthropies, Agence française de développement, and the European Union. We are grateful to community members for data collection, namely Meas Than, Soun Kanil, Chan Saery, Khy Thai, In Khin, Lim Socheat, Torn Ro, Met Mot, Lorn Phal, Loun Kimhan, Eng Vy, Hean Ket, Born Chi, Vy Vut, Ti Neang and Ly Sinan.

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Annex 1 Total carcasses found during surveys conducted between 23 June 2019 and 22 February 2022

IUCN Status: CR=Critically Endangered, NT=Near Threatened, LC=Least Concern.

English name	Scientific Name	No. of Carcasses	IUCN Status
Blue-breasted quail	*Coturnix chinensis*	1	LC
Lesser whistling-duck	*Dendrocygna javanica*	1	LC
Knob-billed duck	*Sarkidiornis melanotos*	7	LC
Cotton pygmy-goose	*Nettapus coromandelianus*	1	LC
Indian spot-billed duck	*Anas poecilorhyncha*	1	LC
Painted stork	*Mycteria leucocephala*	4	NT
Asian openbill	*Anastomus oscitans*	1	LC
Black-crowned night-heron	*Nycticorax nycticorax*	6	LC
Pond-heron sp.	*Ardeola* sp.	4	LC
Eastern cattle egret	*Bubulcus coromandus*	2	LC
Grey heron	*Ardea cinerea*	7	LC
Egret sp.	*Ardea/Mesophyx/Egretta* sp.	17	LC
Spot-billed pelican	*Pelecanus philippensis*	7	NT
Little cormorant	*Phalacrocorax niger*	1	LC
Black-shouldered kite	*Elanus caeruleus*	3	LC
Bengal florican	*Houbaropsis bengalensis*	6	CR
Ruddy-breasted crake	*Porzana fusca*	1	LC
Watercock	*Gallicrex cinerea*	3	LC
Buttonquail sp.	*Turnix* sp.	3	LC
Red-wattled lapwing	*Vanellus indicus*	1	LC

Annex 1 Cont'd

English name	Scientific Name	No. of Carcasses	IUCN Status
Little ringed-plover	*Charadrius dubius*	1	LC
Snipe sp.	*Gallinago* sp.	9	LC
Oriental pratincole	*Glareola maldivarum*	14	LC
Feral pigeon	*Columba livia*	1	LC
Spotted dove	*Steptopelia chinensis*	1	LC
Zebra dove	*Geopelia striata*	1	LC
Pied kingfisher	*Ceryle rudis*	1	LC
Little green bee-eater	*Merops orientalis*	1	LC
Black drongo	*Dicrurus macrocercus*	1	LC
Passerine sp.	Passerine sp.	33	-

