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Short Note

Lack of evasive behaviour by a Martial Eagle *Polemaetus bellicosus* on impact with a turbine blade at a South African wind farm: causes and mitigations

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We describe a collision of Africa's largest raptor, the Martial Eagle *Polemaetus bellicosus* with a spinning blade at a South African wind farm in the Eastern Cape in July 2016, and the abandonment of the territory following a second fatal collision of an adult Martial Eagle at the same farm. Most evidence suggest that the eagle took no evasive action because she did not detect the blade due to the poor contrast abilities among raptors in general. Increasing blade visibility with black or "Signal Red" stripes is a simple and promising cost-effective mitigation action that should be further tested in South African wind farms.

Absence de comportement évasif d'un Aigle martial *Polemaetus bellicosus* lors de l'impact avec une pale d'éolienne dans un parc éolien sud-africain: causes et mesures d'atténuation

Nous décrivons la collision du plus grand rapace d'Afrique, l'Aigle martial *Polemaetus bellicosus*, avec une pale en rotation dans un parc éolien sud-africain du Eastern Cape en juillet 2016, et les conséquences à plus long terme sur l'occupation du territoire suite à une seconde collision mortelle d'un Aigle martial adulte dans le même parc. Nos observations suggèrent que l'aigle n'a pas pris de mesures évasives parce qu'il n'a pas détecté la pale en raison de la faible capacité de détection de contraste par les rapaces en général. Augmenter la visibilité des pales à l'aide de bandes noires ou rouges est une mesure d'atténuation simple qui devrait être testée plus intensivement dans les parcs éoliens d'Afrique du Sud.

Keywords: avian fatality rates, avian vision, patterned blades, raptors, wind energy

How raptors see the world around them has recently come into sharper focus as the renewable energy industry struggles with the high fatality rate apparent in the Accipitridae at operational wind farms. The high proportion of raptors as victims of wind farm collisions first came to light with fatality data from the earliest and largest wind farm at Altamont Pass, USA (Smallwood 2013) and subsequently confirmed in other areas across the globe (Kolar and Bechard 2016, Thaxter et al. 2017, May et al. 2020). More concerning are cases where wind farms placed near sensitive areas (migration routes, breeding sites) can cause breeding population effects on buzzards, large eagles, and harriers (Kolar and Bechard 2016, Stokke et al. 2017, Wilson et al. 2017, Cervantes et al. 2022).

The propensity for high proportions of raptor fatalities is no different at South African wind farms. Among a wide diversity of 130 species fatalities, raptors of all sizes comprised 36% of 848 victims in South Africa from 20 wind farms surveyed from 2014 to 2020 (Perold et al. 2020). On a continent with more raptor species than any other (Clarke and Davies 2018), many species are threatened and, indeed, 8% of the 848 South African fatalities were threatened Red Data species (Perold et al. 2020). Globally Endangered Black Harriers *Circus maurus* (IUCN 2023) are at threat with 12 confirmed fatalities, and the most impacted species was the regionally *Vulnerable* Verreaux's Eagle *Aquila verreauxii* (Taylor et al. 2015), with 33 confirmed fatalities from 2014–2023 (S Ralston-Paton, Birdlife South Africa, pers. comm. 2023).

It is rare, however, for these deaths to be witnessed directly by observers. This is important because determining a bird's behaviour prior to impact may give insights into why collisions occur, and how they can be mitigated.

Here we describe a collision of Africa's largest raptor, the Martial Eagle *Polemaetus bellicosus* (mean female mass = 5 kg; Simmons 2005), with a spinning blade at a South African wind farm in the Eastern Cape in July 2016, and the longer-term consequences on territory occupancy following a second fatal collision of an adult Martial Eagle at the same farm in September 2016.

The study was undertaken at the Jeffreys Bay wind farm (34°00′14″ S, 24°50′38″ E), operational since 2014 and managed by Globeleq (Pty) Ltd. The farm, covering 3 000 ha, supports 60 turbines of 80 m hub height and

50 m blades, generating 138 MW of power, just north of Jeffreys Bay in the Eastern Cape. The habitat is a mix of intact Eastern Cape Grassy Fynbos (Mucina and Rutherford 2011) lightly grazed by livestock. The landscape is topographically flat, other than a central wooded valley, running north-west to south-east, with the land gradually sloping from 200 m asl in the north to 97 m asl in the south. The prevailing winds are from the south-west and strong enough to support the wind farm.

Our aim was to map flight paths of all threatened collision-prone raptors to determine their risk to turbine impacts (known to occur at approximately 1 raptor per month over 54 months, between October 2014 and January 2019). We then describe the circumstances of the eagle collision and a subsequent necropsy on the carcass. Observations were undertaken from equally spaced vantage points 3 km apart, for 6 hours per day covering the entire 2 800-ha wind farm, paying particular attention to breeding birds. This included Black Harriers nesting in Fynbos vegetation 240 m from the nearest turbine, and Martial Eagles breeding in the central valley 900 m from the nearest turbine (and 1 640 m from the fatal turbine). Observations occurred in weekly blocks averaging between 57 h and 105 h per month, every 2–3 months starting in June or July (for breeding birds) and finishing in January (for the migrants). We thus covered all biologically active seasons for a total of 822 observer-hours over three years (2016–2019). In each session two observers recorded the species, its height above ground (against the 80 m high turbine towers) every 15 seconds and recorded its flight path on a printed and laminated Google Earth map in the field. Voice recorders were used when high aerial traffic was encountered. Passage Rates (flights per hour) and fatalities will be reported on elsewhere.

During morning observations at 10:20 on 27 July 2016 we saw a pair of Jackal Buzzards *Buteo rufofuscus* vigorously mobbing a subadult Martial Eagle high over the wind farm. Over 11 minutes, the two buzzards dived persistently at the eagle, forcing it down from about 200 m above the ground to about 120 m before drifting away about 150 m away from an operational turbine.

The eagle headed relatively slowly into the light south-westerly wind (4 m s^{-1}) at about 125 m above ground and as it did so, was struck on her right flank by the end of the blade travelling at 144 km $hour^{-1}$ (P Oosthuizen, Globeleq, pers. comm.). Despite eagles' high acuity vision, this individual took no evasive action to avoid the white blade travelling perpendicularly towards her (Figure 1a). Photographs (Figure 1a,b) shows the bird plummeting earthwards indicating it had been fatally wounded. The lifeless body was recovered 35 m from the base of the turbine (Figure 1c) and taken to the Oribi Animal Clinic in Jeffreys Bay where it was weighed and x-rayed. The bird was in prime condition as judged by her mass of 5.1 kg, a full stomach, no feather lice and good muscle mass. However, her spine was fractured, and she had a fresh, deep gash on her right flank that had penetrated her abdomen. The bird was aged as a four-year-old based on plumage (Figure 1c; Dr R van Eeden, FitzPatrick Institute, University of Cape Town, pers. comm).

Less than two months later (early September 2016) the same turbine brought down a second Martial eagle, this time an adult male from the known nest within the wind farm. As an adult breeder this caused the failure of the active nest and in subsequent years no further breeding was recorded (2016–2019). The territory has remained vacant for 7 years, through 2023 (M Langlands, Kromme Enviro-Trust, pers. comm.) and thus, full displacement has occurred despite the nest tree remaining intact.

These photographs constitute the first visual record of a raptor killed by a turbine blade on the African continent and our observations highlight the lack of evasive action of this great eagle to a large (~10 ton) white blade moving towards it under clear skies. This raises the question how a bird with the legendary visual acuity of an eagle fails to see a moving turbine blade of this size? The immediate possibilities are (i) the eagle did not detect the blade; (ii) it was not aware it was entering a danger area and the blade hit it from behind; (iii) the bird was distracted or (iv) the bird saw the blade, but its high wing loading prevented it from reacting in time. The idea of a blind region due to skull morphology found in some large birds such as *Gyps* vultures (Martin and Shaw 2010; Martin et al. 2012) is unlikely for Martial Eagles because they have binocular vision (Figure 1d) and the blade hit the eagle perpendicularly, not from the front or from behind. Was it aware it was entering a danger zone? If the 50 m blade was travelling at 144 km h^{-1} (40 m s^{-1}) we can calculate that the previous blade would have been in front of the eagle 2.6 seconds before being hit by the following blade. This makes it unlikely that she was unaware of a blade in front of her, unless she could not detect it. The possibility she was still distracted cannot be discounted because the buzzards had stopped mobbing 1 minute before the collision. We suspect that a combination of distraction and the poor contrast abilities of raptors (Potier et al. 2018) lead to her death. This interpretation gains support from both field and laboratory studies. When a population of 47 breeding pairs of White-tailed Eagle *Haliaeetus albicilla* were regularly being killed by 68 spinning white blades on the island of Smøla, Norway (averaging 6 fatalities per year), researchers painted one of the blades (of four turbines) black, resulting in a 100% reduction in eagle fatalities at the patterned blades, compared with an average of 6 birds per year at the remaining turbines (May et al. 2020). Similar experiments with red patterned blades underway at the Umoya Wind farm in Hopefield, South Africa are providing equally promising results (Simmons et al. in prep.). This is also supported by laboratory experiments with kestrels (*Falco* spp.) reacting more often to black patterned blades than white or grey blades (McIsaac 2001). Each experiment supports the idea that eagles have traded high visual acuity (numerous cone receptors) at the expense of (low) contrast abilities (few achromatic rod receptors: Potier et al. 2018, Martin and Banks 2023). Finally, the idea that the large eagle with its heavy wing-loading was not agile enough to avoid the blade cannot explain the 39 raptor fatalities (of 12 raptor species) at the farm in 42 months, including four Black Harriers and 12 Amur Falcons *Falco amurensis,* all highly agile species (Simmons and Martins 2019).

We conclude that the Martial Eagle observed killed by a spinning white turbine blade, probably took no evasive

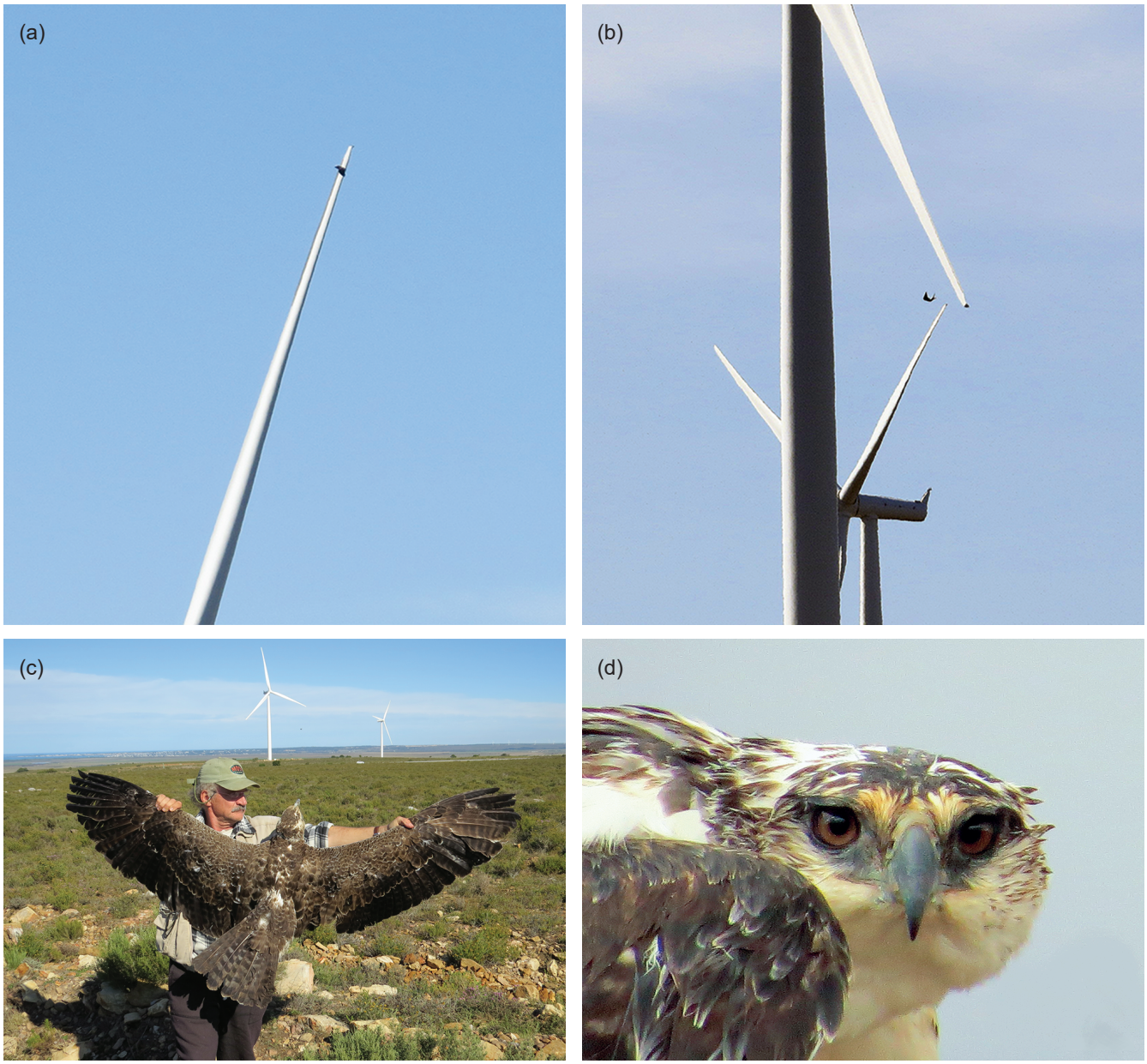

Figure 1: First photographic record of a raptor killed by a turbine blade on the African continent. (a) Moment of impact: a young Martial Eagle *Polemaetus bellicosus*, flying slowly from right to left, is struck on her right flank by a white blade approaching at 144 km/hour from the bird's right, at the Jeffreys Bay Wind Farm, South Africa [RE Simmons]. (b) The Martial Eagle free-falls from about 120m to the ground, seconds after being struck by the turbine blade [RE Simmons]. (c) The lifeless Martial Eagle was found 35 m from the base of the turbine, and spotting on the chest indicates that it was a subadult bird at the time of her death [M Martins]. (d) The binocular vision of a subadult Martial Eagle (photographed in the Karoo) suggests that this species does not suffer from a blind region in its visual fields, as do vultures, and this is unlikely to explain the lack of awareness of moving obstacles in front of them [CLB Simmons]

action because she did not detect the blade due to the poor contrast abilities among raptors in general (Potier et al. 2018). By increasing blade visibility with black or "Signal Red" stripes, wind farms can test the ideas that patterned blades reduce the raptor fatalities that dominate South African wind farms (Perold et al. 2020). This simple and cost-effective mitigation is supported by South African Wind Energy Association (Morkel et al. 2023).

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