OCCASIONAL REPORT SERIES: 3

BirdLife South Africa
Giving Conservation Wings

Summary of Bird Monitoring Reports from Operational Wind Energy Facilities in South Africa

February 2025



Contents

Technical Report by BirdLife South Africa

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BirdLife South Africa is a registered non-profit, public benefit organisation and the only dedicated bird-conservation organisation in South Africa. It strives to conserve birds, their habitats and biodiversity through scientifically-based programmes, through supporting the sustainable and equitable use of natural resources and by encouraging people to enjoy and value nature.

Acknowledgments
This work was made possible thanks to funding from the Lewis Foundation, Investec Rhino Lifeline and the Ingula Partnership (a partnership between Eskom, BirdLife South Africa and Middelpunt Wetland Trust). We are grateful for the support of the Department of Forestry, Fisheries and the Environment, and environmental assessment practitioners whose decisions and recommendations helped ensure that bird impacts are monitored at wind energy facilities and that reports are shared with BirdLife South Africa. We also extend our thanks to the wind energy facilities involved for financing operational-phase monitoring, sharing the reports, and participating in subsequent discussions. A full list of these wind farms is provided in Annexure 1. Special thanks go to the avifaunal specialists who oversaw the monitoring and reporting at these wind energy facilities, as well as the field staff who conducted the surveys. Finally, we thank the Birds and Renewable Energy Specialist Group for their valuable insights and suggestions, particularly Simon Hulka, Kevin Shaw, Dr Rob Simmons and Jon Smallie for their detailed contributions, and Simon Hulka for assistance with the Potential Biological Removal calculations.

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Suggested citation:
BirdLife South Africa 2025. Summary Bird Monitoring Reports from Operational Wind Energy Facilities in South Africa. *BirdLife South Africa Occasional Report Series No. 3.* BirdLife South Africa, Johannesburg, South Africa

Summary of Bird Monitoring Reports from Operational Wind Energy Facilities in South Africa

INTRODUCTION

Renewable energy is gaining traction in South Africa and is a central part of a least-cost, no-regret strategy to generate electricity and achieve climate goals (PCC 2023; SAREM 2023). Wind energy is one of the favoured technologies for renewable power generation and there is good reason to believe that with South Africa's excellent wind energy resource the amount of wind power will grow significantly over the next decade (SAREM 2023).

While wind energy offers numerous benefits, the potential adverse effects of constructing and operating wind energy facilities (WEFs) on biodiversity cannot be overlooked. One well-documented negative impact is the collision of birds with wind turbines (Smallwood and Thelander 2008; Loss et al. 2013; Bennun et al. 2021). Together with the need to fast-track renewable energy projects (SAREM 2023) there is a need to improve the accuracy of impact predictions and evaluate the significance of cumulative effects on bird populations (Bennun et al. 2021).

There is growing evidence that wind turbine fatalities could reach levels that threaten local populations (e.g. the Egyptian Vulture *Neophron percnopterus* in southern Spain (Carrete et al. 2009), the Golden Eagle *Aquila chrysaetos* in the USA (Hunt et al. 2017) and the Red Kite *Milvus milvus* in Germany (Bellebaum et al. 2013)). In South Africa, there is now evidence that wind energy's impacts on the Black Harrier *Circus maurus* could exacerbate the species' risk of extinction (Cervantes et al. 2022). Yet much still needs to be understood about the potential population-level impacts of wind energy on birds (Bennun et al. 2021).

Most WEFs in South Africa monitor their impacts on birds and, if significant impacts arise, wind farms may commit to, or be legally required to, implement adaptive management – i.e. adjust their mitigation strategies to reduce impacts.

This report provides an overview of the outcome of operational-phase monitoring and mitigation of wind energy's impacts on birds in South Africa, covering the period from 2015 to 2023. Drawing on available reports and data, we summarise recorded fatality rates and provide an overview of the species affected and possible risk factors, building on BirdLife South Africa's first review of this kind, published in 2017 (Ralston-Paton et al. 2017). Using case studies, we also present the array of mitigation measures currently employed at South African wind farms and offer practical recommendations to address challenges encountered. This information is intended to be used to refine the planning, environmental impact assessment (EIA) and mitigation for the wave of WEFs in the pipeline, as well as identify priorities for research and policy intervention.

METHODS

GENERAL APPROACH

As a condition of their environmental authorisation, most wind farms in South Africa are required to monitor their impacts on birds and use protocols designed according to the *Best practice guidelines for avian monitoring and impact mitigation at proposed wind energy development sites in southern Africa* (Jenkins et al. 2015, or previous versions thereof). The environmental authorisations and/or environmental management programmes (EMPrs) for many of these wind farms require that the resulting monitoring reports be shared with BirdLife South Africa. Where submission of reports was delayed, or where submission to BirdLife South Africa was not explicitly required, wind farm operators were contacted via email to encourage sharing of reports. Meetings were held with wind farm operators and/or environmental managers to clarify the status of monitoring and mitigation. All reports received up to 1 August 2023 were used in this study (with some more recent notes included where new information could point to critical insights).

The monitoring reports were usually produced by an independent avifaunal specialist, who either employed a team of field observers to conduct carcass searches or oversaw a team employed by the WEF. Data were gleaned from these monitoring reports. The list of reports consulted is provided in Annexure 1. Due to the perceived sensitivity of fatality data by some stakeholders, references linking wind farms to particular impacts have not been provided.

Where technical information about WEFs (e.g. turbine size and commercial operational date) was not available in the above reports, this was obtained from the applicable WEF's website and other online sources.

Thirty-five WEFs were initially considered for the study; two were subsequently eliminated due to a lack of operational-phase monitoring reports. All but one of these WEFs were developed under South Africa's first four tender windows of the Renewable Energy Independent Power Producer Procurement Programme.

LOCATION OF WEFs

All WEFs in the review were located in the Eastern, Northern and Western Cape provinces. The majority of WEFs overlapped the Fynbos, Albany Thicket and Nama-Karoo biomes (as defined in Rutherford et al. 2006), with two or more biomes often overlapping (Figure 1).

WEF DESCRIPTION

The combined nameplate capacity of the 33 WEFs included in the study was 3 210 MW comprising 1 351 turbines. Installed capacity at each WEF ranged from 21–147 MW (average 92 MW) comprising 7–96 turbines. Turbine capacity varied from 1.5–3.6 MW (average 2.6 MW). Hub height varied from 80–117 metres (average 92 metres) with a rotor diameter of 63–125 metres (average 106 metres). A list of the WEFs for which data were provided is included in Annexure 2.

SURVEY DURATION, AREA & FREQUENCY

Operational monitoring at the 33 WEFs ranged from six months to eight years. Monitoring spanned a total of 3 902 turbine-years and 8 747 megawatt-years. Turbine-years were calculated as the number of turbines monitored at a wind farm multiplied by the duration of monitoring. For example, a WEF with 47 turbines, where all turbines were subject to operational-phase monitoring for one year, would equal 47 turbine-years. Megawatt-years were calculated in a similar manner using the installed capacity at the applicable WEF.

Carcass-survey search plots were either squares or circles, centred on a turbine. The survey area and frequency of surveys varied between WEFs, within WEFs, and between years, but most surveys were conducted in a 200 m x 200 m plot and aimed for a weekly survey interval. However, in some cases the survey area was reduced to simply the road and hardstand.

FATALITIES & UNADJUSTED FATALITY RATES

The total number of carcasses found beneath turbines and powerlines was calculated by adding the number of carcasses found at all the WEFs. These figures were not adjusted to account for carcasses missed as a result of search efficiency or scavenger removal.

Unadjusted fatality rates as a result of turbine collisions were calculated as the total number of carcasses found beneath turbines and deemed likely to be the result of turbine collisions, divided by the number of turbine-years monitored. At some WEFs it was not clear if all turbines were monitored using standard monitoring protocols, but it was assumed that these turbines would have been checked occasionally, as recommended by best practice (Jenkins et al. 2015). Unadjusted fatality data based on turbine-years are therefore likely to be substantially underestimated (i.e. much lower than actual). Note that not all fatalities found beneath turbines are due to blade strikes, with some likely to be tower-strike fatalities.

ESTIMATED FATALITY RATES

Most monitoring reports included fatality estimates, calculated from the number of carcasses found and corrected for detection errors (i.e. scavenger removal and searcher efficiency) (see for example Huso and Dalthorp 2014 and Dalthorp et al. 2018). Bird fatality estimates were normally only calculated for the entire WEF, although some reports included estimates for different size classes (i.e. small, medium and large birds, and raptors). Estimates were rarely provided for species.

OVERLAP WITH SPECIES DISTRIBUTION AND LOCATION OF CARCASSES

To determine if a WEF falls within the range of selected priority species, a buffer of 20 km was used around each WEF and Southern African Bird Atlas Project 2 (SABAP2) records for those pentads were consulted. In addition, bird presence data

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were gleaned from monitoring reports and environmental impact assessment (EIA) reports, where available.

The proximity of turbine fatalities to key features (e.g. colonies and nests) was not always clearly indicated in reports. Where possible, distances to features were estimated based on the location of fatalities and features as inferred from the best available information (e.g. maps provided and turbine reference number).

CUMULATIVE IMPACTS

Because not all WEFs monitored and reported impacts annually, the minimum annual number of fatalities attributable to turbine collisions nationally was calculated based on an estimate of the current installed capacity (approximately 3 490 MW and 1 421 turbines in 2024). Due to the uncertainty in the growth trajectory, and size of turbines, the assessment of cumulative impacts did not take into account predicted growth in the number of wind turbines in South Africa. However, it is worth noting that 17 700 MW wind energy is planned to be installed by 2030, according to South Africa's Integrated Resources Plan (Department of Energy 2019).

The annual number of fatalities that populations of some species could sustain without compromising the long-term viability was determined using a simple Potential Biological Removal (PBR) analysis (Dillingham and Fletcher 2011; Diffendorfer et al. 2021). A recovery rate of 0.1 was set for threatened species and the PBR estimate was compared with the minimum number of fatalities predicted to occur, based on the (unadjusted) fatality rates recorded in the review. This use of PBR has limitations, as discussed below, but can provide a useful framework to assess the relative magnitude of human-induced losses.

LIMITATIONS

When interpreting the data presented in this report, it is important to note the limitations associated with the data used. Not all WEFs shared monitoring reports with BirdLife South Africa and some WEFs have recorded their impacts for longer than others. While survey protocols were to some extent standardised, there was inevitably variation in the methodologies and the teams implementing the surveys. The challenges and limitations of operational-phase monitoring are detailed later in this report.

Most operational reports did not provide species-level fatality rate estimates, accounting for search efficiency and scavenger removal, nor did many provide estimates for different size classes. Unless clearly stated in this report, the number of fatalities recorded and species fatality rates presented have not been adjusted for searcher efficiency or scavenger removal. These rates should therefore be considered a minimum and the actual fatality rate may be much higher (e.g. some monitoring reports indicated that estimated fatality rates were double for raptors). For similar reasons, caution should also be exercised when comparing fatality rates between WEFs. Some species are more likely to be detected (due to coloration or size) and some may be more palatable to scavengers than others. Comparing fatality rates between species or groups of species, may not be appropriate.

Although this information would be useful to guide avoidance and mitigation strategies, monitoring of bird activity and abundance was not continued at most WEFs beyond the first year. Reporting bird activity metrics was also not standardised. As a result, it is challenging to assess the correlation between passage rates, abundance and the risk of fatalities.

As a result of uncertainty as regards the expected number, size and location of turbines, as well as the uptake and effectiveness of mitigation measures, the assessment of cumulative impacts did not take into account the substantial growth expected in the industry. According to South Africa's Integrated Resources Plan (2019), 17 700 MW of wind energy should feed into the national grid by 2030, and private-sector investment in large-scale wind projects is also expected to grow significantly. More than 5 GW of wind projects were in the planning pipeline by early 2023 (SAREM 2023).

The use of PBR has a number of limitations, including requiring accurate estimates of minimum population size, maximum net productivity rate and information on other human-caused mortality rates. PBR may not provide adequate protection for species at risk of extinction (Diffendorfer et al. 2021). This approach also assumes that human-caused mortality is the only factor limiting population recovery, while other threats such as habitat loss, pollution, and climate change may be adding pressure to a species. Caution should therefore be exercised when interpreting PBR levels presented in this report. More robust assessments of population viability in the face of increasing pressure are urgently required.

Lastly, the conclusions and recommendations in this report will need to be updated periodically as new information becomes available. Such material may include new data on fatalities, the effectiveness of mitigation measures, and updates to national Red List status.

REPORTED IMPACTS

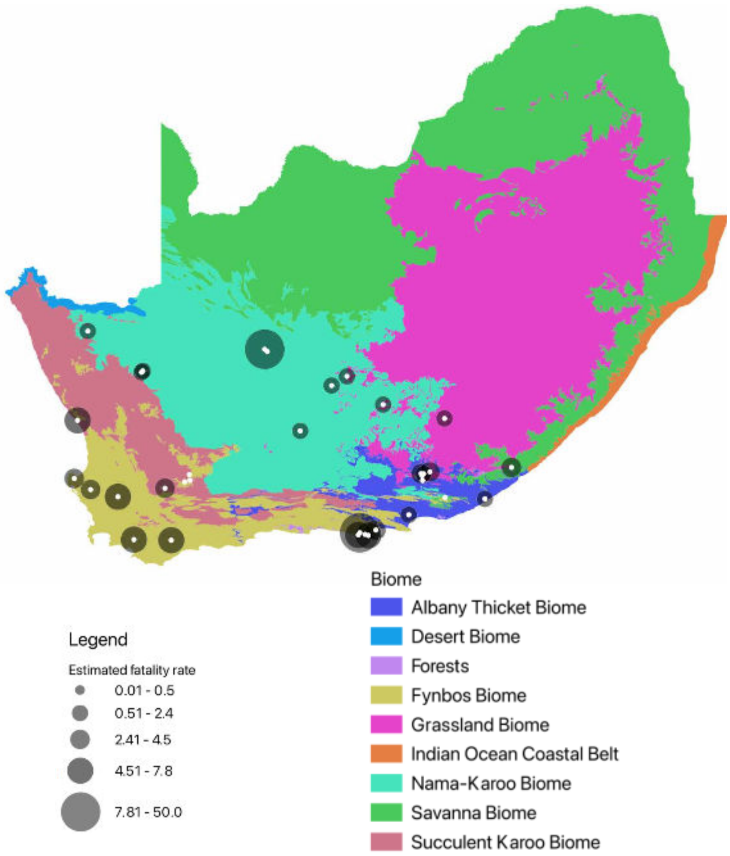

FIGURE 1. The location of WEFs considered in the review. White dots indicate the location of the WEFs. Where data were available, the average estimated annual fatality rate (i.e. birds per turbine per year) is indicated by the size of the grey circles. Biomes were obtained from Rutherford et al. (2006).

ESTIMATED FATALITY RATES

The average estimated fatality rate across all wind farms and all years was 4.25 birds per turbine per year (n = 66 annual fatality estimates, min = 0.13, max = 49.97). The majority (75%) of annual fatality rates reported were less than 4.95 birds per turbine per year, although one wind farm in the Northern Cape reported some 50 fatalities per turbine per year. This was principally driven by a large number of fatalities of swifts (mostly Little and Common swifts) which made up 86% of bird carcasses collected. Monitoring reports available from this WEF spanned only one year and it remains to be seen if the fatality rate will continue or reduce over time.

Estimated turbine fatality rates varied annually within WEFs, and between different WEFs as shown in Figure 2. Estimated fatality rates may vary between biomes, but the results are inconclusive. The two WEFs with highest estimated annual fatality rates are located in the Nama-Karoo and Albany Thicket biomes. The former biome, however, also contains WEFs with the lowest average rates, perhaps indicative of cycles of boom and bust associated with rainfall events in the region. Factors including the number of years of monitoring at each WEF, survey methods, and associated precision of estimates, may all be confounding factors. The sample size also differs between biomes.

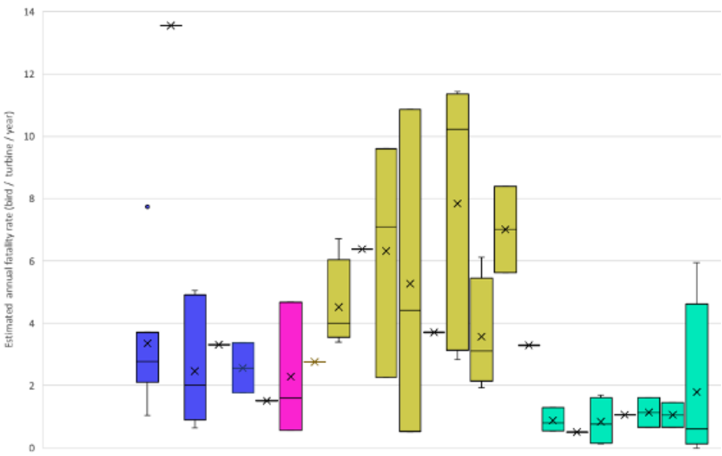

FIGURE 2. The range of estimated annual fatality rates (birds per turbine per year) at different WEFs. Each box plot represents the range in annual estimated fatality rates at an individual WEF. The WEFs are loosely grouped according to biome (blue = Albany Thicket, including sites in a mosaic of Albany Thicket and Fynbos or Grassland; pink = Grassland; lime green = Fynbos, including sites in a mosaic of Fynbos and Succulent Karoo; turquoise = Nama-Karoo, including a mosaic of Nama-Karoo and Grassland). The WEF in the Nama-Karoo with the exceptionally high fatality rate has not been included in the graph.

There was no correlation between turbine height and estimated fatality rates. This may be due to the relatively small variation in turbine size at operational WEFs in South Africa, or other factors (e.g. habitat) playing a more significant role in influencing fatality rates.

Estimated fatality rates for individual species were not often provided in reports. On the rare occasion GenEst (Dalthorp et al. 2018) was used to estimate fatality rates of large terrestrial species (i.e. Secretarybird) and other raptors, these rates were at least double that of the observed rate. Similarly, only a handful of reports provided fatality estimates for small, medium and large birds. Estimated fatality rates for small birds were normally approximately double that of medium and large birds.

SPECIES AFFECTED

The following section provides a more detailed description of the species recorded as fatalities and the unadjusted fatality rates. These data can provide useful insights into which species, or group of species, may be at greater risk of colliding with turbines, but the limitations of these data must be borne in mind.

A total of 2 444 unique bird fatality incidents were recorded at WEFs in this review, with losses attributed to turbine collisions, powerlines and other impacts. These incidents involved 202 species, as listed in Annexure 3 and summarised in Figure 3. Of these, 198 were recorded as turbine collisions. Four species (i.e. Fiscal Flycatcher *Sigelus silens*, Cape Eagle-Owl *Bubo capensis*, White-necked Raven *Corvus albicollis* and African Spoonbill *Platalea alba*) were recorded as fatalities at WEFs in the review, but the cause of death was not likely due to turbine collisions (fatalities were ascribed to powerline and substation incidents). Thirteen per cent of carcasses could not be identified to genus level.

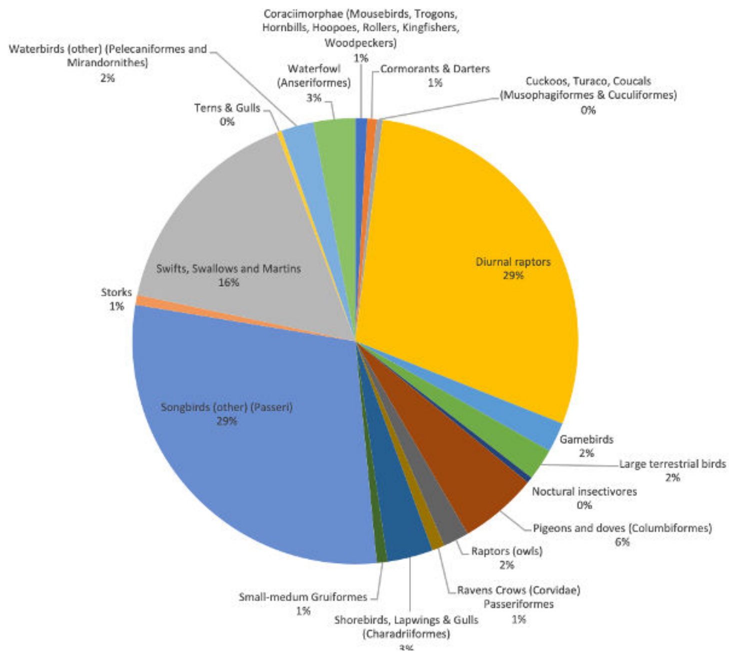

FIGURE 3. The proportion of bird carcasses recorded as turbine collisions summarised according to the family or group of families.

Species of Conservation Concern (SCC)

More than 10% of carcasses found – a total of 213 fatality records – were of SCC (i.e. regionally or globally listed as Near Threatened, Vulnerable, Endangered, or Critically Endangered). These fatalities involved 21 different species. Most (i.e. 172) of these fatalities were ascribed to turbine collisions. Collisions and electrocution with powerlines contributed to fatalities of 36 SCC (see Table 1 below). The remaining fatalities were most probably caused by roadkill, fence entanglement, nest abandonment, incidents at substations, or unknown factors.

The median number of SCC carcasses found annually was 0.05 per turbine, with an interquartile range of 0.02 to 0.1. Fatalities of SCC were not limited to a few 'problem' sites. The majority of WEFs (i.e. 27 out of 33) reported at least one SCC fatality as a result of turbine collisions. The six WEFs that reported no SCC fatalities either had few turbines, or operational-phase monitoring data were only available for a short period. None of the WEFs that reported zero SCC fatalities had monitoring data for more than 24 turbine-years, indicating the increased likelihood of detecting SCC impacts with longer term monitoring.

BLACK HARRIER ROB SIMMONS

TABLE 1. Species of conservation concern, endemic species and raptors reported as fatalities at WEFs.

Species	Scientific name	Red Data Status (Regional, Global)	Ende-mism	# Turbine fatalities	# Power-line fatalities	# Other fatalities		Carcasses/ MW/year
Bulbul, Cape	*Pycnonotus capensis*		E	5	0	0		
Bustard, Denham's	*Neotis denhami*	VU, NT		3	4	0	0.001	0.000
Bustard, Ludwig's	*Neotis ludwigii*	EN, EN		6	3	1	0.002	0.001
Buzzard sp.				2	0	0	0.001	0.000
Buzzard, Common (Steppe)	*Buteo buteo*			17	0	1	0.004	0.002
Buzzard, Forest	*Buteo trizonatus*	LC, NT	SLS	4	0	0	0.001	0.000
Buzzard, Jackal	*Buteo rufofuscus*		NE	146	6	1	0.037	0.017
Canary, Black-headed	*Serinus alario*		NE	2	0	0		
Canary, Forest	*Crithagra scotops*		SLS	2	0	0		
Chat, Sickle-winged	*Cercomela sinuata*		NE	1	0	0		
Cisticola, Cloud	*Cisticola textrix*		NE	3	0	0		
Cormorant, Cape	*Phalacrocorax capensis*	EN, EN		1	0	0	0.000	0.000
Courser, Burchell's	*Cursorius rufus*	VU, LC		2	0	0		
Crane, Blue	*Anthropoides paradiseus*	NT, VU		18	5	0	0.005	0.002
Eagle, African Fish	*Haliaeetus vocifer*			3	0	0	0.001	0.000
Eagle, Black-chested Snake	*Circaetus pectoralis*			6	0	0	0.002	0.001
Eagle, Booted	*Hieraaetus pennatus*			29	1	0	0.007	0.003
Eagle, Long-crested	*Lophaetus occipitalis*			6	0	0	0.002	0.001
Eagle, Martial	*Polemaetus bellicosus*	EN, EN		12	4	1	0.003	0.001
Eagle, Tawny	*Aquila rapax*	EN, VU		2	0	0	0.001	0.000
Eagle, Verreaux's	*Aquila verreauxii*	VU, LC		33	13	0	0.008	0.004
Falcon, Amur	*Falco amurensis*			64	0	0	0.016	0.007
Falcon, Lanner	*Falco biarmicus*	VU, LC		12	1	1	0.003	0.001
Falcon, Peregrine	*Falco peregrinus*			6	0	0	0.002	0.001
Flamingo, Greater	*Phoenicopterus roseus*	NT, LC		1	0	0	0.000	0.000
Flufftail, Striped	*Sarothrura affinis*	VU, LC		1	0	0		
Flycatcher, Fiscal	*Sigelus silens*		NE	0	0	1		
Francolin, Grey-winged	*Scleroptila afra*		SLS	3	1	0		
Goshawk, African	*Accipiter tachiro*			3	0	0	0.001	0.000
Goshawk, Pale Chanting	*Melierax canorus*			15	8	0	0.004	0.002
Harrier, Black	*Circus maurus*	EN, EN	NE	10	0	2	0.003	0.001
Hawk, African Harrier-	*Polyboroides typus*			13	0	0	0.003	0.001
Kestrel, Greater	*Falco rupicoloides*			20	0	0	0.005	0.002
Kestrel, Lesser	*Falco naumanni*			7	0	0	0.002	0.001
Kestrel, Rock	*Falco rupicolus*			77	0	0	0.020	0.009
Kite, Black	*Milvus migrans*			1	0	0	0.000	0.000
Kite, Black-winged	*Elanus caeruleus*			27	0	0	0.007	0.003
Kite, Yellow-billed	*Milvus aegyptius*			10	0	0	0.003	0.001
Korhaan, Blue	*Eupodotis caerulescens*	LC, NT	SLS	2	0	0	0.001	0.000
Korhaan, Karoo	*Eupodotis vigorsii*	NT, LC		3	1	0	0.001	0.000
Korhaan, Northern Black	*Afrotis afraoides*			2	1	0	0.001	0.000
Korhaan, Southern Black	*Afrotis afra*	VU, VU	E	5	0	0	0.001	0.001
Lark, Agulhas Long-billed	*Certhilauda brevirostris*	NT, NR	E	1	0	0		
Lark, Cape Clapper	*Mirafra apiata*		NE	1	0	0		

Species	Scientific name	Red Data Status (Regional, Global)	Ende-mism	# Turbine fatalities	# Power-line fatalities	# Other fatalities		Carcasses/ MW/year
Lark, Cape Long-billed	*Certhilauda curvirostris*		E	1	0	0		
Lark, Large-billed	*Galerida magnirostris*		NE	12	0	1		
Osprey	*Pandion haliaetus*			1	0	0	0.000	0.000
Owl, Cape Eagle-	*Bubo capensis*			0	2	0	0.000	0.000
Owl, Spotted Eagle-	*Bubo africanus*			18	2	0	0.005	0.002
Owl, Western Barn	*Tyto alba*			22	1	0	0.006	0.003
Roller, European	*Coracias garrulus*	NT, LC		1	0	0		
Secretarybird	*Sagittarius serpentarius*	VU, EN		8	0	0	0.002	0.001
Sparrowhawk, Black	*Accipiter melanoleucus*			5	0	0	0.001	0.001
Sparrowhawk, Little	*Accipiter minullus*			1	0	0	0.000	0.000
Spurfowl, Cape	*Pternistis capensis*		NE	7	0	11		
Starling, Pied	*Lamprotornis bicolor*		SLS	7	0	0		
Stork, White	*Ciconia ciconia*			15	0	0	0.004	0.002
Sunbird, Orange-breasted	*Anthobaphes violacea*		E	1	0	0		
Sunbird, Southern Double-collared	*Cinnyris chalybeus*		NE	2	0	0		
Unknown, Raptor				28	0	0	0.007	0.003
Vulture, Cape	*Gyps coprotheres*	EN, VU		41	4	0	0.011	0.005
Vulture, White-backed	*Gyps africanus*	CR, CR		6	1	0	0.002	0.001
Weaver, Cape	*Ploceus capensis*		NE	5	0	0		

SCC are highlighted in colour based on the highest level of threat from either regional or global conservation status listings. Red = Critically Endangered; orange = Endangered; yellow = Vulnerable; light green = Near Threatened.
Red List status: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; NR = Species not recognised by BirdLife International.
Regional status is according to Taylor et al. (2015), and global status from BirdLife International (2024).
Endemism: E = endemic to South Africa; SLS = endemic to South Africa, Lesotho and Eswatini; NE = near endemic (i.e. ~70% or more of population in RSA).

CAPE VULTURE CHRIS VAN ROOYEN

Raptors

Diurnal raptors accounted for 29% of carcasses found beneath turbines as shown in Figure 3 (page 6). Some of these species are discussed in more detail below.

Cape Vulture *Gyps coprotheres*

The Cape Vulture is classified as Endangered in South Africa, Lesotho and Eswatini (Taylor et al. 2015). The global threat status was recently changed from Endangered to Vulnerable. While the population is declining, the rate of decline may not be as high as previously thought and numbers have increased at some colonies (BirdLife International 2024). The Cape Vulture is listed in CITES Appendix II and CMS Appendix II. It is legally protected throughout its range. The species is also included in the Biodiversity Management Plan for the Conservation of Seven Vulture Species in South Africa (published in terms of section 43(1)(b) and (c) and 43(3)(a) and (b) of the National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004) (DFFE 2024)) and the CMS Multi-species Action Plan to conserve African-Eurasian vultures (Botha et al. 2017). BirdLife South Africa has developed guidelines to support the assessment and mitigation of wind energy's impacts on Cape Vultures (Pfeiffer and Ralston-Paton 2018) and the Department of Forestry, Fisheries and the Environment (DFFE) has published its intention to prescribe a '*Protocol for the assessment and minimum report content requirements for determining impacts on Cape Vultures associated with the development of onshore wind energy generation facilities*'.

Several morphological and behavioural characteristics render vultures vulnerable to colliding with wind turbines. Their considerable size and weight and their large wingspans limit their agility and hamper their ability to quickly change course in response to obstacles. Furthermore, their frontal binocular field of vision is restricted, preventing them from accurately gauging distance (Martin et al. 2012). Cape Vultures congregate in numbers when food resources are available, which may increase the risk of collisions.

A total of 45 Cape Vulture fatalities at WEFs were reported, 41 of which were attributed to turbine collisions. The remainder were ascribed to powerline collisions or electrocutions. Averaged across all wind farms, 0.01 fatalities per turbine per year (0.005 per MW per year) were recorded. However, the overlap of wind energy facilities and Cape Vultures' distribution is not equal across the country and many of the WEFs in the study are not within the species' range.

Ten operational WEFs overlap the western part of the Cape Vulture's range in South Africa (defined as medium to very high sensitivity, according to a simplified distribution model developed by Cervantes et al. (2023) and included in the National Web-based Environmental Screening Tool (hereafter referred to as the National Screening Tool; https://screening.environment.gov.za) (Figure 5). No WEFs are located in very high sensitivity areas, seven are in high sensitivity and three in medium sensitivity areas.

Many of the WEFs within the medium and high sensitivity areas have implemented a range of mitigation measures, including Livestock Carcass Management (also known as Vulture Food Management (VFM)) and Observer-led Shutdown on Demand (OLSDOD) (discussed in more detail below). Despite these efforts, WEFs within the high sensitivity area recorded an unadjusted fatality rate of 0.05 Cape Vultures per turbine per year (0.02 per MW per year). No Cape Vulture fatalities occurred in the medium sensitivity area during the reporting period. Three fatalities (two turbine collisions and one powerline electrocution) were reported from WEFs within low sensitivity areas.

Most of the Cape Vulture fatalities occurred in the Eastern Cape, particularly within the cluster of WEFs in the Cookhouse region. The maximum annual rate recorded for a WEF within this area was 0.34 vultures per turbine per year. Two WEFs in this cluster reported that Cape Vulture fatality rates were highest in the first year, dropping off in subsequent years (Figure 6). This could suggest improved implementation of operational-phase mitigation measures, although neither WEFs reduced fatality rates to zero. The limited data available on vulture activity

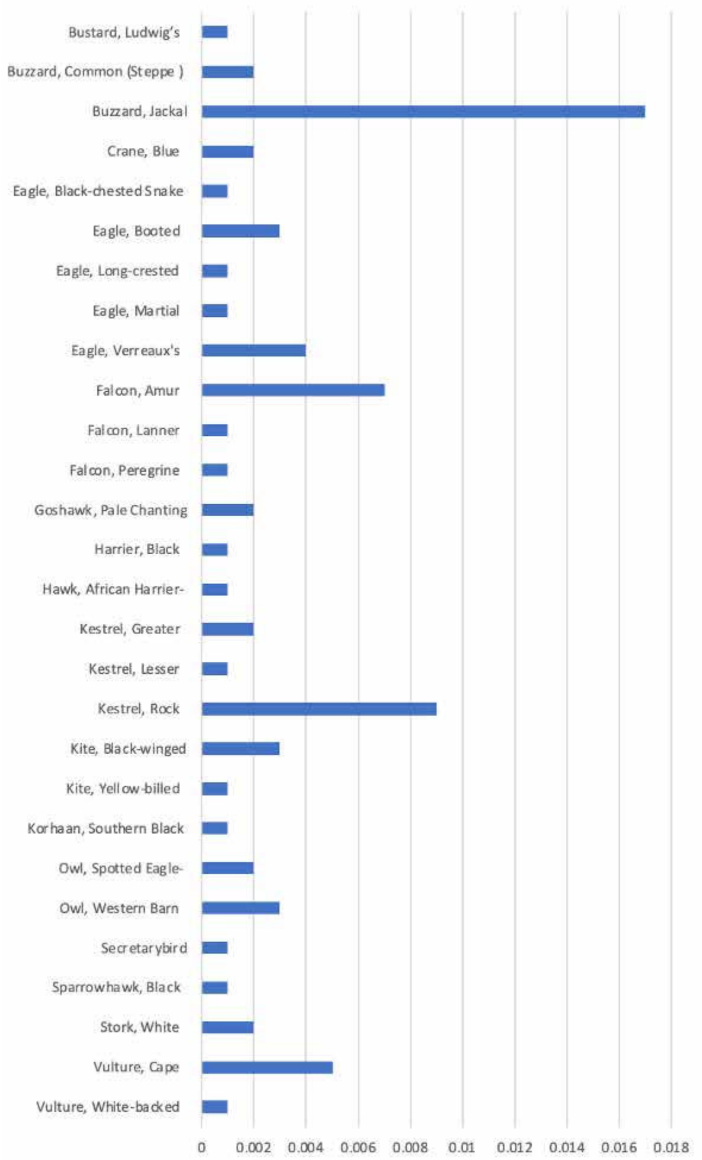

FIGURE 4. Recorded annual fatality rates for select SCC per MW. Note that these figures have not been adjusted to account for searcher efficiency or scavenger removal.

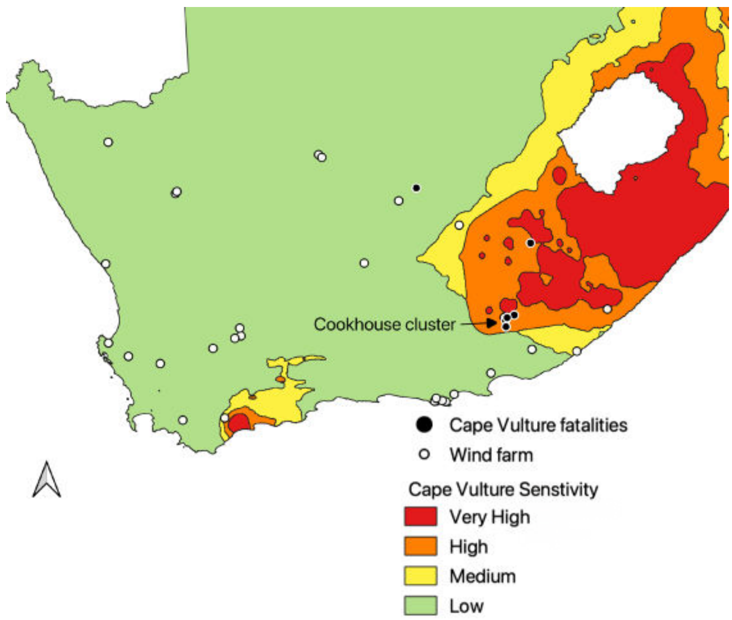

FIGURE 5. The overlap of WEFs with Cape Vulture habitat utilisation/sensitivity in South Africa. Sensitivity is defined according to a simplified distribution model developed by Cervantes et al. (2023) and included in the National Screening Tool (https://screening.environment.gov.za). Black dots indicate WEFs where Cape Vulture fatalities were recorded. White dots are WEFs where no Cape Vulture fatalities have been recorded. Note that there are five WEFs in the Cookhouse cluster, where most fatalities have occurred.

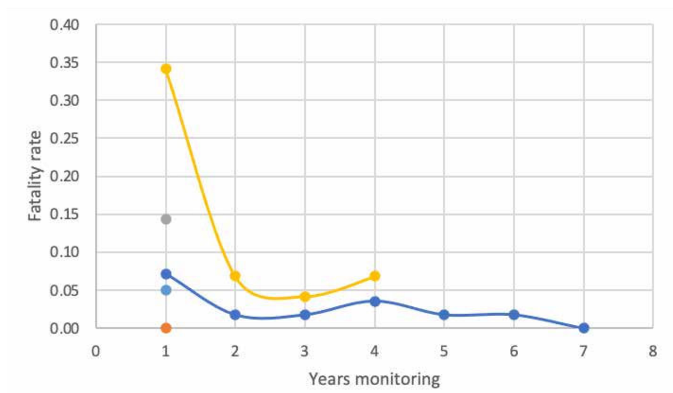

FIGURE 6. Minimum Cape Vulture fatality rates over time within the Cookhouse cluster of wind farms. Each coloured line (or dot) represents a different wind farm.

at operational wind farms do not indicate that vultures are avoiding the facilities over time. However, more comprehensive research on vulture behaviour around turbines is needed.

Although the nearest breeding colony is some 150 km away from the Cookhouse cluster, the WEFs are located within 30 and 40 km of the Agieskloof roost (Boshoff et al. 2009). This roost is not used for breeding, but as many as 300 birds were recorded using the site each summer (November to March). This may explain the peak in the number of carcasses found in January (Figure 7).

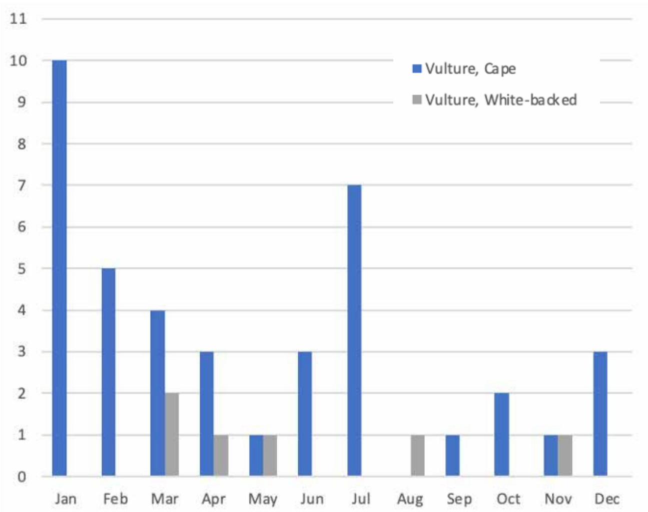

FIGURE 7. The number of vulture carcasses (turbine collisions) recorded each month of the year. Note that the date carcasses were found was not always included in reports, thus this figure does not represent the total number of carcasses discovered.

CASE STUDY: Risk of inadequate survey methods to predict threats to Cape Vultures

A small wind farm in the Overberg, Western Cape, is located within a medium sensitivity area (defined above). The WEF is situated approximately 35 km from the Potberg Cape Vulture colony, the only vulture breeding colony in the Western Cape, consisting of approximately 100 breeding pairs. Despite vultures passing through the site regularly, no fatalities have occurred, thanks to robust VFM and OLSDOD programmes that have been in force since construction.

The combination of OLSDOD and vantage point monitoring at this facility underscores the risk of insufficient survey methods when assessing the threat to vultures. During pre-construction surveys, Cape Vulture flights were recorded in less than 1% of the total vantage point survey duration. Despite 12 hours of survey time per vantage point per season, no Cape Vulture passages were recorded in vantage point surveys during the first year of operational-phase monitoring. However, shutdowns involving 384 Cape Vultures were implemented in the same year. This highlights the need for impact assessments to incorporate all sources of information, including proximity to colonies, SABAP2 data, and robust surveys with increased duration and frequency of vantage point monitoring, as emphasised by Pfeiffer and Ralston-Paton (2018).

During the summer non-breeding season, Cape Vultures disperse widely from the breeding colonies and have been encountered at wind farms beyond the medium to high sensitivity areas. One WEF in a low sensitivity area in the Northern Cape reported three fatalities (two turbine collisions and one electrocution), from May to July 2020. All individuals killed were immatures.

Cape Vulture flights were reported to be generally well above the rotor-swept area, but this behaviour could change rapidly as they swoop down to feed or roost on the nearby infrastructure. The flight patterns were reportedly difficult to predict because the factors influencing the behaviour were also unpredictable. Factors hypothesised to have increased the risk of collisions included attraction to dams (particularly on hot days) and to areas where sheep were lambing, and the use of transmission lines as temporary roosts.

The population in the Eastern Cape, where there is the most overlap with wind energy infrastructure, is estimated at a minimum of 1 702 birds, but more likely approximately 2 000 birds based on 630 breeding pairs (Boshoff et al. 2009). The Cape Vulture population in South Africa is estimated to be 8 800 mature birds (Taylor et al. 2015), while the more recent global population estimate is 9 600 to 12 800 mature individuals (BirdLife International 2024). Assuming age at first breeding to be six years and a 92% annual adult survival rate (Hockey et al. 2005), and an F value of 0.1, the Potential Biological Removal (PBR) for the population in South Africa is estimated at 53 individuals a year (58 based on the global population estimate).

If current fatality rates at operational wind farms continue, at least 37 Cape Vultures could be lost to turbine collisions annually, representing a significant portion of the PBR. This figure is most probably an underestimate (see limitations discussed above) and does not account for the anticipated acceleration of wind energy development. Unless other human-induced threats, such as powerline electrocutions and collisions, and poisoning, are urgently addressed, the population may not be able to withstand the added impact of turbine collisions.

White-backed Vulture *Gyps africanus*

A total of seven White-backed Vulture fatalities were reported, from three WEFs. One of these fatalities was due to electrocution, while the rest were likely collisions with wind turbines. Of these fatalities, one of the birds had been injured and was subsequently euthanised.

The White-backed Vulture is listed as Critically Endangered globally (BirdLife International, 2024) and within South Africa, Lesotho and Eswatini (Taylor et al. 2015). It is listed under CITES Appendix II, CMS Appendices I & II, Raptors MOU Category 1. The species is covered by a Multi-species Action Plan (MsAP) for the conservation of African-Eurasian vultures (Botha et al. 2017) and South Africa's Biodiversity Management Plan Vultures (DFFE 2024).

White-backed Vultures are widespread in Africa and are found in open wooded savanna habitats in West, East and southern Africa (BirdLife International 2024). Within South Africa, the species is found in all provinces, except the Western and Eastern Cape (DFFE 2024). Few WEFs currently overlap with the species distribution, with only two WEFs

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located within 20 km of SABAP2 records. These sites are located in the south-western edge of the species' distribution in the Northern Cape, with the closest breeding aggregations near Kimberley.

Based on SABAP2 records, combined with pre- and post-construction monitoring data, White-backed Vultures are expected to be only occasional visitors to the WEFs that reported fatalities.

One of the WEFs reported three White-backed Vulture fatalities, despite being located approximately 100 km from the nearest SABAP2 record of the species. The closest known regular roosts and colonies are located at least 150 km from the site. All three vultures killed at this site were juveniles, probably dispersing birds. Before first breeding, immature White-backed Vultures are nomadic (Hockey et al. 2005) and have been recorded dispersing up to 900 km from the area where they were tagged (Phipps et al. 2013).

Based on carcasses found, the fatality rate at two WEFs that overlap with the species' distribution was 0.074 vultures per turbine per year (0.025 per MW per year). These two WEFs had not been operational for very long and available monitoring reports spanned no more than one year. The observed fatality rate was reduced to 0.012 vultures per turbine per year (0.007 per MW per year) when the outlier WEF, where fatalities were recorded some distance from previous records, was included in the analysis.

No seasonal pattern of fatalities was evident. Carcasses were found in March, April, May, August and November (Figure 7).

It remains to be seen if the collision rates observed at the three WEFs will persist and, if so, whether it can be effectively mitigated. Mitigation recommended by the specialists included livestock carcass management and additional monitoring to understand population trends in the area. It was also recommended that roosting areas (e.g. powerlines) be delineated to inform mitigation strategies (e.g. curtailment and/or shutdown on demand).

Confidence in population estimates for White-backed Vultures is low, but the last estimate for the population in South Africa, Lesotho and Eswatini was 7 350 mature individuals (Taylor et al. 2015). The species has since suffered severe and ongoing declines in large parts of its range as a result of poisoning, habitat loss, hunting, electrocutions and collisions (BirdLife International 2024).

The annual number of birds killed at WEFs may be small compared to other sources of fatality (e.g. poisonings can result in large numbers of birds being killed in a single event (DFFE 2024)), but the survival of breeding adult vultures is essential for the persistence of their populations and even small changes to adult mortality could result in population declines (Phipps et al. 2013). The risk of turbine collision has not been listed as a threat to the White-backed Vulture in the Biodiversity Management Plan for vultures (DFFE 2024). This may need to be revisited if further WEFs overlap with the species' distribution.

Research recommendations: vultures

From the discussion above, there is a need for additional research into both Cape and White-backed vultures in the following areas:

- Study the movement ecology and ranging behaviour through satellite tracking of adult birds.
- Investigate the feasibility and effectiveness of mitigation measures, including blade patterning, use of supplementary feeding sites, livestock carcass management and shutdown on demand.
- Monitor population size and stability by way of regular censuses of the number of breeding pairs in areas that overlap with good wind resource. These should include surveys of existing colonies, as well as for potential new colonies and roosts.
- Study rates of survival and productivity and feed these into population viability analysis.
- Quantify impacts of other threats, such as lead poisoning and electrical infrastructure, and effectiveness of related mitigation measures.

Verreaux's Eagle *Aquila verreauxii*

All wind farms in the review overlapped with the broad distribution of Verreaux's Eagle, and fatalities of the species were reported at eight WEFs. These WEFs are located in the Fynbos, Grassland and Nama-Karoo Biomes. A total of 46 fatalities were recorded, 33 of which were due to turbine collisions. The remaining fatality records were as a result of electrocution by poorly designed internal collector lines. The strong overlap of proposed wind energy facilities with the mountainous habitat preferred by Verreaux's Eagles, and the current scale of losses, highlights the need for strong avoidance and mitigation.

Based on carcasses found, a rate of 0.008 Verreaux's Eagle carcasses was recorded per turbine per year (0.004 per MW per year), not accounting for searcher efficiency or scavenger removal. Using GenEst, the adjusted fatality rate at one WEF (averaged over four years) was 2.2 times higher than the observed fatality rate.

The majority of carcasses were found at WEFs in the Nama-Karoo, with two WEFs responsible for more than 58% of reported turbine collisions for the species (these sites are described in more detail in the case studies below).

With an estimated regional population of 3 500–3 750 mature individuals and an ongoing decline exceeding 10% in three generations, the regional population of Verreaux's Eagle (in South

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Africa, Lesotho and Eswatini) is classified as Vulnerable (Taylor et al. 2015). Any increase in mortality may be detrimental to the metapopulation (Murgatroyd et al. 2016). While confidence in this population estimate is low, the cumulative fatalities as a result of turbine collisions at existing wind farms comprise a substantial proportion (over 40%) of the PBR. This is estimated at 29 fatalities per year, assuming a population of 3 500, an age at first breeding of four years and a 91% adult survival rate (Murgatroyd et al. 2016). Given the likely underestimation of the fatality rate, the expected exponential increase in the number of turbines, and the fatalities from associated infrastructure and other unaccounted sources, urgent action is needed to prevent further losses.

Adult eagle fatalities were most often reported as turbine collisions (i.e. 21 out of 26 records where the age class was specified). Young eagles may be at greater risk of powerline electrocutions. Nine of the 13 Verreaux's Eagle electrocutions where age class was reported were young birds.

The risk of turbine collisions for eagles may not be evenly distributed across the landscape. Two different WEFs reported that a single turbine was responsible for two Verreaux's Eagle fatalities. Both of these WEFs had monitoring data spanning more than five years.

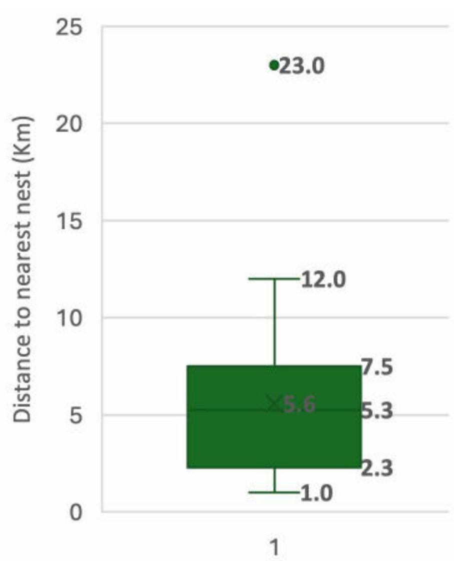

FIGURE 8. Proximity of Verreaux's Eagle fatalities to known breeding sites.

The proximity to suitable breeding habitat may increase the risk of collisions as the majority of Verreaux's Eagle fatalities occurred within 7.5 km of known nest sites. The median distance between known nests and fatalities was 5.6 km (n = 30, upper quartile = 7.5 km; Figure 8). No turbines were erected closer than 800 metres from a known nest.

There are a few examples of nests being overlooked or re-occupied during the period between the impact assessments and operational-phase monitoring. Proximity of turbines to suitable breeding habitat, as delineated in BirdLife South Africa's habitat suitability models included in the National Screening Tool, may therefore provide an additional level of information that can be used in site screening and impact assessment. These areas include cliffs and ridges that may also be good foraging habitat for the species. Seven out of the eight WEFs that reported Verreaux's Eagle fatalities included GPS locations of carcasses in the reports. All but one of these were located within five kilometres of suitable breeding habitat (e.g. see Figure 9).

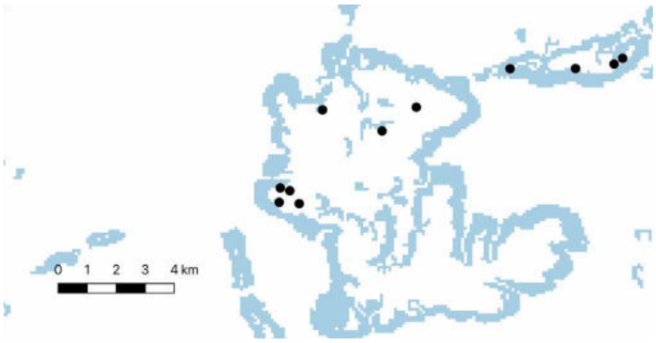

FIGURE 9. Proximity of Verreaux's Eagle turbine fatalities to suitable breeding habitat at a wind farm in the Northern Cape. Black dots indicate the location of Verreaux's Eagle fatalities, and blue areas represent suitable breeding habitat (included in the National Screening Tool).

Another potential risk factor identified was the proximity of fatalities to rock hyrax (dassie) colonies. Although this was not often explicitly mapped in reports, one WEF in the Northern Cape noted that all three fatalities recorded at the site over five years were located near rock hyrax colonies. Another WEF reported a marked increase in Verreaux's Eagle passage rates after construction. The specialist hypothesised that this could have been due to the creation of rock piles during construction which would have formed new rock hyrax habitat. It is recommended that data on local rock hyrax populations should be collected during impact assessments and pre- and post- construction monitoring and that WEFs should avoid creating new habitat for rock hyraxes.Verreaux's Eagle carcasses resulting from turbine fatalities were found throughout the year, peaking from April to August (see Figure 10), coinciding with the breeding season (Hockey et al. 2005). Electrocutions hit their highest point in August, and four out of the six carcasses found during this period were sub-adults. This coincides with the time when young eagles are just beginning to fly. At this stage, landing can involve significant wing flapping to maintain balance, which may have increased the risk of electrocution.

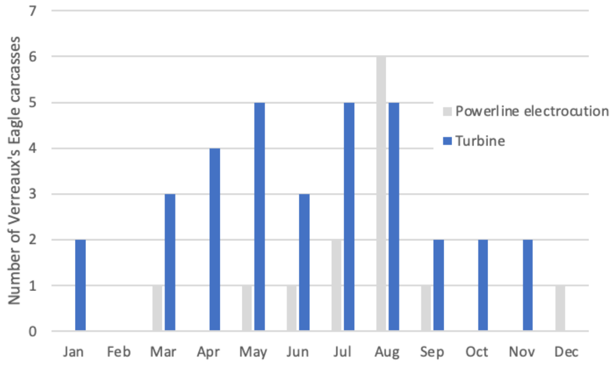

FIGURE 10. The number of Verreaux's Eagle carcasses recorded each month of the year.

Three WEFs reported fatalities of Verreaux's Eagles, despite the species not being recorded on site during pre-construction or in the first year of operational monitoring. One of these WEFs was in an area that was reportedly not ideal habitat for the species and was a significant distance (i.e. at least 17 km) from suitable breeding habitat. It is therefore thought likely that the bird was a non-breeding adult moving through the area. At a second WEF, Verreaux's Eagle was assessed as likely to be an occasional visitor to the site. Although the nearest suitable breeding habitat is located 4.7 km away, no breeding sites were located through surveys. The last of the three WEFs had no Verreaux's Eagles recorded after 192 hours of vantage-point watches conducted over eight seasonal surveys at two vantage points. This WEF subsequently recorded three Verreaux's Eagle fatalities in three years of operational-phase monitoring. A previously unrecorded nest was located on the escarpment 3.2 km from the site. The examples above support the concern that the minimum data collection methods recommended (Jenkins et al. 2015) may not be adequate to predict the risk of Verreaux's Eagle collisions. More robust surveys, combined with the use of precautionary buffers and spatial flight-risk models, as recommended in BirdLife South Africa's *Verreaux's Eagle and Wind Farms Guidelines* (BirdLife South Africa 2021) are required to ensure impacts are accurately predicted and mitigated.

Where fatalities of Verreaux's Eagles occurred, many specialists recommended mitigation in the form of SDOD, to be implemented during daylight hours, when the species is most active. However, at the time of writing there were few reports available providing feedback on the success of such initiatives.

CASE STUDIES: Verreaux's Eagle

The majority of Verreaux's Eagle fatalities were reported from WEFs in the Nama-Karoo, with two WEFs responsible for 58% of fatalities recorded as a result of turbine collisions. These sites were characterised by high SABAP2 reporting rates (greater than 16%), and the wind turbines are located on a plateau, close to cliffs, ridges and other suitable breeding habitat.

After four years of operational monitoring, one of these WEFs (with 96 turbines) reported an estimated annual collision mortality rate (adjusted for searcher efficiency and scavenger removal) of 3.98 Verreaux's Eagles per year. An additional 0.4 Verreaux's Eagle fatalities a year were due to powerline electrocutions. The specialist concerned estimated that the WEF had increased the mortality rate in the directly affected eagle population by 22% and concluded that the population in the area could become a sink.

The EIA and pre-construction monitoring reports for the above WEF underestimated the potential significance of the collision risk. The initial avifaunal impact assessment was based on a single site visit, and a nest buffer of one kilometre was recommended around 'all known Verreaux's Eagle nest sites in the area'. This recommendation was included as a condition of authorisation, issued prior to the pre-construction monitoring being completed.

The subsequent pre-construction monitoring included 12 hours of surveys per vantage point per season, conducted over four seasons. Additional surveys during the breeding season (159 hours over five months, focused on the area around the active breeding site) were also conducted. The pre-construction monitoring report concluded that the risk of Verreaux's Eagle collisions was low, except near a cluster of nests (presumably alternate nests), and to a lesser extent an area on the escarpment edge. A nest buffer of just 800 m was recommended and the nearest turbine was constructed 885 m away from a nest. Only active breeding sites were buffered. A 100 m setback from the plateau edge was also applied.

At this WEF, all but one of the Verreaux's Eagle carcasses attributable to turbine collisions were found within 3.7 km of a nest (active and inactive). The minimum buffer recommended in BirdLife South Africa's guidelines for Verreaux's Eagles and Wind Farms (BirdLife South Africa 2021) is 3.7 km.

The active eagle territory, occupied for four years prior to the construction of the wind farm, became vacant after construction and remained unused for three out of four years thereafter. A second breeding site was located during pre-construction surveys, but the nest was inactive and was not buffered. This territory was only occupied in the fourth year after construction, and it is unclear whether breeding occurred. These levels of territory vacancy are considered to be high, unless food is a limiting factor (Davies 1994; Ngoni 2009). The specialist concluded that the rate of adult mortality due to the WEF was the most likely cause of the high level of territory vacancy. The frequent interruption of the breeding cycle caused by the loss of the breeding adults was also the likely cause of low productivity of Verreaux's Eagles.

The Environmental Management Programme (EMPr) for this WEF states that '(d)epending on the results of the carcass searches, a range of mitigation measures will have to be considered if mortality levels turn out to be significant. This may include the selective curtailment of specific turbines during high-risk periods.' The WEF is considering a few novel mitigation measures, but no operational-phase mitigation to address the risk of collisions had been implemented by the end of the fourth year of operation.

A nearby WEF also reported high Verreaux's Eagle fatality rates. After four years of operational-phase monitoring, the fatality rate of Verreaux's Eagles at the wind farm due to turbine collisions was estimated to be 3.38 per year (taking into account searcher efficiency and scavenger removal). Combined with electrocutions, the total estimated fatality rate was 6.88 eagles per year.

Verreaux's Eagle was not listed as regionally threatened at the time of the EIA for the WEF. The EIA noted that a resident and breeding population of at least five pairs of Verreaux's Eagles may be affected and recommended an 'experimental approach' to development and mitigation. A female bird breeding north of the WEF was fitted with a GPS tracking device, and micro-siting of some turbines was recommended, in which some turbines were set back a minimum of two blade lengths from the escarpment.

Passage rates of eagles over the WEF increased markedly between pre-construction monitoring and operation. It is not clear if this change was due to different survey methods or an increase in prey availability. Forty-one per cent and 58% of Verreaux's Eagle carcasses found and ascribed to turbine collisions were located within 3.7 km and 5.2 km respectively of known nests.

After four years of operational-phase monitoring, the specialist concluded that the WEF had a 'very high impact on the directly affected population' and would have increased the annual mortality by more than 20%. Unlike the first case study, the eagle territories did not remain vacant for more than one season. However, productivity was erratic, and the breeding failure rate was above the average for Verreaux's Eagles in the Karoo. This was considered likely because of breeding birds being killed, interrupting the reproductive cycle. The specialist concluded that the population has most probably become a sink, requiring replenishment from outside populations.

Research recommendations: Verreaux's Eagle

Additional research into Verreaux's Eagles is required in the following areas:

- The cumulative impact of wind energy on the population viability of Verreaux's Eagle, including more accurate assessments of the regional population size.
- Little is known about juvenile dispersal and philopatry (Murgatroyd et al. 2016) and it will be important to understand the movement of individuals between different areas to assess the scale of the risk.
- Spatial risk models that take into account 'floating', non-territorial birds.
- Temporal patterns in collision risk to assist OLSDOD programmes and to inform curtailment programmes should they be required.
- The effectiveness and feasibility of measures to avoid and mitigate collision risk (e.g. blade patterning).
- Metrics, such as data on other threats to the species (e.g. poisoning) and the effectiveness of related mitigation activities, will be valuable in designing effective compensation or offset strategies for unavoidable losses.

Martial Eagle *Polemaetus bellicosus*

Martial Eagles are found throughout sub-Saharan Africa and the species is widespread in South Africa and Eswatini (Taylor et al. 2015). All WEFs in this review overlap with the species' broad distribution (i.e. based on SABAP2 records).

A total of 16 Martial Eagle carcasses were reported from 11 different WEFs. Turbine collisions were probably responsible for 12 of these fatalities (at 10 WEFs), while the remaining four were ascribed to powerline electrocutions. An additional fatality of a nestling was reported, possibly due to the loss of breeding adult birds. Averaged across its range, the fatality rate for the Martial Eagle, unadjusted for searcher efficiency and scavenger removal, was 0.003 birds per turbine per year, 0.001 birds per MW per year (Table 1).

The Martial Eagle is listed as threatened and protected under the National Environmental Management: Biodiversity Act (Act 10 of 2004). It has been assessed as regionally and globally Endangered (Taylor et al. 2015; BirdLife International 2024). However, the global population has undergone declines severe enough to warrant a call for this status to be urgently reassessed (Shaw et al. 2024).

The population in the region is estimated to be approximately 800 mature individuals (Taylor et al. 2015). If current fatality levels continue, it can be assumed that at least 4.6 additional Martial Eagles will be killed each year by wind turbines. At this rate, fatalities may already be exceeding the PBR for the species (estimated as five fatalities a year, assuming a regional population of 800, age at first breeding of five years, and a 93% adult survival (Hockey et al. 2005) and a recovery factor of 0.1). In addition to turbine fatalities, other ongoing direct sources of losses include deliberate and incidental poisoning, and collisions with powerlines. Indirect threats include disturbance, habitat loss, reduction in available prey, and pollution (BirdLife International 2024).

Fatalities were reported at WEFs in all biomes, except Savanna, which has only two WEFs within its area. Two wind farms reported more than one Martial Eagle fatality caused by turbine collisions during the reporting period. Two of the 12 turbine fatalities were reported to be immature birds. All individuals killed by powerlines were immature birds.

No carcasses resulting from turbine collisions were recorded from March to June, nor in November. The former is the peak egg-laying period when the birds are likely to be close to the nest (Hockey et al. 2005).

Martial Eagles were recorded as occasional visitors at most of the WEFs, but few nests were reported near turbines.

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Martial Eagles have particularly large territories (Van Eeden et al. 2017). It is therefore possible that breeding sites were located near, but not overlapping with WEFs, and therefore not recorded in surveys.

One WEF's turbines were located within one kilometre of a nest and fatalities of Martial Eagles were reported (see case study below). Another two WEFs noted nests approximately four kilometres from the nearest turbines. No fatalities have been recorded after two years of monitoring at both these facilities.

Van Eeden et al. (2017) tracked territorial adult Martial Eagles in the Kruger National Park and found that these individuals had an average home range of 108 km^2 (i.e. a radius of six kilometres, assuming a circular territory). However, home ranges vary with habitat and are much larger in the drier regions (i.e. 200 km^2 in the Karoo (A. Amar, unpublished data), 280 km^2 in the Nama-Karoo and Namibia (Hockey et al. 2005)). Given the species' large territories, dedicated surveys to locate their breeding sites should always extend beyond the development footprint. A nest buffer of six kilometres is recommended for Martial Eagles, but the available data suggest that this buffer will not eliminate the risk of collisions and it may therefore be necessary to implement additional mitigation measures outside of this area.

CASE STUDY: Turbines near a Martial Eagle nest

A Martial Eagle nest was identified after environmental authorisation was issued (i.e. during pre-construction monitoring) for a WEF in the Eastern Cape. This nest was located in a deep kloof and a one-kilometre buffer around this site was implemented. This WEF recorded two Martial Eagle fatalities in the second year of monitoring, both at the same turbine and approximately 1.5 km from the breeding site. Monitoring and reporting on the status of this nest has been inconsistent because of access challenges, but it appears that this breeding site has been abandoned.

Other landscape features that specialists hypothesised could be associated with increased collision risk include proximity to powerlines and meteorological masts that were used for perching, particularly in arid environments with few trees. Accordingly, powerlines should be buffered in arid areas to minimise the risk of electrocutions and new powerline structures should be designed to discourage perching.

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Research recommendations: Martial Eagle

There is a need for additional research in respect of Martial Eagles in the following areas:

- Population monitoring and a population viability assessment to quantify potential cumulative impacts on the species.
- Relationships and movements between populations/individuals within the species' range.
- Consistent monitoring and reporting on the status and success of breeding sites near WEFs.
- The effectiveness and feasibility of measures to avoid and mitigate collision risk (e.g. blade patterning).
- Testing of flight-risk models as predictors of fatalities for this species across multiple wind farms (to ground-truth how accurate the models are at predicting areas where turbines should be avoided).
- Metrics on other threats to the species (e.g. poisoning) and the effectiveness of mitigation activities to address these threats. These data can be used when designing compensation or offset strategies.

Tawny Eagle *Aquila rapax*

Although Tawny Eagles are rarely recorded during bird surveys, six WEFs overlap with the species' broad distribution (defined using SABAP2 records). The Tawny Eagle is categorised as regionally Endangered (Taylor et al. 2015), is listed under the Raptors MOU, and is on Appendix II of CITES.

Two Tawny Eagle fatalities as a result of turbine collisions were reported from two WEFs. At one of these WEFs, the eagles were reported to breed on the powerlines in the broader area. The species was recorded during pre-construction monitoring, but not during the first year of operational monitoring, when the fatality occurred. The second reported fatality occurred in the Cookhouse region, beyond the species' normal distribution.

Booted Eagle *Hieraaetus pennatus*

The Booted Eagle is a widespread species and, based on SABAP2 data, it can be expected to be found near all WEFs in the review. Twenty-nine fatalities of Booted Eagles as a result of turbine collisions and one attributable to a powerline were reported from 12 different WEFs. Minimum collision rates were 0.007 Booted Eagles per turbine per year, 0.003 per MW per year.

Fairly common and with a stable population (BirdLife International 2024), the Booted Eagle is listed as Least Concern (BirdLife International 2024; Taylor et al. 2015). However, based on its smaller stature and mitochondrial DNA analysis, it has been proposed that the breeding population in southern Africa is a unique subspecies (i.e. *Hieraaetus pennatus miniscula*) (Yosef et al. 2000) and as such may warrant increased protection. Booted Eagle is listed under CITES Appendix II, CMS Appendix II, Raptor MOU Category 3 and has been reported as vulnerable to turbine collisions elsewhere in its range (Martín et al. 2018; BirdLife International 2024).

Other eagles
Other eagles recorded as fatalities include African Fish Eagle *Haliaeetus vocifer* (*n* = 3), Black-chested Snake Eagle *Circaetus pectoralis* (*n* = 6) and Long-crested Eagle *Lophaetus occipitalis* (*n* = 6).

African Fish Eagle is listed as Least Concern (Taylor et al. 2015; BirdLife International 2024). The species is widespread, but reliant on waterbodies (Hockey et al. 2005). The relatively low number of fatalities may be thanks to recommendations in the EIA and planning processes, which typically advise placing turbines away from rivers and wetlands (e.g. Holness and Oosthuysen 2016).

Long-crested Eagle and Black-chested Snake Eagle are not currently listed as Threatened (Taylor et al. 2015; BirdLife International 2024). Long-crested Eagle has, however, shown marked declines elsewhere in Africa (Shaw et al. 2024).

Jackal Buzzard *Buteo rufofuscus*
The Jackal Buzzard was the most commonly found bird carcass beneath wind turbines in the review (Figure 4). One hundred and forty-six carcasses as a result of turbines collisions were reported from 22 different WEFs. A further six carcasses due to powerline electrocutions and one roadkill were recorded.

Fatality rates did not show a consistent trend over time. One WEF in the Western Cape recorded a very high fatality rate in the first year of monitoring (i.e. 0.3 Jackal Buzzards per turbine). This rate reduced substantially in later years, although the specialist reported that there was no reduction in Jackal Buzzard activity. A number of Jackal Buzzards were still found in and around the WEF and two active nest sites were also located near the facility. This could suggest turbine-scale avoidance. However, a similar pattern was not recorded at other WEFs. Some WEFs reported a slight decline, while others recorded fatality rates that increased over time.

The age-class of birds affected was not provided in most instances, but two of the seven incidents where age-class was reported were of juvenile birds. Carcasses were found throughout the year, with no apparent seasonal pattern in fatality rates (Figure 11).

The species is found throughout South Africa and accordingly all WEFs in the study overlap with the distribution of the species. Averaged across all WEFs, the unadjusted fatality rate was 0.037 Jackal Buzzards per turbine per year

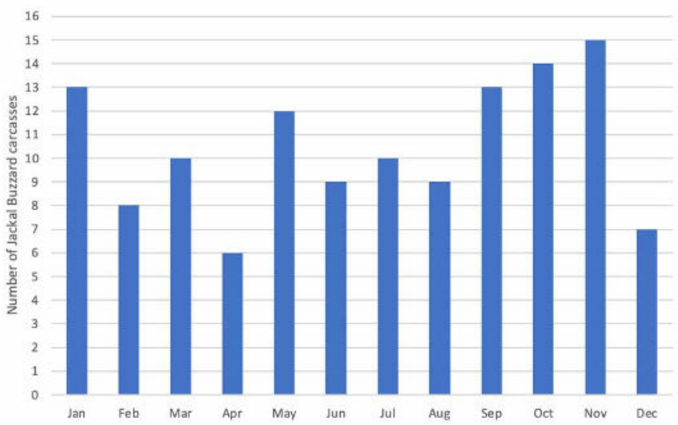

FIGURE 11. The number of Jackal Buzzard carcasses (turbine collisions) recorded each month of the year.

(0.017 per MW per year). The highest rate at any WEF was 0.268 per turbine per year. This high rate was reported from a small wind farm with just over two years of data. WEFs in the Albany Thicket, Fynbos and Savanna biomes recorded high fatality rates. Assuming the current rates continue, a minimum of approximately 56 additional fatalities a year can be expected (Table 1).The Jackal Buzzard is endemic to southern Africa. It is not currently listed as Threatened and the population is believed to be stable, despite pressure from poisoning, persecution, and collisions with vehicles and fences (Taylor et al. 2015). The population is estimated to be in the tens of thousands (BirdLife International 2024). The species is long lived, surviving to at least 25 years, and reaching breeding age after two years (Taylor et al. 2015).At this stage it is unclear if the Jackal Buzzard population can withstand the additional losses arising from wind turbine collisions, but a study of the Common Buzzard *Buteo buteo* in Germany points to the need for caution. The Common Buzzard is regularly found in Germany, yet population models indicate wind energy in northern Germany may have had a negative effect on the population (Grünkorn et al. 2017). Pending an accurate assessment of the Jackal Buzzard's population size and its ability to withstand additional losses, the precautionary principle should apply, with steps taken to mitigate impacts on Jackal Buzzards in planning and operation of WEFs.

Jackal Buzzards use electricity pylons for perching near some WEFs. This may increase the risk of collisions and it is therefore recommended that pylons close to turbines be fitted with bird guards. Jackal Buzzards are also scavengers (Taylor et al. 2015) and may be drawn to the area around turbines in search of food. As with vultures, the removal of animal carcasses near turbines (livestock carcass management) may help mitigate the risk of collisions.

Research recommendations: Jackal Buzzard

- There is a need for additional research to confirm the Jackal Buzzard population size and to assess the species' ability to withstand losses arising from wind turbine impacts.
- Studies of the species' spatial ecology and potential avoidance and mitigation measures are also required. For example, data to inform potential buffer sizes around nests would be useful.

Common Buzzard *Buteo buteo*
Seventeen fatalities of Common (Eurasian) Buzzard were reported from 10 different WEFs in the review (0.004 birds per turbine per year and 0.002 per MW per year). SABAP2 data indicate that most of the WEFs overlap with this species' distribution, but no fatalities were reported from the Succulent and Nama-Karoo biomes, where the species' distribution is expected to be patchy (Hockey et al. 2005).

Most carcasses were found in summer months (see Figure 12), coinciding with the period when numbers of this Palearctic migrant are expected to peak (Hockey et al. 2005).

The Common Buzzard has a very large population and considerable range, spanning across Europe to central Asia and Africa. It is not listed as Threatened (BirdLife International 2024), but it is listed under CITES Appendix II, CMS Appendix

II and Raptors MOU Category 2. As discussed above, this species is commonly reported as a collision-mortality at wind energy developments in Europe (De Lucas et al. 2012; Grünkorn et al. 2017) and population level impacts have been reported likely in northern Germany (Grünkorn et al. 2017).

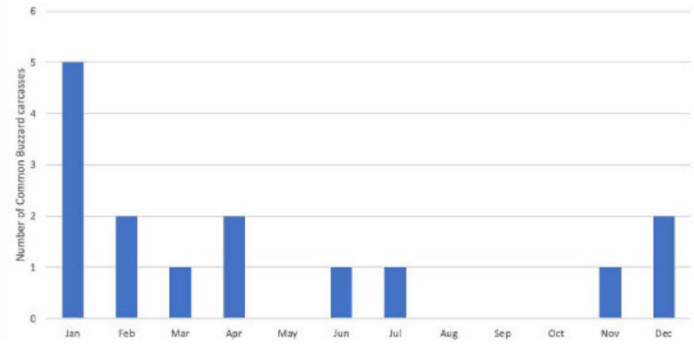

FIGURE 12. The number of Common Buzzard carcasses (turbine collisions) recorded each month of the year.

Forest Buzzard *Buteo trizonatus*
Four fatalities of Forest Buzzard were reported from two WEFs in the Fynbos and Albany Thicket biomes in the Eastern Cape. This species is globally Near Threatened (BirdLife International 2024) and its distribution is limited to South Africa, Lesotho and Eswatini. Eleven operational WEFs overlap with the species' broad distribution.

Black Harrier *Circus maurus*
The Black Harrier is a very uncommon species which is endemic to southern Africa. It is concentrated mainly in the coastal lowlands and mountains of the Western Cape, and grasslands of the Eastern Cape and Free State (Taylor et al. 2015). Based on SABAP2 records, this harrier is likely to be found at or near most (i.e. 27) of the WEFs in this study. During site surveys the species was recorded at 24 of the WEFs in the review, although often in low numbers.

Ten Black Harrier carcasses ascribed to turbine collisions were reported from five different WEFs. The unadjusted fatality rate for all WEFs is 0.003 per turbine per year (0.001 per MW). If only the WEFs where the species was recorded during surveys are used to assess the fatality rate, this increases to 0.004 birds per turbine per year.

An additional possible fatality of a juvenile Black Harrier was recorded at another WEF. However, only a photograph of the carcass was available and the identification was not confirmed.

Further losses were also noted due to breeding failure. An unfledged juvenile died as a result of the provisioning male being killed, and two chicks were found dead near their nest after being abandoned by their parents.

Black Harriers are endemic to southern Africa, Lesotho and Namibia, and listed as Endangered both regionally (Taylor et al. 2015) and globally (BirdLife International 2024). The species is listed under CITES Appendix II and CMS Appendix II. It has a restricted breeding range of approximately 170 000 km^2, centred on south-western South Africa (Simmons and Simmons 2000). Cervantes et al. (2022) conducted a population viability assessment and estimated a global population of approximately 1 300 birds, currently declining at 2.3% per year. The model indicated that the

BLACK HARRIER WESSEL ROUSSOW

population could collapse in less than 100 years, if an average of three to five additional adult birds are killed annually. At the current rate, and without effective mitigation, at least 3.8 Black Harriers could be killed at WEFs each year, indicating that Black Harrier fatalities are already at unsustainable levels. Urgent attention is clearly needed to address this risk.

The fatalities occurred at WEFs in the Fynbos, Albany Thicket and Grasslands biomes. As a ground-nesting raptor, Black Harriers build cryptic nests that can be difficult to detect (Hockey et al. 2005) and breeding was not confirmed at most of the WEFs. The GPS locations of only two carcasses were provided in reports. Both were in suitable Black Harrier habitat as included in the National Screening Tool. However, the specialist at one of these WEFs was of the opinion that the Black Harrier was not resident or breeding, despite the species being recorded in low numbers (a passage rate of 0.01 birds per hour) in pre-construction monitoring. A Black Harrier fatality occurred at another WEF where just a single flight had been recorded during surveys. The potential for Black Harrier fatalities therefore exists even where low passage rates were recorded. Data collection for impact assessment should include dedicated breeding surveys supported by habitat suitability models (Simmons et al. 2020).

As shown in Figure 13, the number of Black Harrier carcasses found peaked in October and November. September is the peak egg-laying season for Black Harriers and November, the peak nestling rearing period (Hockey et al. 2005), supporting the hypotheses that provisioning birds, especially males, are most at risk (Simmons et al. 2020).

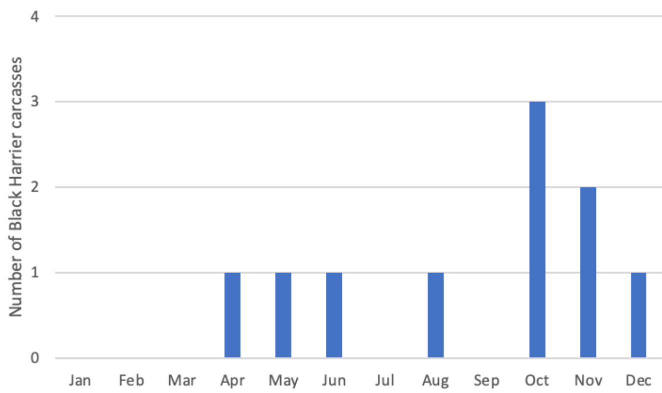

FIGURE 13. The number of Black Harrier carcasses (turbine collisions) recorded each month of the year.

CASE STUDIES: Black Harrier

A WEF located primarily in natural habitat in the Eastern Cape has become a focal point for studying the impact of wind energy infrastructure on the Black Harrier. At the time of the EIA, in 2010, the Black Harrier was listed Vulnerable (it was uplisted to Endangered in 2015). During pre-construction monitoring, the harrier was not identified as a high-risk species, with only eight recorded flights, all below rotor height. After the WEF's construction, post-construction data revealed higher Black Harrier flight activity (0.2 harriers per hour in years one and two, including flights occurring at rotor height). In 2012 it was also discovered that the WEF was located within 10 km of a roost site. This roost is thought to support both resident and migrating harriers. Breeding sites were identified to the north and south-west of the WEF, including within 250 m of turbines. Over seven years, the wind farm reported six Black Harrier fatalities. Most fatalities occurred within approximately three kilometres of breeding sites. A secondary impact of these fatalities was failed breeding attempts.

To address the impact on Black Harriers, OLSDOD was trialled in the seventh year of operation. This was implemented from October to December, to coincide with the period of highest risk. A Black Harrier fatality occurred in June, before the programme was initiated. OLSDOD was implemented again from August to December of the eighth year. No further Black Harrier fatalities were reported, despite Black Harriers being frequently observed on site, with approximately 1 000 observations recorded and close to 100 turbine shutdowns requested during this period.

In another example, the WEF with the highest Black Harrier fatality rate per turbine is a small wind farm in the Overberg region. This site reported an unadjusted fatality rate of 0.04 Black Harriers per turbine per year. Potential risks to the Black Harrier were identified in the EIA, but the species was not observed during the first four seasons of pre-construction monitoring. However, it was recorded in later surveys, although in low numbers.

The turbine layout avoided all areas of remaining Renosterveld, the potential foraging habitat for this species. The closest recorded nest was approximately 3.8 km away, in a patch of Renosterveld of approximately 500 ha. In years when conditions are right, this remnant is used by up to 20 pairs of breeding harriers, making it one of the densest known colonies of this species (O Curtis unpublished. data).

The WEF proactively implemented OLSDOD from construction. Shutdowns involving 85 Black Harriers were implemented in the first year. However, a Black Harrier fatality was recorded in the same year. Although OLSDOD was in place at the time, the bird was not seen approaching the turbines. Without OLSDOD, the fatality rate may have been higher.

Although the fatality rate at this WEF is high, it is important to consider that only one Black Harrier carcass was recorded during the reporting period. This WEF is small, and the monitoring period was shorter compared to the first case study. In other words, the data may not be representative due to the low number of turbine-years monitored. However, two Black Harriers, both birds fitted with tracking devices, have subsequently been recorded as fatalities at this WEF. In one of these cases the impact-damaged GPS tracker was found below a turbine, but not the carcass. While these latter figures have not been included in the analysis of this report as the information was received outside the reporting period, this brings the total number of Black Harrier fatalities reported in South Africa to 13.

Both WEFs are implementing Biodiversity Management Plans and exploring additional measures, such as blade patterning, habitat protection, and habitat enhancement outside the WEFs, to further mitigate risks to the harrier population.

Research recommendations: Black Harrier

Additional research is required into the movement ecology of the Black Harrier and the opportunities to avoid and minimise impacts arising from WEFs. These include:

- A review of the efficacy of observer- and technology-led SDOD in reducing fatalities.
- An assessment of the accuracy of flight-risk models in predicting where fatalities occur.
- A study of the efficacy of patterned blades in reducing harrier fatalities given the difficulty of SDOD mitigations in detecting and reducing fatalities of this highly vulnerable species.
- Given that most fatalities of this species are recorded in the breeding season, a study of the hidden costs of a parent being killed on the breeding outcome is required (for this and other species).

Lanner Falcon *Falco biarmicus*

The Lanner Falcon is widespread and has an extremely large range (BirdLife International 2024). Twelve carcasses resulting from turbine collisions were reported from seven different WEFs – a rate of 0.006 birds per turbine per year (0.002 per MW per year) (see Table 1). The highest fatality rates were recorded from WEFs in the Fynbos Biome. The number of carcasses found peaked slightly in December and January (Figure 14).

Although the species is widespread and has a large global population, it is decreasing in parts of its range (BirdLife International 2024). The regional population, estimated to number fewer than 10 000 mature individuals, is declining rapidly and the species has been categorised as Vulnerable in South Africa, Lesotho and Eswatini (Taylor et al. 2015). The Lanner Falcon is listed under CITES Appendix II, CMS Appendix II, Raptors MOU Category 2 and Berne Convention Appendix II.

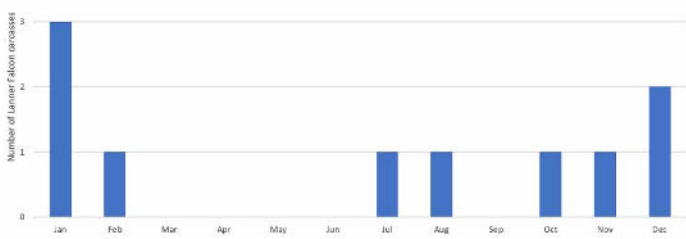

FIGURE 14. The number of Lanner Falcon carcasses (turbine collisions) recorded each month of the year.

Amur Falcon *Falco amurensis*
Sixty-four fatalities of Amur Falcon were reported from eight different facilities, making it one of the most common migrant species killed at WEFs. An average rate of 0.013 birds per turbine per year (0.005 per MW per year) was recorded. The highest rates were reported at three WEFs in the Eastern Cape Province, where the largest overlap with the species is expected.

Amur Falcon is not threatened and has a large population (BirdLife International 2024), but the species is listed under CITES Appendix II, CMS Appendix II, Raptors MOU Category 3.

The species is a summer visitor to South Africa, usually arriving in November or December and staying through May (Hockey et al. 2005). This explains the summer peak in the number of carcasses recorded (Figure 15). A gregarious species, Amur Falcons gather at night in very large roosts (often more than 5 000 individuals). They leave these sites during the day to forage and return in the evenings (Hockey et al. 2005). Turbines within the foraging range of these roost sites are likely to cause fatalities.

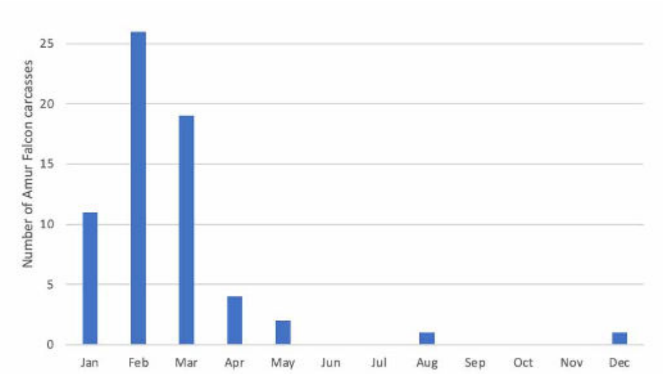

FIGURE 15. The number of Amur Falcon carcasses (turbine collisions) recorded each month of the year.

Kestrels
Another commonly found carcass was the Rock Kestrel *Falco rupicolus* (Figure 4). Seventy-seven fatalities were recorded at 21 different WEFs. The average fatality rate was 0.027 birds per turbine per year (0.011 per MW per year). Fatalities occurred throughout the year, peaking in March (Figure 15). This species is a common resident (Hockey et al. 2005) and not threatened, but the risk of cumulative impacts from a growing wind energy industry needs to be assessed.

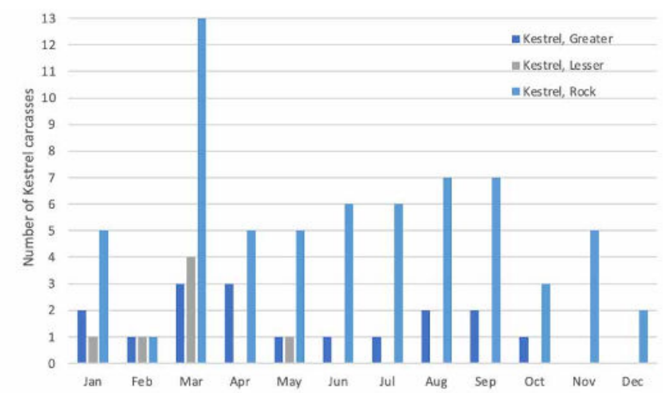

FIGURE 16. The number of kestrel carcasses (turbine collisions) recorded each month of the year.

AMUR FALCON KOSHY KOSHY

Fatalities of Greater Kestrel *Falco rupicoloides* and Lesser Kestrel *Falco naumanni* were also recorded (Table 1, and Figure 16). Lesser Kestrels are migratory, overwintering in South Africa. They roost communally in their thousands, often together with other falcons (Hockey et al. 2005). They are listed under CITES Appendix II, CMS Appendix I and II and the Raptors MOU Category 2.

Secretarybird *Sagittarius serpentarius*
The Secretarybird has recently been uplisted to Endangered on the IUCN Red List due to rapid population declines throughout its range as a result of habitat degradation, disturbance, hunting, and trade (BirdLife International 2024). It is listed in CITES Appendix II. The regional population of Secretarybirds was estimated to range from 3 500 and 5 000 breeding individuals in 2015, but the confidence in this estimate is low (Taylor et al. 2015).

The species has a broad distribution in South Africa, where it occurs in grasslands, open savanna and Karoo shrubland. It occurs in low densities (Hockey et al. 2005). During site surveys it was recorded at 26 of the 27 WEFs in this review.

Eight Secretarybird carcasses at five different WEFs were reported, with an average rate of 0.001 carcasses per turbine per year (0.001 per MW per year). The unadjusted fatality rate doubles to 0.002 carcasses per turbine per year if only WEFs that recorded Secretarybirds during surveys are used in calculations.

Three wind farms reported two Secretarybird fatalities, with the highest rate at any WEF reported as 0.013 birds per turbine per year (see case study below).

Four of the eight fatalities occurred in Critical Biodiversity Areas, but no specific risk factors were identified in the monitoring reports. One specialist concluded that the two fatalities that occurred at a WEF were unavoidable because Secretarybirds roam widely across the grasslands while foraging and no consistent pattern of turbine collision risk was evident.

Carcasses were found from May to December, with the most fatalities (three) recorded in September (Figure 17). Although breeding varies between regions, it peaks in late winter to early summer (Hockey et al. 2005). The peak in fatalities may therefore have coincided with the breeding season. If so, there may have been hidden costs associated with these deaths. The age-class was only specified for two of the carcasses, both of which were adult birds.

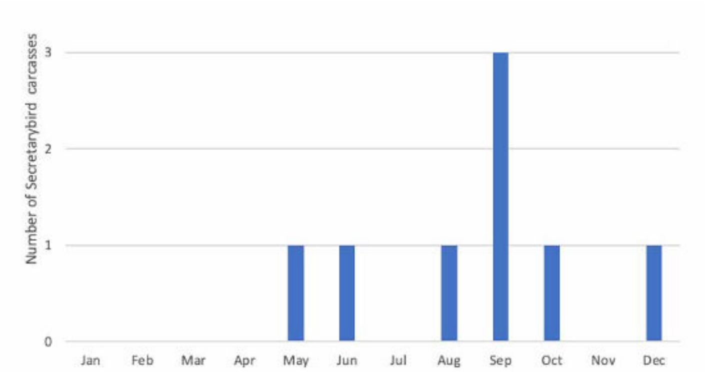

FIGURE 17. The number of Secretarybird carcasses (turbine collisions) recorded each month of the year.

CASE STUDY : Secretarybird

The initial EIA for a WEF that documented two Secretarybird fatalities (a rate of 0.004 birds per turbine per year) was completed in 2010 and suggested that there may be 'occasional' interaction with Secretarybirds. The EIA concluded that no mitigation was necessary due to low expected frequency of interactions. A nest in the middle of the WEF was subsequently recorded in the second year of operational-phase monitoring. Although this nest was located as close as 350 m from the nearest wind turbine, the location or status of the nest was not mentioned in any further reports.

An OLSDOD programme was in place when these fatalities occurred. The first incident occurred during bad weather and in misty conditions. It is suspected that weather (mist and rain) may have also played a role in the second failure of OLSDOD. The fatalities occurred approximately 1.4 km and 2.2 km from the above-mentioned nest. It may be that turbine curtailment (predictive shutdown) may be required in misty conditions in high-risk areas (i.e. near active nests).

Although after this reporting period, a new Secretarybird nest was reportedly occupied on the outskirts of the WEF and a further two fatalities have been reported (one of these occurred in 'the first few months' of the year and the other in May), bringing the total number of fatalities reported in South Africa to 10.

Research recommendations: Secretarybird

- Up-to-date population estimates for this rapidly declining species.
- An assessment of the population viability (e.g. following similar methods to those used by Cervantes et al. 2022 applying SABAP2 detection records).
- As with other species, comparing flight-risk models based on pre-construction data, with post-construction fatality data, can ground-truth the ability to correctly identify high-risk areas for this species.
- Movement ecology, especially around operational wind farms, including in different weather conditions. The trapping of adult Secretarybirds is near-impossible, and the current dataset is based mostly on movements of juveniles, skewing the available movement ecology data.
- Breeding success at operational WEFs needs to be intensely monitored.
- Consideration should be given to effective land use and biodiversity stewardship practices that could contribute to proactive conservation and/or compensation for unavoidable losses.

Large terrestrial bird species

Denham's Bustard *Neotis denhami*

Three turbine fatalities of Denham's Bustard (regionally Vulnerable; Taylor et al. 2015) were reported from three different WEFs, with an average rate of 0.003 birds per turbine per year (0.001 per MW per year). A larger number of fatalities were reported as a result of powerline interactions.

Ludwig's Bustard *Neotis ludwigii*

Ludwig's Bustard is classified as Endangered both regionally (Taylor et al. 2015) and globally (BirdLife International 2024). The population of this nomadic, near-endemic species is decreasing (BirdLife International 2024). Six fatalities were reported from four different WEFs, with an average rate of 0.003 birds per turbine per year (0.001 per MW per year). A further three fatalities were recorded below powerlines.

LUDWIG'S BUSTARD ALBERT FRONEMAN

Southern Black Korhaan *Afrotis afra*
Five fatalities of the endemic and regionally Vulnerable (Taylor et al. 2015) Southern Black Korhaan were reported. All carcasses were found at a single WEF in the western part of the Western Cape. Further monitoring was recommended by the specialist.

Blue Crane *Anthropoides paradiseus*
Eighteen Blue Crane fatalities were reported from 10 different WEFs, an average rate of 0.007 birds per turbine per year (0.002 per MW per year). An additional five powerline fatalities were reported. Fatalities peaked in summer (Figure 18).

Blue Cranes were confirmed as breeding and successfully fledged chicks at two WEFs.

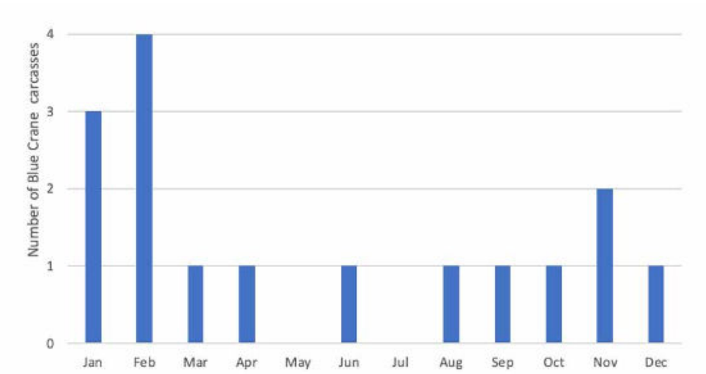

FIGURE 18. The number of Blue Crane carcasses (turbine collisions) recorded each month of the year.

Songbirds (Passerines)

Twenty-nine per cent of all carcasses found beneath turbines were passerines (Figure 3), mirroring results in North America, where small passerines constitute the largest percentage of fatalities (American Wind Wildlife Institute 2020).

Despite its small size, the Red-capped lark *Calendrella cinerea* was the third most common species carcass recorded beneath turbines. This is potentially concerning as South Africa has a high number of endemic lark species and knowledge of many of these is still limited (Hockey et al. 2005). Carcasses of endemic and near-endemic larks, including Agulhas Long-billed *Certhilauda brevirostris*, Cape Clapper *Mirafra apiata,* Cape Long-billed *Certhilauda curvirostris* and Large-billed *Galerida magnirostris* were found at WEFs, albeit in low numbers.

It is encouraging that no Red Lark *Calendulauda burra* (Vulnerable) carcasses were reported, despite this being the most numerous priority species recorded during the first year of monitoring at a WEF in the Northern Cape. Red Lark also had the second-most flight activity at this site, but all recorded flight activity was below the rotor-swept area. A decrease in abundance in the direct vicinity of the turbines was however noted and found to be statistically significant as evidence of displacement.

There is growing interest in expending wind energy into Grassland Biome, and given concerns regarding the sensitivity of certain endemic lark populations, it is recommended that the precautionary principle be applied such that:

- Habitat of threatened and range-restricted larks should be avoided when locating wind turbines; and
- Where turbines are located within or near habitat of larks of conservation concern, carcass surveys should be intensified (i.e. using more frequent and narrower transects) during the breeding season to increase the probability of detection.

Research recommendations: Endemic larks

Further research is needed to better understand and define habitat requirements for different lark species, as well as their sensitivity to disturbance, risk of displacement, and collision risk. Key research questions should include an examination of display flight heights, and the duration spent within blade-swept zones, with consideration of variations across seasons and weather conditions.

Swifts, Swallows and Martins

Collectively, swifts, swallows and martins accounted for 16% of carcasses found beneath turbines (Figure 3). The exceptionally high estimated fatality rate at a wind farm in the Northern Cape mentioned earlier in this report was mainly driven by a large number of swift fatalities (mostly Little and Common swifts) which comprised 86% of bird carcasses collected. Although this group is widespread and commonplace, the specialist report noted a concern that the species are largely overlooked in mitigation strategies despite high fatality rates and, as aerial insectivores, they occupy a similar ecological niche to bats, which already receive significant attention in impact assessments and mitigation efforts.

Research recommendation: impact on ecosystem services

In addition to focusing on SCC, avifaunal impact assessments and research should consider impacts on species that are widespread but may face high fatality rates. In particular impacts on species that provide valuable ecosystem services (e.g. pest management) such as Amur Falcon, Lesser Kestrel, Rock Kestrel, swifts and swallows need to be monitored and where necessary, mitigated.

RED-CAPPED LARK GRAHAM & TRISH McGILL

RECOMMENDED MITIGATION MEASURES

The following mitigation measures were proposed in operational monitoring reports.

HABITAT MANAGEMENT (REDUCE ATTRACTANTS)

Several specialists recommended habitat management measures to reduce the attractiveness of the WEF to species at risk of collisions. Recommendations included installing anti-perching devices and livestock carcass management, which are discussed in more detail below. Other suggestions included reducing rock piles created during road construction as they provide habitat for dassies, which are prey for Verreaux's Eagles, and mowing and fire management. Managing water resources was also proposed. For example, a wind farm in the Cookhouse cluster reported a vulture fatality during a heatwave. The consulting specialist hypothesised that the bird was drawn to the area to bathe or drink at a nearby farm dam, as no livestock carcasses were present on the project site at the time. It was suggested that the artificial farm dam be drained and alternative water sources for livestock be provided in a way that prevents access by large birds. Many of these measures are likely to be site- and species-specific, and their effectiveness still needs to be tested. The management of factors like food availability and suitable perching or roosting sites beyond the wind farm's immediate boundary may also require attention.

Anti-perching devices (powerlines and meteorological masts)

Electricity cables and pylons are used by raptors for perching, roosting and breeding. There were also reports of raptors (e.g. Martial and Verreaux's eagles) perching on the horizontal bars of meteorological masts. When considering the design of associated infrastructure, care should be taken not to create additional places for raptors to perch close to operational turbines, particularly in habitats where perching structures are naturally limited.

Some specialists have also recommended that existing overhead powerlines near operational WEFs should be checked for evidence of roosting by species at risk (e.g. Cape Vultures) and that consideration should be given to installing anti-perching devices on these structures. This will require the support of Eskom (or other relevant power utility) and such devices will need to be regularly checked and maintained. The availability of suitable anti-perching devices, and the willingness of the utility company to install them, will influence the success of such measures. Maintenance is also important, as these devices have a finite life.

Livestock carcass management

Livestock carcasses may attract scavengers, including vultures. Livestock carcass management, also known as Vulture Food Management (VFM), involves a dedicated team of full-time staff who patrol a wind farm site and remove any dead animals, with the aim of reducing attraction of the area to vultures and thus minimising the risk of collisions. VFM has been implemented at five WEFs, with the intention of minimising the risk to Cape Vultures and other raptors.

Managing livestock carcasses could also involve establishing supplementary feeding sites, or 'vulture restaurants', outside the WEF with the aim of attracting vultures away from the turbines. While proposed as a potential mitigation strategy, this approach has not yet been successfully implemented at the WEFs reviewed here. The reasons for this are discussed further under 'Monitoring, mitigation and proactive conservation beyond the WEF footprint'.

One WEF in the Eastern Cape implemented VFM in the first year of operation. The Cape Vulture fatality rate was reduced from 0.07 vultures per turbine per year in the first year to an average of 0.02 (range 0 to 0.04) vultures per turbine per year over the next six years following implementation of VFM. A second WEF implemented VFM in the fourth year of operation (more than three years after it was recommended by the specialist), but reported no decrease in Cape Vulture fatalities.

There are a number of practical challenges associated with VFM that can affect the success of this measure. In particular, the approach relies on the buy-in and support of the landowner(s). Where responsibility for removing a reported carcass lies with the landowner, some wind farms have reported significant delays in the carcasses being removed. Agreements and incentives should therefore be put in place to ensure the prompt removal of animal carcasses or, preferably, landowner agreements should allow the WEF staff to dispose of or cover carcasses.

Even where carcass removal appeared to be running well, vulture fatalities occurred, presumably because the vultures were searching for food, rather than approaching or departing from a feeding site.

Vulture fatalities have occurred at sites where the birds are expected to be only occasional visitors and, while vultures have been the primary driver for livestock carcass management, other scavenging species would also benefit from this measure. As far as possible and with due regard to lease agreements, all WEFs should consider implementing livestock carcass management as a standard mitigation measure.

SHUTDOWN ON DEMAND

Observer-led shutdown on demand (OLSDOD) was implemented at four WEFs included in this review (although more have reportedly followed suit).

One WEF implemented OLSDOD from two vantage points after six years of operation. This targeted eight bird SCC and occasionally included non-threatened (raptor) species. OLSDOD was implemented only during the anticipated peak risk period (spring–summer). During this time it appears to have been effective in reducing the number of fatalities of SCC, although bird carcasses of SCC were still found.

Another WEF implemented OLSDOD from the outset of operation. In the first year of operation, it shut down one or more of its 13 turbines 219 times, involving 384 observations of Cape Vulture, 85 of Black Harrier and one Verreaux's Eagle. The consulting avifaunal specialist estimated that between seven and 19 Cape Vulture and one to four Black Harrier fatalities were avoided thanks to this programme, although two fatalities of SCC (one Black Harrier and one Blue Crane) were recorded over a period of 20 months. Investigation into these incidents concluded that the Black Harrier fatality was due to the sub-optimal location of the observation point combined with human error, as the monitor failed to see the bird approaching the turbine. Another challenge noted was that the OLSDOD programme did not cover all daylight hours.

A third WEF implemented OLSDOD, combined with the use of 'deterrents', but without the oversight and reporting of an avifaunal specialist. Without robust reporting, it is difficult to assess how effective this measure was, but both Cape Vulture and eagle fatalities occurred during the period OLSDOD was in place.

As a relatively new project, there was limited data available from the fourth WEF implementing OLSDOD.

While OLSDOD has prevented fatalities, its effectiveness may be compromised by inclement weather, human error and/or communication (network) issues. In addition to fatalities, there were a number of 'near-misses' reported, when a turbine could not be switched off in time. These were in general due to communication network problems.

Based on experience to date, the following good practice OLSDOD principles are highlighted:

- Observers should be on site during all high-risk periods, including weekends and public holidays.
- Observers must be provided with shelter and Personal Protection Equipment (PPE) to protect them from adverse weather conditions.
- Observation points should be located to offer good coverage of turbines.
- Ensure prompt and clear communication between the monitors in the field and the staff in the control centre. Back-up plans should be in place in the event of network failure.
- Consider transport requirements to get observers to and from monitoring points, and have back-up plans in the event of vehicle breakdowns (especially where the road conditions are poor).
- In remote areas, accommodation may need to be provided for observers either at or near the site.
- Clear protocols and procedures for OLSDOD are required, and all parties must be informed of these, including the control room responsible for shutting down turbines.
- Consideration should be given to including all raptors and other priority species in the OLSDOD programmes.
- To ensure the effectiveness of SDOD, it is crucial to combine OLSDOD with carcass surveys. The design and implementation of surveys and associated reporting should be overseen by an avifaunal specialist.
- Should fatalities of priority species occur when an OLSDOD is in place, a root cause analysis should be done to determine the risks and reasons for failure and make corrections where necessary.
- At high-risk sites, a combination of automated systems and OLSDOD may be required.

BLADE PATTERNING

Spurred on by success of the experiment in Norway (May et al. 2020), blade patterning as mitigation was mooted for several WEFs and has been implemented at one operational facility (i.e. Umoya, near Hopefield). Although received

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Patterned turbine blades at Hopefield WEF.

outside of the review period, the results from the first year of monitoring are encouraging (Birds & Bats Unlimited 2024). Resources to support WEFs and specialists considering this passive mitigation strategy have been recently published (i.e. Morkel et al. 2023; SAWEA 2024).

MONITORING, MITIGATION AND PROACTIVE CONSERVATION BEYOND THE WEF FOOTPRINT

A compelling argument exists for expanding mitigation efforts beyond the confines of a WEF's footprint. This may be especially necessary to effectively mitigate the impacts on wide-ranging species such as vultures, as well as eruptive species like swifts and falcons. Monitoring of roosting sites, colonies, and overall species abundance across the broader landscape provides an early indication of potential heightened collision risk, and the associated need to step up on-site mitigation.

In cases where a cluster of wind developments exists, a logical approach emerges – collaboration among wind farms to pool resources and expertise. Such synergistic endeavours not only promote effective mitigation within the landscape but also pave the way for additional conservation actions.

WEFs in the Eastern Cape commissioned the Endangered Wildlife Trust (EWT) to implement a Cape Vulture Safe Zone project. This initiative includes engaging with landowners and encouraging them to pledge to manage their properties in a vulture-friendly manner and declare their properties as Vulture Safe Zones. Bird flight diverters have also been purchased to retrofit powerlines in high-risk areas, although obtaining permissions for deployment can be a challenge. The potential to establish supplementary feeding sites was investigated, but challenges from scavenging by jackals and bushpigs were encountered. Concerns regarding the lead content of animal carcasses were also raised and this project was not pursued further.

CHALLENGES WITH THE IMPLEMENTATION OF OPERATIONAL-PHASE MITIGATION

Despite often clear requirements in EMPrs and recommendations from avifaunal specialists, the implementation of operational-phase mitigation has often been slow, and at times lacking.

CASE STUDIES: poor implementation of operational-phase mitigation requirements

A WEF in the Eastern Cape reported at least 13 Cape Vulture fatalities, an average of three vultures a year, over a five-year period. Fatalities of other threatened species, including Secretarybird (Vulnerable), Lanner Falcon (Vulnerable) and Denham's Bustard (Vulnerable), were also recorded. The EMPr clearly stated that should any significant impacts of the facility on priority bird and bat populations be detected, the necessary mitigations should be applied. Following monitoring, the specialist recommended the introduction of VFM and that the WEF should participate in a research and mitigation programme with nearby WEFs and NGOs. The WEF took three years to partially implement a VFM and, five years on, no other recommendations have been applied.

In a similar example, another WEF in the Eastern Cape was responsible for three Cape Vulture fatalities a year, in addition to Martial Eagle (Endangered), Verreaux's Eagle (Vulnerable) and Lanner Falcon (Vulnerable) fatalities. The EMPr stated that if unacceptably high fatality rates are recorded, additional mitigation measures should be implemented. OLSDOD was recommended by the specialist for all turbines during daylight hours. Alternatively, the specialist recommended that turbines should be curtailed during the high-risk period. No such measures had been effected more than a year after the need to implement OLSDOD or curtailment was first raised.

Taking account of the experience to date, it is recommended that:

- Impact management objectives in EMPrs should be specific, time-bound and measurable.
- Compliance with operational-phase EMPrs should be regularly audited; and
- WEFs not implementing mitigation measures within a reasonable timeframe should be fined and/or prosecuted by the competent authority.

POWERLINES

Powerline electrocutions and collisions accounted for only four per cent of bird carcasses found. However, powerlines are not normally subjected to the same robust survey methods as the turbines. Despite this, at least eight threatened species were reported as powerline fatalities (see Table 1).

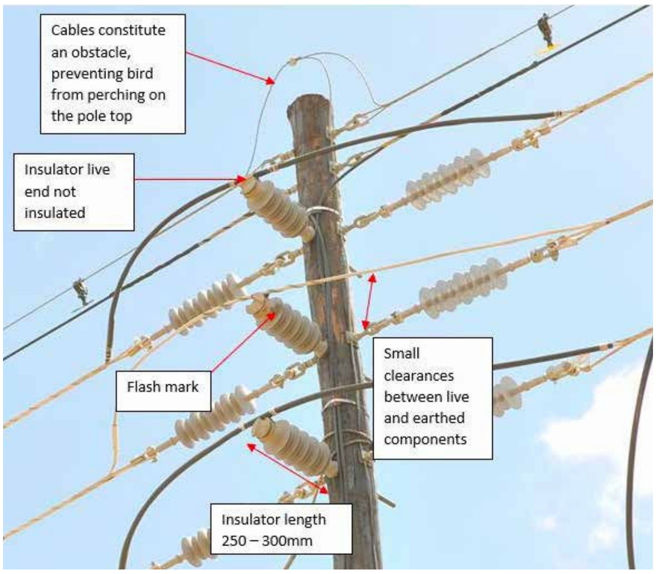
CASE STUDY

Although it is considered good practice to bury internal collector lines, as far as is technically possible (Bennun et al. 2021), this does not always happen. Two wind farms in the Northern Cape installed above-ground collector lines. Unfortunately, these lines were designed in a way that presents a risk of electrocution to birds that perch on the structures. After five years of operation at one of these WEFs, the rate of electrocutions was approximately 4.4 birds per year and 2.8 Threatened species of birds per year. During this period 12 Verreaux's Eagles and three Martial Eagles were considered likely to have been killed by electrocution.

Most of the electrocutions occurred on uninsulated strain structures on the suspension poles. To mitigate the threat, wooden perches were installed, encouraging birds to perch away from risk areas and additional insulation on the most dangerous structures was recommended. Resolving these avoidable impacts has proved to be a challenging mistake for the WEF to rectify.

Taking account of the experience to date, it is recommended that:

- Where technically feasible, internal reticulation (collector) lines should be located underground.
- Powerlines installed above ground should be designed to be raptor-friendly and fitted with flight diverters to minimise the risk of electrocution and collisions; and
- Powerlines associated with WEFs must be systematically monitored for bird fatalities alongside the turbines (Jenkins et al. 2015) and fatality rates (birds killed per kilometre of line) be included in the avian monitoring report.



AFRIAVIAN

RIGHT An in-line strain pole at a WEF, highlighting multiple risks of potential bird electrocution.

CHALLENGES WITH OPERATIONAL-PHASE MONITORING

A number of challenges to operational-phase monitoring were noted while preparing this report and these are discussed below. Some of these issues were explicitly highlighted in the monitoring reports, while others have been inferred from the review of the reports.

Time to start monitoring

The Best Practice Guidelines recommend that post-construction monitoring should start on or soon after the Commercial Operation Date (COD) (Jenkins et al. 2015). While some WEFs did initiate monitoring close to this deadline, others reported significant delays in initiating monitoring. The average time between COD and monitoring was five months. In an extreme example, two WEFs had not started monitoring more than 17 months after COD. These sites reportedly had experienced challenges with appointing suitable local service providers. Other WEFs reportedly needed to resolve access challenges with the landowner(s).

Recommendations:

- Landowner agreements should include provision for monitors to access the site for monitoring.
- WEFs should be proactive and engage with and support potential service providers before and during construction. If they are unable to secure suitable local staff, WEFs may need to revisit their commitments to employ local staff.

Survey area

Carcass search areas were sometimes smaller than recommended in the Best Practice Guidelines (Jenkins et al. 2015). Reasons for these included areas being inaccessible due to fences, agricultural crops and/or dense thicket. In one case, a decision to reduce the survey area was made by the bat specialist overseeing the monitoring. The rationale for this decision was based on the low number of bird fatalities, with no fatalities of threatened avifauna being documented in the first year of monitoring. It is not clear if the bat specialist consulted the pre-construction monitoring report, the EIA report for birds or an avifaunal specialist before making this decision, but this WEF has recorded fatalities of threatened species.

Recommendation:

- Any changes to the survey protocols should be supported by an avifaunal specialist, be based on the outcome of monitoring and predicted risk to birds and draw on all available information (including the pre-construction monitoring data).

HUMAN RESOURCES

Surveys were sometimes not conducted due to public holidays, training and other human resource issues (e.g. strikes, leave or termination). In some cases, specialist recommendations to expand monitoring to other infrastructure (i.e. powerlines) resulted in capacity being reallocated from turbine searches, compromising the robustness of the turbine surveys.

In other examples, after the initial two years of monitoring by contracted staff under the specialist's supervision, wind farms have opted to establish local companies to manage carcass search teams as part of their 'enterprise development' initiative. While this has provided valuable business opportunities for local staff, it has sometimes resulted in a decline in the quality of the work performed.

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Landowner agreements must grant monitors access to the WEF throughout its operational phase.

Recommendation:

- WEFs must ensure that they have the necessary capacity to meet monitoring requirements.
- Carcass surveys should always be overseen by a suitably qualified specialist. If the WEF is responsible for contracting and managing carcass survey teams, the WEF must play an active role in managing the team and ensure clear lines of communication between the specialist and monitors.

HEALTH AND SAFETY

The turbine carcass searches were at times interrupted due to health and safety concerns (e.g. inclement weather, snakes and turbine maintenance). The longest interruption was the national Covid-19 lockdown from 27 March to 22 May 2020.

Recommendations:

- Protocols must be in place prescribing when monitoring should be halted. These protocols must be communicated to the responsible bird specialist overseeing monitoring, so

that provision can be made to adjust survey methodologies, if necessary.
- Carcass survey teams must have appropriate Personal Protection Equipment (PPE).

LANDOWNERS CONCERNS AND FARMING PRACTICES

At some WEFs, landowners discouraged and even prevented carcass searchers from accessing their property to conduct surveys. Concern about impacts on crops and livestock (e.g. new-born lambs) limited access to some areas, and farming practices such as newly planted fields and spraying pesticides further restricted access. In addition, some landowners objected to the use of externally sourced carcasses for searcher efficiency and scavenger removal trials, due to concerns about biosafety. Access to control sites that had been monitored during the pre-construction period was also limited at times, due to disgruntled landowners.

Recommendations:
- WEFs must ensure that landowners understand the potential access requirements and impacts associated with monitoring throughout the lifespan of a project.
- Lease agreements must be detailed enough to ensure that the effectiveness of monitoring is not compromised.
- Any potential restrictions regarding land access must be discussed with the relevant bird specialist and reflected in the EIA, EMPr and monitoring reports.
- Agreements should be put in place to ensure access to control sites throughout the lifespan of a WEF.
- If access to control sites or certain parts of the WEF (including at different times of the year) is not possible, survey protocols should be adapted to compensate for this.


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EQUIPMENT FAILURE AND LACK OF SUITABLE EQUIPMENT

There were examples reported where carcass survey teams did not always have access to suitable equipment such as fridges, vehicles and cameras. One WEF reported that a freezer malfunction caused carcasses to defrost and decompose, creating challenges with the identification of species killed. Carcass surveys were also disrupted by frequent vehicle breakdowns as a result of mechanical wear and tear, especially on poorly maintained roads.

Recommendations:
- Survey teams must have all the equipment required to conduct surveys (e.g. vehicles, freezers, GPS and cameras); and
- Equipment must be regularly checked and there should be back-up plans in place in the event of equipment failure.

BIRD CARCASSES FOR BIAS TRIALS

Suitable bird carcasses, particularly raptors, were not always available for searcher efficiency and scavenger removal trials. As a result, estimates for fatality rates for species, or even groups, were often not provided.

Recommendations:
- Fatalities from operational turbines should be frozen on site and used for searcher efficiency and scavenger removal trials.
- Nearby WEFs could collaborate to share carcasses; and
- In the absence of suitable carcasses, literature on raptor persistence rates should be used when estimating fatality rates.

DATA CAPTURE AND REPORTING

Several monitoring reports highlighted poor record-keeping by the carcass survey team. GPS locations of carcasses were not always provided, and labels on specimens were sometimes illegible. At times, photo records of carcasses were either missing or of poor quality, making it challenging to identify species due to the state of the carcasses.

Recommendations:
- Clear data capture, reporting and back-up procedures must be put in place and overseen by a specialist and/or WEF responsible for managing the carcass survey team.
- A GPS or smartphone should be used to take coordinates of carcasses and downloaded and backed up at the end of each day.
- Several in situ photos should be taken to aid identification, preferably including the GPS with the coordinates of the location of the carcass visible; and
- Distance and direction from the nearest turbine should be noted.

DURATION OF MONITORING

Some EIAs and EAs included open-ended recommendations regarding the duration of operational-phase monitoring, with the assumption that EMPrs would be updated in response to new information, and that specialists could recommend extending monitoring if there were an increased risk of significant impacts. However, in some cases, recommendations by specialists to continue monitoring were ignored. For example, at one WEF in the Eastern Cape, monitoring was significantly delayed after the first year despite Cape Vultures passing through the site and despite the specialist's recommendation that monitoring be extended.

Recommendations:

- Plan for the worst. All WEFs should plan to monitor and report impacts on birds for the lifespan of the facility. It is safer to assume requirements in EMPrs will be amended to be less onerous, should data support this, than the other way around; and
- EMPrs should include a specific, measurable and time-bound framework for decision-making regarding the duration of monitoring, so that there is no question about when monitoring should be extended or curtailed.

RECOMMENDATIONS FOR ADDITIONAL RESEARCH

At times, specialists recommended additional research to improve the knowledge of the risk to certain species (e.g. Jackal Buzzard) or as part of an adaptive management strategy. These recommendations were not always implemented, although additional studies could have been valuable in determining the significance of potential cumulative impacts and need for further mitigation.

Recommendations:

- Wind farms should include a contingency budget for additional research.
- EMPrs should be clear on when additional research is required; and
- WEFs should consider collaborating with each other to unlock resources for research.

AVIFAUNAL SPECIALIST OVERSIGHT

Carcass survey teams were usually contracted directly by the WEF, leading to communication and reporting challenges with the avifaunal specialist overseeing the monitoring. In some cases, the specialist was unclear about the frequency of carcass searches or the areas of the wind farm being surveyed. Reporting of carcasses to specialists was slow at times and when the carcass survey team had limited species identification skills, impacts on threatened species took a long time to be reported. There were also examples where searcher efficiency trials were not conducted because there was no contract with a specialist in place at the time carcass surveys were conducted.

There were several examples where specialists recommended that monitoring continue beyond the minimum outlined in Best Practice (Jenkins et al. 2015). While this was usually implemented, there seems to be confusion about the need for a bird specialist to oversee monitoring and reporting, and about the need to submit the reports to DFFE, BirdLife South Africa and other stakeholders. There were instances where monitoring continued with little or no oversight by an independent avifaunal specialist. Some of these surveys were conducted by teams with no professional qualifications,

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Infrastructure associated with wind turbines, including powerlines and substations may also present risks to birds.

resulting in poorly designed survey protocols, inadequate species identification and limited analysis and interpretation of results. Some reports were authored by employees of the wind farm, with the specialist assigned 'inspector' status, but the influence of the specialist appeared to be limited.

Reporting on the implementation and effectiveness of operational-phase mitigation (adaptive management) was also limited or lacking in several cases.

Recommendations:

- If the WEF is responsible for contracting and managing carcass survey teams, the WEF must play an active role in managing the team and ensure clear lines of communication between the specialist and monitors.
- A log of carcass searches indicating the date and area searched must be maintained and made available for inspection during audits.
- If an avifaunal specialist recommends extending the duration of monitoring due to potential impacts on avifauna, the survey protocols and reporting must be overseen by a qualified and independent avifaunal specialist. This will help ensure that data collection is appropriate and properly interpreted.

CONCLUSION

To address the electricity supply crisis and achieve South Africa's Nationally Determined Contribution (NDC) targets and decarbonisation goals, the Just Energy Transition Implementation Plan 2023–2027 estimates that approximately six gigawatts of new renewable electricity capacity must be added to the grid annually. While this expansion promises numerous positive environmental impacts, it also poses growing risks of cumulative negative impacts on birds.

EIAs draw on existing baseline information together with surveys that, at best, provide a snapshot of the environmental conditions likely to be encountered at proposed wind energy development sites. It is therefore crucial that the predictions and recommendations made in an EIA are tested through monitoring and adaptive management at operational WEFs.

This report, based on data obtained from operational WEFs, supplements existing baseline information. It provides a high-level summary of bird species at risk of fatalities at WEFs and highlights risks to some species that were overlooked in early EIAs. Species at risk are, however, likely to change as wind energy expands into new parts of the country.

Fatalities of SCC are not limited to a few problem WEFs – 80% of WEFs in this review reported at least one SCC fatality. Rather, impacts on SCC should be expected and planned for, even after avoidance and mitigation measures have been implemented. Wind farms are therefore encouraged to consider proactive mitigation and conservation measures to compensate for unavoidable losses.

Potential risk factors, such as weather, breeding season and proximity to breeding sites, were noted, but many of these require further investigation and research.

The minimum expected fatality rates for SCC presented must be interpreted with extreme caution due to data limitations, most notably as they do not take into account searcher efficiency or scavenger removal. However, they do provide a crude benchmark and a starting point for assessing cumulative impacts. These data suggest that, for some species, the cumulative fatality rates may already be at unsustainable levels. For most species, more research is needed to robustly assess the cumulative effects, compare impacts with other anthropogenic threats, including powerlines, poisoning and habitat loss, and provide metrics for potential biodiversity offsets.

Impact assessments tend to focus on avoiding and mitigating impacts on SCC, particularly raptors. However, the wide diversity of species killed is a reminder that risks to smaller species, ecosystems and ecosystem services should not be overlooked.

The risks that WEFs pose to birds can change during the lifespan of a wind farm and even between the time of the EIA and construction. These changes may be because of fluctuations in species conservation status, occupancy and/or abundance. Species distribution ranges may also shift in response to environmental changes as they adapt to new conditions. To meet environmental sustainability objectives, WEFs may need to respond to these changes. Creative ways need to be found and budgets set aside to manage unexpected challenges. Operational measures like shutdown on demand and blade patterning are promising mitigation strategies, but require further research, auditing and oversight to ensure that they are effectively implemented.

This report primarily focuses on the direct impact of mortality resulting from collisions with wind turbines and, to a lesser extent, associated powerlines. These impacts are widely recognised and studied outside of this continent. Indirect impacts, such as displacement and the potential alteration of habitats associated with wind farm development affecting ecological processes (e.g. predator–prey interactions) (Bennun et al. 2021), have received less attention. There is a need for more research in this area, particularly for range-restricted endemic species.

While wind power is crucial for transitioning to renewable energy and mitigating climate change, it is equally important to balance this need with the conservation of South Africa's diverse avifauna. To effectively quantify and address potential population-level impacts of wind energy on birds, ongoing monitoring, mitigation, data sharing, and more robust research are essential to ensure this balance is achieved.

Acronyms

BMP	Biodiversity Management Plan
CMS	Convention on Migratory Species
COD	Commercial Operation Date
CITES	The Convention on International Trade in Endangered Species of Wild Fauna and Flora
DFFE	Department of Forestry, Fisheries and the Environment
EA	Environmental Authorisation
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme
GPS	Global Positioning SystemIUCN - International Union for Conservation of Nature.
IUCN	International Union for Conservation of Nature
OLSDOD	Observer-led Shutdown on Demand
PBR	Potential Biological Removal
SABAP2	Southern African Bird Atlas Project 2
SCC	Species of Conservation Concern
SDOD	Shutdown on Demand
VFM	Vulture Food Management
WEF	Wind Energy Facility

Glossary

BEST PRACTICE GUIDELINES	Best practice guidelines for avian monitoring and impact mitigation at proposed wind energy development sites in southern Africa (Jenkins et al. 2015, or previous versions thereof).
BIODIVERSITY MANAGEMENT PLAN	A Biodiversity Management Plan that is adopted in terms of the National Biodiversity Management Act (Act No. 10 of 2004) which provides for the long-term survival of a species in the wild and a platform for an implementing organisation or responsible entity, as appointed by the Minister, to monitor and report on the progress regarding the implementation of the plan. A Biodiversity Management Plan may also refer to a plan developed for a project (e.g. wind energy facility), and outlines the project's strategy for managing biodiversity-related risks and achieving net gains for biodiversity.
CITES	The Convention on International Trade in Endangered Species of Wild Fauna and Flora is an international agreement between governments. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival.
CRITICAL BIODIVERSITY AREA	Areas required to meet biodiversity targets for ecosystems, species and ecological processes, as identified in a systematic biodiversity plan.
CUMULATIVE IMPACTS	Combined effects of a project when considered alongside other existing, planned, or anticipated future projects, and pressures.
ENVIRONMENTAL IMPACT ASSESSMENT	A process of identifying, assessing and reporting environmental impacts associated with an activity. Here it includes basic assessments and scoping and environmental impact reporting.
ENVIRONMENTAL MANAGEMENT PROGRAMME	A report contemplated in subsection 24N of the National Environmental Management Act (107 of 1998, as amended), containing information on any proposed management, mitigation, protection or remedial measures that will be undertaken to address the environmental impacts that have been identified in a report contemplated in the EIA report. The holder of an environmental authorisation must manage all environmental impacts in accordance with his or her approved environmental management programme, where appropriate; and must monitor and audit compliance with the requirements of the environmental management programme.

IUCN RED LIST STATUS	Species listed according to the IUCN Red List Categories and Criteria. The IUCN Red List Categories and Criteria provide a system for classifying species at high risk of global extinction, so as to focus attention on conservation measures designed to protect them. Red List statuses are assessed at a global and regional (or national) scale.
LIVESTOCK CARCASS MANAGEMENT	Also known as Vulture Food Management, it involves a dedicated team of staff who patrol a wind farm site and remove any dead animals, with the aim of reducing the attraction of the site to vultures and other scavenging birds, thus minimising the risk of turbine collisions.
MIGRATORY SPECIES	Species which have a significant proportion of the population, or geographically separate parts of the population, that move cyclically and predictably from one seasonal range to another. This includes species that cross one or more national jurisdictional boundaries and those that are listed under the Convention on the Conservation of Migratory Species of Wild Animals (CMS) or the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA).
MITIGATION	Measures taken to predict and prevent, then minimise, restore or repair negative impacts associated with an activity.
NATIONAL SCREENING TOOL	The National Web-based Environmental Screening Tool, a geographically-based online resource that supports the pre-screening for environmental sensitivities in the landscape before an application for environmental authorisation is submitted. This tool, developed by the DFFE, generates a Screening Report, as referred to in Regulation 16(1)(v) of the Environmental Impact Assessment Regulations 2014 (as amended), which is required to accompany any application for Environmental Authorisation.
PENTAD	In the context of SABAP2, a pentad is a spatial unit measuring five minutes of latitude by five minutes of longitude (covering about 9 km north-south and 7 km east-west in South Africa.
POTENTIAL BIOLOGICAL REMOVAL	A simple test that uses species-specific biological and demographic parameters, specifically adult survival rate and year of first breeding, to calculate an anthropogenically driven increase in annual rate mortality that would likely enable that population to reach or maintain its optimum sustainable population.
REGIONAL POPULATION	For the purposes of this report, the regional population refers to the population in South Africa, Lesotho and Eswatini.
SHUTDOWN ON DEMAND	The practice of temporarily stopping the operation of wind turbines under specific conditions to minimise their negative impacts. This can be observer- or technology-led.
SPECIALIST	In the context of these guidelines, a specialist is an expert in the field of ornithology, responsible for the oversight of avifaunal impact assessment and monitoring. Also known as a bird specialist or an avifaunal specialist.
SOUTHERN AFRICAN BIRD ATLAS PROJECT 2	A citizen science project where volunteers help map bird distributions across several southern African countries. Data are collected at the 'pentad' scale. See https://sabap2.birdmap.africa for more information.
SPECIES OF CONSERVATION CONCERN	Species that are assessed according to the IUCN Red List Criteria as Near Threatened (NT), Vulnerable (V), Endangered (EN), or Critically Endangered (CR). This includes range-restricted species nationally listed as Rare.
THREATENED SPECIES	Species that are facing a high risk of extinction, i.e. any species classified as Critically Endangered, Endangered or Vulnerable, using the IUCN categories. In relation to section 56(1) of the Environmental Management: Biodiversity Act (No.10 of 2004), 'threatened species' means indigenous species listed under the Act as critically endangered, endangered or vulnerable.
TURBINE YEAR	The number of turbines multiplied by the number of years that carcass searches were conducted at those turbines. For example, a WEF with 47 turbines, where all turbines were subject to operational-phase monitoring for one year, would equal 47 turbine-years. Please refer to the limitations section for assumptions made.
UNADJUSTED FATALITY RATE	The number of carcasses found beneath turbines, expressed annually either per turbine or per megawatt (MW). These figures have not been adjusted to account for carcasses not found.

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Annexure 1 BIRD MONITORING REPORTS USED IN THIS REVIEW

PROJECTS NAME	OPERATIONAL-PHASE MONITORING REPORTS USE IN THE STUDY
Amakhala Emoyeni Wind Farm	Smallie and MacEwan. 2017. Amakhala Emoyeni Wind Farm (AE01) Eastern Cape Operational-phase bird and bat monitoring programme. Year 1, final report. For Amakhala Emoyeni RE Project 1 RF (Pty) Ltd (AEO1). Smallie and MacEwan. 2018. Amakhala Emoyeni Wind Farm (AE01) Eastern Cape Operational-phase bird and bat monitoring programme. Year 2, final report, December 2018. Smallie and MacEwan. 2019. Amakhala Emoyeni Wind Farm (AE01) Eastern Cape Operational-phase bird and bat Monitoring programme. Year 3, final report, November 2019. Unknown. 2020. Semi-annual review of Bird and Bat Monitoring and Impact Mitigation Measures. Reporting period from 7 October 2019 to 20 March 2020. Date 12 May 2020. Unknown. 2021. Amakhala Emoyeni Semi-annual review of Bird and Bat Monitoring and Impact Mitigation Measures. Reporting period from 7 October 2019 to 2 October 2020. Version: final. Date 31 March 2021. Unknown. 2021. Amakhala Emoyeni Semi-annual review of Bird and Bat Monitoring and Impact Mitigation Measures. Reporting period from 5 October 2020 to 15 May 2021. Version: draft 1. Date 9 June 2021. Unknown. 2022. Amakhala Emoyeni Semi-annual review of Bird and Bat Monitoring and Impact Mitigation Measures. Reporting period from 16 May to 1 October 2021. Version: draft 1. Date 13 January 2022. Unknown. 2022. Amakhala Emoyeni Semi-Annual Review of Bird and Bat Monitoring and Impact Mitigation Measures. Reporting period from 4 October 2021 to 27 May 2022. Date 22 July 2022. Unknown. 2023. Semi-annual review of Bird and Bat Monitoring and Impact Mitigation. Period from 30 May to 30 September 2022. Date 13 February 2023. Unknown. 2023. Amakhala Emoyeni Wind Farm Semi-annual Review of Bird and Bat Monitoring and Impact Mitigation Measures. Reporting period from 1 October 2022 to 19 May 2023. Version: final. Date 10 July 2023.
Chaba	WildSkies Ecological Services and Inkululeko Wildlife Services. 2017. Chaba Wind Farm, Eastern Cape. Post-construction Bird and Bat Monitoring programme. Year 1, final report. March 2017. CES Environmental and Social Advisory Services. 2022. Chaba Wind Farm. Year 5. Operational-phase Bird Monitoring Progress Report (Q1).
Cookhouse	Inkululeko Wildlife Services and WildSkies Ecological Services. 2016. Cookhouse Wind Farm Operational Bird and Bat Monitoring. Year 1, final report, May 2016.
Copperton	Copperton Wind Farm (Pty) Ltd. Post-construction monitoring of avifauna and bats. Copperton, Northern Cape Province, South Africa. Annual Report #1, 2022–2023. Enviro-Insight CC in collaboration with Terramanzi Group (Pty) Ltd. 20 May 2023.
De Aar 1	Chris van Rooyen Consulting. Undated. Avifaunal operational monitoring at the De Aar 1 Wind Farm. Year 1. Chris van Rooyen Consulting. 2020. Avifaunal operational monitoring at the De Aar 1 Wind Farm. Year 2. April 2020. Chris van Rooyen Consulting. 2021. Avifaunal operational monitoring at the De Aar 1 Wind Farm. Year 3. April 2021. Chris van Rooyen Consulting. 2023. Avifaunal operational monitoring at the De Aar 1 Wind Farm. Year 4. Chris van Rooyen Consulting. 2023. Longyuan Mulilo De Aar 1 Wind Power Facility (Da1). Year 5. Avifaunal Summary Report, January–December 2022.
De Aar 2	Chris van Rooyen Consulting. Undated. Avifaunal operational monitoring at the De Aar 2 North Wind Farm. Year 1 Chris van Rooyen Consulting. Undated. Avifaunal operational monitoring at the De Aar 2 North Wind Farm. Year 2 Chris van Rooyen Consulting. Undated. Avifaunal operational monitoring at the De Aar 2 North Wind Farm. Year 3 Chris van Rooyen Consulting. 2022. Avifaunal operational monitoring at the De Aar 2 North Wind Farm. Year 4. April 2022. Chris van Rooyen Consulting. 2023. Longyuan Mulilo De Aar 2 North Wind Power Facility (Da2n). Year 5. Avifaunal Summary Report, January–December 2022. Chris van Rooyen Consulting. Undated. Longyuan Mulilo De Aar 2 North Wind Power Facility (Da2n). Year 5. Avifaunal Summary Report.
Dorper	Smallie J, MacEwan K. 2015. Dorper Wind Farm, Molteno, Eastern Cape. Post-construction bird and bat monitoring programme. Year 1, final report, September 2015. Smallie J, MacEwan K. 2016. Dorper Wind Farm, Molteno, Eastern Cape. Post-construction bird and bat monitoring programme. Year 2, final report, October 2016. Smallie J, MacEwan K. 2020. Dorper Wind Farm, Molteno, Eastern Cape. Operational bird and bat monitoring programme. Year 5, final report, March 2020.
Excelsior	Chris van Rooyen Consulting. 2022. Avifaunal operational monitoring at the Excelsior Wind Farm. Year 1, August 2022. Chris van Rooyen Consulting. 2022. Progress Report 1, Operational-phase Monitoring of Birds at the Excelsior Wind Energy Facility. Year 2, December 2021 to August 2022.
Garob	Arcus. 2023. Technical Note 1: Sensitive Species Fatality at Garob Wind Farm. 13 June 2023.
Gibson Bay	Smallie J, MacEwan K. 2018. Gibson Bay Wind Farm, Eastern Cape. Operational-phase bird and bat monitoring programme. Year 1, final report, July 2018. Jon Smallie & Kate MacEwan, WildSkies Ecological Services and Inkululeko Wildlife Services. Inkululeko Wildlife Services and Wildskies. 2019. Gibson Bay Wind Farm. Bird and Bat Operational Monitoring Report. Year 2, October 2019. Inkululeko Wildlife Services and Wildskies. 2020. Gibson Bay Wind Farm. Bird and Bat Operational Monitoring Report. Year 3, December 2020. Lötter CA, Smallie JJ. 2022. Gibson Bay Wind Farm. Bird and Bat Operational Monitoring Report. Year 4. Unpublished report submitted to Gibson Bay Wind Farm. Lötter CA, Smallie JJ. 2022. Gibson Bay Wind Farm Biodiversity Management Plan. Unpublished report submitted to Gibson Bay Wind Farm. Inkululeko Wildlife Services and Wildskies. 2023. Gibson Bay Wind Farm. Operational Bird and Bat Monitoring. Year 5, progress report 1, April 2023.

PROJECTS NAME	OPERATIONAL-PHASE MONITORING REPORTS USE IN THE STUDY
Golden Valley	WildSkies Ecological Services. 2022. Golden Valley Wind Energy Facility. Operational bird monitoring. Progress report 1. WildSkies Ecological Services. 2022. Golden Valley Wind Energy Facility. Operational bird monitoring. Progress reports 2 and 3, 6 September 2022.
Gouda	Arcus. 2017. Operational Bat and Bird Monitoring. Gouda Wind Farm. Final report on behalf of Savannah Environmental for Blue Falcon 140 (Rf) Pty Ltd. 30 June 2017. Arcus. 2019. Post-construction Bat and Bird Monitoring. Gouda Wind Energy Facility. Year 2, final report, on behalf of Savannah Environmental for Blue Falcon 140 (Rf) Pty Ltd. May 2019. Arcus. 2020. Post-construction Bat and Bird Monitoring. Years One to Three. Gouda Wind Energy Facility. Final report on behalf of Savannah Environmental (Pty) Ltd for Blue Falcon 140 (Rf) Pty Ltd. August 2020.
Grassridge	Smallie J, MacEwan K. 2016. Grassridge Wind Farm, Eastern Cape. Post-construction bird and bat monitoring programme. Year 1, final report, September 2016. Smallie J, MacEwan K. 2017. Grassridge Wind Farm, Eastern Cape. Post-construction bird and bat monitoring programme. Year 2, final report, September 2017. CES Environmental and Social Advisory Services. May 2022. Progress report (Q1), Grassridge Wind Farm, Eastern Cape Province, May 2022. Grassridge Wind Farm, year 5, operational-phase bird monitoring.
Hopefield (Umoya)	Arcus Consultancy Services. 2016. Operational bird and bat monitoring. Hopefield Wind Energy Facility, Western Cape. Final progress report. On behalf of Umoya Energy (RF) (Pty) Ltd. April 2016.
Jeffreys Bay	Inkululeko Wildlife Services and Wildskies. 2015. Jeffreys Bay Wind Farm. Operational bird and bat monitoring. Year 1, final report, September 2015. Inkululeko Wildlife Services and Wildskies. 2016. Jeffreys Bay Wind Farm. Bird and bat operational monitoring. Year 2, report, August 2016. MacEwan K, Smallie J. 2018. Jeffreys Bay Wind Farm. Bird and bat operational monitoring. Year 3 report. MacEwan K, Smallie, J. 2018. Jeffreys Bay Wind Farm. Bird and bat operational monitoring. Year 4 report. Birds and Bats Unlimited. 2018. Raptors and wind farms: Fatalities, behaviour and mitigations for the Jeffreys Bay Wind Farm (2018 monitoring report No. 2). Birds and Bats Unlimited, South Africa. MacEwan K, Smallie J, Morgan, T. 2020. Bird and bat operational monitoring. Year 5 report. Inkululeko Wildlife Services. Camissa Sustainability Consulting. 2021. Analysis of bat and bird fatality at Jeffreys Bay Wind Farm, Eastern Cape, South Africa. December 2021. Camissa Sustainability Consulting. 2022. Analysis of bat and bird fatality 2021 at Jeffreys Bay Wind Farm, Eastern Cape, South Africa. August 2022. Inkululeko Wildlife Services. 2022. Jeffreys Bay Wind Farm: Bird and bat operational monitoring report for 2022. Conservation Outcomes. 2022. Jeffreys Bay Wind Farm: Black Harrier net gain feasibility study. Inkululeko Wildlife Services. 2023. Jeffreys Bay Wind Farm: bird and bat operational monitoring report for 2022. June 2023.
Kangnas	Chris van Rooyen Consulting. 2022. Avifaunal operational monitoring at the Kangnas Wind Farm. Year 1, July 2022. Chris van Rooyen Consulting. 2023. Kangnas Wind Energy Facility. Year 2, Avifaunal progress report 3. Q1–3. May 2022–January 2023.
Karusa	No reports available.
Khobab	Chris van Rooyen Consulting. 2020. Avifaunal operational monitoring at the Khobab Wind Farm. Years 1 and 2, August 2020.
Klipheuwel/Dassiesfontein (Dassieskilp)	Inkululeko Wildlife Services and Wildskies. 2016. Klipheuwel-Dassiefontein Wind Energy Facility. Bird and bat operational monitoring. Year 2 report. IWS Ref No. 2005. June 2016. Inkululeko Wildlife Services and Wildskies. 2017. Klipheuwel-Dassiefontein Wind Energy Facility. Bird and bat operational monitoring. Year 1. IWS Ref No. 2005. July 2015. Chris van Rooyen Consulting. 2017. Operational bird and bat fatality monitoring. Dassieklip Wind Energy Facility. Year 3, November 2017. Chris van Rooyen Consulting. 2018. Dassieklip Wind Energy Facility. Operational fatality monitoring. Year 3. Operational bird and bat fatality monitoring. Dassieklip Wind Energy Facility. Year 4, August 2018. Chris van Rooyen Consulting. 2019. Operational bird and bat fatality monitoring. Klipheuwel-Dassiefontein Wind Energy Facility. Year 5, September 2019.
Kouga	Wildskies. 2016. Kouga Wind Farm, Oyster Bay, Eastern Cape. Operational bird monitoring programme. Year 1, final report, May 2016. Submitted to Kouga Wind Farm (Pty) Ltd. Wildskies. 2017. Kouga Wind Farm, Oyster Bay, Eastern Cape. Operational bird monitoring programme. Year 2, final report, July 2017.
Loeriesfontein 2	Chris van Rooyen Consulting. 2019. Avifaunal operational monitoring at the Loeriesfontein 2 Wind Farm. Year 1, September 2019. Chris van Rooyen Consulting. 2020. Avifaunal operational monitoring at the Loeriesfontein 2 Wind Farm. Years 1 and 2.
Noblesfontein	Bioinsight. 2016. Noblesfontein Wind Farm. Bird operational monitoring. First year operational phase. Final monitoring report 2014/2015. Bioinsight. 2017. Noblesfontein Wind Farm. Bird operational monitoring. Second year operational phase. Final monitoring report 2015/2016. Bioinsight. 2017. Noblesfontein Wind Farm. Bird operational monitoring. Third year operational phase. Final monitoring report 2016/2017. Bioinsight. 2020. Noblesfontein Wind Farm. Bird operational monitoring. Fifth year operational phase. Final monitoring report 2016/2019. Bioinsight. 2020. Mitigation plan for Noblesfontein WEF.
Nojoli	WildSkies Ecological Services, Inkululeko Wildlife Services. 2018. Nojoli Wind Farm, Eastern Cape. Operational-phase bird and bat monitoring programme. Year 1, final report, August 2018. Inkululeko, Wildskies, Ecological Logistics. 2019. Nojoli Wind Farm. Bird and bat operational monitoring report. Year 2, October 2019. Inkululeko, Wildskies, Ecological Logistics. 2020. Nojoli Wind Farm. Bird and bat operational monitoring report. Year 3, December 2020. Inkululeko, Wildskies. 2022. Nojoli Wind Farm. Bird and bat operational monitoring report. Year 4, February 2022.

PROJECTS NAME	OPERATIONAL-PHASE MONITORING REPORTS USE IN THE STUDY
Noupoort	Chris van Rooyen Consulting. 2017. Noupoort avifaunal monitoring. Operational phase, year 1, October 2017. Chris van Rooyen Consulting. 2018, Noupoort avifaunal monitoring. Operational phase, year 2, October 2018. Chris van Rooyen Consulting. 2021. An assessment of the Verreaux's Eagle population and mortality at the Noupoort Wind Energy Facility. April 2021.
Nxuba	Arcus. 2022. Operational bat and bird monitoring for Nxuba Wind Farm. Year 1. Final report for Nxuba Wind Energy Facility (Pty) Ltd. October 2022. Arcus. 2022. Technical Note 3. Sensitive species fatality at Nxuba Wind Farm. 13 December.
Oyster Bay	Arcus. 2023. Operational bat and bird monitoring for Oyster Bay Wind Energy Facility. Year 1, progress report 2. May 2023.
Perdekraal East	Chris van Rooyen Consulting. 2022. Perdekraal East Wind Energy Facility. Avifaunal progress report 2, March–December 2022. Chris van Rooyen Consulting. 2022. Avifaunal operational monitoring at the Perdekraal East Wind Farm. Year 1, May 2022.
Roggeveld	Terramanzi. 2023. Site Operations Report, November 2022 to January 2023. Operations summary, January 2023. Terramanzi. 2023. Site Operations Report, January 2023 to March 2023. Operations summary, April 2023.
Sere	WildSkies Ecological Services. 2016. Sere Wind Farm, Western Cape. Operational bird monitoring programme. Year 1, final report, September 2016. WildSkies Ecological Services. 2017. Sere Wind Farm, Western Cape. Operational bird monitoring programme. Year 2, final report, August 2017.
Soetwater	No reports available.
Tsitsikamma Community Wind Farm	Chris van Rooyen Consulting. 2017. Avifaunal operational monitoring at the Tsitsikamma Community Wind Farm. Year 1, August 2017. Chris van Rooyen Consulting. 2018. Avifaunal operational monitoring at the Tsitsikamma Community Wind Farm. Year 2, September 2018. Chris van Rooyen Consulting. 2020. Avifaunal operational monitoring at the Tsitsikamma Community Wind Farm. Year 3, January 2020. Chris van Rooyen Consulting. 2021. Avifaunal operational monitoring at the Tsitsikamma Community Wind Farm. Year 4, April 2021. Chris van Rooyen Consulting. 2022. Tsitsikamma Wind Energy Facility. Year 6, avifaunal progress report 1, January–June 2022. Chris van Rooyen Consulting. 2022. Avifaunal operational monitoring at the Tsitsikamma Community Wind Farm. Year 5, March 2022.
Van Stadens	Martin P. 2014. Metrowind Wind Energy Facility, Van Stadens, Nelson Mandela Bay Municipality, Eastern Cape. One year of post-construction avifauna monitoring. April 2014; August 2014; December 2014; February/March 2015. Report for SRK Consulting, Port Elizabeth. Jordaan S. 2018. Bat activity and bird and bat fatality study at the Van Stadens Wind Energy Facility. Year 2, quarterly report 3, May 2018. Heshu A. 2021. Bat Activity and Bird and Bat Fatality Study And Activity at the Van Stadens Wind Energy Facility. Quarterly report (May–July), 29 July 2021. Heshu A. 2021. Bat Activity and Bird and Bat Fatality Study and Activity at the Van Stadens Wind Energy Facility. Quarterly report, 28 April 2021. Basandi K, Martin P. 2022. Bat Activity and Bird and Bat Fatality Study and Activity at the Van Stadens Wind Energy Facility. Quarterly report (March 2022–June 2022). Heshu A. 2022. Bat Activity and Bird and Bat Fatality Study And Activity at the Van Stadens Wind Energy Facility. Quarterly report (July 2022–September 2022), September 2022. Prepared by Khanyani Basandi; Bird and Bat Inspector Dr Anthony Paul Martin.
Waainek	Coastal and Environmental Services. Undated. Waainek Avifaunal Monitoring Report. Draft 12-month post-construction Avifaunal Report. Prepared for Waainek Wind Power (Pty) Ltd. Coastal and Environmental Services. 2018. Waainek Avifaunal Monitoring Report. 24-month post-construction Avifaunal Report. DEA Reference Number: 12/12/20/1697. Prepared for Waainek Wind Power (Pty) Ltd. Coastal and Environmental Services. 2022. Progress report (Q1) Waainek Wind Farm, Eastern Cape Province. May 2022. Waainek Wind Farm, Year 5 operational-phase bird monitoring.
Wesley–Ciskei	CES Environmental and Social Advisory Services. 2023. Year 1 final bird monitoring report. Wesley–Ciskei Wind Farm, Eastern Cape Province. April 2023.
West Coast One	Jenkins AR, du Plessis J, Millikin R, Benn G. 2017. West Coast One Wind Energy Facility. Post-construction avian impacts and mitigation study. Year 1, 2015–2016. Arcus Consultancy Services. 2019. Operational bat and bird monitoring. West Coast One Wind Farm. Final report on behalf of Aurora Wind Power (Rf) Pty Ltd, August 2019. Arcus Consultancy Services. 2021. Operational bat and bird monitoring. West Coast One Wind Farm. Final report on behalf of Aurora Wind Power (Rf) (Pty) Ltd, December 2021. Arcus Consultancy Services. 2022. Operational bat and bird monitoring at West Coast One Wind Farm, Western Cape. Final report, year 5 for Aurora Wind Power (Rf) (Pty) Ltd, August 2022.

Annexure 2 WIND ENERGY FACILITIES CONSIDERED IN THIS REVIEW

Projects name	COD	Total MW	Number of Turbines	MW per turbine	Hub Height	Rotor diameter
Amakhala-Emoyeni Wind Farm	Jul. 2016	134	56	2.4	91	117
Chaba	Sept. 15	21	7	3.0	84	112
Cookhouse	May.14	136.6	66	2.1	80	88
Copperton	Dec. 2021	102	34	3.15	100	125
De Aar 1	Nov 2017	100.5	67	1.5	80	86
De Aar 2	Nov 2017	140	96	1.5	80	86
Dorper	Aug. 2014	100	40	2.5	80	100
Excelsior	Dec. 2020	32	13	2.5	90	121
Garob	Dec. 2021	136	46	3.15	100	125
Gibson Bay	May 2017	111	37	3.0	90	119
Golden Valley	May 2021	117	48	2.5	90	121
Gouda	Sept. 2015	138	46	3.0	100	100
Grassridge	Jan. 2015	60	20	3.0	84	112
Hopefield	Feb. 2014	66.6	37	1.8	95	100
Jeffreys Bay	May 14	138	60	2.3	80	101
Kangnas	Nov. 2020	137	61	2.3	115	106
Karusa*	Jul. 2022	140	35	3.0	91.5	117
Khobab	Dec. 2017	140.3	61	2.3	99.5	106
Klipheuwel / Dassiesfontein	May 2014	30	9	3.3	90	113
Kouga	Mar. 2015	80	32	2.5	80	90
Loeriesfontein 2	Dec. 2017	140	61	2.3	99.5	106
Nobelsfontein	Jun. 2014	73.8	41	1.8	80	110
Nojoli	Oct. 2016	88	44	2.0	80	100
Noupoort	Jul. 2016	80.5	35	2.3	99.5	106
Nxuba	Dec. 2020	139	47	3.15	100	100
Oyster Bay	Jul. 2021	140	41	3.6	91.5	117
Perdekraal East	Oct. 2020	108	48	2.3	105	106
Roggeveld	Mar. 2022	147	47	3.0	100	123
Sere	Apr. 2015	100	46	2.3	115	110
Soetwater*	Jul. 2022	139	35	4.2	0	0
Tsitsikamma	Aug. 2016	95	31	3.1	100	112
Van Stadens	Feb. 2014	27	9	3.0	90	110
Waainek	Feb. 2016	24	8	3.0	84	112
Wesley-Ciskei	Aug. 2021	34.5	10	3.45	117	63
West Coast One	Jun. 2015	94	47	2.0	80	90

* No monitoring reports available, not included further.

Annexure 3 NUMBER AND LIKELY CAUSES OF BIRD FATALITIES REPORTED FROM WEFs

Red List status: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern.
Endemism: E = endemic to South Africa (RSA); SLS = endemic to South Africa, Lesotho and Eswatini; NE = near-endemic (i.e. ~70% or more of population in RSA)

Species	Scientific name	Red List (regional, global)	Endemism	Turbine	Powerline	Other	Total
Apalis, Yellow-breasted	*Apalis flavida*	-	-	1			1
Barbet, Acacia Pied	*Tricholaema leucomelas*	-	-	1			1
Barbet, Black-collared	*Lybius torquatus*	-	-	3			3
Batis, Chinspot	*Batis molitor*	-	-	1			1
Bishop, Southern Red	*Euplectes orix*	-	-	2			2
Bishop, Yellow	*Euplectes capensis*	-	-	11			11
Bokmakierie	*Telophorus zeylonus*	-	-	50			50
Budgerigar	*Melopsittacus undulatus*	-	-	1			1
Bulbul, Cape	*Pycnonotus capensis*	-	E	5			5
Bunting, Cape	*Emberiza capensis*	-	-	1			1
Bunting, Golden-breasted	*Emberiza flaviventris*	-	-	1			1
Bunting, Lark-like	*Emberiza impetuani*	-	-	8			8
Bustard, Denham's	*Neotis denhami*	VU, NT	-	3	4		7
Bustard, Ludwig's	*Neotis ludwigii*	EN, EN	-	6	3	1	10
Buttonquail, Common (Kurrichane)	*Turnix sylvaticus*	-	-	1			1
Buzzard sp.	-	-	-	2			2
Buzzard, Common (Steppe)	*Buteo buteo*	-	-	17		1	18
Buzzard, Forest	*Buteo trizonatus*	LC, NT	SLS	4			4
Buzzard, Jackal	*Buteo rufofuscus*	-	NE	146	6	1	153
Canary, Black-headed	*Serinus alario*	-	NE	2			2
Canary, Brimstone	*Crithagra sulphurata*	-	-	1		1	2
Canary, Cape	*Serinus canicollis*	-	-	20			20
Canary, Forest	*Crithagra scotops*	-	SLS	2			2
Canary, Yellow	*Crithagra flaviventris*	-	-	8			8
Canary, Yellow-fronted	*Crithagra mozambica*	-	-	2			2
Chat, Ant-eating	*Myrmecocichla formicivora*	-	-	3			3
Chat, Familiar	*Cercomela familiaris*	-	-	3			3
Chat, Karoo	*Cercomela schlegelii*	-	-	1			1
Chat, Mocking Cliff	*Thamnolaea cinnamomeiventris*	-	-	1			1
Chat, Sickle-winged	*Cercomela sinuata*	-	NE	1			1
Cisticola sp.	-	-	0	10			10
Cisticola, Cloud	*Cisticola textrix*	-	NE	3			3
Cisticola, Grey-backed	*Cisticola subruficapilla*	-	-	2			2
Cisticola, Lazy	*Cisticola aberrans*	-	-	1			1
Cisticola, Wing-snapping	*Cisticola ayresii*	-	-	2			2
Cisticola, Zitting	*Cisticola juncidis*	-	-	1			1
Coot, Red-knobbed	*Fulica cristata*	-	-	3	1		4
Cormorant sp.	-	-	-	2			2
Cormorant, Cape	*Phalacrocorax capensis*	EN, EN	-	1			1
Cormorant, Reed	*Phalacrocorax africanus*	-	-	8			8

Species	Scientific name	Red List (regional, global)	Endemism	Turbine	Powerline	Other	Total
Cormorant, White-breasted	*Phalacrocorax lucidus*	-	-	3			3
Coucal, Burchell's	*Centropus burchellii*	-	-	1			1
Courser, Burchell's	*Cursorius rufus*	VU, LC	-	2			2
Courser, Double-banded	*Rhinoptilus africanus*	-	-	1			1
Crane, Blue	*Anthropoides paradiseus*	NT, VU	-	18	5		23
Crow, Cape	*Corvus capensis*	-	-	7	4		11
Crow, Pied	*Corvus albus*	-	-	12	6	3	21
Cuckoo, Black	*Cuculus clamosus*	-	-	1			1
Cuckoo, Diederik	*Chrysococcyx caprius*	-	-	2			2
Cuckoo, Great Spotted	*Clamator glandarius*	-	-	1			1
Cuckoo, Jacobin	*Clamator jacobinus*	-	-	4			4
Dove sp.	-	-	-	6		1	7
Dove, Cape Turtle	*Streptopelia capicola*	-	-	20			20
Dove, Laughing	*Streptopelia senegalensis*	-	-	12			12
Dove, Namaqua	*Oena capensis*	-	-	2			2
Dove, Red-eyed	*Streptopelia semitorquata*	-	-	14		2	16
Dove, Rock	*Columba livia*	-	-	13		1	14
Drongo, Fork-tailed	*Dicrurus adsimilis*	-	-	4			4
Duck, sp		-	-	1			1
Duck, White-faced Whistling	*Dendrocygna viduata*	-	-	2		1	3
Duck, Yellow-billed	*Anas undulata*	-	-	15			15
Eagle, African Fish	*Haliaeetus vocifer*	-	-	3			3
Eagle, Black-chested Snake	*Circaetus pectoralis*	-	-	6			6
Eagle, Booted	*Hieraaetus pennatus*	-	-	29	1		30
Eagle, Long-crested	*Lophaetus occipitalis*	-	-	6			6
Eagle, Martial	*Polemaetus bellicosus*	EN, EN	-	12	4	1	17
Eagle, Tawny	*Aquila rapax*	EN, VU	-	2			2
Eagle, Verreaux's	*Aquila verreauxii*	VU, LC	-	33	13		46
Egret, Western Cattle	*Bubulcus ibis*	-	-	19		1	20
Egret, Yellow-billed	*Egretta intermedia*	-	-	4			4
Falcon, Amur	*Falco amurensis*	-	-	64			64
Falcon, Lanner	*Falco biarmicus*	VU, LC	-	12	1	1	14
Falcon, Peregrine	*Falco peregrinus*	-	-	6			6
Finch, Red-headed	*Amadina erythrocephala*	-	-	1			1
Fiscal, Southern (Common)	*Lanius collaris*	-	-	9		2	11
Flamingo, Greater	*Phoenicopterus roseus*	NT, LC	-	1			1
Flufftail, Buff-spotted	*Sarothrura elegans*	-	-	7			7
Flufftail, Red-chested	*Sarothrura rufa*	-	-	5			5
Flufftail, Striped	*Sarothrura affinis*	VU, LC	-	1			1
Flycatcher, African Dusky	*Muscicapa adusta*	-	-	2			2
Flycatcher, African Paradise	*Terpsiphone viridis*	-	-	2			2
Flycatcher, Blue-mantled Crested	*Trochocercus cyanomelas*	-	-	3			3
Flycatcher, Fiscal	*Sigelus silens*	-	NE			1	1
Francolin, Grey-winged	*Scleroptila afra*	-	SLS	3	1		4
Francolin, Red-winged	*Scleroptila levaillantii*	-	-	1			1

Species	Scientific name	Red List (regional, global)	Endemism	Turbine	Powerline	Other	Total
Goose, Egyptian	*Alopochen aegyptiaca*	-	-	33	11	3	47
Goose, Spur-winged	*Plectropterus gambensis*	-	-	10	2		12
Goshawk, African	*Accipiter tachiro*	-	-	3			3
Goshawk, Pale Chanting	*Melierax canorus*	-	-	15	8		23
Grebe, Black-necked	*Podiceps nigricollis*	-	-	2			2
Grebe, Little	*Tachybaptus ruficollis*	-	-	3			3
Greenbul, Sombre	*Andropadus importunus*	-	-	3			3
Guineafowl sp.	-	-	-	1			1
Guineafowl, Helmeted	*Numida meleagris*	-	-	11	1	5	17
Gull sp.	-	-	-	2			2
Gull, Kelp	*Larus dominicanus*	-	-	3			3
Harrier, Black	*Circus maurus*	EN, EN	NE	10		2	12
Hawk, African Harrier-	*Polyboroides typus*	-	-	13			13
Heron sp	-	-	-	1			1
Heron, Black-headed	*Ardea melanocephala*	-	-	2	1		3
Honeyguide, Lesser	*Indicator minor*	-	-	1			1
Ibis, African Sacred	*Threskiornis aethiopicus*	-	-	13	1	1	15
Ibis, Hadeda	*Bostrychia hagedash*	-	-	6	1	1	8
Kestrel sp.	-	-	-	2			2
Kestrel, Greater	*Falco rupicoloides*	-	-	20			20
Kestrel, Lesser	*Falco naumanni*	-	-	7			7
Kestrel, Rock	*Falco rupicolus*	-	-	77			77
Kingfisher, Brown-hooded	*Halcyon albiventris*	-	-	2			2
Kingfisher, Pied	*Ceryle rudis*	-	-	2			2
Kite, Black	*Milvus migrans*	-	-	1			1
Kite, Black-winged	*Elanus caeruleus*	-	-	27			27
Kite, Yellow-billed	*Milvus aegyptius*	-	-	10			10
Korhaan sp.	-	-	-	1			1
Korhaan, Blue	*Eupodotis caerulescens*	LC, NT	SLS	2			2
Korhaan, Karoo	*Eupodotis vigorsii*	NT, LC	-	3	1		4
Korhaan, Northern Black	*Afrotis afraoides*	-	-	2	1		3
Korhaan, Southern Black	*Afrotis afra*	VU, VU	E	5			5
Lapwing sp.	-	-	-	1			1
Lapwing, Black-winged	*Vanellus melanopterus*	-	-	3			3
Lapwing, Blacksmith	*Vanellus armatus*	-	-	1			1
Lapwing, Crowned	*Vanellus coronatus*	-	-	46			46
Lark sp.	-	-	-	4			4
Lark, Agulhas Long-billed	*Certhilauda brevirostris*	NT, NR	E	1			1
Lark, Cape Clapper	*Mirafra apiata*	-	NE	1			1
Lark, Cape Long-billed	*Certhilauda curvirostris*	-	E	1			1
Lark, Eastern Clapper	*Mirafra fasciolata*	-	-	5	1		6
Lark, Karoo Long-billed	*Certhilauda subcoronata*	-	-	1			1
Lark, Large-billed	*Galerida magnirostris*	-	NE	12		1	13
Lark, Red-capped	*Calandrella cinerea*	-	-	68			68
Lark, Rufous-naped	*Mirafra africana*	-	-	3			3

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Lark, Sabota	*Calendulauda sabota*	-	-	5	1		6
Lark, Spike-heeled	*Chersomanes albofasciata*	-	-	8			8
Lark, Stark's	*Spizocorys starki*	-	-	1			1
Longclaw, Cape	*Macronyx capensis*	-	-	8			8
Martin, Rock	*Hirundo fuligula*	-	-	2			2
Moorhen, Common	*Gallinula chloropus*	-	-	1			1
Mousebird, Red-faced	*Urocolius indicus*	-	-	2			2
Mousebird, Speckled	*Colius striatus*	-	-	6			6
Mousebird, White-backed	*Colius colius*	-	-	1			1
Neddicky	*Cisticola fulvicapilla*	-	-	5			5
Nightjar, Fiery-necked	*Caprimulgus pectoralis*	-	-	9			9
Osprey	*Pandion haliaetus*	-	-	1			1
Owl, Cape Eagle-	*Bubo capensis*	-	-		2		2
Owl, Spotted Eagle-	*Bubo africanus*	-	-	18	2		20
Owl, Western Barn	*Tyto alba*	-	-	22	1		23
Pigeon, African Olive	*Columba arquatrix*	-	-	10			10
Pigeon, feral	-	-	-	2			2
Pigeon, Speckled	*Columba guinea*	-	-	44	1	7	52
Pipit sp.	-	-	-	5			5
Pipit, African	*Anthus cinnamomeus*	-	-	41			41
Pipit, Buffy	*Anthus vaalensis*	-	-	1			1
Pipit, Plain-backed	*Anthus leucophrys*	-	-	8			8
Plover, Kittlitz's	*Charadrius pecuarius*	-	-	3			3
Pochard, Southern	*Netta erythrophthalma*	-	-	1			1
Quail, Common	*Coturnix coturnix*	-	-	17	1	1	19
Quailfinch, African	*Ortygospiza fuscocrissa*	-	-	2			2
Quelea, Red-billed	*Quelea quelea*	-	-	2			2
Raven, White-necked	*Corvus albicollis*	-	-		3		3
Robin-chat, Cape	*Cossypha caffra*	-	-	6			6
Robin, Karoo Scrub	*Erythropygia coryphoeus*	-	-	3			3
Robin, White-browed Scrub	*Erythropygia leucophrys*	-	-	1			1
Roller, European	*Coracias garrulus*	NT, LC	-	1			1
Secretarybird	*Sagittarius serpentarius*	VU, EN	-	8			8
Sparrow sp.	-	-	-	3			3
Sparrow, Cape	*Passer melanurus*	-	-	45			45
Sparrow, House	*Passer domesticus*	-	-	14		2	16
Sparrow, Southern Grey-headed	*Passer diffusus*	-	-	6			6
Sparrowhawk, Black	*Accipiter melanoleucus*	-	-	5			5
Sparrowhawk, Little	*Accipiter minullus*	-	-	1			1
Spoonbill, African	*Platalea alba*	-	-		1		1
Spurfowl, Cape	*Pternistis capensis*	-	NE	7		11	18
Spurfowl, Red-necked	*Pternistis afer*	-	-	4			4
Starling, Common	*Sturnus vulgaris*	-	-	12		2	14
Starling, Pied	*Lamprotornis bicolor*	-	SLS	7			7
Starling, Red-winged	*Onychognathus morio*	-	-	9		1	10

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Starling, Wattled	*Creatophora cinerea*	-	-	1			1
Stonechat, African	*Saxicola torquatus*	-	-	5			5
Stork, White	*Ciconia ciconia*	-	-	15			15
Sunbird, Amethyst	*Chalcomitra amethystina*	-	-	1			1
Sunbird, Malachite	*Nectarinia famosa*	-	-	7			7
Sunbird, Orange-breasted	*Anthobaphes violacea*	-	E	1			1
Sunbird, Southern Double-collared	*Cinnyris chalybeus*	-	NE	2			2
Swallow, Barn	*Hirundo rustica*	-	-	11			11
Swallow, Greater Striped	*Cecropis cucullata*	-	-	12			12
Swallow, Lesser Striped	*Cecropis abyssinica*	-	-	1			1
Swamphen, African (Purple)	*Porphyrio madagascariensis*	-	-	1			1
Swift sp.	-	-	-	88			88
Swift, African Black	*Apus barbatus*	-	-	14			14
Swift, Alpine	*Tachymarptis melba*	-	-	23			23
Swift, Common	*Apus apus*	-	-	49			49
Swift, Horus	*Apus horus*	-	-	6			6
Swift, Little	*Apus affinis*	-	-	60			60
Swift, White-rumped	*Apus caffer*	-	-	67			67
Teal, Red-billed	*Anas erythrorhyncha*	-	-	3		1	4
Tern, Common	*Sterna hirundo*	-	-	2			2
Tern, Swift	*Thalasseus bergii*	-	-	4			4
Tern, Whiskered	*Chlidonias hybrida*	-	-	1			1
Thick-knee, Spotted	*Burhinus capensis*	-	-	7			7
Thick-knee, Water	*Burhinus vermiculatus*	-	-	1			1
Tit-Babbler, Chestnut-vented	*Sylvia subcaerulea*	-	-	1			1
unknown	-	-	-	155	3	22	180
Unknown, Passerine	-	-	-	96		1	97
Unknown, Raptor	-	-	-	28			28
Unknown, waterbird	-	-	-	4		1	5
Vulture, Cape	*Gyps coprotheres*	EN, VU	-	41	4		45
Vulture, White-backed	*Gyps africanus*	CR, CR	-	6	1		7
Wagtail, Cape	*Motacilla capensis*	-	-	10		2	12
Warbler, African Reed	*Acrocephalus baeticatus*	-	-	1			1
Warbler, Dark-capped Yellow	*Iduna natalensis*	-	-	1			1
Warbler, Lesser Swamp	*Acrocephalus gracilirostris*	-	-	2			2
Warbler, Marsh	*Acrocephalus palustris*	-	-	2			2
Warbler, Rufous-eared	*Malcorus pectoralis*	-	-	4			4
Waxbill, Common	*Estrilda astrild*	-	-	1			1
Weaver, Cape	*Ploceus capensis*	-	NE	5			5
Weaver, Sociable	*Philetairus socius*	-	-	2			2
Weaver, Southern Masked	*Ploceus velatus*	-	-	2			2
Wheatear, Mountain	*Oenanthe monticola*	-	-	2			2
White-eye, Cape	*Zosterops virens*	-	NE	9			9
Whydah, Pin-tailed	*Vidua macroura*	-	-	1			1

BirdLife South Africa is a registered non-profit, non-governmental organisation (NGO) that works to conserve wild birds, their habitats and wider biodiversity in South Africa, through research, monitoring, lobbying, conservation and awareness-raising actions. It was formed in 1996 when the South African Ornithological Society became a country partner of BirdLife International.

BirdLife SOUTH AFRICA
Giving Conservation Wings

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