SHUTDOWN ON DEMAND

for the mitigation of bird collision risk at onshore wind farms in South Africa

2025

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WildSkies ecological services · BirdLife South Africa Giving Conservation Wings · AfriAvian Environmental

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Cover image: © ENGIE
An Engie employee scans the airspace of Excelsior Wind Farm for target bird species entering the collision risk sphere, recording metrics such as the time taken to shut down the relevant turbine(s), total shutdown time, and the species and number of individuals involved.

BirdLife SOUTH AFRICA
Giving Conservation Wings

Technical Report by BirdLife South Africa

Shutdown on Demand for the mitigation of bird collision risk at onshore wind farms in 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.

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Disclaimer
The authors of this Shutdown on Demand (SDoD) handbook are specialist avifaunal consultants who have been involved with the impacts of wind energy development on birds since the industry commenced in South Africa. The authors have attempted to present all information contained in this document from an independent and impartial perspective, considering the implications of the various operational mitigation strategies proposed for each affected party and have engaged with wind farm stakeholders, financiers, non-governmental organisations (NGOs), SDoD service providers, SDoD field observers, government representatives and local and international spokespeople.

Rapid technological advancements in the field of SDoD research and development may necessitate regular revisions of this handbook, particularly for automated SDoD systems for which external validation is largely still pending. In the interests of brevity, only fully-fledged automated SDoD systems for onshore wind farms are discussed, omitting systems not yet commercially available, those exclusive to offshore wind farms, or systems used simply for bio-monitoring.

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Foreword

BirdLife South Africa, the only dedicated, nationwide, bird-conservation organisation in South Africa, recognises the value of renewable energy to help address the global climate crisis and support South Africa's transition to a green economy. However, while renewable energy is relatively benign in environmental terms compared to conventional thermal generation, the technologies involved can have negative direct and indirect bird and biodiversity impacts through habitat loss, disturbance and displacement (solar and wind), turbine collision (wind) and electrocution and collisions (transmission and distribution).

Wind energy is of particular concern, given the potentially fatal impact of turbine blade collisions on vultures, raptors and other soaring birds; these long-lived species are often already threatened with extinction due to other anthropogenic pressures and may therefore be unable to sustain additional losses. BirdLife South Africa supports the use of practical measures that can help mitigate the risk of avifaunal turbine collision, with Shutdown on Demand offering particular promise.

This handbook is intended to identify best practice and facilitate the deployment of Shutdown on Demand methods at both new and existing wind energy facilities. Although focused on South Africa, the handbook draws on wider international experience and has the potential to be of value across the southern African region and beyond.

As part of BirdLife South Africa's long-term commitment to work with the wind energy sector for the benefit of bird species in South Africa, we are delighted to have commissioned this handbook with financial support from the Lewis Foundation. We would like to thank the team at WildSkies and AfriAvian for their efforts in compiling the handbook and to acknowledge the support of the numerous contributors who generously provided insight and advice.

It is envisaged that the handbook will be updated periodically as technology and methodologies evolve, providing a point of reference for the industry and facilitating the wider uptake of Shutdown on Demand by the wind power sector in coming years.

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Keywords

Shutdown on Demand
Collision Prevention
Wind Farm
Operational Mitigation
Adaptive Management
Mitigation Hierarchy
Turbine Shutdown
Impact Minimisation
Best Practice Guidelines
Avian Risk
Fatality Threshold
Target Bird Species
Species of Conservation Concern
Climate Change
Precautionary Principle

Glossary of terms and abbreviations

AI	Artificial Intelligence
ASDoD	Automated Shutdown on Demand
Avifaunal Specialist	SACNASP-registered scientist with sufficient expertise regarding relevant pre- and post-construction avifaunal monitoring, EIA processes and SDoD Programmes
BACI	Before-After Control-Impact
BAP	Biodiversity Action Plan
BMP	Biodiversity Management Plan
CBA	Critical Biodiversity Area
COD	Commercial Operations Date
DFFE	Department of Forestry, Fisheries and the Environment
EA	Environmental Authorisation
EAP	Environmental Assessment Practitioner
ED	Enterprise Development
EIA	Environmental Impact Assessment
EMPr	Environmental Management Plan or Programme
Endemic	Found nowhere else; restricted to one geographical area
ESMS	Environmental and Social Management System
False Positive	A turbine shutdown ordered unnecessarily when no avian risk was present
False Negative	A turbine shutdown not ordered when it was necessary
GIIP	Good International Industry Practice
GIS	Geographical Information System
GPHB	Good Practice Handbook
GPS	Global Positioning System
IFC	International Finance Corporation

IPP	Independent Power Producer
IT	Information Technology
IUCN	International Union for Conservation of Nature
JET IP	Just Energy Transition – Implementation Plan
KBA	Key Biodiversity Area
KPA	Key Performance Area
MW	Megawatt
NDP	National Development Plan
NERSA	National Energy Regulator of South Africa
NGO	Non-governmental Organisation
NMI	Near-Miss Incident. This occurs when a necessary order to shut down is either delayed or not issued by observers, or when an order is issued but not carried out by Supervisory Control and Data Acquisition (SCADA) operators
OHL	Overhead line
OHS	Occupational Health and Safety
OSDoD	Observer-led Shutdown on Demand
OP	Observation Point
PBR	Potential Biological Removal
PDP	Professional Driving Permit
PPA	Power Purchase Agreement
PPE	Personal Protective Equipment
PCFM	Post-Construction Fatality Monitoring
Priority bird species	A bird species identified by the wind farm's BMP to require mitigation. Note: not all priority bird species are target species
PVA	Population Viability Analysis
Red List	Species classified as Near-Threatened, Vulnerable, Endangered or Critically Endangered by the International Union for Conservation of Nature (IUCN)
REIPPPP	Renewable Energy Independent Power Producers Procurement Programme
RSZ	Rotor-Swept Zone
SAWEA	South African Wind Energy Association
SACNASP	South African Council for Natural Scientific Professions
SAQA	South African Qualifications Authority
SCADA	Supervisory Control and Data Acquisition
SDoD	Shutdown on Demand
SEA	Strategic Environmental Assessment
SED	Socio-Economic Development
SSV	Site Sensitivity Verification
Surveillance Area	The extent of airspace to be monitored by SDoD
Surveillance Period	The time period to be monitored by SDoD
Target bird species	Bird species which a wind farm's SDoD Programme has been designed to protect. These are usually, but not always, species of conservation concern

Shutdown on Demand for the mitigation of bird collision risk at onshore wind farms in South Africa

1. INTRODUCTION

The harnessing of wind energy is rapidly emerging as an alternative to the burning of fossil fuels in the South African energy sector and although the market is globally well established, the technology is relatively novel locally. Wind energy was first introduced to the country in 2002 with three small pilot turbines at the Western Cape's Klipheuwel Wind Farm (www.thewindpower.net). Currently, 1 411 wind turbines with a combined capacity of 3 426 MW are operational across 34 wind farms nationally (South African Wind Energy Association, SAWEA, August 2024). Procuring at least 20 000 MW of renewable energy by 2030 is a core objective of the National Development Plan 2030 (NDP, www.gov.za) on the pathway to achieving net-zero carbon emissions by 2050.

Wind energy affords substantial environmental advantages over the use of fossil fuels, although it also presents its own ecological challenges including, in particular, fatal turbine collision risk to birds. Demographic impacts imposed by wind turbines on birds have been noted both globally (Orloff and Flannery 1992; Hunt et al. 1998; Smallwood and Thelander 2005; Drewitt and Langston 2006; Sovacool 2009) and in South Africa (Ralston-Paton et al. 2017; Perold et al. 2020; Simmons and Martins 2024a), with many of the bird species most susceptible to turbine collision mortalities being those already at risk of extinction. Given that numerous new applications for wind farm authorisations are being processed by the Department of Forestry, Fisheries and the Environment (DFFE) each year, the interface between turbines and birds will continue to expand across the country for the foreseeable future. Consequently, both operational and prospective wind farms must mitigate against bird mortality impacts pre-emptively and adaptively in accordance with the National Environmental Management Act 107 of 1998 (NEMA, www.dffe.gov.za) 'Duty of Care' principle (Section 28), Environmental Impact Assessments (EIA), Environmental Management Programmes (EMPr), Environmental Authorisation (EA) conditions, Avifaunal Specialist recommendations, lender requirements, or simply the operator's commitment to sustainability.

Shutdown on Demand (SDoD) is a promising mitigative strategy involving the temporary shutdown of wind turbine operation to reduce the risk of bird–turbine collisions. Incoming priority birds are detected by human observers (Observer-led Shutdown on Demand or OSDoD) or by cameras and/or radar (Automated Shutdown on Demand or ASDoD). Turbines that have a high likelihood of causing bird fatalities are then shut down until the bird has departed the risk zone. As of mid-2024, OSDoD Programmes of varying duration have been established at five wind farms in South Africa: Dorper, Excelsior, Jeffreys Bay, Golden Valley and Roggeveld.

SECRETARYBIRD ALBERT FRONEMAN

While SDoD may prove effective from an avifaunal preservation perspective, start-up and operational expenses associated with this mitigation, as well as the ensuing revenue loss due to periodic interruptions in power production, present possible drawbacks for wind farm operators. For renewable energy solutions and bird conservation to co-exist sustainably, the strategies employed to protect birds must be informed, dynamic and, ultimately, cost-effective.

This handbook aims to guide practitioners on the implementation of effective SDoD at onshore wind farms in South Africa, with extended applicability to elsewhere in Africa and beyond. The intended audience of this handbook is Avifaunal Specialists, Environmental Assessment Practitioners (EAPs), government officials, wind farm developers and operators, and other industry stakeholders. To this end, the report considers available local and international SDoD research and experience in the context of South African wind farms and bird species. Interviews were conducted with representatives from local wind farms already employing SDoD to identify common challenges that arise in situ, as well as representatives of automated SDoD system suppliers to gain insights into the present capabilities of these technologies. A workshop with the South African target audience was also held to obtain collaborative input from across the intended readership of this handbook. To the authors' best knowledge, this handbook stands as the first of its kind for the African continent.

2. SHUTDOWN ON DEMAND: AN OVERVIEW

SDoD principally involves the complete, temporary shutdown of wind turbine rotors to minimise the risk of avian collision. SDoD Programmes are tailored to protect resident or migratory 'target' bird species which have been identified to be at collision risk at the wind farm. The list of target birds typically encompasses threatened species classified as Near-Threatened, Vulnerable, Endangered or Critically Endangered by the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (www.iucnredlist.org), or the Red Data Book of Birds of South Africa, Lesotho and Eswatini (Taylor et al, 2015; updated Lee et al, 2025). However, target bird species may also include any bird species with Least Concern status for which a wind farm presents a significant demographic concern or where the affected species provides valued ecosystem services locally.

Broadly, SDoD comprises two forms of turbine shutdown: predictive and responsive. Predictive approaches use theoretical or experiential knowledge of heightened collision-risk periods for target species at specified times of day or season, or under certain weather conditions, to implement turbine stoppage pre-emptively. Robust insight into a temporal window of elevated collision risk and near-term ecological forecasting is required (Bradarić et al. 2024). By contrast, responsive approaches involve wind turbine shutdown events in response to 'real-time' observations of a target bird species approaching the rotor-swept zone (RSZ) of one or more turbines, with the immediate resumption of turbine operations once the risk has abated. Responsive shutdown can be undertaken either by field observers (OSDoD, see Section 5), or be rendered fully automated (ASDoD, see Section 6).

Responsive shutdown requires the ability to detect incoming birds, which can be compromised for small species and in low-visibility conditions. In such cases, predictive shutdown may be an attractive solution since it can provide more certainty. As an example, offshore wind farms 'Borssele' and 'Egmond aan Zee' set a historic precedent by shutting down for four hours in May 2023 in anticipation of predicted peak bird migration in the North Sea (Recharge News, 16 May 2023). While bats benefit from predictive approaches (Bennett et al. 2022), evidence for a sustainable solution for both energy companies and avifauna from this strategy is uncertain (Smallwood and Bell 2020).

At the most precautionary end of the scale, predictive SDoD should theoretically always be effective, since turbines can be shut down for long periods of predicted risk. Scheduled shutdowns may include a large number of turbines for an extended period when minimal risk to birds may materialise. However, this is seldom financially viable for the project, and so the need arises to fine-tune the approach and minimise the loss of energy production when no real risk transpires. Given that responsive approaches involve turbine shutdown only when real, rather than anticipated, collision risks arise, these entail considerably fewer 'unnecessary' shutdown events, as well as substantially shorter shutdown times than predictive approaches.

SAMANTHA RALSTON-PATON

Therefore, responsive shutdown has emerged as the preferred approach both globally and locally, in many cases because it is the more practical and financially feasible solution of these two options. In exchange for this reduced loss of energy production, some risk of continued bird fatalities is introduced if the system fails in any way. This makes appropriate implementation extremely important. The chosen SDoD system must be effectively and correctly implemented at all times if it is to succeed in mitigating the risk of bird collision. This handbook deals primarily with responsive Shutdown on Demand.

3. SOUTH AFRICAN CONTEXT

While South Africa can gain worthwhile insights from the more established international wind energy industry's implementation of SDoD, unique opportunities and challenges are presented locally. The country boasts impressively high avifaunal richness and endemism across significantly distinct ecosystems, producing many conditions in which protection is required and for which there is no global proxy. A high unemployment rate persists in the country, equating to a large pool of prospective employees, but the majority of whom are unskilled. Unfavourable exchange rates with countries typically providing automated SDoD solutions present a financial disadvantage to South African investors considering the automated SDoD approach, and security risks to technology once installed are important considerations.

3.1. THE PROJECT DEVELOPMENT PROCESS IN SOUTH AFRICA

To date, most wind farms in South Africa have been developed through the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), an initiative instituted in 2011 by the South African government to increase electricity capacity through investment by the private sector into sources other than coal-fired power, namely solar photovoltaic and concentrated solar, onshore wind power, small hydroelectric (<40 MW), landfill gas, biomass, and biogas (www.gov.za; www.sawea.co.za). Only one facility (Sere Wind Farm) is presently owned by the national electrical utility, Eskom (a state-owned enterprise), with the remainder belonging to privately-owned Independent Power Producers (IPP). Since 2011, a total of six rounds of REIPPPP have been completed, with tenders for the seventh Bid Window submitted in August 2024. More recently, projects have also had the opportunity to develop through 'private offtake agreements' concluded with private customers or end users.

To attain commercial operation, wind farm developers in South Africa must meet rigorous environmental criteria prior to receiving Environmental Authorisation (EA) by avoiding and minimising impacts, following the mitigation hierarchy (see Section 4.1). Initial screening of the site must remove obvious environmental sensitivities from the proposed developmental footprint, pre-construction monitoring of at least one year (if not two) will have refined the list of target species and identified further constraints, and formal impact assessment methodology will have quantified the predicted risks to avifauna based on a final wind farm layout. Throughout these processes, the project must adhere to and consider various guidelines and protocols.

Once approval for the development is granted by the governing competent authorities, the wind farm may be constructed, subject to compliance with an Environmental Management Programme (EMPr), which may include a Biodiversity Management Plan (BMP), species-specific fatality thresholds and a commitment to an adaptive management strategy.

Wind farm developments are required to protect the environment by global, national and provincial legislation, not least of which are the National Environmental Management Act (NEMA, No. 107 of 1998), the National Environmental Management Biodiversity Act (NEMBA, Act 10 of 2004) and the Threatened or Protected Species (TOPS) Regulations, 2015.

3.2. SOUTH AFRICA'S AVIFAUNA

To date, approximately 850 species of birds have been recorded in South Africa, Lesotho and Eswatini, of which 39 are endemic and 132 are considered regionally threatened (Taylor et al. 2015; see speciesstatus.sanbi.org for up-to-date species statuses). Beyond avifauna, the region hosts high levels of biodiversity and endemism across other taxa. Consequently, prospective wind farm sites invariably harbour unique assemblages of biota, with numerous threatened species presenting ecological concerns for development.

The spatial overlap between avian movements and wind farms is most acute along migration flyways where the biannual trans-continental passage of several million birds concentrates over narrow land corridors, such as across the East African Rift Valley and Red Sea Flyway (BirdLife International 2015). The relevance of this concern, however, diminishes over southern Africa. Despite South Africa receiving a large influx of migratory birds during the austral summer, to date neither diurnal nor nocturnal migratory bird species appear disproportionately represented in national wind farm mortality data (Ralston-Paton et al. 2017). The birds most likely to be found as turbine collision fatalities are resident species (Ralston-Paton et al. 2017), although the composition of species mortalities may soon change following the recent shift in wind farm development interest towards the eastern parts of the country; currently no wind farms operate in this region. Migratory birds typically fly at higher altitudes than resident species (Katzner et al. 2012), with the latter more frequently engaging in flight activity, such as foraging or breeding displays, within turbine-collision risk height[1]. Exposure of resident birds to risk is also more protracted, while migrants pass through or overhead perhaps once or twice a year. SDoD vigilance will thus by necessity be more year-round for mostly resident species at South African projects, especially when compared with those situated in Egypt and Jordan, for example.

Avian fatality rates vary widely across wind farms and depend on a complex interplay between the following:

- **Species' characteristics** – species' size, morphology, abundance, flight behaviour, gregariousness and avoidance capabilities (Bevanger 1994; Barrios and Rodríguez 2004; reviewed in Marques et al. 2014),
- **Physical aspects of a wind farm's specifications and configuration** – topography, turbine height and inter-turbine spacing (Thelander et al. 2003; Smallwood and Thelander 2004; de Lucas et al. 2008), and
- **Dynamic conditions on site** – food resource fluctuations for both predator and prey species, and weather patterns; these vary from daily to inter-annual scales (reviewed in Marques et al. 2014).

Predicting and effectively mitigating the risk to avifauna at a wind farm is thus imperfect and an ever-evolving science for which no single solution may suffice. Several operational mitigation tools are available and worthy of consideration, however not all are considered equal. Options such as blade patterning[2] and timely livestock and wildlife carcass removal can be considered and are relatively easily implemented, but should not replace or be a substitute for the more substantial mitigation measure of SDoD without further evidence of efficacy.

Of the 79 raptor species occurring in South Africa, Lesotho and Eswatini, 22 (28%) are considered regionally threatened (Taylor et al. 2015). In an analysis of the composition of avian fatalities at South Africa's first eight wind farms, raptors represented

[1]Collision risk height is dependent on the individual wind turbine's physical dimensions and is generally taken to mean the rotor-swept zone (RSZ), the height above ground level spanning the turbine blades' minimum and maximum reach.

[2]Following success with this mitigation in Norway (May et al. 2020), turbine blade patterning trials in South Africa are showing promise (Simmons and Martins, 2024b; *www.birds-and-bats-unlimited.com/research-and-innovation/*). While retrospective blade painting at operational wind farms poses challenges (high costs and voiding of warranties, for example), if painting is done by the manufacturer, costs are significantly lower.

36% of all avian turbine-collision fatalities (Ralston-Paton et al. 2017). Concerns have also been raised internationally that large soaring birds (including many raptors) are particularly susceptible to this threat (Orloff and Flannery 1992; Smallwood and Thelander 2005; Marques et al. 2014). Raptor collision susceptibility is complex and not all raptors are susceptible in all circumstances (e.g. see Watson et al. 2018).

3.3. SOCIO-ECONOMIC FACTORS

REIPPPP requirements in South Africa have in some cases required awarded projects to spend a designated percentage of generated revenue on Socio-Economic Development (SED) and Enterprise Development (ED). This has been incentivised by higher scoring of projects committed to job creation sourced from local communities within a geographical radius of 50 km of the project. The nuances of this have been discussed in detail in WWF (2015) and Wlokas (2017). These factors may have contributed in part to the choice to employ human observers over automated technology (for which evidence of efficacy also only started emerging more recently) at some of the pioneering SDoD programmes in South Africa. More recently it appears that the REIPPPP scoring system places less emphasis on this factor. This, coupled with greater availability of automated solutions (some with now proven efficacy), means that newer projects will probably need to closely evaluate both OSDoD and ASDoD options.

The country's 34 operational wind farms are all situated in the western half of the country: 16 in the Eastern Cape, 11 in the Northern Cape, and seven in the Western Cape. This stands in contrast to the predominance of coal power plants in the eastern half of the country. As the country transitions towards renewable energies, there are concerns over rising job losses as the coal industry wanes. Furthermore, the REIPPPP Bid Window 6 in 2022 was constrained by the lack of available grid connection capacity, and no new wind projects were awarded by the National Energy Regulator of South Africa (NERSA) during this Bid Window. The government's Just Energy Transition Implementation Plan (JET IP, www.gov.za) seeks to remedy this constraint by utilising current and future grid capacity to the east of the country, with a special focus on renewable energy in Mpumalanga as its coal power plants are decommissioned. This eastward shift in wind energy may impose higher biodiversity risks, necessitating urgent formulation of a unified national mitigation strategy. An updated Strategic Environmental Assessment (SEA, previous version DFFE, 2019) is currently under way, presumably to address this shift.

4. HOW TO IMPLEMENT A RESPONSIVE SDOD PROGRAMME

This section describes when to initiate an SDoD programme and the process that should be followed to design and implement this mitigation successfully.

4.1. WHEN IS SDOD APPROPRIATE?

An SDoD programme should be considered when either of the two cases below occurs:

- The **predicted risk** of bird collisions as determined in the **pre-construction phase** is high enough to warrant mitigation. The sources of this predictive knowledge stem from pre-construction avifaunal monitoring data (e.g. flight-path mapping and collision-risk modelling), Avifaunal Specialist site visits, Site Sensitivity Verification (SSV) and formal impact assessment ratings.
- **The actual measured impact** as determined through Post-construction Fatality Monitoring (PCFM, Section 4.2.2 and 4.8) in the **operational phase** is high enough to warrant mitigation. This is only applicable where, despite adherence to good practice standards in the pre-construction phase, impacts requiring an adaptive management approach emerge unexpectedly.

Observer-led or automated SDoD may not be a suitable avian impact minimisation strategy at every wind farm or for every species. The primary reasons for this are related to the detectability of target birds. Where detectability is compromised, effective shutdown is not possible. Target bird detectability can be affected by:

- **The size of the species.** The smaller the bird, the more difficult it will be to locate and identify in the monitored airspace at a distance sufficient to effect a successful shutdown. This applies to both OSDoD and current ASDoD capabilities.
- **Flight behaviour.** Nocturnal flyers (such as flamingos, for example) will not be detected by human observers (who only work by day) nor by currently available camera technology. These birds may be detected by radar-based systems.
- **On-site topography.** Ridges, winding valleys, tall trees and buildings may create blind spots in the Surveillance Area. This impairs the ability of both human observers and automated systems to effect successful shutdowns when a bird suddenly emerges into visible airspace. This issue may, subject to cost, be suitably remedied by increasing the number of OPs or detection systems.

Technical factors may also be relevant, such as:

- **Turbine model.** Turbine specifications must allow for complete shutdown to occur rapidly enough to be effective.
- **Manufacturer warranties.** Implementation of SDoD may void certain turbine manufacturer's warranties or service agreements and bear significant insurance implications.

An SDoD programme is a significant undertaking, and its suitability should be carefully evaluated on a site-specific basis. In certain instances, the resources required to implement an SDoD programme to protect against the risk of a rare, albeit high-impact event may not be warranted, and alternative measures may be preferred. For example, in some cases predictive SDoD may need to be considered as a 'safety net' to fall back on where responsive shutdown is not likely to be effective.

Black Harriers have proven to be susceptible to fatal turbine collisions at operational wind farms in the country, even those which have implemented an otherwise effective OSDoD Programme.

ALBERT FRONEMAN

TEXT BOX 1:

THE BLACK HARRIER – A SPECIAL CASE?

The Endangered Black Harrier *Circus maurus* is a species in crisis. A recent population viability assessment conducted by Cervantes et al. (2022) estimated that at an average rate of five annual adult mortalities, the population would collapse within 75 years, with a 50% certainty. Perold et al. (2020) state that between 2016 and 2020 at least eight birds fell victim to South African wind farms. These statistics continue to mount, in certain cases **despite active OSDoD programmes that have otherwise been performing effectively** at maintaining low levels of fatality across other target bird species.

Black Harriers arguably present the greatest challenge for SDoD programmes at South African wind farms, since:

1. They have a zero-fatality threshold, meaning the species cannot sustain any further mortality at all.
2. Their black-and-white colouration, wingspan of 1.1–1.2 m and relatively small size for a raptor (350–600 g) generally match that of the abundant Pied Crow *Corvus albus*; image-recognition algorithms need to be finely tuned in order to correctly judge between them. Failure to do so could result in unacceptably high levels of False Positive triggers (unnecessary shutdowns) or, if configured too conservatively, no action to be taken on the rare occasions when it is critical to do so (False Negative events).
3. Collisions have occurred just before sunrise or just after sunset. If landowner lease agreements do not provide for it, observers may not be allowed to cover the full Surveillance Period prescribed for the species. This issue highlights the need for mandatory buy-in from landowners before the use of OSDoD can be approved. Where this issue cannot be resolved, ASDoD may be the only alternative. Species recognition is critical to this end, and thus the detection system must have this capability to be effective, which is not possible across the full spectrum of suppliers. Stand-alone camera-based systems do not currently operate nocturnally, either.
4. In at least one incident, inclement weather (mist) decreased visibility to the point where performance of duties was impossible. In this circumstance, camera-based technology could have performed no better.
5. Typical flight behaviour of a foraging harrier occurs less than five metres above the ground. Detection of a very low-flying bird against a complex background (e.g. shrubs/moving grass) must be possible within a distance sufficient to effect successful shutdowns. Correctly siting an OP and/or a detection system while taking topography and potential blind spots into consideration is critical for shutdown success. Such blind spots may include the area directly beneath a turbine-mounted detection unit (up to 10 m), although this is a system-specific constraint.

Black Harriers appear to be most susceptible to turbine collisions in their breeding season (July to November, peaking in August and September) when flight height overlaps more closely with the RSZ during displays and food delivery (Simmons and Martins, unpubl. data). Where wind farms are located near breeding habitat, this is the period when mitigation efforts should be concentrated.

The species is on a critical trajectory and urgent action needs to be taken to prevent further collisions. As more wind farms become operational, the risks to the Black Harrier population (ca. 1000 adults), which is already subject to a range of anthropogenic impacts (Simmons et al. 2005), will increase.

4.2. DECIDING TO IMPLEMENT AN SDOD PROGRAMME

Irrespective of whether an observer-led or automated approach is favoured, the implementation of an SDoD programme should broadly follow the steps detailed below, while bearing in mind that this mitigation differs slightly for pre-construction versus operational projects (defined above).

4.2.1. Pre-construction phase projects

According to NEMA Section 2(4)(a) (to be read with Environmental Impact Assessment Regulations, 2014), sustainable development requires the consideration of all relevant factors, including the following:

- That the disturbance of ecosystems and loss of biological diversity are avoided or, where they cannot be altogether avoided, are minimised and remedied,
- That a risk-averse and cautious approach is applied, which considers the limits of current knowledge about the consequences of decisions and actions, and
- That negative impacts on the environment and on people's environmental rights be anticipated and prevented and, where they cannot be altogether prevented, are minimised and remedied.

The International Finance Corporation (IFC) Performance Standard 6 further states:

> 'As a matter of priority, the client should seek to avoid impacts on biodiversity and ecosystem services. When avoidance of impacts is not possible, measures to minimise impacts and restore biodiversity and ecosystem services should be implemented. Given the complexity in predicting project impacts on biodiversity and ecosystem services over the long term, the client should adopt a practice of adaptive management in which the implementation of mitigation and management measures are responsive to changing conditions and the results of monitoring throughout the project's life cycle.'

The Impact Mitigation Hierarchy is: ***avoid***, then ***minimise/ mitigate,*** then ***restore/rehabilitate***; and finally ***offset*** or ***compensate*** (see Figure 1). A holistic overview of this topic can be found in the 'IUCN Guidelines for Developers' (Bennun et al. 2021). Section 2 (4)(a)(vii) of NEMA underpins the Precautionary Principle which urges erring on the side of caution, providing for adjustment before negative consequences are irreversible.

Avoidance of impacts is sometimes the only means to prevent irreplaceable loss of biodiversity and is arguably the most important strategy associated with planning a wind farm, with respect to birds. Avoidance may involve locating wind farms in areas of low sensitivity, for example, as identified through a Strategic Environmental Assessment (SEA) or the National Web-based Screening Tool. It may also include avoiding placing turbines in Protected Areas, Critical Biodiversity Areas (CBAs), Key Biodiversity Areas (KBAs), and other habitats important for threatened species, as well as nest buffers, landscape features and migratory routes that concentrate bird movements.

THE IMPACT OF MITIGATION HIERARCHY

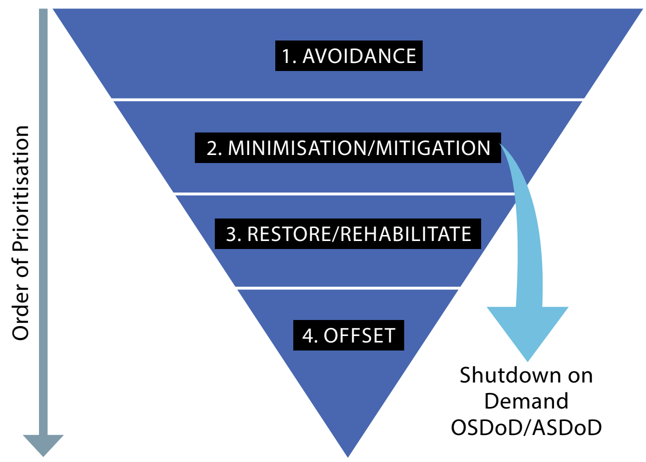

FIGURE 1. Conceptualisation of the Impact Mitigation Hierarchy

The emphasis on avoidance in the mitigation hierarchy should be proportional to the irreplaceability, conservation importance (e.g. Red Data Book status), risk of irreversible impacts (including cumulative impacts), the desired state of the habitat and the availability of feasible alternatives. Once avoidance has been employed, residual impacts[3], as assessed by the Avifaunal Specialist through the EIA process, will need to be reduced to acceptable levels.

Interviews and workshops held for the development of this handbook revealed a consensus that SDoD as a mitigation measure for bird–turbine collision fits into this second tier of the hierarchy: minimisation (see Figure 1). It follows that SDoD may only be applied once all avoidance options have been fully implemented.

The extent to which the application of SDoD as a mitigation measure can reduce the impact significance is currently uncertain as the measure is not yet widely proven in South Africa. It is suggested that until it is proven, this uncertainty must be taken into account when assessing the significance after mitigation. In many instances a reduction of one category may be reasonable (e.g. High to Moderate, or Moderate to Low). However, in some cases it may not be appropriate to reduce the significance ratings at all.

The wind farm's minimisation/mitigation strategy should rely on a combination of approaches which are specific to the characteristics and requirements of the wind farm in question and the relevant bird species of conservation concern. Although this handbook focuses on SDoD as a mitigation measure, other options exist and may be more appropriate in some instances.

The third tier, rehabilitation, may include vegetation restoration, soil remediation, invasive species control and removal of project infrastructure. To compensate for significant residual impacts on biodiversity after the prior steps in the mitigation hierarchy have been applied, as a last resort the project may consider the use of biodiversity offsets.[4]

[3]Environmental Impact Assessment (EIA) methodology is guided by the Environmental Assessment Practitioner (EAP) appointed for the development's EA application. Residual impacts are those which are predicted to remain despite adherence to other minimisation methods.

[4]According to IFC PS6 (2019): 'Biodiversity offsets are measurable conservation outcomes resulting from actions designed to compensate for significant residual adverse biodiversity impacts arising from project development and persisting after appropriate avoidance, minimisation and restoration measures have been taken.'

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The mitigation hierarchy should always be applied. Commitment to implementation of SDoD as a mitigative strategy cannot, therefore, be used to fast-track a development's application process or negate the obligation of a thorough pre-construction assessment. It is imperative that all relevant and most updated versions of the South African best practice guidelines be followed consistently. These are freely available at www.birdlife.org.za/what-we-do/policy-and-advocacy/what-we-do/birds-renewable-energy/

4.2.2. Operational phase projects

It should be evident from the results of a well-executed pre-construction baseline study (designed with the above good practice standards in place) which projects will require SDoD mitigation from the outset in order to safeguard priority species. However, when unpredicted risks emerge only once a wind farm has already been constructed, the primary trigger of operational phase implementation of SDoD is the PCFM findings. SDoD should be considered when bird–turbine collision fatalities have exceeded thresholds of acceptability, derived from either pre-determined species fatality thresholds, collision-risk model fatality estimates, national guidance, or lender requirements. It is thus essential that the financial implications of potential future mitigation measures be built into the wind farm's financial model before construction, and that thresholds of acceptability are clearly defined in the EMPr and as part of the operational monitoring plan.

As part of the decision to implement an SDoD programme, the supervising Avifaunal Specialist will describe the conditions under which a programme is required. Similarly, the conditions under which the programme may be terminated should be considered. This is more complex, as discussed in Section 4.11. Figure 2 summarises the process from pre-construction avifaunal monitoring through the lifespan of an approved wind farm.

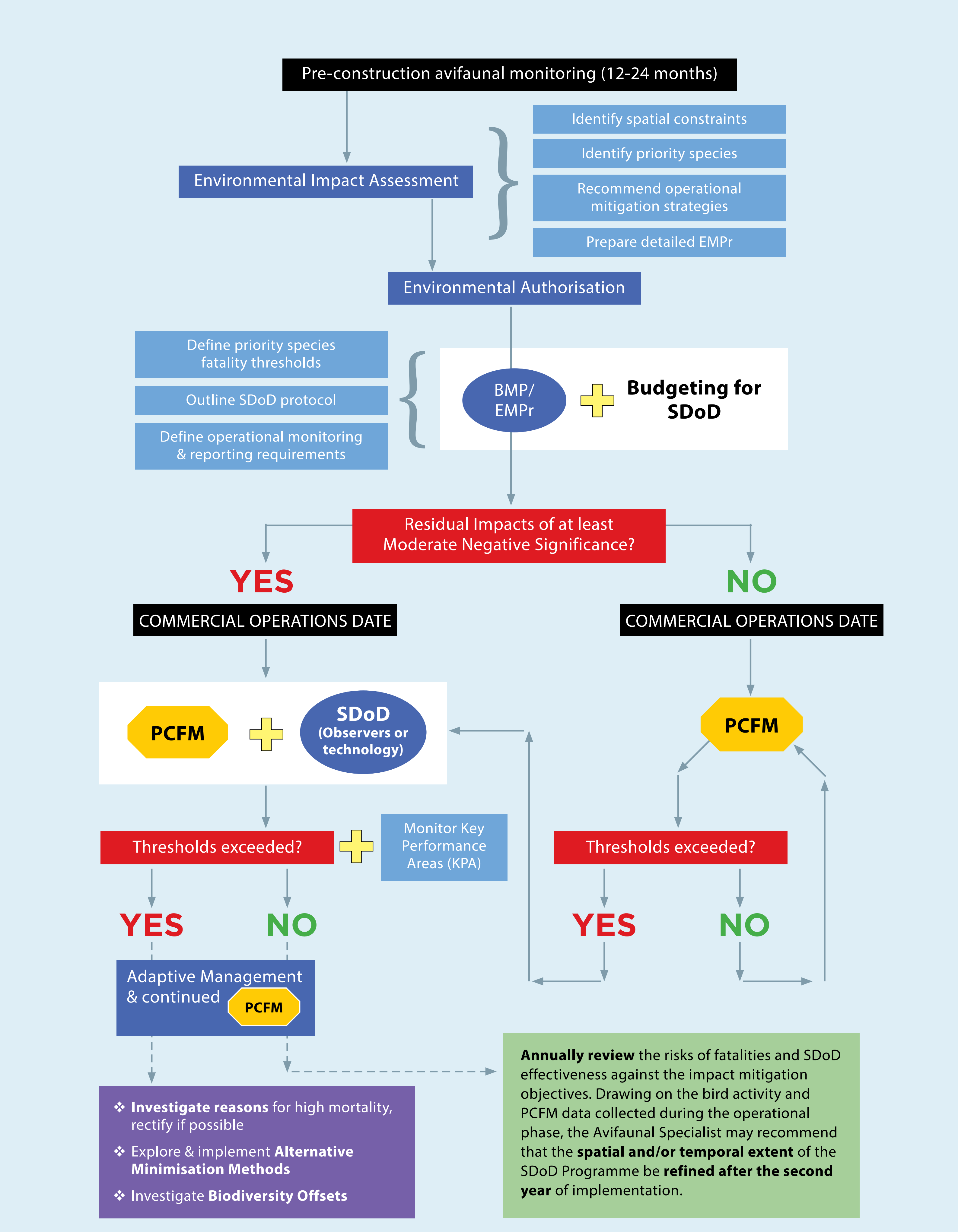

FIGURE 2. Contextual flowchart showing the stages of SDoD implementation

4.3. PROGRAMME DESIGN

Once a decision has been taken to implement SDoD at a wind farm, the programme should be carefully designed to best protect the target bird species, accounting for the relevant avifaunal requirements alongside practical and financial constraints, site characteristics, and wind farm layout. This is to be undertaken in close consultation with a suitably qualified supervising Avifaunal Specialist, who should be appointed as early as possible in the process to oversee performance of the programme for its lifespan. Careful consideration should be given to where a predictive shutdown schedule would perform more satisfactorily than responsive SDoD, and whether OSDoD or ASDoD would best achieve the project's targets. The programme design should be presented in an 'SDoD Protocol' and included in the EMPr or BMP for the project. For pre-construction projects, the SDoD Protocol should be finalised at least six months before the Commercial Operations Date (COD), to allow sufficient time for preparing the programme. This lead time may be longer in the case of ASDoD to allow for equipment supplier delays, import processes, installation and the testing phase.

Key considerations in the design phase include:

- Identification of target bird species (see Table 2).
- Delineation of areas of the site considered to be of higher risk to target species.
- Configuration of spatial coverage, accounting for blind spots or blind angles above/below the horizon. This includes optimising the locations and numbers of OPs for OSDoD and the position of automated detection apparatus (likely to be done by the supplier) for automated systems (ASDoD) to ensure sufficient time between detection and a successful response. In both cases, although desktop methods (GIS, viewshed analysis, etc.) may be used to identify draft locations, the final ground truthing should be done on site by the Avifaunal Specialist. The total area to be covered reliably by the SDoD programme is termed the Surveillance Area. For OSDoD, the Surveillance Area should include, as a minimum, a horizontal distance of two kilometres surrounding all risk turbines in any direction; for ASDoD, the Surveillance Area depends on the detection abilities of the specific technology.
- Configuration of temporal coverage. The daily, weekly, and monthly time periods requiring reliable surveillance is termed the Surveillance Period. The Surveillance Period should account for the anticipated daily or seasonal periods of heightened risk, determined by the target bird species' ecology and behavioural characteristics. Species may exhibit annual variation in flight behaviour based on breeding activity and/or migration. Diurnal birds (flamingos, for example) may disperse or migrate at night (Alerstam 2009; García-Jiménez et al. 2020). In addition, bird flight activity patterns are generally susceptible to fluctuations in temperature, humidity and wind speed (Robbins 1981; Xu et al. 2023; Aschwanden et al. 2024), but do not necessarily cease in what humans consider 'poor' weather conditions. Red Kites *Milvus milvus*, for example, have been shown to increase their flight activity (but at a lower average flight height) in stronger vs weaker winds (Pfeiffer and Meyburg 2022; Aschwanden et al. 2024) and the mortality risk for large soaring birds may rise in colder weather when thermals do not develop well (de Lucas et al. 2008). The Surveillance Period can be impaired by low visibility conditions (e.g. fog, precipitation or dust storms), as well as human resource complications (weekends, public holidays) and equipment malfunctioning, power supply interruption, internet connectivity failure, or complications within the wind farm's internal network.
- Given the above considerations, the SDoD approach chosen should ideally be sufficiently robust in the face of harsh weather conditions under which the wind farm will operate, and (if necessary) be capable of detecting and identifying target species at night. These requirements currently cannot be met solely by OSDoD, or in any one stand-alone ASDoD system (but could be bolstered by a predictive shutdown component).
- The choice between OSDoD and ASDoD will dictate further distinct requirements. For example, OSDoD will require ablution facilities, a shelter, and property access via landowners, whereas ASDoD may require proximity to a Wi-Fi or fibre connection and heightened security against theft.

4.4. BUDGETING AND APPROVAL

Given the high species diversity and other factors described elsewhere in this handbook, it is likely that most wind farms will at some point be required to mitigate impacts, perhaps through SDoD. It follows that even if a wind farm initially commences operations without the need for SDoD, it is good practice to be financially prepared for a scenario in which the need does unexpectedly arise. Consideration should thus be given to including budgetary provision for SDoD or other mitigation measures within every project's financial model from the start.

With an optimised SDoD design in place, budget preparation for the programme may need to include a comparison of OSDoD and ASDoD options. This budget will need approval from senior wind farm management and/or lenders and should take place as early as possible to allow time for adequate preparation.

It is recommended that the industry move towards a standard default budgetary provision for additional avifaunal mitigation (SDoD) for every project, relative to the number of turbines planned, to account for unanticipated avifaunal impacts.

4.4.1. Estimation of energy loss and turbine wear and tear

The decision to shut down a turbine or group of turbines has significant implications for a wind farm. Firstly, turbine downtime represents lost energy production or revenue. IPPs are contractually obligated by Power Purchase Agreements (PPA) to fulfil their contracted generation and distribution outputs; shutdown periods must therefore be taken into consideration. To estimate this yield loss requires an understanding of the expected frequency and duration of shutdown events. The target bird species triggering the need for turbine shutdowns and the SDoD decision-making criteria should have been determined in the design phase. If site- and species-specific collision risk modelling data are available, a first approximation can be made of anticipated shutdown frequency at a project. It is recommended that a cautious approach be taken in these estimates and that leeway be built in for uncertainty. The estimate should in no way be construed by the project as a 'maximum' which cannot be exceeded once operational. The onus is on the project to adequately mitigate impacts on target bird species throughout its lifespan. Building in allowance for variability is recommended; this could include a range from best-case to worst-case scenarios. If pre-construction data are not available, surrogate data for the same species at similar sites or use of other models may be valuable. Additional considerations in this regard are any specific requirements in the PPA pertaining to maximum capacity shutdown per event, grid balancing and cumulative effects on the grid of multiple adjacent wind farms shutting down turbines simultaneously.

Secondly, shutting down turbines to a complete standstill (particularly using emergency braking) has technical implications for machinery; mechanical wear and tear on braking systems and gear boxes can be of concern. **It is incumbent on all wind farm developers to ensure the turbine equipment selected is capable of Shutdown on Demand.**

4.4.2. Capital expenses

As described above and below, preparing for implementation of an SDoD programme is complex. Certain aspects of this preparation come at significant cost. Compilation of a site-specific SDoD protocol must include design and optimisation of the Surveillance Area and Period which will require specialist ground truthing site visits and perhaps specialised modelling skills. In the case of OSDoD, the hiring and training of staff, procurement of vehicles and other equipment, provision of OP shelters, ablutions and office facilities are required. For ASDoD, the obvious additional cost is procurement of the technological equipment itself, which is the most significant expense for such an approach. Exchange rates and import duties are additional considerations.

4.4.3. Operational expenses

While the capital investment of initiating ASDoD is higher relative to OSDoD, the latter entails a more complex portfolio of expenses and logistics during the operational phase. The human resources management element is also significant in terms of staff training, turnover and retention, remuneration, transport, and the provision of on-site amenities. These are ongoing costs throughout the lifespan of the programme and will be subject to annual escalation and fuel price fluctuations. Furthermore, SDoD Surveillance Periods will include weekends and public holidays, and so overtime costs should be factored in. The SDoD programme must by default strictly adhere to relevant national labour laws, Occupational Health and Safety (OHS) protocols and other national legislation.

Coverage of the Surveillance Area during the Surveillance Period by observers should be viewed as an essential service. No gaps due to preventable factors can be accepted. Consequently, shift systems (standby staff) should be instituted to accommodate illness, annual leave, and observer absenteeism.

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It is critical that adequate management resources be in place to ensure the smooth functioning of the programme.

Depending on site characteristics and remoteness, OSDoD may not necessarily be more cost-effective than ASDoD over the long term. ASDoD, however, is not without its own operational costs. Routine maintenance may or may not be included in a detection system's purchase package. Troubleshooting or replacement parts could involve international travel expenses for a certified agent, and the non-compliance status of the project for the periods while any device is out of service is an important consideration. The site-specific SDoD Protocol must make provision for contingency plans during any technology downtime. This could include the temporary shutdown of relevant turbines, or temporary manning of the Surveillance Area by trained observers.

4.5. PREPARATION

A wind farm should allow at least six months before COD for the hiring of qualified staff, their off-site training, and the acquisition of gear and equipment. Three months prior to COD, staff should undergo on-site training (possibly including liaison with nearby established projects and even job shadowing) to familiarise themselves with the resident avifauna, the topography and layout of the wind farm and dry-run effective communication procedures with operators. This phase should sort out staff's compliance with any ancillary requirements such as OHS inductions, first-aid courses and emergency fire drills. These start-up requirements must be met before the turbine blades begin turning so as not to interfere with the observer's duties once risk to avifauna is present.

Through consultation with the service provider of the chosen ASDoD product, the Avifaunal Specialist and the wind farm, the number of units and their spatial configuration should be confirmed. The service provider should liaise with the wind farm regarding realistic timeframes surrounding product availability, installation times and on-site software training (where applicable). Where automated systems require pre-operational setup and fine-tuning, on-site power requirements may not yet be available for this purpose and arrangements will need to be made for the installation technicians to perform necessary trialling. A suitable time buffer should be built into product purchase, scheduled delivery, installation and testing to prevent unforeseen delays in effective operation from COD.

4.6. IMPLEMENTATION

Once preparation is complete and the start date is reached (COD for new projects; per agreement for already operational projects), the SDoD programme should be implemented in accordance with the BMP, the detailed site-specific SDoD protocol, and the adaptive management plan. The way in which the programme is to be implemented is expanded on in Section 5 for OSDoD and Section 6 for ASDoD.

4.7. DATA CAPTURE

Whether a wind farm employs a team of observers or makes use of technology (or a combination of these) for SDoD, evidence for how birds use the airspace in and surrounding the wind farm once it becomes operational is invaluable. An important component of SDoD implementation is therefore data capture. **It is essential that the SDoD programme collects data not only on shutdown events, but also on target bird species' activity on site.** The use of the wind farm airspace by target bird species must be documented by either the observers or the installed automated detection systems, recording: (a) bird species and number of individuals; (b) the observation time and duration; and (c) flight height. For a detailed breakdown of this procedure, see Section 5.1. The intention is not to capture data in the same detail as pre-construction or operational live bird monitoring, but rather to detect and track priority birds that may require turbine shutdowns. Capturing of data should never be allowed to distract observers from their primary function.

For OSDoD, data are to be captured daily on standard datasheets or on electronic devices if this option is chosen by the project (a decision can be taken during project setup). Hard copies or electronic data are to be submitted to the team management at the close of each shift. The team management should capture and collate data for submission to the Avifaunal Specialist by month end (or at predetermined frequency; in high-risk periods more frequent submissions may be necessary). Template datasheets are provided in Appendix 2 for the key information to be collected by observers.

Data metrics recorded through ASDoD must be stored in an electronic format determined by the technology used, and must be accessible to the relevant authorised personnel, including the local advising Avifaunal Specialist. Granting of data access and associated permissions should be negotiated at the outset so that a full dataset may be collected from COD and any problems can be identified timeously. A good rapport between the wind farm operators, Avifaunal Specialist and product technicians, built through early and inclusive engagement, will streamline the programme.

4.8. MONITORING AND EVALUATION OF THE PROGRAMME

The fundamental aim of SDoD is to prevent target bird species fatalities at wind farms. The ultimate measure of effectiveness is therefore the number of target bird species fatalities recorded at the wind farm. These fatalities should be measured on site through the implementation of a sound Good International Industry Practice (GIIP) PCFM programme. PCFM design is outside the scope of this handbook but should be conducted according to the latest national best practice guidelines (e.g. Jenkins et al. 2015, update in prep.) and GIIP, and under the supervision of a local Avifaunal Specialist.

A particularly comprehensive source of guidance is the Good Practice Handbook (GPHB) recently published by the International Finance Corporation (IFC 2023). It is important that the species-specific goals of SDoD are considered when evaluating the success of a programme. In many instances a single target bird species will be the main driver for the design of an SDoD Programme, but other target species may be added to the target species list as secondary goals. Where species contrast in ecological behaviour, it may not be possible to optimise a programme for all species. Priority may need to be given to the species of highest concern. In such cases it would not be reasonable to measure programme effectiveness for secondary species in the same manner as for primary species of concern.

Where SDoD is under way at a wind farm, PCFM should always continue. Without it, the success or failure of SDoD cannot be measured. Since PCFM is the ultimate method for measuring the effectiveness of SDoD, it would be preferable for the PCFM programme to run independently of the SDoD programme, rather than for the same service provider to co-implement the two programmes to save costs.

In some cases, observers may be rotated with the carcass searchers to provide more variety in the job. In such cases the Avifaunal Specialist will be responsible for verifying that the PCFM results are fit for purpose. Commencement of an SDoD programme at an operational wind farm may be a good time to re-evaluate whether the quality of established PCFM methods meet GIIP standards and to make readjustments where necessary.

In many cases, SDoD will be implemented to mitigate an impact with a likely low frequency of occurrence (but a high consequence). Critically Endangered and Endangered target bird species will likely have few fatalities per annum, but these could have significant consequences for the species' populations. As such, achieving sufficient statistical power to analyse SDoD effectiveness may be a challenge, but multi-year comparisons, grouping of species by guild (e.g. 'diurnal raptors'), comparison with live bird monitoring (Section 4.7) and any other available means should be considered.

The success of SDoD is best evaluated through a species-specific threshold-setting process that combines biologically derived fatality threshold values, robust PCFM and an adaptive management plan. South African avian fatality threshold guidelines do not yet exist. Where population viability analysis (PVA) has been conducted for a species, and where sufficient input data exist to conduct a potential biological removal (PBR)[5] analysis, these outputs serve as the recommended source of a project's fatality thresholds.

[5]Potential biological removal (PBR) is derived from three species-specific data inputs: 1) a conservative estimation of population size, 2) maximum annual recruitment rate, and 3) a population recovery factor between 0.1 and 1.0 relating to conservation status. For more information on calculating PBR, refer to the IFC's GPHB (IFC 2023).

TEXT BOX 2: NEAR-MISS INCIDENTS (NMI) IN AN SDoD PROGRAMME

Near-Miss Incidents (NMI) occur when a necessary order to shut down is either delayed or not issued by observers, or when an order is issued but not timeously carried out by Supervisory Control and Data Acquisition (SCADA) operators. During an NMI, a target bird flies through the RSZ of one or more turbines while the rotors are still turning, yet somehow evades injury or death. These incidents should be recorded as a matter of high priority, as they provide insight into how effectively an SDoD programme is performing and where it can be improved.

The date, time, turbine number(s) involved and reasons for NMI should be clearly recorded on field datasheets, preferably using a pre-defined selection of unambiguous reasons, for example:

1. Bird(s) appeared suddenly/unexpectedly with little time for observers to react under conditions of typical visibility.
2. Operators not responding to observer, despite radio and/or mobile phone communication attempts.
3. Operators received shutdown signal (verbal confirmation), but did not initiate the ordered shutdown(s).
4. Operators responded, but there was a delay in shutting down turbine(s) (i.e. > 1 minute).
5. Blades turning below cut-in wind speed.
6. 'Other reason' – must be clearly described (e.g. 'Misty conditions reduced visibility to about one kilometre').

The aim of an effective SDoD programme should be to achieve zero target bird species fatalities and zero NMIs. It is likely that NMIs will occur from time to time. Where trends in the reasons for NMIs emerge, management should respond with improvements. Management and the team need to strike a balance in which reporting of NMIs is not seen in a negative light, but rather as an early warning system and an opportunity to improve.

NMIs in ASDoD programmes are most likely to occur when visibility is poor (fog/dust/snow) or when birds approach a turbine at high velocity. They could include misidentification of targets with respect to size and species. Detection of NMIs during technological surveillance may require configuration of software to classify exactly when and why these events occurred. In response to this information, detection units may need to be repositioned, or shutdown parameters adjusted.

4.9. REPORTING

The SDoD programme will in most cases form part of a broader programme of avifaunal work at a wind farm, including:

- Live bird monitoring for the first two years of operations. This is done by a separate team to the SDoD team.
- PCFM for the first two years (but also continuing for as long as SDoD is in place) (Jenkins et al. 2015, update in prep.) and
- Other monitoring activities, such as vulture roost surveys, bird-tracking studies.

The contracted Avifaunal Specialist will be responsible for reporting on the outcomes of these programmes to the project, and the project is required to share these reports with the relevant government departments, non-governmental organisations (NGOs) and lenders, as required. The SDoD component of the reporting must include (at a minimum) the information as per the following suite of Key Performance Areas (KPA):

- Number of recorded and estimated[6] target bird species fatalities.
- Number of Shutdown Events successfully implemented as a proportion of target bird species flight/presence records.
- Number of Near-Miss Incidents (NMI, see Text Box 2) as a proportion of Shutdown Events, tabulated by species.
- Mean, minimum and maximum 'time to shutdown' from instruction.
- Coverage compliance, i.e. percentage of the Surveillance Period and Surveillance Area with adequate coverage.
- Evaluation of ASDoD system performance as described in full in Section 6.3.

In addition to quantitative data, the report must include an evaluation of how well the programme is performing and identify areas for improvement. Modifications to the existing SDoD protocol can be made if necessary but would need to be agreed upon and approved by site management and the supervising Avifaunal Specialist.

4.10. ADAPTIVE MANAGEMENT

Adaptive management is 'the process of informing and updating the approach to biodiversity management by incorporating the results of monitoring or integrating new findings' (IFC Performance Standard 6). As described in the IFC's Guidance Note 6 (IFC 2019), although adaptive management may be described as a practical approach to managing uncertainty, it is not a trial-and-error process but rather a structured learning-by-doing process informed by monitoring. Adaptive management is also a key aspect of an effective Environmental and Social Management System (ESMS), which draws on the elements of 'Plan, Do, Check, and Act' in accordance with established business management processes.

The IFC's Guidance Note 1, which accompanies its Performance Standard 1 (IFC 2012), captures the objective of adaptive management by stating that 'effective management programmes have an adaptive approach', and that 'The

[6]The total number of fatalities estimated after correcting for scavenger removal, searcher efficiency and searchable area (GenEst Fatality Estimator; Dalthorp et al. 2018; IFC 2023).

client should develop and implement procedures to adjust policies and operations, and adapt actions and mitigations as appropriate based on the environmental and social monitoring data. This iterative process promotes flexible decision-making that takes into consideration uncertainties, recognises the importance of variability of the social and natural systems, and can be adjusted as outcomes from management actions, mitigations and other events become better understood.' (IFC Guidance Note 1, 2012, para. GN70)

Where SDoD is implemented, this should be in accordance with a BMP (and/or EMPr) to which the SDoD Protocol is appended, incorporating 'fatality thresholds' and an adaptive management component. The BMP will include: i) confirmation of priority biodiversity values; ii) biologically derived fatality thresholds for priority birds (target species); iii) an adaptive management framework; iv) protocols for SDOD, PCFM programmes and all other on-site operational-phase monitoring and mitigation activities. It will also include a semi-annual reporting template for centralised reporting of all bird and bat monitoring, mitigation, and documenting of adaptive management.

The BMP should be a live document, revised as frequently as annually in some cases, in response to data collected on site through SDoD and PCFM programmes and any other relevant avifaunal activities. The BMP revisions must also respond to external factors, such as global or regional changes to species' conservation status or updated population estimates. Vigilance is necessary across a scope broader than the confines of the wind farm boundary and its SDoD programme; alterations in the abundance and composition of bird communities may well result from changes to land-use practices in the broader landscape (e.g. new irrigation schemes or carcass dumpsites).

Although not directly related to the effectiveness of the SDoD programme, the energy yield loss (%) is an important factor to measure and should not be unnecessarily high as a result of a poorly functioning SDoD programme, or unrealistically low due to observers' fear of management repercussion for shutdowns.

The reader is encouraged to refer to Chapter 6 of the IFC's Good Practice Handbook on PCFM (IFC 2023) for detailed guidance on adaptive management.

4.11. PROGRAMME TERMINATION

The decision to terminate an SDoD programme needs to be evidence based. It is useful if the conditions under which an SDoD programme could be concluded are pre-defined from the outset in the BMP. However, it should be strongly considered that SDoD programmes suppress bird fatality levels and that these levels may increase significantly without SDoD. Comprehensive collection of target bird species' flight data on site may provide insight into trends in collision risk in the absence of SDoD. Where possible, it is advisable to phase out the programme gradually, beginning in lower risk Surveillance Areas and Surveillance Periods. **In most cases, however, it will be necessary to take a risk-averse approach and continue SDoD until there are sufficiently strong grounds to stop.** Wind farm operators should make provision for these considerations in their budgeting and set target species thresholds on a 'project lifespan' basis rather than an annual basis.

TEXT BOX 3:

WHAT IF TARGET BIRD SPECIES FATALITY THRESHOLDS ARE EXCEEDED OR THE PROGRAMME IS NOT PERFORMING ADEQUATELY?

Once an SDoD Programme has been in place for at least two years, and concurrent PCFM has demonstrated that the mitigation methods are not sufficient for particular prioritised bird species, the adaptive management principle dictates that alternative mitigation options be investigated and implemented. Projects should at all times be cognisant of their obligations to mitigate their impacts through their full lifespan. Available options for the project include:

- Improvement of the existing programme where possible.
- Switching to an alternative SDoD methodology (e.g. from OSDoD to ASDoD or vice versa, or from one device service provider to another), as long as there is a reasonable likelihood of improved outcomes. This is likely to be costly, however, and enhanced training of existing staff (OSDoD) or neural networks (ASDoD) may achieve the desired improvement.
- Concurrently introduce additional mitigation measures that have a proven record of success.
- As a last resort, the possibility of biodiversity offsets/ compensation may need to be considered.

4.12. PROGRAMME SUPERVISION

Certain components of an SDoD programme may be managed and supervised by contractors or by the wind farm themselves. Furthermore, some specialised skills may need to be contracted in to ensure a smooth programme. Examples include human resources management in the case of OSDoD, and Information Technology (IT) assistance in the case of ASDoD. Regarding specialised detection systems, service providers may have valuable experience gained elsewhere in the world, but at this stage they will most likely lack experience with South African bird species. The overall supervision of the wind farm's avifaunal impact mitigation strategies should thus remain the role of the local Avifaunal Specialist. They should be integrally involved in the programme design stage and should lead data analysis, reporting and adaptive management strategies through evaluation of the KPAs.

CAPE VULTURES ALBERT FRONEMAN

JON SMALLIE

Observers (Atef Khawaldeh & Mohammad Ibrahim) stationed at an Observation Point at a Jordanian wind farm in the Tafila Governorate. Fewer than ten priority bird fatalities have been collectively recorded at three such wind farms with OSDoD Programmes in effect, despite very high passage rates of migratory soaring birds

5. OBSERVER-LED SHUTDOWN ON DEMAND (OSDoD)

This section describes how the Observer-led SDoD approach is implemented and key factors to consider in implementation.

5.1. HOW DOES OSDoD WORK?

OSDoD is a responsive shutdown approach involving a team of trained observers monitoring the airspace within and surrounding the wind farm for flight activity of target species from strategically located OPs. When individuals or flocks of a target species are detected, the observer visually follows their flight path and requests shutdown of specific turbines if flight behaviour suggests that the bird(s) are likely to fly through their RSZ. Shutdown orders must be made to allow sufficient time for the turbines presenting the risk to shut down before the birds reach the RSZ. Once the risk has abated, the relevant turbines are restarted by the operator when observers give the reinitiation order.

During surveillance, observers are required to:

- Be stationed at the OP for their full shift. Shifts should cover the full predetermined Surveillance Period. In most cases this will be seven days a week, every day of the year, including public holidays.
- Be stationed at a sufficient number of OPs to cover the Surveillance Area.
- Be stationary at the OP, except if previously agreed where some flexibility is necessary to optimise the view in variable conditions.
- Conduct surveillance by continuous unaided, binocular- and field scope-assisted scanning of the OP radius as well as the wider landscape (to ensure early detection of approaching birds).
- Give particular focus to the direction(s) from which target bird species are expected to approach, and the speed of approach (time to arrival), based on prior experience at the site.
- Identify situations when turbine collision is likely and implement effective shutdown of an appropriate number of turbines to avoid collision fatalities for identified target bird species.
- Communicate with each other via hand-held two-way radios or group-chat applications on mobile phones to allow potential collision risk to be effectively tracked through the whole Surveillance Area by all observers.
- Record target bird species' flight records when passing through or using the site when there is no potential collision risk to these birds. All target bird flights detected should be recorded on a standard datasheet (example provided in Appendix 2). This type of data capture should not compromise the efficiency of shutdown protocols and therefore can be suspended immediately and at any time to ensure that collision of target birds is prioritised and avoided. This data collection may also not be possible in instances where observers work alone, and not in pairs.
- Record the initiation time, duration and length of all ordered shutdowns, the identities of all affected turbines and the species for which the shutdowns were initiated.
- Record all Near-Miss Incidents (NMI), including the reasons.
- Communicate on a daily basis to agree on the start of observation for the next day, and continue to communicate throughout the day to decide on the timing of breaks and extension of observations. Decisions on rest breaks and extensions during

monitoring should be made by team management (see Section 5.5.5).

- Pause or completely stop surveillance during unfavourable weather conditions that severely limit visibility for the observers or would threaten their health and safety. These decisions should be taken by team management, rather than the observers themselves. Such unfavourable weather conditions might include wind above a certain velocity, dust storms, electrical storms, snowstorms, thick fog, etc. During such conditions, turbines may continue to operate and observers must remain on site to monitor the development of the weather conditions. Pausing or stopping monitoring for the remainder of a day will be informed by local weather conditions on the OP.
- Record the start and end times of all pauses or extensions of monitoring on the datasheets, and the appropriate reason(s) for doing so. If a target bird species is observed flying at risk height towards the wind turbines during periods when monitoring has been suspended, then the shutdown procedure should still be enacted.

It is recommended that observers always work in pairs. When one team member is capturing data or taking a short break, the other member can maintain full vigilance in the OP viewshed. At particularly busy wind farms or those with flocking target bird species (e.g. vultures), vigilance in at least two different directions may be critical to handle instances when flocks split up and numerous turbines are involved in potential shutdowns. It is also an advantage to be able to pair a seasoned observer with a less experienced one until the latter gains sufficient experience.

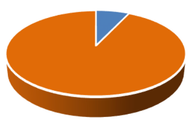
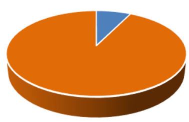
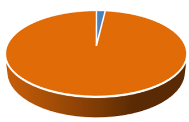
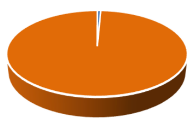
5.2. WHERE HAS OSDoD WORKED?

In an international example of OSDoD success, Ferrer et al. (2022) reported a 61.7% reduction in large soaring bird fatality across 20 wind farms (269 turbines) in the Cadiz region of southern Spain once an OSDoD programme was initiated. Over the 13-year period from 2008 to 2020, and despite a significant increase in the presence of Griffon Vultures *Gyps fulvus* on site, a 92.8% reduction in fatalities was achieved compared to the pre-shutdown period (Ferrer et al. 2022). Importantly, the authors reported an estimated loss of less than 0.51% in energy production.

OSDoD programmes are currently in progress at three operational wind farms in the Tafila Governorate in Jordan (IFC 2024, unpubl. data). During a three-year operational monitoring period for each of these facilities for which comparable data were available, almost 60 000 target birds have been recorded passing over, 690 shutdowns have been effected for these birds and fewer than 10 observed priority bird species fatalities have been documented collectively[7]. Table 1 summarises these results. Power losses were greatest over the autumn migration periods when the majority of shutdowns were ordered. At one of the three wind farms, peak loss amounted to 0.025% of total power output during one autumn season, but averaged 0.007% across the three years. At the other two wind farms, total turbine shutdown duration for three years averaged 92 turbine hours per wind farm, or 0.023% of turbine operating time.

OSDoD programmes are still a relatively new undertaking at a limited number of wind farms in South Africa and peer-reviewed scientific publications regarding efficacy are not yet available. Our understanding of how local programmes have been performing is thus based on statistics and insights released by project spokespeople where disclosure has been permitted.

TABLE 1. Results from three years of OSDoD at three wind farms in Jordan (IFC 2024, unpubl. data).

	WIND FARM1	WIND FARM2	WIND FARM3
Number of turbines	38	15	
Commercial operation date	September 2015	July 2021	
Review period	September 2015 – August 2019	July 2021 – April 2024	
Records of target species* (# individuals)	(18 465)	3 278 (15 380)	4 537 (25 314)
Number of target species (# causing shutdown events)	29 (5)	28 (13)	25 (11)
Shutdown events	121	233	336
Number of shutdown events as a percentage of target species records		 7.11%	 7.41%
Near-miss incidents (NMI)	14	61	34
NMI as a percentage of target species records		 1.86%	 0.75%
Actual fatalities of priority birds**	1	3	5

** Priority birds and/or other migratory soaring birds*

[7] Uncorrected number (likely close to 100% detection probability due to high carcass detection rate and long carcass persistence).

VERREAUX'S EAGLE ALBERT FRONEMAN

Excelsior Wind Farm near Swellendam in the Western Cape Province of South Africa is a 32 MW facility with 13 turbines, previously operated by BTE Renewables (since acquired by ENGIE Africa). In accordance with the Biodiversity Action Plan (BAP) developed for the wind farm, full-time OSDoD has been operating at Excelsior since COD (24 December 2020). The programme is run by nine observers and a Biodiversity Team Lead who are stationed on a shift basis at three OPs which are manned daily from 08h00 until 18h00. The team was fully trained prior to COD to ensure readiness from the first day of operations. Shutdowns are triggered for six priority bird species: Black Harrier, Cape Vulture, Verreaux's Eagle, Martial Eagle, White Stork and Blue Crane.

Data available from the first 32 months of operations show that all turbines had been involved in the 775 shutdowns ordered during this time, ranging from 20 to 85 shutdowns per turbine. The most shutdown orders were issued for Cape Vultures, followed by Black Harriers. As part of this project's adaptive management strategy, one OP location was adjusted, and additional observers were stationed here in response to the first Black Harrier fatality at the wind farm. Blue Cranes, although not initially considered to be at collision risk, were included among the priority birds to trigger shutdowns following the first fatality of this species. No further crane fatalities were recorded during this first 32-month period, although a second Black Harrier carcass was found beneath a turbine. No Cape Vulture fatalities were recorded at the wind farm during this time, despite its rating as one of the priority species at highest collision risk. Overall, just more than 56 hours of downtime occurred as a result of OSDoD in almost three years, equating to less than one per cent of revenue being lost.

5.3. INITIATING A SHUTDOWN EVENT

Turbine shutdown orders are to be issued for target bird species that are identified in the project's BMP/EMPr. In the South African context, it will probably be rare for an SDoD programme to focus on only one bird species. Where multiple target bird species are relevant, it is recommended that species be categorised. Where birds assessed to be at risk of collision cannot be identified to species level, shutdown will be ordered in situations where the unidentified bird(s) could be one of the target bird species. Table 2 shows a categorisation example.

TABLE 2. Target bird species: categories and actions (to be identified in the BMP/EMPr)

LEVEL 1 TARGET BIRD SPECIES
Shutdown of the relevant turbine(s) will be required when one or more individuals of the species listed in this category are identified during surveillance to be at risk of collision with turbines.
LEVEL 2 TARGET BIRD SPECIES
'Extreme event' safeguarding for flocks: Shutdown of the relevant turbine(s) will be required when a flock of 10 or more individuals from any of the species listed in this category are identified during surveillance to be at risk of collision with turbines.
LEVEL 3 TARGET BIRD SPECIES
Other globally or regionally threatened collision-susceptible species: Shutdown may also be ordered for globally/regionally threatened species or collision-susceptible species not listed as Level 1 or 2 when individuals from these species show flight behaviour likely to result in collision with turbines.

TABLE 3. Description of reporting zones

REPORTING ZONE	YELLOW ZONE	ORANGE ZONE	RED ZONE
EXAMPLE DISTANCE (SPECIES-SPECIFIC)	>2 000 m horizontal, >1 000 m vertical	1 000–2 000 m horizontal, 500–1 000 m vertical	<1 000 m horizontal, <500 m vertical
RISK	Informing	Warning	ACTION
MEANING	Target bird(s) detected	Standby for possible shutdown	SHUTDOWN

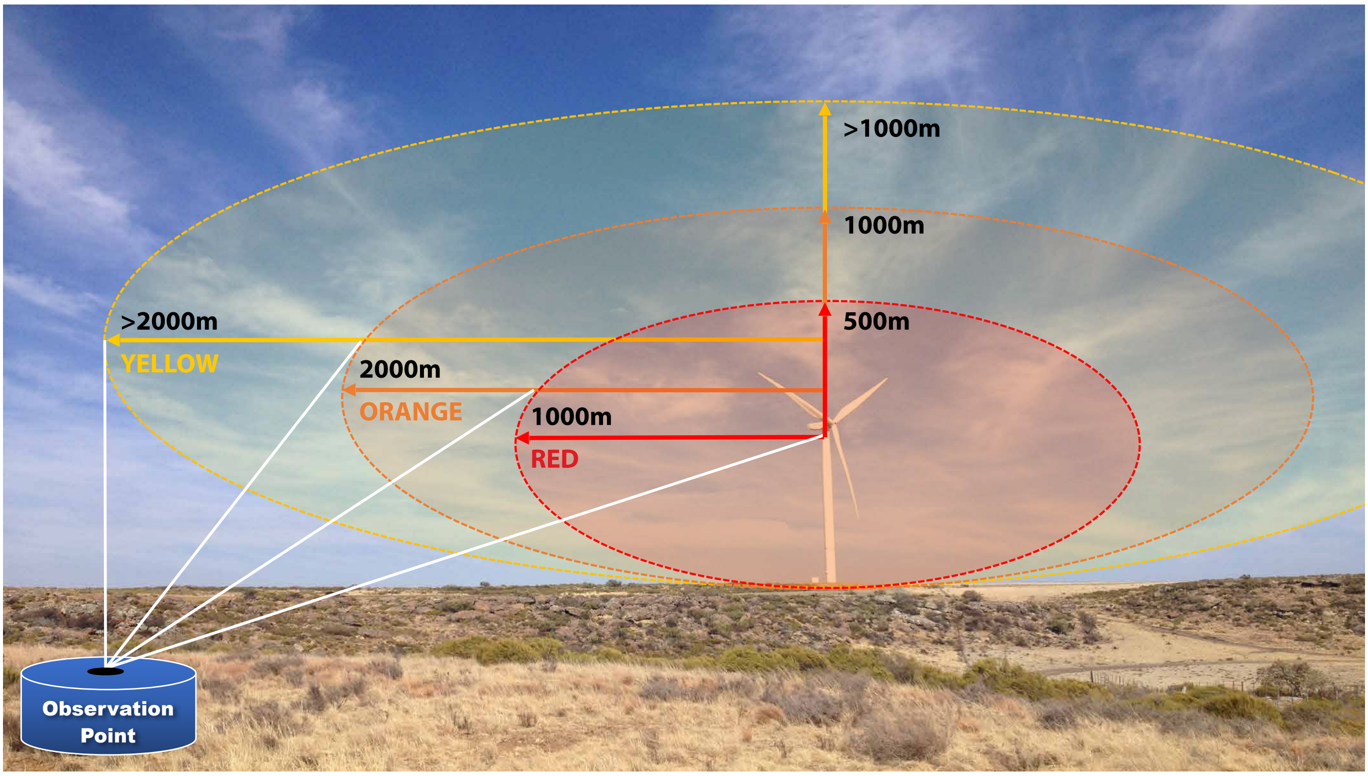


FIGURE 3. Visual illustration of the OSDoD reporting zones for a single turbine

Observers should provide four different instructions to the control room and other observers based on the proximity of the target bird species to the turbine(s) and the assessed risk. An example of a communication system is presented below and in Table 3 and Figure 3. The actual distances for each zone will be determined by the site-specific protocol and may be reviewed periodically based on operational experience[8].

1. The first '**yellow**' warning occurs as soon as one or more individuals from a target bird population are observed (at any distance). [Information only – no action required yet, but other observers can also track the bird]
2. The second warning will be '**orange**', and this takes place when a target bird is flying towards the turbine(s) within the predetermined risk zone or is perched within the risk zone; the control room must be informed for them to be on standby for possible shutdown(s). [Standby]
3. The last warning is '**red**', and this will be reported to the control room when the target bird enters the species-specific risk zone, the bird would be considered at risk of collision, and the shutdown procedure of the specified turbine(s) must be initiated. [Action required]
4. Once the target bird returns to the '**yellow**' zone, the control room can be instructed to return the turbine(s) to operational status. [Action required]

5.4. FATALITY EVENTS

Target bird fatalities will typically be recorded through a wind farm's PFCM programme. However, should an observer record a collision fatality in real time, the team management must be notified immediately and staff sent to the area to find the carcass or injured bird and remove it. If other target birds are present at or near the carcass, the observer must inform the control room to shut down any turbine that presents an imminent collision risk. In addition to completing a Collision Risk Event Log (example datasheet in Appendix 2), the observers should provide any additional information regarding the circumstances that led

[8] The risk zones will be periodically reviewed and revised where necessary, based on actual turbine shutdown time and other on-site conditions. Observers should be looking well beyond the risk zones to track birds and be sure that there is enough time to order a shutdown if needed. It is assumed that the time between the issuing of a shutdown request to the time when the relevant turbine rotors have stopped rotating will be between 40 and 60 seconds. However, it is understood that this depends on wind speed, and this should be taken into account by the observer during the decision-making process when assessing risky flight behaviour.

to the fatality to team management as soon as possible, so that all information relating to the incident can be compiled into a Target Bird Incident Report (example datasheet in Appendix 2). This should be submitted to the Avifaunal Specialist within at least 24 hours of the incident. The next step is to evaluate the incident and act in accordance with adaptive management principles.

5.5. KEY CONSIDERATIONS FOR IMPLEMENTING A SUCCESSFUL OSDoD PROGRAMME

5.5.1. Reliability

To be effective, an OSDoD programme needs to be managed as an essential service. It is vital that the full Surveillance Area is covered for the full Surveillance Period, without exception. Given the remoteness of most projects and other logistical challenges, the programme needs to be tightly managed to achieve this by building redundancy into key aspects at various levels. Additional staff should be trained and on standby to replace absent staff, and teams should have more than one licenced driver. Vehicle reliability and maintenance is of utmost importance if the programme is to run smoothly. It may be necessary to structure contracts with OSDoD service providers to include financial penalties for any gaps in coverage. Where the Surveillance Period exceeds a wind farm's standard operating hours (particularly in summer, for example), a strategy to accommodate the programme must be agreed upon by management, landowners and security officials.

5.5.2. Qualifications and aptitude of staff

Observers employed to implement OSDoD should be reliable, committed and conservation-driven people who understand and appreciate the importance of the role. **The single most important aspect for the successful implementation of an OSDoD programme is the quality of work done by the observers. The observer role is a skilled function, requiring dedication, concentration, and commitment, usually sustained over long hours.**

In addition to basic qualifications, it is important to hire staff with an aptitude for outdoor work, and a genuine passion for birds. If these basic ingredients are present, skills can be trained and developed over time. However, if these aptitudes are not initially present, it will be challenging to develop a good observer. Selection of staff is key and should take place through in-person interviews, or ideally even a prolonged 'on-the-job' trial. Useful formal qualifications include a matriculation certificate, basic literacy and good communication skills (in English). A certain number of observers in a programme should possess a valid Professional Driving Permit (PDP) licence (or a professional transport service provider can be used), to drive the team to and around the wind farm. Additional drivers should always be available to ensure that the absence of a driver does not impact an entire shift. Staff must pass annual occupational health medicals (including eye tests, since visual acuity is fundamentally important to the role) and comply at all times with their employment contract, site rules, and relevant legislation. The team leader is critically important in terms of inspiring and motivating the observers to effectively implement the programme and will not be able

TEXT BOX 4: THE 'O' IN OSDoD

Staff new to the observer role will likely initially underestimate the challenges of the position. It is best to warn prospective observers that extreme heat and cold, strong wind and long periods of inactivity are to be expected on the job. Concentration may be difficult to maintain at these times, but when a high-risk situation does occur, focus and rapid, decisive action will be required. Good preparation on the observer's part (e.g. appropriate clothing, snacks) and a curiosity regarding the site's overall biodiversity will assist the observer greatly. Implementing an OP rota which ensures that observers move between OPs and are regularly partnered with different members of the team, as well as having regular, short breaks in shifts can help to improve focus.

Clarissa Mars, Senior Biodiversity Team Lead overseeing OSDoD at two wind farms in South Africa says:
'I ensure that monitors write an internal bird-identification test at least once a month and also do practical field tests. Internal training and awareness talks on biodiversity and conservation issues keep the team inspired to protect the birds. There are challenging factors to Observer-led Shutdown on Demand, such as keeping motivated while working in harsh weather conditions, but my team has been doing well throughout the years. Our aim is to achieve not only no net loss of these species, but also a net gain.'

TERRAMANZI

A Terramanzi employee on duty at the Roggeveld Wind Farm tracks target bird flight paths in relation to turbine locations. Their job requires unwavering commitment to the role; momentary distraction or miscommunication can be fatal for the birds they are tasked to protect.

to achieve this effectively if they are not present on site with the field team or are distracted by other, unrelated duties.

The use of locally based unskilled staff for carcass searching at wind farms (PCFM Programmes) has been effective in general. However, the observer role (for OSDoD) is more skilled and the consequences of not performing the role to a high standard are greater than for PCFM. OSDoD programmes require a certain proportion of the workforce to possess relatively higher education levels (see Table 4). It may be challenging to meet these requirements from within 50 kilometres of a wind farm, particularly for a large OSDoD programme in remote areas. While a significant opportunity for local job creation exists (and can hopefully be realised), this should be secondary to prioritising the employment of the correct staff for the role, to ensure an effective programme. Furthermore, given the importance of selecting appropriate staff and the investment that will be made into them through training, it will be valuable to ensure that good staff are retained in the programme. Likewise, any underperforming staff should be carefully managed in accordance with national labour law.

5.5.3. Staff training

Adequate training of observers is fundamental to the success of the programme. Training before implementation should be comprehensive, and refresher training should be ongoing throughout the operational phase. Any incoming staff will need to be trained before fulfilling their role.

Key competencies to develop during training include:

- **Basic use of equipment**, including binoculars, spotting scope, cameras, and hand-held radios.
- **Identification of target bird species**, as well as common residents and similar species.
- **Excellent spatial awareness of distances** between the OPs and the turbines, the distances between the turbines and notable landscape features, and inter-turbine distances. Initial exploration of the site on foot is encouraged, as well as the ability to interpret site maps (topographical and satellite imagery).
- **Site orientation.** Even if turbine numbers are not visible on the structures from the OP, they must be perfectly recalled by memory (although a map must also be available at the OP).
- **Communication skills**, e.g. mobile phone and standard radio operating protocol.
- **Data capture skills**.
- **Interaction with PCFM staff** is important. A working knowledge of the protocols and an opportunity to handle carcasses will be beneficial to promoting personal investment into the programme as a conservation tool.

Ideally, other relevant wind farm staff, including control room operators, should attend at least certain parts of this training. This will ensure that all relevant parties understand and are aware of the intricacies of the programme. It is strongly recommended that the industry move towards accreditation of training material with the South African Qualifications Authority (SAQA) as far as possible, so that consistency can be assured, and staff can be credited with formal qualifications.

5.5.4. Communication

Effective communication is critical to the success of the OSDoD programme. This includes communication between two observers working at the same OP, among all observers in the Surveillance Area, between observers and the team management, and between observers and the SCADA control room. There should be no room for ineffectual or interrupted communication at any of these levels. The OSDoD Protocol should include a Communication Protocol in which the up-to-date names, mobile phone numbers, radio channels and weekly duty rosters for all relevant staff members (observers and operators) should be available to the applicable team members. Two-way radio communication on site is preferable to mobile phone communication, as it allows all observers and operators to provide and receive the most updated information immediately. Observers should be trained in the use of radios and maintain reliable communication channels with one another at all times.

By far the most important of these communication steps is the shutdown order itself. When a shutdown is required, this must be quickly and clearly communicated to the control room operator. Any delay in this process places the incoming target bird at risk of fatality. The exact process of communicating a shutdown must be discussed and agreed for each site. **It is essential that this communication is located in-country, and preferably on site.** It is not advisable to depend on international communication to effect a shutdown as this introduces further complexity and delays.

In advanced programmes with experienced staff, it may be possible for observers to shut down turbines directly (i.e. without passing through an operator), thereby reducing time to shutdown and allowing a less cautious approach to be taken (see Text Box 5). The applicability of this approach would depend on site-specific contractor/third party liability issues, however.

TEXT BOX 5:

A CASE FOR OBSERVER-SCADA CONTROL

OSDoD was implemented from COD at the Barão de São João wind farm in Portugal's south-western Sagres Region in 2010 and supplemented with radar technology. In the following four years, Tomé et al. (2017) report that no fatalities of soaring birds occurred while shutdown protocols were in place, and that direct access to the SCADA system by the field-monitoring team significantly decreased the total equivalent shutdown period from 1.2% (105 hours) of the annual available equivalent time to 0.2% (15 hours). Without the need for wind farm staff mediation, the field team could wait until the last moment to directly initiate a shutdown, reinitiating production instantly once the risk to the bird(s) had passed. This is a highly significant reduction in downtime, although it should be noted that some improvement in efficiency could be expected in any SDoD programme through refinement and troubleshooting.

5.5.5. Team management

The key to a successful OSDoD programme lies in its staff. For staff to continue performing optimally over an extended period, effective management is essential. It is vital that the

TABLE 4. Suggested team management structure and responsibilities within an OSDoD Programme

ROLE OR RESPONSIBILITY	A) SUPERVISING AVIFAUNAL SPECIALIST	B) SDOD SITE MANAGER	C) SDOD TEAM LEADER	D) OBSERVER
MINIMUM QUALIFICATION	SACNASP Registered Professional Scientist with relevant experience	NQF 6 Administrative experience is an advantage	Matric certificate *or* Proven excellence and reliability in observer role of at least 12 months. To be approved by B)	Passing of observer training course Matriculation certificate is an advantage
LOCATION	Based remotely, with at least semi-annual site visits	Full-time, based on site	Full-time, based on site	Full-time, based on site
PARTAKE IN PCFM (IF FEASIBLE)?				✓
PDP (Professional Driving Permit)		✓	✓	As required
KEY RESPONSIBILITIES	• Compile and submit semi-annual reports to DFFE, BirdLife South Africa and other relevant parties • Oversee PCFM methodology • Liaise with B) regarding identified issues and potential solutions • Liaise with senior wind farm management regarding non-compliance or high-level issues	• Liaise with A) regarding high-level staffing, disciplinary processes and/or environmental issues • Perform quality control of submitted data; submit to A), highlighting issues • Provide minor retraining or standardisation of methods • Purchase and distribute new and replacement PPE and essential equipment/consumables in accordance with project budget • Ethically handle injured birds/bats and relocate to rehabilitation centre immediately	• Perform key responsibilities of D) and in addition: • Oversee staff attendance registers, leave and duty rosters • Communicate timeously with D) regarding upcoming shifts and start/end times • Mediate minor conflict resolution among D) • Report non-compliance or undue absenteeism to B) • Collect incident reports from D), actioning immediate bird/bat carcass collection and carrion removal • Collate or capture data and submit timeously to A) or B) • Be responsible for ensuring radios, mobile phones and tablets etc. are charged before daily duties commence • Be responsible for ensuring first-aid kits and stationery/consumables are adequately stocked	• Perform surveillance and shutdown orders as per OSDoD programme protocols • Capture data accurately at all times • Report observed incidents and discovered carcasses immediately to B) and/or C), providing additional details when possible

management role is resourced adequately on a wind farm to ensure that all aspects of the programme run smoothly. Table 4 shows a summary of recommended roles and responsibilities. The ratio of managers to staff should be set to reasonable limits to ensure effective management. There may also be a need for an administrative position, particularly on larger projects as the amount of data produced could be significant.

5.5.6. Contracting

OSDoD is a large and important programme and must be contracted and managed as such. Observers and management should not have other tasks in addition to OSDoD (apart from PCFM, where agreed). The OSDoD programme may be contracted out to a service provider or implemented by the wind farm itself. It is preferable that a private service provider is contracted for the sake of independence and the avoidance of any conflict of interest. A hybrid approach could be considered, whereby observers are hired by the wind farm, but management-level staff are independent. In all cases, the programme should be conducted under the overall guidance and supervision of an independent Avifaunal Specialist.

5.5.7. Legal requirements

OSDoD programmes should always be implemented within the parameters of South African law. This means that where the Surveillance Period includes unusual hours, weekends, etc., all national labour law requirements in terms of overtime are observed. Project OHS requirements should cover risks relating to all activities undertaken by OSDoD staff, e.g. guidance on working on OPs in dangerous weather conditions, such as lightning storms.

5.5.8. Stakeholder engagement

Several external stakeholders may be relevant to an OSDoD programme and should be consulted and made aware of the programme as early as possible in the preparation phase. Landowners should be made aware of the need for additional staff and vehicles accessing their properties (often outside of normal office hours) and for the construction of OP shelters and ablutions. Other examples include local communities, taxi associations (where transport is relevant) and any others (local NGOs, bird clubs, rehabilitation centres) identified as relevant during construction.

5.5.9. Staff development

An OSDoD programme represents a significant opportunity for the creation of jobs and skill development. Consideration should be given to how staff can be developed during the course of their employment. The ethos should always be for staff to be better off after the OSDoD programme than before. Where possible, training programmes should be accredited, and additional non-core training should be encouraged. These steps will ideally foster a sense of professionalism within the OSDoD team and improve staff satisfaction and retention.

It may be an advantage to a wind farm for staff from an OSDoD programme to be involved in more than one facet of the business (although not simultaneously), as they will already be inducted, possess approved medicals and have a working knowledge of the wind farm. Fire-fighting and alien vegetation removal may be avenues to pursue for staff on a rotational basis, although care should be taken that the number of working hours is not exceeded and that avifaunal duties are always prioritised.

6. AUTOMATED SHUTDOWN ON DEMAND (ASDoD)

This section describes how automated systems perform Shutdown on Demand. Information was collected through a combination of online research, interviews with practitioners and suppliers, and general networking. Reference to individual products is made where appropriate to make a general point, not to showcase or criticise any particular product. Products receiving more mention are those better represented in online information and grey literature, and omission of any particular system is accidental. The information is structured into system types rather than actual products.

6.1. HOW DOES ASDoD WORK?

Automated Shutdown on Demand (ASDoD) makes use of camera and/or radar-based automated detection systems to detect target bird species at risk of turbine collision and to effect shutdown of the relevant turbines through software that communicates with the wind farm's SCADA control system. Advancements in surveillance technology and information processing algorithms have increased the dependability and affordability of ASDoD options in recent years (discussed in Section 6.2, with further details in Appendix 4[9]). Moreover, the integration of AI algorithms (e.g. machine learning, deep learning neural networks etc.) with these biomonitoring systems has accelerated automated bird species classification capabilities (see Section 6.3.3).

The ongoing fine-tuning of ASDoD technologies renders the efficacy of these responsive measures comparable to that of OSDoD according to some authors (McClure et al. 2018; Corbeau et al. 2021; Bennun et al. 2021; Gradolewski et al. 2021). Many ASDoD systems are coupled with a first-level audio and/or visual deterrent signal to discourage approaching target birds, with the goal of reducing the number of shutdowns and associated power losses, while still safeguarding the birds.

GREENBACKER CAPITAL

IdentiFlight® is an automated SDoD system utilising high performance stereoscopic and wide-field-of-view technology to detect and classify approaching birds and enact turbine shutdowns via its integration with the control room. Through proprietary AI image-recognition capabilities, identification of detected birds to species level is possible, ensuring shutdowns take place only when necessary, minimising energy loss. IdentiFlight units are not mounted directly onto the turbines but on stand-alone towers.

[9] Appendix 4 is a source of supplementary information regarding the specifications of available automatic detection-reaction systems for the purposes of responsive SDoD.

At present, there are three main classes of ASDoD technologies (detailed in Sections 6.1.1 to 6.1.3). An ASDoD programme may also incorporate supplementary biomonitoring technologies (see Section 8) to bolster wind farm surveillance. Technical aspects of commercially available automated detection systems for onshore wind farms are provided in Appendix 4.

6.1.1. Monoscopic and stereoscopic camera systems

While monoscopic and stereoscopic camera systems are regarded as different classes of ASDoD technologies (see Corbeau et al. 2021; Ballester et al. 2024), both operate according to similar principles. These cameras principally detect moving objects through the analysis of pixel contrast variation between successive images or video footage, relying primarily on the visual light spectrum, although they can be paired with infrared thermal imaging for increased night-time functionality.

Monoscopic camera systems optically detect birds within 1 000 metres. The key drawback of this class of systems is the lack of depth perception, which impairs size and distance estimations, both of which are necessary to minimise turbine collisions proactively (Gradolewski et al. 2021). Monoscopic camera systems are also subject to shorter detection distances than stereoscopic camera and radar systems, as well as OSDoD. Monoscopic systems primarily classify birds by size, as inferred from the number of pixels, with detection sensitivity limited to birds with wingspans greater than 0.5 metres. Certain systems such as SafeWind® can distinguish broad categories of birds and offer limited species identification.

Stereoscopic camera systems combine stereoscopic and monoscopic cameras to perform more precise distance estimations of approaching birds. Consequently, stereoscopic systems can assess a bird's position and flight trajectory in three-dimensional space, affording higher classification power than standalone monoscopic camera systems. In general, currently available stereoscopic systems can detect objects reliably at distances up to 1.5 kilometres under ideal conditions. As with monoscopic systems, stereoscopic systems classify birds by size but are better able to classify groups and species identity (see Section 6.3 and the ASDoD Compendium).

The detection ability of these camera-based systems is influenced by:

- **Magnification.** Stronger magnification allows for increased detection distance. Magnification is determined by the camera's focal length, with longer focal lengths affording stronger zoom abilities. Camera focal lengths tend to differ between fixed and movable cameras (discussed below), and so the required magnification may dictate the choice in this regard.
- **Optic resolution.** The cameras which can resolve fine-scale details can better detect and classify approaching birds.
- **Fixed or moving angle of view.** Cameras mounted on the turbine tower offer a fixed-angle field of view, and typically employ a short focal length to maximise coverage ahead of the risk zone, potentially at the expense of stronger magnification (Hüppop and Hill 2007). By contrast, pan-tilt-zoom (PTZ) cameras are mounted on their own towers and have a movable angle of view. These cameras typically use large focal lengths and offer magnification strengths 20-100x greater than those of fixed-angle counterparts (Skov 2023), but with a smaller field of view.
- **Coverage.** Coverage is the product of camera magnification, optic resolution, and field of view. Typically, a single camera affords half the coverage of a single human observer, although this can be overcome by installing multiple cameras.
- **Depth perception.** Depth perception is necessary for distance estimation and reliable bird size classification. Depth perception is possible with stereoscopic (but not monoscopic) camera systems (Gradolewski et al. 2021).
- **Visual and/or thermal lenses.** Thermal/infrared cameras can be used to augment detection at night and during inclement weather, although these typically have significantly lower magnification and resolution than visual lenses.

6.1.2. Radar-based systems

Radar-detection systems analyse the echo signal reflected off objects in the Surveillance Area to provide real-time detection of objects moving well beyond the boundaries of the wind farm (Schmaljohann et al. 2008; Nilsson et al. 2018). Radar-based ASDoD distinguishes birds from man-made objects by the unique echo signals produced by the high water content of bird bodies – a trait which was incidentally discovered in 1941 (see Fox and Beasley 2010) – and aims to be sensitive enough to detect objects as small as birds, without being confounded by insects or rain. Radar-detection systems mostly classify birds by size (Harmata et al. 1999), although some options such as BirdScan MV1 and MS1 (Swiss Birdradar Solution AG, Switzerland) can classify birds into groups using wingbeat frequency (Zaugg et al. 2008; Schmid et al. 2019), among other flight pattern cues.

Radar-based ASDoD generally have detection ranges of five to 15 kilometres, surpassing even OSDoD (Krijgsveld et al. 2011; Gerringer et al. 2016; Nilsson et al. 2018). This coverage is further bolstered by radar's continuous performance throughout day and night, as well as in inclement weather such as fog, mist, and moderate rain – an ability absent from other SDoD options without further interventions (thermal imaging, scheduled shutdowns, etc.). However, at shorter distances, radar may underperform relative to other SDoD options (Corbeau et al. 2021), and spatial coverage may also be hampered by landscape characteristics. Radar ASDoD systems are well suited to flatter terrain and are frequently employed at offshore wind farms (Nicholls et al. 2022; Skov 2023).

Radar ability to detect birds is influenced by:

- **Radar type.** There are several radar options relevant to ornithology.
  - Surveillance radar is the most widely adopted radar for ASDoD (Skov 2023). It provides higher spatial resolution than other radar types, enabling the collection of more detailed aerial movements of individual birds and bats (Skov 2023).

- Doppler radar tracks the Doppler shift – the perceived change in wave frequency – to infer the speed of flying birds. Doppler radar is also more impervious to background noise, although it is not sensitive enough to resolve the number of individual birds approaching a wind farm, and crucially cannot detect birds flying tangentially (head-on) to the radar (Bruderer 1997; Gauthreaux and Belser 2003; Diehl and Larkin 2005).
- Tracking radar can fixate on individual birds, tracking three-dimensional flight paths.

- **Wavelength.** Longer-wave (lower frequency) radar is more robust against weather disturbance, whereas short-wave (higher frequency) radar is more sensitive to detecting small objects such as birds (Bruderer 1997; Gauthreaux et al. 2019). While there is a broad spectrum of radio wavelengths for bird biomonitoring (Gauthreaux et al. 2019; Garcia-Rosa 2022), radar-based ASDoD employ either X-band (higher frequency) or S-band (lower frequency) radio waves (Skov 2023). Of these, X-band may be more attractive for onshore wind farms, which do not need to factor oceanic disturbances as readily as offshore counterparts do (Nicholls et al. 2022; Skov 2023).
- **Power output and antenna size.** The average power output (kW) of a radar system, and the antenna size thereof, determines the strength of signal and consequently the radar detection distances.
- **Receiver sensitivity.** The higher the signal-to-noise levels of the receiver, the better the radar can distil bird presence, and the smaller a bird the radar can detect at a given distance. To this end, radar ASDoD may employ noise-filtering software, although effective noise removal remains a challenge, especially with respect to heavy rain (Nicholls et al. 2022; Skov 2023). Relatedly, the spatial resolution of the radar determines the tracking precision of bird flights (Diehl and Larkin 2005; Gauthreaux and Belser 2003) and may deteriorate with increasing distance from the radar (Nicholls et al. 2022; Skov 2023).
- **Horizontal or vertical orientation.** Horizontally oriented radar scans the two-dimensional spatial distribution of birds, tracking flight speed and trajectory across the horizontal plane (360°). By contrast, vertically oriented radar tracks bird flight heights along the vertical plane (90°). Combined use of both horizontally and vertically oriented radar affords three-dimensional flightpath tracking and is recommended for ASDoD (Nicholls et al. 2022; Skov 2023).
- **Continuous or pulsed waveform.** Pulsed radar uses delayed transmission and reception of pulsed signal to measure the distance to a bird. Pulsed radar is generally preferred for bird ASDoD (Nicholls et al. 2022; Skov 2023). By contrast, continuous wave radar constantly transmits signals, and can perceive the Doppler shifts to infer flight species, while being able to determine distance to a bird if the wave frequency is modulated. However, continuous wave radar affords only short-range detection and therefore is seldom used for bird monitoring (Bruderer 1997).
- **Radar beam width.** Fan-beam radar emits signals with wide vertical (10–30°) and narrow horizontal (≤2°) widths. Fan-beam radar resolves bird position well only in the horizontal plane, but gauges flight altitude poorly (Bruderer 1997). Pencil beams are either fixed-width or conical signals used for scanning the three-dimensional spatial distribution of birds in half-spheres above the radar and provide better clarity of flight height, although they have short-range applicability only (Eastwood 1967; Bruderer 1997).

6.1.3. Optic-radar composite systems

The integration of camera and radar technologies into a single system is a promising prospect. Such 'composite' automated detection systems confer the benefits of short-range optics monitoring and species classifications, with the anticipatory power of long-range radar detection. Currently, the only commercially viable integrated optic-radar system is the Detect True3DTM Radar (Detect®, USA). Several novel integrated systems are in development, although the implementation, reliability and cost effectiveness of these systems remains to be determined.

6.2. WHERE HAS ASDoD WORKED?

Despite the international adoption of ASDoD approaches at wind farms, with many ASDoD system suppliers claiming dependable track records, there remain comparatively few independent, peer-reviewed studies validating the effectiveness of these systems in reducing avian collisions with wind farm infrastructure. In addition, wind farm operators are in general reluctant to disclose facility fatality data in the public domain. Non-standardised approaches for evaluating effectiveness further complicate the comparison of system performance (Conkling et al. 2022; Ballester et al. 2024). A significant impediment to robust ASDoD evaluation is the ethical concern surrounding the intentional, multi-year delay in system installations at focal wind farms that would be necessary to conduct Before-After-Control-Impact (BACI) assessments (Huso and Dalthorp 2023; Smallwood and Bell 2020), as well as for comparison between equipped versus unequipped wind farms. Newer ASDoD technologies may also require several more years of deployment before such data would become available. While it intuitively follows that surveillance systems that can reliably detect birds and issue timely shutdown instructions when necessary should reduce bird–turbine collisions, the lack of independent verification for many of these systems and the equivocal results in the grey literature, together with continued avian mortalities at some ASDoD-adopting wind farms (McClure et al. 2021, 2022; Rogers 2022; ERA Planning and Environment 2024), remain a hurdle to be overcome.

In South Africa, the use of ASDoD as an alternative to OSDoD is still undergoing experimental trialling. Verifying the efficacy of these systems in a local context will take time and relevant information specific to South Africa is currently limited.

6.2.1. Monoscopic systems

No peer-reviewed studies demonstrating the effectiveness of monoscopic ASDoD systems have been published, although the following case studies assessing the reliability of several systems were uncovered.

Calandawind wind turbine, Switzerland – DTBird® (2014–2015)

The Swiss Ornithological Institute assessed DTBird® detection efficacy at the Calandawind wind turbine in Haldenstein, Switzerland, in 2014 (Aschwanden et al. 2015). While bird-flight detection rates were not determined, 69.3% of video records were not triggered by birds. Red Kite (1.75–1.95 m wingspan) was detectable from 150 m, and Common Kestrel (0.75 m wingspan) from 70 m. Smaller birds were less reliably detected. This report also commented that it was challenging to assess the effectiveness of the shutdown protocol itself, as few birds breached the relatively small risk sphere for triggering deterrence/shutdowns.

Manzana Wind Power Project, USA – DTBird® (2016–2018)

The American Wind Wildlife Institute assessed DTBird® detection and deterrence efficacy at the 189 MW Manzana Wind Power Project in California, USA, in 2016–2017 (Harvey et al. 2018). Screening of bird-detection records revealed that 36% of detection events were caused by objects other than birds, namely aircraft, clouds, insects and even rotating turbine blades. Of these false detections, 80% triggered the deterrence sirens. Among detected raptors which triggered the deterrence sirens, 36–40% showed definite flight response (ranging from 20–52% among identified raptor species). Harvey et al. (2018) additionally assessed DTBird® detection using two unmanned aerial vehicles with two-metre wingspans, modelled to resemble Golden Eagles. DTBird® detected an average of 63% of these controlled flights, with detection rates increasing from 51% at over 230 m distances to more than 85% at 80–140 m distances. Harvey et al. (2018) determined that DTBird® conferred a collision risk reduction of 33–53% for the Golden Eagle, based on apparent detection and deterrent effectiveness for the species.

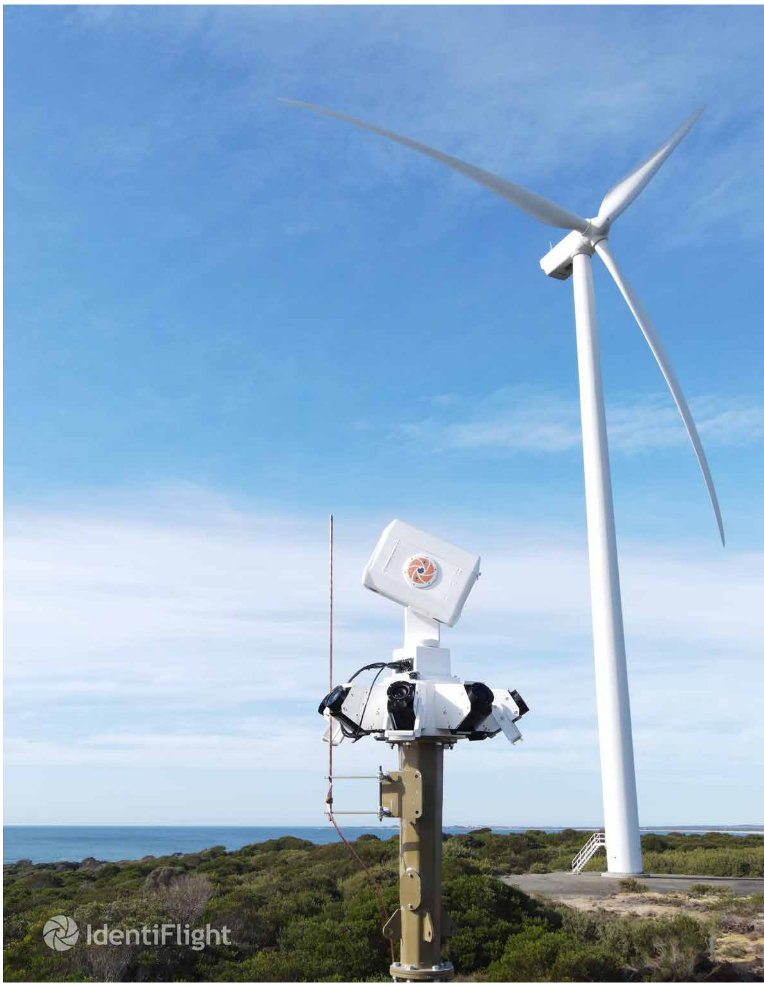
6.2.2. Stereoscopic systems

Currently, IdentiFlight® (Boulder Imaging, USA) is the only automated detection system for which effectiveness at reducing bird–turbine collisions has undergone independent, peer-reviewed assessment, although evaluations are available for Bird Protection System (Bioseco SA, Poland).

Top of the World Windpower Project, USA – IdentiFlight® (2016–2023)

McClure et al. (2021) determined that IdentiFlight® reduced Bald Eagle and Golden Eagle mortalities at the 200 MW Top of the World Windpower Project in Wyoming, USA, by 82% (95% CI: 75–89%). This finding was later disputed by Huso and Dalthorp (2023), who amended this estimate to a 50% reduction (95% CI: -159–89%). In a follow-up response, however, McClure et al. (2023) defended their original study design and asserted that the findings of McClure et al. (2021) remain valid.

McClure et al. (2018), investigated how well IdentiFlight® can detect the flight paths of birds the size of the American Kestrel (51–61 cm wingspan) or larger, within a 1 000 m survey radius, and how frequently IdentiFlight® correctly classifies birds as 'eagles' and 'non-eagles' (defined in this study as any bird species which is neither a Bald Eagle nor a Golden Eagle). These authors found that IdentiFlight® detected 6.6 times more bird flights than did field observers, and nearly all (96%) of the flights detected by field observers. However, field observers were better able to recognise eagles than IdentiFlight®, which failed to classify 6% of eagles of confirmed eagle flights, and misclassified 28% of non-eagles (particularly Turkey Vultures, Red-tailed Hawks and Common Ravens) as eagles. This study also showed that, on average, IdentiFlight® could correctly classify eagles further away (793 m) than non-eagles (537 m).



RYAN LUTTRELL

An Identiflight stereoscopic multi-camera system installed near to a wind turbine.

Manzana Wind Power Project, USA – IdentiFlight® (2018–2019)

Duerr et al. (2023) tested the detection-classification ability of IdentiFlight® at the 189 MW Manzana Wind Power Project in California, USA, and determined that IdentiFlight® could correctly classify 77.0% of detected eagles, and 85.2% of non-eagles (non-eagle bird species, inanimate flying objects, and objects of uncertain identity), with an overall accuracy of 86% across all records. This study found that IdentiFlight® failed to identify 13% of confirmed eagles, and classified 20% of non-eagles – especially Common Ravens – as eagles. When the IdentiFlight® system was updated to include a neural network for better classification of Common Ravens, the system could better classify non-eagles, but at the expense of recognising eagles. Interestingly, this study also found that the initial feature-based identification algorithm outperformed the combined feature-based and neural network algorithms eventually used and upgraded, and that equipment issues – namely gasket failures occluding the cameras with oily residue – had a surprisingly low impact on classification error rates. Overall, Duerr et al. (2023) found that six times as many shutdown events were triggered for non-eagles compared to eagles, and that the trade-off in error rates between eagle non-recognition vs potential misclassification of non-eagles as eagles can be adjusted depending on the wind farm's risk tolerance level.

Six wind farms in Germany – IdentiFlight® (2018–2020)

An independent assessment of IdentiFlight® was conducted by The Regional Planning and Environmental Research Group across six wind farms in Germany from 2018 to 2020 to determine how well the system could protect Red Kites (Reichenbach et al. 2021). This investigation found that IdentiFlight® was functional for 93% of the survey period, with interruptions in temporal coverage due to system and power supply failures. IdentiFlight® was found to have a 92% detection rate for Red Kites, detecting this species at an average distance of 803 m (maximum 1 199 m). In addition, IdentiFlight® was able to estimate distance to within eight metres and flight heights to within 1.7–3.2 m. Among detected bird flights, IdentiFlight® was eventually able to correctly classify 96.5–97.55% of Red Kites within 750 m but misclassified 2–16% of other bird species as Red Kites. It was also found that 77–91% of shutdown events could be achieved before Red Kites entered the RSZ. Overall, Reichenbach et al. (2021) concluded that IdentiFlight® conferred a 75% protection efficacy for Red Kite mortalities across the six assessed wind farms in Germany.

Cattle Hill Wind Farm, Australia – IdentiFlight® (2020–2023)

For the first Australian installation of IdentiFlight® at the 150 MW Cattle Hill Wind Farm in Tasmania, the system underwent a state-mandated 18-month trial period from the start of wind farm operation (August 2020), undertaken by Goldwind Australia (Rogers et al. 2022). Sixteen IdentiFlight® towers were installed at this wind farm from November 2019 for the protection of Wedge-tailed Eagles and White-bellied Sea Eagles. After a year of fine-tuning, the system was able to correctly classify 92.24–93.00% of detected flight tracks, failing to recognise 0.92–2.82% of eagle flights. The system misclassified 14.04–24.13% of other bird species flights – particularly ravens – as eagles.

During this trial period, three Wedge-tailed Eagle mortalities were reported, which were determined to be attributable to either operator error or occlusion by vegetation, rather than failure of IdentiFlight® effectiveness. Consequently, the turbine shutdown protocol was amended to prevent manual override of IdentiFlight® instructions, and occluding vegetation was removed. Rogers et al. (2022) further remarked that the number of Wedge-tailed Eagle mortalities (three) was less than the five to eight mortalities predicted by the pre-construction collision risk model.

From July 2022 to June 2023, five more Wedge-tailed Eagle mortalities were reported (Rogers 2023). Root cause analysis revealed that seven of the eight cumulatively recorded Wedge-tailed Eagle mortalities were due to vegetation occluding detection of low-flying birds. Following this, additional vegetation was cleared and certain IdentiFlight® towers were relocated. Additionally, a 30-m IdentiFlight® tower was installed to detect eagles above the vegetation heights. Rogers (2023) also highlighted that the increased eagle flight activity over the operational wind farm compared to pre-construction surveys, as well as a distinct south-westward spatial shift in eagle flight activity, may have contributed to the unexpected mortalities.

Despite the concerns over Wedge-tailed Eagle mortalities, no White-bellied Sea Eagle mortalities were recorded during the 3.8 years of assessed IdentiFlight® operation at the wind farm. During this time, IdentiFlight® issued on average 444 shutdown requests per day for eagle protection.

Poland – Bird Protection System (2021)

Gradolewski et al. (2021) produced a peer-reviewed publication evaluating a prototype of their Bird Protection System (BPS) at an undisclosed wind farm in northern Poland in 2020 and found that this prototype detected 91.4% of human-observed flights. While BPS could detect all human-observed bird flights within 100 m, detection reliability decreased beyond 150 m. The BPS prototype distance estimation was found to be accurate to within 2.85 m at a distance of 143.3 m. Small birds (0.68–1.25 m wingspan) were stated to be detectable up to 150 m, medium birds (1.26–1.50 m wingspan) up to 250 m, and large birds (>1.50 m wingspan) up to 300 m.

Szurlej-Kielanska and Pilacka (2022) provided a follow-up peer-reviewed evaluation of their BPS from a wind farm in northern Poland in 2020. This study showed BPS to have a detection rate of 91.5% for birds of >0.5 m wingspan, varying from 88.6% for Common Buzzard to 100% for Marsh Harrier and White-tailed Eagle. Small birds (0.5–1.1 m wingspan) and large birds (>1.1 m wingspan) were 100% detectable within 200 m and 300 m respectively, with the latter being 75% detectable at 600 m. BPS employs a size-based classification scheme, which was shown in this study to correctly estimate or over-estimate the size of 91% of detected birds, while underestimating 9%.

Wind Energy Research Cluster South, Switzerland – Bird Protection System (2019)

The Swiss Ornithological Institute assessed the detection-classification performance of BPS at the Wind Energy Research Cluster South in Switzerland in 2019 (Aschwanden and Liechti 2019). This independent investigation assessed detection of bird flight paths within a 500 m radius of the mounted modules, taking into account that the system has 'blind spots' above and below the 60° vertical opening angle. Small birds (0.6–1.0 m wingspan) were detectable with 60% efficiency up to 100–150 m. Medium birds (1.0–1.5 m wingspan) were detectable with 25% efficiency up to 250–300 m. Large birds (>1.5 m) were detectable with 12.5% efficiency up to 350–400 m. Of the flights recorded by the system, 7.0% were not triggered by birds (false positives), while 6.2% of bird flights tracked by laser range-finder failed to be recognised by the system as birds (false negatives). Bird size-based classification accuracy was 50% for Red Kite (large/medium-sized bird), 10% for Common Buzzard (medium-sized bird), and 75% for Common Kestrel (small bird). The reaction performance of BPS, and the effectiveness thereof, was not assessed during this investigation.

6.2.3.Radar systems

Radar-based biomonitoring has been extensively applied to assess the bird collision risks at wind farms, especially as this relates to nocturnal migrations/movements (Aschwanden et al. 2018; Bradarić et al. 2024; Hirschhofer et al. 2024), as well as the potential displacement of migratory bird populations from offshore wind farms (Plonczkier and Simms 2012). The U.S. Fish and Wildlife Service (USFWS) has employed MERLIN Avian Radar System (Detect Inc., USA) to develop the Avian Radar Project and Great Lakes Airspace Decision Support Tool to inform the planning of wind farms and other developments relevant to aeroconservation (USFWS 2024). In South Africa, radar (EchoTrack™) and observer-based biomonitoring has helped highlight the vulnerability of Great White Pelicans to a prospective wind farm in the Western Cape (Jenkins et al. 2018), and has been shown to outperform human-based detection of Cape Vultures approaching wind farms (Becker et al. 2020).

No independent studies into the mortality-reducing efficacy of radar ASDoD are currently available, although using BirdTrack® (STRIX) along with field observers (OSDoD, see Section 6) purportedly prevented turbine collision mortalities of large, soaring birds during the boreal spring migration events at a wind farm in southern Portugal from 2010–2014 (Tomé et al. 2017).

JACKAL BUZZARD ALBERT FRONEMAN

6.3. EVALUATION OF ASDoD PERFORMANCE

As with OSDoD, ASDoD seeks to prevent turbine collisions of target bird species, an aim which requires effecting turbine curtailment well in advance of anticipated collision events. This objective is achieved through the same set of operating principles across the three classes of ASDoD, namely:

1) Functional specifications
2) Detection of targets
3) Classification of targets
4) Reaction

A standardised framework for ASDoD performance evaluation has been developed by the MAPE (Reduction of Avian Mortality in Operating Wind Farms) Research Project in France (see Corbeau et al. 2021) and elaborated upon by Ballester et al. (2024). Sections 6.3.1.–6.3.4. briefly distil the assessment framework, to inform ASDoD implementation in South Africa. The comprehensive in-field assessment protocols are available via the MAPE Research Project website (www.mape.cnrs.fr). It is recommended that ASDoD performance be evaluated at each wind farm, as generalised capabilities of each automated detection system are frequently obtained under ideal conditions only.

6.3.1. Functional performance

As with OSDoD, the Surveillance Period and the Surveillance Area must both be well defined prior to implementation of ASDoD. Accordingly, both the temporal and spatial coverage must be sufficiently optimised for the ASDoD programme to be considered feasible. Some authors have expressed concern over limited rigour in evaluating the functioning of automated systems (Conkling et al. 2022). It is therefore imperative that the ASDoD functionality be properly understood to ensure dependability of the system's downstream processes.

To evaluate ASDoD temporal coverage, the frequency of complete failures (system non-operation) can be most effectively determined by assessing the number of days with zero detection/classification events from a randomised selection of recorded data over several months/years. This can be used to provide a daily probability of the system experiencing complete failure. Alternatively, randomised site visits (>100 visitations) can be conducted to assess whether the system does not respond appropriately to known targets. To evaluate ASDoD spatial coverage, the blind spots within the detection sphere of each of the system's modules will need to be exhaustively mapped (detailed in Ballester et al. 2024).

6.3.2. Object detection

Automated detection systems should be able to detect nearly all airborne objects within the Surveillance Area and Surveillance Period. In general, object detection and classification are performed simultaneously, so both Corbeau et al. (2021) and Ballester et al. (2024) evaluate these aspects together, although some aspects of classification performance can be considered separately (see Section 6.3.1.). Detection capabilities vary greatly across automated detection systems and are further impacted by operating conditions and characteristics of the approaching target, such as:

- **Distance.** The further away an object is, the less likely it will be detected.
- **Object size (bird species).** The smaller an object, the less likely it will be detected at a given distance.
- **Object/bird velocity.** It may be harder to detect and classify objects moving at high speeds.
- **Object position and trajectory.** The detection system should not only be able to detect birds from any direction, but also birds dropping steeply from high altitudes, as well as birds ascending steeply from the ground or along cliffs (which often present blind spots in the Surveillance Area).
- **Sun position.** Cameras directly facing the sun may be 'blinded' momentarily, or the glare from the sun may impede the classification.
- **Weather conditions.** Low-visibility conditions and inclement weather can make it harder to detect and classify objects.
- **Background.** Objects are best detected and classified against a uniform background, such as a clear blue sky. However, real-world scenarios often involve complex or moving backgrounds (clouds, mountains, trees, etc.).

ASDoD detection-classification performance can be assessed by the probability of target species correctly being detected/classified prior to reaching the risk zone threshold. This can be broadly achieved by comparing detection-classification data from the automated detection system to that obtained from an independent monitoring regime.

To this end, four methods are commonly employed.

- **Human observers** (recommended, see Ballester et al. 2024). Field observers monitor birds, tracking flight paths of incoming birds using laser rangefinders (see McClure et al. 2018).
  - Pro: robust approach yielding unbiased estimates which directly translate to detection-classification capabilities in situ.
  - Con: time and labour intensive, with smaller sample sizes.

- **GPS tracking of wild birds** (recommended, see Ballester et al. 2024). Resident individuals of target species at the wind farm are equipped with GPS-tracking devices to precisely monitor their 3D geolocation data (latitude, longitude and altitude) in real time at fine timescales (see Khosravifard et al. 2020).
  - Pro: based on real-time wild bird flight trajectories, and so yields unbiased detection-classification estimates.
  - Con: requires specialised labour to tag relevant birds and only a few birds can be tagged, yielding smaller sample sizes and weaker inferential power.

- **Drones** (not recommended, see Ballester et al. 2024). Drones are deployed to mimic approaching birds at the wind farm (see Gradolewski et al. 2021).
  - Pro: precisely controlled drone flight trajectories enable potentially exhaustive assessment of detection abilities.
  - Con: drone flights do not reflect wild bird flight behaviour, potentially presenting misleading estimates of detection abilities.

- **Falconry** (not recommended by Ballester et al. (2024). Trained raptor species are used to mimic target birds approaching the wind farm (see Brighton et al. 2017).
  - Pro: as with drones, trained falcon flights can afford rigorous assessment of detection abilities.
  - Con: trained raptor flight behaviour does not necessarily correspond to that of wild birds, which can bias detection ability assessments.

Separate detection-classification evaluation protocols are provided for system suppliers and wind farms:

- **System supplier protocol.** Detection probabilities (with 95% confidence intervals) should be obtained at 100-metre intervals up to the maximum expected detection distance. The evaluations should be repeated across the following variables, to account for a range of operating conditions: visibility (m), luminosity (lx), global radiation (J/cm2/hr), rainfall (mm/10 min), background (sky, vegetation, mountain), sun azimuth (°), sun incidence (°), bird horizontal position (°), and bird vertical angle (°). In addition, these evaluations should be repeated for different bird size classes, such as those recommended by Corbeau et al. (2021):
  - Small – 0.4- to 1.0-metre wingspan
  - Medium – 1.0- to 2.0-metre wingspan
  - Large – >2.0-metre wingspan

- **Wind farm protocol.** Detection-classification probabilities should be obtained for all target species, at predetermined distances from the turbines, based on known flight behaviour of each bird species and site characteristics of the wind farm.

To further inform the ASDoD reliability, detection-classification probabilities should be presented according to the following three parameters:

- True positive rate. The rate at which the system correctly detects and classifies approaching objects.
- False negative rate. The rate at which the system fails to detect and classify target species.
- False positive rate. The rate at which a non-relevant object is misclassified.

6.3.3. Classification of targets

Classification is the information processing undertaken to distinguish approaching birds from bats, insects, aircraft, clouds, and moving vegetation, as well as to determine whether detected birds warrant triggering a reaction. This decision-making process is broadly informed by the size and configuration of an object, and possibly by its flight speed and trajectory.

As explained in Section 6.3.2., classification is a nested function within detection, with the detection-classification performance being a pivotal aspect of an ASDoD system. If detection-classification performance is reliable, then the downstream shutdown protocol can better protect the target species. ASDoD systems with more precise classification capabilities, especially to species level, help focus required shutdowns to incoming target species only, reducing the yield loss and mechanical wear incurred through unnecessary shutdowns (Allison et al. 2017; Duerr et al. 2023). As such, innovations behind the classification process remain the proprietary knowledge of automated detection system suppliers, further precluding an understanding of the criteria driving the decision-making process. Nevertheless, automated classification is an integral component of ASDoD and a major appeal of this responsive mitigation measure.

The purported bird-classification abilities of an automated detection system, however, can be appreciated in advance of purchase. Bird-classification schemes broadly fall into two categories:

- **Size-based classification**. All automated detection systems discriminate birds by size. This may be an artefact of poor sensitivity, limiting detection to larger birds, the predominant size class of target species. More advanced detection systems, however, can classify bird size algorithmically, defaulting to this classification scheme when inclement/low-visibility conditions preclude species identification. Monoscopic and stereoscopic systems infer bird size through pixel count, although the latter can factor in distance of the approaching bird, yielding more accurate size estimates (Aschwanden and Liechti 2019; Gradolewski et al. 2021; Duerr et al. 2023). For radar, bird size is inferred through echo characteristics and wingbeat frequency (Zaugg et al. 2008; Schmid et al. 2019).

- **Bird group and species identification.** Ongoing advancements in AI are expanding automated bird-classification abilities (such as Niemi and Tantu 2018; Ragib et al. 2020; Manna et al. 2023; Vo et al. 2023), and monoscopic and stereoscopic systems are increasingly employing these technologies to algorithmically resolve bird identification to group or species level in real time. The dependability of such automated bird classification has been independently validated for one system, IdentiFlight® (Boulder Imaging, USA), which correctly identified 77–85% of assessed birds (Duerr et al. 2023). High-confidence classification (>90% correct) bird group/species classification requires training the AI software on very large samples of more than 10 000 images/videos (Wäldchen and Mäder 2018). Crucially, the AI models must be trained to account for intraspecific variation, particularly among raptor species, as well as bird appearance under different lighting conditions and at different flight angles (bottom view, top view, side view). These AI-model training procedures may be time consuming, although are being increasingly expedited, with IdentiFlight® purportedly requiring only two to three weeks to 'learn' a new bird species (Nesbitt, pers. comm. May 2024).

The classification abilities of commercially available automated detection systems are provided in the ASDoD Compendium.

6.3.4. Reaction

Two types of automated reactions are commonly deployed upon detection of target bird(s): deterrence and turbine shutdown.

Deterrents comprise audio or visual signals (or both) to discourage incoming target birds from approaching a risk zone, but not all systems include deterrent options. Auditory deterrents are considered the most effective (May et al. 2015; Harvey et al. 2018), although long-term use of these deterrents may reduce their efficacy due to habituation by birds to the stimuli (Hanagasioglu et al. 2015; Avery and Werner 2017; Harvey et al. 2018). Habituation may also apply to strobe lights and laser deterrents (visual deterrents), a less common, albeit potentially effective deterrent approach in low-light conditions (Cook et al. 2011). In South Africa, audio deterrents have been deployed only at the Jeffreys Bay Wind Farm (Lötter and MacEwan 2024), and their efficacy remains to be determined. The use of deterrents to bolster OSDoD programmes may have relevance in certain instances, preferably after trialling of the technology has proven successful in the long term.

Turbine shutdown is the pivotal reaction of an automated detection system. Automated turbine shutdown requires finely tuned integration of the automated detection system with the SCADA, which necessitates the involvement of skilled technicians. Calibration, configuration and troubleshooting of this system coupling may be time-consuming. It is crucial that configuration considers likely deceleration time (dependent on turbine model) across a range of wind speeds. Depending on wind farm requirements and the capabilities of the automated detection system, shutdown may be applied to individual or multiple turbines.

Reaction performance depends on stable internet connection, as well as the integrity of the internal network of the wind farm, as both are required to relay turbine shutdown orders to the SCADA. Connectivity failures may delay or prevent reactions. In addition, it should be noted that certain wind turbines may ignore newer shutdown orders while still processing an earlier order.

For an ASDoD programme's reaction performance to be considered reliable, it is expected that the reaction measures be fully deployable prior to the incoming birds breaching the RSZ. Reaction performance can be evaluated by determining the probability that i) the automated detection system will couple correctly with the SCADA to engage turbine shutdown protocols, and ii) that the deterrents (if applicable) are appropriately engaged upon triggering. The former probability can be obtained by comparing the number of turbine shutdowns instructed by the automated detection system with the number enacted by the SCADA, while the latter can be obtained by comparing detection-reaction data from the system (these probabilities need only consider the expected number of instructions vs. enactment events). **As with OSDoD, the most important success metric will be determined through a concurrent PFCM programme.**

6.4. KEY CONSIDERATIONS FOR IMPLEMENTING A SUCCESSFUL ASDoD PROGRAMME

A number of practical considerations have emerged as being relevant to the successful implementation of ASDoD. These are unlikely to be anticipated by operators and may also not be fully transparent during procurement from suppliers. In order to avoid delays in implementation or compromised efficacy, it is recommended that projects consider the following factors:

- **Reliable internet connectivity** is required for automated systems to function, and in particular to communicate with the SCADA system. Important factors to consider are firewall settings and constraints (including cross-border implications), cyber security, and wind farm in-house IT skills for trouble-shooting on site.
- **Software and hardware updates.** For most systems it is unclear how frequently these could take place and whether these would incur additional costs.
- **Turbine warranty/insurance implications.** In the case of systems that are installed on turbine towers, this may have implications for warranties.
- **Power supply.** Automated systems need to be powered, and the implications of getting power cabling to camera/radar locations need to be considered. This is particularly important in instances where automated systems need to be installed and trained early on, in order to be fully operational by COD.
- **Security of equipment.** Expensive electronic equipment invariably attracts attention in rural landscapes, and measures will need to be taken to guard against theft and vandalism.
- **Ongoing operational support, trouble-shooting.** The extent to which system suppliers will provide this, and the costs thereof are currently a little unclear.
- **Local bird species recognition.** Despite claims by system suppliers, the extent to which systems can learn South African species within the time frames promised remains to be seen. In all cases it is recommended that projects obtain support in evaluating and training systems from a local avifaunal specialist.
- **Data access, availability, ownership, intellectual property.** The extent to which automated systems collect and store bird flight data, and the extent to which this is made available to wind farms and their avifaunal specialists, is an unknown at this stage.
- **Upgrading** of detection systems (hardware and software) may need to be considered as newer models become available over the long-term. This is especially true if the original installation has been underperforming in terms of the project's KPAs.
- **Collective responses.** It may be possible for multiple projects to collaborate in order to train systems for local bird species' recognition more easily or more effectively.

WHITE-BACKED VULTURES ALBERT FRONEMAN

7. COMPARISON OF THE TWO SDoD APPROACHES

Common themes and challenges frequently emerged through consultation with wind farm developers, independent service providers and managers of South African and international OSDoD and ASDoD programmes. Table 5 provides these findings in the format of a generalised summary. For decision-makers to implement the most successful and cost-effective strategy, they are encouraged to consult directly with the supervising Avifaunal Specialist to determine the mitigation's limiting factors based on target bird species' requirements, and for careful liaison with a variety of service providers to be conducted as part of the project's due diligence. Unique site specificity emerged as the single largest barrier to simple comparison between mitigation options or extrapolation across project scales. It is also noted that hybrid systems employing a combination of OSDoD and ASDoD are possible and could capitalise on the strengths of both approaches. A successful example of this is provided in Text Box 5.

TABLE 5. Summarised comparisons between stand-alone options for Shutdown on Demand.

CRITERIA	PREDICTIVE SDoD	OSDoD	MONOSCOPIC ASDoD	STEREOSCOPIC ASDoD	RADAR ASDoD
Effectiveness peer-reviewed	No	No	No	Yes	No
Deployment in South Africa	Trials	Five wind farms	Trials	Trials	No
Use at night	Yes	No/limited	Limited[1]	Limited[1]	Yes
Use in inclement weather	Yes	Limited	Limited[1]	Limited[1]	Mostly yes
Detection rate	-	Unassessed	76–96 % (DTBird®)[1]	96% (IdentiFlight®)[1]	Unassessed, very high
Detection range overall	-	>2 km	300–1 300 m[1,2]	600–1 300 m[1,2]	10–15 km[1,2]
Minimum detectable wingspan at 1 000 m	-	ca. 1.0 m	ca. 2.0 m[1]	ca. 1.0–2.0 m[1]	ca. 1.0m
Target species resolution	-	Species-level	Group-level[1]	Species-level[1]	Size-based
False positive target species classification rate	-	Unassessed, very low	~50%[1,3]	28%[1,3]	Unassessed, moderate
Flight path mapping	-	Limited	No	Yes	Yes
Use in remote locations	Very easy	Challenging	Easy	Easy	Easy
Use in inaccessible areas of the wind farm	Very easy	Challenging	Easy	Easy	Easy
Spatial constraints	None	Site remoteness and accessibility. Landowner consent required in restricted-access areas	None	None	Radar-restricted areas
Connectivity requirement to communicate with operator/ SCADA	-	Cellphone reception; none if using hand-held transceivers	Secure internet	Secure internet	Secure internet
Theft concern	None	None	High	High	High
Installation costs	Very low	Low	Moderate	High	Very high
Operational costs	Very low	Very high	Moderate	Moderate	Moderate
Key operational requirements	Species-specific collision risk models	Observer training Staff salaries Staff transport Amenities	System cleaning Skilled technicians for trouble-shooting High installation costs	Routine maintenance Skilled technicians for trouble-shooting High installation costs	Routine maintenance Skilled technicians for trouble-shooting Very high installation costs
Drawbacks for the wind farm	Prolonged shutdowns (lessened using predictive models)	High operational costs and logistical constraints	Long lead times	Long lead times	Long lead times

[1] denotes ASDoD system-dependent values, [2] denotes bird size-dependent values, and [3] denotes values subject to refinement

8. SUPPLEMENTARY MEASURES

SDoD can in some cases be supplemented with additional avifaunal activities, which may aid and augment the overall system performance. It is noted that limited experience exists with the use of these measures, and so evidence of efficacy is generally not yet available. Examples of these supplementary approaches include:

Tracking of resident birds. Tagging individual birds with tracking devices can provide detailed insights into the movements of key individuals thought to be vulnerable to turbine collisions. Global positioning system (GPS) devices can only be deployed on species of birds that have a body mass greater than approximately 100 g, due to ethical weight constraints (Casper 2009 and references therein). Radio-tagging offers an alternative solution for smaller-bodied species. Telemetry can be used to supplement OSDoD by providing precise whereabouts of the at-risk individuals to the observers. As with standard OSDoD, if the tracking data show these individuals to have breached the risk-sphere threshold, shutdown instructions can be made by the team; it is also possible that this protocol can be automated. Telemetry-assisted shutdown has the advantage of potentially providing continuous monitoring, albeit of select resident individuals.

Infrared and thermal cameras can detect infrared (~10 µm) and thermal (~100 µm) wavelengths of light respectively, and can be implemented alongside visual cameras to provide potentially continuous diurnal and nocturnal functionality, as well as in foggy conditions. However, the detection distance of thermal cameras is greatly diminished compared to visual cameras. In addition, thermal camera resolution is lower than that of visual cameras. The resolution of the thermal lens may depend on whether the lens is cooled or uncooled. Cooled thermal cameras are more expensive and use an integrated cryogenic cooler, which chills the thermal image core to increase the sensitivity and accuracy of the thermal image. Certain systems, such as DTBird® (Liquen Consultoría Ambiental, Spain), BLSA® (Volacom AD, Bulgaria) and Bird Protect™ (Irida Technologies, Greece), allow for combined visual and thermal recordings.

Acoustic monitoring through microphones deployed on the wind farms, along the outer perimeter, on the tower and/or on the nacelle. Depending on where the microphone is positioned, background noise can become more pronounced, resulting in the application not functioning effectively. Acoustic monitoring is more relevant as a bat mitigation tool, but may have applicability for birds, though only for species which vocalise reliably when in flight. Species identification is possible using acoustic recognition (this is the primary means of field-based bat identification), although there is the risk of potentially more false positive detections than camera-based ASDoD and OSDoD. Available acoustic monitoring options are self-contained units which do not have remote-controlled access, and the full implementation of this monitoring type in SDoD is pending.

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9. CONCLUSION

The avian fatality rate at South Africa's pioneering wind farms has been estimated to average 4.1 birds per turbine per year (Ralston-Paton et al. 2017), falling within the range of that observed at wind farms in North America (median 1.6 birds/turbine/year) and Europe (median 6.5 birds/turbine/year) (Rydell et al. 2012).

Forecasts for the continued growth in South Africa's wind energy output thus indicate that many thousands of the country's avifauna may be at increasing risk of fatal collision. Given the mounting threats to birds posed by other existing anthropogenic sources, many species, including some most at risk from turbine collisions, are already at the tipping point towards extinction and accordingly may not be able to withstand this additional threat.

Against this it is recognised that investment in renewable energies provides enormous economic development potential and a practical trajectory towards a carbon-neutral future; one in which significantly fewer avian deaths may result when compared to those projected as a result of an ongoing reliance on fossil fuels (Sovacool 2009). Adherence to the impact mitigation hierarchy through avoidance, minimisation, restoration and biodiversity offsets therefore provides the best framework currently available for the sustainable management of South Africa's avifaunal biodiversity.

Implementation of responsive SDoD programmes at wind farms around the world has shown great promise in mitigating the negative impacts of wind energy on avifauna. It is however not a panacea, and even a highly successful SDoD programme is likely to require complementary mitigation in the form of blade patterning, carcass removal practices, deterrents or predictive shutdown schedules, which should be investigated in tandem with SDoD. Accordingly, the application of SDoD does not replace the need for compliance with other EA conditions relating to avifaunal mitigation, and commitment to its use cannot invalidate the supervising Avifaunal Specialist's further recommendations. In all cases, PCFM should continue for as long as SDoD is in place as this remains the golden standard for assessing the efficacy of mitigation measures.

This report has outlined when SDoD is appropriate, detailed the stages to be followed for the implementation of an effective SDoD programme over the lifespan of a wind energy facility, reviewed currently available options, and summarised the comparable advantages and disadvantages of both OSDoD and ASDoD.

Through consultation with various experts in this sector, it has emerged that each wind farm will face a unique interplay of environmental challenges that stem from a tangled web of variables. The site's location will determine the envelope of affected target bird species, environmental sensitivity and other constraints. Project specifications such as turbine layout, number, size and spacing relative to topography influence the risk sphere and how it may be adequately covered by SDoD methods. Dynamic conditions such as weather and drought cycles influence bird activity unpredictably and on very different temporal scales. It is easy to see how general comparisons between SDoD programmes and costing evaluations quickly become impractical.

Over time it is reasonable to expect that shutdowns at a wind farm may become less frequent as observers become more familiar with flight behaviour in the landscape and better at predicting risky situations. As communication channels are optimised between observers and operators, shutdown calls may be initiated later and production recommenced sooner. Automated systems may also be fine-tuned and upgraded to make use of the latest technology. Conversely, it may be that as more species are added to the Red Data Book of Birds of South Africa, Lesotho and Eswatini (Taylor et al, 2015; updated Lee et al, 2025) and the cumulative impacts of multiple facilities become better understood, legislation may dictate a stricter enforcement of mitigation.

Evidence regarding the effectiveness of SDoD at local and international wind farms is largely to be found through service provider websites or in media articles, instead of in peer-reviewed articles published in the scientific literature. It is recommended that this gap is urgently addressed in South Africa. A wealth of future research opportunities is immediately available and more collaboration, transparency and engagement will increase our collective understanding of how local bird species respond to wind energy and will improve our predictive power, not to mention optimising renewable energy output.

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Appendix 1

OBSERVER REQUIREMENTS AND JOB DESCRIPTION

OSDoD protocol requires that observers be stationed at OPs for all daylight hours, seven days a week, 365 days a year, through a wide range of weather conditions. The nature of the job requires that in addition to possessing the necessary skill set to perform their jobs well, staff members must have a true interest in and commitment to the task, a passion for avian conservation and an appreciation for its importance in the greater context of biodiversity preservation.

Equipment list

At all times during working hours, observers must be in possession of:

- Suitable binoculars. One pair per observer. A telescope (one per OP) is recommended
- Suitable chair. One per observer
- Personal Protective Equipment (PPE, e.g. high-visibility clothing and hard hats) in accordance with the wind farm's safety standards
- Clipboard, stationery and sufficient datasheets and/or charged tablet (method of data capture to be determined during project setup)
- Reliable access to other observers and the SCADA officials via charged devices such as two-way radios
- Charging station for two-way radios/mobile phones and/or portable battery station, or a charged power bank
- Printed and laminated map clearly displaying the layout of the wind farm with turbine numbers, key landscape features and location of OP(s)
- Smartphone or tablet with multimedia bird identification app such as Roberts Bird Guide 2 or equivalent (at least one per every four OPs)
- Printed bird field guide (book), e.g. Sasol Birds of Southern Africa or equivalent (one per OP)
- Stocked first-aid kit (one per OP)
- Access to ablution facilities
- On-site transport

Observation Point shelter requirements

- Preferably a raised platform with as near to 360° visibility as possible, with a view not obstructed by trees or buildings and positioned where typical approach of birds can be seen with sufficient time to initiate an effective shutdown (based on spatial input from pre-construction monitoring or on-site experience).
- Sufficiently large so that the observer(s) can freely move within the shelter without restrictions. It is suggested that this size is no smaller than 2 m x 2 m.
- Closed sides with a countertop height to break most of the wind, but comfortable to stand next to and not so high as to restrict the view when the observer is sitting.
- A fixed roof should be fitted to protect the observer from the elements such as sun, small amounts of rain, etc. The roof should be high enough so a tall person can stand and still have comfortable head clearance.
- It is suggested that the stands are built on four posts with a solid wood floor, raised above the ground to increase the lifespan of the structure. The height of the posts on which the stand is built will depend on the viewshed necessary to have a clear sight of the turbines.
- A solid staircase with railing is necessary for higher stands so observers can enter safely.
- It is suggested that a lightning rod is fitted to the stand to avoid lightning damaging the structure.

SAMANTHA RALSTON-PATON

An active Observation Point. A raised platform provides an elevated viewpoint on which observers can sit or stand, and from which 360° views are possible. Some shelter against the elements is also provided.

Appendix 2

FIELD DATASHEETS

Routine bird monitoring

A set of example datasheets is provided in **Table A1** and **Table A2**. To complete the **Field Data Recording Sheet (Table A1)**, each record will be given a specific number and include the following information:

a. **Species.** In situations where a record comprises an individual bird or a group of birds that cannot be identified to species level, the observer will assign the record to the nearest taxonomic level. For example, a harrier not identified as a particular species would be recorded as 'Harrier sp.'

b. **Number of individuals**. A record may range from a single individual to a flock of birds. If an observation of a flock of birds includes more than one species, the observer will record each species as a separate record in the bird movement table and label each of these records as part of a multi-species flock. For example, a large flock of Common Buzzards *Buteo buteo* could include a smaller number of Black Kites *Milvus migrans* and other species.

c. **Flying height**. The average height band in which the bird flew while in the wind farm should be recorded. Each record is assigned to one of three height bands: below collision-risk height (1) (0–40 m), at collision-risk height (2) (40–180 m) and above collision-risk height (3) (above 180 m). There is no need to record a detailed breakdown of flight height per 15-second interval during operational in-flight monitoring; this method is only important during the pre-construction phase.

d. **Direction**. The direction in which bird(s) are heading is entered as one of eight orientation categories: N, S, W, E, NW, NE, SW, SE.

e. **Duration within 500 m**. The length of time that the bird spent flying within 500 m of a turbine is recorded.

f. **Avoidance behaviour**. Any evidence of a bird or flock of birds changing direction due to the presence of turbines is indicated as either Yes (Y) or No (N).

g. **Notes**. These would normally include any further observations that the observer finds are valuable to add to the record. For example, this could include the age and/or sex of the bird being recorded or any unusual plumage or loss of feathers, etc.

h. **Elevated Risk Situations**[10]. Recorded during monitoring. The existence of an Elevated Risk Situation is recorded hourly during OP monitoring using the relevant row in the 'Weather Conditions and Elevated Risk Situations' field recording form. Where the reason for elevated risk is known, this is given in the **Additional Notes** section of the form. Examples of Elevated Risk Situations include a temporary high food availability, for example, an insect emergence for gregarious small raptors such as the Amur Falcon *Falco amurensis*, or dead livestock for vultures.

Collision Risk Event Log

To complete the **Collision Risk Event Log (Table A2)**, each record number must be cross-referenced with the ID number in the Field Data Recording Sheet. The observer will fill in the following information:

a. Species involved
b. Number of individuals involved
c. ID number of turbine(s) ordered for shutdown
d. Time of shutdown call
e. Time of actual turbine shutdown (i.e. turbine rotors stop moving)

After the end of a collision risk event (i.e. once the bird has moved back into the YELLOW zone), the observer will contact the operation unit to inform them to resume operation of the specified turbine(s) and will fill in the following information:

f. Time of call to resume turbine operation
g. Time of actual operation resumption (i.e. time rotors started moving)
h. Outcome of event (collision or no collision)
i. Were the correct turbines shut down?
j. Avoidance behaviour of bird(s)

Target Bird Species Incident Report

The Target Bird Species Incident Report (**Table A3**) should be completed after a target bird species collision has been recorded. This may be witnessed by observers occurring in real-time or may be the outcome of PCFM (as discussed in **Section 5.3**). It should be clearly stated exactly where the carcass or injured bird was found – this will indicate the implicated turbine or location under any overhead power lines (OHL) included in the PCFM. A detailed investigation should be conducted regarding the incident.

[10] Where supplementary ASDoD (e.g. radar) is implemented on a site, this may become the primary source of information available. Under pre-agreed-upon circumstances, predictive shutdown schedules come into effect.

TABLE A1. Field Data recording sheet (bird movements, weather conditions etc.)

FIELD DATA RECORDING SHEET _Page 1											
SITE:		DATE:		OP:		START TIME:		END TIME:		OBSERVERS:	
REC	ID	SPECIES	MULTI-SPP FLOCK CODE	NO.	START TIME	FLIGHT HEIGHT	DURATION INSIDE 500 m	FLIGHT DIRECTION	AVOIDANCE (Y/N)	NOTES (AGE, SEX, BEHAVIOUR ETC)	IN/OUT

WEATHER CONDITIONS AND ELEVATED RISK SITUATION STATUS_Page 2										
HOUR										
CLOUD/MIST (%)										
PRECIPITATION										
VISIBILITY (KM)										
ELEVATED RISK SITUATION										

INCIDENTAL OBSERVATION / NOTES

Note: The birds registered in the collision risk event log have a **Record #** that is cross-referenced with **Record ID** in the bird movement table

TABLE A2. Collision Risk Event Log (including all Near-Miss Incidents)

COLLISION RISK EVENT LOG (INCLUDING ALL NEAR-MISS INCIDENTS)									
SITE:		**DATE:**		**OP #:**	**START TIME:**		**END TIME:**		**OBSERVERS:**
REC	**Shutdown Order TIME**	**Shutdown Effect TIME**	**Turn On Order TIME**	**Turn On Effect TIME**	**TURBINES/ CLUSTERS**	**CONDITION**	**COLLISION Y/N**	**AVOIDANCE Y/N**	**NOTES (incl. correct turbine shutdown?)**

TABLE A3. Target bird species incident report

NATURE OF INCIDENT (TICK)	Fatality	Injury
	Other (state):	
GEOGRAPHIC LOCATION	Wind Turbine Generator #:	Coordinates:
	Other (state):	
REPORTED BY		
COMPANY		
INCIDENT DATE AND TIME	Date:	Time:
REPORT DATE AND TIME	Date:	Time:
REPORT AUTHOR		
INCIDENT DESCRIPTION		
MANAGEMENT RESPONSE		
PHOTOGRAPHS (ATTACH)		

Appendix 3

CONTRIBUTORS

Individual meetings and interviews

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BirdLife South Africa online Shutdown on Demand Workshop

A virtual Shutdown on Demand Workshop took place on 27 June 2024, facilitated by BirdLife South Africa. The objective was to obtain input from a South African target audience on key points relating to SDoD. The key discussion points and participants are detailed below.

- Welcome and introduction to the handbook
- When can/should SDOD be used?
- Observer-led Shutdown on Demand
- Automated Shutdown on Demand (technology)
- Comparison between Observer-led and Automated SDoD
- Wrap up, summary, way forward

Participants: John Gibbs and Samantha Ralston-Paton (BirdLife South Africa); Jon Smallie and Diane Smith (WildSkies Ecological Services); Albert Froneman and Jake Mulvaney (AfriAvian Environmental); Simon Hulka (IFC); Anja Albertyn; Anthony van Zyl; Caryn Clarke; Clarissa Mars; Dee Fischer DFFE; Eduard Drost; Fabio Venturi; Francois le Roex; Gareth Tate; Gavin Cowden; Jacob Claassen; Janine Brasington; Liam Leetz; Liandra Scott-Shaw; Libby Hirshon; Luke Strugnell; Maggie Langlands; Mariaan Claassen; Matthew Law; Megan Murgatroyd; Oscar Mohale; Owen Davies; Rob Simmons; Robin Colyn; Robyn Luyt; Tim Ponton.

IFC in-person workshop on Shutdown on Demand

An in-person workshop took place on 23 July 2024, facilitated by IFC. The objective was to workshop bird collision mitigation in the South African context. The key points on the agenda were:

- Introduction to IFC and its role in wind power projects
- The mitigation hierarchy. Net gain, net loss, impacts on birds at wind energy facilities
- Overview of strategies to avoid and mitigate collision impacts on birds
- Turbine shutdown measures to mitigate collision impacts on birds: global good practice and lessons learned
- Turbine Shutdown on Demand: how and why does collision mitigation in South Africa differ from global practices; actions to overcome the challenges in South Africa to implementing OSDoD; what strategies and initiatives can be employed to move toward effective implementation
- Why PCFM is essential at wind energy projects: What constitutes GIIP PCFM; Overview of the IFC Good Practice Handbook; Good Practice in South Africa ; Integrating the IFC approach into PCFM good practice in South Africa
- IFC approach to fatality threshold setting and adaptive management
- Which aspects of IFC's approach are useful for safeguarding birds in South Africa.

Participants: Abulele Adams; Albert Froneman; Anthony van Zyl; Arjun Amar; Brent Coverdale; Caryn Clarke; David Tidhar; Diane Smith; Elsabe Swart; Gavin Cowden; Greer Hawley-McMaster; Humbo Mafumo; Jacob Claassen; Jake Mulvaney; Jeffrey Manuel; John Gibbs; Jon Smallie; Kirsten Day; Liandra Scott-Shaw; Libby Hirshon; Lourens Leeuwner; Luanita Snyman-Van der Walt; Mark Botha; Matt Law; Megan Murgatroyd; Mervyn Lotter; Mohamed A. Ezat; Naledi Shai; Namita Vanmali; Oliver Cowan; Owen Davies; Pamela Kershaw; Paul Lochner; Peter Cloete; Portia Makitla; Rhett Smart; Rob Simmons; Robin Luyt; Rory Haschick; Sam Ralston-Paton; Shaun Taylor; Tilana De Meillon.

Appendix 4

SUPPLEMENTARY INFORMATION ON AUTOMATED DETECTION-REACTION SYSTEMS

Introduction

This Appendix supplements BirdLife South Africa's 2025 report on Shutdown on Demand for the mitigation of bird collision risk at onshore wind farms in South Africa, providing information on commercially available automated detection systems (ADS) for the application of automated Shutdown on Demand (ASDoD) programmes at onshore wind farms in South Africa.

Commercially available ADS products available at the time of publication of this report were identified from a literature review of available guidelines relating to bird monitoring technologies for wind farms. Information is provided in respect of:

- Monoscopic camera ADS options;
- Stereoscopic camera ADS options; and
- Radar-based ADS options.

For each of the ADS products presented, relevant suppliers were invited to provide information on their products. Additional information sources regarding each ADS product are presented in the table for each ADS product.

In the interest of brevity, ADS products which are still under development or being trialled, as well as those applicable to offshore wind farms only, have not been presented in this Appendix. Additionally, biomonitoring systems which have applicability to wind farms, but which are not fully-fledged ADS products, have also been excluded.

Readers should note that BirdLife South Africa accepts no responsibility for the accuracy or the completeness of the information provided herein. Readers remain responsible for all due diligence necessary to confirm the suitability of products listed for their specific requirements.

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.

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