MITIGATION GUIDANCE FOR BATS AT WIND ENERGY FACILITIES IN SOUTH AFRICA

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1. Introduction

The Mitigation Guidance for Bats at Wind Energy Facilities (WEFs) in South African is intended as a first attempt at a practical guidance document for the implementation of appropriate and proportional mitigation measures at WEFs, based on the interpretation of pre-construction and operational monitoring results (acoustic monitoring and bat carcasses collected over time). It includes guidance on the assessment of the impact of the interpreted bat activity at a locality and the selection of the appropriate mitigation measure(s) to remove or ameliorate that impact. This guidance should be read in conjunction with *South African Bat Fatality Threshold Guidelines May 2018* (or subsequent editions).

This document is intended as guidance for WEF EIA practitioners, relevant Specialists and their clients and is not, as yet, a formal government document. The principal aim is to provide advice on appropriate mitigation measures to reduce impacts of WEFs on bats and when these may be required. Consideration should be given to setting up a technical advisory committee for each WEF consisting of the specialist, WEF operators, researches and practitioners. This committee should provide input and guidance on the detailed implementation of proposed mitigation strategies in this document. For example, specific high-risk turbines and time periods where reducing blade movement might be most needed can be established through collaboration between such a committee.

This document does not attempt to provide an exhaustive prescription of how to mitigate impacts of WEFs on bats. All mitigation measures proposed for WEFs should be informed by robust, site-specific research: pre-construction monitoring, operational monitoring and/or the results of independent bat research. The mitigation proposals MUST be justified by the monitoring and/or research results at each specific site. It is intended that this document will evolve as new information, results from research and new technologies become available in future, aiding our understanding of wind energy impacts to bats and the techniques available to mitigate these impacts.

2. Review of Current Mitigation Strategies

The following are the types of mitigation measures that have been and are currently used internationally, arranged according to the standard mitigation hierarchy. These are designed to help reduce/minimize negative impacts if these cannot be avoided. Avoidance strategies should be prioritised over these mitigation strategies.

2.1. Avoidance

The primary measure to promote avoidance relates to the siting of wind turbines to avoid roosts, commuting or migration routes or extensive foraging areas. This is determined by pre-construction monitoring results (acoustic monitoring and roost searches) and these data can be used to design WEFs and inform specific turbine placement to avoid areas that are used by bats. To design and implement a pre-construction survey that will adequately inform avoidance strategies, please refer to the *South African Good Practice Guidelines for Surveying Bats at Wind Energy Facility Developments - Pre-construction: Edition 4.1* (or subsequent editions).

2.2. Minimize/Mitigate

If avoidance strategies are not possible or if residual impacts are likely, the following represent methods available to minimize or mitigate impacts on bats.

2.2.1. Reduce blade movement

The premise behind this mitigation strategy is that bat fatality does not occur at non-operational turbines (Arnett 2005). Therefore, limiting the amount of time turbine blades are in motion could reduce or prevent bat fatalities. This can be achieved by feathering blades and raising turbine cut-in speeds during times of risk. Currently, this type of mitigation strategy is the only proven method to reduce bat fatalities at operational wind energy facilities (Arnett et al. 2013a, Arnett et al. 2013c). Time periods and locations of specific turbines when and where curtailment can be applied should be determined based on analysed bat fatality and/or bat acoustic activity data in conjunction with meteorological data, particularly wind speed. This could highlight peak periods and locations of bat fatality and bat activity.

Curtailment regimes should be based on this detailed information to increase the likelihood of successfully reducing potential impacts on bats while also limiting interruptions to WEF operation. Few studies have disclosed actual power loss and economic costs of curtailment, but those that have, suggest that <1 % of total annual output would be lost if curtailment was employed during high-risk periods for bat fatalities (Arnett et al. 2016). These studies were conducted for temperate regions in Northern Hemisphere regions and more year-round and costly mitigation may be required in the more tropical Southern Hemisphere regions.

The reduction in blade movement can be implemented by using situation-dependent operation protocols (or algorithms), which are being developed for operating wind turbines. These algorithms consider a number of parameters such as ambient temperature, wind speed, season, and time of day, as well as recorded bat activities for defining a set of operational rules for wind turbines (Korner-Nievergelt et al. 2013). However, to date, these algorithms have been formulated for a single type of turbine and for a limited number of sites in Europe. Thus, the suggested algorithms may be unsuitable for other places with varied geographical and topographic characteristics, bat communities, and turbine types (Voigt et al. 2015). Further research is needed in this area.

Some methods to reduce blade movement are as follows:

2.2.1.1. Low speed idling

The cut-in speed of a wind turbine is the wind speed at which the generator is producing electricity and turbine blades are moving at maximum rotation speed (Arnett et al. 2013c, Berthinussen et al. 2014). Below the cut-in speed, the turbine rotor blades rotate at a slow rate that increases with wind speed until generator rotation is triggered, coinciding with the cut-in speed (Baerwald et al. 2009). Manipulating the pitch angle of the blades and lowering the generator speed required to trigger energy production causes turbine blades to be motionless in low wind speeds. This mitigation strategy can result in a small reduction in electricity and revenue generation but has the benefit of reducing wear and tear on the rotor blades and the generator (Baerwald et al. 2009).

2.2.1.2. Blade feathering

Normally operating turbine blades are angled perpendicular to the wind at all times. Adjusting the angle of the rotor blades to parallel with the wind, or turning the nacelle out of the wind, can slow or stop blade rotation (Arnett et al. 2013b). Young et al. (2011) and Good et al. (2012) demonstrated that blade feathering below the manufacturer's cut-in speed can reduce bat fatalities. Further reductions in fatalities can be achieved by blade feathering and raising the cut-in speed simultaneously (Good et al. 2012). All turbines should be feathered up to the manufacturer's cut-in speed, regardless of the level of impact. Advances in turbine software and modern turbine designs allow for this to be achieved.

2.2.1.3. Raise the cut-in speed

Below the manufacturer's cut-in speed, rotor blades can still rotate [but at lower revolutions per minute (RPM)], without producing electricity. Both bat activity and bat fatality are greater in lower wind speeds (Baerwald and Barclay 2011, Amorim et al. 2012, Koppel et al. 2014). Therefore, increasing the cut-in speed will reduce the amount of time turbine blades are rotating at maximum RPM when bats are most active and hence, reduce opportunities for bats to encounter rapidly rotating turbine blades. This strategy has significantly reduced bat mortality at a number of operational wind energy facilities (Baerwald et al. 2009, LEA 2010, Arnett 2011).

2.2.2. Deter bats

Altering turbine operation as described above might present operational and financial difficulties for some WEFs. Alternative solutions to prevent reductions in turbine operation include deterring bats, aiming to prevent them from entering the air space near turbine blades.

2.2.2.1. Ultrasound

Echolocating bats make use of ultrasound to perceive their environment by producing vocal signals and analysing the returning echoes, which reflect off targets in the path of the sound waves (Griffin 1944). These signals have a range of functions including orientation, hunting, navigation and communication with other bats. For example, bats produce different types of social calls (Middleton et al. 2014) and some species are known to avoid the territorial social calls emitted by members of the same species. Additionally, some moths have evolved the ability to avoid hunting bats by jamming their echolocation system by producing their own ultrasound (Conner and Corcoran 2012). It has therefore been hypothesized that broadcasting ultrasound from wind turbines might disrupt bats and serve as a deterrent by creating an uncomfortable or disorienting airspace that bats would avoid (Arnett et al. 2013b).

Some studies have found evidence to suggest that this mitigation measure might be successful (Horn et al. 2008, Arnett et al. 2013b, Weaver et al. 2017). For example, ultrasonic deterrents may be effective in reducing fatalities of lower frequency calling bats such as Molossids (free tailed bats), who are affected by high fatality losses in SA (Perold and MacEwan 2017). However, using ultrasonic deterrents do have limitations associated with the physics of sound. It is not possible to transmit higher frequency sounds with enough intensity (dB) to deter high-frequency calling bats out to the tips of the turbine blades. Ultrasonic deterrents are also not a viable mitigation option for fruit bats, which do not use ultrasound.

Currently, the only systems that are available commercially are those developed specially for Siemens turbines (produced by NRG Systems) and by General Electric (GE), produced only for their turbines

2.2.2.2. Radar

Nicholls and Racey (2007) found reduced bat activity in habitats exposed to a high electromagnetic field, suggesting that bats might avoid radio frequency radiation associated with radar installations. In additional studies, an electromagnetic signal from a small radar with a fixed antenna reduced bat activity, suggesting that this could deter some bats (Nicholls and Racey 2009). This study showed that only a constant and intense signal showed a significant effect on activity. These signals might harm small-bodied animals and it would be difficult to create such an intense signal at every turbine.

2.3. Offset/Compensation

In its purest sense, it is unlikely that this type of mitigation would be an appropriate operational mitigation strategy at WEFs. However, for completeness, examples of how this could be undertaken are included here. Where avoidance, pure mitigation or deterrence cannot be undertaken, habitat improvement to create food, roosting resources and safe commuting corridors for bats (through planting and creation of wetland/dams) in a 'safe' area might be considered in order to attract bats away from the zone of WEF influence.

To justify offset/compensation mitigation techniques, pre-construction and operational monitoring would need to have been undertaken and the assessments robustly indicate that this type of mitigation was appropriate. There is no published evidence where this has been used and monitored in relation to WEFs, therefore offset/compensation has not been included in Table 3 Mitigation Decision Matrix as a mitigation option.

2.4. No mitigation

No action required other than continuing fatality and acoustic monitoring as per established best practice guidelines to assess developing situations and then responding accordingly.

3. Interpretation of Operational Monitoring Field Results

Collecting bat fatality data at operational WEFs is crucial to assessing the impacts on bats. These data can be used as a basis for selecting appropriate mitigation measures that might need to be used to reduce the observed impacts. These data can also be used to refine or adapt existing mitigation strategies developed during the pre-construction phase or early operational monitoring. The analysis of field results (specifically the estimated number of bat fatalities) and subsequent interpretation will allow appropriate mitigation measures to be selected.

The South African Bat Assessment Association have proposed a method of determining site specific bat fatality levels that trigger mitigation measures. Please refer to the document *South African Bat Fatality Threshold Guidelines May 2018* (or subsequent editions).

4. Assessing Impact of WEFs

Whilst the implementation of mitigation is triggered by exceeding an overall annual threshold, the type and intensity of mitigation, and at which turbines and during which periods it should be implemented, must be based on a combination of bat activity data in relation to weather conditions, times of night and times of year, and based on the unadjusted fatality data per turbine. Based on site specific results and taking into consideration which turbines have the highest fatalities and which weather conditions bats were most active in, turbine specific mitigation measures should be implemented (*South African Bat Fatality Threshold Guidelines May 2018).*

Mitigation measures should also consider the scale of the impact and, as our understanding of the impacts of wind energy on bat populations in South Africa grows, mitigation measures can be adjusted and developed to reflect these scales. The specific mitigation choice (e.g. reduction in blade movement, deterrents, offsetting etc.) should therefore be appropriate for the scale of the impact. As a guide to the level of impact, the following definitions are provided to assist with assessing the scale of population level impacts that can occur:

International – An impact that could affect the loss of the ecosystem services of bats of adjacent countries.
National – An impact that could affect the loss of the ecosystem services of bats across South Africa.
Provincial – An impact that could affect the loss of the ecosystem services of bats across and within a province.
District – An impact that could affect the loss of the ecosystem services of bats within a magisterial district.
Local – An impact that could affect bats locally.
Zone of immediate influence – A low level of impact that could affect bats within a radius of 1 km^2.

Table 1 Potential Impacts of Field Results and Associated Impact Scale

Interpretation	Potential Impact	Potential Scale of Impact
Presence of a major migration route, or fatalities of rare species or species of conservation concern, or fatalities of migratory species exceeding threshold levels	Loss of an important migration route or loss of important roosts of rare species or species of conservation concern	International or National
Presence of a minor migration route, fatalities of rare species or species of conservation concern, or fatalities of any species exceeding threshold levels	Loss of part of a migration route or loss of important roosts of rare species or species of conservation concern	National or Provincial
Nearby local maternity roost of or fatalities of any species exceeding threshold levels	Loss of local resident colony resulting in loss of pest control or loss of roosts of rare species or species of conservation concern	Provincial or District
Either small nearby maternity roost or larger roost farther away from WEF site or fatalities of any species exceeding threshold levels	Loss of local resident colony or colonies and resulting in some loss of local pest control	District
Foraging/commuting routes of local resident bats or fatalities of any species exceeding threshold levels	Loss of foraging bats and the possible impact of bat colonies farther afield	District
Foraging of local resident bats or fatalities of any species exceeding threshold levels	Loss of foraging bats and the possible impact of bat colonies farther afield	Local
Low level foraging activity or fatalities of any species exceeding threshold levels	Possible loss of a small number of foraging bats	Zone of immediate influence

5. Conclusions

Without robust information with which to inform mitigation, appropriate, proportional and successful mitigation cannot be designed. This information can be gathered in a number of ways: through pre-construction and operational monitoring (fatality searches and acoustic surveys), as recommended in the respective South African Pre-Construction and Operational Bat Monitoring Guidelines and through data from independent bat research projects. Such research could be generated by the WEF operators agreeing to conduct scientifically rigorous studies on impact reduction strategies.

Consideration should also be given to setting up a technical advisory committee for each WEF to provide input and further guidance on the detailed implementation of proposed mitigation strategies such as duration, as well as operational procedures such as feathering turbines up to the manufacturer’s cut-in speed. Specific high-risk turbines and time periods where reducing blade movement might be most needed can also be established through collaboration between such a committee, researchers and practitioners.

It is important to monitor and then publish the results of bat mitigation measures used (Berthinussen et al. 2014). Mitigation of the impacts of WEFs in South Africa is in its infancy and the monitoring/testing of mitigation measures will help to robustly justify their use, but only if the monitoring results are published and made available so that documents of this kind can be built upon. This should be an iterative process and subsequent guidance documents should be amended to reflect the findings.

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