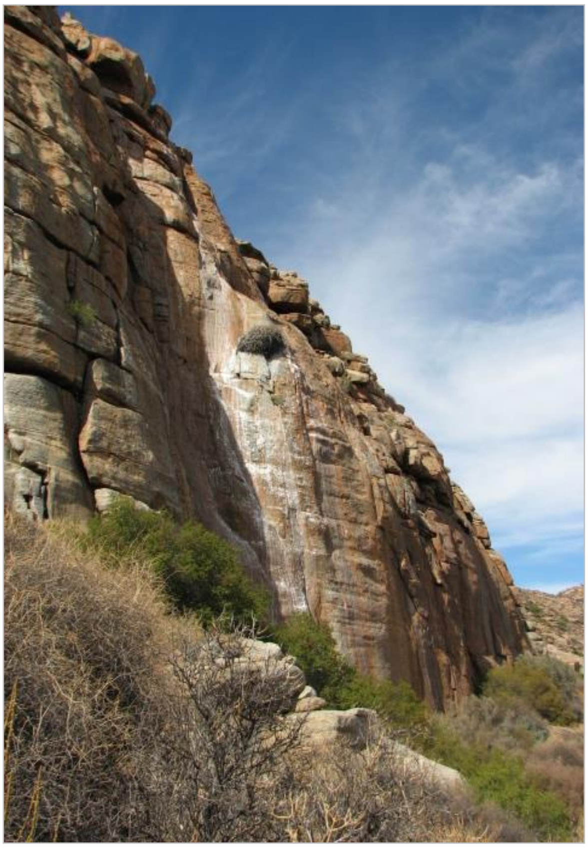
Amendment Report

SPRINGBOK WIND ENERGY FACILITY



Hub height and blade length considerations for birds

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CONTENTS

1. SUMMARY

This study contains an appraisal of the amendments made for the proposed Springbok Wind Energy Facility and their likely effects on the avian community. The avian component was previously reported on in 2010 and again in 2015 (Simmons 2010, Simmons and Martins 2015) and several large collision-prone birds were found to use the area. The amendments suggested to the authorised layout of 37 turbines of 80-m hub height by the developer, Mulilo Springbok Wind Power (Pty) Ltd, in 2016, may influence these species, both positively and negatively. The proposed structural/engineering amendments are (i) a 32% decrease in the overall number of turbines from 37 to 25; (ii) a 75% increase in hub height of the remaining turbines from 80-m to 140-m; and (iii) an 82% increase in rotor diameter from 88-m to 160-m.

The effect of the changes proposed on the authorised project are both positive (reduced number of turbines and, thus, disturbance or displacement of birds), and negative (increased probability of fatalities) for a suite of collision-prone birds (some red-listed), highlighted by Simmons and Martins (2015). Collision with the blades of the wind turbines, and the associated power line network, are the biggest potential risk with turbines placed on the upland ridges or near foraging areas. Theoretically, if the rotor blade length is doubled, a three-fold greater risk area is created. If hub height is also increased then birds flying higher could be impacted. Two meta-analyses from North America reported different results: in the first, hub height and blade-swept were found to have no significant effect on mortality of birds, but in the second more comprehensive study, a strong significant effect was revealed with a larger sample size. Our statistical modelling with South African data introduced found that fatalities may increase four-fold. We conclude that taller turbines are likely to increase avian fatalities, but more empirical data from South African turbines above 80-m are required to verify these predictions.

The impact zone of the originally proposed facility lies in a small area north-east of Springbok in the Nama/Succulent Karoo biomes, an area that holds a suite of southern African endemic birds and some Red Data species (e.g. eagle, harriers and bustards). Our surveys indicated that 9 collision-prone species (CPSs) occur in the area of which 7 are Red Data species. The passage rate of these species through the authorised project was medium at 0.74 CPBs.h^{-1}.

By statistically modelling the number of fatalities that longer blades or taller turbines may have on fatality rates, we find that even with a 32% decrease in turbines from 37 to 25, potential fatalities are forecast to increase about three-fold. Based on flight heights of eagles alone, potential fatalities are forecast to increase about two-fold over the authorised 37 turbines. However, by identifying four turbines that are most likely to cause fatalities based on pre-construction flight data, the fatalities can

be reduced to acceptable levels by reducing the hub height from the proposed 140-m to 105-m for the four highest risk turbines. This is an acceptable form of mitigation. Mulilo have agreed to this form of mitigation, together with a detailed post-construction monitoring, to determine the effectiveness of the reduced heights. Operational-phase monitoring is essential to determine the actual impacts on birds and, therefore, the required mitigation measures and thresholds. Such an approach requires an exceptionally flexible Adaptive Management Plan to be implemented during operation. This plan must allow for: (i) changes to be implemented within a maximum time-frame of three weeks; (ii) the Wind Farm must agree to follow the mitigation measures that may result from the operational monitoring and Adaptive Management Plan; and (iii) in accordance with the Adaptive Management Plan, appropriate mitigation measures, such as curtailment during specific environmental conditions or during high risk periods. If data shows one Red Data species is killed per year, then deterrent technology needs to be implemented at that turbine.

1.1 Consultant's Declaration of Independence

Dr Rob Simmons of Birds & Bats Unlimited is an independent consultant to Mulilo Springbok Wind Power (Pty) Ltd. He has no business, financial, personal or other interest in the activity, application or appeal in respect of which he was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of this specialist performing such work.

1.2 Qualifications of Specialist Consultants

Dr Rob Simmons, of Birds & Bats Unlimited Environmental Consultants (http://www.birds-and-bats-unlimited.com/) was approached to undertake the specialist avifaunal addendum to the Avian impact assessments to determine the effect of changes in the number, size and blade swept areas of the wind turbines proposed at the Springbok Wind energy facility, Northern Cape. Dr Simmons is an ecologist and ornithologist, with 30 years' experience in avian research and impact assessment work. He has published over 100 peer-reviewed papers and two books, (see http://www.fitzpatrick.uct.ac.za/fitz/staff/research/simmons for details). He was the State Ornithologist for Namibia's Ministry of Environment for 14-years. He has undertaken more than 50 avian impact assessments in Angola, Namibia, South Africa and Lesotho. He also undertakes long-term research on threatened species (raptors, flamingos and terns) and their predators (cats) at the FitzPatrick Institute, UCT.

Marlei Martins, co-director of Birds & Bats Unlimited, has 6 years' consultancy experience in avian wind and solar farm impacts as well as environmental issues, and has been employed by several consultancy companies throughout South Africa because of her expertise in this field. She has published papers on her observations including a new species of raptor to South Africa (http://www.birds-and-bats-unlimited.com/).

2. TERMS OF REFERENCE

The Terms of Reference for the avian impact assessment are to:

Compile an addendum to the 2010 and 2015 specialist avian reports addressing the following:

- The implications of the proposed amendments in terms of the potential impact(s);
- A re-assessment of the significance (before and after mitigation) of the identified impact(s) in light of the proposed amendments (as required in terms of the 2014 EIA Regulations), for the construction and operational phases, including consideration of the following:
  - Cumulative impacts;
  - The nature, significance and consequence of the impact;
  - The extent and duration of the impact;
  - The probability of the impact occurring;
  - The degree to which the impact can be reversed;
  - The degree to which the impact may cause irreplaceable loss of resources;
  - The degree to which the impact can be avoided, managed or mitigated.

This addendum to the 2015 report must include an impact summary table outlining the findings of the re-assessment in terms of the above-mentioned assessment criteria.

- A statement as to whether the proposed amendments will result in a change to the significance of the impact assessed in the original EIA for the proposed project (and if so, how the significance would change).
- A detailed description of measures to ensure avoidance, management and mitigation of impacts associated with the proposed changes.
- The re-assessment must take into account and address public comments.
- An outline of the potential advantages and disadvantages of the proposed amendments in terms of potential impacts (within your area of expertise)
- Provide confirmation as to whether or not the proposed amendments will require any changes or additions to the mitigation measures recommended in our original specialist report. If so, provide a detailed description of the recommended measures to ensure avoidance, management and mitigation of impacts associated with the proposed amendments.
- Should any comments be raised during the Public Participation Process for the Application for Amendment of the EA relating to your area of expertise, provide responses to such comments

raised (as part of the Comments and Response Report for the amendment application). Such comments would be provided to you, on conclusion of the 30 day public comment period.

- The re-assessment must take into account the findings of the 12 month pre-construction monitoring.

2.1 Study Area

The proposed wind farm lies 7-km north-north-east of Springbok, and is centred around high ground east of the small mining town of Okiep. The central wind mast was at S29°36'38.40" E17°54'14.82". The WEF area covers approximately 28-km^2. The substrate is rocky, and the topography of the WEF is highly undulating varying from ~940-m asl to the highest point at 1260-m asl. Two wind masts, a water pipeline, and some shepherds' huts are the only man-made structures on the WEF.
The study area of the WEF is dominated by huge granite and gneiss domes described as Namaqualand Klipkoppe Shrubland, (Mucina & Rutherford 2006, p253). The vegetation comprises well-known species such mature *Aloe dichotoma* (Quiver Trees) on the north slopes, with other dwarf shrubs and succulent plants in shallow soil pockets or fissures. This region just north of Springbok lies in the winter rainfall region with mean rainfall of only 161-mm/yr. The area has components of both the Nama and Succulent Karoo biomes.

The habitat is not threatened and is well conserved in two protected areas – the Namaqua National Park and Goegap Nature Reserve. Other regions are subsistence-farmed with small livestock in among the large granite domes, and the area is pocketed with old and current mining claims.

2.2 Background

The following report is an Addendum to the avian impacts EIA report (Simmons and Martins 2015) for the proposed Springbok wind energy facility. This is required to re-examine possible impacts arising from proposed changes in the number and size of the proposed wind turbines at the proposed Mulilo (now Mulilo Springbok Wind Power (Pty) Ltd) wind farm north-east of Springbok, Northern Cape.

Specifically, the proposed amendments to the authorized wind farm include the following:

- 25 turbines reduced from 37 turbines;
- increased hub heights from 80-m to 140-m;
- increased rotor diameter from 88-m to 160-m;
- increased WTG size from 1.5MW to 2.0MW - 4.5MW.

The overall generation capacity has not changed and remains at 55.5MW. The layout, as defined earlier (and discussed with Mulilo) has not changed, except for minor micro-siting due to bat and bird considerations.

3. SUMMARY OF FINDINGS OF ORIGINAL EIA REPORT

The original avian component of the 2015 EIA avian pre-construction report assessed the possible impacts to birds (Simmons and Martins 2015), and identified seven Red Data species that may be impacted by turbine placements (either by direct impact or disturbance and displacement). These included: four raptors, one stork, one bustard and one lark species (Table 1). Four of these have a very low likelihood of occurrence on the site (<1%, last column Table 1), and were, therefore, deemed unlikely to be negatively affected by turbines.

Table 1: Seven Red Data species identified in the avian EIA report (Simmons and Martins 2015).

Common name	Conservation status	Relative importance of local population[1]	Susceptibility to collision	Susceptibility to electrocution	Susceptibility to disturbance	Likelihood of occurrence* [our records]**
Black Stork	Near Threatened	Low?	High	High	High	1% **[0%]**
Verreaux's Eagle	Vulnerable	Moderate	High	Low	Medium	29% **[100%}**
Black Harrier	Vulnerable*	Moderate to High	High	-	Moderate	9% **[0%]**
Martial Eagle	Vulnerable	Low?	Moderate	High	Moderate	7% **[8%]**
Lanner Falcon	Near-threatened	Low?	High	Moderate	-	4% **[17%]**
Ludwig's Bustard	Vulnerable	Low?	High	Moderate	Moderate	1% **[0%]**
Red Lark	Vulnerable	High	Low	Low	Moderate	1% **[0%}**

1. An indication whether the population is a core, or marginal, one relative to the main population
*Likelihood is based on the reporting rate: the number of times recorded divided by the number of bird atlas cards =43.
**Likelihood of occurrence based on our own records on site over six visits x two area (WEF and Control), divided by 12]

The threatened species that remain vulnerable to impacts include:

- **Verreaux's Eagle** *Aquila verreauxii* – a *Vulnerable* species (Taylor et al. 2015) and No. 2 in the list of collision-prone species. This species had a 100% chance of occurring on site as it breeds there (Simmons and Martins 2015);
- **Martial Eagle** *Polemaetus bellicosus* – a *Vulnerable* species (Taylor et al. 2015), and No. 5 in the list of collision-prone species. This species had a 7-8% chance of occurring on site but does not breed there (Simmons and Martins 2015);

- **Lanner Falcon** *Falco biarmicus* – a *Vulnerable* species (Taylor et al. 2015), and No. 22 in the list of collision-prone species. This species had a 17% chance of occurring on site and may breed there (Simmons and Martins 2015).

Two additional species that are not Red Data species in South Africa (Taylor et al. 2015) but are vulnerable to collision with wind farms:

- **Booted Eagle** *Aquila pennatus* - ranked 55th in the Top 100 collision-prone birds (BAWESG 2014). This species was recorded on 25% of all visits and, thus, has a medium chance of occurring (Photo 1). It is known to breed within the wind farm site and is designated Red Data in Namibia (Simmons et al. 2015);
- **Jackal Buzzard** *Buteo rufofuscus* – ranked 42nd in the Top 100 collision-prone birds (BAWESG 2014). This species was recorded on 75% of all visits and, thus, has a high chance of occurring.

Given that the European Booted Eagle is at higher risk than other eagles in European wind farms it may require revision in the South African (BAWESG) rankings (A. Camina unpubl data).

Photo 1: Booted Eagles were seen around the study site about 25% of the time and probably breed there.

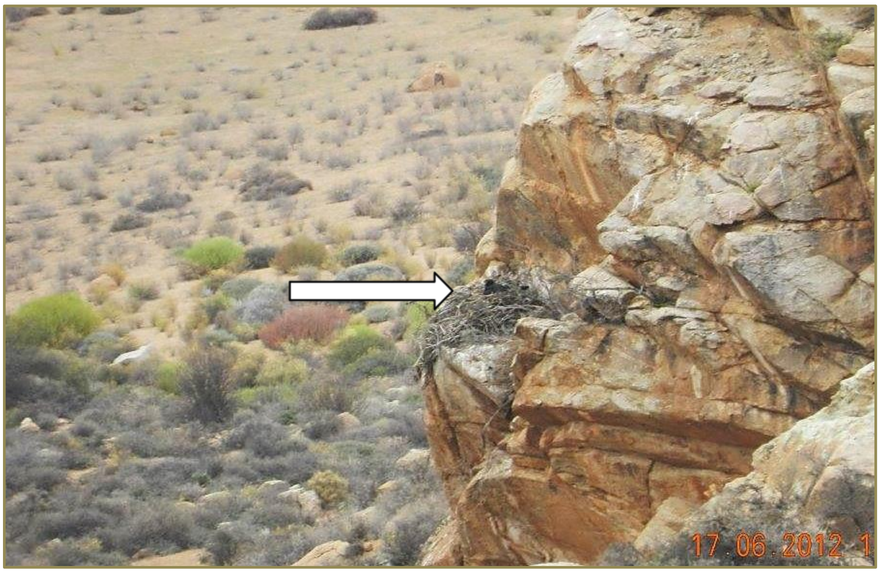

Photo 2: The female Verreaux's Eagle at nest (No. 3) in the southern section of the proposed WEF, June 2012.

4. REVIEW OF POTENTIAL AVIAN IMPACTS DUE TO CHANGES IN TURBINE NUMBERS AND DIMENSIONS

4.1 Interactions between wind energy facilities and birds

Literature reviews (e.g. Kingsley & Whittam 2005, Drewitt & Langston 2006, 2008, Kuvlevsky et al. 2007, Loss et al. 2013) and personal communications (P Whitfield pers comm.) are excellent summaries of avoidance, displacements and impacts, due to wind farms in other parts of the world. Few data exist for southern Africa on the impacts of operational wind farms, partly because of the recent advent of operational farms (the first came on line in 2010), and partly because of non-disclosure agreements with clients. However, Birdlife South Africa have recently collated data on annual mortality at eight operational farms in South Africa (Ralston-Paton et al. 2017).

What will be assessed here is the likely change in risk to the birds passing through the wind farm where the following is altered:

- the number of turbines are reduced by 32% (37 to 25);
- the locations remain largely unchanged from the original 37, i.e. only micro-siting changes based on bat avoidance studies;
- the hub height is increased by 75% from 80-m to 140-m;
- the rotor diameter is increased by 82% from 88-m to 160-m.

There are three major ways wind farms can influence birds:

a) Through displacement and disturbance (birds avoid the area, through the disturbance caused by the operation of the turbines);
b) Through habitat loss and fragmentation (the infrastructure and building phase directly destroys or divides habitat); and
c) Through direct mortality (birds are struck by the turbines and die).

The final report (Simmons and Martins 2015) covered all three points (displacement/disturbance; habitat-loss/destruction; and direct mortality).

We can summarize **general** findings on bird-wind farm interactions as follows:

- On average 5.25 bird fatalities/turbine/year in the USA (range 2.92 - 7.85 birds killed); (Loss et al. 2013);
- Collisions in South Africa average 4.1 birds/turbine/year, (reviewed below);
- A few turbines are responsible for most deaths;
- Some wind farms on migration routes, and those employing lattice turbine towers, suffer high

mortality rates (Loss et al. 2013) so, poorly sited wind farms can be risky;

- Identifying and mitigating individual turbines causing most mortality reduces that risk;
- Landscape features such as ridges for soaring, or valleys for commuting, are high-risk areas for raptors or migrants;
- Poor weather and high winds induce birds to fly lower and increase the chances of collision;
- Illuminating towers or buildings increases avian mortality, but gaps left in corridors of turbines may reduce overall mortality risk, and intermittent flashing lights have been found to attract fewer birds;
- High risk species include those with low manoeuvrability (cranes, vultures), or high air speed (raptors, wetland birds), or distracted fliers (raptors chasing prey, courting birds), and soaring species that seek lift off slopes (pelicans, storks);
- The most recent research shows exciting possibilities of reducing eagle mortalities by 71% by painting half of one blade black (Stokke et al. 2017);
- A sensitivity map for South Africa's most collision-prone species has been produced for bird-wind farm interactions and can be downloaded from: http://www.birdlife.org.za/conservation/terrestrial-bird-conservation/birds-and-renewable-energy/wind-farm-map/item/298-avian-wind-farm-sensitivity-map-documentation

Mitigating the risks is compromised by fast-moving objects being difficult to detect – even for raptors, due to retinal blur (i.e. turbine blades moving at 300-km/ h^{-1}). However, exciting work has been done in Smøla, Norway, where recent experiments with black-painted turbine blades showed 71% reductions in fatalities of White-tailed Eagles *Haliaeetus albicilla* and other collision-prone species (Stokke et al. 2017) http://cww2017.pt/images/Congresso/presentations/oral/CWW17_talk_S07_5_Stokke%20et%20al.pdf

Other mitigations include:

- Site wind farms away from: (i) large concentrations of birds (e.g. roosts, wetlands or breeding colonies); (ii) migration corridors; (iii) slopes used by soaring birds; and (iv) breeding collision-prone birds,
- Monitor deaths per turbine and be prepared to shut down high-mortality turbines at times of high risk (i.e. migration or breeding seasons). Those individual turbines that kill more than one Red Data birds per year should be given particular attention. The likely position of these turbines can be identified pre-construction from the number of flights (Passage Rates) near them and the

proportion of flights at blade-swept height (BSH).

- The use of intense, flashing, short wavelength LED (light emitting diode) lights to deter raptors from close approaches to turbines in risky positions (Foss et al. 2017).

Here we review just the collisions with the turbines, and particularly the effect of changing the number of turbines, hub height, and blade length.

4.2 Collision rates at wind farms in South Africa

Approximately 10 wind farms are operational in South Africa including facilities at Klipheuwel and Darling in the Western Cape (van Rooyen 2001, Jenkins 2001, 2003, Simmons et al. 2011), in the Karoo and several in the Eastern Cape (Doty and Martin 2011, Ralston-Paton et al. 2017).
In a review of data from six operational farms in South Africa that have been monitored for over a year, Ralston-Paton et al. (2017) found that raptorial birds are the most impacted group, with 36% of all 271 known fatalities in 285 turbine-years to be small to large birds of prey. This gives a relatively high rate of mortality (adjusted for observer error and carcass removal) at 4.1 birds.turbine^{-1}year^{-1} (Ralston-Paton et al. 2017). This ranges from 2.1 to 8.6 birds.turbine^{-1}year^{-1}. This is similar to that reported elsewhere in the world at 5.2 birds.turbine^{-1}year^{-1} (Loss et al. 2013).

4.3 Avian effects of changing hub heights and blade-swept area

Probably the two most important papers on mortality and the effect of increased hub height and blade length is that of Barclay et al. (2007), and Loss et al. (2013). They assessed collision rates of birds and bats at 33 and 53 sites (respectively) in North America, with a range of turbines from 3 to 454, and assessed the effect of variation in turbine height and blade-swept area on the mortality rates of birds and bats.

Barclay et al. (2007) found:

- no significant effect of increased height or blade length on the number of birds killed;
- the number of birds killed at these facilities is represented by the equation: Number of bird fatalities/turbine = 0.052height -0.450 (R^2 = 0.1, and thus no significant relationship);
- There was a marginal increase in the number of birds killed with height up to about 80-m.

Loss et al (2013), re-analysing all data from Barclay et al and new studies, found:

- A significant effect of hub height on the number of avian mortalities at 53 wind farm sites in the USA. Blade length could not be assessed because of statistical collinearity with hub height;
-

- ➢ In a model that included region and hub height, avian fatalities increased from about 2 birds.turbine.year^{-1} at hub heights of 40-m to 6.2 birds.turbine.year^{-1} at 80-m hub height;
- ➢ This represents a ~3-fold increase in mortalities between 40-m and 80-m hub height.

In their review of facilities in Europe and the USA combined, Drewitt and Langston (2008) found that taller communication towers were more likely to kill birds, than shorter ones. Similarly, taller transmission lines (i.e. 400 kV vs 220 kV lines) are more likely to kill collision-prone birds than shorter ones (J Pallett unpubl. Data).

4.5 Collision-prone birds

Collision-prone birds (CPBs) are generally either:

- large species and/or species with high ratios of body weight to wing surface area, and low manoeuvrability (cranes, bustards, vultures, gamebirds, waterfowl, falcons);
- species that fly at high speeds (gamebirds, pigeons and sandgrouse, waterfowl, swifts, falcons);
- species that are distracted in flight - predators or species with aerial displays (many raptors, aerial insectivores, some open-country passerines);
- species that habitually fly in low light conditions (owls, dikkops, flamingos); and
- species with narrow fields of forward binocular vision (Drewitt & Langston 2006, 2008, Jenkins et al. 2010, Martin & Shaw 2010, Ralston-Paton et al. 2017).

Our own research data from a wind farm in the Eastern Cape indicates that four Black Harrier *Circus maurus* mortalities were associated with the months when they spent more time at blade-swept height. No fatalities occurred when the harriers were flying at low levels (Simmons and Martins 2017).

Photo 3: The southern-most pair of Verreaux's Eagles in the wind farm overlooking their territory in the shade at midday, a favoured perch-site away from their nest.

These traits confer high levels of susceptibility, which may be compounded by high levels of exposure to man-made obstacles such as overhead power lines and other wind farm infrastructure (Jenkins et al. 2010). Exposure is greatest in (i) highly aerial species; (ii) species that make regular and/or long distance movements (migrants and species with widely separated resources food, water, roost and nest sites); and (iii) species that fly in flocks such as vultures (increasing the chances of incurring multiple fatalities in single collision incidents). Soaring species may be particularly prone to colliding with wind turbines or power lines where these are placed along ridges – where turbines would exploit the same updrafts favoured by birds – such as, vultures, storks, cranes, and most raptors (Erickson et al. 2001, Drewitt & Langston 2006, 2008, Jenkins et al. 2010). In Europe, most mortalities recorded are large vultures and eagles (e.g. de Lucas et al. 2008).

The collision-prone birds (CPBs) found at the proposed Springbok facility were assessed over six visits and 218-hours of observation at the proposed facility, and from bird atlas cards. The seasonal presence of the nine species are updated in Table 2 (from Table 4 in our final pre-construction report: Simmons and Martins 2015).

Table 2: The seasonal presence of all Collision-prone species (CPS) recorded in the Springbok WEF, in 6 visits (2012-2014). Columns in orange are in the WEF site and those in green are the Control site. Red Data species shown in red.

Months	**Jan**	**Jan**	**Apr**	**Apr**	**June**	**June**	**Aug**	**Aug**	**Nov**	**Nov**	**Feb**	**Feb**
Verreaux's Eagle [2]	●	●	●	●	●	●	●	●	●	●	●	●
Martial Eagle [5]					●							
Lanner Falcon [30]			●						●			
Jackal Buzzard [44]	●		●	●	●	●	●	●	●		●	
Booted Eagle [56]								●	●		●	
Gymnogene [85]			●						●		●	
Black-chest Snake Eagle [56]									●			
Pale-chanting Goshawk [73]					●							
Cape Eagle Owl [41]				●								

5. IMPLICATIONS TO BIRDS FROM THE PROPOSED AMENDMENTS

5.1 General considerations: hub height and blade length

The question arises: do taller turbines (from 80-m hub height to 140-m) with longer blades (88-m to 160-m), increase the risk of mortality of birds through direct impact?

This question was posed by the two papers reviewed above based on extensive North America data (Barclay et al. 2007, Loss et al. 2013).

Barclay et al. (2007) showed that birds were generally unaffected by increasing hub heights, and neither did blade-swept area have any significant influence on the (low) number of birds killed. In data from 50 Spanish wind farms, A Caminã (unpubl data and pers comm), also noted no negative effects of taller turbines or larger blade-swept areas for larger birds. These are the data sources we used for our first amendment (in 2015). At the time we did not have access to the study of Loss et al (2013) and Caminã's data is unavailable.

The Loss et al. study, using a larger data set (from 53 wind farms in the USA), showed that there was a *significant* effect of increasing height on bird fatalities. With an increase in hub height from 40-m to 80-m, avian fatalities increased from about 2 to 6.2 birds per turbine per year.

Therefore, the increase in hub height from 80-m to 140-m is predicted to have some influence on the background mortality rates for birds such as eagles in the Springbok setting. By exactly how much is the question; we attempt to answer below.

5.2 Modelling fatalities for increased hub heights beyond 80-m

We have taken the fatality-hub height data of Loss et al. (2013) and asked two statisticians (Dr Birgit Erni and Francisco Cervantes) from UCT's Department of Statistical Sciences, to model the American data beyond the 80-m hub heights. To strengthen the forecast for fatalities at 140-m hub heights, and to make them more applicable to South African conditions, we included the South African data (6 points from Ralston et al. 2017). These included two wind farms with 90-m and 95-m hub heights. The results (Appendix 1), indicate that fatalities are expected to increase exponentially over four-fold from 6.2 to 28.0 (95% CI = 12, 65) birds.turbine^{-1}year^{-1}.

This increased risk is supported by records of the flight heights of two main collision-prone eagles on site, and their flight heights over six site visits (Appendix 1). For both Verreaux's (n = 418 records) and Booted Eagles (n = 160 records), the proportion of flight heights at the higher blade-swept heights (BSH) of 60-m to 220-m increased from about 35% to 69% for both species as hub heights increased from 80-m to 140-m.

This has yet to be assessed for South African wind farms alone and we note that few data exist for turbines >80-m hub height in either South African or North American data sets. We conclude, however, that given our statistical model (Appendix 1) and the fact that twice as many eagle flights occur at these heights, between two-fold and four-fold more avian fatalities are forecast by increasing turbines from 80-m to 140-m.

Why are taller turbines forecast to lead to high fatalities? There are two possible reasons, one ecological, one statistical:

(i) Ecologically, taller turbines and their greater blade-swept height are more likely to intersect migrating eagles studied in North America, which tend to fly two- to four-fold higher (average 135-m to 341-m) than resident birds (63-m to 83-m: Katzner et al. 2012). In Springbok this is corroborated by the higher proportion of flights at the BSHs for two species of eagle (Appendix 1);

(ii) Statistically, longer blades are associated with taller turbines. For example, 140-m high turbines have 80-m blades (while 80-m turbines have 44-m blades). This 1.8-fold increase in blade-length triples the blade-swept area from 6,082-m2 to 20,106-m2. Thus, by chance, a passing bird has a three-fold higher probability of intersecting a blade from a taller turbine. With avoidance behaviour this may well be decreased, but data are lacking for South African species.

Thus, the *location* of turbines becomes increasingly important if increased height should not increase the chances of fatalities. In this sense, choosing the best sites from the 37 turbine sites that have already been assessed and authorised, the remaining 25 turbines will go a long way in reducing the higher number of fatalities expected for the 140-m turbines.

5.3 Siting of turbines

Following the release of the avian findings of the EIA report in 2010, Mulilo reduced the number of turbines in areas around the two known, active, Verreaux's Eagle and Booted Eagle nests. These were in the north and the west of the WEF site for the Verreaux's Eagles and in the east (near the cell phone tower) for the Booted Eagle. However, an inactive Verreaux's Eagle nest in the far south became active in 2015 (Simmons and Martins 2015) and increased the activity recorded in the southern sections of the wind farm.

Data on the flights of the Verreaux's Eagles from (i) GPS data for the adult female provided by Alvaro Caminã; and (ii) Birds & Bats Unlimited pre-construction monitoring, indicate that this pair occurs close to turbines 3, 4, and 9 (Figure 1). Rather than the birds using all parts of their territory equally, most activity is aligned linearly east-west along the valley – along the rock faces where their nests and their prey typically occur (Rock Hyrax *Procavia capensis*) (Simmons 2005). That the female is often accompanied by her mate (personal observation) suggests that GPS positions are a good proxy for the presence/position of both eagles from nest No. 3 (Figure 1). Our own observations support this. Few flights were recorded over turbines 3 and 9 in 12-months monitoring.

However, more flights by two or more collision-prone eagle species were recorded within 150-m of the following turbines in our six site visits (Simmons and Martins 2015):

- WTG4 – Verreaux's Eagle (6 flights) single or paired eagles (once carrying food);
- WTG 8 – Verreaux's Eagle (2 flights), Booted Eagle (1 flight);
- WTG 15 – Verreaux's Eagle (3 flights), Booted Eagle (1 flight), Black-chested Snake Eagle (1 flight);
- WTG 16 - Verreaux's Eagle (3 flights), Booted Eagle (5 flights, once by a pair).

Given that collisions are more likely with taller turbines, then these four turbines are most likely to cause negative impacts (direct fatalities).

Several mitigation measures are possible: (i) these four turbines are moved from their present positions; (ii) automatic deterrent, multi-sensor system would be required as mitigation as suggested by Simmons and Martins (2015); (iii) the turbine hub heights (and the blade lengths) of these turbines are reduced to original levels.

The DT bird system http://www.detect-inc.com/avian.html has been independently tested once on eagles in Norway (May et al. 2012). It correctly identified more than 80% of the eagle flights and took corrective action. However, the number of false positives (detecting birds that were not eagles) was also above 50%. This means that the system was successful in reducing mortality but was inefficient in that it stopped turbines when no risk to eagles was apparent. The system costs ~ZAR500,000 per turbine. Other, newer, systems may be required and will be available by the time Mulilo's Springbok WEF becomes operational. Such a "multi-sensor" system is being tested now (2017) in South Africa (J Avni pers comm) and works on video surveillance in preference to radar-detection which has reliability issues.

A new possibility for deterring raptorial birds from collisions, with the multi-sensor system, is the use of intense short wavelength LED lights. These were recently investigated on Red-tailed Hawks *Buteo jamaicensis* in the USA – one of the most collision-prone species there (Foss et al. 2017). The lights produced >5-fold more aborted approaches at hawk lures at a banding station than those at a control without the LED lights (Foss et al. 2017). This should be investigated in South Africa where hawks and other raptors feature prominently in all fatality reports (Ralston-Paton et al. 2017).

5.3 Numbers of turbines vs increased hub height

Will a decrease from 37 turbines at 80-m hub height, to 25 turbines at 140-m hub height decrease the probability of avian fatalities? By quantifying the increased number of fatalities with a 140-m hub height we can determine if the reduced number of turbines can, indeed, compensate for this.

From the model forecasting the number of fatalities at the new hub heights of 140-m (Appendix 1) the predicted total number of fatalities for 25 turbines is 700 birds (with 95% confidence limits of 300 to 1,625). This is higher than the number predicted for 37 turbines at 80-m hub heights of 229 birds. Thus, increasing hub heights to 140-m for the 25 turbines is forecast to have a marked negative affect on avian fatalities.

These effects are great enough that they would require mitigation as suggested above. That is either:

(i) the riskiest turbines (identified above) need to be moved to less risky areas;

(ii) all turbines killing one or more Red Data bird per year will need to be fitted with automated deterrent or shut-down-on-demand; or

(iii) the four most risky turbines should be of reduced hub height and blade length to reduce the risk of impacts.

Table 3. Re-assessing the potential number of avian fatalities per year with increases or decreases in turbine heights and turbine numbers. These are based on fatality estimates modelled by Erni and Cervantes (see Figures 3 and 4). This increases the average fatality estimates from 6.2 birds.turbine.year^{-1} to 28 birds.turbine.year^{-1} for 140-m turbines. Note that these figures are provided for theoretical modelling purposes and are not included as alternatives in the amendment application.

	Turbine number		
Turbine height	Ave No. fatalities/ turbines/yr*	**37 turbines**	**25 turbines**
80-m	6.2	229 birds	155 birds
140-m	28 (12-65)	1,036 (444-2,405) birds	**700 (300-1,625) birds**

* extrapolated from model results in Appendix 1

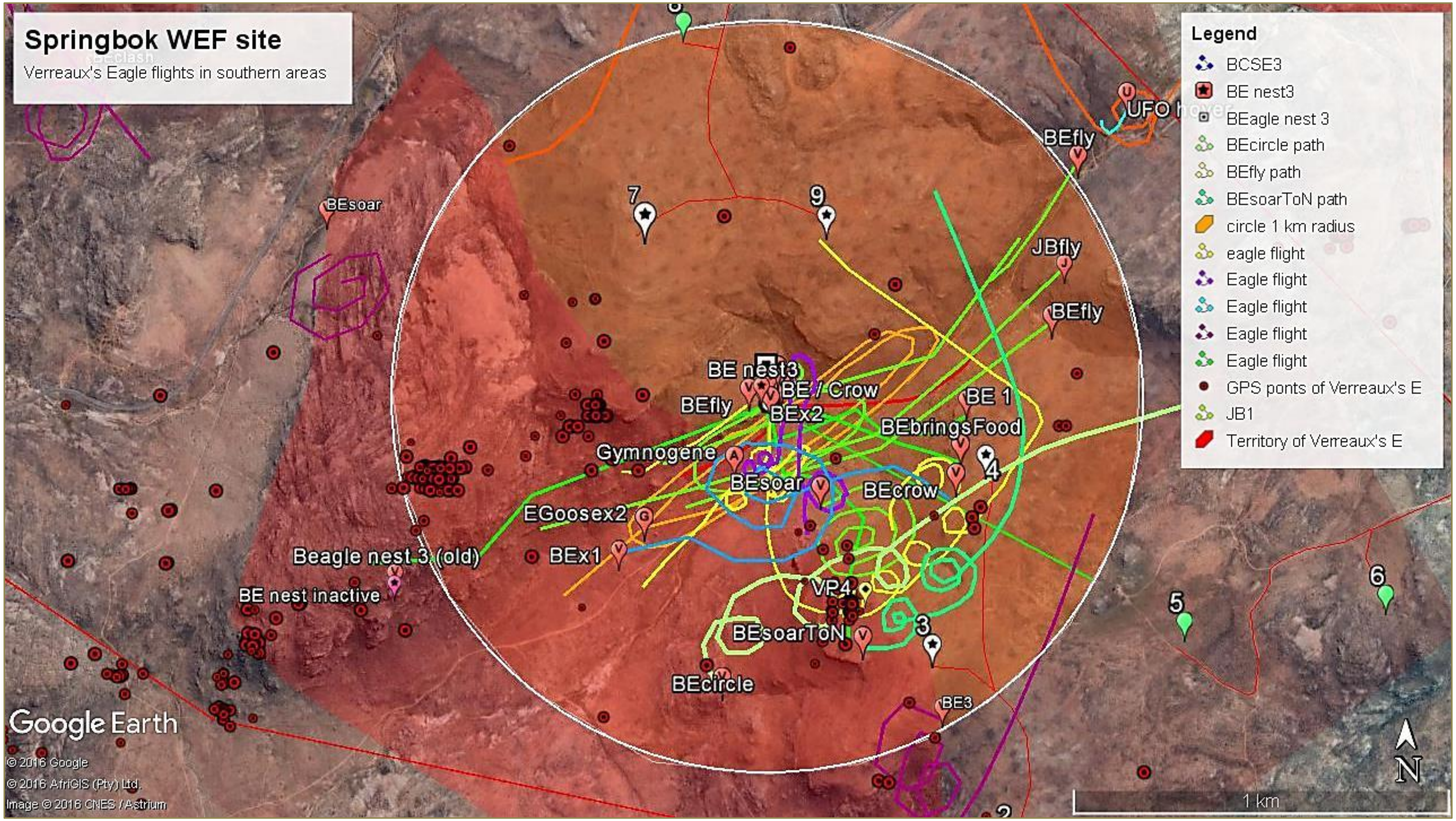

Figure 1: The southern study area indicating the January 2015 WTG positions (white balloons 3 ,4, 7 and 9). The hourly GPS positions of the female Verreaux's Eagle between October 2014 and 12 January 2015 are shown (red dots) in relation the nest (BE nest 3) and the turbines. Most activity occurs along the valley side (Hyrax habitat) while little activity is apparent for the eagles over the hill tops within 1-km of the nest (white circle = 1-km radius). Turbine 4 is a high-use area for the eagle pair (6 flights, once with food, recorded here) and is a risky turbine.

5.4 Quantifying the impacts

Several raptors were previously identified (Simmons and Martins 2015) as likely to be negatively affected by displacement, loss of habitat or direct mortality. These are all in the top 100 collision-prone species: Verreaux's Eagle (Vulnerable, 2nd), Martial Eagle (Endangered, 5th), Black Harrier (Endangered, 6th), Lanner Falcon (Vulnerable, 22nd), Booted Eagle (55th), and Jackal Buzzard (42nd). The following tables quantify the impacts for these raptors, particularly South African Red Data birds (Taylor et al. 2015). This incorporates the data from 2010 and 2015 and reflects the amended layout. The first table indicates the Construction Phase impacts, the second the Operational Phase impacts.

The significance of the impact (S) is given by the equation (NEMA 2010):

S = (E+D+M)P

Where
E = Extent (local or wide-scale, ranked from 1 to 5)
D= Duration (length of time of the effect, ranked from 1 to 5)
M= Magnitude (the size of the negative effect, ranked from 1 to 10)
P=Probability (the likelihood of the event happening, ranked from 1 to 5)

The Nature of the impact will be negative in that birds will either be: (i) displaced by habitat alteration; (ii) displaced by disturbance during or after construction; (iii) impacted by turbine blades directly; (iv) impacted by the existing and proposed 132 kV lines.

The Extent of the impact will be local **(1)** reducing foraging habitat in the immediate wind farm area for the raptors, but may be higher if the space created by the death of territorial individuals brings in other birds to be killed (the sink effect), or they are displaced from breeding through disturbance.

The Duration will be short-term (**2)** for the duration of the construction (1-2 years?) but **(5)** for the operational lifetime of the wind farm for all species.

The Magnitude is ranked as a medium-high impact **(6)** for the raptors, particularly those frequently flying at 80m rotor height (Verreaux's Eagles, Booted Eagles and Jackal Buzzards). However, this will increase to **(8)** as hub height increases to according to fatalities forecast by Loss et al. (2013) and statistical inference in Appendix 1.

The Probability of occurrence of the raptors flying into the rotor blades is ranked as high **(4)** given their aerial nature and the high proportion of time that both Verreaux's and Booted Eagles spend at these blade-swept heights (see Appendix). The regular use of known perch sites (data from Alvaro Caminã: Figure 1) and nest sites on the WEF site may reduce this risk for Verreaux's Eagles given that turbines can be placed away from the main centres of activity or be fitted with automated shut-down-on demand or deterrence technology if found to be killing birds.

The Significance [S = (E+D+M)P] is as follows for the species identified as at risk:

All raptors S = (1 + 5 + 8)4 = 56

These ratings indicate that, for all raptorial species, the resultant significance weightings (56) has a direct influence on the decision to develop and, therefore, must be mitigated.

Table 4. Significance table explaining the relevance of the scores used.

Parameter	Scores	Interpretation
Extent (Area) **E**	1-5	1-2 (Local), 3-4 (regional) 5 (national)
Duration (period of impact) **D**	1-5	1 (v short term, 0-5 yr) 2 (short term, 2-5 yr) 3 (Medium term of 5-15 yr) 4 (long term > 15 yr) 5 (life time of the development)
Magnitude (size of impact) **M**	1-10	1 (negligible) 2 (minor) 4 (low, and cause an impact on the process) 6 (moderate, process continue but modified) 8 (high) 10 (v high, destruction of patterns and cessation of processes)
Probability (likelihood the impact will occur) **P**	1-5	1 (improbable) 2 (improbable, but still low likelihood) 3 (distinct probability) 4 (highly probably, most likely to occur) 5 (definite, will occur regardless of any prevention)
Significance **S** = (E+D+M)P	3-100	3-30 (low, impact will not have a direct influence on decision to develop) 30-60 (Medium, impact could influence the decision to develop unless effectively mitigated) 60-100 (High, impact must have an influence on the decision to develop the area).
Confidence		Sureness that the input variables are sound and well researched in determining the final significance level.

Table 5a. A summary of the quantified impacts during construction to the raptors likely to be impacted by the wind farm for the amended layout and turbine dimensions. We compare the impacts with those estimated for the pre-construction report.

Construction Phase

Nature: Direct mortality, disturbance or avoidance of area around the wind farm for the raptors identified as at risk above, due to disturbance, or impacts with turbine blades and overhead lines, during construction.		
	Without mitigation	**With mitigation**
Extent	1 (local)	1 (local)

Duration	2 (short-term)	2 (short-term)
Magnitude	4 (low)	3 (low)
Probability	3 (distinct possibility)	3 (distinct probability)
Significance (E+D+M)P	21 (Low significance = impact will not have direct influence on decision to develop)	18 (Low significance = impact will not have direct influence on decision to develop)
Status (+ve or –ve)	Negative	Negative to neutral
Confidence	High	High
Reversibility	High	High
Irreplaceable loss of species?	No (Both Verreaux's and Booted Eagles may suffer short term disturbance, displacement, and loss of breeding but return after construction)	Reduced
Can impacts be mitigated?		Partially, yes

	Authorised Project		**Proposed Amendment**	
	Pre-mitigation impact rating	**Post-mitigation impact rating**	**Pre-mitigation impact rating**	**Post-mitigation impact rating**
Extent	**1**	**1**	**1**	**1**
Duration	**2**	**2**	**2**	**2**
Magnitude	**4**	**3**	**4**	**3**
Probability	**3**	**3**	**3**	**3**
Reversibility	high	high	high	high
Irreplaceable loss of species?	No (Both Verreaux's and Booted Eagles may suffer short term disturbance, displacement, and loss of breeding but return after construction)		No (Both Verreaux's and Booted Eagles may suffer short term disturbance, displacement, and loss of breeding but return after construction)	
Significance rating	**21 (low)**	**18 (low)**	**21 (low)**	**18 (low)**

Mitigation: There are generally two classes of mitigation to avoid disturbing Red Data birds around wind farms during construction: (i) limit construction activities (building, blasting etc) to seasons when birds are not breeding – to reduce disturbance causing nest failure; (ii) limit construction activities (building, worker-presence, power-line-stringing) from areas within 500 m of known Red Data species' nests at times when eagles or other Red Data species are incubating/feeding small nestlings.

We therefore recommend as mitigations: (i) not constructing within 500m of Verreaux's Eagle nests during their early breeding season (May to June) or small-chick rearing season (June-July). This applies to turbines 7 and 9 in the southern sections of the site. For breeding Booted Eagles, the seasons to avoid are August-

September (ii) avoid blasting or causing noise disturbance in the same seasons anywhere within 3 km of active nests for all Red Data species.

Table 5b. A summary of the quantified impacts during operations to the raptors likely to be impacted by the wind farm for the amended layout and turbine dimensions. We compare the impacts with those estimated for the pre-construction report.

Operational phase

Nature: Direct mortality, disturbance or avoidance of area around the wind farm for the raptors identified as at risk above, due to disturbance, or impacts with turbine blades and overhead lines during operations.		
	Without mitigation	**With mitigation**
Extent	1 (local)	1 (local)
Duration	5 (very high)	5 (very high)
Magnitude	8 (high)	6 (moderate)
Probability	4 (highly probable)	3 (distinct probability)
Significance (E+D+M)P	56 (Medium significance = impact should influence decision to develop unless mitigated)	36 (Medium significance impact could influence the decision to develop unless effectively mitigated)
Status (+ve or –ve)	Negative	Negative to neutral
Confidence	High	High
Reversibility	Low	High
Irreplaceable loss of species?	No (Verreaux's Eagles are not uncommon and the rarer Booted Eagles may be less susceptible to collision and displacement)	Reduced
Can impacts be mitigated?	Yes	Partially, yes

	Authorised Project		**Proposed Amendment**	
	Pre-mitigation impact rating	**Post-mitigation impact rating**	**Pre-mitigation impact rating**	**Post-mitigation impact rating**
Extent	**1**	**1**	**1**	**1**
Duration	**5**	**5**	**5**	**5**
Magnitude	**6**	**4**	**8**	**6**
Probability	**4**	**3**	**4**	**3**
Reversibility	Low	Medium	Low	Medium
Irreplaceable loss of species?	No (Verreaux's Eagles are not uncommon and rarer Booted Eagles may be less susceptible to		No (Verreaux's Eagles are not uncommon and rarer Booted Eagles may be less susceptible to	

	collision and displacement)		collision and displacement)		
Significance rating	**48 (medium)**	**30 (low)**	**56 (medium-high)**	**36 (medium)**	

Mitigation: There are generally five classes of mitigation for birds around wind farms: (i) re-position the turbines to avoid impacts or disturbance for the birds; (ii) redesign the turbines to alter the present pattern/shape/size of the turbines so birds see them more readily and avoid contact; (iii) shut-down-on-demand the turbines when collision-prone birds approach; (iv) manipulate the habitat to reduce the attractiveness of the site to collision-prone raptors; (v) reduce the overall number of turbines. That is, reduce from 37 to 25 the 140 m hub-height, turbines.

Appendix 1 indicates that the predicted avian fatalities from statistical and flight-height interpretations are predicted to increase about 2-4 fold with taller turbines. However, by combining the reduction in turbine numbers from 37 to 25 and either taking out the 12 turbines with highest impact, or reducing the hub heights and blade lengths of the four most problematic turbines (T4, T8, T15, T16) we can achieve an optimal layout (in conjunction with Mulilo staff) that will reduce overall avian impacts. Note: this does not involve altering the original layout, but simply choosing the optimal positions for the remaining 25 turbines.

We, therefore, recommend as mitigations:

(i) not siting turbines in high-risk areas where collision-prone raptors are shown to be perching or flying or aerially abundant;

(ii) specifically reduce the hub heights (to 105 m) and blade lengths of the turbines WTGs 4, 8, 15 and 16 as the most likely turbines to experience fatalities of Verreaux's and Booted Eagles;

(iii) maintaining or even increase the grazing pressure (by sheep and goats) on the wind farm site to reduce the attractiveness of the site for mammal-eating raptors (livestock compete with hyrax and mice for food resources and reduce the prey available for large-medium raptors).

Operational phase monitoring is essential to determine the actual impacts on birds and therefore, the required mitigation measures and thresholds. However, such an approach requires an exceptionally flexible Adaptive Management Plan to be implemented during operation. Such an Adaptive Management Plan must allow for changes to be implemented within a maximum timeframe of 3 weeks.

The Wind Farm must agree to follow the mitigation measures that may result from the operational monitoring and Adaptive Management Plan.

(iv) In accordance with the Adaptive Management Plan, appropriate mitigation measures, such as curtailment at specific environmental conditions or during high-risk periods (i.e. post construction monitoring shows 1 Red Data species killed at these turbines per year then the use of appropriate automatic shut down or deterrent technology, will have to be implemented in the case of mortality of Red Data species [defined as: 1 Red Data species killed per year]).

The operational monitoring study design must determine the exact environmental conditions as well as the turbines that require appropriate mitigation measures.

We recommend two adaptive management mitigations if Red Data species are found to be killed: (i) the automated "Multi-sensor" video system, presently under test by J Avni, which deters incoming birds or feathers the blades, or turns off turbines as collision-prone species approach within 500-m of these turbines; (ii) investigate painting half a blade black to deter raptors as undertaken by Norwegian wind farms to reduce white-tailed Eagle deaths with great success (Stokke et al. 2017). For **all** overhead power lines to be fitted with diurnal and nocturnal bird diverters to reduce collisions and burying all internal power lines in the WEF, wherever that is possible. We understand that some rare small succulent plants can be displaced by attempting to bury lines in rocky terrain, so only areas where this impact is avoided should this be attempted.
Cumulative impacts: Cumulative impacts (Masden et al. 2010) are those that may affect a species in a small area (e.g. a wind farm) yet have a wide-scale influence. If resident territorial birds are killed by turbines for example, then other individuals will be pulled in to take up the vacant territory. A wide-spread population reduction may occur as a result of the WEF acting as a sink. This is less likely for the Verreaux's Eagles given that they are a relatively common (but iconic) montane species. For breeding Booted Eagles, however, this may have a greater impact on their population because there are an estimated 700 breeding pairs in South Africa (Martin 2005). All renewable energy applications within 50-km of Springbok are assessed below.
Residual impacts: After mitigation, direct mortality or area avoidance by the species identified above may still occur and further mitigation (e.g. turbine shut-down) will be needed.

Table 6: A comparative assessment of the impacts of the Authorised Project (37 turbines at 80-m hub height) and the Proposed Amendment (25 turbines at 140-m hub height).

Option	Nature	Extent	Duration	Magnitude	Status of impact	Confidence	Mitigation	Significance post mitigation
Operational phase								
Authorised	Fatality of Red Data birds on site. Displacement of same species	Local	Long term	Moderate	-ve	High	Re-location of some turbines; Fitment of automated detect and deter systems	low
Proposed amendment	Fatality of Red Data birds on site.	Local	Long term	High	-ve	High	Re-location of most risky turbines to less used areas;	medium

	Displacement of same species						reduction of hub height to 105 m of the riskiest turbines (4, 8, 15, 16) Fitment of automated detect and deter systems at any turbine killing one or more red data species per year.	

5.5 Cumulative impacts

Cumulative impacts are defined as "Impacts that result from incremental changes caused by either past, present or reasonably foreseeable actions together with the project" (Hyder 1999, in Masden et al. 2010).

Thus, in this context, cumulative impacts are those that will impact the avian communities in and around the Springbok development, mainly by other renewable energy facilities (wind and solar farms) and associated infrastructure in the Nama and Succulent Karoo biome. This will happen via the same factors identified here viz: collision, avoidance and displacement.

As a starting point, we need to determine the number and nature of the renewable energy farms around the region within a 50-km radius, and secondly, to know their impact on avifauna (Figure 2).

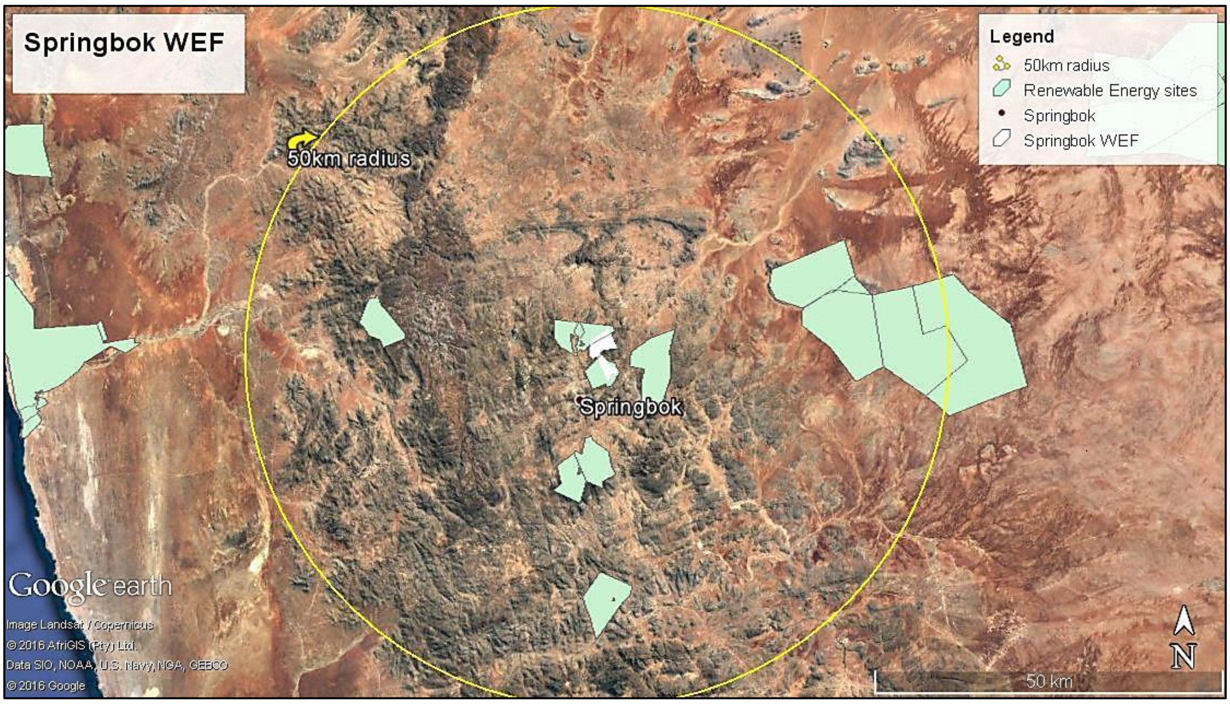

Figure 2: All renewable energy applications lodged with the DEA within a 50-km radius of the Springbok WEF site. Eight of the nine sites are solar, and one is a wind farm.

Table 6: All renewable energy projects within a 50-km radius of the Springbok WEF, and their approval status with the DEA. Source: https://www.environment.gov.za/mapsgraphics DEA last quarter 2016.

	Project Title	**Distance from Springbok WEF (km)**	**Technology**	**Megawatts**	**Current Status**
1	O'Kiep 2 PV Solar Energy	0	Solar PV	15	Approved
2	Kgabalatsane Solar	3.57	Solar PV	30	In Process
3	O'Kiep 2 PV Solar Energy	5.38	Solar PV	15	Approved
4	Melkboschkuil	8.51	Solar PV	20	Approved
5	Biesjesfontein	15.89	Solar PV	300*	Withdrawn/Lapsed
6	Kokerboom	19.23	Solar PV	10	Approved
7	Nigramoep	31.15	Solar PV	30	In Process
8	Nama-Khoi Municipality	31.65	Wind & PV	280**	In Process
9	Baobab Mesklip	35.56	Solar PV	10	Approved
		Totals:	**1 wind farm + 7 solar farms: 410 MW**		

*Excluded from further analysis

**Corrected from the DEA website (of 1000 MW) K. Low and N Holland pers comm.

Given the general assumption that footprint size and bird impacts are probably linearly-related for wind farms, a starting point in determining cumulative impacts is to calculate:

- the number of birds displaced per unit area, by habitat destruction, or disturbed or displaced by human activity;
- the number of birds killed by collision with the turbines on site; and
- the number of birds killed by collision with infrastructure leading away from the site.

Nine renewable energy developments are currently on record with the DEA (Table 5) and all but four are approved. One is lapsed/withdrawn and is omitted from further calculations. Most are south and east of the Springbok study site (Figure 2) and they are mainly solar sites. The total output from the eight approved sites is 410MW (Table 5).

We searched for data to populate the Cumulative Impacts table from the internet for proposed wind and solar farms. We sourced data from (i) data from Birdlife South Africa on 1-2-years' post-construction monitoring of avian fatalities at wind farms (Ralston-Paton et al. 2017); and (ii) an MSc study of the avian mortalities recorded at the Jasper solar PV farm in the Northern Cape (Visser 2016). Other unpublished post-construction Mulilo reports made available to us from Copperton and Prieska PV sites indicate that there are no avian fatalities there (K Low pers comm). The reports noted that Martial Eagles breeding successfully nearby had been displaced and were no longer breeding, but they have since returned to the area and are again breeding successfully (K Low pers comm).

The national review of post-construction **avian fatalities at wind farms** (Table 6), including data from the Karoo and Eastern and Western Cape wind farms, indicate that South African wind farms kill about 4.1 birds/turbine/year (range 2.1 – 8.6 fatalities/turbine/year). This is similar to the international mean of about 5.25 birds/turbine/year. Of more concern is that a majority of the fatalities recorded (36%) in South Africa are raptors (Table 6).

The equivalent number of fatalities per Megawatt averages 2.43 birds/MW/year (Ralston-Paton et al. 2017). Using this value of 2.43 bird fatalities/MW/year we can calculate that:

1. the number of birds likely to be killed by the single Nama-Khoi 280MW wind farm to be <680 birds/year.

Note that this may be a slightly inflated figure given that many early wind farms in South Africa did not have stringent mitigation measures, especially appropriate buffers and siting of turbines, potentially inflating fatality rates.

Table 6: Summary of all birds and Red Data raptors killed at six wind farms in South Africa from 2014–2016. From Birdlife South Africa (Ralston-Paton et al. 2017).

Wind farms	Turbines	Months monitored	Avian fatalities	Adjusted mortality rate*
6	46, 9, 41, 40, 60, 32	69	309	4.1 birds/turbine/yr
Main groups		Proportion of all avian fatalities		Ranking
Raptors (small-medium)		33%		1
Raptors (eagles)		3%		6
Others/unknown		16%		2
Swifts, swallow and martins		14%		3
Passerine (small perching birds)		14%		3
Waders and wetland birds		10%		5
Red Data raptors as a proportion of all birds killed		12/309 = 3.9%		

For solar farms, we could only use the available data from Visser (2016) who undertook a short post-construction study of a large solar PV site at the Jasper facility. She estimated that 4.5 birds/MW are killed annually by the solar panels and associated infrastructure. A second MSc study by Jeal (2017) of trough technology is not comparable with the PV solar here. It should be noted, however, that he recorded very few avian fatalities. We can use this to roughly estimate mortality as follows:

2. if the cumulative total power output of the six solar PV farms operating within 50-km of Springbok is 130MW (Table 5), then an estimated (130 x 4.5 birds/MW =) 585 birds/year could be killed by the six PV facilities. If most of these are non-threatened korhaans (Visser 2016) or smaller species, then the impact on the avian community of this part of the Northern Cape is expected to be relatively minor.

Combining the two estimates (1 and 2 above) of potential avian fatalities from the wind farm (<680 fatalities) and the six solar facilities (~<585 fatalities), the potential cumulative impact in terms of birds killed by all renewable energy facilities within 50-km of the Springbok site will be approximately 1,265 avian fatalities. This is likely to be a maximum figure (with few threatened species) given that other unpublished studies of PV facilities in from the Karoo show very low fatality figures (K Low pers comm).

This number must be put in context to account for the threat status of the species of birds killed. Present limited evidence suggests that PV solar facilities are unlikely to kill many Red Data species (Visser 2016). A review of the wind farm data collated by Ralston-Paton et al. (2017) suggests that of all birds killed, about 12 of 309 fatalities (4%) were Red Data species of raptor. Hence, of the <680 fatalities at the only other wind farm, approximately (4% x 680) 27 Red Data raptors are predicted to be killed per year. Short-term displacement of raptors from PV sites was observed based on unpublished reports from Copperton and Prieska (Jenkins and du Plessis 2017), but no fatalities have been reported, and other breeding raptors have returned. Thus, a total of only 27 Red Data raptors is calculated for the cumulative impacts.

Table 7: Cumulative impacts of the Springbok wind farm in the Northern Cape, relative to 8 other renewable energy facilities within 50-km of the site.

Nature*:* The impact of the wind energy facilities proposed in the Northern Cape is expected to be negative and arise from disturbance, displacement and collision for birds around the wind turbines. The associated infrastructure will also impact species in the form of impacts with un-marked power lines.

The direct impact of the wind farms (Table 5) was gauged using unpublished data released by Birdlife South Africa for fatalities at 6 wind farms in South Africa (Ralston-Paton et al. 2017). About 4.1 birds/turbine/yr, or ~2.43 birds/MW/year are killed annually. If a total of 280MW is generated per year from the sole (Nama-Khoi Municipality) wind farm, then we estimate <680 birds killed per year there.

For the remaining seven solar farms (omitting the lapsed/withdrawn Biesjesfontein site), totalling 130MW, the total number of fatalities is estimated at 585 birds. In total about 1,265 avian fatalities are predicted as the cumulative total for all renewable energy sites within 50-km of Springbok. This is likely to be a maximum figure given that unpublished reports from elsewhere report no fatalities but some displacement.

About 4% of the total of the wind farm fatalities are expected to be threatened Red Data raptors (data from Ralston-Paton et al. 2017). Thus, we can predict a maximum of 27 threatened raptors may be included in this total per year without mitigation.
Thus, the likely impact varies from medium to high without mitigation. Careful mitigation can reduce this to acceptable levels.

	Cumulative Impact with Authorised project*	**Cumulative Impact with Proposed Amended Project****
Extent	Regional (3)	Regional (3)
Duration	Long-term (5)	Long-term (5)
Magnitude	Moderate (5)	Moderate (6)
Probability	Most likely (3)	Most likely (3)
Significance	**Medium (39)**	**Medium (42)**
Status (positive/negative)	Negative	Negative
Reversibility	Medium	Medium
Loss of resources/species?	Possible	Possible
Can impacts be mitigated?	Probably, Yes	Yes

Confidence in findings:

Medium: the mortality data released by Birdlife South Africa for wind farms allows us to estimate the probable mortality, but the mitigation measures suggested to avoid major raptor fatalities are unknown for each wind farm. Without mitigation measures (i.e. the avoidance of high use and high risk avian areas by turbines) will increase the chances of mortality greatly.

Low for the solar farms: only one study of post-construction mortality has been released and we have relied on that single study. Therefore, the confidence is low for fatality estimates of solar farms. Because individual wind or solar farms in South Africa rarely release data, it is difficult to gain accurate data without specific studies (e.g. the MSc thesis of Visser, or the compilation by Birdlife SA). Thus, these cumulative impact assessments will remain of low confidence until all specialist studies are made public.
Mitigation: Reducing avian impacts at wind energy facilities is in its infancy in South Africa. Recommended measures specifically for the proposed Springbok facility include: • Avoiding all nest areas and foraging/roosting areas of Red Data species in the siting of said facilities. Appropriate buffers around nests (e.g. 3 km for Verreaux's Eagles-Ralston-Paton 2017) should be applied, particularly to the most collision-prone species; • The turbines 4,8,15 and 16 are likely to be the riskiest due to flights paths of eagles and they should be replaced with turbines of lower hub height (105-m); • If operational-phase monitoring indicates that one or more Red Data bird is killed at any turbine, then we recommend that multi-sensor deterrent/shut down systems are placed on those turbines; • Multi-sensor radar detection of collision-prone birds can deter birds through audible or visual deterrence to prevent birds from approaching close to the turbines; • Intense Short-wave radiation (Foss et al. 2017) should also be tested as a deterrent. • If audible or visual deterrence is ineffective then selective stopping of turbines should be tried; • Marking all new overhead power lines with bird diverters to avoid large birds colliding with them; • Reduce leakages (in the pipe crossing the wind farm) and cover all water points so they are not visible from above to prevent/reduce arid-zone species being attracted to them; • Introduce livestock into the area around the turbines to reduce the attractiveness of the habitat to raptors through increased grazing pressure reducing prey populations.

** With 37 turbines of 80-m hub height ** with 25 turbines of 140-m hub height*

6. CONCLUSIONS

The presence of breeding collision-prone and Red Data bird species in the Springbok Wind Farm area (in the form of Verreaux's and Booted Eagles) and the presence of other collision-prone species requires careful siting of the proposed turbines. This was largely undertaken by Mulilo for the authorised project, based on the original avian impact assessment (Simmons 2010, Simmons and Martins 2015), and in discussions with the specialists. The suggested amendment of increasing the hub height (and power output) of each turbine are considered here, as an addendum, for the effect it may have on the large collision-prone eagles.

In general, the change in hub height of the proposed turbines is expected to have a negative influence on the mortality experienced by sensitive birds in the study area. This arises from a new analysis of 53 wind farms in the USA by Loss et al. (2013). Their meta-analysis indicates a significant effect of hub height on avian fatalities (the higher the turbine the greater the chance of avian fatality). However, they did not include turbines with hub height above 80-m. To forecast how many fatalities 140-m high turbines may incur we modelled the USA data, and incorporated South African data, with the assistance of two UCT-based statisticians. Fatalities of 6.2 birds/turbine/year for 80-m turbines were predicted to increase four-fold to 28 fatalities/turbine/year (95% confidence limits 12-65) at 140-m hub heights. Using these new data, we calculate that – in terms of potential avian fatalities:

- 37 turbines of 80-m hub height (229 fatalities) have lower avian costs than
- 25 turbines of 140-m hub height (700 fatalities).

Therefore, the proposed amendments (increased hub height and fewer turbines) will result in a change to the significance of the impact(s) assessed for birds in the original EIA. This probably arises because the area swept by the blades triples, when blade length increases 1.8-fold , increasing the chance that passing birds will be impacted by the blades. Both eagles on site (Verreaux's and Booted) were also found to fly more often at the higher blade-swept heights, strengthening this theoretical conclusion (Appendix 1).

The significance will change in a negative manner (higher impact) if the turbine height is increased (to 140-m). Therefore, we propose mitigations that can reduce the significance of this impact to acceptable levels.

In particular, we recommend (i) reducing the hub height of four of the riskiest turbines (WTG 4, 8,15 and 16) to reduce the possibility of collision, given that most recorded flights of the Verreaux's and Booted Eagles were close to these turbines (Simmons and Martins 2015). Additional mitigations previously proposed (Simmons and Martins 2015) included shut-down-on-demand by automatic systems such as the Multi-sensor systems currently under test in South Africa (J Avni pers comm). New deterrent systems such as intense shortwave LED lighting (Foss et al. 2017) should also be considered where turbines kill one or more Red Data birds per year from data collected during post-construction monitoring. Increasing grazing pressure around turbines, and across the wind farm in general, will reduce the attractiveness of the site to resident and migrating raptors. Mitigations during construction should include (i) avoiding construction within 500-m of active nests of Red Data species during the early breeding season.

All overhead power lines should be marked with nocturnal and diurnal bird diverters. Where possible, (where this does not cause disturbance to rare plants as recommended out by the botanical specialist) those power lines on site should be buried. With this mitigation and the marking of the overhead lines, the risks to collision-prone birds on the WEF site can be reduced to minimal acceptable levels.

The cumulative impacts for the eight renewable energy facilities (i.e. seven solar and one wind farm) surrounding the Springbok site are expected to be medium-low as gauged by an estimated 1,260 birds and 27 Red Data raptor mortalities per year. If all wind and solar farms enact suitable mitigation measures, these impacts, too, can be reduced to acceptable levels.

In conclusion, the currently proposed amendments (i.e. 25 turbines with hub heights of 140-m), is likely to incur more fatalities than the authorised 37 turbines of 80-m height. However, with suitable mitigations, that is: either (i) the 4 most risky turbines (identified above) have their hub heights reduced to 105-m and blade length reduced; and (ii) all turbines killing one or more Red Data birds per year will need to be fitted with automated deterrent or shut-down on demand, then Mulilo can reduce their environmental/avian footprint to acceptable levels. We recommend a minimum of 12 months' of post-construction monitoring to determine the effects of the wind farm on the Red Data species identified as at risk. With these mitigations, we can recommend that the Springbok wind farm, as amended, can be allowed to proceed.

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8. Appendix 1: The use of statistical inference to forecast possible bird fatalities when turbine heights are increased

Please note: the turbine numbers and avian fatalities used here are for indicative purposes only. The statistical model uses empirically-derived real data from wind farm studies in North America and South Africa and is used to forecast what avian fatalities may occur for different hub heights in real-life situations in South Africa.

The proposed Mulilo Springbok wind farm facility is contemplating increasing hub height of the wind turbines from 80-m to 120-m or 140-m. Environmental Consultants, Birds & Bats Unlimited, were requested to assess the possible impact to birds of this increased height.

Our report (Simmons and Martins 2017) used the trends from meta-analysis of Loss et al (2013) who analysed data from 53 studies of avian fatalities and hub height in the USA. They found a significant positive relationship between avian fatalities and hub height for turbines from 36-m to 80-m. Avian fatalities increased 10-fold over this size range (0.6 to 6.2 birds/turbine/year). We originally used these trends to estimate that a minimum of 9 birds/turbine/year are likely to be killed for the 120-m turbines and 10 birds/turbine/year for the 140-m turbines that may be used by Mulilo.

It must be noted that Smallwood (2013) found the opposite trend (decreasing fatalities per turbine with increased height). However, his data were skewed by a plethora of older small turbines with lattice towers – that attract perching birds – with very high fatality rates. Since lattice towers are no longer used, this bias no longer exists and his results are not a true reflection of avian fatalities into the future. Loss et al. (2013) accounted for this bias in their re-assessment. Their results are shown below (Figure A1).

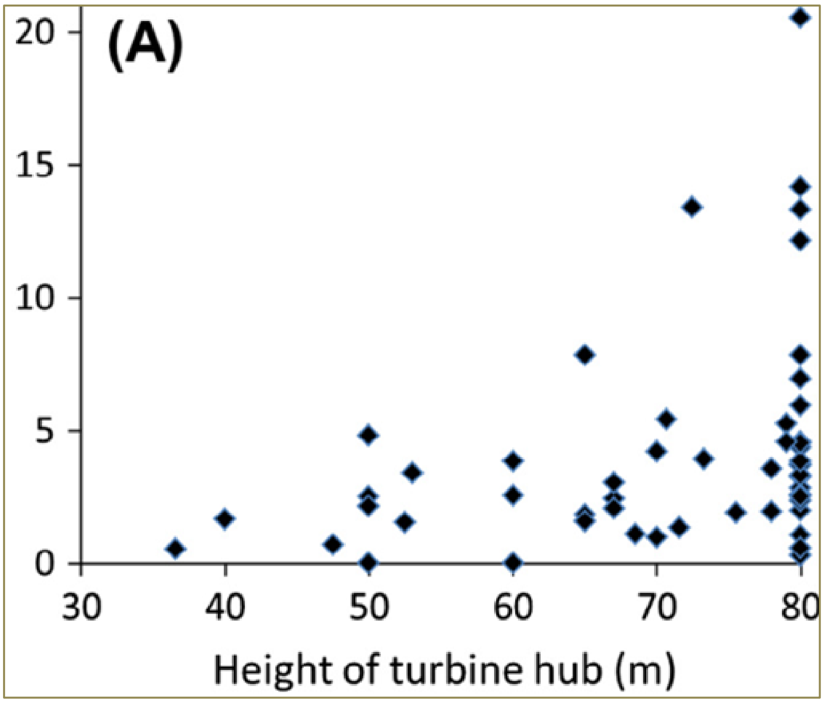

Figure A1: Results from Loss et al. (2013) indicating the significant relationship between hub height and avian mortality for 53 studies from the USA.

Modelling fatality/hub height estimates

To determine what the avian fatalities might be for taller turbines we asked two statisticians to help forecast what these rates might be, using statistical modelling. Dr Birgit Erni of the Department of Statistical Sciences at UCT and her PhD student Francisco Cervantes modelled the results provided in the supplementary material by Loss et al. (2013) to determine what the effects may be.

Their results are shown in Figure A2 using only the results from the USA.

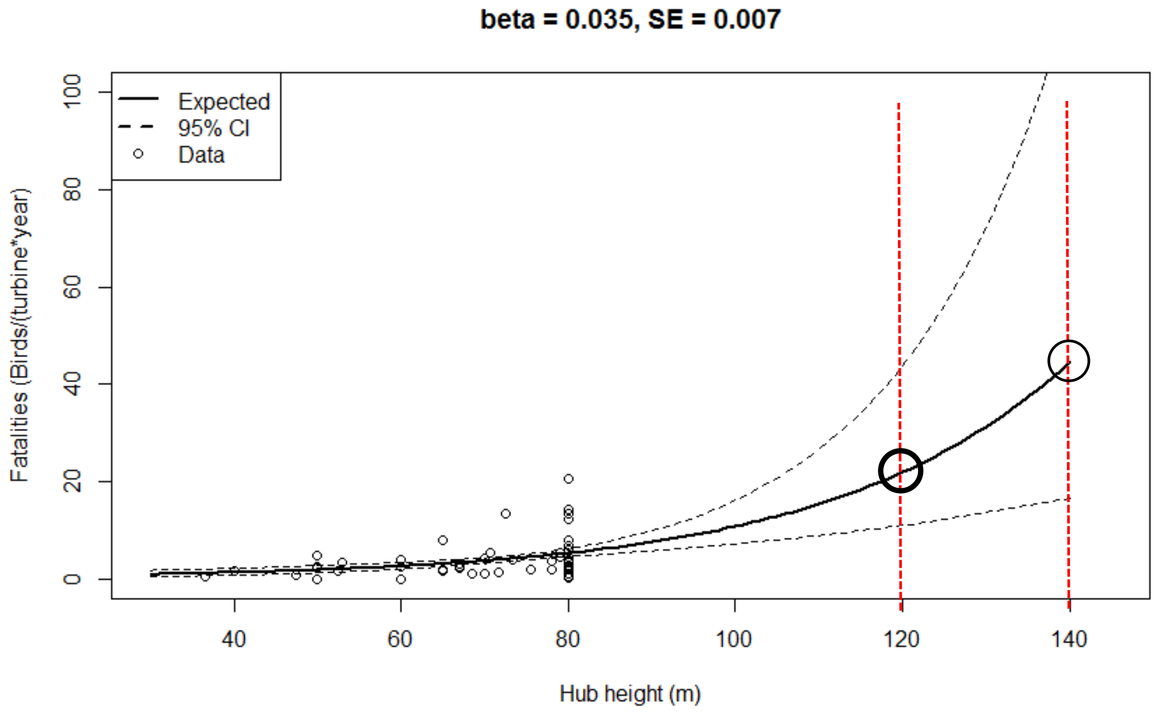

Figure A2: Modelled results of avian fatalities in relation to hub height for turbines above 80-m. Data taken from Loss et al. (2013) and modelled with 95% confidence limits (dashed lines). Circled on the graph are the projected average number of fatalities for 120-m (22 fatalities/turbine/year) and 140-m turbines (44 fatalities/turbine/year).

Their modelling indicates that the relationship between turbine height and fatalities was exponential and a predicted 22 birds (95% CI = 11, 44) may be killed on average per turbine per annum by 120-m turbines and 44 birds (95% CI = 17, 119) per annum by 140-m turbines (Figure A2).

Such models are only statistical constructs of what may happen in reality, and it is dangerous to extrapolate too far beyond real data. This is reflected in the wide confidence intervals for the predicted average (dashed lines in the graph above).

To determine how robust they are we went a step further and added empirically-derived South African data to the models from that reported by Ralston-Paton et al. (2017). These data, like those extracted from Loss et al. (2013), were corrected for observer biases and scavenger-removal of carcasses below turbines. They are useful because, of the eight South African wind farms with post-construction fatality data, two farms had (32) turbines of 90-m and (37) turbines of 95-m (Ralston-Paton et al. 2017).

The results indicate (Figure A3) that the model predicts slightly lower average fatalities and decreases the uncertainty around the estimates of avian fatalities for turbines of 120 m (16 birds, 95% CI = 9, 28) and 140-m turbines (28 birds – 95% CI = 12, 65).

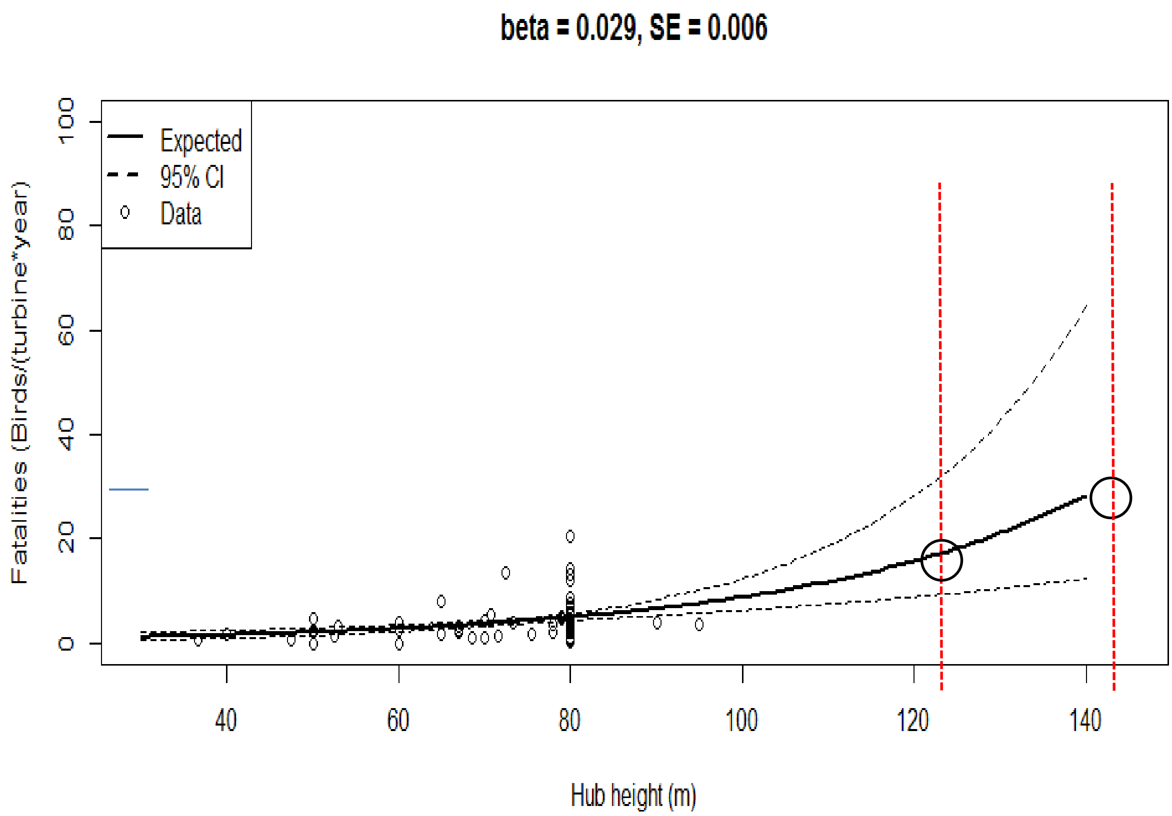

Figure A3: Modelled data combining avian fatalities from the USA (Loss et al. 2013) and from South Africa (Ralston-Paton et al. 2017) and their relation to hub height. The South African data (n = 8 farms) include two with hub heights of 90-m and 95-m. The combined data and 95% confidence limits predict that 16 birds (95% CI = 9, 28) will be killed on average per year for 120-m-high turbines and 28 (95% CI = 12, 65) birds on average for 140-m-high turbines.

We can also determine the confidence intervals around the extrapolated fatalities beyond 80-m hub height using a boot-strapping method. These are 95% bootstrap prediction intervals. These intervals predict the actual observations, rather than the average.

These confidence intervals are based on the original data of Loss et al (2013), and we used them to determine if the South African data points fall within the 95% confidence limits derived from the North American data (Figure A4). One would expect to see about 5% of actual observations to fall outside these limits.

The results indicate that the South African data all lie within the 95% confidence intervals. This means that the inference on fatalities at hub heights beyond 80-m, derived from the data of Loss et al. (2013) and applied to South African data (red points in Figure A4) is relatively robust and we can draw some conclusions on South African wind farms where taller turbines may be used.

Again, these are only valid if the same relationship between fatalities and height holds beyond 90-95-m. Further data for taller turbines are, thus, required to validate these models.

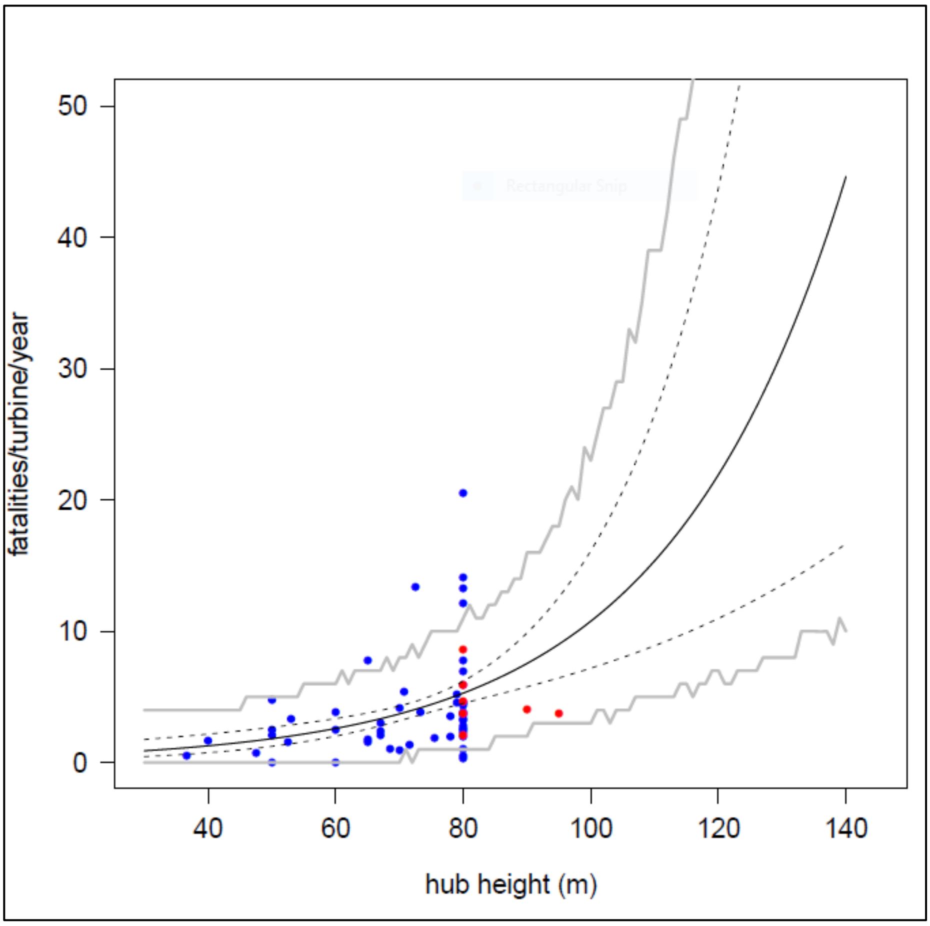

Figure A4: Prediction intervals from bootstrapping analyses based on North American hub height/fatality data (Loss et al. 2013 = blue data points) to determine if South African data (= Red Data points) fall within 95% confidence intervals.

Validating predictions with eagle flight height data

We can only apply these fatality estimates as rough estimates to how many birds may be impacted, because:

- different wind farms will have a different suite of at-risk collision-prone species, and
- those species may also fly at different heights depending on topography, behaviour (hunting, displaying or commuting), or weather.

For the proposed Springbok wind farm site, we collected flying heights of the Collision-Prone Species (CPSs) by estimating flight heights in each visit (January, April, June and August 2012, November 2014 and February 2015). We recorded heights in bands (1-20m, 20-40m, 40-120m, 120-160m, 160+m) at first sighting for Verreaux's Eagles *Aquila verreauxii,* and Booted Eagles *Aquila pennatus*).

We calculated the proportion of flights for the following combination of hub-heights corresponding to the highest and lowest Blade-swept heights (BSH) for the different turbines:

- 80-m turbines – BSH: 36 – 124-m
- 120-m turbines – BSH: 54 – 186-m
- 140-m turbines - BSH: 60 – 220-m

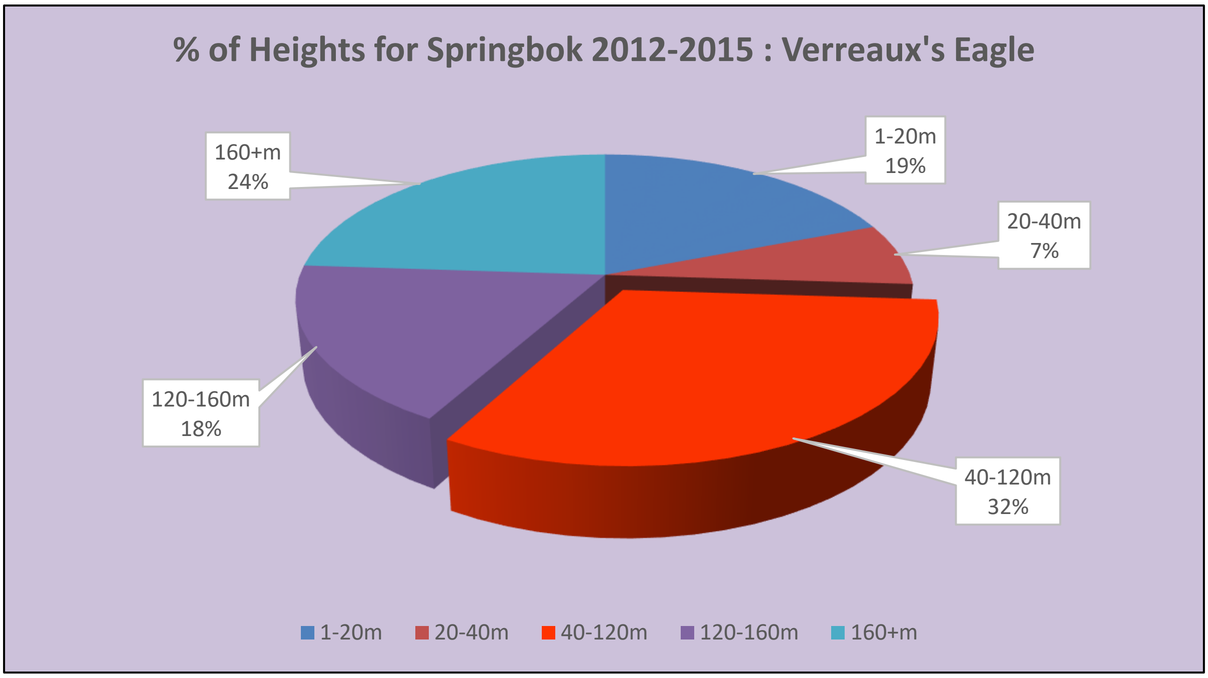

Figure A5: Flight heights recorded for Verreaux's Eagles at the proposed Springbok WEF. Data collected January, April, June, August 2012; November 2014 and February 2015, covering all seasons, and based on 418 records of flying eagles.

The results (Figure A5) indicated that:

- most flights of Verreaux's Eagles were recorded in the height band 40-120-m (32%),
- fewest flights, of the 418 recorded across all seasons, were recorded in the band 20-40-m (7%). This is not necessarily surprising for a large species of eagle.

What proportion of flights occur in the "risky" blade-swept zone for different height turbines?

Because we recorded in height bands (0-20m, 20-40m, 40–120m, 120-160m and 160^{+}m) we had to estimate the proportions of flights in the important BSH category of 36-124-m for the 80-m turbines. We did so in the following way:

We started with the proportion of flights in the band 40-120-m (= **32%**). We then calculated the proportion of flights that occurred down to 36 m in the 20-40-m band as a fifth of the flights occurring there (4/20 of 7% = **1.4%**). At the upper end, for the proportion of flights from 120-130-m, we took the "first 4-m" of all flights in 120-160-m band, or 4-m/40-m = 10%. Thus 10% of 18% = **1.8%**.

Similar procedures were followed to estimate the proportion of risky flights for the 120-m and 140-m turbines (Table A1).

Table A1. The estimated proportion of risky flights by **Verreaux's Eagles** for different-sized turbines, based on 418 recorded flights, 2012-2105.

Turbine Hub Height (blade length)	**Blade-swept height (m)** Lowest :	Highest	**Proportion of flights in these risky zones**
80 m (44-m)	36	124	35.2%
120 m (66-m)	54	186	60.4%
140 m (80-m)	60	220	68.7%

The estimates of the proportion of risky flight at blade-swept heights (BSH) doubled from 35% for the 80-m turbines to almost 70% for the 140-m turbines (Table A1). The 120-m high turbines were intermediate at 60%.

Thus, for **Verreaux's Eagles**, the likelihood that more deaths might occur with taller turbines (from statistical models: Figure A4) is corroborated by the behaviour of the birds in their natural environments: the proportion of risky flights almost doubled from 35% for the 80-m turbines to 69% for the 140-m turbines.

For **Booted Eagles** the proportion of risky flight at BSH was similar to that for their larger-bodied cousins (Table A2). Based on 160 flights recorded from 2012 to 2015 across all seasons, the proportion of flights in the BSH rose from ~35% to ~70% with an increase in hub height from 80-m to 140-m. For this species, equal numbers of risky flights were calculated for 120-m hub heights.

Table A2. The estimated proportion of risky flights by **Booted Eagles** for different-sized turbines, based on 160 recorded flights, 2012-2105.

Turbine Hub Height (blade length)	**Blade-swept height (m) Lowest :**	**Highest**	**Proportion of flights in these risky zones**
80-m (44-m)	36	124	34.5%
120-m (66-m)	54	186	70.6%
140-m (80-m)	60	220	69.2%

Thus, for both eagle species recorded on the Springbok site during the fieldwork performed, we can conclude that the proportion of risky flights in the BSA increase almost two-fold when turbines are increased from 80-m to 140-m. This concurs with the statistical inference based on North American and South African data that fatalities may increase four-fold when turbines are increased from 80- to 140-m.

Reasons for higher fatalities

Why would higher turbines be predicted to kill more birds than smaller turbines? There are two possibilities, one ecological, one statistical:

(iii) Ecologically, taller turbines and their greater blade-swept height are more likely to intersect migrating eagles studied in North America which tend to fly two- to four-fold higher (average 135-341-m) than resident birds (63-83-m: Katzner et al. 2012);

(iv) Statistically, longer blades are associated with taller turbines. For example, 140-m high turbines have 80-m blades (while 80-m turbines have 44-m blades). This 1.8-fold increase in blade-length triples the blade-swept area from 6,082-m^2 to 20,106-m^2. Thus, by chance, a passing bird has a three-fold higher probability of intersecting a blade from a taller turbine.

These possibilities can, therefore, explain why fatalities are predicted to increase from an average of 6 to 28 (95% CI = 12,65) birds per turbine per year when hub height is increased from 80-m to 140-m.

Note that the lower 95% confidence limit (12 birds/turbine/year) is the same figure predicted if the future fatalities were based solely on the increased proportion of risky flights in the BSH for the two eagles assessed (Table 1 and 2).

What combination of turbine numbers and height will minimise avian fatalities?

In Table A3 below we use the statistically inferred fatality estimates for different numbers and heights of turbines to determine which combination gives the lowest number of fatalities (authorised vs proposed). The results indicate that 37 turbines of 80 m hub-height gives the lowest average number of (229) number of fatalities in the windfarm.

Table 3 Re-assessing the potential number of avian fatalities per year with increases or decreases in turbine heights and turbine numbers. These are based on fatality estimates modelled by Erni and Cervantes (see Figures 3 and 4). This increases the average fatality estimates from 6.2 birds.turbine.year^{-1} to 16 birds.turbine.year^{-1} for 120 m turbines and 28 birds.turbine.year^{-1} for 140 m turbines.

	Turbine number		
Turbine height	Ave No. fatalities/ turbines/yr[a] (95% CI)[b]	**37 turbines** Total fatalities (95% CI)	**25 turbines** Total fatalities (95% CI)
80-m	6.2	**229 birds**	155 birds
120-m	16 (9-28)	592 (333-1036) birds	400 (225-700) birds
140-m	28 (12-65)	1036 (444-2405) birds	**700 (300-1625) birds**

[a] extrapolated from trends in Figure 3. [b] CI= Confidence limits, derived from Figure A3

We conclude from these new fatality estimates that 37 turbines of 80-m hub-height are preferable to the proposed 25 turbines of 120-m or 140-m (highlighted above) in terms of the estimated numbers of avian fatalities (229). More data from turbines taller than 80-m are required to firm up these modelled estimates.

It is notable that even if the lowest 95% confidence interval (300 fatalities) for the 25 turbines at 140-m is used, then 37 turbines of 80-m is still preferable.

Also note, however, that the confidence limits for 25 turbines of 120-m (225 birds) is almost identical to the average estimated for 80-m (229 birds). Therefore, if these estimated fatalities lie at the lowest end of that forecast, then 25 turbines of 120-m turbines may be a suitable option.

This differs from our previous conclusions because we under-estimated the increased number of fatalities likely with increasing hub height. The more robust, statistically-modelled, fatality estimates

- supported by "risky" flight heights from real eagle data at the Springbok site - unfortunately increases the likelihood that more avian fatalities will occur with taller turbines. This probably arises because longer blades occur as turbines increase and the blade-swept area triples, increasing the chance event that a bird will be struck by the blades.

We conclude that taller turbines are likely to increase avian fatalities but much more empirical data from South African turbines above 80-m are required to verify these predictions. On present evidence, by staying with 37 turbines of 80-m hub height the number of avian fatalities will be reduced to a minimum.

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