WITBERG WIND FARM: STATEMENT ON THE EFFECT OF THE NEW PROPOSED 25-TURBINE LAYOUT ON THE PREVIOUS 27-TURBINE COLLISION RISK MODELLING

The proposed layout for the Witberg wind farm has been updated subsequent to the collision risk modelling that I undertook and reported for a 27-turbine layout (Percival 2018). This comprised removal of two turbines (turbines 10 and 18), and a movement of one turbine (turbine 14) by about 60m to the south of its previous position.

I have examined the new layout in relation to the previous one and the ornithological baseline (specifically the flight lines obtained during the vantage point surveys), and I can confirm that the collision risk would likely be slightly reduced for both of the two species previously modelled (Verreaux's Eagle and Booted Eagle), and that this change would not have any material effect on the conclusions that I reached in my previous report.

Steve Percival

Dr Steve Percival

Ecology Consulting

21 August 2018

Reference

Percival, S.M. 2018. Witberg Wind Farm: ornithological collision risk modelling update report July 2018 for 136m rotor diameter and revised 27-turbine layout. Ecology Consulting report to Witberg Wind Power (Pty) Ltd.

WITBERG WIND FARM: ORNITHOLOGICAL COLLISION RISK MODELLING UPDATE REPORT JULY 2018 FOR 136M ROTOR DIAMETER AND REVISED 27-TURBINE LAYOUT

Report to Witberg Wind Power (Pty) Ltd.

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SECTION 1 - INTRODUCTION

1. The purpose of this report is to update the collision risk modelling for the proposed Witberg wind farm that was reported in the Shoney Renewables Consulting (2013) report. An alternative 27-turbine layout is now being considered, with a larger (136m) rotor diameter and various hub height alternatives. The layout revision included moving turbines to ensure that there are none located within 1.5km of any Verreaux's Eagle nest (as recommended by Dr Rob Simmons[1]). This report provides a comparison of the predicted collision risk to key bird species for this new layout with the authorized 27-turbine scheme reported previously.
2. The specific scope of work included:
   - An update of the collision risk modelling using a 136m diameter rotor, for hub heights from 92-120m and an alternative 27-turbine layout;
   - A re-assessment of the likely impacts of the updated Witberg wind farm scheme on birds.
3. The same baseline survey data have been used in this assessment update as previously and as described in the 2013 report. Those data remain sufficient to inform this assessment, despite the fact that they were collected some 6-7 years ago, as there have not been any material changes to the habitat at the site that would be likely to increase the avifaunal activity. The area did experience an extensive fire in February 2015, resulting in damage to much of the grazing veld in the area and natural vegetation, but the most likely outcome of that would have been reduced food availability for birds such as eagles in the vicinity of the wind farm. The same modelling approach has also been used as previously, following the method of Band et al. (2007).
4. Five wind farm layouts were modelled previously up to and including the current authorized 27-turbine layout (layout E below). These were as follows:
   A. The initial 70 WTG layout using Turbine Type B (Vestas V100 2MW);
   B. The 40 WTG layout using Turbine Type C (Vestas V90 3MW) that was originally authorized by the DEA.
   C. The 27 WTG layout using Turbine Type A (Acciona AW116 3MW);
   D. The 27 WTG layout but with two turbines (located within an area of higher eagle use) removed, using the same Type A Acciona turbine;
   E. An updated 'reduced eagle collision risk' 27 WTG layout with 5 turbines moved from an area of higher eagle activity to a lower activity area, using the same Type A Acciona turbine (92m hub height, 116m rotor diameter). This layout is the one referred to in this report as the 'previous 27-turbine layout'. This is Layout Alternative 7, currently authorised by the Department of Environmental Affairs.
5. Layouts A to D were subsequently abandoned by the applicant as the collision risk either remained unchanged, increased or for technical reasons the layouts were no longer supported. Layout 'E' is currently authorized and this therefore forms the base scenario for the comparisons of collision risk made in this report.
6. A revised 27-turbine layout is now being considered (see Figure 1, below) with a larger rotor diameter (136m). Three different hub height options are also being considered as follows:
   - Scenario 1: 136m rotor diameter, 92m hub height;

[1] 2015, Birds Unlimited. Witberg Wind Farm Juvenile Verreaux's Eagle Monitoring. Final Report.

- Scenario 2: 136m rotor diameter, 105m hub height;
- Scenario 3: 136m rotor diameter, 120m hub height.

7. The proposed wind turbine co-ordinates for the revised 27-turbine scheme are given in Appendix 1.

8. Two key species, Verreaux's Eagle and Booted Eagle have been modelled for each of the three scenarios. The collision risks for Martial Eagle and Black Harrier were not modelled as the collision risk associated with both the authorized and the revised layouts would be zero (no flights of either species were recorded flying through the collision risk zone of either layout). No other key species were recorded flying through the collision risk zone at rotor height during the baseline surveys.

9. The collision modelling requires a range of input data on the wind turbine specifications, which were provided by Witberg Wind Power (WWP) and the turbine manufacturer. They are summarised in Table 1. As previously, where any uncertainties exist as to any specifications of the turbines a worst-case approach has been adopted to deliver a precautionary but robust analysis.

Table 1. Wind turbine data used in the July 2018 collision risk modelling

Specification	Value used in previous collision risk modelling (authorised 27-turbine scheme)	Scenario 1	Scenario 2	Scenario 3
Hub height	92m	92m	105m	120m
Rotor diameter	116m	136m	136m	136m
Height to blade tip	150m	160m	173m	188m
Minimum height of blade above ground	34m	24m	37m	52m
Rotational speed (variable – mean value)	11.9 (eastern turbine block), 11.68 (western turbine block)	9.8 (mean overall)	9.8 (mean overall)	9.8 (mean overall)
Blade maximum chord	3.28m	4.1m	4.1m	4.1m
Blade pitch (variable – mean value calculated from local wind speed data measured by WWP)	4.13° (eastern turbine block), 3.34° (western turbine block)	4.13° (eastern turbine block), 3.34° (western turbine block)	4.13° (eastern turbine block), 3.34° (western turbine block)	4.13° (eastern turbine block), 3.34° (western turbine block)
Turbine operation time (when not constrained by high/low wind speed or maintenance activity)	92% (eastern turbine block), 90% (western turbine block)	92% (eastern turbine block), 90% (western turbine block)	92% (eastern turbine block), 90% (western turbine block)	92% (eastern turbine block), 90% (western turbine block)

SECTION 2 - KEY SPECIES BASELINE UPDATE

10. There were three key differences in relation to the collision risk modelling, (a) a revised site layout and hence updated collision risk zone, (b) updated minimum heights of blades above the ground resulting in a difference proportion of flights at rotor height, and (c) a larger rotor swept area resulting in an increased collision risk volume but with reduced rotational speed.

11. The revised 27-turbine layout and its collision risk zone (i.e. the wind farm plus a 200m buffer) are shown in Figure 1, together with the collision risk zone of the authorised 27-turbine layout for comparison. The Vantage Points (VPs) monitored during the monitoring campaigns are also indicated on the Figure. The coordinates are as follows:

- VP – West (the most western VP): 33°17'27.29"S; 20°23'48.73"E
- VP – Mid (the VP in the middle of the project site): 33°16'53.85"S; 20°26'38.27"E
- VP – East (the most eastern VP): 33°16'49.27"S; 20°30'16.11"E

Key Species Flight Activity within the revised site collision risk zone

12. The flight activity of Verreaux's Eagle and Booted Eagle within the collision risk zones of the authorized and the revised layouts are summarised in Table 2 and Table 3 respectively. These Tables shows the occupancy rate (% of time when present within the zone) for each of these species, in each of the three main zones of the wind farm, for each layout.

Table 2. Over-flying rates of key target species within the potential collision risk zone (wind farm plus 200m buffer): occupancy rates: authorized 27-turbine layout

Species	Wind farm/VP zone	Occupancy rate of collision risk zone (% observation time present)					
		Jan	Apr	Jun	Aug	Nov	OVERALL MEAN
Verreaux's Eagle	East	0%	0.127%	0%	0%	0%	0.025%
	Mid	0%	1.851%	0.280%	0%	0.295%	0.485%
	West	0%	0%	1.628%	0%	0.017%	0.329%
Booted Eagle	East	0%	0.004%	0%	0%	0%	0.001%
	Mid	0%	0%	0.039%	0%	0.255%	0.059%
	West	0%	0%	0%	0%	0%	0%

Table 3. Over-flying rates of key target species within the potential collision risk zone (wind farm plus 200m buffer): occupancy rates: revised 27-turbine layout

Species	**Wind farm/VP zone**	**Occupancy rate of collision risk zone (% observation time present)**					
		Jan	**Apr**	**Jun**	**Aug**	**Nov**	**OVERALL MEAN**
Verreaux's Eagle	East	0%	0%	0%	0%	0%	0%
	Mid	0%	0.794%	0.329%	0%	0.281%	0.281%
	West	0%	0%	0.200%	0%	0%	0.040%
Booted Eagle	East	0%	0%	0%	0%	0%	0%
	Mid	0%	0%	0.031%	0%	0.295%	0.065%
	West	0%	0%	0%	0%	0%	0%

13. Flight lines in relation to the revised 27-turbine collision risk zone are shown in Figure 2, below for Verreaux's Eagle, Figure 3, below for Booted Eagle, and Figure 4, below for Martial Eagle and Black Harrier.

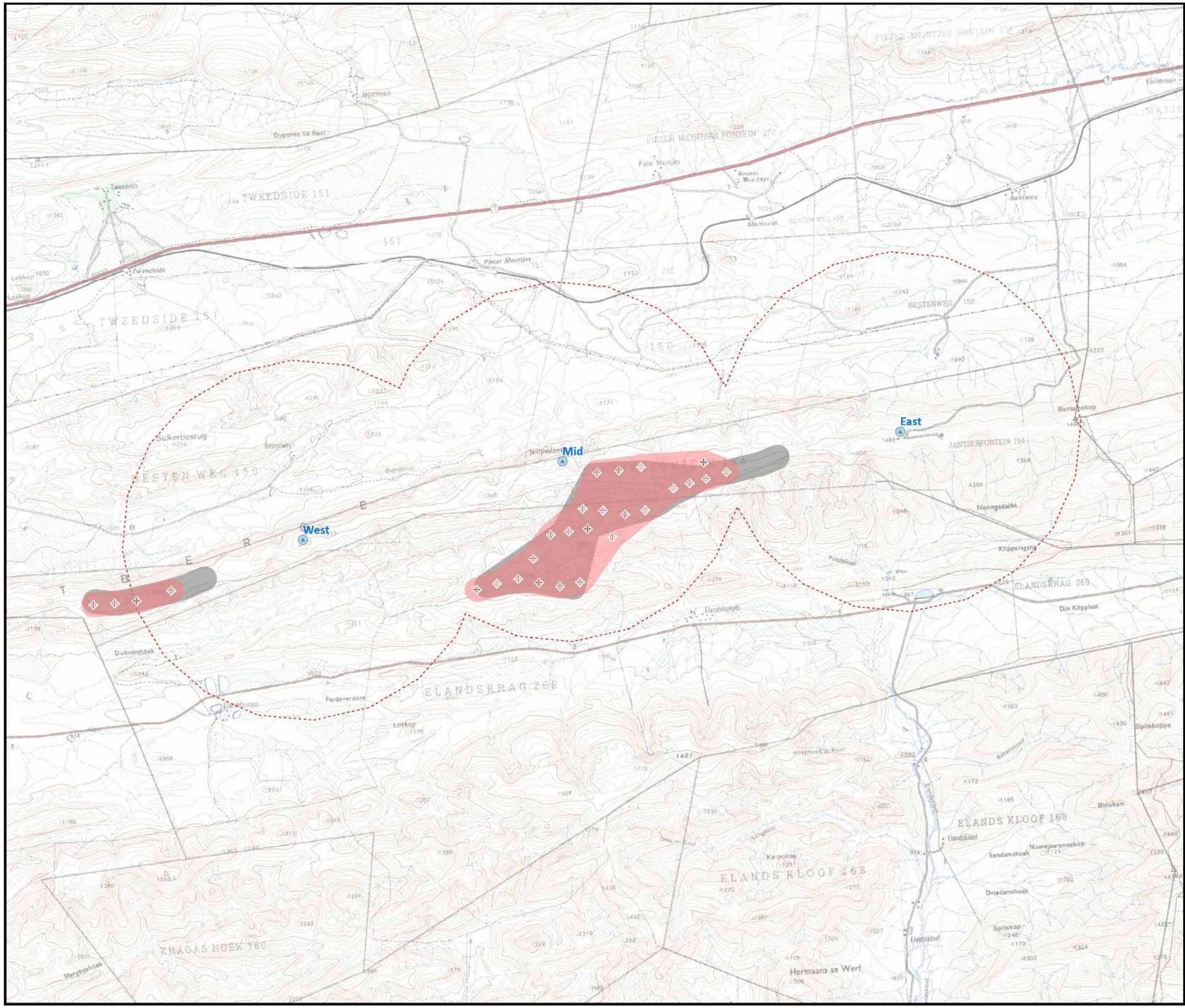

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FIGURE 1

Comparison of collision risk zones: authorized and revised 27-turbine layouts

KEY:

- Revised 27-turbine layout
- Revised 27-T collision zone
- Authorized 27-T collision zone
- Vantage point (VP) locations
- VP 3km viewing area

N

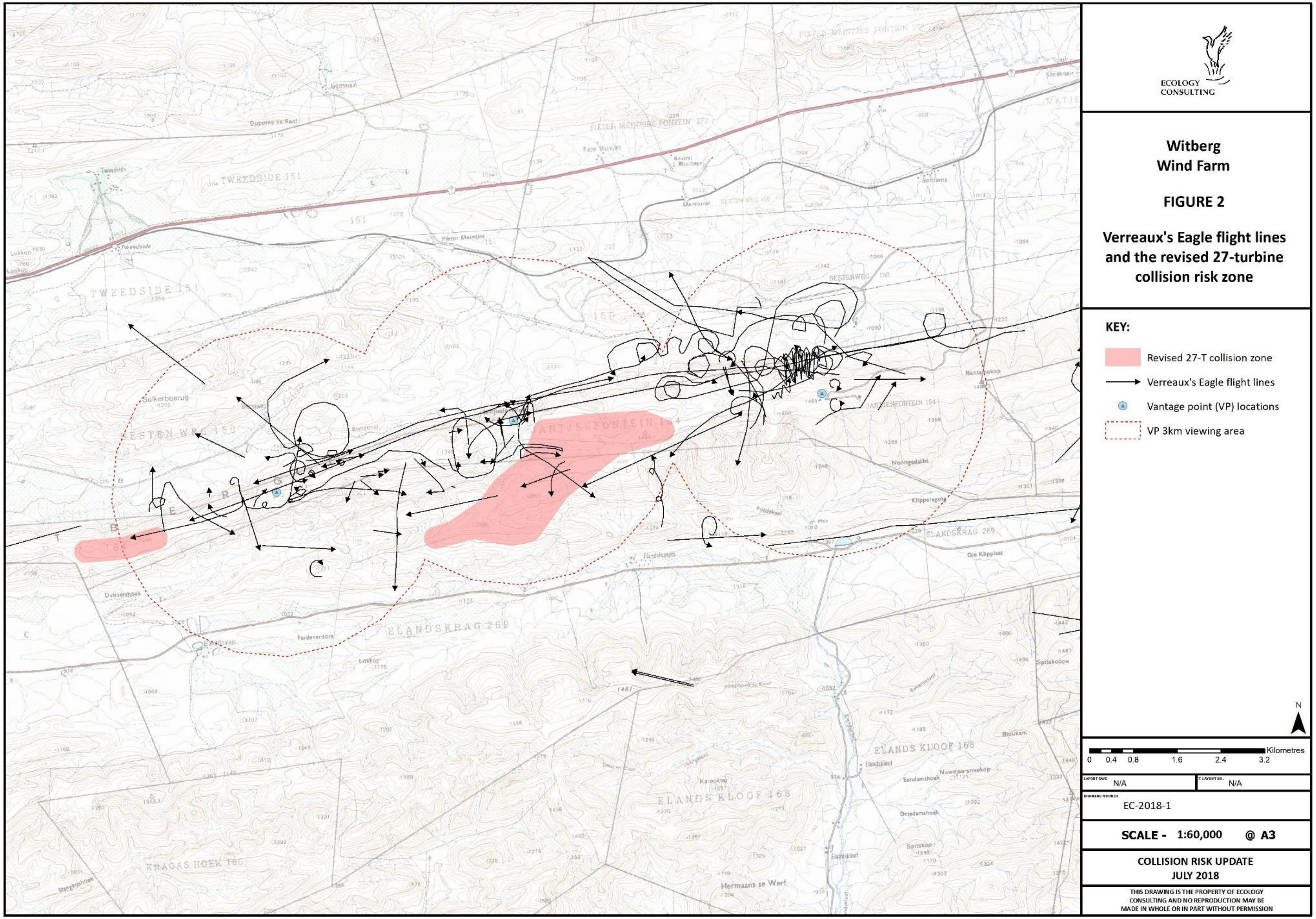
0 0.4 0.8 1.6 2.4 3.2 Kilometres

N/A	N/A

EC-2018-1

SCALE - 1:60,000 @ A3

COLLISION RISK UPDATE
JULY 2018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Witberg Wind Farm
FIGURE 2
Verreaux's Eagle flight lines and the revised 27-turbine collision risk zone
KEY:
Revised 27-T collision zone
Verreaux's Eagle flight lines
Vantage point (VP) locations
VP 3km viewing area
Kilometres
0 0.4 0.8 1.6 2.4 3.2
N/A
N/A
EC-2018-1
SCALE - 1:60,000 @ A3
COLLISION RISK UPDATE
JULY 2018
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TWEEDSIDE 151
BESTENWEG 150
ANTJESFONTEIN 164
ELANDSKRAG 269
ELANDS KLOOF 168
KRAGAS HOEK 160
PIETER MEINTJES FONTEIN 272

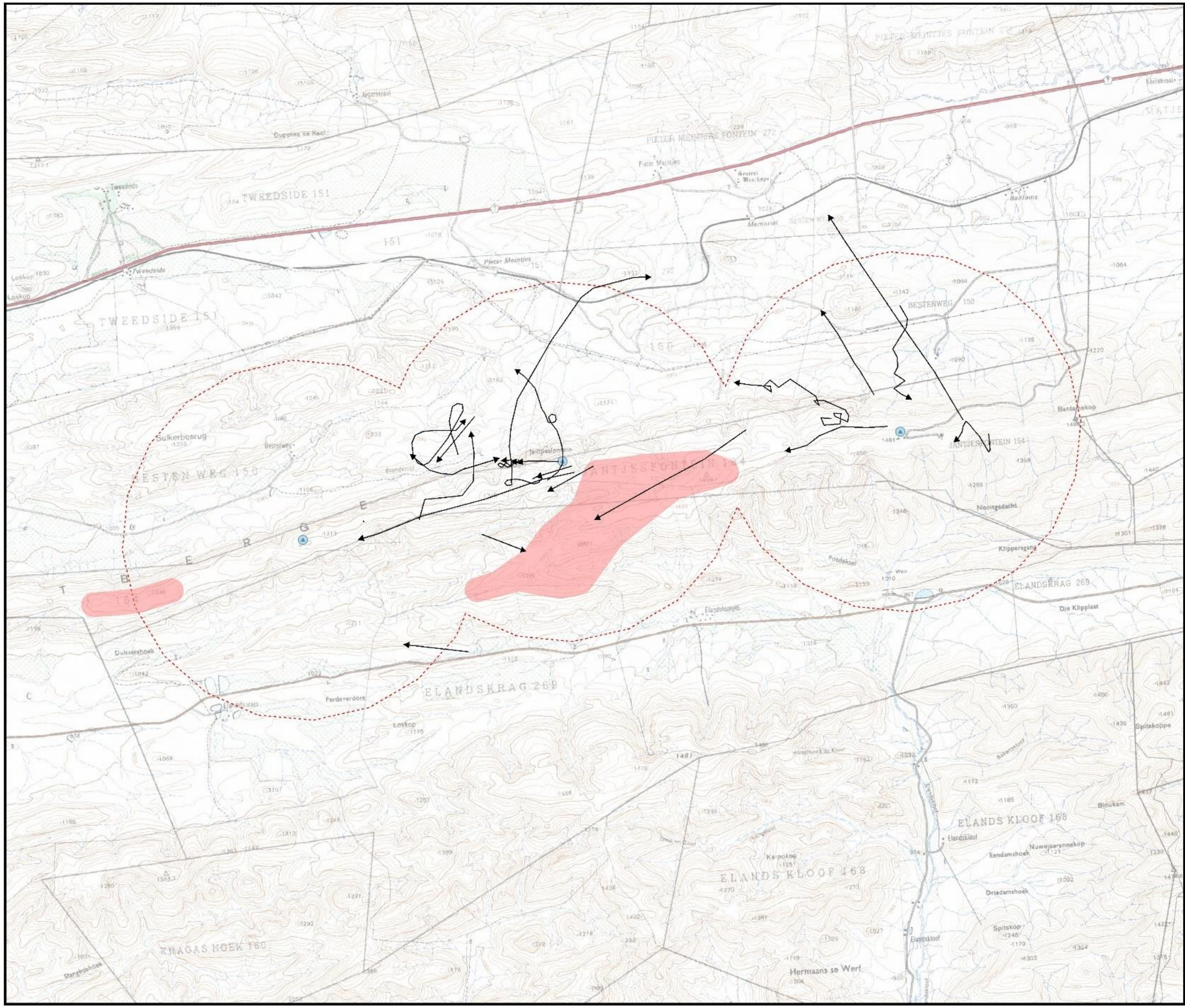

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FIGURE 3

Booted Eagle flight lines and the revised 27-turbine collision risk zone

KEY:

- Revised 27-T collision zone
- Booted Eagle flight lines
- Vantage point (VP) locations
- VP 3km viewing area

N

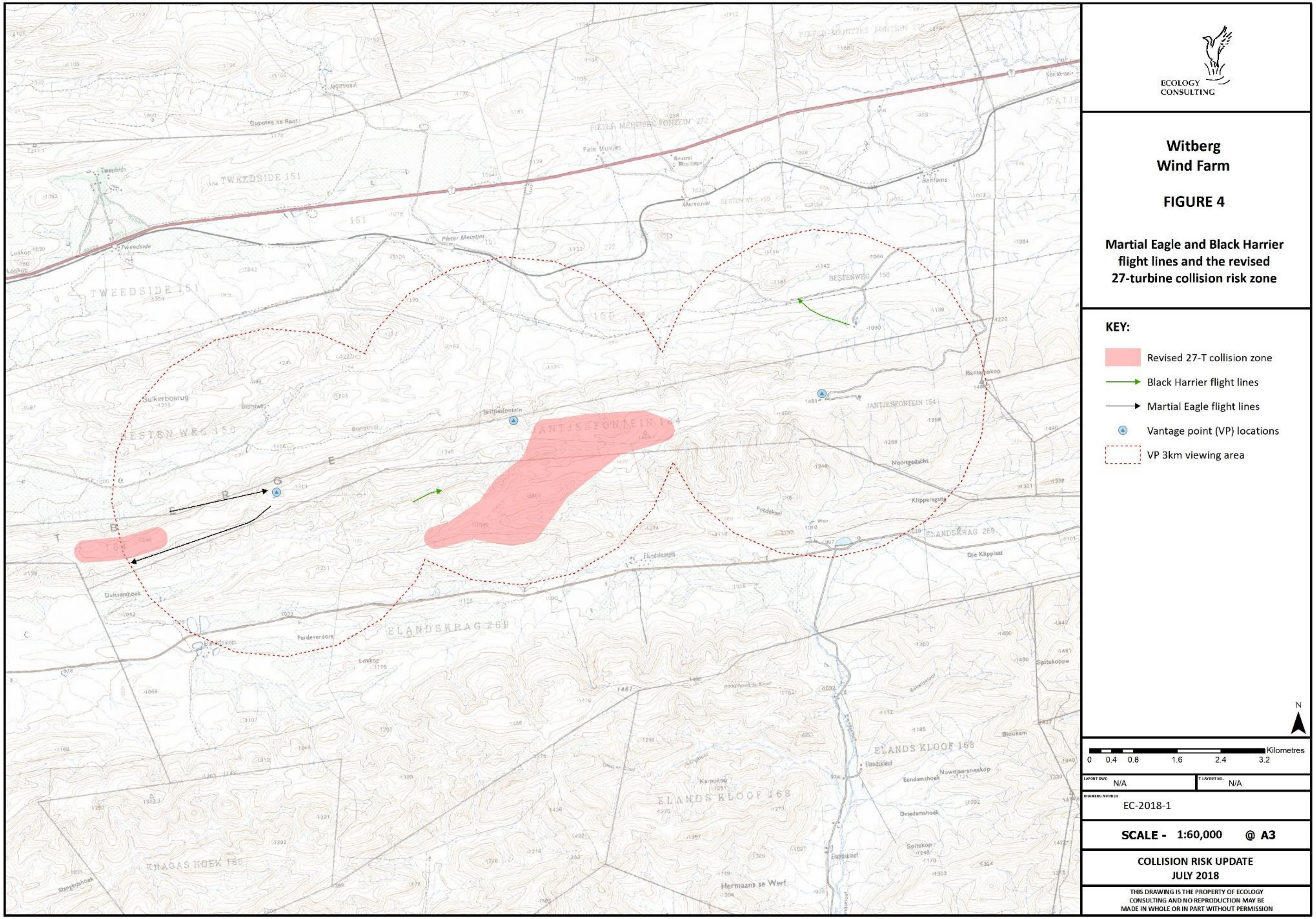
Kilometres
0 0.4 0.8 1.6 2.4 3.2

N/A | N/A

EC-2018-1

SCALE - 1:60,000 @ A3

COLLISION RISK UPDATE JULY 2018


ECOLOGY CONSULTING
Witberg Wind Farm
FIGURE 4
Martial Eagle and Black Harrier flight lines and the revised 27-turbine collision risk zone
KEY:
Revised 27-T collision zone
Black Harrier flight lines
Martial Eagle flight lines
Vantage point (VP) locations
VP 3km viewing area
N
0 0.4 0.8 1.6 2.4 3.2 Kilometres
N/A
N/A
EC-2018-1
SCALE - 1:60,000 @ A3
COLLISION RISK UPDATE JULY 2018
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Key Species Flight Heights

14. Flight heights were recorded to wide zone bands during the baseline surveys, which did not perfectly match up to the proposed turbine/rotor heights. The proportion of flights at rotor height for each of the different rotor heights for the revised turbine layout was estimated, as previously, assuming that flight activity was uniform within each band, so, for example, 6/40 (15%) of flights in the 'Low' category were assumed to be at rotor height for the Scenario 1 turbine (as per Band et al. 2007). The calculated percentage of flights at rotor height for each key species for each of the three hub height scenarios are shown in Table 4. The percentage at rotor height for the authorized 27-turbine layout is also given for comparison.

Table 4. Key species percentage of flights at rotor height (i.e. rotor swept area) for each scenario used in the July 2018 collision risk modelling

Species	**Value used in previous collision risk modelling (authorized 27-turbine scheme)**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Verreaux's Eagle	68%	78%	69%	61%
Booted Eagle	57%	64%	62%	59%

SECTION 3 – COLLISION MODELLING UPDATE

Collision Risk Modelling Methodology

15. The collision risk modelling (CRM) was undertaken following the method of Band et al. (2007), as extensively used in the UK, and as used for the previous Witberg collision risk modelling (Shoney Renewables Consulting 2013). Details of the original SNH guidance on this model (Band 2000) are available from the SNH web site at <www.snh.gov.uk/docs/C205425.pdf>. The model runs as a two-stage process. Firstly, the risk is calculated making the assumption that flight patterns are unaffected by the presence of the wind turbines, i.e. that no avoidance action is taken. This is essentially a mechanistic calculation, with the collision risk calculated as the product of (i) the probability of a bird flying through the rotor swept area, and (ii) the probability of a bird colliding if it does so. This probability is then multiplied by the estimated numbers of bird movements through the wind farm rotors at the risk height (i.e. the height of the rotating rotor blades) in order to estimate the theoretical numbers at risk of collision if they take no avoiding action.

16. The second stage then incorporates the probability that the birds, rather than flying blindly into the turbines, will actually take a degree of avoiding action, as has been shown to occur in all studies of birds at existing wind farms (Urquhart 2010). The results of any collision risk modelling using the Band et al. (2007) approach is highly sensitive to the avoidance rate used (Chamberlain et al. 2006). Application of an appropriate rate is therefore of fundamental importance in undertaking such modelling. However, there are very few studies at existing wind farm where avoidance rates have been fully determined, comparing pre-construction flight activity with the actual numbers of collisions post-construction (Urquhart 2010). The approach generally used to address this is to apply a precautionary rate based on the available data, such that any collision prediction is unlikely to be exceeded (i.e. represents a reasonable worst case). Where data on actual avoidance rates of particular species/groups have been established, then this has usually enabled a higher rate to be safely applied. For example, SNH currently recommends using a value of 99.8% as an avoidance rate for geese (Douse 2013), 99% for several birds of prey (including golden eagle and hen harrier), and 98% for most other species (Urquhart 2010).

17. There is a lack of specific avoidance rate data from South Africa and on the species of concern at Witberg. It was agreed for the previous collision risk modelling that as collision avoidance rates are not yet known for the species of concern, suitable overseas species should be used as proxies. They have been selected following SNH guidance and with reference to the bird-wind farm literature. A precautionary 98% has been adopted as the default value (Urquhart 2010) but the work has also explored whether particular species exhibit similar behaviour to more vulnerable species such as white-tailed sea eagle and kestrel, or such behaviour that would reduce risk (and hence allow higher rates to be used as is recommended by SNH for golden eagle and hen harrier for example). The collision risk modelling results have been presented for each layout for a range of avoidance rates to inform the assessment but the most appropriate rate to apply in each specific case is also indicated. Most weight has been given to the precautionary SNH position of applying a 98%, though Verreaux's Eagle in particular shares an ecological similarity with golden eagle (albeit at a generally higher breeding density), for which SNH recommends a 99% avoidance rate, so applying that rate could be justified (particularly in relation to adult birds). The Golden Eagle is recognised as the Verreaux's Eagle's closest relative (Wink and Sauer-Gürth 2000). However, a more precautionary approach has been adopted in this assessment. The collision risk to juvenile Verreaux's Eagle has been assessed separately, and, given experience of higher juvenile mortality of eagles at the Smøla wind farm in particular, a lower avoidance rate (95%) has been considered for these birds. Given that the

Witberg eagles occur at a much lower density (3.7/100km^2) than the white-tailed eagles at Smøla, where a density of 73/100km^2 has been recorded with 13 pairs of white-tailed eagle nesting in the wind farm which extends over 17.3km^2, Bevanger et al. 2009) and that the eagle core ranges have been buffered, it is not considered appropriate to apply as low a rate as 95% to the adult Verreaux's Eagle at Witberg.

18. The main collision risk zones for the layouts were defined, as per Band et al (2007) and SNH guidance (Whitfield et al. 2010) as a 200m zone around the proposed wind turbine locations. These zones were divided into three parts for the purposes of the collision modelling (Figure 1, above), relating to the three vantage points used for surveying the WEF (east, middle and west), and the collision modelling undertaken for each separately. The two westernmost turbines of both the authorized and the revised layouts fell outside the main VP survey area, so the flight densities within part of the collision zone were assumed to be the same as for the main part of the western block that was visible to a sufficient distance. The eastern zone has been retained in the analysis for comparison with the authorized layout, though for the revised layout no turbines would be located in that area.

Collison Risk Modelling Results

19. Tables 5a-c summarise the results of the collision risk analyses for each of the two key species for the revised layout for each wind turbine scenario. Previous results for the authorized turbine layout are given in Table 5d for comparison. There were no records of Martial Eagle or Black Harrier flying through the collision risk zone of either layout, so the modelled collision risk would be zero for both of these species for this layout in all cases. Details of the modelling are given in Appendix 2.

20. These Tables give the number of collisions predicted per year based on a range of avoidance rates (95% - 99%). Verreaux's Eagle is a large non-colonial eagle, and the area in proximity to its nest sites has been avoided in the site layout design process (so 'riskier' display flights and early juvenile flights would be less likely to occur in the wind farm). As a result, 99% should be a suitable precautionary avoidance rate to apply (as is used in the UK for Golden Eagle, an ecologically similar species), though as set out in the methodology section above, a more precautionary 98% has been adopted for the purpose of this assessment.

21. Booted Eagle is more ecologically similar to buzzard species, so on the basis of the information currently available, the possibility of lower avoidance cannot be excluded, so the Scottish Natural Heritage (SNH)[2] default 98% value has been applied.

[2] *Urquhart, B. 2010. Use of Avoidance Rates in the SNH Wind Farm Collision Risk Model. SNH Guidance Note.*

*Table 5a. Collision risk modelling predictions for the proposed Witberg wind farm **revised 27-turbine layout** Scenario 1 (136m rotor diameter turbine **at 92m hub height**), for each part of the collision risk zone and applying a range of avoidance rates. Predictions in bold represent the precautionary result used in the further assessment.*

Species	Precautionary predicted number of collisions per year											
	East zone[3]			Mid zone			West zone			TOTAL		
Avoidance rate:	95%	98%	99%	95%	98%	99%	95%	98%	99%	95%	98%	99%
Verreaux's Eagle	0	**0**	0	0.79	**0.31**	0.16	0.27	**0.11**	0.05	1.06	**0.42**	0.21
Booted Eagle	0	**0**	0	0.11	**0.04**	0.02	0	**0**	0	0.11	**0.04**	0.02

*Table 5b. Collision risk modelling predictions for the proposed Witberg wind farm **revised 27-turbine layout** Scenario 2 (136m rotor diameter turbine **at 105m hub height**), for each part of the collision risk zone and applying a range of avoidance rates. Predictions in bold represent the precautionary result used in the further assessment.*

Species	Precautionary predicted number of collisions per year											
	East zone			Mid zone			West zone			TOTAL		
Avoidance rate:	95%	98%	99%	95%	98%	99%	95%	98%	99%	95%	98%	99%
Verreaux's Eagle	0	**0**	0	0.70	**0.28**	0.14	0.24	**0.10**	0.05	0.94	**0.37**	0.19
Booted Eagle	0	**0**	0	0.11	**0.04**	0.02	0	**0**	0	0.11	**0.04**	0.02

*Table 5c. Collision risk modelling predictions for the proposed Witberg wind farm **revised 27-turbine layout** Scenario 3 (136m rotor diameter turbine **at 120m hub height**), for each part of the collision risk zone and applying a range of avoidance rates. Predictions in bold represent the precautionary result used in the further assessment.*

Species	Precautionary predicted number of collisions per year											
	East zone			Mid zone			West zone			TOTAL		
Avoidance rate:	95%	98%	99%	95%	98%	99%	95%	98%	99%	95%	98%	99%
Verreaux's Eagle	0	**0**	0	0.62	**0.25**	0.12	0.21	**0.09**	0.04	0.83	**0.33**	0.17
Booted Eagle	0	**0**	0	0.10	**0.04**	0.02	0	**0**	0	0.10	**0.04**	0.02

Table 5d. Collision risk modelling predictions for the proposed Witberg wind farm ***authorized 27-turbine layout*** *Scenario 4 (116m rotor diameter turbine at 92m hub height), for each part of the collision risk zone and applying a range of avoidance rates. Predictions in bold represent the precautionary result used in the further assessment.*

Species	Precautionary predicted number of collisions per year											
	East zone			Mid zone			West zone			TOTAL		
Avoidance rate:	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**
Verreaux's Eagle	0.10	**0.04**	0.02	1.06	**0.42**	0.21	0.99	**0.39**	0.20	2.14	**0.86**	0.43
Booted Eagle	0	**0**	0	0.08	**0.03**	0.02	0	**0**	0	0.08	**0.03**	0.02

Juvenile Verreaux's Eagle collision risk assessment

22. As the baseline surveys did not include any period of juvenile flights for the Verreaux's Eagle, a theoretical approach has been adopted to inform the assessment further (as for the previous collision risk modelling). This was carried out as follows:
    - Breeding success is about 0.5 young/pair/year (L. Rodrigues[4]]), so with up to 3 pairs with territories overlapping the wind farm this would give an average number of 1.5 juveniles at risk;
    - The period of key risk of the wind farm to juvenile birds would be about 2 months each year. Collision risk in the first 1-2 months after fledging would not be an issue as flights then are largely restricted to the proximity of the nest and would be outside the collision risk zone (given the 1.5km buffer applied to each nest site).
    - An estimate then needs to be made of the juvenile flight activity (which has not been measured in the field) in relation to that of the adults (for which we do have field data). A precautionary approach has been adopted, assuming that juvenile flight activity over this period was double that of the adults, though further consideration has also been given to how this might change if the juvenile flight activity were higher.
23. The results of the collision risk assessment for juvenile Verreaux's Eagles are summarised in Table 6. As for the assessment presented above, the results have been given for a range of avoidance rates. As previously, this would suggest that even adopting a highly precautionary 95% avoidance rate for the juveniles, the collision risk would be low, all of the three scenarios resulting in a slightly lower collision risk in comparison with the previous 116m rotor diameter at 92m hub height.

[4] verreaux.wordpress.com/

Table 6. Collision risk predictions for juvenile Verreaux's Eagle at Witberg.

Layout	**Precautionary predicted number of collisions per year**		
Avoidance rate:	**95%**	**98%**	**99%**
Scenario 1: 136m rotor diameter, 92m hub height	0.10	0.04	0.02
Scenario 2: 136m rotor diameter, 105m hub height	0.09	0.04	0.02
Scenario 3: 136m rotor diameter, 120m hub height	0.08	0.03	0.02
Authorized 27-turbine layout	0.21	0.08	0.04

SECTION 4 – COLLISION RISK MODELLING INTERPRETATION

Assessment Methodology

24. The same assessment methodology has been used in this report as used previously in the Shoney Renewables Consulting (2013) report, but is repeated here for completeness.

25. Whilst the Band collision model produces a quantitative estimate of the numbers of birds that might collide with the wind turbines, those numbers need to be put into the context of the existing mortality to enable their significance to be assessed. The same level of additional mortality on a population that has a low level of background mortality could potentially have a much more important effect than on a population with a higher level of existing mortality. The collision mortality needs to be assessed in the context of each species population dynamics. In the UK a 1% increase over the baseline mortality is now frequently being used as an initial filter threshold above which they may be a concern with the predicted collision mortality (and hence requiring further investigation). Collision risks below this level are usually considered not to be significant.

26. A methodology to undertake this assessment in a transparent objective way has been produced in the UK and is now widely used in the wind industry, both onshore and offshore (Maclean et al. 2009). This draws on the methodology developed by SNH and the British Wind Energy Association [BWEA] (Percival et al. 1999) and updated by Percival (2007), and with SNH (2006) guidance on assessing the impacts from onshore wind farms on birds in the wider countryside. The assessment first identifies the sensitivity (conservation importance; as defined in Table 7) of the receptors present in the study area, then determines the magnitude of the possible effect on those receptors (as described in Table 8).

Table 7. Sensitivity (conservation importance) of bird species.

Sensitivity	Definitions
VERY HIGH	Cited interest of an internationally or nationally important statutory protected sites. Cited means mentioned in the citation text for those protected sites as a species for which the site is designated.
HIGH	Other species that contribute to the integrity of an internationally or nationally important statutory protected sites species for which the site is designated. A local population of more than 1% of the national population of a species. Any ecologically sensitive species, e.g. large birds of prey or rare birds (usually taken as <300 breeding pairs in the UK). Species recognised as requiring special conservation measures or otherwise specially protected (in a UK context this includes EU Birds Directive Annex 1, EU Habitats Directive priority habitat/species and/or W&C Act Schedule 1 species. *Note: all of the raptor species assessed fall into this category*
MEDIUM	Regionally important population of a species, either because of population size or distributional context. Biodiversity Action Plan priority species (if not covered above).
LOW	Any other species of conservation interest.

Table 8. Definition of terms relating to the magnitude of ornithological effects

Magnitude	Definition
VERY HIGH	Total loss or very major alteration to key elements/ features of the baseline conditions such that post development character/ composition/ attributes will be fundamentally changed and may be lost from the site altogether. Guide: >80% of population/habitat lost
HIGH	Major alteration to key elements/ features of the baseline (pre-development) conditions such that post development character/composition/attributes will be fundamentally changed. Guide: 20-80% of population/habitat lost
MEDIUM	Loss or alteration to one or more key elements/features of the baseline conditions such that post development character/ composition/ attributes of baseline will be partially changed. Guide: 5-20% of population/habitat lost
LOW	Minor shift away from baseline conditions. Change arising from the loss/ alteration will be discernible but underlying character/ composition/ attributes of baseline condition will be similar to pre-development circumstances/patterns. Guide: 1-5% of population/habitat lost
NEGLIGIBLE	Very slight change from baseline condition. Change barely distinguishable, approximating to the "no change" situation. Guide: <1% of population/habitat lost

27. The combined assessment of the magnitude of an effect and the sensitivity of the receptor has been used to determine whether or not an adverse effect is significant. These two criteria have been cross-tabulated to assess the overall significance of that effect (Table 9).

Table 9. Matrix of magnitude of effect and sensitivity used to test the significance of effects. The significance category of each combination is shown in each cell. Shaded cells indicate potentially significant effects.

		SENSITIVITY			
		Very high	High	Medium	Low
MAGNITUDE	Very high	Very high	Very high	High	Medium
	High	Very high	Very high	Medium	Low
	Medium	Very high	High	Low	Very low
	Low	Medium	Low	Low	Very low
	Negligible	Low	Very low	Very low	Very low

28. The interpretation of these significance categories is as follows (though careful use of professional judgment should also be a key component of this assessment process):

- **Very low** and **low** are not normally of concern, though normal design care should be exercised to minimise adverse effects;
- **Very high** and **high** represent adverse effects on bird populations which are regarded as significant for the purposes of EIA;
- **Medium** represents a potentially significant adverse effect on which professional judgment has to be made. In the event that mitigation were not possible, it is likely to be significant but if mitigation is possible it may well be taken below the significance threshold.

Wind farm mortality and background mortality at Witberg

29. The predicted wind farm collision mortality has been assessed in the context of the background mortality, as previously, using the same baseline population data as in the previous reports. The predicted collision mortality has been set against the regional background mortality for each of the key species at risk of collision. The population data used in this analysis are summarised in Table 10. The region has been taken, through discussions with Rob Simmons, as the Karoo biome (Mucina and Rutherford 2006, and with reference to the WWF Karoo eco-region).

Table 10. Background population data for Verreaux's Eagle, Booted Eagle and Martial Eagle. Source: Roberts VII (Hockey et al. 2005) and Gargett (1990).

Species	**Regional population**	**Adult mortality rate**	**Immature mortality rate**	**Annual productivity (chicks/pair /year)**	**Age at first breeding**	**Baseline mortality**
Verreaux's Eagle	940 pairs	5%	20%	0.5	5	94 (adult)
Booted Eagle	700 pairs	10%	20%	1.0	3	500

30. Rob Simmons has provided a minimum population estimate for the Karoo Verreaux's Eagle, and identified, through consultation with Rob Davies, a conservative estimate of 600 pairs for the Karoo escarpment (Roggeveld, Nuweveld, Sneeuberge and Winterberge) plus a further 100 pairs for the smaller inselbergs outside of the main mountain ranges. These numbers were derived primarily from information collected by Rob Davies for his PhD work (together with other published population density estimates; Simmons in Hockey et al. 2005) and since then the population is thought to have declined by about 15% on the basis of recent field surveys carried out by Rob Davies. This would therefore give a current population estimate for the escarpment plus the inselbergs of about 600 pairs. The area on which this estimate is based does not include approximately 24,000km^2 of other Karoo mountain ranges that would provide suitable habitat Verreaux's Eagle habitat. Using a very conservative nesting density of 1 pair per 60km^2 (the lowest recorded according to Davies 1994, densities at the Karoo National Park and around the Witberg site are considerably higher than this) over this entire area, this gives a further 400 pairs over this area. That too should be scaled down from the 1994 density by 15%, giving an estimated 340 additional pairs, and hence a more realistic total of about 940 pairs for the Karoo.
31. Table 11 shows the predicted collision risks for each of the two key species that were recorded flying through the collision risk zone, for each of the three wind turbine scenarios. This Table also gives the context of their background mortality and the percentage increase over the

baseline that each risk represents, for each scenario and for the previous authorized 27-turbine layout. For Verreaux's Eagle, the assessment summarised in this Table assesses the collision risk against the adult population, as the large majority of records from the site relate to adult birds. Juveniles are assessed separately below.

32. Collision risks for the revised 27-turbine layout were lower than for Verreaux's Eagle but slightly higher for Booted Eagle those presented previously in the 2013 report for the authorized 27-turbine layout, with the higher hub height scenarios giving a reduced risk.

33. For Booted Eagle, the predicted collision risk of all three scenarios was very small both numerically and in a population context (though was marginally higher for the revised 27-turbine layout than the previous 27-turbine one). It represented considerably less than a 1% increase over the existing baseline mortality of the regional population (and was therefore classed as being of negligible magnitude). With such a negligible magnitude risk, there would not be likely to be any regionally significant population impact for this species for any of the scenarios assessed.

34. For Verreaux's Eagle, the authorized 27-turbine layout using a 116m rotor diameter turbine and 92m hub height, had a collision risk of 0.86 adult Verreaux's Eagle per year. It was concluded in the previous report that this would be a negligible magnitude effect, less than a 1% increase over the baseline mortality, which would be of very low significance and not a significant impact.

35. The three scenarios being currently investigated produced predictions of 0.42, 0.37 and 0.33 Verreaux's Eagle collisions per year, equivalent to increases over the baseline mortality of 0.45%, 0.40% and 0.35% respectively. All three were lower risk for this species than the authorized 27-turbine layout, with lower risks for the higher hub height scenarios. All of the risks would be negligible magnitude, and not significant, giving no material change to the conclusion reached previously.

36. As noted in the Shoney Renewables Consulting (2013) report, it should also be noted that this is the result of a precautionary assessment, not the most likely outcome. The analysis has adopted a precautionary approach throughout, including:

- Use of a precautionary 98% avoidance rate rather than the more evidence-based 99% for the closely related Golden Eagle (and use of an even more precautionary 95% avoidance rate for juvenile eagles);
- Use of a conservative regional population estimate against which to assess the predicted wind farm mortality;
- Assessment of mortality has been made against only the existing adult mortality rather than the usual assessment against all of the predicted mortality;
- Flight activity through the wind farm will continue at the same rate after construction. Given that mitigation measures will be implemented to improve the food resource within nest buffers away from the wind farm and the observed behaviour of Golden Eagles (which are similar in their behaviour to the Verreaux's Eagles), some reduction in flight activity is more likely.

Table 11. Collision risk for Verreaux's Eagle and Booted Eagle for each of the three wind turbine scenarios, and the increases that these represent over baseline mortality, and comparison with the authorized 27-turbine layout shown in italics.

Species	Scenario	Rotor diameter (m)	Hub height (m)	Predicted collision risk (98% avoidance rate)	% increase over baseline mortality	Magnitude of effect	Likely significant effect?
Verreaux's Eagle	Revised 27-turbine layout: scenario 1	136	92	0.42	0.45%	Negligible	No
	Revised 27-turbine layout: scenario 2	136	105	0.37	0.40%	Negligible	No
	Revised 27-turbine layout: scenario 3	136	120	0.33	0.35%	Negligible	No
	Authorized 27-turbine layout	*116*	*92*	*0.86*	*0.92%*	*Negligible*	*No*
Booted Eagle	Revised 27-turbine layout: scenario 1	136	92	0.044	0.009%	Negligible	No
	Revised 27-turbine layout: scenario 2	136	105	0.043	0.009%	Negligible	No
	Revised 27-turbine layout: scenario 3	136	120	0.041	0.008%	Negligible	No
	Authorized 27-turbine layout	*116*	*92*	*0.031*	*0.006%*	*Negligible*	*No*

Juvenile Verreaux's Eagle collision risk assessment

37. The assessment of the collision risk for juvenile Verreaux's Eagle, expressed in the context of their background mortality and the % increase over the baseline that each risk represents is summarised in Table 12. For all of the layouts and turbine specification scenarios the predicted juvenile mortality, even applying a highly precautionary 95% avoidance rate, would be a negligible magnitude impact, being less than a 1% increase over the regional baseline mortality.

Table 12. Additional collision risk assessment for Verreaux's Eagle juveniles and the increases that these represent over baseline mortality, with previous results for the authorized 27-turbine layout shown in italics.

Scenario	Rotor diameter (m)	Hub height (m)	Predicted collision risk (95% avoidance rate)	% increase over baseline mortality	Magnitude of effect	Likely significant effect?
Revised 27-turbine layout: scenario 1	136	92	0.19	0.07%	Negligible	No
Revised 27-turbine layout: scenario 2	136	105	0.17	0.06%	Negligible	No
Revised 27-turbine layout: scenario 3	136	120	0.15	0.05%	Negligible	No
Authorized 27-turbine layout	*116*	*92*	*0.21*	*0.08%*	*Negligible*	*No*

38. As in the previous collision risk assessments for this site, consideration was also given to the consequences of increasing the juvenile flight activity, assessing the risk on a precautionary theoretical basis rather than using field data. Even if flight activity were increased 10-fold over the observed adult rate, the collision risk would still be a negligible magnitude effect for all of the three scenarios (and would be lower risk than the authorized 27-turbine layout).

Conclusions and Summary

39. There were three key differences in relation to the collision risk modelling compared with the authorized 27-turbine layout: (a) a revised site layout and hence an updated collision risk zone; (b) updated minimum heights of blades above the ground resulting in a difference proportion of flights at rotor height, for three different hub heights; and (c) a larger rotor swept area resulting in an increased collision risk volume but reduced rotational speed.

40. Overall this assessment update of the collision risk for three turbine scenarios (all with the revised 27-turbine layout) found a reduced collision risk for Verreaux's Eagle in comparison with the authorized 27-turbine layout with a 116m rotor diameter turbine and 92m hub height. For Booted Eagle a small increase in risk was found. Collison risk to both species was lowest for the highest hub height (reflecting a lower proportion of flights at rotor height for that scenario). This did not, however, make any material difference to the conclusions reached. **There would be negligible magnitude collision risks to all of the key species assessed, which would not result in any significant ornithological impacts**. **All three of the new scenarios tested yielded negligible magnitude collision risks across the range of 92m-120m hub height which would not be significant, and the same conclusion would be valid for any hub height between those values. In other words, should Witberg Wind Power in the future consider an alternative turbine with a hub height between 92m and 120m, no additional collision risk assessments would be required as the results included in this report would remain valid.**

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APPENDIX 1. PROPOSED WIND TURBINE CO-ORDINATES FOR THE CURRENT REVISED 27-TURBINE LAYOUT

WG21 coordinate reference system

Turbine ID	x	y
WTG-01	3684448,69	49082,14
WTG-02	3684539,96	49426,33
WTG-03	3684268,91	49454,02
WTG-04	3684597,9	49706,99
WTG-05	3684666,87	49979,88
WTG-06	3685003,36	50470,85
WTG-07	3684282,19	50499,51
WTG-08	3685057,09	50806,05
WTG-09	3684318,81	50867,65
WTG-10	3685416,39	51040,14
WTG-11	3684968,03	51170,83
WTG-12	3684333,81	51235,57
WTG-13	3685260,82	51439,92
WTG-14	3684922,39	51502,37
WTG-15	3686135,51	51620,3
WTG-16	3685288,05	51758,22
WTG-17	3686188,03	51955,31
WTG-18	3685323,13	52056,81
WTG-19	3686104,94	52298,66
WTG-20	3685700,93	52366,39
WTG-21	3686022,75	52639,86
WTG-22	3686081,01	52999,25
WTG-23	3686164,27	53335,45
WTG-24	3685886,43	58410,19
WTG-25	3686023,41	58996,26
WTG-26	3686040,61	59362,41
WTG-27	3686047,23	59714,89

APPENDIX 2. COLLISION RISK MODELLING RESULTS REVISED 27-TURBINE LAYOUT (136M ROTOR DIAMETER TURBINE)

This Appendix sets out the collision risk modelling that has been undertaken for the proposed Witberg wind farm in July 2018. Firstly, the standard Band model spreadsheets are presented for each of the two species modelled in turn for the 136m rotor diameter turbine. These provide the information used to calculate the risk that individuals of each species would face if they flew through the wind farm rotor swept area. For the first species, for example, Verreaux's Eagle, this gives an overall 7.9% chance of collision.

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Verreaux's Eagle: 136m rotor											
Only enter input parameters in blue											
K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	4.13		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.88	m	0.025	0.575	6.82	32.58	1.00	0.00125	32.24	1.00	0.00125
Wingspan	2.4	m	0.075	0.575	2.27	10.97	0.45	0.00339	10.63	0.44	0.00328
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.36	7.39	0.30	0.00381	6.98	0.29	0.00359
			0.175	0.860	0.97	6.02	0.25	0.00434	5.51	0.23	0.00397
Bird speed	11.9	m/sec	0.225	0.994	0.76	5.19	0.21	0.00481	4.61	0.19	0.00427
RotorDiam	136	m	0.275	0.947	0.62	4.17	0.17	0.00472	3.61	0.15	0.00409
RotationPeriod	6.12	sec	0.325	0.899	0.52	3.45	0.14	0.00462	2.92	0.12	0.00391
			0.375	0.851	0.45	2.93	0.12	0.00452	2.42	0.10	0.00374
			0.425	0.804	0.40	2.52	0.10	0.00441	2.04	0.08	0.00358
			0.475	0.756	0.36	2.21	0.09	0.00433	1.77	0.07	0.00345
Bird aspect ratioo: β	0.37		0.525	0.708	0.32	2.03	0.08	0.00439	1.61	0.07	0.00348
			0.575	0.660	0.30	1.88	0.08	0.00444	1.49	0.06	0.00352
			0.625	0.613	0.27	1.74	0.07	0.00449	1.38	0.06	0.00356
			0.675	0.565	0.25	1.63	0.07	0.00453	1.30	0.05	0.00360
			0.725	0.517	0.24	1.53	0.06	0.00457	1.22	0.05	0.00366
			0.775	0.470	0.22	1.44	0.06	0.00460	1.16	0.05	0.00371
			0.825	0.422	0.21	1.36	0.06	0.00462	1.11	0.05	0.00378
			0.875	0.374	0.19	1.29	0.05	0.00464	1.07	0.04	0.00385
			0.925	0.327	0.18	1.22	0.05	0.00466	1.03	0.04	0.00392
			0.975	0.279	0.17	1.16	0.05	0.00466	1.00	0.04	0.00400
				Overall p(collision) =			**Upwind**	**8.6%**		**Downwind**	**7.2%**
								Average	**7.9%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Booted Eagle: 136m rotor											
Only enter input parameters in blue											
K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	4.1	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	4.13		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.5	m	0.025	0.575	6.59	23.78	1.00	0.00125	23.44	1.00	0.00125
Wingspan	1.23	m	0.075	0.575	2.20	8.04	0.34	0.00257	7.70	0.33	0.00246
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.32	5.61	0.24	0.00299	5.20	0.22	0.00277
			0.175	0.860	0.94	4.72	0.20	0.00352	4.22	0.18	0.00314
Bird speed	11.5	m/sec	0.225	0.994	0.73	4.17	0.18	0.00400	3.59	0.15	0.00344
RotorDiam	136	m	0.275	0.947	0.60	3.34	0.14	0.00391	2.78	0.12	0.00325
RotationPeriod	6.12	sec	0.325	0.899	0.51	2.75	0.12	0.00381	2.22	0.09	0.00308
			0.375	0.851	0.44	2.32	0.10	0.00371	1.82	0.08	0.00291
			0.425	0.804	0.39	2.01	0.09	0.00364	1.54	0.07	0.00278
			0.475	0.756	0.35	1.80	0.08	0.00363	1.35	0.06	0.00273
Bird aspect ratioo: β	0.41		0.525	0.708	0.31	1.62	0.07	0.00362	1.20	0.05	0.00268
			0.575	0.660	0.29	1.47	0.06	0.00360	1.08	0.05	0.00264
			0.625	0.613	0.26	1.34	0.06	0.00357	0.98	0.04	0.00261
			0.675	0.565	0.24	1.23	0.05	0.00354	0.90	0.04	0.00258
			0.725	0.517	0.23	1.13	0.05	0.00350	0.83	0.04	0.00256
			0.775	0.470	0.21	1.05	0.04	0.00346	0.77	0.03	0.00254
			0.825	0.422	0.20	0.97	0.04	0.00341	0.72	0.03	0.00253
			0.875	0.374	0.19	0.90	0.04	0.00335	0.68	0.03	0.00253
			0.925	0.327	0.18	0.83	0.04	0.00329	0.64	0.03	0.00253
			0.975	0.279	0.17	0.78	0.03	0.00322	0.61	0.03	0.00254
				Overall p(collision) =			**Upwind**	**6.8%**		**Downwind**	**5.4%**
								Average	**6.1%**		

The second section of this Appendix provides details of the calculations that have been made of the key species flight activity within the collision risk zone.

The first part of the Table (Section 1) below gives the survey effort (number of hours observation) for each month.

Both of the key species showed variable non-direct flights through the collision risk zone so were modelled using that variant of the Band model (which required the amount of time that each species was presented within the collision risk zone as its bird activity input).

The times each species was observed within the collision risk zone is summarised in Section 2, and the calculated occupancy rate (the % of observation time observed) are given in Section 3 (which feed into the following section of the modelling).

WITBERG COLLISION RISK MODELLING DATA INPUT: BIRD USAGE														
1. Hours observation														
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
East	18.8	0	0	26.2	0	21.0	0	15.2	0	0	20.5	0		
Mid	18.8	0	0	6.0	0	13.8	0	8.3	0	0	18.8	0		
West	15.2	0	0	18.8	0	7.3	0	10.0	0	0	18.5	0		
2. Bird occupancy of collision zone (seconds)														
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Black Eagle: East	0.0			0.0		0.0		0.0			0.0			
Black Eagle: Mid	0.0			171.6		163.0		0.0			190.8			
Black Eagle: West	0.0			0.0		52.8		0.0			0.0			
Booted Eagle: East	0.0			0.0		0.0		0.0			0.0			
Booted Eagle: Mid	0.0			0.0		15.1		0.0			200.0			
Booted Eagle: West	0.0			0.0		0.0		0.0			0.0			
Martial Eagle: East	0.0			0.0		0.0		0.0			0.0			
Martial Eagle: Mid	0.0			0.0		0.0		0.0			0.0			
Martial Eagle: West	0.0			0.0		0.0		0.0			0.0			
3. Bird occupancy rate of collision zone (% time present)														
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		**Mean occupanc**
Black Eagle: East	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
Black Eagle: Mid	0.000%			0.794%		0.329%		0.000%			0.281%			**0.281%**
Black Eagle: West	0.000%			0.000%		0.200%		0.000%			0.000%			**0.040%**
Booted Eagle: East	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
Booted Eagle: Mid	0.000%			0.000%		0.031%		0.000%			0.295%			**0.065%**
Booted Eagle: West	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
Martial Eagle: East	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
Martial Eagle: Mid	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
Martial Eagle: West	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**

The last part of the Appendix shows the details of the collision risk modelling for each zone of the wind farm for each of the two key species that were observed within the collision risk zone at rotor height, for each of the four scenarios. The total risk is the sum of the risks for each zone of the wind farm, plus the additional risk from the 2 further turbines on the western edge of the layout that fell outside the main vantage point survey area (estimated from the mean risk per turbine in the western zone that were fully covered by the VP survey).

WITBERG WIND FARM						
BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)						
SCENARIO 1: 136M ROTOR DIAMETER, 92M HUB HT						
	Black Eagle			**Booted Eagle**		
	East	***Mid***	***West***	***East***	***Mid***	***West***
Collision Zone Area (ha)	40	460	33	40	460	33
Hub Ht	92	92	92	92	92	92
Rotor diameter	136	136	136	136	136	136
Upper rotor ht	160	160	160	160	160	160
Lower rotor ht	24	24	24	24	24	24
Percentage of observation time seen flying in collision zone	**0.000%**	**0.281%**	**0.040%**	**0.000%**	**0.065%**	**0.000%**
Proportion of observation time seen flying at rotor height	78%	78%	78%	64%	64%	64%
Adjusted proportion of observation time seen flying at rotor height	0.000%	0.219%	0.031%	0.000%	0.042%	0.000%
Season length	365	365	365	365	365	365
Activity per day	12.1	12.1	12.1	12.1	12.1	12.1
Total flight activity in collision zone at rotor ht	0.000	9.680	1.379	0.000	1.840	0.000
Flight risk volume	5.440E+07	6.256E+08	4.488E+07	5.440E+07	6.256E+08	4.488E+07
No Turbines	**0**	**23**	**2**	**0**	**23**	**2**
Rotor radius	**68**	**68**	**68**	**68**	**68**	**68**
Rotor depth	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**
Bird length	**0.88**	**0.88**	**0.88**	**0.5**	**0.5**	**0.5**
Swept volume	0	1663891	144686	0	1536927	133646
Bird occupancy of swept volume	0.00	92.68	16.00	0.00	16.28	0.00
Bird speed	**11.9**	**11.9**	**11.9**	**11.5**	**11.5**	**11.5**
Rotor transit time	0.418	0.418	0.418	0.400	0.400	0.400
No of rotor transits	0.0	221.5	38.2	0.0	40.7	0.0
Turbine downtime	8%	10%	10%	8%	10%	10%
Band collision rate	7.9%	7.9%	7.9%	6.1%	6.1%	6.1%
Non-avoid collisions	0.0	15.7	2.7	0.0	2.2	0.0
Avoidance rate	98%	98%	98%	98%	98%	98%
Collision prediction	**0.00**	**0.31**	**0.05**	**0**	**0.04**	**0**
Total collisions (inc. additional 2 western turbines)			**0.42**			**0.04**

WITBERG WIND FARM						
BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)						
SCENARIO 2: 136M ROTOR DIAMETER, 105M HUB HT						
	Black Eagle			**Booted Eagle**		
	East	***Mid***	***West***	***East***	***Mid***	***West***
Collision Zone Area (ha)	40	460	33	40	460	33
Hub Ht	105	105	105	105	105	105
Rotor diameter	136	136	136	136	136	136
Upper rotor ht	173	173	173	173	173	173
Lower rotor ht	37	37	37	37	37	37
Percentage of observation time seen flying in collision zone	**0.000%**	**0.281%**	**0.040%**	**0.000%**	**0.065%**	**0.000%**
Proportion of observation time seen flying at rotor height	69%	69%	69%	62%	62%	62%
Adjusted proportion of observation time seen flying at rotor height	0.000%	0.194%	0.028%	0.000%	0.040%	0.000%
Season length	365	365	365	365	365	365
Activity per day	12.1	12.1	12.1	12.1	12.1	12.1
Total flight activity in collision zone at rotor ht	0.000	8.563	1.220	0.000	1.783	0.000
Flight risk volume	5.440E+07	6.256E+08	4.488E+07	5.440E+07	6.256E+08	4.488E+07
No Turbines	**0**	**23**	**2**	**0**	**23**	**2**
Rotor radius	**68**	**68**	**68**	**68**	**68**	**68**
Rotor depth	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**
Bird length	**0.88**	**0.88**	**0.88**	**0.5**	**0.5**	**0.5**
Swept volume	0	1663891	144686	0	1536927	133646
Bird occupancy of swept volume	0.00	81.99	14.15	0.00	15.77	0.00
Bird speed	**11.9**	**11.9**	**11.9**	**11.5**	**11.5**	**11.5**
Rotor transit time	0.418	0.418	0.418	0.400	0.400	0.400
No of rotor transits	0.0	195.9	33.8	0.0	39.4	0.0
Turbine downtime	8%	10%	10%	8%	10%	10%
Band collision rate	7.9%	7.9%	7.9%	6.1%	6.1%	6.1%
Non-avoid collisions	0.0	13.9	2.4	0.0	2.1	0.0
Avoidance rate	98%	98%	98%	98%	98%	98%
Collision prediction	**0.00**	**0.28**	**0.05**	**0**	**0.04**	**0**
Total collisions (inc. additional 2 western turbines)			**0.37**			**0.04**

WITBERG WIND FARM						
BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)						
SCENARIO 3: 136M ROTOR DIAMETER, 120M HUB HT						
	Black Eagle			**Booted Eagle**		
	East	***Mid***	***West***	***East***	***Mid***	***West***
Collision Zone Area (ha)	40	460	33	40	460	33
Hub Ht	120	120	120	120	120	120
Rotor diameter	136	136	136	136	136	136
Upper rotor ht	188	188	188	188	188	188
Lower rotor ht	52	52	52	52	52	52
Percentage of observation time seen flying in collision zone	**0.000%**	**0.281%**	**0.040%**	**0.000%**	**0.065%**	**0.000%**
Proportion of observation time seen flying at rotor height	61%	61%	61%	59%	59%	59%
Adjusted proportion of observation time seen flying at rotor height	0.000%	0.171%	0.024%	0.000%	0.038%	0.000%
Season length	365	365	365	365	365	365
Activity per day	12.1	12.1	12.1	12.1	12.1	12.1
Total flight activity in collision zone at rotor ht	0.000	7.570	1.078	0.000	1.697	0.000
Flight risk volume	5.440E+07	6.256E+08	4.488E+07	5.440E+07	6.256E+08	4.488E+07
No Turbines	**0**	**23**	**2**	**0**	**23**	**2**
Rotor radius	**68**	**68**	**68**	**68**	**68**	**68**
Rotor depth	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**	**4.1**
Bird length	**0.88**	**0.88**	**0.88**	**0.5**	**0.5**	**0.5**
Swept volume	0	1663891	144686	0	1536927	133646
Bird occupancy of swept volume	0.00	72.48	12.51	0.00	15.00	0.00
Bird speed	**11.9**	**11.9**	**11.9**	**11.5**	**11.5**	**11.5**
Rotor transit time	0.418	0.418	0.418	0.400	0.400	0.400
No of rotor transits	0.0	173.2	29.9	0.0	37.5	0.0
Turbine downtime	8%	10%	10%	8%	10%	10%
Band collision rate	7.9%	7.9%	7.9%	6.1%	6.1%	6.1%
Non-avoid collisions	0.0	12.3	2.1	0.0	2.0	0.0
Avoidance rate	98%	98%	98%	98%	98%	98%
Collision prediction	**0.00**	**0.25**	**0.04**	**0**	**0.04**	**0**
Total collisions (inc. additional 2 western turbines)			**0.33**			**0.04**

Shoney Renewables Consulting (Pty) Ltd

WITBERG WIND FARM:

ORNITHOLOGICAL COLLISION

RISK MODELLING

24 JUNE 2013

FINAL

FINAL

Witberg Wind Farm

Ornithological Collision Risk Modelling 2013

Report

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7.0	24/6/13	various	KH client comments
8.0	24/6/13	various	QA review + KH client comments
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CONTENTS

SECTION 1
INTRODUCTION

SECTION 1 - INTRODUCTION

The purpose of this study is to address Birdlife South Africa's (BLSA) concerns about the ornithological impacts of the proposed Witberg wind farm by:

- Conducting collision risk modelling based on international best practice to determine and classify collision risk across the entire Witberg wind energy facility (WEF) site; and
- Drawing up recommended mitigation measures based on the results of the collision risk modelling and after considering the key issues in order to reduce the predicted impacts of the WEF on birds to an environmentally acceptable level.

The work covered in this proposal presents the results of collision risk modelling undertaken by Steve Percival (the international specialist) to inform the further assessment of the impacts, with additional input from Rob Simmons' as Anchor Environmental's local raptor specialist discussing detailed habitat preferences and behaviour of the selected bird species of concern, and examination of other mitigation options in more detail.

The study draws on international best practice and experience from other countries with substantial onshore wind capacity installed and similar raptor concerns as encountered at Witberg (such as Golden Eagles in Scotland and the USA, White-tailed Sea Eagles in Norway and raptors in Spain).

The study follows the Terms of Reference signed by BirdLife on 19 April 2013 (which is attached as Appendix 3 to this report).

The work undertaken by the international expert in collision modelling was follows:

- Review of the international literature as it pertains to sites and bird species similar to what is found at Witberg;
- Application of best practice in collision risk modelling to consider the entire Witberg area (to be supplied by WWP), irrespective of current bird nest buffers, to identify areas of low, medium and high bird collision risk, as well as no go areas if possible;
- Assessment of the conservation value of the various bird species at high risk of collision with rotating wind turbine blades and/or displacement caused by the WEF (international perspective);
- Re-assessment of the likely impacts on birds at the Witberg site, if necessary;
- Consideration of alternative mitigation measures in lieu of or in addition to those measures already suggested, including but not limited to temporary curtailment of turbines with pro-active bird detection measures (e.g. radar or optics based); and
- Comment on whether an offset site for bird conservation is both appropriate and practical in the circumstances (based on international experience of bird-wind farm issues and management of those issues).

The work that has been undertaken by local ornithological experts (including Rob Simmons and the Anchor Environmental team), reported in the previous Anchor report and with additional input to the current report comprised:

- Evaluation of the sensitivity, uniqueness and replaceability of the Witberg site;
- Discussion of the biology and behaviour of Verreaux's Eagles, Booted Eagles, Martial Eagles and Black Harrier;

- Assessment of the conservation value of the various bird species at high risk of collision with rotating wind turbine blades and/or displacement caused by the WEF (local and South African perspective);
- A site visit to enable a better assessment the issues listed above. Birdlife South Africa as well as WWP representatives would also be present at this site visit. As the CRM modeling does not take account of site characteristics (i.e. it is a mathematical model), it was not considered necessary for Dr Steve Percival to undertake a site visit, as Dr Rob Simmons is well acquainted with the site and he was able to provide the site-specific input together with the Anchor Environmental team.

Details of the author experience and statement of independence are given in Appendix 1.

The layouts which were modelled were as follows

- The initial 70 WTG layout using Turbine Type B (Vestas V100 2MW);
- The 40 WTG layout using Turbine Type C (Vestas V90 3MW) that was authorized by the DEA.
- The 27 WTG Layout current at the start of this study using Turbine Type A (Acciona AW116 3MW);
- The 27 WTG layout but with two turbines (located within an area of higher eagle use) removed, using the same Type A Acciona turbine;
- An updated 'reduced eagle collision risk' 27 WTG layout with 5 turbines moved from an area of higher eagle activity to a lower activity area, using the same Type A Acciona turbine.

The history of the scheme is summarised in Table 1. Each of the layouts is shown in Figure 1a-3.

Table 1. History of the Witberg wind farm proposal layout

Revision	CRM Modelled?	Potential impact addressed	Project Phase	Number of Turbines
0 - Initial Layout	Yes	First indicative layout with 70 turbines across northern, main and southern ridges	Scoping Phase of the EIA application in late 2010	70
1 (aka Layout 2)	No	Avoidance of northern ridge altogether because of the two 2.5km Martial Eagle nest buffers and high visual impact concerns due to proximity to N1. All turbines are now on main and southern ridges	EIA phase	70
2 (aka Final Layout 3)	Yes	Avoidance of further high sensitivity ares for birds (single 1.5km Verreaux's Eagle nest buffer), heritage impacts (turbines east of Sentech mast closest to Matjiesfontein) and various ecological concerns according to the inputs identified by the specialist assessments and the ones provided by the commenting authorities	EIA phase conclusion and as per Environmental Authorisation (issued by the DEA on 13 October 2011)	40

Revision	CRM Modelled?	Potential impact addressed	Project Phase	Number of Turbines
3	No	Implementation of the bird pre-construction monitoring results, undertaken by Anchor Environmental: discovery of 2 additional Verreaux's Eagle nests and 2 Booted Eagle nests, turbines numbers consequently were further decreased and their positions shifted in respect of the 1.5km Buffer for Verreaux's Eagles and 1.2km for booted Eagles, this final turbine layout was agreed on with Anchor Environmental subject to the implementation of an offset	After completion of pre-construction bird monitoring (8 May 2012)	26
4	Yes	Further technical layout optimisation was undertaken strictly outside all identified bird buffers and respecting the recommendations of the pre-construction monitoring and other specialist reports. Change of impacts likely negligible	Apr-13	27
5	Yes[1]	Identified high activity areas in the Collision Risk Modelling (CRM), using the pre-construction monitoring data as input were used in a sensitivity scenario to determine the impact of turbine position 9 and 10, only for the case that it is possible to shift the turbines to lower sensitivity areas of the wind farm	CRM modelling	25 (rev 4 minus 2 turbines)
6	Yes	Another test on the high sensitive areas was undertaken by removing turbine positions 6-10, only for the case that it is possible to shift the turbines to lower sensitivity areas of the wind farm. Resulted in demonstration that turbines 6-10 resulted in circa 50% of collisions. New locations for turbines 6-10 were then considered during a site visit	CRM modelling	22 (rev 4 minus 5 turbines)
7 – Final	Yes	After having conducted further flight path analysis and site inspections to investigate for 5 replacement turbine positions, turbines 6-10 were relocated into much lower sensitivity areas with low or no flight activity, resulting in the final layout design	After CRM modelling	27

[1] Various iterations of layout modelled to understand which turbines create greatest collision risk, in order to understand which turbines should be relocated as part of design mitigation

SECTION 2

BASELINE DATA AVAILABLE

SECTION 2 - BASELINE DATA AVAILABLE:

The collision risk modelling primarily uses the raw baseline monitoring data collected during the 12 month bird monitoring campaign conducted by Dr Jane Turpie from June 2011 until April 2012. It also draws, where appropriate, from the original Avian Impact Assessment by Dr Andrew Jenkins dated October 2010.

Flight Activity Data

The June 2011 – April 2012 surveys included vantage point surveys to determine priority species (plus any other large bird species) flight activity over and around the WEF site and a nearby control site. Bird movements were simultaneously monitored by four observers stationed at three vantage points at the WEF site and one at the control site, located about 7.5 km to the east of the WEF site (Figure 1).

The vantage points are higher than the surrounding landscape and were strategically chosen to achieve maximum coverage of the study area. There was little overlap between the view sheds of each vantage point. Observers were stationed at the vantage points over a three day period, and observations were made for blocks of time within the day. Observations involved continuous slow scanning of a 360° area, alternately with telescopes and binoculars. Once a large bird was spotted, it was followed till out of sight and its flight path recorded on a 1: 50 000 topographic map in addition to height and behavioural data. For each sighting, the following information was recorded as far as possible:

- Date and time;
- Species and number;
- Mode of flight (gliding, flapping, soaring);
- Flight activity (commuting, hunting);
- Vertical zoning relative to the proposed turbines (low, <40m above ground, medium 40-120m, high 120-150m and very high (>150m);
- Horizontal distance and bearing from the observer at start and end of observation;
- Direction of flight, or flight path plotted on map.

These data were then mapped digitally in ArcView and ported to MapInfo for the collision risk assessment.

Body Size and Flight Speeds

The collision model requires data on bird body size and flight speed. Body sizes and baseline mortality rates were taken from Roberts Birds of South Africa (Hockey et al. 2005). Flight speeds were taken from Alerstam et al. (2007)) for ecologically similar species, as none were available for any of the three key Witberg species (Golden Eagle for Verreaux's Eagle, the mean of all of the available *Aquila* eagle species for Martial Eagle and the mean of all of the available *Buteo* species for the smaller Booted Eagle). The data used in the collision risk modelling are shown in Table 2.

Table 2. Key species body size and flight speed data used in the collision risk modelling

Species	Body length (m)	Wing span (m)	Flight speed (m/s)
Verreaux's Eagle	0.88	2.4	11.9
Booted Eagle	0.50	1.23	11.5
Martial Eagle	0.81	2.15	10.4
Black Harrier *	0.51	1.0	9.7

**no flight activity of black harrier was observed within the collision risk zone so this species was not modeled, but for completeness details are included here.*

Wind Farm Technical Data

The collision modelling requires a range of input data on the wind turbine specifications, which were provided by Witberg Wind Power (WWP) and the turbine manufacturer. They are summarised in Table 3. Typical candidate wind turbines were modelled for each of the three layouts. Where any uncertainties exist as to any specifications of the turbines a worst-case approach has been adopted to deliver a precautionary but robust analysis.

Table 3. Wind turbine data used in the collision risk modelling

Specification	Value used in collision risk modelling
Turbine Model A: Acciona 116 3MW **27 Turbine layout**	
Hub height	92m
Rotor diameter	116m
Height to blade tip	150m
Minimum height of blade above ground	34m
Rotational speed (variable – mean value calculated from local wind speed data measured by WWP)	11.9 (eastern turbine block), 11.68 (western turbine block)
Blade maximum chord	3.28m
Blade pitch (variable – mean value calculated from local wind speed data measured by WWP)	4.13° (eastern turbine block), 3.34° (western turbine block)
Turbine operation time (when not constrained by high/low wind speed or maintenance activity)	92% (eastern turbine block), 90% (western turbine block)

Turbine Model B: Vestas v100 2MW **70 Turbine layout**	
Hub height	80m
Rotor diameter	100m
Height to blade tip	130m
Minimum height of blade above ground	30m
Rotational speed (variable – mean value calculated from local wind speed data by WWP)	12.25 (eastern turbine block), 11.63 (western turbine block)
Blade maximum chord	3.28m
Blade pitch (variable – Acciona values plus a precautionary 2° due to lack of data provided by manufacturer)	6° (eastern turbine block), 5° (western turbine block)
Turbine operation time (when not constrained by high/low wind speed or maintenance activity)	91% (eastern turbine block), 90% (western turbine block)
Turbine Model C: Vestas v90 3MW **40 Turbine layout**	
Hub height	80m
Rotor diameter	90m
Height to blade tip	125m
Minimum height of blade above ground	35m
Rotational speed (variable – mean value calculated from local wind speed data by WWP)	11.04 (eastern turbine block), 10.24 (western turbine block)
Blade maximum chord	3.28m
Blade pitch (variable – Acciona values plus a precautionary 2° due to lack of data provided by manufacturer)	6° (eastern turbine block), 5° (western turbine block)
Turbine operation time (when not constrained by high/low wind speed or maintenance activity)	90% (eastern turbine block), 87% (western turbine block)

Data Issues

There were a number of issues identified with the baseline data, each of which is discussed in turn below, including how they have been dealt with in the analysis.

Lack of recording of flight times - there was not any specific recording of the length of time of each flight line during the vantage point surveys. It was assumed therefore that bird flight speed was constant, and applying a mean value for each species (see Table 1) to convert the flight path length to flight time (where time = distance/speed), and hence overall occupancy of the collision risk zone. The collision risk zone for each layout was defined, as per Band et al (2007) and SNH guidance (Whitfield et al. 2010) as a 200m zone around the proposed wind turbine locations.

Viewing distances - the viewing distances from the vantage points are in some cases rather long (up to 5-6km) in comparison with the 2km maximum usually used in the UK, though it is acknowledged in BLSA guidance that "*capacity constraints are likely to stretch this distance*" in a South African context. In relation to the modelled collision risk zone, it was clear from the flight line mapping that viewing was possible over a considerably greater distance than 2km. For the analysis a viewing distance of up to 3km was used (as a reasonable assumption given the data collected), and any data exceeding this viewing distance was not used in this part of the analysis. Rob Simmons has confirmed that this is a reasonable assumption from his experience on site. For the two 27-turbine layouts this gave complete coverage of the eastern WEF block and coverage of 70% of western block, but did mean that there was no effective coverage of the westernmost two turbines of the western block. For the 40-turbine scheme 3 turbines were further than 3km from any vantage point, and for the 70-turbine scheme 9 turbines. Allowance was made for the turbines that lay outside the 3km distance by assuming that flight activity in that area was the same as that in rest of western block, hence the collision risk there was proportionate to number of turbines. In discussion with Rob Simmons it was also clear that the northern ridge of the 70-turbine layout was not well-covered by these surveys, so account has been taken of that in the 70-turbine modelling (this specific point does not affect the other turbine layouts).

Flight height recording - flight heights were recorded to wide zone bands that did not perfectly match up to the proposed turbine/rotor heights. The 'Medium' and 'High' categories were both fully within the rotor swept area, and the 'Very High' category above that area. The 'Low' category (<40m), however, included part within the rotor swept area (34-40m) and part below it. It was assumes that flight activity was uniform within that band, so 6/40 (15%) of flights in that category were assumed to be at rotor height for the Type A turbine (as per Band et al. 2007), 10/40 (25%) for the Type B turbine and 5/40 (12.5%) for the Type C turbine.

360-degree viewing – it is usual practice during vantage point surveys to focus ahead of the observer, so the 360-degree viewing may have reduced detectability overall (Whitfield et al. 2010). The BLSA guidance on this topic states that "Bird movement taking place further 'behind' the observers may be relevant, and should be included at the discretion of the site specialist or the fieldworkers at the time, but not at the expense of effective 'forward' coverage". Given the low bird densities overall recorded, it is not considered that this would have been likely to have materially affected the results and that the large majority of birds would have been recorded.

Low numbers of juvenile flights - for the Verreaux's Eagle, the baseline surveys did not include any period of juvenile flights, so a theoretical approach has been adopted to inform the assessment further. No juveniles were seen on the wing during Nov/Jan surveys (presumably as a result of breeding failure of all three pairs in that year), and by the following April surveys none had yet fledged (though nests were then active). From discussions with Rob Simmons, the Verreaux's Eagle young would usually fledge in September, spend 1-2 months in close proximity to (within 1km) the nest, then explore the wider area of their parents territories and the surrounds for a further 2 months. They then leave the parental territories, 3-4 months after fledging. This has been addressed in the assessment by using a precautionary theoretical approach to estimate the number of juvenile flights, so that account could be taken of these in the collision risk modelling.

SECTION 3

LITERATURE REVIEW: WIND TURBINES AND RAPTORS

SECTION 3 – LITERATURE REVIEW: WIND TURBINES AND RAPTORS

The key ornithological issue with the Witberg WEF is the potential effect of the scheme on large raptors, specifically Verreaux's Eagle *Aquila verreauxii*, Booted Eagle *Aquila pennata*, Martial Eagle *Polemaetus bellicosus* and Black Harrier *Circus maurus*. The purpose of this literature review is to draw on the experience from existing wind farms to provide further information about how these species might be affect by the Witberg WEF. There are two main sources of potential impact, collision and disturbance.

Collision Risk

There have been a number of wind farms that have caused bird mortalities through collision but their characteristics are very different to those at the proposed Witberg site. Most notably, at Altamont Pass in California and Tarifa in southern Spain, large numbers of raptors have been killed (Orloff and Flannery 1992, Janss 1998, Thelander et al. 2003). Such problems have occurred where large numbers of sensitive species occur in close proximity to very large numbers (hundreds/thousands) of turbines, and usually also where the wind farm area provides a particularly attractive feeding resource. At Altamont, for example, the wind turbine bases provided an attractive shelter for ground squirrels which themselves provided an attractive raptor foraging resource (Thelander et al 2003).

A specific problem has been identified for old world vultures, which have much the highest numbers of reported raptor collisions (Hotker et al. 2004, Illner 2011). Martin et al. (2012) reported that these species have large blind areas in their field of vision above, below and behind the head, such that with the head positions typically adopted by foraging vultures, they will often be blind in the direction of travel. This would make them particularly vulnerable to collision with wind turbines and the studies that have been undertaken bare out this conclusion (Janss 1998, de Lucas et al. 2012). In addition to this wind farms have been located in areas of high vulture food resource and several of their populations are vulnerable to additional mortality (Carrete et al. 2009).

Another species clearly more vulnerable to collision with wind turbines is the white-tailed eagle. Small numbers of collisions have been reported at several wind farms including in Germany and Poland, but at one particular site rather more fatalities have occurred, Smøla in NW Norway (an average of 8 collisions per year, May et al. 2010). In Australia white-bellied sea eagle and wedge-tailed eagle have also both been demonstrated to be vulnerable to collision (Hull and Muir 2013).

Outside the UK Golden eagles have been reported as collision victims at wind farms, but generally at a low rate in comparison with vultures and white-tailed eagles. Whitfield (2009) reviewed the avoidance rates that this species has exhibited and reported estimates varying between 98.64 % and 99.89 % depending on site and uncertainty associated with observed mortality rates before and after adjustment for potential biases. An overall 'worst case' estimate weighted by the scale of study was 99.33 % and the mean unweighted 'worst case' (lowest) avoidance rate for the four wind farms was 99.19 %, and adoption of a precautionary value of 99.0 % was advised for use in wind farm assessments (and adopted by SNH in their guidance, Urquhart 2010).

In wind farm sites in the UK, with similar large raptor flight densities to Witberg, collision rates have generally been very low and are not considered to be significant (Meek et al. 1993, Tyler 1995, Dulas 1995, EAS 1997, Bioscan 2001, Percival et al. 2008, Percival et al. 2009a). There have been no golden eagle collision at all reported to date in the UK, despite their presence at several operational sites. A study of this species at Beinn an Tuirc (Walker et al. 2005) has shown them to largely avoid the wind farm site after construction, with a resultant reduction in collision risk. Marsh harrier, too, has been found to show a similar avoidance of the proximity of wind turbines, with flight density post-construction reduced by 94% within 200m of turbines (Percival et al. 2009a, Percival et al. 2009b). Again no collision at all of this species have been reported in the UK. Studies of red kite and hen harrier in the UK have found they too have exhibited high rates of avoidance of collision (Whitfield and Madders 2006a and 2006b).

Sites where higher numbers of raptor collisions have occurred generally have supported a high density of flight activity that has been maintained post-construction, often associated with attractive ecological resource within the wind farm site, resulting in attraction into the wind farm rather than avoidance. The key risk features can be summarised as:

- High turbine numbers
- Turbine design – older design lattice towers can provide a perching resource
- High bird density within the wind farm – particularly where there is a rich food resource within the wind farm, or attractive breeding sites
- Source of distraction in close proximity to turbines, e.g. food resource in turbine bases, breeding displays.
- Vultures have a specific issue with their limited field of vision
- Particular vulnerability of populations to additional mortality (e.g. Egyptian vulture – where wind farms have been implicated in population decline often where acting in combination with other factors, Carrete et al. 2009).

It is noted few of these factors operating at Witberg, but the assessment of the magnitude of collision risk at Witberg will be informed by the modelling presented in this report.

Disturbance

Several of the studies referred to above (e.g. Walker et al. 2005, Percival et al. 2009a, Percival et al. 2009b, Whitfield et al. 2006) have noted some displacement of raptors from a zone around wind turbines. This has typically been reported over a distance of 1-200m of turbines. Displacement effects have also been reported for white-tailed eagles at Smøla (May et al. 2013). Though this reduces the collision risk it does mean that the development of a wind farm could result in effective loss of habitat if birds are dissuaded from using the area in proximity to turbines. Any impact on the population would be dependent on importance of that area from which displaced and the availability of alternative areas, but any assessment should take into account the possibility of such small-scale displacement.

Barrier Effects

A further potential disturbance effect could be disruption to important flight lines (barrier effect; Percival 2005, Drewitt and Langston 2006). Birds may see the wind farm and change their route to fly around (rather than through) it. This would reduce the risk of collision but could possibly have other effects, for example potentially making important feeding areas less attractive (by acting as a barrier to the birds reaching them) and (if diversions were of a sufficient scale) resulting in increased energy consumption.

The distance needed to divert around the Witberg WEF would be relatively small and would not be expected to act as a major barrier to movements. Accordingly, the ecological consequences of any such changes in flight lines would be of negligible magnitude and not significant.

SECTION 4 – KEY SPECIES STATUS

SECTION 4 - KEY SPECIES STATUS

Four species of particular concern have been identified and agreed with BLSA; Verreaux's Eagle, Booted Eagle, Martial Eagle and Black Harrier. The conservation status of each is reviewed in turn. This was all included in the Anchor Environmental report but is repeated here for completeness.

Verreaux's Eagle (or Black Eagle) is an important apex predator that occurs throughout Africa and into the Middle East, and is fairly common in South Africa. It is of 'Least Concern' in terms of its global conservation status, with a populations estimated to be in the tens of thousands (BirdLife International 2013a). It is not listed on the South Africa 'Red List'. Within southern Africa, the density of Verreaux's Eagles is highest in a band from the south-western Cape to KwaZulu-Natal, incorporating the study area. There are an estimated 400 – 2000 pairs in the old Cape Province (Northern Cape, the Eastern Cape and the western edge of the North West Province; Boshoff and Vernon 1980, Hockey et al. 2005). Of these there are probably a maximum of 800 pairs in the Western Cape (L. Rodriguez, pers. comm.). Densities of 1 pair per 24km^2 have been recorded in the Karoo (Davies 1994, Hockey et al. 2005), with the lowest density found in that region of 1 pair per 60km^2 (Davies 1994).

Verreaux's Eagle is found in mountainous and rocky areas with cliffs, and because of this their populations have remained relatively secure in the past. Verreaux's Eagles are monogamous and defend territories year round, the pairs staying together most of the day. Most territories contain multiple nest sites (up to 5), although one nest might be favoured for several years in a row. Verreaux's Eagles tend to hunt by soaring along ridges and their diet is dominated by small mammals, particularly hyrax. They tend to rest during the middle of the day. Verreaux's Eagles were present in high densities in the study area, where they nested on cliffs just below the ridge top, and hunted mainly along the ridges and slopes.

Booted Eagle is another important apex predator and is found throughout much of Africa and Eurasia. It is of 'Least Concern' in terms of its global conservation status, with a populations estimated to be in the tens of thousands (BirdLife International 2013a). It is not listed on the South Africa 'Red List'. Within southern Africa, they are most common in the south and south west part, which includes the study area. An estimated 700 breeding pairs occur in the 'Cape' area, breeding mainly in mountainous areas, where they nest on cliffs. The Palearctic breeders migrate to southern Africa spending November to March here, so at this time the population at Witberg could be a mix of residents and Palearctic migrants. The population resident in southern Africa move into the south-western areas to breed during July-August, remaining until March. This population is a separate subspecies to the Palearctic migrants, but they are not considered threatened. In southern Africa, Booted Eagles are monogamous, and while they are territorial, they are often known to have nest sites in close proximity to their neighbours (e.g. less than 300m), as was the case in the study area. Booted Eagles are agile aerial foragers, and their diet is dominated by birds. At least two pairs of Booted Eagles nested on the cliffs at the WEF site and foraged over the ridges.

Martial Eagle is classified as 'Near Threatened' globally (BirdLife International 2013c) because it is suspected to have undergone moderately rapid declines during the past three generations (56 years) owing to habitat loss and incidental poisoning and pollution, and is consequently believed to approach the threshold for classification as Vulnerable. It is on the South Africa Red List, where it is listed as 'Vulnerable'. It is widespread throughout Africa, but occurs only sparsely within southern Africa, and is more common in flat country than in mountainous areas. In the study area, their nests are on pylons at the base of the Witberg mountains (north of the proposed turbine ridge), but they forage over the ridges as well as over the lower hills and valleys in the surrounding areas. Martial Eagles tend to be resident, with a monogamous pair defending a territory for several seasons. Although the majority of pairs have one nest site (typically on a pylon or tree fork), multiple nest sites (up to 4) are not uncommon. They defend large territories of at least 280 km^2 in the Nama Karoo.

Black Harrier is classified as Vulnerable globally, as, despite its huge range, it has a very small population (only 500-1000 breeding pairs). It is on the South Africa Red List, where it is listed as ‘Near Threatened’. It has virtually disappeared from the agricultural lowlands and is now highly reliant on protected areas in its core breeding range in South Africa and Namibia, and is uncommon. It is territorial, nesting on or near the ground. It feeds aerially, being particularly active on windy days. Its main concentrations are associated with coastal lowlands and mountains and high altitude grasslands. Black Harrier was seen several times on the WEF site, as well as in the valleys below, where some breeding behaviour was also observed. However no flights were observed through the current proposed 27-turbine collision risk zone.

SECTION 5

COLLISION RISK MODELLING: METHODOLOGY

SECTION 5 - COLLISION RISK MODELLING: METHODOLOGY

Band Methodology

The collision risk modelling (CRM) was undertaken following the method of Band et al. (2007), as extensively used in the UK. Details of the original SNH guidance on this model (Band 2000) are available from the SNH web site at <www.snh.gov.uk/docs/C205425.pdf>. The model runs as a two-stage process. Firstly the risk is calculated making the assumption that flight patterns are unaffected by the presence of the wind turbines, i.e. that no avoidance action is taken. This is essentially a mechanistic calculation, with the collision risk calculated as the product of (i) the probability of a bird flying through the rotor swept area, and (ii) the probability of a bird colliding if it does so. This probability is then multiplied by the estimated numbers of bird movements through the wind farm rotors at the risk height (i.e. the height of the rotating rotor blades) in order to estimate the theoretical numbers at risk of collision if they take no avoiding action.

The second stage then incorporates the probability that the birds, rather than flying blindly into the turbines, will actually take a degree of avoiding action, as has been shown to occur in all studies of birds at existing wind farms (Urquhart 2010[2]). Discussion as to the most appropriate avoidance rates to apply is included in the following section.

Species Modelled

It was agreed with BLSA, that the CRM would be carried out on four key raptor species of concern; Verreaux's Eagle, Booted Eagle, Martial Eagle and Black Harrier.

There were only two Black Harrier flights recorded during the VP surveys and none of those through the collision risk zone. Collision risk would be zero applying the Band et al (2007) model. The collision risk to this species would clearly be negligible and not significant.

There were records of all of the other three key species within the collision risk zone, so modelling has been undertaken for all of them.

Study Area

The study area for the CRM was defined as the entire Witberg ridge including all currently existing eagle buffer zones outlined in the Avian Impact Assessment by Dr Andrew Jenkins dated October 2010 and the "Pre-construction Monitoring Report" by Dr Jane Turpie of Anchor Environmental dated May 2012 (2.5km for Martial, 1.5km for Verreaux's and 1.2km for Booted). However the collision modelling was focussed on five layouts, (a) the initial 70-turbine layout, (b) the 40-turbine layout that was approved by the DEA, (c) the first 27-turbine proposed layout, (d) that 27-turbine layout with two turbines removed, and (e) an updated lower risk 27-turbine layout, and was also limited by the geographical extent of the vantage point surveys (which provided the baseline data on bird flight activity for the modelling). As agreed with BLSA, however, these results are used in this report to address the appropriateness and benefits from applying these buffers.

[2] See SNH web site: www.snh.gov.uk/docs/B721137.pdf

The main collision risk zones for the layouts were defined, as per Band et al (2007) and SNH guidance (Whitfield et al. 2010) as a 200m zone around the proposed wind turbine locations. These zones were divided into three parts for the purposes of the collision modelling (Figure 1), relating to the three vantage points used for surveying the WEF (east, middle and west), and the collision modelling undertaken for each separately. As discussed above, the two westernmost turbines of the 27-and the 25-turbine layouts, the three westernmost turbines of the 40-turbine layout and the 9 westernmost turbines of the 70-turbine layout of the western turbine blocks fell outside the main VP survey area, so the flight densities within part of the collision zone were assumed to be the same as for the main part of the western block that was visible to a sufficient distance. The same assumption was made for the northern ridge of the 70-turbine layout, as that too was not well-covered by the baseline surveys.

Figure 1a. Vantage point locations and the collision risk modelling zones for the initial 70-turbine layout (Rev 0)

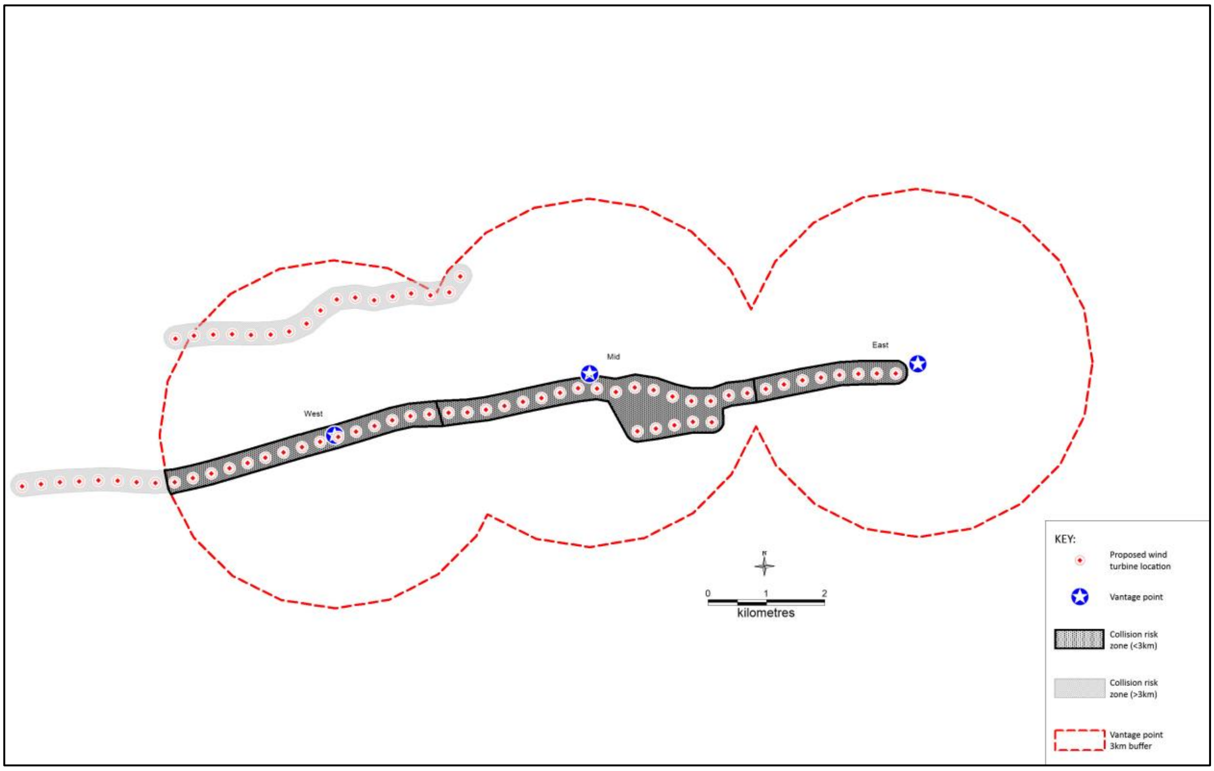


Figure 1b. Vantage point locations and the collision risk modelling zones for the DEA-authorised 40-turbine layout (Rev 2)

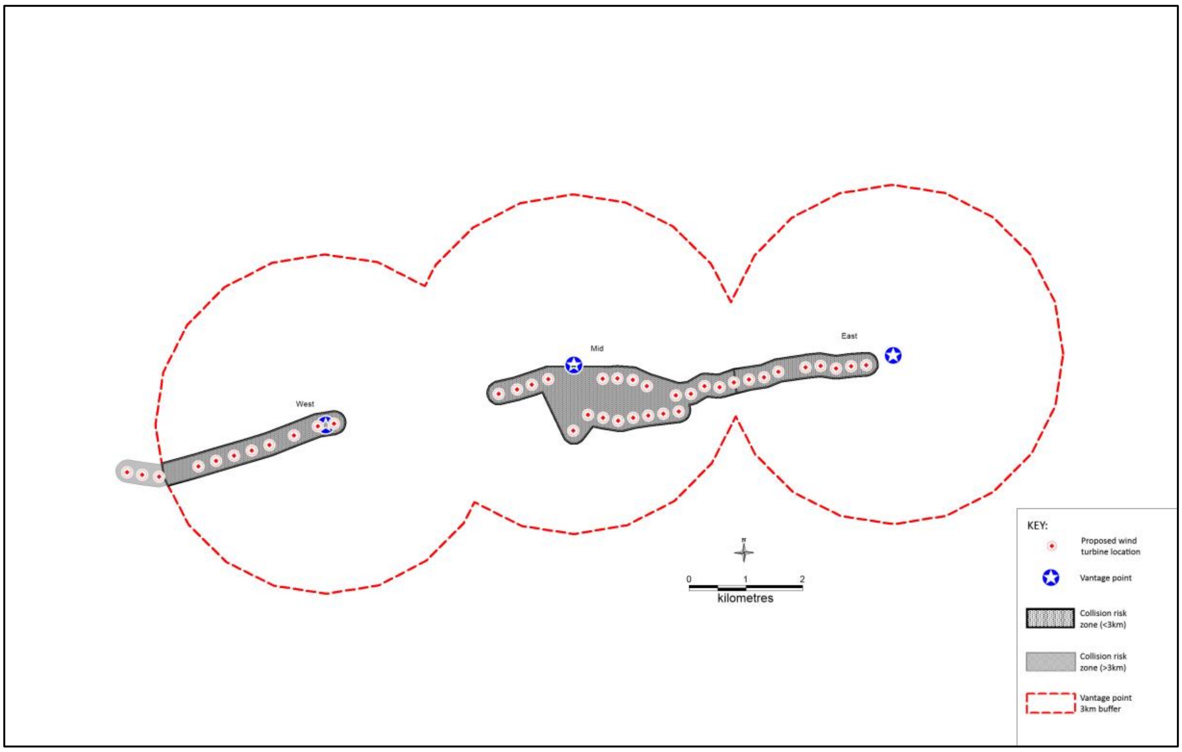


Figure 1c. Vantage point locations and the collision risk modelling zones for the first 27-turbine layout (Rev 4)

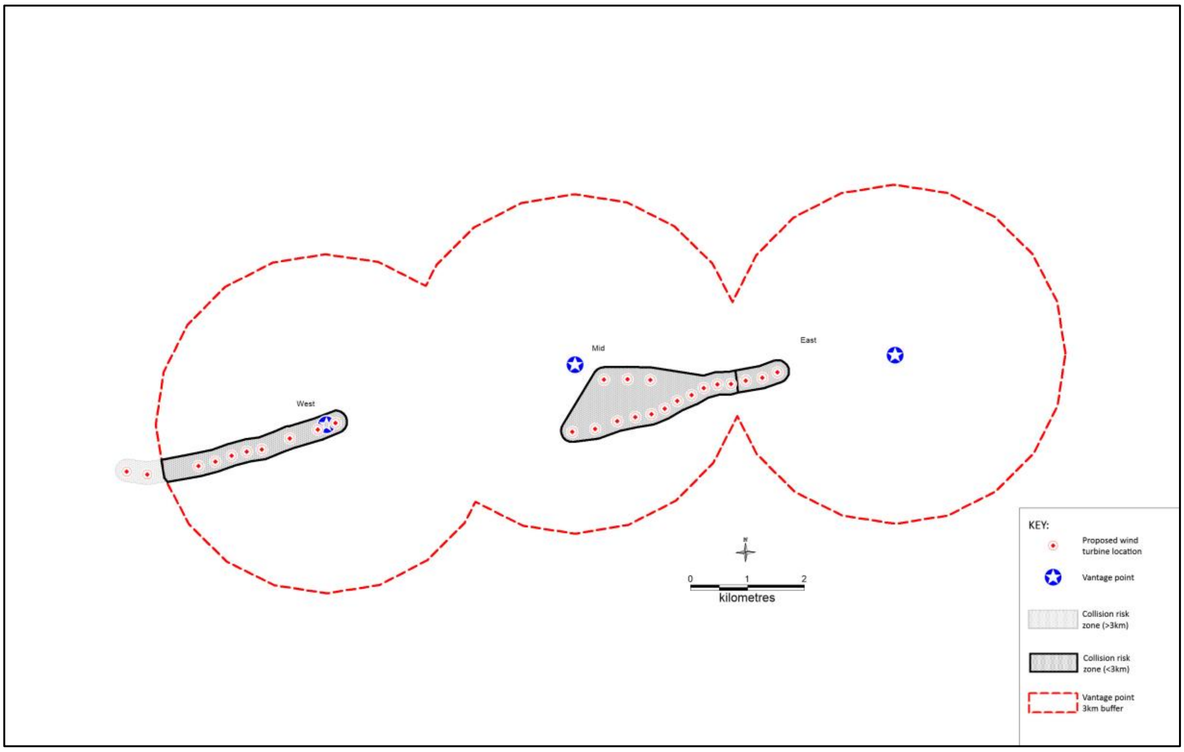


Figure 1d. Vantage point locations and the collision risk modelling zones for the 25-turbine layout (first 27-turbine layout minus turbines 9 and 10; Rev 6).

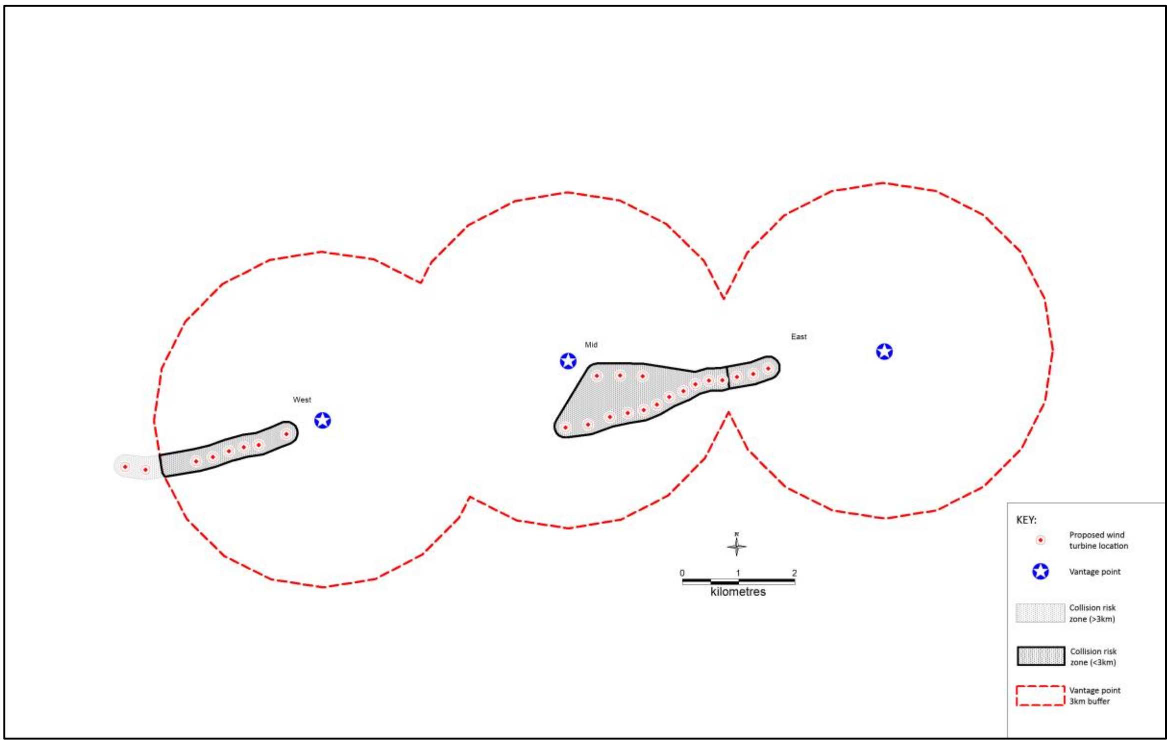
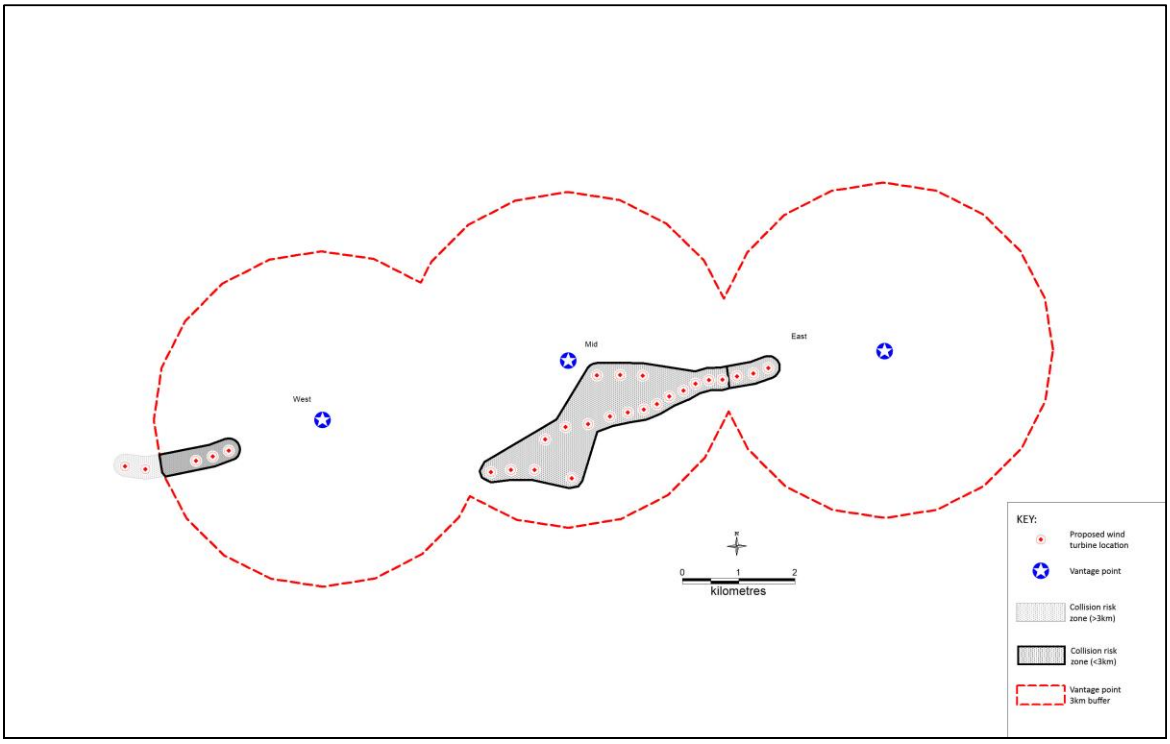


Figure 1e. Vantage point locations and the collision risk modelling zones for the updated lower-risk 27-turbine layout (Rev 7)



Avoidance Rates

The results of any collision risk modelling using the Band et al. (2007) approach is highly sensitive to the avoidance rate used (Chamberlain et al. 2006). Application of an appropriate rate is therefore of fundamental importance in undertaking such modelling. However there are very few studies at existing wind farm where avoidance rates have been fully determined, comparing pre-construction flight activity with the actual numbers of collisions post-construction (Urquhart 2010). The approach generally used to address this is to apply a precautionary rate based on the available data, such that any collision prediction is unlikely to be exceeded (i.e. represents a reasonable worst case). Where data on actual avoidance rates of particular species/groups have been established, then this has usually enabled a higher rate to be safely applied. For example, SNH has recently recommended a move from a 99% rate to 99.8% for geese based on recent research (Douse 2013). SNH now recommends using a value of 99.8% as an avoidance rate for geese (Douse 2013), 99% for several birds of prey (including golden eagle and hen harrier), and 98% for most other species (Urquhart 2010; see Annex 3 to this report).

As acknowledged in the agreed Terms of Reference for this study, there is a lack of specific avoidance rate data from South Africa and on the species of concern at Witberg. It was agreed that as collision avoidance rates are not yet known for the species of concern, suitable overseas species should be used as proxies, and that these should be selected by the specialist. This selection has been undertaken following SNH guidance and with reference to the bird-wind farm literature. As recommended in SNH guidance, a precautionary 98% has been adopted as the default value (Urquhart 2010) but the work has also explored whether particular species exhibit similar behaviour to more vulnerable species such as white-tailed sea eagle and kestrel, or such behaviour that would reduce risk (and hence allow higher rates to be used as is recommended by SNH for golden eagle and hen harrier for example). The collision risk modelling results have been presented for each layout for a range of avoidance rates to inform the assessment but the most appropriate rate to apply in each specific case is also indicated. Most weight has been given to the precautionary SNH position of applying a 98%, though Verreaux's Eagle in particular shares an ecological similarity with golden eagle (albeit at a generally higher breeding density), for which SNH recommends a 99% avoidance rate, so applying that rate could be justified (particularly in relation to adult birds). The Golden Eagle is recognised as the Verreaux's Eagle's closest relative (Wink and Sauer-Gürth 2000). However a more precautionary approach has been adopted in this assessment. The collision risk to juvenile Verreaux's Eagle has been assessed separately, and, given experience of higher juvenile mortality of eagles at the Smøla wind farm in particular, a lower avoidance rate (95%) has been considered for these birds. Given that the Witberg eagles occur at a much lower density (3.7/100km^2) than the white-tailed eagles at Smøla where a density of 73/100km^2 has been recorded with 13 pairs of white-tailed eagle nesting in the wind farm which extends over 17.3km^2, Bevanger et al. 2009) and that the eagle core ranges have been buffered, it is not considered appropriate to apply as low a rate as 95% to the adult Verreaux's Eagle at Witberg.

Wind farm scenarios

It was set out in the Terms of Reference that the CRM would be used to test various scenarios and different layouts, including the original 70-turbine layout, the DEA-authorised 40-turbine layout, the initial 27-turbine layout, and explore an alternative layout that further reduced eagle collision risk, and that this would be done as a modelling exercise to indicate potential mortality rates from the different scenarios.

Modelling of Juvenile Collision Risk

As the baseline surveys did not include any period of juvenile flights for the Verreaux's Eagle, a theoretical approach has been adopted to inform the assessment further. This was carried out as follows:

- Breeding success is about 0.5 young/pair/year (L. Rodrigues[3]]), so with up to 3 pairs with territories overlapping the wind farm this would give an average number of 1.5 juveniles at risk;
- The period of key risk of the wind farm to juvenile birds would be about 2 months each year. Collision risk in the first 1-2 months after fledging would not be an issue as flights then are largely restricted to the proximity of the nest and would be outside the collision risk zone (given the 1.5km buffer applied to each nest site).
- An estimate then needs to be made of the juvenile flight activity (which has not been measured in the field) in relation to that of the adults (for which we do have field data). A precautionary approach has been adopted, assuming that juvenile flight activity over this period was double that of the adults, though further consideration has also been given to how this might change if the juvenile flight activity were higher.

Updates to Collision Modelling from Previous Draft Versions of the Report

Previous versions of the report have been circulated for comment, and this current version includes several updates to that modelling to address the concerns raised by Dr Rob Simmons and Lucia Rodrigues:

- Bird dimensions have been updated to follow Roberts VII (Simmons in Hockey et al. 2005);
- An error was corrected on the GIS file whereby the number of individuals had previously not been entered correctly (cross-checked from main sightings database);
- A more precautionary avoidance rate has been used as the primary rate for the assessment for eagles (98%);
- A separate analysis has been undertaken for adult and juvenile Verreaux's Eagles, in recognition of the lack of field data on juveniles from the baseline surveys and their higher potential vulnerability to collision using a precautionary 95% juvenile avoidance rate;
- For the 70-turbine layout flight activity data from the northern ridge have not been used as these are considered to be less reliable (given the local topography and location of the western vantage point) and to underestimate flight activity. The surveys had not been designed to cover that area. Instead it has been assumed that flight density in that area was the same as in the western part of the main survey zone.

[3] verreaux.wordpress.com/

SECTION 6

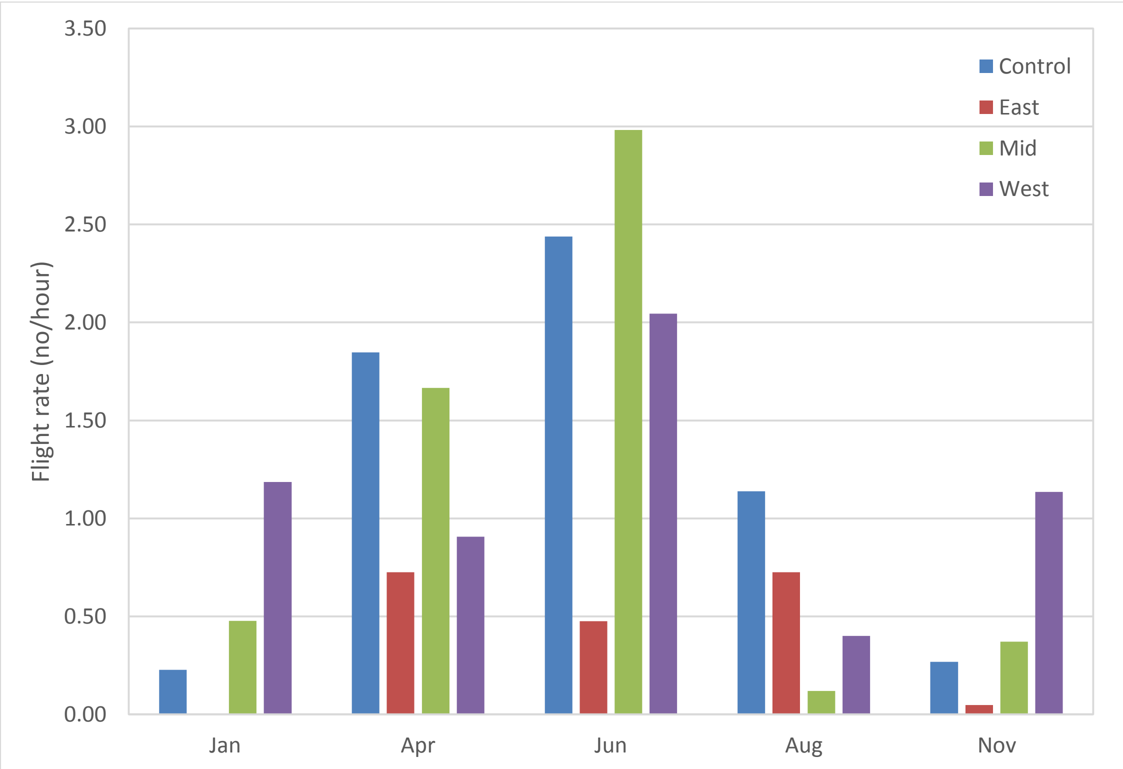
KEY SPECIES FLIGHT ACTIVITY

SECTION 6 - KEY SPECIES FLIGHT ACTIVITY

Overall flight activity rates recorded during the vantage point surveys were reported in the Anchor Environmental report but are also presented here for completeness and to include further analysis of the seasonal patterns of occurrence of each key species.

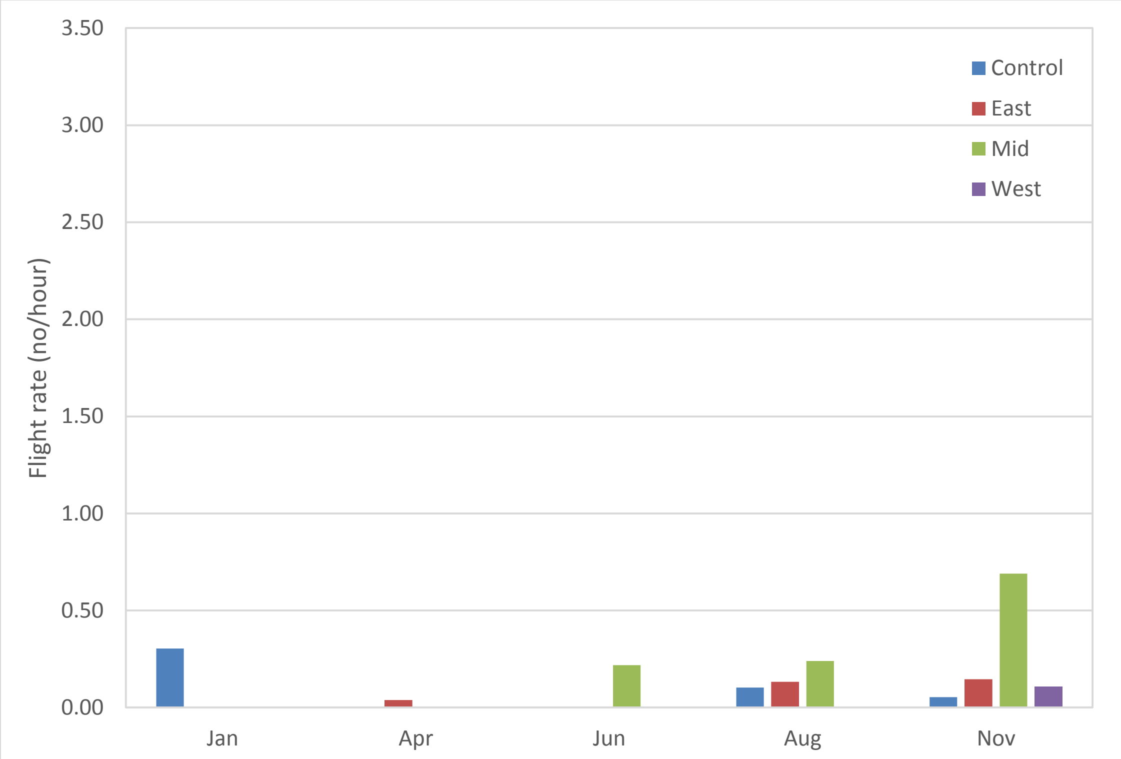
The flight rates (number of bird flights per hour of vantage point survey) from each vantage point in each month are summarised in Figures 2-5. **Verreaux's Eagle** (Figure 2) was much the most frequently recorded of the four key species, being most abundant in April and June. It was seen regularly from all of the vantage points, though less from the Eastern one.

Figure 2. Verreaux's Eagle flight rates observed from each of the four vantage points in each survey month.



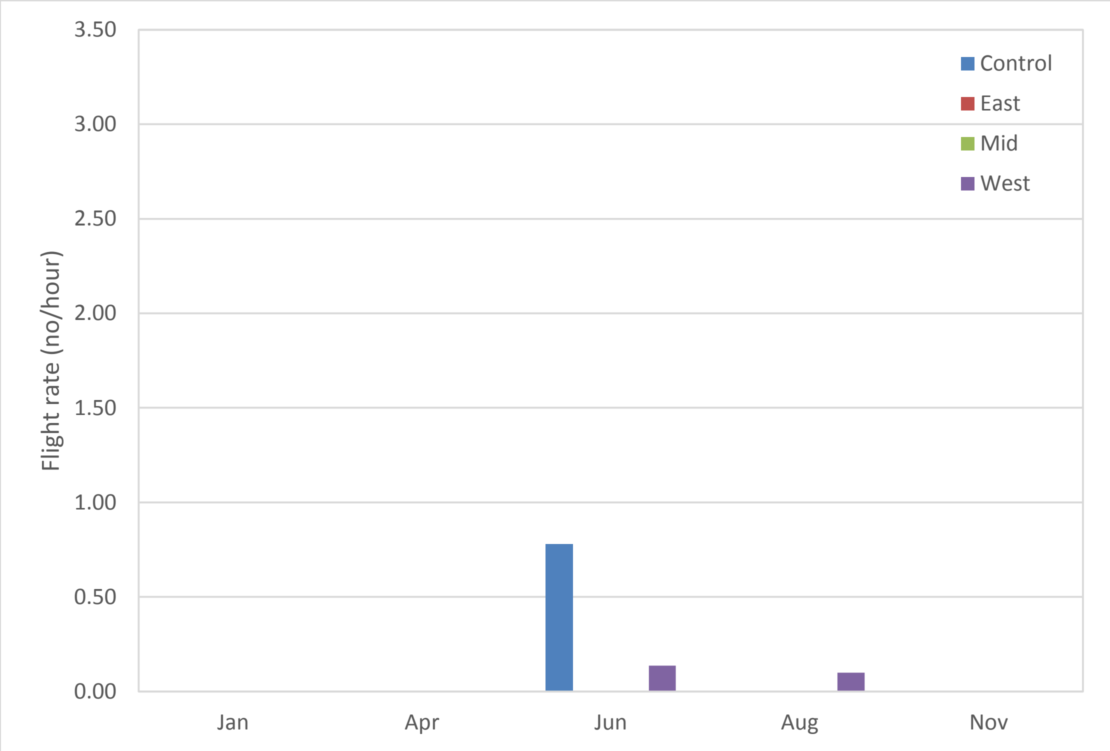
Booted Eagle (Figure 3) was seen in low numbers from all of the vantage points through most of the surveys, with peak flights recorded in November.

Figure 3. Booted Eagle flight rates observed from each of the four vantage points in each survey month.



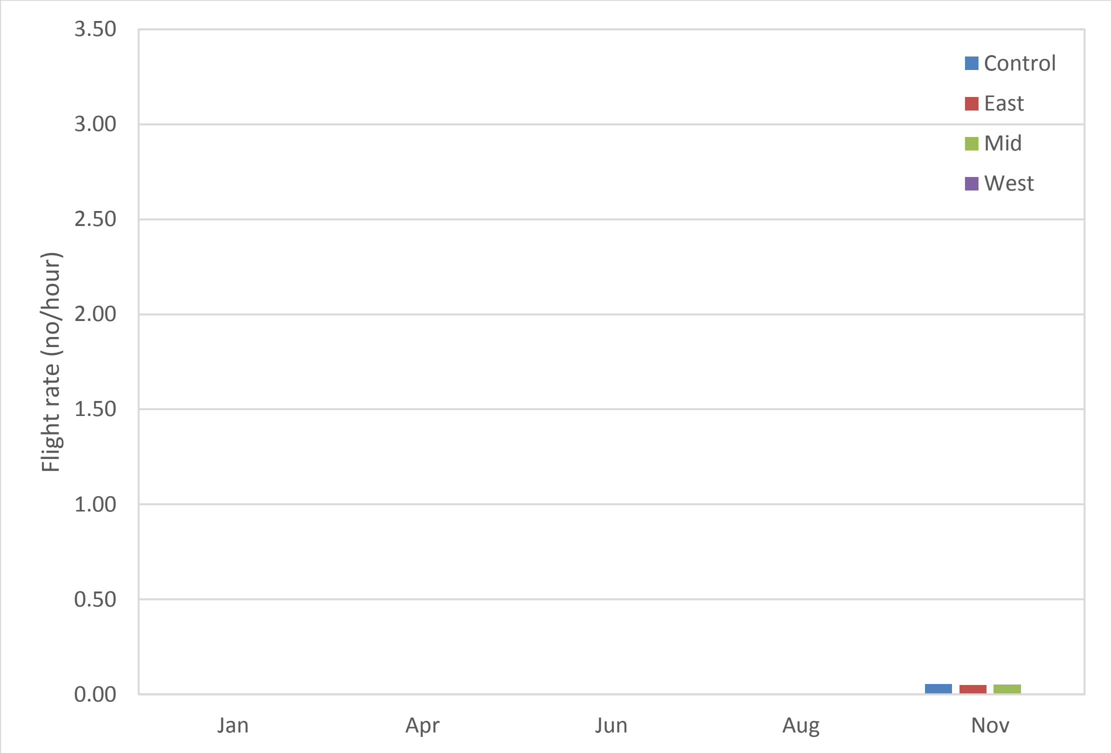
Martial Eagle (Figure 4) was only seen during the vantage point surveys in June and August, with most records from the control site and the only others from the western vantage point.

Figure 4. Martial Eagle flight rates observed from each of the four vantage points in each survey month.



Black Harrier (Figure 5) was only recorded during the vantage point surveys in November, with single sightings from each of the control, east and mid vantage points in that month.

Figure 5. Black Harrier flight rates observed from each of the four vantage points in each survey month.



The flight activity of the key target species observed within the collision risk zones (the wind farm plus a 200m buffer, Whitfield et al. 2010) during the vantage point surveys for each of the five modelled layouts is summarised in Tables 4a-e. It should be noted that these occupancy rates presented relate to the observed part of the collision zone within 3km of the three vantage points, so may not necessarily directly relate to the collision risk (particularly for the 70-turbine layout where 25 turbines fell outside the main observation zone).

Of the key raptor target raptor species seen flying through the collision risk zone at rotor height (Verreaux's Eagle, Booted Eagle and Martial Eagle), Booted Eagle and Martial Eagle were seen only infrequently but their collision risks have been modelled and are presented in the following section. Sightings of Verreaux's Eagle were more frequent. Verreaux's Eagle flight activity within the collision risk zone was higher in the mid- and western zone, with activity recorded through the year (though higher in the winter breeding period, with peak activity in the middle area in April and in the west area in June).

Table 4a. Over-flying rates of key target species within the potential collision risk zone (wind farm plus 200m buffer): occupancy rates: 70-turbine layout

Species	Wind farm/VP zone	Occupancy rate of collision risk zone (% observation time present)					
		Jan	Apr	Jun	Aug	Nov	OVERALL MEAN
Verreaux's Eagle	East	0%	0.493%	0.159%	0.134%	0%	0.157%
	Mid	0.376%	1.845%	0.426%	0%	0.071%	0.544%
	West	0.454%	0.048%	6.421%	0.195%	1.117%	1.647%
Booted Eagle	East	0%	0.060%	0%	0%	0%	0.012%
	Mid	0%	0%	0.790%	0%	0.528%	0.264%
	West	0%	0%	0%	0%	0.009%	0.002%
Martial Eagle	East	0%	0%	0%	0%	0%	0%
	Mid	0%	0%	0%	0%	0%	0%
	West	0%	0%	0.045%	0.161%	0%	0.041%

Table 4b. Over-flying rates of key target species within the potential collision risk zone (wind farm plus 200m buffer): occupancy rates: 40-turbine layout

Species	Wind farm/VP zone	Occupancy rate of collision risk zone (% observation time present)					
		Jan	Apr	Jun	Aug	Nov	OVERALL MEAN
Verreaux's Eagle	East	0%	0.494%	0.117%	0.093%	0%	0.141%
	Mid	0.378%	3.058%	0.574%	0%	0.106%	0.823%
	West	0.015%	0.045%	5.645%	0.195%	0.154%	1.211%
Booted Eagle	East	0%	0.060%	0%	0%	0%	0.012%
	Mid	0%	0%	0.569%	0%	0.391%	0.192%
	West	0%	0%	0%	0%	0%	0%
Martial Eagle	East	0%	0%	0%	0%	0%	0%
	Mid	0%	0%	0%	0%	0%	0%
	West	0%	0%	0%	0.163%	0%	0.033%

Table 4c. Over-flying rates of key target species within the potential collision risk zone (wind farm plus 200m buffer): occupancy rates: 27-turbine layout

Species	Wind farm/VP zone	Occupancy rate of collision risk zone (% observation time present)					
		Jan	Apr	Jun	Aug	Nov	OVERALL MEAN
Verreaux's Eagle	East	0%	0.127%	0%	0%	0%	0.025%
	Mid	0%	1.848%	0.280%	0%	0.236%	0.473%
	West	0.014%	0.041%	5.210%	0.195%	0.162%	1.124%
Booted Eagle	East	0%	0.004%	0%	0%	0%	0.001%
	Mid	0%	0%	0.039%	0%	0.239%	0.056%
	West	0%	0%	0%	0%	0%	0%
Martial Eagle	East	0%	0%	0%	0%	0%	0%
	Mid	0%	0%	0%	0%	0%	0%
	West	0%	0%	0.047%	0.132%	0%	0.036%

Table 4d. Over-flying rates of key target species within the potential collision risk zone (wind farm plus 200m buffer): occupancy rates: 27-turbine layout minus turbines 9 and 10.

Species	Wind farm/VP zone	Occupancy rate of collision risk zone (% observation time present)					
		Jan	Apr	Jun	Aug	Nov	OVERALL MEAN
Verreaux's Eagle	East	0%	0.127%	0%	0%	0%	0.025%
	Mid	0%	1.848%	0.280%	0%	0.236%	0.473%
	West	0%	0.041%	3.987%	0%	0.089%	0.823%
Booted Eagle	East	0%	0.004%	0%	0%	0%	0.001%
	Mid	0%	0%	0.039%	0%	0.239%	0.056%
	West	0%	0%	0%	0%	0%	0%
Martial Eagle	East	0%	0%	0%	0%	0%	0%
	Mid	0%	0%	0%	0%	0%	0%
	West	0%	0%	0%	0%	0%	0%

Table 4e. Over-flying rates of key target species within the potential collision risk zone (wind farm plus 200m buffer): occupancy rates: updated lower risk 27-turbine layout

Species	Wind farm/VP zone	Occupancy rate of collision risk zone (% observation time present)					
		Jan	Apr	Jun	Aug	Nov	OVERALL MEAN
Verreaux's Eagle	East	0%	0.127%	0%	0%	0%	0.025%
	Mid	0%	1.851%	0.280%	0%	0.295%	0.485%
	West	0%	0%	1.628%	0%	0.017%	0.329%
Booted Eagle	East	0%	0.004%	0%	0%	0%	0.001%
	Mid	0%	0%	0.039%	0%	0.255%	0.059%
	West	0%	0%	0%	0%	0%	0%
Martial Eagle	East	0%	0%	0%	0%	0%	0%
	Mid	0%	0%	0%	0%	0%	0%
	West	0%	0%	0%	0%	0%	0%

Flight lines in relation to the updated lower-risk 27-turbine collision risk zone are shown in Figures 6-9 for Verreaux's Eagle, Booted Eagle, Martial Eagle and Black Harrier respectively.

Figure 6. Verreaux's Eagle flight lines observed during the baseline surveys, and the final 27-turbine lower-risk layout.

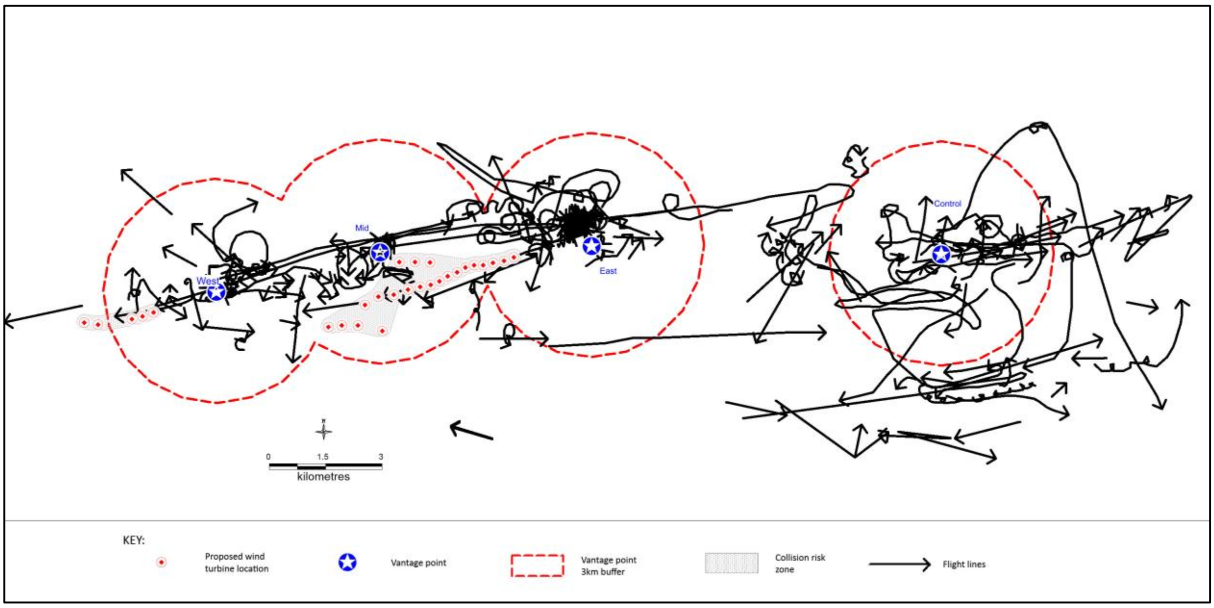


Figure 7. Booted Eagle flight lines observed during the baseline surveys.

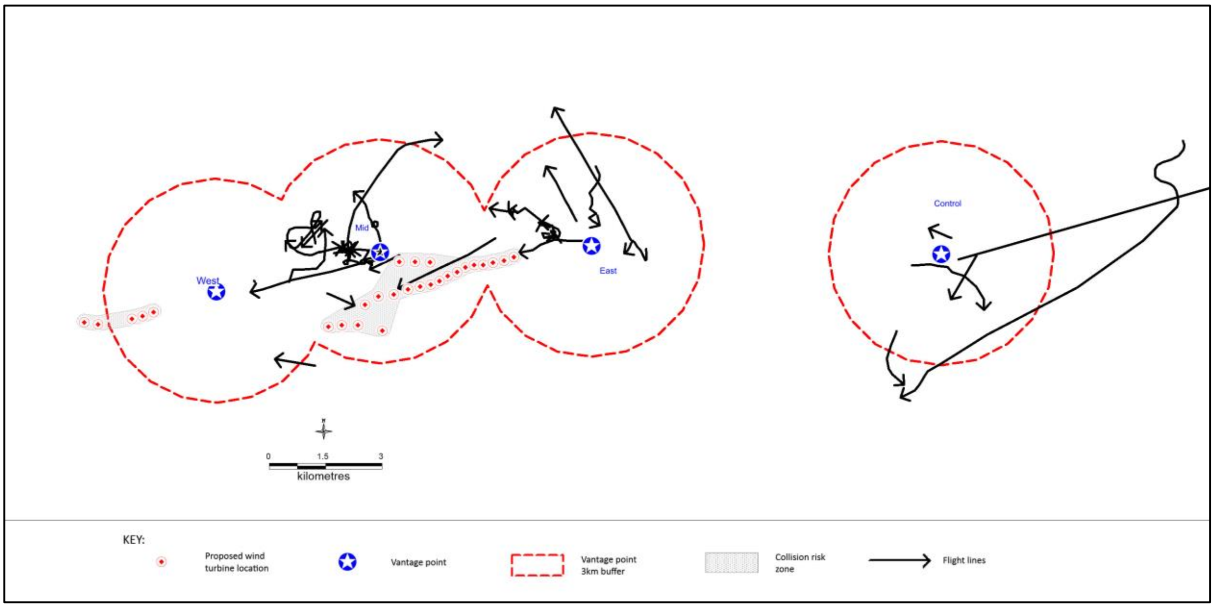


Figure 8. Martial Eagle flight line observed during the baseline surveys.

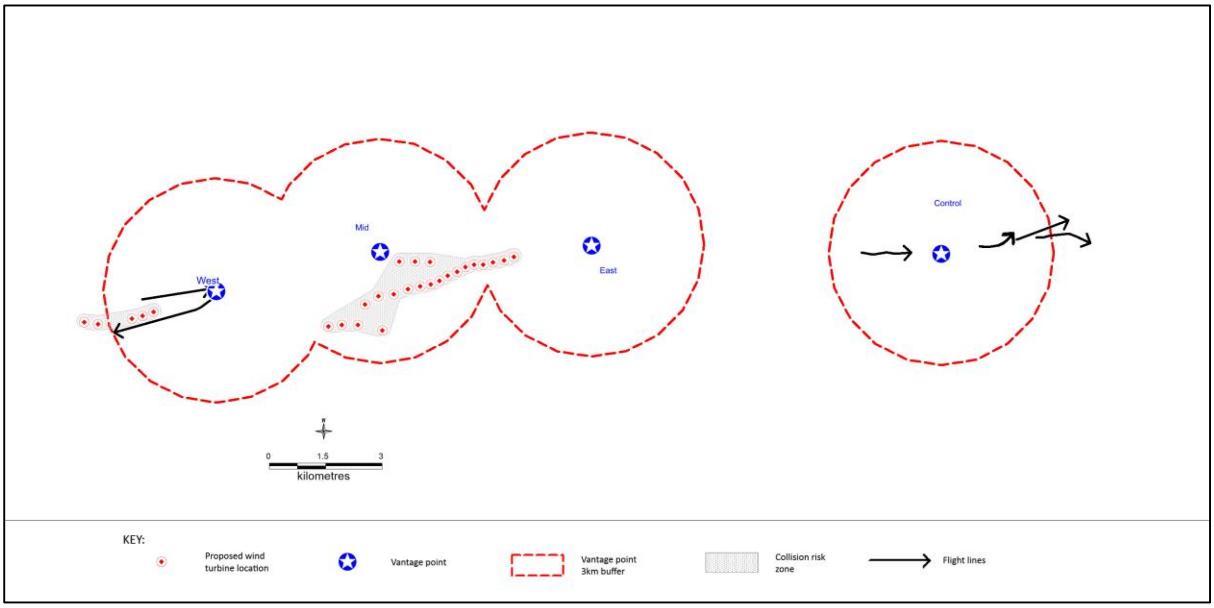
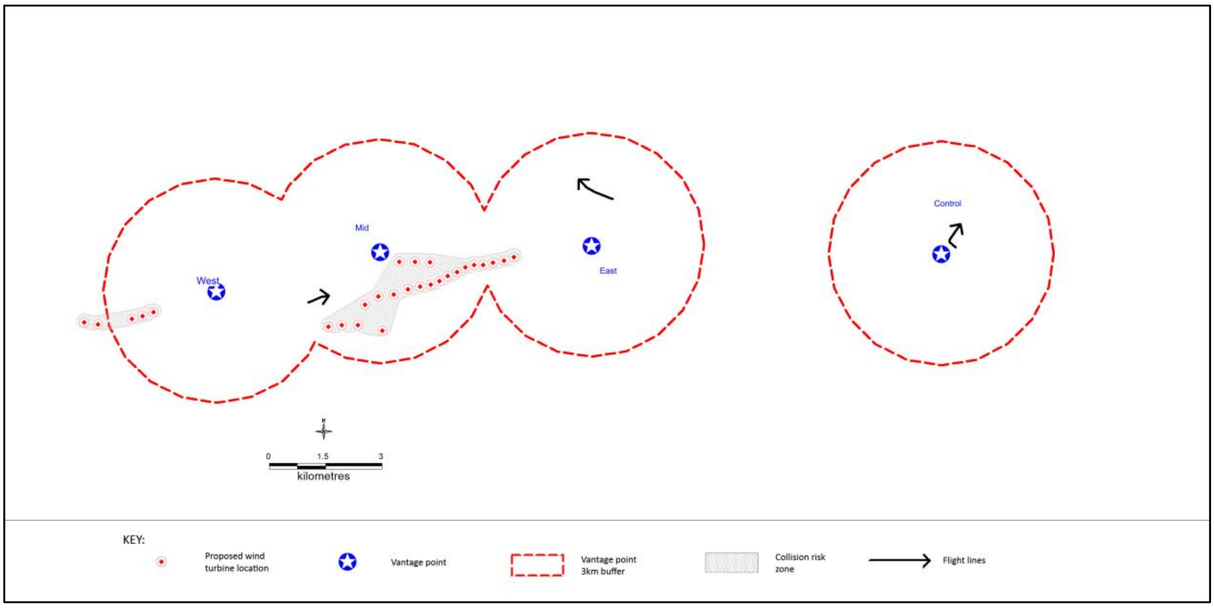


Figure 9. Black Harrier flight line observed during the baseline surveys.



SECTION 7

COLLISON MODELLING RESULTS

SECTION 7 – COLLISION MODELLING RESULTS

Tables 5a-e summarise the results of the collision risk analyses for each of the three key species for each of the five modelled layouts. Details of the modelling are given in Appendix 2. Table 5 gives the number of collisions predicted per year based on a range of avoidance rates (95% - 99%). Verreaux's and Martial Eagle are both large non-colonial eagles, and the area in proximity to their nest sites has been avoided in the design process (so 'riskier' display flights and early juvenile flights would be less likely to occur in the wind farm). As a result 99% should be a suitable precautionary avoidance rate to apply (as is used in the UK for Golden Eagle, an ecologically similar species), though as discussed above a more precautionary 98% has been adopted for the purpose of this assessment. Booted Eagle is more ecologically similar to buzzard species, so on the basis of the information currently available, the possibility of lower avoidance cannot be excluded so the SNH default 98% value has been applied.

Table 5a. Collision risk modelling predictions for the initial Witberg wind farm 70-turbine layout, for each part of the collision risk zone and applying a range of avoidance rates. Predictions in bold represent the precautionary result used in the further assessment.

Species	Precautionary predicted number of collisions per year											
	East zone			Mid zone			West zone			TOTAL		
Avoidance rate	95%	98%	99%	95%	98%	99%	95%	98%	99%	95%	98%	99%
Verreaux's Eagle	0.55	0.22	0.11	1.51	0.75	0.38	14.21	5.68	2.84	16.27	**6.66**	3.33
Booted Eagle	0.02	0.01	0	0.20	0.22	0.11	0.01	0	0	0.23	**0.23**	0.11
Martial Eagle	0	0	0	0	0	0	0.22	0.09	0.04	0.22	**0.09**	0.04

Table 5b. Collision risk modelling predictions for the DEA approved Witberg wind farm 40-turbine layout, for each part of the collision risk zone and applying a range of avoidance rates. Predictions in bold represent the precautionary result used in the further assessment.

Species	Precautionary predicted number of collisions per year											
	East zone			Mid zone			West zone			TOTAL		
Avoidance rate	95%	98%	99%	95%	98%	99%	95%	98%	99%	95%	98%	99%
Verreaux's Eagle	0.45	0.18	0.09	2.07	0.83	0.41	3.81	1.52	0.76	6.32	**2.53**	1.26
Booted Eagle	0.02	0.01	0.00	0.29	0.12	0.06	0.00	0.00	0.00	0.32	**0.13**	0.06
Martial Eagle	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.03	0.01	0.07	**0.03**	0.01

Table 5c. Collision risk modelling predictions for the previously proposed Witberg wind farm 27-turbine layout, for each part of the collision risk zone and applying a range of avoidance rates. Predictions in bold represent the precautionary result used in the further assessment.

Species	Precautionary predicted number of collisions per year											
	East zone			Mid zone			West zone			TOTAL		
Avoidance rate	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**
Verreaux's Eagle	0.10	0.04	0.02	1.21	0.49	0.24	3.78	1.51	0.76	5.09	**2.04**	1.02
Booted Eagle	0	0	0	0.09	0.03	0.02	0	0	0	0.09	**0.03**	0.02
Martial Eagle	0	0	0	0	0	0	0.08	0.03	0.02	0.08	**0.03**	0.02

Table 5d. Collision risk modelling predictions for the previously proposed Witberg wind farm 27-turbine layout minus turbines 9 and 10, for each part of the collision risk zone and applying a range of avoidance rates. Predictions in bold represent the precautionary result used in the further assessment.

Species	Precautionary predicted number of collisions per year											
	East zone			Mid zone			West zone			TOTAL		
Avoidance rate	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**
Verreaux's Eagle	0.10	0.04	0.02	1.21	0.49	0.24	2.82	1.13	0.56	4.13	**1.65**	0.83
Booted Eagle	0	0	0	0.09	0.03	0.02	0	0	0	0.09	**0.03**	0.02
Martial Eagle	0	0	0	0	0	0	0	0	0	0	**0**	0

Table 5e. Collision risk modelling predictions for the Witberg wind farm updated lower risk 27-turbine layout, for each part of the collision risk zone and applying a range of avoidance rates. Predictions in bold represent the precautionary result used in the further assessment.

Species	Precautionary predicted number of collisions per year											
	East zone			Mid zone			West zone			TOTAL		
Avoidance rate	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**	**95%**	**98%**	**99%**
Verreaux's Eagle	0.10	0.04	0.02	1.06	0.42	0.21	0.99	0.39	0.20	2.14	**0.86**	0.43
Booted Eagle	0	0	0	0.08	0.03	0.02	0	0	0	0.08	**0.03**	0.02
Martial Eagle	0	0	0	0	0	0	0	0	0	0	**0**	0

Juvenile Verreaux's Eagle collision risk assessment

The results of the collision risk assessment for juvenile Verreaux's Eagles is summarised in Table 6. As for the assessment presented above, the results have been given for a range of avoidance rates. This would suggest that even adopting a highly precautionary 95% avoidance rate for the juveniles, the collision risk would be comparatively low

Table 6. Preliminary collision risk predictions for juvenile Verreaux's Eagle at Witberg.

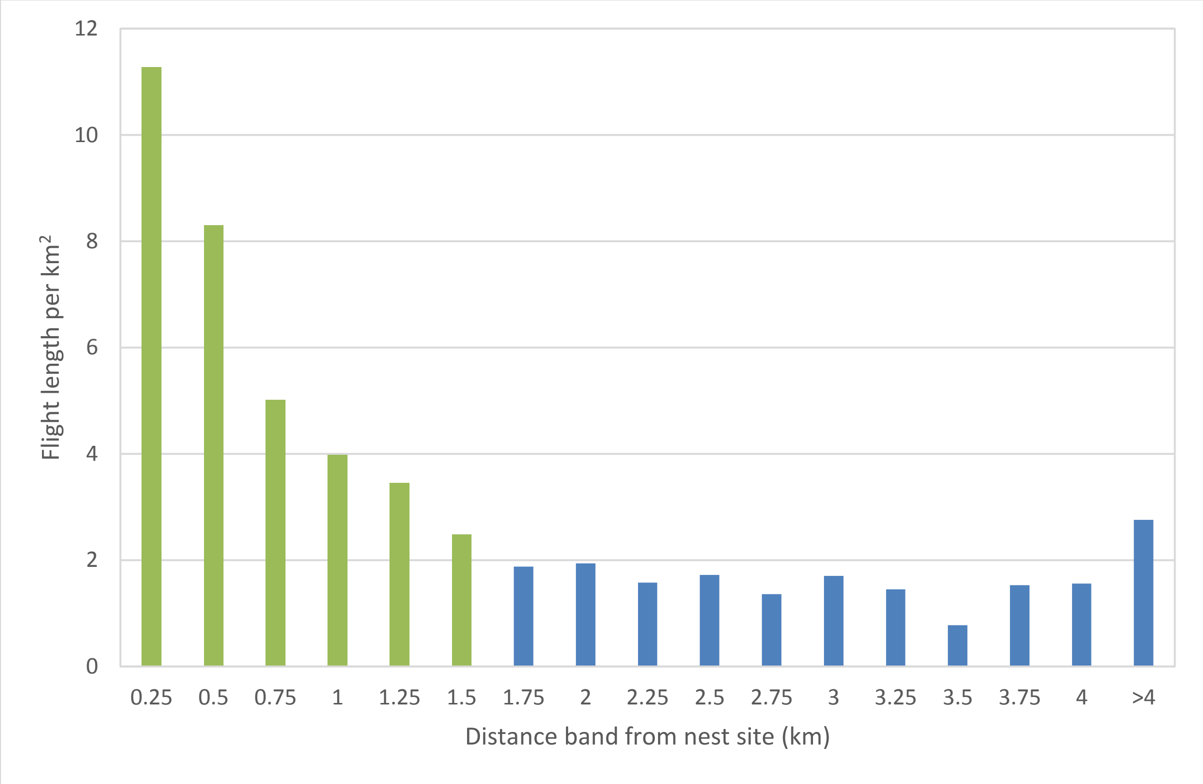
Layout	**Precautionary predicted number of collisions per year**		
Avoidance rate:	**95%**	**98%**	**99%**
70 turbines	1.39	0.56	0.28
40 turbines	0.55	0.22	0.11
27 turbines (original)	0.49	0.20	0.10
27 minus turbines 9 and 10	0.40	0.16	0.08
27 updated lower risk	0.21	0.08	0.04

Verreaux's Eagle Flight Activity and Distance from the Nest

One of the project remits was to explore the effectiveness of the buffers implemented around each of the eagle nest sites in reducing collision risk. That has been done by examining the relationship between eagle flight density and distance from nest sites, though this has only been possible for the most abundant key species (Verreaux's Eagle), as the flight activity of the other species was too low to undertake a meaningful analysis.

Flight activity was calculated for each 250m band from each Verreaux's Eagle nest site up to 4km, and standardised for the area of each buffer (expressed as flight length per unit area). This analysis was restricted to the main vantage point surveys area, i.e. within 3km of each vantage point. The results are summarised in Figure 10, which shows the flight length per km^2 for each 250m band. Flight activity was generally higher within 1km of the nest sites, marginally higher between 1 and 1.5km but not beyond that distance, suggesting that a 1.5km buffer would be sufficient to minimise collision risk.

Figure 10. Verreaux's Eagle flight activity in relation to distance from nest sites. Green bands indicate flight activity that would be avoided by the wind farm by implementation of a 1.5km buffer.



SECTION 8

COLLISON RISK MODELLING INTERPRETATION

SECTION 8 – COLLISION RISK MODELLING INTERPRETATION

Assessment Methodology

Whilst the Band collision model produces a quantitative estimate of the numbers of birds that might collide with the wind turbines, those numbers need to be put into the context of the existing mortality to enable their significance to be assessed. The same level of additional mortality on a population that has a low level of background mortality could potentially have a much more important effect than on a population with a higher level of existing mortality. The collision mortality needs to be assessed in the context of each species population dynamics. In the UK a 1% increase over the baseline mortality is now frequently being used as an initial filter threshold above which they may be a concern with the predicted collision mortality (and hence requiring further investigation). Collision risks below this level are usually considered not to be significant.

A methodology to undertake this assessment in a transparent objective way has been produced in the UK and is now widely used in the wind industry, both onshore and offshore (Maclean et al. 2009). This draws on the methodology developed by SNH and the British Wind Energy Association [BWEA] (Percival et al. 1999) and updated by Percival (2007), and with SNH (2006) guidance on assessing the impacts from onshore wind farms on birds in the wider countryside. The assessment first identifies the sensitivity (conservation importance; as defined in Table 7) of the receptors present in the study area, then determines the magnitude of the possible effect on those receptors (as described in Table 8).

Table 7. Sensitivity (conservation importance) of bird species.

Sensitivity	Definitions
VERY HIGH	Cited interest of an internationally or nationally important statutory protected sites. Cited means mentioned in the citation text for those protected sites as a species for which the site is designated.
HIGH	Other species that contribute to the integrity of an internationally or nationally important statutory protected sites species for which the site is designated. A local population of more than 1% of the national population of a species. Any ecologically sensitive species, e.g. large birds of prey or rare birds (usually taken as <300 breeding pairs in the UK). Species recognised as requiring special conservation measures or otherwise specially protected (in a UK context this includes EU Birds Directive Annex 1, EU Habitats Directive priority habitat/species and/or W&C Act Schedule 1 species. **Note: All of the four raptor species assessed fall into this category**
MEDIUM	Regionally important population of a species, either because of population size or distributional context. Biodiversity Action Plan priority species (if not covered above).
LOW	Any other species of conservation interest.

Table 8. Definition of terms relating to the magnitude of ornithological effects

Magnitude	Definition
VERY HIGH	Total loss or very major alteration to key elements/ features of the baseline conditions such that post development character/ composition/ attributes will be fundamentally changed and may be lost from the site altogether. Guide: >80% of population/habitat lost
HIGH	Major alteration to key elements/ features of the baseline (pre-development) conditions such that post development character/composition/attributes will be fundamentally changed. Guide: 20-80% of population/habitat lost
MEDIUM	Loss or alteration to one or more key elements/features of the baseline conditions such that post development character/ composition/ attributes of baseline will be partially changed. Guide: 5-20% of population/habitat lost
LOW	Minor shift away from baseline conditions. Change arising from the loss/ alteration will be discernible but underlying character/ composition/ attributes of baseline condition will be similar to pre-development circumstances/patterns. Guide: 1-5% of population/habitat lost
NEGLIGIBLE	Very slight change from baseline condition. Change barely distinguishable, approximating to the "no change" situation. Guide: <1% of population/habitat lost

The combined assessment of the magnitude of an effect and the sensitivity of the receptor has been used to determine whether or not an adverse effect is significant. These two criteria have been cross-tabulated to assess the overall significance of that effect (Table 9).

Table 9. Matrix of magnitude of effect and sensitivity used to test the significance of effects. The significance category of each combination is shown in each cell. Shaded cells indicate potentially significant effects.

		SENSITIVITY			
MAGNITUDE		Very high	High	Medium	Low
	Very high	Very high	Very high	High	Medium
	High	Very high	Very high	Medium	Low
	Medium	Very high	High	Low	Very low
	Low	Medium	Low	Low	Very low
	Negligible	Low	Very low	Very low	Very low

The interpretation of these significance categories is as follows (though careful use of professional judgment should also be a key component of this assessment process):

- Very low and low are not normally of concern, though normal design care should be exercised to minimise adverse effects;
- Very high and high represent adverse effects on bird populations which are regarded as significant for the purposes of EIA;
- Medium represents a potentially significant adverse effect on which professional judgment has to be made. In the event that mitigation is not possible it is likely to be significant but if mitigation is possible it may well be taken below the significance threshold.

Wind farm mortality and background mortality at Witberg

In the context of the Witberg site, the predicted collision mortality has been set against the regional background mortality for each of the three key species at risk of collision. The population data used in this analysis are summarised in Table 10. The region has been taken, through discussions with Rob Simmons, as the Karoo biome (Mucina and Rutherford 2006, and with reference to the WWF Karoo eco-region).

Table 10. Background population data for Verreaux's Eagle, Booted Eagle and Martial Eagle. Source: Roberts VII (Hockey et al. 2005) and Gargett (1990).

Species	**Regional population**	**Adult mortality rate**	**Immature mortality rate**	**Annual productivity (chicks/pair /year)**	**Age at first breeding**	**Baseline mortality**
Verreaux's Eagle	940 pairs	5%	20%	0.5	5	94 (adult)
Booted Eagle	700 pairs	10%	20%	1.0	3	500
Martial Eagle	300 pairs	7%	20%	0.6	5	150

Rob Simmons has provided a minimum population estimate for the Karoo Verreaux's Eagle, and identified, through consultation with Rob Davies, a conservative estimate of 600 pairs for the Karoo escarpment (Roggeveld, Nuweveld, Sneeuberge and Winterberge) plus a further 100 pairs for the smaller inselbergs outside of the main mountain ranges. These numbers were derived primarily from information collected by Rob Davies for his PhD work (together with other published population density estimates; Simmons in Hockey et al. 2005) and since then the population is thought to have declined by about 15% on the basis of recent field surveys carried out by Rob Davies. This would therefore give a current populations estimate for the escarpment plus the inselbergs of about 600 pairs. The area on which this estimate is based does not include approximately 24,000km^2 of other Karoo mountain ranges that would provide suitable habitat Verreaux's Eagle habitat. Using a very conservative nesting density of 1 pair per 60km^2 (the lowest recorded according to Davies 1994, densities at the Karoo National Park and around the Witberg site are considerably higher than this) over this entire area, this gives a further 400 pairs over this area. That too should be scaled down from the 1994 density by 15%, giving an estimated 340 additional pairs, and hence a more realistic total of about 940 pairs for the Karoo.

Table 11 shows the predicted collision risk and associated impact significance for each of the three species in the context of their background mortality and the % increase over the baseline that each risk represents, for each of the five layouts. For Verreaux's Eagle, the assessment summarised in this Table assesses the collision risk against the adult population, as the large majority of records from the site relate to adult birds. Juveniles are assessed separately below.

For Booted Eagle and Martial Eagle, the predicted collision risks were very small both numerically and in a population context. Those increases were considerably less than 1% when assessing the collision risk against the regional population. With such a negligible magnitude risk there would not be likely to be any regionally significant population impact for either of these species for any of the layouts.

For Verreaux's Eagle, the predicted collision risk for the 70-turbine layout of 6.66 collisions per year was assessed as a medium magnitude effect, which would be considered to be of high significance on a high sensitivity species, and hence a significant impact applying the assessment methodology described in Tables 7-9 above. The predicted risks for the 40-, original 27- and 25-turbine layouts were all assessed as low magnitude effects, which would be of low significance and not significant (though above a 1% increase in the baseline mortality). The updated lower-risk 27-turbine layout, i.e. the one that is currently proposed for the scheme, has a reduced collision risk of 0.86 adult Verreaux's Eagle per year. That would be a negligible magnitude effect, less than a 1% increase over the baseline mortality, which would be of very low significance and not a significant impact.

It should also be noted that this is the result of a precautionary assessment, not the most likely outcome. The analysis has adopted a precautionary approach throughout, including:

- Use of a precautionary 98% avoidance rate rather than the more evidence-based 99% for the closely related Golden Eagle (and use of an even more precautionary 95% avoidance rate for juvenile eagles);
- Use of a conservative regional population estimate against which to assess the predicted wind farm mortality;
- Assessment of mortality has been made against only the existing adult mortality rather than the usual assessment against all of the predicted mortality;
- Assuming that flight activity through the wind farm will continue at the same rate after construction. Given that mitigation measures will be implemented to improve the food resource within nest buffers away from the wind farm (see next section) and the observed behavior of Golden Eagles at existing wind farms (e.g. Walker et al. 2005), some reduction in risky flight activity is more likely.

Table 11. Collision risk for Verreaux's Eagle, Booted Eagle and Martial Eagle and the increases that these represent over baseline mortality.

Species	**Layout (number of turbines)**	**Predicted collision risk (98% avoidance rate)**	**% increase over baseline mortality**	**Magnitude of effect**	**Likely significant effect?**
Verreaux's Eagle	70	6.66	7.1%	Medium	Yes
	40	2.53	2.7%	Low	No
	27 (original)	2.04	2.2%	Low	No
	25 (27 minus T9&T10)	1.65	1.8%	Low	No
	27 (updated lower risk)	0.86	0.9%	Negligible	No
Booted Eagle	70	0.23	0.05%	Negligible	No
	40	0.13	0.03%	Negligible	No
	27 (original)	0.03	0.01%	Negligible	No
	25 (27 minus T9&T10)	0.03	0.01%	Negligible	No
	27 (updated lower risk)	0.03	0.01%	Negligible	No
Martial Eagle	70	0.09	0.06%	Negligible	No
	40	0.03	0.02%	Negligible	No
	27 (original)	0.03	0.02%	Negligible	No
	25 (27 minus T9&T10)	0	0%	Nil	No
	27 (updated lower risk)	0	0%	Nil	No

Juvenile Verreaux's Eagle collision risk assessment

The assessment of the collision risk for juvenile Verreaux's Eagle, expressed in the context of their background mortality and the % increase over the baseline that each risk represents is summarised in Table 12. For all of the layouts the predicted juvenile mortality, even applying a highly precautionary 95% avoidance rate, would be a negligible magnitude impact, being less than a 1% increase over the regional baseline mortality.

Table 12. Additional collision risk assessment for Verreaux's Eagle juveniles and the increases that these represent over baseline mortality.

Species	Layout (number of turbines)	Predicted collision risk (95% avoidance)	% increase over baseline mortality	Magnitude of effect	Likely significant effect?
Verreaux's Eagle	70	1.39	0.50%	Negligible	No
	40	0.55	0.20%	Negligible	No
	27 (original)	0.49	0.18%	Negligible	No
	25 (27 minus T9&T10)	0.40	0.14%	Negligible	No
	27 (updated lower risk)	0.21	0.08%	Negligible	No

Consideration has also been given to the consequences of increasing the juvenile flight activity, as this assessment has been carried out on a precautionary theoretical basis rather than using field data. For all of the layouts apart from the initial 70-turbine one, even if flight activity were increased 10-fold over the observed adult rate the collision risk would still be a negligible magnitude effect.

Specific impact concerns: localised extinction

Whilst the site surveys showed that a high proportion of raptor flights were observed at rotor height; showing that about 52% of raptor flights were observed to occur within the zone occupied by the envisaged rotors[4] , this alone does not translate into a high collision risk due to other important factors such as avoidance rates as discussed in Section 5.

There is no evidence to suggest that the wind farm would cause local extinction of all raptors in the short term. Even at the small number of wind farm sites where high levels of raptor mortality have been recorded, such local extinction has never been documented. There undoubtedly are circumstances under which high levels of raptor mortality can occur, most notably of golden eagles at Altamont Pass in California (Orloff and Flannery 1992, Hunt et al. 2002, Thelander et al. 2003), griffon vultures at Tarifa in Spain (Janss 1998, de Lucas et al. 2004) and white-tailed sea eagles in Norway (Nygard et al 2010, May et al. 2010).

- The Altamont Pass wind farm in California supports rich raptor feeding habitat within the wind farm, particularly around wind turbine bases, and as a result large numbers of raptors were attracted into the wind farm to feed. It has many more turbines than would be at Witberg (about 7,000 compared with 27) and those turbines are predominantly of an

[4] Table 6 on page 21 of the Anchor Environmental (2012) report shows an average raptor flying height of 36% at 40-120m and 16% at 120-150m above ground, these two zones together approximating to the area occupied by the planned rotors of the turbines (92m hub height, 116m rotor diameter)

old design (small turbines with a fast rotational speed rotors relatively close to the ground and with turbines often packed close together). Many also have lattice towers, which can provide a perch particularly for raptors, attracting them into the collision risk zone. The Witberg site is only a small part of wider higher quality raptor habitat, with no specific habitat features within the wind farm that would not be available to raptors elsewhere, and nothing likely to be associated with turbines bases that would result in high prey density there.

- The issue at the Tarifa site in southern Spain has been mainly with griffon vulture collisions, and again this is at a very much larger wind farm (about 750 turbines) than Witberg. Vultures have also been demonstrated to be a species group at much higher risk of collision than other raptors, probably as a result of a much more limited field of vision than other species (Martin *et al.* 2012). Numbers of vulture collisions with wind turbines have been much higher than those reported for other raptors (Percival 2005). Vultures are not present at Witberg, so would not be an issue.

- At one wind farm site in Norway (Smøla) collision rates of white-tailed sea eagles have been high (a 68-turbine development in the NW of that country). That site is located within an important breeding area for this species where the species nests semi-colonially; 13 nests were located within the wind farm site itself (in an area of 17.3km^2, equivalent to 73 pairs/100km^2, Bevanger et al. 2009, and a further 47 on the same archipelago, i.e. nesting densities are considerably higher than at Witberg (where a density of 3.7/100km^2 has been recorded). Nests were located in close proximity to wind turbines and within the wind turbine footprint (unlike the buffer zones that have been applied at Witberg).

Apart from these small number of examples, all of which are ecologically and physically different to the Witberg proposal, raptor mortality has generally only been recorded at a low level from the large majority of operational wind farms.

The Witberg wind farm site supports a relatively high breeding density of raptors in a national/ regional context (as described in the 2012 Anchor Environmental report) but does not have vulture populations at risk (the key problem in Spain), does not support an otherwise limited foraging habitat that would be likely to attract birds into the wind farm site (the key issue at Altamont) and does not have any semi-colonial raptors nesting at very high density within the wind farm (the key issue with white-tailed sea eagle in Norway).

Witberg does not therefore share any of the key ecological characteristics that have been identified as resulting in the higher raptor mortality recorded at these other wind farm sites. Whilst the collision risk of the original 70-turbine scheme would have represented a significant impact, revisions to the scheme to the current 27-turbine lower-risk layout have reduced that risk to a negligible level that would not be significant.

Specific impact concerns: sink effect

Specific concerns have been raised with regard to a possible sink effect of any additional eagle mortality, drawing birds into the wind farm site to exploit territory vacancies and exposing those new birds to the risk of collision. Such effects have been demonstrated for golden eagle at Altamont Pass, though the scale of the wind farm there (about 7,000 turbines) and the collision risk were both much greater than at Witberg. As a result it is considered very unlikely that any sink effect at Witberg would occur at Witberg that could possibly be significant in a regional population context.

Given the local eagle population dynamics (Anchor Environmental 2012 report) and experience from other wind farms (such as Altamont in California; Hunt et al. 2002) the sink effect is theoretically more likely than local extinction if high levels of mortality occur. However, for any sink effect to occur, the level of mortality would need to be high, and the results of the Collision Risk Modelling show, particularly for the current proposed lower-risk 27-turbine layout, that is not likely to occur. In addition, to that, and unlike Altamont, the Witberg wind farm site supports habitat typical of the surrounding wider countryside. The Altamont wind farm site, in contrast, provides highly attractive open grassland habitat to raptors that is not so widely available in the surrounding land.

SECTION 9

RECOMMENDATIONS FOR AVOIDANCE AND/OR MITIGATION OF THE IMPACTS AND ALTERNATIVE MITIGATION MEASURES VS. THE OFFSET PROPOSED

SECTION 9 – RECOMMENDATIONS FOR AVOIDANCE AND/OR MITIGATION OF THE IMPACTS AND ALTERNATIVE MITIGATION MEASURES VS. THE OFFSET PROPOSED

Design Mitigation

Design mitigation has included the application of the Anchor Environmental-recommended buffers from known eagle nest sites; 2.5km from Martial Eagle, 1.5km from Verreaux's Eagle and 1.2km from Booted Eagle. It is understood that these distances were derived from local expert opinion (R. Simmons pers. comm.), but the results of the vantage point surveys so show for Verreaux's Eagle that this did indeed cover the zone of higher flight activity (see Figure 10).

BirdLife South Africa has strongly encouraged the developer to explore different layouts to reduce the risk of ornithological impacts. The scheme has been reduced from the original 70-turbine design to the 40-turbine layout that was approved by the DEA, and down further to a 27-turbine scheme that has again been revised to reduce its potential collision risk to eagles.

As a consequence of that, there is relatively low flight activity within the current proposed wind farm collision risk zone (and hence collision risk). The collision risk for the updated 27-turbine scheme would give no more than a negligible magnitude collision risk to any raptor species and would not be significant.

The Anchor report suggests that such design mitigation was inadequate to avoid a significant impact, though this conclusion was reached without the quantitative assessment of collision risk that has now been undertaken. The collision risk modelling has informed a further design iteration, moving of 5 turbines from within an area of higher eagle activity to an area of lower activity, and as a result the collision risk has been approximately halved.

Biodiversity Offset

In order to mitigate the residual impacts the Anchor report proposed a biodiversity offset, based on 4 Verreaux's Eagle territories, proposing that 20-30,000 ha. would be required. BirdLife South Africa, however, has stated that it considers biodiversity offsetting to be a last resort and has strongly objected to the implementation of an offset. Cape Nature has also objected to a biodiversity offset as an acceptable measure. Given the results of the collision risk modelling, together with the further layout design changes that were made and the proposed mitigation measures that would be implemented to reduce the collision risk further, any such offsetting is not considered necessary.

Curtailment

Whilst curtailment of the operation of wind turbines could potentially be a useful mitigation measure to reduce collision risk, the results of the collision risk modelling show that such measures should not be necessary for the current updated lower-risk 27-turbine layout. In addition to this, curtailment has usually only been economically viable where a specifically defined period has been identified during which such curtailment might operate. With raptors present in the Witberg area year-round such a period would be difficult to identify at this site.

Given the predicted collision risk for the updated 27-turbine lower risk layout would not be significant, and that this would be reduced further by the mitigation measures described below, any curtailment of wind turbine activity is not considered necessary for the current Witberg scheme.

Land management/ habitat attractiveness to raptor prey

It needs to be ensured that raptor food resource does not become more attractive within the wind farm site, drawing foraging birds into the site. For instance during access track construction, there may be periods of time where imported or excavated aggregate is stockpiled forming potentially attractive habitat for hyrax. During construction of the wind farm all mounds of aggregate or rocks which could serve as hyrax habitat should be removed prior to the commencement of operation of the turbines and through the operational phase of the wind farm. Consideration should also be given to clearance of any hyrax-suitable rock piles from the immediate wind farm site itself (within 200m of the turbines), where practical. However, it is accepted that the area itself has rock fissures and clefts which are likely to utilised as refuges for hyrax. Nevertheless, it would be good practice to ensure that the wind farm does not create or enhance favourable habitat for hyrax. Due to the limited distances that hyrax travel from refuge to refuge, any measures to minimize the attractiveness of the immediate wind farms site (within 200m of turbines) should be considered.

In addition, the proposed turbine bases will not serve as a refuge for small mammals, and thus the turbines themselves will not create attractive habitat for potential prey species such a hyrax.

A management programme should be implemented within the Verreaux's Eagle nest buffers to deliver measures to enhance the food resources in those areas (where there would be no turbines), and hence reduce eagle flight activity outside those zones (where the wind turbines would be located). Following discussions with Rob Simmons, it was agreed that the best way to achieve this would be to provide the eagles' main prey resource, the rock hyraxes, with supplementary feeding. Provision of this in the form of potatoes, cabbage and carrots has been found to substantially increase hyrax populations in this region (R. Simmons, pers. comm.).

As none of key species are predominantly carrion-feeders it is not considered necessary to have a programme of carrion removal from the wind farm site, though this should be reviewed in light of the results of the post-construction monitoring programme.

Post-Construction Monitoring

Post-construction bird monitoring should be undertaken to better understand the impacts that actually occur and inform future wind farm design. This should include continuation of the pre-construction baseline surveys (raptor surveys and vantage point surveys) to compare bird distribution, abundance and behaviour before and after construction, and a programme to monitor the actual collisions that occur. The vantage point surveys should follow the same methodology as used previously, but should record flight times as well as plotting flight tracks and should record flight heights as accurately as possible (rather than just to wide height bands). The collision monitoring should follow the standard methodology developed for this purpose in the United States (Morrison 1998). A core area of 100m radius around each turbine should be carefully searched on foot. The 100m distance has been set conservatively as bird fatalities have rarely been documented over 70 m from turbines at other wind farms (Johnson et al. 2000). Sectors around the turbine should be slowly searched, taking particular care to search any taller clumps of vegetation, rocks and openings of animal burrows. In addition a further area 250m around each turbine should be checked for larger bird carcasses by scanning the ground with binoculars. The precise location of any dead birds found should be recorded and mapped (by reference to the distance and direction to the nearest wind turbine, and using a GPS). All carcasses should be photographed as found then placed in a plastic bag, labelled as to the location and date (turbine number, distance and direction from turbine base), and preserved (refrigerated or frozen) until identified. Feather spots (e.g., a group of feathers attached to skin) and body parts should also be collected. For all casualties found, data recorded should include species, sex, age, date and time collected, location, distance and direction (degrees) to nearest turbine, condition, and any comments regarding possible causes of death. The condition of each carcass found should be recorded using the following condition categories:

- Intact - carcass that is completely intact, is not badly decomposed, and shows no sign of being fed upon by a predator or scavenger.
- Scavenged - entire carcass that shows signs of being fed upon by a predator or scavenger or a portion(s) of a carcass in one location (e.g., wings, skeletal remains, legs, pieces of skin, etc.).
- Feather Spot - 10 or more feathers at one location indicating predation or scavenging.

A sample of 50 dead birds (e.g. dark-feathered chickens) should be obtained in order to study the rate of carcass removal and to test observer search efficiency. These should be placed within the search area at intervals through the study by someone independent of the carcass searcher, at precise recorded locations (mapped in relation to distance and direction from the wind turbines), and marked appropriately (e.g. with coloured tape) to identify them as experimental birds. They should then be recorded by the observer on all subsequent visits, noting their precise location (distance and direction from nearest wind turbine) and condition, and left in place on site until they disappear. The amount of scavenger activity should inform the survey frequency, but an initial programme of weekly visits is recommended as a starting point.

SECTION 10

REFERENCES

SECTION 10 – REFERENCES

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APPENDIX 1- (A) SKILLS, EXPERTISE AND EXPERIENCE OF THE REPORT AUTHOR

(B) STATEMENT OF INDEPENDENCE FROM WWP AND THE WITBERG WEF

APPENDIX 1 –

Appendix 1a: Skills expertise and experience of the report author

Dr Steve Percival has a B.Sc. (Hons) degree in Biological Sciences from the University of Durham (awarded in 1984) and a Ph.D. in Zoology from the University of Glasgow (awarded in 1988). He is a member of the Chartered Institute for Ecology and Environmental Management, the British Ecological Society and the British Ornithologists' Union.

As principal of his own private practice, Ecology Consulting, he has a wide experience of nature conservation and wind energy issues. His clients have included English Nature, the Wildfowl and Wetlands Trust, Scottish Natural Heritage, the Countryside Agency, the Department of Trade and Industry's Energy Technology Support Unit, the European Bank for Reconstruction and Development and the New Zealand Department of Conservation and numerous wind energy companies. He has been involved in over 340 wind energy projects, including carrying out ecological assessments, preparation of ecological material for environmental statements and giving evidence at public inquiries. He has published papers on the interactions between birds and wind farms and on assessing the potential effects, and given conference papers both within the UK and internationally (including as an invited guest speaker).

From 1991 to 2001 he was employed by the University of Sunderland as a Senior Lecturer in Environmental Biology. He took up the post in 1991, moving from the University of Durham where he had been working as a Senior Research Fellow with the late Professor Evans on waterfowl population ecology. This included the development of ecological models to predict the consequences of habitat change on bird populations. Prior to that he worked two years for the British Trust for Ornithology on the population dynamics of Barn and Tawny Owls, which included the analysis of data from the national bird monitoring schemes to assess the trends in owl numbers and the factors that were affecting them.

He has been studying the conservation ecology of bird populations since 1983. This has included work on population changes of waders in the Outer Hebrides and detailed ecological studies of barnacle geese (including a long-term project extending over 29 years), brent geese, wigeon, golden plover and curlew. His work has been published in major international scientific journals including the Journal of Applied Ecology, Biological Conservation, Ecography and Ibis.

Appendix 1b: Statement of independence from WWP and the Witberg WEF

Dr Steve Percival is independent from WWP and the Witberg WEF.

APPENDIX 2a. COLLISION RISK MODELLING RESULTS INITIAL 70-TURBINE LAYOUT

WITBERG COLLISION RISK MODELLING DATA INPUT: BIRD USAGE													
1. Hours observation													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
East	18.8	0	0	26.2	0	21.0	0	15.2	0	0	20.5	0	
Mid	18.8	0	0	6.0	0	13.8	0	8.3	0	0	18.8	0	
West	15.2	0	0	18.8	0	7.3	0	10.0	0	0	18.5	0	
2. Bird occupancy of collision zone (seconds)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Black Eagle: East	0.0			464.2		120.3		73.4			0.0		
Black Eagle: Mid	255.0			398.4		211.0		0.0			48.1		
Black Eagle: West	248.0			32.6		1695.2		70.1			744.0		
Booted Eagle: East	0.0			56.7		0.0		0.0			0.0		
Booted Eagle: Mid	0.0			0.0		391.3		0.0			357.8		
Booted Eagle: West	0.0			0.0		0.0		0.0			5.8		
Martial Eagle: East	0.0			0.0		0.0		0.0			0.0		
Martial Eagle: Mid	0.0			0.0		0.0		0.0			0.0		
Martial Eagle: West	0.0			0.0		11.8		57.8			0.0		
3. Bird occupancy rate of collision zone (% time present)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Mean occupanc**
Black Eagle: East	0.000%			0.493%		0.159%		0.134%			0.000%		**0.157%**
Black Eagle: Mid	0.376%			1.845%		0.426%		0.000%			0.071%		**0.544%**
Black Eagle: West	0.454%			0.048%		6.421%		0.195%			1.117%		**1.647%**
Booted Eagle: East	0.000%			0.060%		0.000%		0.000%			0.000%		**0.012%**
Booted Eagle: Mid	0.000%			0.000%		0.790%		0.000%			0.528%		**0.264%**
Booted Eagle: West	0.000%			0.000%		0.000%		0.000%			0.009%		**0.002%**
Martial Eagle: East	0.000%			0.000%		0.000%		0.000%			0.000%		**0.000%**
Martial Eagle: Mid	0.000%			0.000%		0.000%		0.000%			0.000%		**0.000%**
Martial Eagle: West	0.000%			0.000%		0.045%		0.161%			0.000%		**0.041%**
4. Number of hours for which birds were assumed to be potentially active over the time period that they were present													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mean daylight hrs	14.6	12.0	12.7	10.9	10.4	10.6	10.1	11.2	11.5	13.3	13.4	14.4	
Mean nocturnal hours	9.4	12.0	11.3	13.1	13.6	13.4	13.9	12.8	12.5	10.7	10.6	9.6	
No days birds present	30	31	30	31	31	28	31	30	31	30	31	31	
Total hours day	438	373	382	338	322	298	314	337	356	400	416	445	
Total hours day&night	744	672	744	720	744	720	744	744	720	744	720	744	

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA
Black Eagle
Only enter input parameters in blue

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	3.28	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.88	m	0.025	0.575	7.42	31.93	1.00	0.00125	31.53	1.00	0.00125
Wingspan	2.4	m	0.075	0.575	2.47	10.77	0.55	0.00416	10.38	0.53	0.00401
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.48	7.20	0.37	0.00463	6.72	0.35	0.00432
			0.175	0.860	1.06	5.81	0.30	0.00524	5.22	0.27	0.00471
Bird speed	11.9	m/sec	0.225	0.994	0.82	4.99	0.26	0.00578	4.31	0.22	0.00499
RotorDiam	100	m	0.275	0.947	0.67	4.03	0.21	0.00570	3.38	0.17	0.00478
RotationPeriod	4.90	sec	0.325	0.899	0.57	3.35	0.17	0.00561	2.74	0.14	0.00458
			0.375	0.851	0.49	2.85	0.15	0.00551	2.27	0.12	0.00438
			0.425	0.804	0.44	2.47	0.13	0.00540	1.92	0.10	0.00419
			0.475	0.756	0.39	2.16	0.11	0.00528	1.64	0.08	0.00401
Bird aspect ratioo: β	0.37		0.525	0.708	0.35	1.94	0.10	0.00524	1.45	0.07	0.00393
			0.575	0.660	0.32	1.80	0.09	0.00533	1.35	0.07	0.00399
			0.625	0.613	0.30	1.68	0.09	0.00542	1.26	0.07	0.00406
			0.675	0.565	0.27	1.58	0.08	0.00549	1.19	0.06	0.00414
			0.725	0.517	0.26	1.49	0.08	0.00556	1.13	0.06	0.00423
			0.775	0.470	0.24	1.41	0.07	0.00562	1.09	0.06	0.00433
			0.825	0.422	0.22	1.33	0.07	0.00567	1.04	0.05	0.00444
			0.875	0.374	0.21	1.27	0.07	0.00571	1.01	0.05	0.00455
			0.925	0.327	0.20	1.21	0.06	0.00574	0.98	0.05	0.00467
			0.975	0.279	0.19	1.15	0.06	0.00576	0.96	0.05	0.00481
				Overall p(collision) =			**Upwind**	**10.4%**		**Downwind**	**8.4%**
								Average	**9.4%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA
Booted Eagle
Only enter input parameters in blue

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	3.28	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.5	m	0.025	0.575	7.17	22.47	1.00	0.00125	22.08	1.00	0.00125
Wingspan	1.23	m	0.075	0.575	2.39	7.62	0.41	0.00304	7.23	0.38	0.00289
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.43	5.29	0.28	0.00352	4.81	0.26	0.00320
			0.175	0.860	1.02	4.43	0.24	0.00413	3.84	0.20	0.00358
Bird speed	11.5	m/sec	0.225	0.994	0.80	3.91	0.21	0.00468	3.22	0.17	0.00386
RotorDiam	100	m	0.275	0.947	0.65	3.14	0.17	0.00460	2.49	0.13	0.00365
RotationPeriod	4.90	sec	0.325	0.899	0.55	2.60	0.14	0.00451	1.99	0.11	0.00344
			0.375	0.851	0.48	2.21	0.12	0.00441	1.62	0.09	0.00324
			0.425	0.804	0.42	1.90	0.10	0.00430	1.35	0.07	0.00305
			0.475	0.756	0.38	1.69	0.09	0.00428	1.17	0.06	0.00296
Bird aspect ratioo: β	0.41		0.525	0.708	0.34	1.53	0.08	0.00428	1.05	0.06	0.00293
			0.575	0.660	0.31	1.40	0.07	0.00428	0.95	0.05	0.00290
			0.625	0.613	0.29	1.28	0.07	0.00427	0.86	0.05	0.00287
			0.675	0.565	0.27	1.18	0.06	0.00425	0.80	0.04	0.00286
			0.725	0.517	0.25	1.09	0.06	0.00423	0.74	0.04	0.00286
			0.775	0.470	0.23	1.02	0.05	0.00419	0.69	0.04	0.00286
			0.825	0.422	0.22	0.94	0.05	0.00415	0.65	0.03	0.00288
			0.875	0.374	0.20	0.88	0.05	0.00409	0.62	0.03	0.00290
			0.925	0.327	0.19	0.82	0.04	0.00403	0.59	0.03	0.00293
			0.975	0.279	0.18	0.76	0.04	0.00396	0.57	0.03	0.00297
				Overall p(collision) =			**Upwind**	**8.0%**		**Downwind**	**6.0%**
								Average	**7.0%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Martial Eagle											
Only enter input parameters in blue											
K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	3.28	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.81	m	0.025	0.575	6.49	26.31	1.00	0.00125	25.91	1.00	0.00125
Wingspan	2.15	m	0.075	0.575	2.16	8.90	0.52	0.00393	8.51	0.50	0.00376
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.30	6.00	0.35	0.00442	5.52	0.32	0.00406
			0.175	0.860	0.93	4.89	0.29	0.00504	4.30	0.25	0.00443
Bird speed	10.4	m/sec	0.225	0.994	0.72	4.23	0.25	0.00560	3.55	0.21	0.00470
RotorDiam	100	m	0.275	0.947	0.59	3.41	0.20	0.00553	2.76	0.16	0.00448
RotationPeriod	4.90	sec	0.325	0.899	0.50	2.84	0.17	0.00544	2.23	0.13	0.00426
			0.375	0.851	0.43	2.42	0.14	0.00535	1.84	0.11	0.00406
			0.425	0.804	0.38	2.10	0.12	0.00525	1.54	0.09	0.00387
			0.475	0.756	0.34	1.91	0.11	0.00535	1.39	0.08	0.00390
Bird aspect ratioo: β	0.38		0.525	0.708	0.31	1.77	0.10	0.00546	1.28	0.08	0.00396
			0.575	0.660	0.28	1.64	0.10	0.00557	1.19	0.07	0.00403
			0.625	0.613	0.26	1.54	0.09	0.00566	1.12	0.07	0.00412
			0.675	0.565	0.24	1.45	0.09	0.00575	1.06	0.06	0.00421
			0.725	0.517	0.22	1.36	0.08	0.00583	1.01	0.06	0.00431
			0.775	0.470	0.21	1.29	0.08	0.00589	0.97	0.06	0.00443
			0.825	0.422	0.20	1.23	0.07	0.00595	0.94	0.06	0.00455
			0.875	0.374	0.19	1.16	0.07	0.00600	0.91	0.05	0.00468
			0.925	0.327	0.18	1.11	0.07	0.00604	0.88	0.05	0.00482
			0.975	0.279	0.17	1.06	0.06	0.00607	0.87	0.05	0.00497
				Overall p(collision) =			**Upwind**	**10.5%**		**Downwind**	**8.3%**
								Average	**9.4%**		

WITBERG WIND FARM BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)									
	Black Eagle			**Booted Eagle**			**Martial Eagle**		
	East	***Mid***	***West***	***East***	***Mid***	***West***	***East***	***Mid***	***West***
Collision Zone Area (ha)	105	315	195	105	315	195	105	315	195
Hub Ht	80	80	80	80	80	80	80	80	80
Rotor diameter	100	100	100	100	100	100	100	100	100
Upper rotor ht	130	130	130	130	130	130	130	130	130
Lower rotor ht	30	30	30	30	30	30	30	30	30
Percentage of observation time seen flying in collision zone	**0.157%**	**0.544%**	**1.647%**	**0.012%**	**0.264%**	**0.002%**	**0.000%**	**0.000%**	**0.041%**
Proportion of observation time seen flying at rotor height	72%	72%	72%	59%	59%	59%	50%	50%	50%
Adjusted proportion of observation time seen flying at rotor height	0.112%	0.389%	1.178%	0.007%	0.154%	0.001%	0.000%	0.000%	0.021%
Season length	365	365	365	365	365	365	365	365	365
Activity per day	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
Total flight activity in collision zone at rotor ht	4.967	17.166	52.012	0.311	6.811	0.045	0.000	0.000	0.907
Flight risk volume	1.050E+08	3.150E+08	1.950E+08	1.050E+08	3.150E+08	1.950E+08	1.050E+08	3.150E+08	1.950E+08
No Turbines	**8**	**22**	**15**	**8**	**22**	**15**	**8**	**22**	**15**
Rotor radius	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**50**
Rotor depth	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**
Bird length	**0.88**	**0.88**	**0.88**	**0.5**	**0.5**	**0.5**	**0.81**	**0.81**	**0.81**
Swept volume	261381	718796	490088	237504	653137	445321	256982	706701	481842
Bird occupancy of swept volume	44.51	141.01	470.59	2.53	50.84	0.37	0.00	0.00	8.07
Bird speed	**11.9**	**11.9**	**11.9**	**11.5**	**11.5**	**11.5**	**10.4**	**10.4**	**10.4**
Rotor transit time	0.350	0.350	0.350	0.329	0.329	0.329	0.393	0.393	0.393
No of rotor transits	127.3	403.4	1346.2	7.7	154.7	1.1	0.0	0.0	20.5
Turbine downtime	9%	9%	10%	9%	9%	10%	9%	9%	10%
Band collision rate	9.4%	9.4%	9.3%	7.0%	7.0%	6.9%	9.4%	9.4%	9.2%
Non-avoid collisions	10.9	34.6	112.2	0.5	9.9	0.1	0.0	0.0	1.7
Avoidance rate	98%	98%	98%	98%	98%	98%	98%	98%	98%
Collision prediction	**0.22**	**0.69**	**2.24**	**0.01**	**0.20**	**0.00**	**0.00**	**0.00**	**0.03**
Total collisions (inc. additional 23 western turbines & 2 additional mid turbines)			**6.66**			**0.23**			**0.09**

APPENDIX 2B. COLLISION RISK MODELLING RESULTS 40-TURBINE DEA-AUTHORISED LAYOUT

WITBERG COLLISION RISK MODELLING DATA INPUT: BIRD USAGE													
1. Hours observation													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
East	18.8	0	0	26.2	0	21.0	0	15.2	0	0	20.5	0	
Mid	18.8	0	0	6.0	0	13.8	0	8.3	0	0	18.8	0	
West	15.2	0	0	18.8	0	7.3	0	10.0	0	0	18.5	0	
2. Bird occupancy of collision zone (seconds)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Black Eagle: East	0.0			464.9		88.6		50.9			0.0		
Black Eagle: Mid	256.0			660.6		284.2		0.0			72.0		
Black Eagle: West	8.2			30.2		1490.4		70.1			102.8		
Booted Eagle: East	0.0			56.4		0.0		0.0			0.0		
Booted Eagle: Mid	0.0			0.0		281.4		0.0			265.4		
Booted Eagle: West	0.0			0.0		0.0		0.0			0.0		
Martial Eagle: East	0.0			0.0		0.0		0.0			0.0		
Martial Eagle: Mid	0.0			0.0		0.0		0.0			0.0		
Martial Eagle: West	0.0			0.0		0.0		58.6			0.0		
3. Bird occupancy rate of collision zone (% time present)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Mean occupanc**
Black Eagle: East	0.000%			0.494%		0.117%		0.093%			0.000%		**0.141%**
Black Eagle: Mid	0.378%			3.058%		0.574%		0.000%			0.106%		**0.823%**
Black Eagle: West	0.015%			0.045%		5.645%		0.195%			0.154%		**1.211%**
Booted Eagle: East	0.000%			0.060%		0.000%		0.000%			0.000%		**0.012%**
Booted Eagle: Mid	0.000%			0.000%		0.569%		0.000%			0.391%		**0.192%**
Booted Eagle: West	0.000%			0.000%		0.000%		0.000%			0.000%		**0.000%**
Martial Eagle: East	0.000%			0.000%		0.000%		0.000%			0.000%		**0.000%**
Martial Eagle: Mid	0.000%			0.000%		0.000%		0.000%			0.000%		**0.000%**
Martial Eagle: West	0.000%			0.000%		0.000%		0.163%			0.000%		**0.033%**
4. Number of hours for which birds were assumed to be potentially active over the time period that they were present													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mean daylight hrs	14.6	12.0	12.7	10.9	10.4	10.6	10.1	11.2	11.5	13.3	13.4	14.4	
Mean nocturnal hours	9.4	12.0	11.3	13.1	13.6	13.4	13.9	12.8	12.5	10.7	10.6	9.6	
No days birds present	30	31	30	31	31	28	31	30	31	30	31	31	
Total hours day	438	373	382	338	322	298	314	337	356	400	416	445	
Total hours day&night	744	672	744	720	744	720	744	744	720	744	720	744	

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Black Eagle

Only enter input parameters in blue

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	3.28	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.88	m	0.025	0.575	9.15	39.32	1.00	0.00125	38.92	1.00	0.00125
Wingspan	2.4	m	0.075	0.575	3.05	13.24	0.61	0.00461	12.84	0.60	0.00447
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.83	8.82	0.41	0.00511	8.34	0.39	0.00484
			0.175	0.860	1.31	7.10	0.33	0.00576	6.51	0.30	0.00528
Bird speed	11.9	m/sec	0.225	0.994	1.02	6.08	0.28	0.00634	5.40	0.25	0.00563
RotorDiam	90	m	0.275	0.947	0.83	4.89	0.23	0.00624	4.24	0.20	0.00541
RotationPeriod	5.43	sec	0.325	0.899	0.70	4.06	0.19	0.00612	3.44	0.16	0.00519
			0.375	0.851	0.61	3.45	0.16	0.00600	2.87	0.13	0.00499
			0.425	0.804	0.54	2.98	0.14	0.00587	2.43	0.11	0.00478
			0.475	0.756	0.48	2.60	0.12	0.00573	2.08	0.10	0.00459
Bird aspect ratioo: β	0.37		0.525	0.708	0.44	2.29	0.11	0.00559	1.81	0.08	0.00441
			0.575	0.660	0.40	2.04	0.09	0.00544	1.59	0.07	0.00423
			0.625	0.613	0.37	1.82	0.08	0.00528	1.40	0.07	0.00406
			0.675	0.565	0.34	1.70	0.08	0.00532	1.31	0.06	0.00410
			0.725	0.517	0.32	1.59	0.07	0.00535	1.24	0.06	0.00415
			0.775	0.470	0.30	1.49	0.07	0.00537	1.17	0.05	0.00421
			0.825	0.422	0.28	1.41	0.07	0.00538	1.12	0.05	0.00427
			0.875	0.374	0.26	1.33	0.06	0.00539	1.07	0.05	0.00435
			0.925	0.327	0.25	1.26	0.06	0.00539	1.03	0.05	0.00443
			0.975	0.279	0.23	1.19	0.06	0.00538	1.00	0.05	0.00451
				Overall p(collision) =			**Upwind**	**10.7%**		**Downwind**	**8.9%**
								Average	**9.8%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Booted Eagle

Only enter input parameters in blue

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	3.28	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.5	m	0.025	0.575	8.84	27.66	1.00	0.00125	27.26	1.00	0.00125
Wingspan	1.23	m	0.075	0.575	2.95	9.35	0.45	0.00337	8.96	0.43	0.00322
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.77	6.46	0.31	0.00388	5.98	0.29	0.00359
			0.175	0.860	1.26	5.39	0.26	0.00453	4.80	0.23	0.00403
Bird speed	11.5	m/sec	0.225	0.994	0.98	4.74	0.23	0.00511	4.05	0.19	0.00438
RotorDiam	90	m	0.275	0.947	0.80	3.80	0.18	0.00501	3.15	0.15	0.00415
RotationPeriod	5.43	sec	0.325	0.899	0.68	3.14	0.15	0.00490	2.52	0.12	0.00394
			0.375	0.851	0.59	2.65	0.13	0.00478	2.07	0.10	0.00373
			0.425	0.804	0.52	2.28	0.11	0.00465	1.73	0.08	0.00352
			0.475	0.756	0.47	1.98	0.09	0.00451	1.46	0.07	0.00333
Bird aspect ratioo: β	0.41		0.525	0.708	0.42	1.73	0.08	0.00437	1.25	0.06	0.00314
			0.575	0.660	0.38	1.55	0.07	0.00429	1.10	0.05	0.00304
			0.625	0.613	0.35	1.42	0.07	0.00425	1.00	0.05	0.00299
			0.675	0.565	0.33	1.30	0.06	0.00420	0.91	0.04	0.00295
			0.725	0.517	0.30	1.19	0.06	0.00415	0.84	0.04	0.00291
			0.775	0.470	0.29	1.10	0.05	0.00408	0.78	0.04	0.00289
			0.825	0.422	0.27	1.01	0.05	0.00401	0.72	0.03	0.00287
			0.875	0.374	0.25	0.94	0.04	0.00393	0.68	0.03	0.00286
			0.925	0.327	0.24	0.87	0.04	0.00385	0.64	0.03	0.00285
			0.975	0.279	0.23	0.80	0.04	0.00375	0.61	0.03	0.00286
				Overall p(collision) =			**Upwind**	**8.3%**		**Downwind**	**6.5%**
								Average	**7.4%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Martial Eagle											
Only enter input parameters in blue											
K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	3.28	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	6		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.81	m	0.025	0.575	8.00	32.39	1.00	0.00125	31.99	1.00	0.00125
Wingspan	2.15	m	0.075	0.575	2.67	10.93	0.58	0.00435	10.53	0.56	0.00419
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.60	7.34	0.39	0.00487	6.86	0.36	0.00455
			0.175	0.860	1.14	5.96	0.32	0.00553	5.37	0.28	0.00498
Bird speed	10.4	m/sec	0.225	0.994	0.89	5.13	0.27	0.00613	4.45	0.24	0.00532
RotorDiam	90	m	0.275	0.947	0.73	4.13	0.22	0.00603	3.48	0.18	0.00508
RotationPeriod	5.43	sec	0.325	0.899	0.62	3.43	0.18	0.00592	2.82	0.15	0.00486
			0.375	0.851	0.53	2.92	0.15	0.00581	2.33	0.12	0.00465
			0.425	0.804	0.47	2.52	0.13	0.00568	1.97	0.10	0.00444
			0.475	0.756	0.42	2.20	0.12	0.00555	1.68	0.09	0.00424
Bird aspect ratioo: β	0.38		0.525	0.708	0.38	1.94	0.10	0.00541	1.46	0.08	0.00406
			0.575	0.660	0.35	1.79	0.09	0.00545	1.33	0.07	0.00407
			0.625	0.613	0.32	1.66	0.09	0.00550	1.24	0.07	0.00411
			0.675	0.565	0.30	1.55	0.08	0.00555	1.16	0.06	0.00416
			0.725	0.517	0.28	1.45	0.08	0.00559	1.10	0.06	0.00423
			0.775	0.470	0.26	1.37	0.07	0.00562	1.04	0.06	0.00430
			0.825	0.422	0.24	1.29	0.07	0.00564	1.00	0.05	0.00437
			0.875	0.374	0.23	1.22	0.06	0.00565	0.96	0.05	0.00446
			0.925	0.327	0.22	1.15	0.06	0.00566	0.93	0.05	0.00456
			0.975	0.279	0.21	1.09	0.06	0.00565	0.90	0.05	0.00466
				Overall p(collision) =			**Upwind**	**10.7%**		**Downwind**	**8.7%**
								Average	**9.7%**		

WITBERG WIND FARM									
BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)									
	Black Eagle			**Booted Eagle**			**Martial Eagle**		
	East	***Mid***	***West***	***East***	***Mid***	***West***	***East***	***Mid***	***West***
Collision Zone Area (ha)	100	331	132	100	331	132	100	331	132
Hub Ht	80	80	80	80	80	80	80	80	80
Rotor diameter	90	90	90	90	90	90	90	90	90
Upper rotor ht	125	125	125	125	125	125	125	125	125
Lower rotor ht	35	35	35	35	35	35	35	35	35
Percentage of observation time seen flying in collision zone	**0.141%**	**0.823%**	**1.211%**	**0.012%**	**0.192%**	**0.000%**	**0.000%**	**0.000%**	**0.033%**
Proportion of observation time seen flying at rotor height	67%	67%	67%	56%	56%	56%	50%	50%	50%
Adjusted proportion of observation time seen flying at rotor height	0.095%	0.554%	0.814%	0.007%	0.108%	0.000%	0.000%	0.000%	0.016%
Season length	365	365	365	365	365	365	365	365	365
Activity per day	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
Total flight activity in collision zone at rotor ht	4.182	24.451	35.964	0.297	4.770	0.000	0.000	0.000	0.719
Flight risk volume	9.000E+07	2.979E+08	1.188E+08	9.000E+07	2.979E+08	1.188E+08	9.000E+07	2.979E+08	1.188E+08
No Turbines	**8**	**21**	**8**	**8**	**21**	**8**	**8**	**21**	**8**
Rotor radius	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**45**	**45**
Rotor depth	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**
Bird length	**0.88**	**0.88**	**0.88**	**0.5**	**0.5**	**0.5**	**0.81**	**0.81**	**0.81**
Swept volume	211718	555760	211718	192379	504994	192379	208156	546409	208156
Bird occupancy of swept volume	35.42	164.21	230.74	2.29	29.11	0.00	0.00	0.00	4.53
Bird speed	**11.9**	**11.9**	**11.9**	**11.5**	**11.5**	**11.5**	**10.4**	**10.4**	**10.4**
Rotor transit time	0.350	0.350	0.350	0.329	0.329	0.329	0.393	0.393	0.393
No of rotor transits	101.3	469.7	660.0	7.0	88.6	0.0	0.0	0.0	11.5
Turbine downtime	10%	10%	13%	10%	10%	13%	10%	10%	13%
Band collision rate	9.8%	9.8%	9.6%	7.4%	7.4%	7.3%	9.7%	9.7%	9.5%
Non-avoid collisions	8.9	41.4	55.4	0.5	5.9	0.0	0.0	0.0	0.9
Avoidance rate	98%	98%	98%	98%	98%	98%	98%	98%	98%
Collision prediction	**0.18**	**0.83**	**1.11**	**0.01**	**0.12**	**0.00**	**0.00**	**0.00**	**0.02**
Total collisions (inc. additional 3 western turbines)			**2.53**			**0.13**			**0.03**

APPENDIX 2C. COLLISION RISK MODELLING RESULTS FIRST 27-TURBINE LAYOUT

WITBERG COLLISION RISK MODELLING DATA INPUT: BIRD USAGE													
1. Hours observation													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
East	18.8	0	0	26.2	0	21.0	0	15.2	0	0	20.5	0	
Mid	18.8	0	0	6.0	0	13.8	0	8.3	0	0	18.8	0	
West	15.2	0	0	18.8	0	7.3	0	10.0	0	0	18.5	0	
2. Bird occupancy of collision zone (seconds)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Black Eagle: East	0.0			119.2		0.0		0.0			0.0		
Black Eagle: Mid	0.0			399.2		138.7		0.0			160.0		
Black Eagle: West	7.7			27.5		1375.6		70.1			108.1		
Booted Eagle: East	0.0			3.9		0.0		0.0			0.0		
Booted Eagle: Mid	0.0			0.0		19.4		0.0			161.8		
Booted Eagle: West	0.0			0.0		0.0		0.0			0.0		
Martial Eagle: East	0.0			0.0		0.0		0.0			0.0		
Martial Eagle: Mid	0.0			0.0		0.0		0.0			0.0		
Martial Eagle: West	0.0			0.0		12.3		47.6			0.0		
3. Bird occupancy rate of collision zone (% time present)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Mean occupanc**
Black Eagle: East	0.000%			0.127%		0.000%		0.000%			0.000%		**0.025%**
Black Eagle: Mid	0.000%			1.848%		0.280%		0.000%			0.236%		**0.473%**
Black Eagle: West	0.014%			0.041%		5.210%		0.195%			0.162%		**1.124%**
Booted Eagle: East	0.000%			0.004%		0.000%		0.000%			0.000%		**0.001%**
Booted Eagle: Mid	0.000%			0.000%		0.039%		0.000%			0.239%		**0.056%**
Booted Eagle: West	0.000%			0.000%		0.000%		0.000%			0.000%		**0.000%**
Martial Eagle: East	0.000%			0.000%		0.000%		0.000%			0.000%		**0.000%**
Martial Eagle: Mid	0.000%			0.000%		0.000%		0.000%			0.000%		**0.000%**
Martial Eagle: West	0.000%			0.000%		0.047%		0.132%			0.000%		**0.036%**
4. Number of hours for which birds were assumed to be potentially active over the time period that they were present													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mean daylight hrs	14.6	12.0	12.7	10.9	10.4	10.6	10.1	11.2	11.5	13.3	13.4	14.4	
Mean nocturnal hours	9.4	12.0	11.3	13.1	13.6	13.4	13.9	12.8	12.5	10.7	10.6	9.6	
No days birds present	30	31	30	31	31	28	31	30	31	30	31	31	
Total hours day	438	373	382	338	322	298	314	337	356	400	416	445	
Total hours day&night	744	672	744	720	744	720	744	744	720	744	720	744	

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Black Eagle											
Only enter input parameters in blue											
K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	3.28	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	4.13		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.88	m	0.025	0.575	6.59	28.33	1.00	0.00125	28.06	1.00	0.00125
Wingspan	2.4	m	0.075	0.575	2.20	9.53	0.48	0.00358	9.26	0.46	0.00347
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.32	6.35	0.32	0.00397	6.02	0.30	0.00376
			0.175	0.860	0.94	5.11	0.26	0.00447	4.70	0.24	0.00411
Bird speed	11.9	m/sec	0.225	0.994	0.73	4.37	0.22	0.00492	3.90	0.20	0.00439
RotorDiam	116	m	0.275	0.947	0.60	3.51	0.18	0.00483	3.07	0.15	0.00422
RotationPeriod	5.04	sec	0.325	0.899	0.51	2.92	0.15	0.00474	2.49	0.12	0.00405
			0.375	0.851	0.44	2.48	0.12	0.00465	2.08	0.10	0.00389
			0.425	0.804	0.39	2.14	0.11	0.00454	1.76	0.09	0.00374
			0.475	0.756	0.35	1.92	0.10	0.00455	1.56	0.08	0.00370
Bird aspect ratioo: β	0.37		0.525	0.708	0.31	1.77	0.09	0.00466	1.44	0.07	0.00378
			0.575	0.660	0.29	1.65	0.08	0.00476	1.34	0.07	0.00386
			0.625	0.613	0.26	1.55	0.08	0.00485	1.26	0.06	0.00395
			0.675	0.565	0.24	1.46	0.07	0.00494	1.20	0.06	0.00404
			0.725	0.517	0.23	1.39	0.07	0.00503	1.14	0.06	0.00414
			0.775	0.470	0.21	1.32	0.07	0.00510	1.10	0.05	0.00424
			0.825	0.422	0.20	1.26	0.06	0.00518	1.06	0.05	0.00436
			0.875	0.374	0.19	1.20	0.06	0.00524	1.02	0.05	0.00447
			0.925	0.327	0.18	1.15	0.06	0.00531	0.99	0.05	0.00459
			0.975	0.279	0.17	1.10	0.05	0.00536	0.97	0.05	0.00472
				Overall p(collision) =			**Upwind**	**9.2%**		**Downwind**	**7.9%**
								Average	**8.5%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Booted Eagle											
Only enter input parameters in blue											
K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	3.28	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	4.13		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.5	m	0.025	0.575	6.36	19.94	1.00	0.00125	19.66	1.00	0.00125
Wingspan	1.23	m	0.075	0.575	2.12	6.74	0.35	0.00261	6.46	0.33	0.00251
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.27	4.65	0.24	0.00301	4.32	0.22	0.00279
			0.175	0.860	0.91	3.88	0.20	0.00351	3.47	0.18	0.00314
Bird speed	11.5	m/sec	0.225	0.994	0.71	3.41	0.18	0.00396	2.94	0.15	0.00342
RotorDiam	116	m	0.275	0.947	0.58	2.73	0.14	0.00388	2.28	0.12	0.00324
RotationPeriod	5.04	sec	0.325	0.899	0.49	2.25	0.12	0.00379	1.83	0.09	0.00308
			0.375	0.851	0.42	1.90	0.10	0.00370	1.50	0.08	0.00291
			0.425	0.804	0.37	1.67	0.09	0.00368	1.29	0.07	0.00285
			0.475	0.756	0.33	1.51	0.08	0.00370	1.15	0.06	0.00283
Bird aspect ratioo: β	0.41		0.525	0.708	0.30	1.37	0.07	0.00372	1.03	0.05	0.00281
			0.575	0.660	0.28	1.25	0.06	0.00373	0.94	0.05	0.00280
			0.625	0.613	0.25	1.16	0.06	0.00374	0.87	0.04	0.00280
			0.675	0.565	0.24	1.07	0.06	0.00373	0.80	0.04	0.00280
			0.725	0.517	0.22	0.99	0.05	0.00373	0.75	0.04	0.00281
			0.775	0.470	0.21	0.93	0.05	0.00371	0.70	0.04	0.00282
			0.825	0.422	0.19	0.87	0.04	0.00370	0.67	0.03	0.00285
			0.875	0.374	0.18	0.81	0.04	0.00367	0.63	0.03	0.00287
			0.925	0.327	0.17	0.76	0.04	0.00364	0.61	0.03	0.00290
			0.975	0.279	0.16	0.71	0.04	0.00361	0.58	0.03	0.00294
				Overall p(collision) =			**Upwind**	**7.0%**		**Downwind**	**5.6%**
								Average	**6.3%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA

Martial Eagle

Only enter input parameters in blue

K: [1D or [3D] (0 or 1)	1		**Calculation of alpha and p(collision) as a function of radius**								
NoBlades	3						Upwind:			Downwind:	
MaxChord	3.28	m	r/R	c/C	α	collide		contribution	collide		contribution
Pitch (degrees)	4.13		radius	chord	alpha	length	p(collision)	from radius r	length	p(collision)	from radius r
BirdLength	0.81	m	0.025	0.575	5.76	23.34	1.00	0.00125	23.07	1.00	0.00125
Wingspan	2.15	m	0.075	0.575	1.92	7.87	0.45	0.00338	7.60	0.43	0.00326
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.15	5.28	0.30	0.00378	4.95	0.28	0.00354
			0.175	0.860	0.82	4.28	0.25	0.00429	3.88	0.22	0.00388
Bird speed	10.4	m/sec	0.225	0.994	0.64	3.69	0.21	0.00475	3.22	0.18	0.00415
RotorDiam	116	m	0.275	0.947	0.52	2.97	0.17	0.00467	2.52	0.14	0.00397
RotationPeriod	5.04	sec	0.325	0.899	0.44	2.47	0.14	0.00459	2.04	0.12	0.00380
			0.375	0.851	0.38	2.09	0.12	0.00449	1.69	0.10	0.00363
			0.425	0.804	0.34	1.89	0.11	0.00460	1.51	0.09	0.00367
			0.475	0.756	0.30	1.74	0.10	0.00472	1.38	0.08	0.00375
Bird aspect ratioo: β	0.38		0.525	0.708	0.27	1.61	0.09	0.00484	1.28	0.07	0.00384
			0.575	0.660	0.25	1.51	0.09	0.00496	1.19	0.07	0.00393
			0.625	0.613	0.23	1.42	0.08	0.00506	1.13	0.06	0.00403
			0.675	0.565	0.21	1.34	0.08	0.00517	1.07	0.06	0.00413
			0.725	0.517	0.20	1.27	0.07	0.00526	1.02	0.06	0.00425
			0.775	0.470	0.19	1.21	0.07	0.00535	0.98	0.06	0.00436
			0.825	0.422	0.17	1.15	0.07	0.00543	0.95	0.05	0.00449
			0.875	0.374	0.16	1.10	0.06	0.00551	0.92	0.05	0.00462
			0.925	0.327	0.16	1.05	0.06	0.00557	0.90	0.05	0.00476
			0.975	0.279	0.15	1.01	0.06	0.00564	0.88	0.05	0.00490
				Overall p(collision) =			**Upwind**	**9.3%**		**Downwind**	**7.8%**
								Average	**8.6%**		

WITBERG WIND FARM									
BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)									
	Black Eagle			**Booted Eagle**			**Martial Eagle**		
	East	***Mid***	***West***	***East***	***Mid***	***West***	***East***	***Mid***	***West***
Collision Zone Area (ha)	36	246	133	36	246	133	36	246	133
Hub Ht	92	92	92	92	92	92	92	92	92
Rotor diameter	116	116	116	116	116	116	116	116	116
Upper rotor ht	150	150	150	150	150	150	150	150	150
Lower rotor ht	34	34	34	34	34	34	34	34	34
Percentage of observation time seen flying in collision zone	**0.025%**	**0.473%**	**1.124%**	**0.001%**	**0.056%**	**0.000%**	**0.000%**	**0.000%**	**0.036%**
Proportion of observation time seen flying at rotor height	68%	68%	68%	57%	57%	57%	50%	50%	50%
Adjusted proportion of observation time seen flying at rotor height	0.017%	0.322%	0.766%	0.000%	0.032%	0.000%	0.000%	0.000%	0.018%
Season length	365	365	365	365	365	365	365	365	365
Activity per day	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
Total flight activity in collision zone at rotor ht	0.761	14.224	33.820	0.021	1.391	0.000	0.000	0.000	0.790
Flight risk volume	4.176E+07	2.854E+08	1.543E+08	4.176E+07	2.854E+08	1.543E+08	4.176E+07	2.854E+08	1.543E+08
No Turbines	**3**	**14**	**8**	**3**	**14**	**8**	**3**	**14**	**8**
Rotor radius	**58**	**58**	**58**	**58**	**58**	**58**	**58**	**58**	**58**
Rotor depth	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**
Bird length	**0.88**	**0.88**	**0.88**	**0.5**	**0.5**	**0.5**	**0.81**	**0.81**	**0.81**
Swept volume	131893	615499	351714	119845	559275	319586	129673	605142	345795
Bird occupancy of swept volume	8.66	110.45	277.56	0.21	9.82	0.00	0.00	0.00	6.37
Bird speed	**11.9**	**11.9**	**11.9**	**11.5**	**11.5**	**11.5**	**10.4**	**10.4**	**10.4**
Rotor transit time	0.350	0.350	0.350	0.329	0.329	0.329	0.393	0.393	0.393
No of rotor transits	24.8	315.9	794.0	0.7	29.9	0.0	0.0	0.0	16.2
Turbine downtime	8%	10%	10%	8%	10%	10%	8%	10%	10%
Band collision rate	8.5%	8.5%	8.5%	6.3%	6.3%	6.3%	8.6%	8.6%	8.5%
Non-avoid collisions	1.9	24.3	60.5	0.0	1.7	0.0	0.0	0.0	1.2
Avoidance rate	98%	98%	98%	98%	98%	98%	98%	98%	98%
Collision prediction	**0.04**	**0.49**	**1.21**	**0**	**0.03**	**0**	**0**	**0**	**0.02**
Total collisions (inc. additional 2 western turbines)			**2.04**			**0.03**			**0.03**

APPENDIX 2D. COLLISION RISK MODELLING RESULTS 25-TURBINE LAYOUT (FIRST 27-TURBINE LAYOUT MINUS TURBINES 9 AND 10)

WITBERG COLLISION RISK MODELLING DATA INPUT: BIRD USAGE													
1. Hours observation													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
East	18.8	0	0	26.2	0	21.0	0	15.2	0	0	20.5	0	
Mid	18.8	0	0	6.0	0	13.8	0	8.3	0	0	18.8	0	
West	15.2	0	0	18.8	0	7.3	0	10.0	0	0	18.5	0	
2. Bird occupancy of collision zone (seconds)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Black Eagle: East	0.0			119.2		0.0		0.0			0.0		
Black Eagle: Mid	0.0			399.2		138.7		0.0			160.0		
Black Eagle: West	0.0			27.5		1052.4		0.0			59.5		
Booted Eagle: East	0.0			3.9		0.0		0.0			0.0		
Booted Eagle: Mid	0.0			0.0		19.4		0.0			161.8		
Booted Eagle: West	0.0			0.0		0.0		0.0			0.0		
Martial Eagle: East	0.0			0.0		0.0		0.0			0.0		
Martial Eagle: Mid	0.0			0.0		0.0		0.0			0.0		
Martial Eagle: West	0.0			0.0		0.0		0.0			0.0		
3. Bird occupancy rate of collision zone (% time present)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Mean occupanc**
Black Eagle: East	0.000%			0.127%		0.000%		0.000%			0.000%		**0.025%**
Black Eagle: Mid	0.000%			1.848%		0.280%		0.000%			0.236%		**0.473%**
Black Eagle: West	0.000%			0.041%		3.987%		0.000%			0.089%		**0.823%**
Booted Eagle: East	0.000%			0.004%		0.000%		0.000%			0.000%		**0.001%**
Booted Eagle: Mid	0.000%			0.000%		0.039%		0.000%			0.239%		**0.056%**
Booted Eagle: West	0.000%			0.000%		0.000%		0.000%			0.000%		**0.000%**
Martial Eagle: East	0.000%			0.000%		0.000%		0.000%			0.000%		**0.000%**
Martial Eagle: Mid	0.000%			0.000%		0.000%		0.000%			0.000%		**0.000%**
Martial Eagle: West	0.000%			0.000%		0.000%		0.000%			0.000%		**0.000%**
4. Number of hours for which birds were assumed to be potentially active over the time period that they were present													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mean daylight hrs	14.6	12.0	12.7	10.9	10.4	10.6	10.1	11.2	11.5	13.3	13.4	14.4	
Mean nocturnal hours	9.4	12.0	11.3	13.1	13.6	13.4	13.9	12.8	12.5	10.7	10.6	9.6	
No days birds present	30	31	30	31	31	28	31	30	31	30	31	31	
Total hours day	438	373	382	338	322	298	314	337	356	400	416	445	
Total hours day&night	744	672	744	720	744	720	744	744	720	744	720	744	

Calculations of collision risk for bird passing through the rotor area are the same as for the first 27-turbien layout so are not repeated here.

WITBERG WIND FARM BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)									
	Black Eagle			**Booted Eagle**			**Martial Eagle**		
	East	***Mid***	***West***	***East***	***Mid***	***West***	***East***	***Mid***	***West***
Collision Zone Area (ha)	36	246	98	36	246	98	36	246	98
Hub Ht	92	92	92	92	92	92	92	92	92
Rotor diameter	116	116	116	116	116	116	116	116	116
Upper rotor ht	150	150	150	150	150	150	150	150	150
Lower rotor ht	34	34	34	34	34	34	34	34	34
Percentage of observation time seen flying in collision zone	**0.025%**	**0.473%**	**0.823%**	**0.001%**	**0.056%**	**0.000%**	**0.000%**	**0.000%**	**0.000%**
Proportion of observation time seen flying at rotor height	68%	68%	68%	57%	57%	57%	50%	50%	50%
Adjusted proportion of observation time seen flying at rotor height	0.017%	0.322%	0.561%	0.000%	0.032%	0.000%	0.000%	0.000%	0.000%
Season length	365	365	365	365	365	365	365	365	365
Activity per day	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
Total flight activity in collision zone at rotor ht	0.761	14.223	24.762	0.021	1.391	0.000	0.000	0.000	0.000
Flight risk volume	4.176E+07	2.854E+08	1.137E+08	4.176E+07	2.854E+08	1.137E+08	4.176E+07	2.854E+08	1.137E+08
No Turbines	**3**	**14**	**6**	**3**	**14**	**6**	**3**	**14**	**6**
Rotor radius	**58**	**58**	**58**	**58**	**58**	**58**	**58**	**58**	**58**
Rotor depth	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**
Bird length	**0.88**	**0.88**	**0.88**	**0.5**	**0.5**	**0.5**	**0.81**	**0.81**	**0.81**
Swept volume	131893	615499	263785	119845	559275	239689	129673	605142	259347
Bird occupancy of swept volume	8.66	110.44	206.85	0.21	9.82	0.00	0.00	0.00	0.00
Bird speed	**11.9**	**11.9**	**11.9**	**11.5**	**11.5**	**11.5**	**10.4**	**10.4**	**10.4**
Rotor transit time	0.350	0.350	0.350	0.329	0.329	0.329	0.393	0.393	0.393
No of rotor transits	24.8	315.9	591.7	0.7	29.9	0.0	0.0	0.0	0.0
Turbine downtime	8%	10%	10%	8%	10%	10%	8%	10%	10%
Band collision rate	8.5%	8.5%	8.5%	6.3%	6.3%	6.3%	8.6%	8.6%	8.5%
Non-avoid collisions	1.9	24.3	45.1	0.0	1.7	0.0	0.0	0.0	0.0
Avoidance rate	98%	98%	98%	98%	98%	98%	98%	98%	98%
Collision prediction	**0.04**	**0.49**	**0.90**	**0**	**0.03**	**0**	**0**	**0**	**0.00**
Total collisions (inc. additional 2 western turbines)			**1.65**			**0.03**			**0.00**

APPENDIX 2E. COLLISION RISK MODELLING RESULTS FOR UPDATED LOWER-RISK 27-TURBINE LAYOUT

WITBERG COLLISION RISK MODELLING DATA INPUT: BIRD USAGE														
1. Hours observation														
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
East	18.8	0	0	26.2	0	21.0	0	15.2	0	0	20.5	0		
Mid	18.8	0	0	6.0	0	13.8	0	8.3	0	0	18.8	0		
West	15.2	0	0	18.8	0	7.3	0	10.0	0	0	18.5	0		
2. Bird occupancy of collision zone (seconds)														
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Black Eagle: East	0.0			119.3		0.0		0.0			0.0			
Black Eagle: Mid	0.0			399.8		138.8		0.0			200.1			
Black Eagle: West	0.0			0.0		429.7		0.0			11.0			
Booted Eagle: East	0.0			3.9		0.0		0.0			0.0			
Booted Eagle: Mid	0.0			0.0		19.5		0.0			172.7			
Booted Eagle: West	0.0			0.0		0.0		0.0			0.0			
Martial Eagle: East	0.0			0.0		0.0		0.0			0.0			
Martial Eagle: Mid	0.0			0.0		0.0		0.0			0.0			
Martial Eagle: West	0.0			0.0		0.0		0.0			0.0			
3. Bird occupancy rate of collision zone (% time present)														
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		**Mean occupanc**
Black Eagle: East	0.000%			0.127%		0.000%		0.000%			0.000%			**0.025%**
Black Eagle: Mid	0.000%			1.851%		0.280%		0.000%			0.295%			**0.485%**
Black Eagle: West	0.000%			0.000%		1.628%		0.000%			0.017%			**0.329%**
Booted Eagle: East	0.000%			0.004%		0.000%		0.000%			0.000%			**0.001%**
Booted Eagle: Mid	0.000%			0.000%		0.039%		0.000%			0.255%			**0.059%**
Booted Eagle: West	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
Martial Eagle: East	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
Martial Eagle: Mid	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
Martial Eagle: West	0.000%			0.000%		0.000%		0.000%			0.000%			**0.000%**
4. Number of hours for which birds were assumed to be potentially active over the time period that they were present														
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Mean daylight hrs	14.6	12.0	12.7	10.9	10.4	10.6	10.1	11.2	11.5	13.3	13.4	14.4		
Mean nocturnal hours	9.4	12.0	11.3	13.1	13.6	13.4	13.9	12.8	12.5	10.7	10.6	9.6		
No days birds present	30	31	30	31	31	28	31	30	31	30	31	31		
Total hours day	438	373	382	338	322	298	314	337	356	400	416	445		
Total hours day&night	744	672	744	720	744	720	744	744	720	744	720	744		

Calculations of collision risk for bird passing through the rotor area are the same as for the first 27-turbine layout so are not repeated here.

WITBERG WIND FARM									
BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)									
	Black Eagle			Booted Eagle			Martial Eagle		
	East	*Mid*	*West*	*East*	*Mid*	*West*	*East*	*Mid*	*West*
Collision Zone Area (ha)	36	393	56	36	393	56	36	393	56
Hub Ht	92	92	92	92	92	92	92	92	92
Rotor diameter	116	116	116	116	116	116	116	116	116
Upper rotor ht	150	150	150	150	150	150	150	150	150
Lower rotor ht	34	34	34	34	34	34	34	34	34
Percentage of observation time seen flying in collision zone	**0.025%**	**0.485%**	**0.329%**	**0.001%**	**0.059%**	**0.000%**	**0.000%**	**0.000%**	**0.000%**
Proportion of observation time seen flying at rotor height	68%	68%	68%	57%	57%	57%	50%	50%	50%
Adjusted proportion of observation time seen flying at rotor height	0.017%	0.330%	0.224%	0.000%	0.033%	0.000%	0.000%	0.000%	0.000%
Season length	365	365	365	365	365	365	365	365	365
Activity per day	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
Total flight activity in collision zone at rotor ht	0.762	14.595	9.889	0.021	1.472	0.000	0.000	0.000	0.000
Flight risk volume	4.176E+07	4.559E+08	6.496E+07	4.176E+07	4.559E+08	6.496E+07	4.176E+07	4.559E+08	6.496E+07
No Turbines	**3**	**19**	**3**	**3**	**19**	**3**	**3**	**19**	**3**
Rotor radius	**58**	**58**	**58**	**58**	**58**	**58**	**58**	**58**	**58**
Rotor depth	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**	**3.28**
Bird length	**0.88**	**0.88**	**0.88**	**0.5**	**0.5**	**0.5**	**0.81**	**0.81**	**0.81**
Swept volume	131893	835320	131893	119845	759017	119845	129673	821264	129673
Bird occupancy of swept volume	8.66	96.27	72.28	0.21	8.83	0.00	0.00	0.00	0.00
Bird speed	**11.9**	**11.9**	**11.9**	**11.5**	**11.5**	**11.5**	**10.4**	**10.4**	**10.4**
Rotor transit time	0.350	0.350	0.350	0.329	0.329	0.329	0.393	0.393	0.393
No of rotor transits	24.8	275.4	206.8	0.7	26.9	0.0	0.0	0.0	0.0
Turbine downtime	8%	10%	10%	8%	10%	10%	8%	10%	10%
Band collision rate	8.5%	8.5%	8.5%	6.3%	6.3%	6.3%	8.6%	8.6%	8.5%
Non-avoid collisions	1.9	21.1	15.8	0.0	1.5	0.0	0.0	0.0	0.0
Avoidance rate	98%	98%	98%	98%	98%	98%	98%	98%	98%
Collision prediction	**0.04**	**0.42**	**0.32**	**0**	**0.03**	**0**	**0**	**0**	**0.00**
Total collisions (inc. additional 2 western turbines)			**0.86**			**0.03**			**0.00**

APPENDIX 3. TERMS OF REFERENCE FOR THE COLLISON RISK MODELLING, AS AGREED WITH BIRDLIFE SOUTH AFRICA

BirdLife
SOUTH AFRICA
Giving Conservation Wings

Member of IUCN, International Union for Conservation of Nature and Natural Resources
Reg No: 001 - 298 NPO
PBO Exemption No: 930004518

19 April 2013

Dr Kilian Hagemann

Witberg Wind Power (Pty) Ltd

5th floor, 125 Buitengracht Street,

Cape Town

8001

Dear Kilian

BirdLife South Africa would like to thank you for considering our input in developing the attached Terms of Reference for the Bird Impacts and Mitigation Measures Review for Witberg. We confirm that we are happy with the proposed study, as outlined in the Terms of Reference.

We trust that the study results will assist Witberg Wind Power to make informed decisions with regards to the mitigation options available and ultimately ensure that impacts on birds are minimised.

We would like to thank you for your on-going commitment to find a mutually agreeable solution.

Yours sincerely,

Mark D. Anderson

Chief Executive Officer

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Terms of Reference

Witberg Bird Impacts and Mitigation Measures Review

1 Background

Witberg Wind Power (Pty) Ltd (WWP) is the holder of the environmental authorisation (EA) dated 13 October 2011 for the construction and operation of 40 wind turbines and associated infrastructure on a wind swept mountain ridge 9km west of Matjiesfontein, near Laingsburg in the Western Cape province of South Africa. As part of the conditions of the EA, and in accordance with an agreement with BirdLife South Africa, WWP has to conduct pre-construction bird monitoring in order to inform further mitigation measures that may be required in order to minimise any impacts the Witberg wind energy facility (WEF) may have on birds at or near the site. The bird monitoring has now been completed. In terms of the agreement with BirdLife South Africa and comments received from BirdLife South Africa dated 15 May 2012, the layout of the wind turbines must be adapted in response to the monitoring results and if necessary the number of turbines may need to be reduced.

Mitigation measures, such as curtailment, were dismissed as unfeasible by WWP, the avifaunal monitoring report therefore suggested that an offset site be implemented in order to compensate for any residual impacts that may remain after mitigation. BirdLife South Africa, as an important and concerned stakeholder to this process, has suggested that effort should be invested in avoiding negative impacts on avifauna rather than investing in the development of an offset. BirdLife South Africa has therefore requested that further mitigation measures and/or changes to the layout be considered in more detail. BirdLife South Africa has suggested that more detailed analysis of the available information, including collision risk modelling, would help ensure that decisions are made on the best available information.

2 Study Purpose

The purpose of this study would be to address BirdLife South Africa's concerns by:

1. Conducting collision risk modelling based on international best practice to determine and classify collision risk across the entire Witberg wind energy facility(WEF) site; and
2. Based on the results of the collision risk modelling and after considering the key issues outlined below, drawing up recommended mitigation measures in order to reduce the predicted impacts of the WEF on birds to an environmentally acceptable level.

3 Key Study Inputs

The study should be based on the following previously completed reports:

1. The original Avian Impact Assessment by Dr Andrew Jenkins dated October 2010
2. the "Pre-construction Monitoring Report" by Dr Jane Turpie of Anchor Environmental dated May 2012

The study should further be based on international best practice and experience from other countries with substantial onshore wind capacity installed and similar raptor concerns as encountered at

Witberg. Furthermore the study will require Rob Simmons' input as Anchor Environmental's local raptor specialist to discuss detailed habitat preferences and behaviour of the selected bird species of concern and examine other mitigation options in more detail.

The collision risk modelling must use the raw baseline monitoring data collected during the 12 month bird monitoring campaign conducted by Dr Jane Turpie from June 2011 until April 2012. Additionally several technical inputs such as turbine hub height, rotor diameter, mean rpm, and blade max chord width will have to be provided by WWP for this purpose.

4 Key Issues to be Considered

The following key issues must be carefully considered by the study:

- a broad review of the international literature as it pertains to sites and bird species similar to what is found at Witberg;
- best practice in collision risk modelling which should consider the entire Witberg area (to be supplied by WWP), irrespective of current bird nest buffers, to identify areas of low, medium and high bird collision risk, as well as no go areas if possible;
- the sensitivity, uniqueness and replaceability of the Witberg site;
- the biology and behaviour of Verreaux's Eagles, Booted Eagles, Martial Eagles and Black Harrier;
- the conservation worthiness of the various bird species at high risk of collision with rotating wind turbine blades and/or displacement caused by the WEF;
- a reassessment of the likely impacts on birds at the Witberg site, if necessary;
- alternative mitigation measures in lieu of or in addition to those measures already suggested, including but not limited to temporary curtailment of turbines with pro-active bird detection measures (e.g. radar or optics based); and
- a short comment on whether an offset site for bird conservation is both appropriate and practical in the circumstances.

A site visit must be undertaken by the specialist to enable a better assessment the issues listed above. BirdLife South Africa as well as WWP representatives would also be present at this site visit.

5 Collision Risk Modelling Methodology

The methodology of the Collision Risk Modelling (CRM) is herewith defined in the points below:

1. The method of CRM to be followed should be based on Band et al 2007 which is extensively used in the UK.
2. To keep the volume of work down and the results digestible the CRM shall only be carried out on the species of concern (Verreaux's, Booted, Marshall Eagles and Black Harrier) and not on all species present on site.
3. The study area for the CRM will be defined as the entire Witberg ridge (input provided by WWP) including all currently existing eagle buffer zones outlined in the Avian Impact Assessment by Dr Andrew Jenkins dated October 2010 and the "Pre-construction Monitoring Report" by Dr Jane Turpie of Anchor Environmental dated May 2012 (2.5km for Marshall, 1.5km for Verreaux's and 1.2km for Booted). These buffers (effectively No-Go areas) will be re-defined subject to the outcome of the CRM.
4. Considering that collision avoidance rates are not yet known for the species of concern, suitable overseas species should be used as a proxy, to be selected by the specialist.

5. The CRM will be used to test some scenarios and different layouts e.g. original layout, current layout and a hypothetical 50-70 turbine layout used only to select the at most 32 lowest risk turbine positions. This would be done purely in a modelling fashion to indicate potential mortality rates.
6. To account for turbine availability levels per month, an average annual figure such as 90% should be used across the year, taking account of down time for O&M as well as wind speeds.

6 Requirements of Specialist

The specialist must meet the following requirements:

1. have substantial ornithological skills and expertise;
2. have at least two years of experience with wind farm impact assessment with emphasis on birds, including at least three operational wind farm projects; and
3. have at least two years of experience with the application of collision risk models to predicting bird impact risk.

7 Report Requirements and Output

The deliverable must be a comprehensive report written in English which is prepared for Witberg Wind Power (Pty) Ltd. In addition to standard methodology, analysis and results sections, the report must include at least the following:

- a literature review;
- as an appendix, the skills expertise and experience of the specialist(s) involved in drawing up the report;
- a statement of independence from WWP and the Witberg WEF; and
- Detailed discussion on recommendations for avoidance and/or mitigation of the impacts and alternative mitigation measures vs. the offset proposed.