Shoney (Seonaidh) Wind Limited

INYANDA ROODEPLAAT WIND FARM: ORNITHOLOGICAL REVIEW AND ASSESSMENT UPDATE: FINAL REPORT

30 JUNE 2015

Inyanda Roodeplaat Wind Farm

Ornithological Review and Assessment Update: Final Report

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Statement of Independence: Shoney Wind Limited and its subcontractor Ecology Consulting were contracted by Afri-coast Engineers to review the baseline data and the assessment of ornithological impacts for the Inyanda Roodeplaat wind energy facility (WEF). Neither Shoney Wind Limited nor Ecology Consulting are subsidiaries or affiliates of Afri-coast Engineers, and both are independent of the Inyanda Roodeplaat WEF.

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INTRODUCTION

SECTION 1 - INTRODUCTION

This report reviews the baseline data and the assessment of ornithological impacts for the Inyanda Roodeplaat wind energy facility (WEF). It updates the previous interim report on the work completed on Tasks 1-3 and 6 listed below and completes the work for the other outstanding Tasks.

Potential impacts on Verreaux's Eagle have been identified by the client's ornithological consultants as a key issue at this site. This report here provides an international expert review of the information available and how best to address this issue (and any other ornithological impacts) going forward.

A review of the available documentation (including a draft ornithological assessment), has identified key gaps to be addressed as: quantitative assessment of effects, particularly in relation to collision risk and its potential population impacts, inclusion of more reference to experience of similar species at existing wind farms and more discussion of potential mitigation measures (including the extent of design mitigation buffer zones).

Project Tasks

1. Review baseline data currently available
2. Review draft ornithological impact assessment
3. Produce advice note on ornithological issues based on 1 and 2, including gap analysis identifying additional work required.
4. Undertake site visit
5. Provide wider review of relevant literature
6. Carry out quantitative collision risk modelling for key species
7. Recommend ornithological mitigation measures
8. Incorporate 5, 6 and 7 into an ornithological assessment to support the main assessment.

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 Inyanda Roodepeaat (such as Golden Eagles in Scotland and the USA, White-tailed Sea Eagles in Norway and raptors in Spain).

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

The detailed scope of works was as follows:

1. Review the information currently available on the baseline conditions at this site.

This included the following documents:

- Ornithological baseline reports by Jon Smallie of Wildskies Ecological Services (no. 1 August 2013, no. 2 February 2014 and no. 3 June 2014), including raw data.
- “Black Eagle Nest Survey 2013” by A. Barkhuysen (15-9-13).
- “Survey of Verreaux’s Eagle and other cliff-nesting birds in the vicinity of the proposed Inyanda-Roodeplaat wind farm site near Uitenhage, Eastern Cape” by Andrew Jenkins and Johan du Plessis (August 2014).

The aims of this part of the work were to:

- Determine the adequacy of the baseline data against relevant current guidance
- Identify any data gaps
- Review the reporting of the baseline conditions

2. Review the ornithological assessment work that has been undertaken to date:

A draft ornithological assessment entitled “*Avifaunal Impact Assessment*” has been produced by Jon Smallie of Wildskies Ecological Services, initially dated November 2014 and then updated in February 2015. The review of that document has included:

- Assessment methodology
- Results of the assessment and conclusions reached
- Effectiveness of mitigation proposed

3. Produce an advice note on ornithological issues

This task comprised a high level review the overall proposal in light of the outcome of Tasks 1 and 2, providing advice on whether further survey and assessment work may be required, and setting out a route map to address eagle and any other ornithological issues at the site.

4. Site Visit

A site familiarisation visit was undertaken in April 2015, to provide an on-site assessment of the survey methodology (checking survey locations and methods) and the site’s bird populations. This has enabled a better appreciation and assessment of the ornithological issues to be made.

5. Literature Review

A wider review of the relevant literature has been provided, as it pertains to sites and bird species similar to those found at Inyanda Roodeplaat.

6. Collision Risk Modelling.

Collision risk modelling has been carried out, based on international best practice to determine and classify collision risk across the Inyanda Roodeplaat wind energy facility (WEF) site. The methodology used for the Collision Risk Modelling (CRM) was as follows:

- The CRM has been undertaken following the method of Band et al. 2007, as extensively used in the UK (and for which we have very considerable experience).
- The CRM has been carried out on the two key species of concern (Verreaux's and Martial Eagles), though other species have been considered where there could be potential for a significant collision risk.
- The study area for the CRM has been defined as the entire Inyanda Roodeplaat WEF for which baseline data are available. The appropriateness and benefits from applying the buffers proposed in the draft ornithological assessment (2.5km for Martial, 2km for Verreaux's Eagle) has been tested with the field baseline data.
- Considering that collision avoidance rates are not yet known for the species of concern, suitable overseas species have been used as a proxy. Avoidance rates have been applied following Scottish Natural Heritage (SNH) guidance and with reference to the bird-wind farm literature (in particular for eagle species). As recommended in SNH guidance a precautionary 98% avoidance rate has been adopted as a default value 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 avoidance rates to be used). The collision risk modelling results has been presented for a range of avoidance rates to inform the assessment but as part of work it has also been determined the most appropriate to apply in this specific case.
- The CRM has focused on the current proposed 55-turbine layout, the same layout as used by Jon Smallie in his draft ornithological assessment report.
- An average annual figure of 90% turbine availability has been used across the year, to take into account down time for O&M as well as wind speeds.
- Technical inputs such as turbine hub height, rotor diameter, rotor rotational speed and blade maximum chord width have been provided by Afri-Coast Engineers SA (Pty) Ltd for the collision modelling, and where uncertainties exist as to any specifications of the turbines to be chosen a worst-case approach has been adopted to deliver a precautionary but robust analysis.

7. Mitigation Measures.

Mitigation measures have been proposed, based on the results of the collision risk modelling and after considering the key issues to ensure that the predicted impacts of the WEF on birds are at an environmentally acceptable level. This included specific consideration of the ornithological benefits that could accrue from the proposed stewardship agreement and how those benefits could be maximised.

8. Ornithological Assessment Update

Tasks 5, 6 and 7 have been incorporated into an ornithological assessment addendum to support the main assessment. Additional range analysis is also provided to inform the assessment of disturbance/displacement.

SECTION 2

REVIEW OF BASELINE DATA AVAILABLE

SECTION 2 – REVIEW OF BASELINE DATA AVAILABLE

The raw baseline ornithological data available were collected during a 12 month monitoring campaign organised by Jon Smallie. This was carried out between July 2013 and May 2014, with an additional breeding eagle survey in July/August 2014.

Surveys were stated to have been designed to follow the BirdLife South Africa (BLSA)/Endangered Wildlife Trust (EWT) best practice guidance (Jenkins et al 2012, 2014) guidance. Jon Smallie is also listed on the BirdLife South Africa web site[1] as one of the consultants that has "*agreed to conduct their work in accordance with the Best Practice Guidelines*".

A range of surveys were conducted, including a preliminary desk study, walked transect surveys for small terrestrial birds, vehicle-based transect surveys for large terrestrial species and raptors, eagle breeding/nest surveys and vantage point surveys to quantify/map key species flight activity. It is the latter two of these that provided the main data set for the key raptor species that comprised the major ornithological issue at this site, and it is therefore these that provide the main focus of this report. The other surveys did not raise any significant ornithological issues so have not been considered further in this report.

Flight Activity Data

The July 2013 – May 2014 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 (within an active Verreaux's Eagle territory).

Bird movements were monitored by two observers at each of three vantage points at the WEF site and one at the control site, located about 3km to the north-east from the WEF site (Figure 1). The vantage points were strategically chosen to achieve maximum coverage of the study area, though there was some overlap between their viewing areas and areas of the WEF site that were not visible from any VP. Surveys were spread throughout the day, with each VP surveyed over 'early to mid-morning', 'mid to late morning', 'early to mid-afternoon', and 'mid-afternoon to evening'. Each session was 3 hours long, resulting in a total of 12 hours of observation being conducted at each vantage point on each site visit. Three hours was considered to be the upper limit of observer concentration span (in line with current UK guidance). Observations involved continuous slow scanning of a 360° area, alternately with telescopes and binoculars. A 2km viewing distance was stated to have been used (again in line with current UK guidance). All target species flight paths were 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);
- Flight height above ground, estimated as accurately as possible;
- Horizontal distance from the observer at start of observation;
- Direction of flight;

[1] http://www.birdlife.org.za/conservation/terrestrial-bird-conservation/birds-and-renewable-energy. Accessed 14-5-15. See link to 'Specialists 2015'.

- Flight path plotted on map.

Actual flight height was estimated rather than assigning flight height to broad bands. As noted in the baseline report, this allowed flexibility in assigning to classes later on depending on final turbine specifications. Smallie states that flight height estimation was difficult and that his data should be treated cautiously but it is not clear how this was achieved. Smallie used a height of 30m as the lower threshold for flights at rotor height, which, given that heights were estimated to 10m means that all flights recorded as being above 25m were considered as being at rotor height. The actual distance between the lowest point of the rotor blade and the ground would depend on the exact turbine model chosen, but would likely be in the range 32.6-37.5m (unless a much higher hub height was used, as would be an option for one turbine model). This is considered to be appropriately precautionary given the difficulties in accurate estimation of rotor height in such uneven terrain.

These data were then digitised in ArcGIS for subsequent analysis.

The surveys recorded a range of key species, including Verreaux's Eagle, Martial Eagle, Booted Eagle and Black Harrier, though the overall flight activity was quite low apart from in the vicinity of an active Verreaux's eagle nest (VP4 was selected to observe this nest but was located outside the proposed wind farm – see Figure 1 and 1b). The main focus of this review was the most frequently observed key raptor species, Verreaux's Eagle. Its recorded flight lines are shown in Figure 1 of this report in relation to the VPs and proposed wind turbines, and also in Figure 1b (which just shows the flight lines and VPs in order to pick out the flight lines more clearly). The other key raptor species have also though been considered (including using collision modelling).

Eagle Breeding/Nest Surveys

Two eagle breeding surveys of the site were commissioned as part of the baseline surveys, from which the following reports have been produced:

- Barkhuysen, A. 2013. Black Eagle Nest Survey for the proposed development of the Roodeplaat WEF on the farm Perdehoek (northwest of Uitenhage).
- Andrew R. Jenkins, A.R and du Plessis, J. 2014. Survey of Verreaux's Eagle and other cliff-nesting birds in the vicinity of the proposed Inyanda-Roodeplaat wind farm site near Uitenhage, Eastern Cape. AVISENSE Consulting report.

The 2013 survey identified five Verreaux's Eagle nest sites. Surveys were carried out during August and September 2013. Active nests (with chicks or eggs) were recorded at four of these five sites. A pair was present at the fifth (behaving as if breeding) though the traditional site was not being used and no alternative site was located. The author of the 2013 report has specific local knowledge of the area, having initiated a nest search and monitoring project to determine the density and breeding success of Black eagles between the towns of Uitenhage and Steytlerville. This found a population of 27 territories with active eagle pairs in this area, with 13 along the northern slopes of the Groot Winterhoek mountain range (stretching 50km in a linear line) and the rest in a more open area (over a 90km distance). The five nests at/around the WEF site form part of the 13 pairs. The author also noted 14 non-territorial adult Black eagles seen regularly within the mountain range.

The 2014 survey was carried out in late July/early August 2014 by Avisense Consulting. Coverage of the proposed development area was described by the report authors as "*adequate but far from complete*". Four of the five sites recorded in the previous year's surveys were checked (the 'missing' one being further from the WEF and hence less likely to be affected by it). Verreaux's Eagle pairs were present at all four of the checked locations, definitely breeding at one, probably breeding at a second, possibly breeding at a third, and probably not breeding at the fourth. An additional Verreaux's Eagle nest site was located in the south-west of the proposed development area, which contained an incubating/brooding adult. The 2014 report concluded that the 2013 survey was "*completely accurate and reliable*", though did have an additional nest in 2014 and also commented that "*this region could easily hold a seventh pair somewhere to the east along the river, on one of the many cliffs that we weren't able to assess*".

It would appear from the comment made in relation to the survey adequacy and the results that the 2014 survey was a less intensive survey that the 2013 one (though covered a wider area), with greater uncertainty as to the status of the key nest sites. However it is still clear that most eagle sites were occupied in both years. Most of the eagles were observed using the same nest sites as previous surveys, though an alternative site was used in one case.

The 2014 survey also reported an active Martial Eagle territory to the south of the central ridge-line of the wind farm site, in a forested ravine. The authors noted that "*we did not have sight of the contents of this nest, but the behaviour of the attendant adults suggested that it contained a developing chick*", and in further communication with the client confirmed that no nest was actually seen and that their conclusions had been based on the behavior of the adult pair. There remains therefore a degree of uncertainty as to the status of this observation, in terms of a lack of confirmation of breeding and of the location of any such breeding. It is clear though that a pair was probably breeding in this area.

An African Crowned Eagle was also reported in the 2014 survey, though only a single sighting. That survey identified that there was more suitable habitat for this species to the east and west of the site that could hold a pair (though no specific evidence of that was included in their report). Adri Barkhuysen (pers comm) indicated that there are many nests in the moist, forested on the southern side of the mountain but as perch hunters they would be likely to make little use of the open ground in which the WEF would be located (as found in the VP surveys).

Incidental flight lines were observed during the breeding surveys but these are of less value in assessing the collision risk than the more systematic recording of flight activity over the wind farm site during the VP surveys.

The 2013 survey was more focused specifically on Verreaux's Eagle but did comment that this mountain range provides suitable habitat for Martial Eagle (and African Crowned Eagle) as well as the Verreaux's Eagle.

Baseline Data Issues

Coverage of wind farm site – the area of airspace visible at the minimum height above ground of the lowest part of the rotor swept area (32.6m, the minimum height from the ground of all of the turbines being considered) from each VP is shown in Figure 1. This shows the zone over which all target species should have been visible from the VPs when flying at a height that could potentially put them at risk of collision with the rotors. This is based on relatively coarse digital terrain data (Shuttle Radar Topography Mission data obtained from the USGS web site) but is considered sufficient for this analysis (and has now been ground-truthed during the site visit).

This Figure highlights a number of issues with the baseline data:

- **Coverage gaps** – there are substantial parts of the wind farm (20 of the 55 proposed turbine locations) that are not within the stated 2km viewing area of any VP (and 27 fell outside the viewing area when further limitations on viewing are considered). This required assumptions to be made about flight activity in these areas for input into the collision modelling (carried out for this report), adding further uncertainty to that assessment.
- **Overlap of viewing areas** – there is substantial overlap in the viewing areas of VP 2 with both VP 1 and VP 3). This should be taken into account in any analysis, as the viewing time of these overlap areas is effectively twice that of the other parts of the survey area (as they were viewed from two VPs). However, limitations to the viewing distances (see below) make this less of an issue that it would be with a full 2km distance, as the actual effective viewing areas had less overlap between VPs.
- **Potential incomplete recording of flight lines** – many of the flight lines are short and terminate in areas where eagles would have been expected to still be visible from the VP.
- **Viewing distances** – it was reported in the survey methodology that a 2km maximum viewing distance was adopted. However, examination of the raw plotted flight lines in Figure 1 and 1b suggested that flights were recorded much less frequently in the 1-2km zone from the VPs than within 1km.

Further analysis of the data has been carried out for one key species for which detectability would be expected to be high and for which there was sufficient data for that analysis, Verreaux's Eagle. The Verreaux's Eagle flight lines observed from each of the four VPs are shown in Figure 1. If, as set out in the methodology description, viewing was effective to 2km, then the eagle flight activity would be expected to be approximately uniform across the 0-2km zone from the VP (though not in the case of VP4 as that contained an active eagle nest), taking into account the visible viewing area.

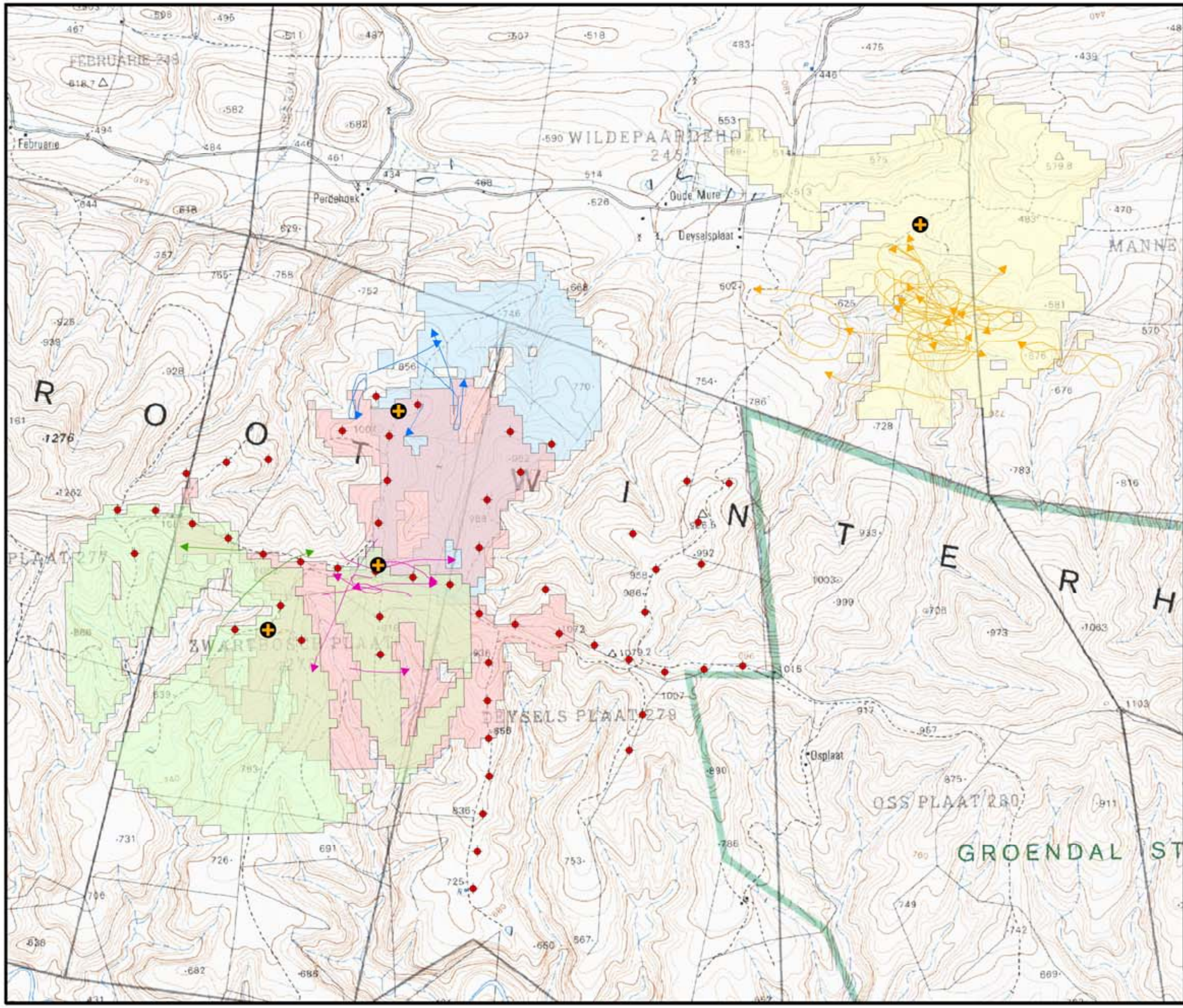

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FIGURE 1

Vantage Point Survey 2013-14 Viewsheds (airspace visible at 32.6m above ground to 2km from VP)

KEY:

- Vantage_points
- Proposed wind turbines

Verreux's Eagle Flight Lines

- VP1
- VP2
- VP3
- VP4
- VP1 Viewshed
- VP2 Viewshed
- VP3 Viewshed
- VP4 Viewshed

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Base map from Chief Directorate National Geo-spatial Information of South Africa: reprojected and collar-cropped for seamless mosaic by MadMappers.com

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ORNITHOLOGICAL ASSESSMENT REVIEW FIGURES MAY 2015

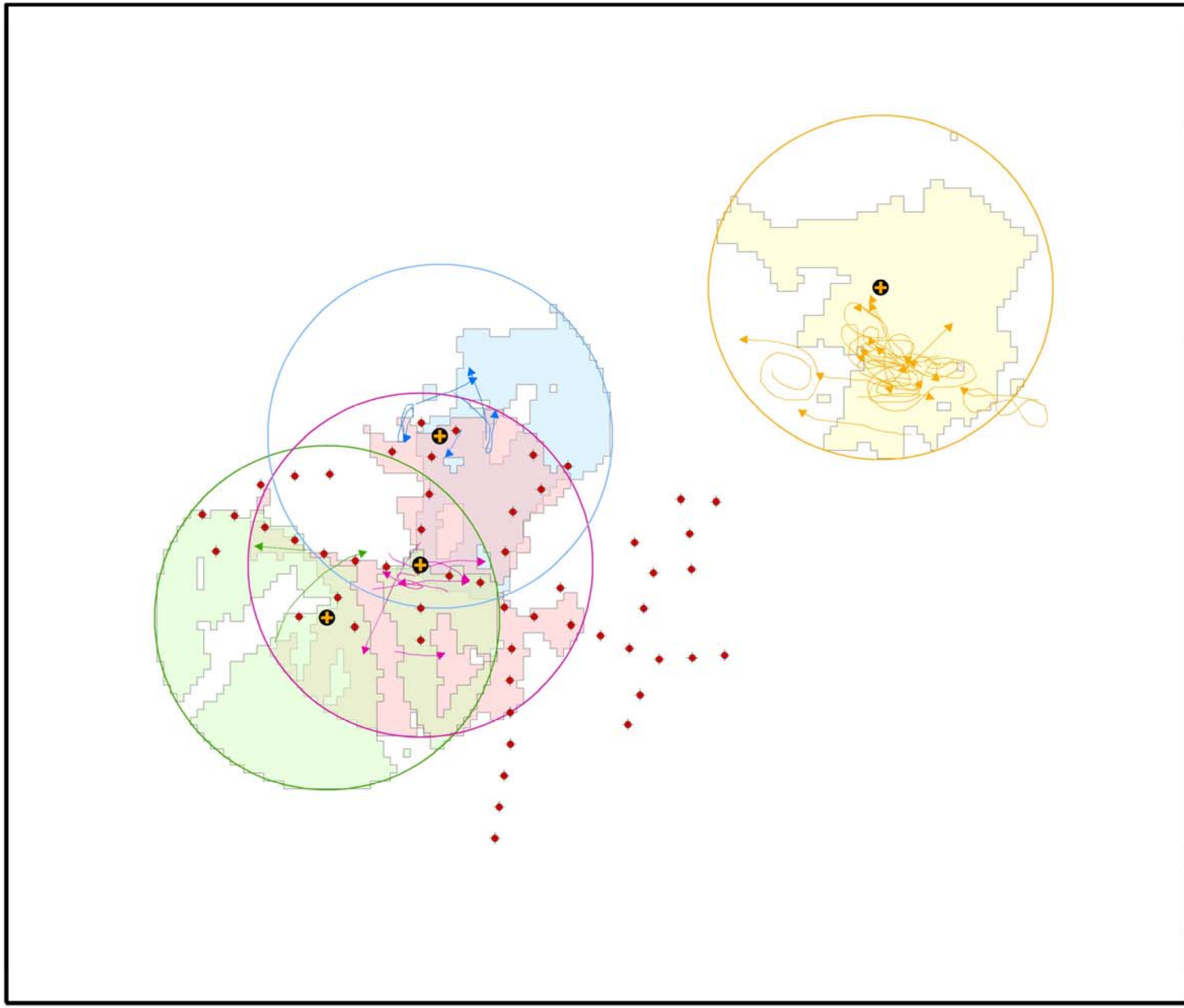

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FIGURE 1b

Vantage Point Survey 2013-14 Viewsheds (airspace visible at 32.6m above ground to 2km from VP)

KEY:

Vantage_points

Proposed wind turbines

Verreux's Eagle Flight Lines

VP1

VP2

VP3

VP4

VP1 Viewshed

VP2 Viewshed

VP3 Viewshed

VP4 Viewshed

VP 2km buffer

VP1

VP2

VP3

VP4

ECOLOGY CONSULTING

N

Base map from Chief Directorate National Geo-spatial Information of South Africa: reprojected and collar-cropped for seamless mosaic by MadMappers.com

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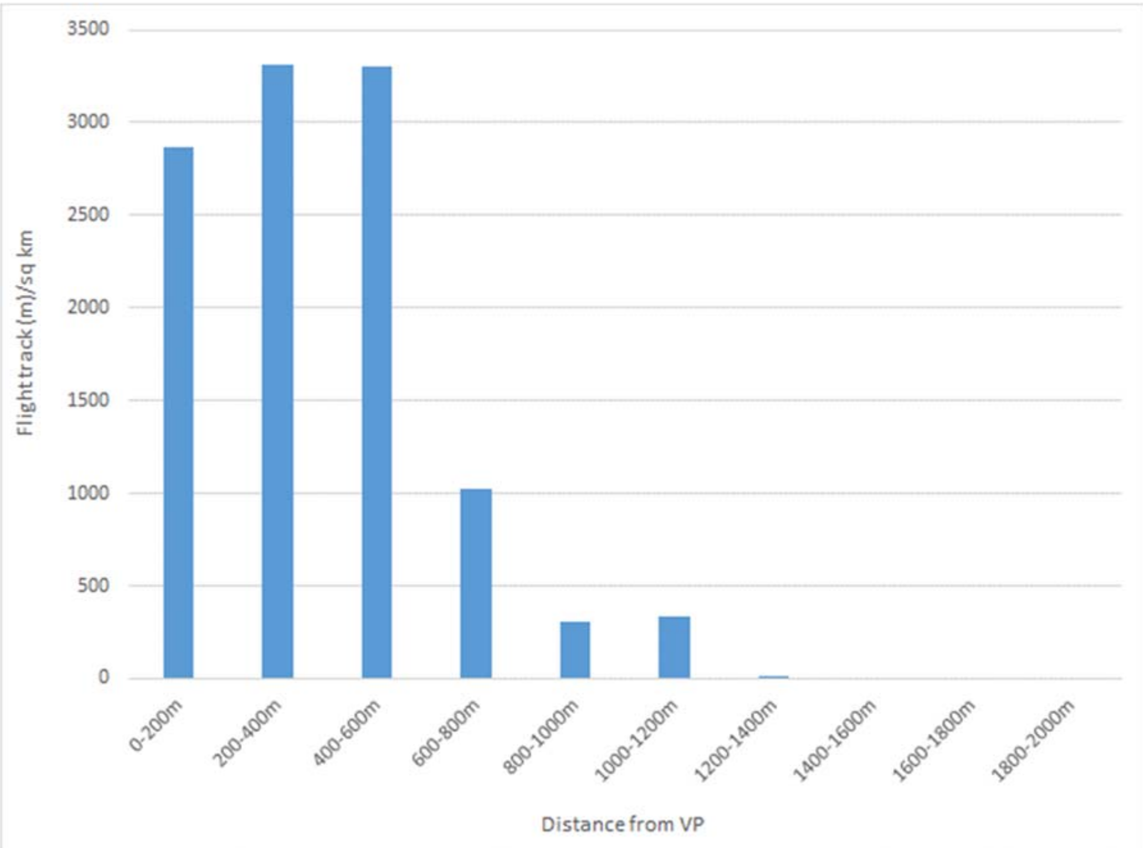
SCALE - 1:50,000 @ A3

ORNITHOLOGICAL ASSESSMENT REVIEW FIGURES MAY 2015

Figure 2 shows the flight track lengths recorded in the Smallie pre-construction surveys in 200m distance bands from the main site VPs (VP 1-3), allowing for the visible area in each band (hence presenting the data as track length per unit area visible at 32.6m above ground level). Eagle flight activity was relatively high in the three 200m bands closest to the VPs, but beyond that there was a major decline in recorded activity. This is also shown visually in Figure 1 and 1b, where there are very few flight lines further from the VPs. There was very little recording of Verreaux's Eagle beyond 600m and none beyond 1400m from the main three VPs within the wind farm site. This is difficult to explain given that this is such a highly detectable species. This question was raised with Jon Smallie, who clarified that the low initial detection distances could have resulted from the fact that observers scanned only with the naked eye (and only used binoculars to follow birds and track them after they had been initially detected by eye). This does not however explain the almost complete absence of flight activity beyond 1.2km from all three vantage points.

Many of the mapped flight lines are unexpectedly short (as noted above). The result is very important in the main analysis though, in that the coverage gaps may actually be substantially greater than those identified from Figure 1 - these results suggest that there was not effective viewing to the stated 2km.

Figure 2. Verreaux's Eagle flight activity in relation to distance from vantage points (VPs 1-3 covering the main WEF site).



The same analysis for the Smallie pre-construction survey data from VP4 adjacent to an active eagle nest (Figure 3) showed recording over a much greater distance, and fits better with what would be expected from such surveys (with flights up to 2km recorded). A peak of eagle flight activity was recorded 800-1000m from the VP, though this would not be entirely as expected, given that the nest site was located 1500m to the SSE of the VP.

Figure 3. Verreaux's Eagle flight activity in relation to distance from vantage points (VP 4 covering an eagle nest site).

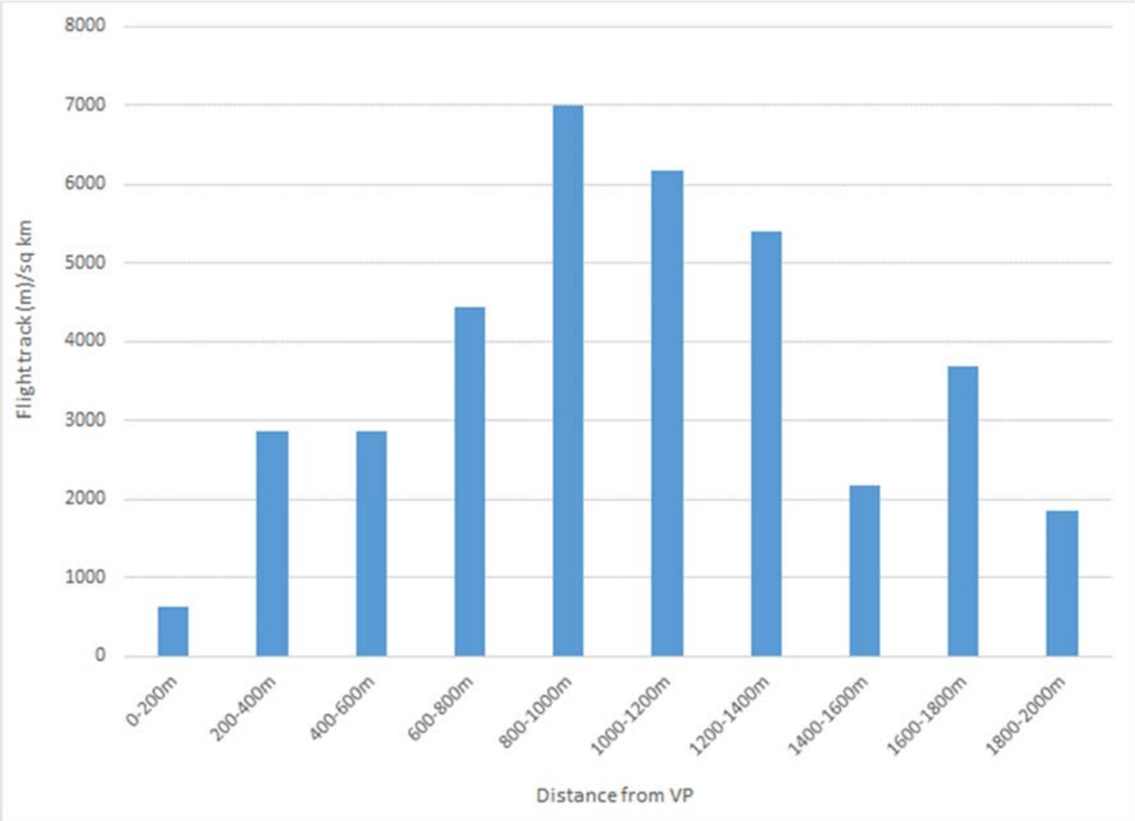
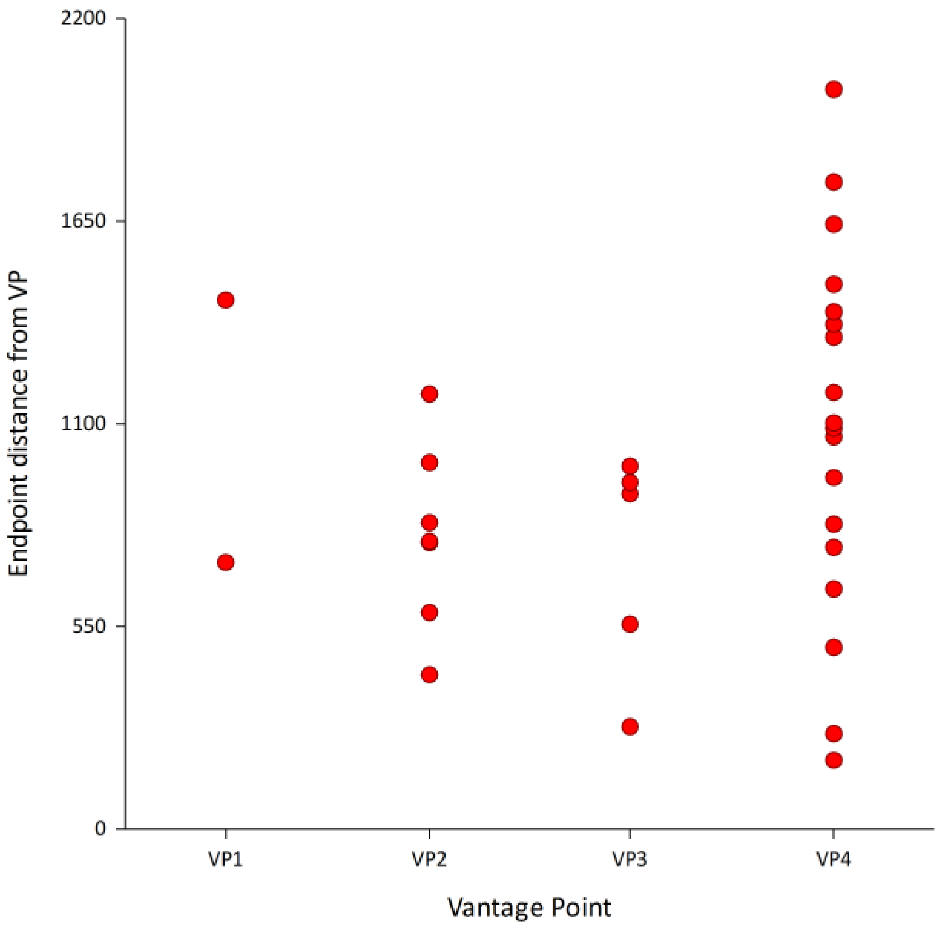


Figure 4 shows a dot plot of the distributions of the endpoint locations of each Verreaux's Eagle flight from each VP from the Smallie pre-construction survey data. This further highlights the relatively short distances (to the stated 2km viewing distance) at which the eagles were being recorded as disappearing from view, particularly from the three main site VPs (1-3).

Figure 4. Dot plot of distances (in metres) of Verreaux's Eagle flight line end points from each of the four vantage points.



This rather limited apparent viewing distance is surprising as much greater distances have been achieved in similar environments elsewhere. For the Witberg WEF, for example, it was agreed with the local ornithological expert that 3km viewing was a reasonable assumption (and some observations in that study ranged to 5-6km) (Percival 2013).

This reduced viewing distance has been discussed in detail with Jon Smallie. His primary explanation was that all scanning during the vantage point surveys was done by naked eye rather than by using binoculars (in his words to try to standardize viewing effort) then tracking birds with binoculars once they had been spotted by naked eye. This limited viewing was exacerbated by the fact that large areas were viewed against land rather than sky (reducing detectability further). Actual coverage was initially confirmed by Jon Smallie as 1km (which would have included only 19 of 55 turbine locations), though he subsequently accepted in further discussion that the 1km viewing limit would only have been applicable to birds viewed against the ground, and that Verreaux's Eagles could be seen with the naked eye against the sky up to 2km from an observer.

For any robust assessment of the effect of a wind farm on large raptor species it would be usual best practice to have baseline data from large majority of turbine locations (current BLSA/EWT guidance, Jenkins et al. 2014, for example recommends a minimum 75% coverage). Such a baseline would be required for any informed collision risk assessment, whether carried out as a qualitative assessment (as by Jon Smallie) or quantitative collision modelling.

Reliable flight activity data are also essential to provide advice on site design to reduce collision risk. Normally data on the spatial patterns of key species flight activity would be used to avoid particular concentrations of flight activity where possible to reduce risk. However flight activity over a large part of site cannot be determined from baseline surveys due to lack of coverage.

In order to address this issue further, the author of this report undertook some further field tests of Verreaux's Eagle viewing distances during a site visit in April 2015. This work was focused on observations from VP4, within the Holbak eagle range, where Jon Smallie reported been considerably more Verreaux's Eagle activity in his assessment report.

As expected, higher flight activity was observed at VP4 during these observations, with a total of 35 minutes eagle flight activity logged during a three-hour observation session on 24/4/15. In comparison no Verreaux's Eagles at all were recorded within the wind farm collision risk zone during nine hours observations from VPs 1-3 (3 hours at each of these three VPs during 20-24/4/15).

It was immediately clear from these field surveys that in clear viewing conditions Verreaux's Eagles could be seen against the sky with the naked eye at considerably greater distances than 1km. Rather they could actually be seen with the naked eye at up to 2km. It was true that against the ground detectability by eye was much reduced, and a 1km detection distance in that case was reasonable.

As a result, the effective coverage from the survey VPs reported by Jon Smallie would have been dependent on the viewing area. Verreaux's Eagles should usually have been detected at approximately 1km when viewed against the ground and at approximately 2km when seen against the sky.

The author also undertook a field survey (as well as a desk-based GIS assessment from a digital terrain model) to determine the viewing of each of the turbines' rotor swept areas, estimating the percentage of each swept area that would be against the sky for each turbine location. These data were then used to determine the overall proportion of the collision zone viewed against sky (and hence with 2km viewing distance), to achieve a more realistic estimate of the actual viewing zones. The locations of the turbines that could be viewed at these distances (and those that fell outside the VP viewing area) is shown in Figure 5.

One key consequence of the vantage point survey coverage relating to the ornithological assessment is that the incomplete coverage of the wind farm means that advising on site design to reduce collision risk is very challenging. There are simply no data for the eastern part of the wind farm, or from the areas of reduced cover within the other parts of the wind farm. It would normally be good design practice to undertake modelling to explore the collision risk for a range of possible layouts to demonstrate to both the regulator and the developer the benefit of altering layouts. Good iterative design can make a very useful contribution to the mitigation of potential impacts. Such an approach was adopted successfully, for example, at the Witberg wind farm in the Western Cape (Percival 2013). However, it should also be noted that for this site there are considerable limitations on alternative layouts due to topography.

A further problem here is the disappearance of the eagles at rather shorter distances than 2km from observer (Figure 4). Jon Smallie has stated that his observers followed target birds with binoculars once spotted by naked eye, so whilst initial detection was reduced this should not have affected the subsequent tracking (which should have been to at least 2km where visibility was not impeded by topography). It remains unclear as to how this has happened. Jon Smallie has suggested several possible explanations; "*birds are not always detected immediately as they enter the survey area; birds are sometimes lost for various reasons, they are obscured from view by topography, weather etc,, they land, they may disappear against a dark background, in which case a decision has to be taken whether to stop the record or hope to re-detect the bird.*" None of these would however in my opinion fully explain the clear spatial concentration of flight activity in relation to distance from the vantage points. It is though clear that this problem is specific to the wind farm site and not the VP closer to an eagle nest at Holbak (VP4).

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. Additionally two observers were used at each VP simultaneously, so effectively giving 180 degree viewing per observer.

In summary regarding the Vantage Point Surveys, the key issues are that birds have been recorded over limited distances (not the full 2km stated), that mapped flight lines frequently cover only short distances, even for apparent direct flights through the observation area, and that the overall effective coverage of the WEF was low (covering only 28 of the proposed 55 wind turbines). This is still sufficient to enable a quantitative assessment to be made of the risk that the wind farm would pose to the birds in the area, but these issues do need to be taken into account in the assessment process, and the confidence in the outcome of that assessment is reduced.

Breeding Survey Issues

The main concern with regard to the eagle breeding surveys was the variation in the locations of nests reported by different authors. For Verreaux's Eagle, whilst the reported locations of the nests recorded as Perdehoek, February and Tygerberg were consistent, those of the Holbak and Guntia nests were not. Following confirmation from Adri Barkhuysen, the position of the Holbak nest used in 2013 had been mis-plotted by Jon Smallie in Figure 6 of his November 2014 draft assessment report, though that has now been corrected. The actual site lies about 750m to the south of the one plotted. The older Holbak nest was also been wrongly plotted – this should be 1.4km south from its location in Figure 6 of Smallie's November 2014 report. The Guntia nest was also wrongly plotted on Figure 6 – it was actually 2.5km to the ESE of its plotted location. This mis-plotting has now been addressed and definitive locations identified. However it would appear that the choice of location of VP4 which was specifically set up to observe over a Verreaux's Eagle nest site was not optimal for the actual nest site (which was located further from the VP behind a ridge and hence with a substantial part of its flight area in proximity to the nest that was not visible).

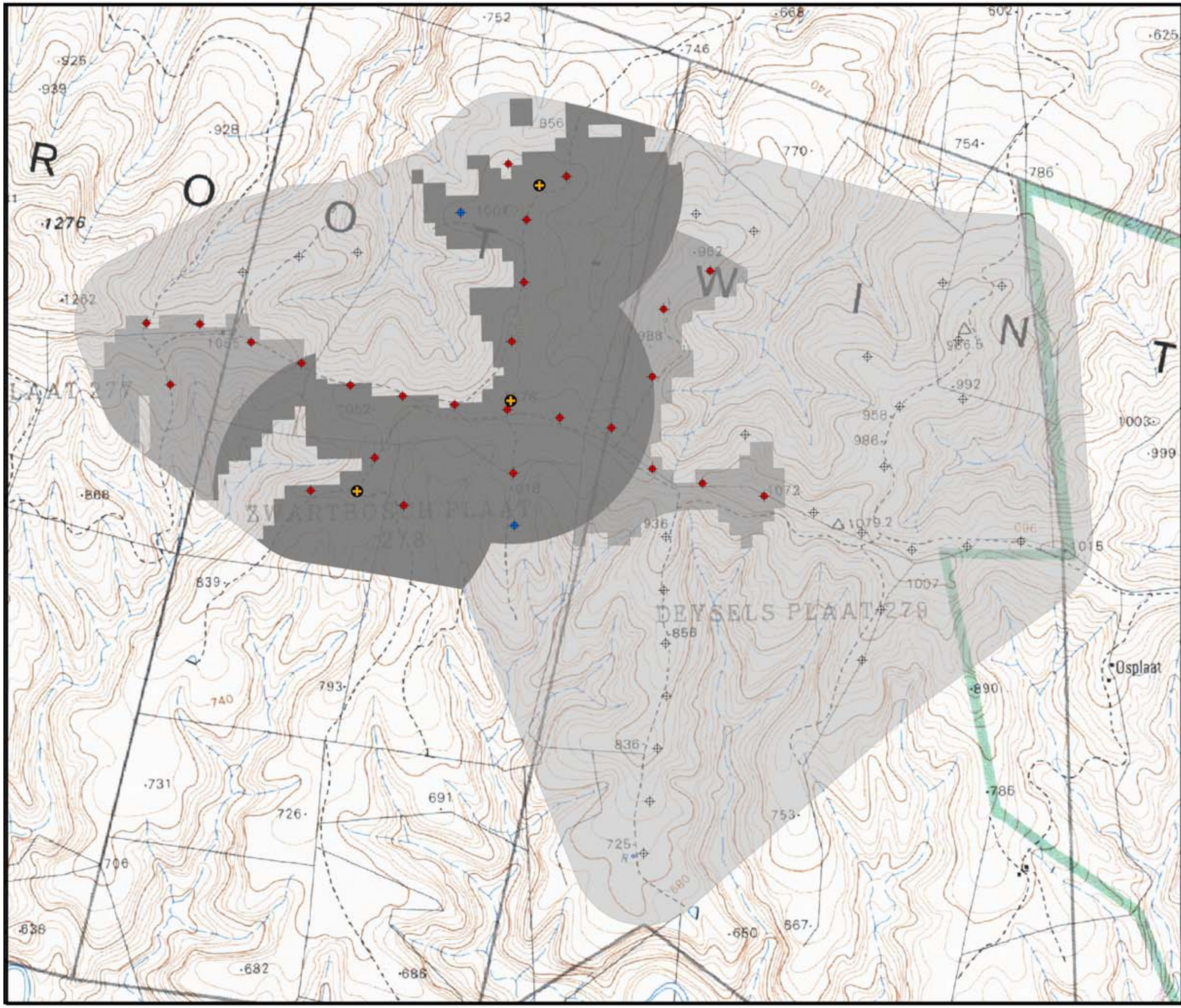
Jon Smallie has added a comment in his updated draft report that eagle nest sites are not fixed (as exemplified by the Holbak nest, for example) and may move location over the lifetime of the wind farm. Whilst this is true and does need consideration in the ornithological assessment, it does not negate the fact that current/historic nesting locations should be accurately reported.

Table 1 gives the actual confirmed distances between the nest locations and the nearest proposed wind turbine for the 55-turbine layout.

Table 1. Verreaux's and Martial Eagle nest sites and distance from nearest proposed wind turbines.

Nest site	Distance from nearest proposed turbine (km)	Altitude of nest site (m)	Comments
Perdehoek	1.4	667	
February	3.4	693	
Tygerberg	5.0	590	
Holbak I	2.4	591	
Holbak II	2.3	619	Alternative site used in 2013, 300m NW from site used in 2003 and 2007
Guntia	8.5	593	
New Verreaux's Eagle site found in 2014	4.1	553	
New Martial Eagle site found in 2014	2.3	597	Nest site not confirmed but behavior suggested nest with young. Extent of suitable nesting habitats – woodland within gorge – limited in extent.

The confirmed nest locations are shown in Figure 6 in relation to the proposed 55-turbine layout.



Shoney (Seonaidh) Wind Limited

Inyanda Roodeplaat Wind Farm

FIGURE 5

Wind farm collision risk zone, proposed wind turbine locations and viewing zones

KEY:

Proposed Turbines

- Viewed against sky <2km
- Viewed against ground <1km
- Outside viewing area
- Vantage points
- VP 1-3 viewshed <1km
- VP 1-3 additional viewshed 1-2km against sky
- Collision Risk Zone (500m buffer)

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N

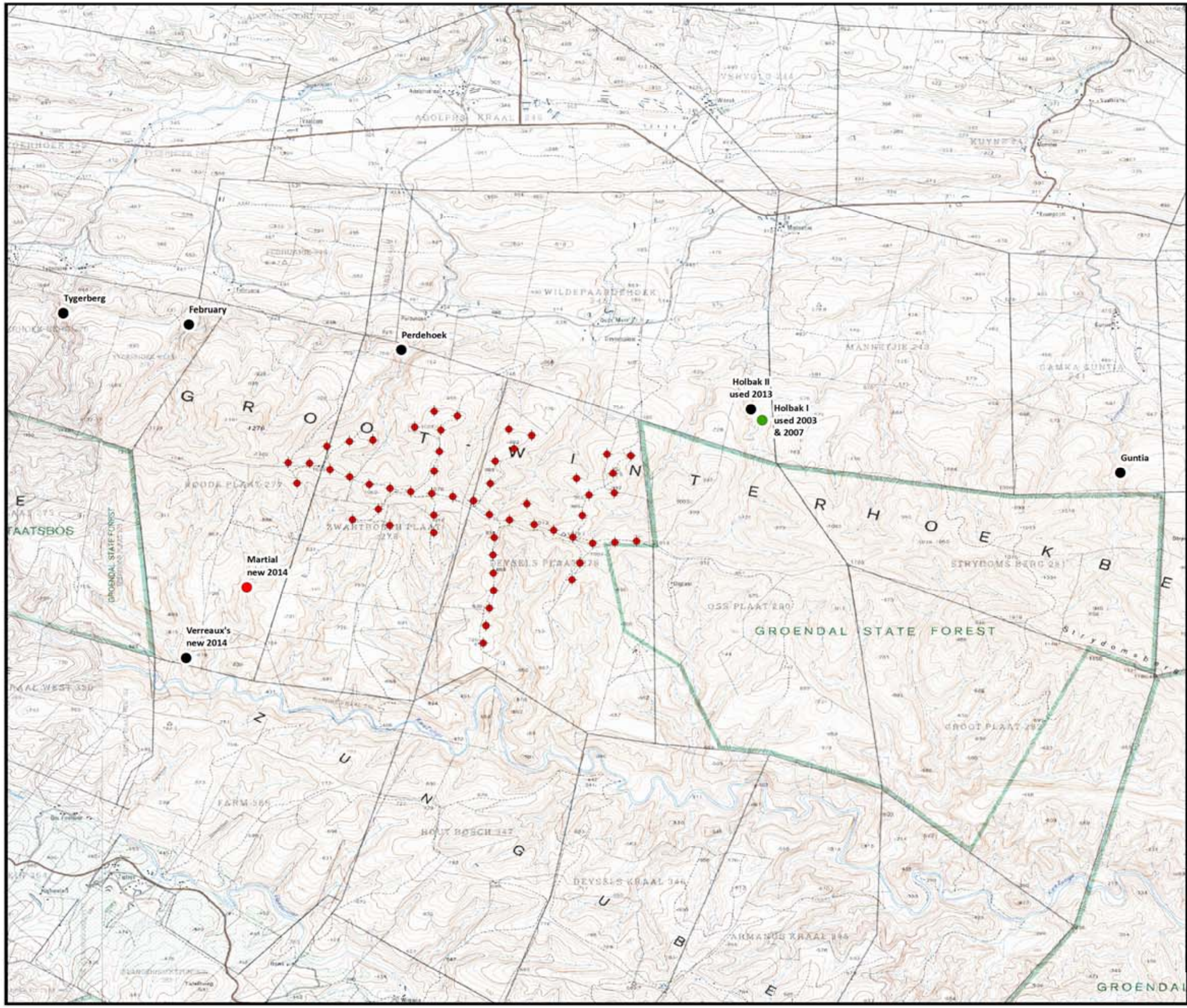
Base map from Chief Directorate National Geo-spatial Information of South Africa: reprojected and collar-cropped for seamless mosaic by MadMappers.com

LAYOUT DWG	N/A	T-LAYOUT NO.	N/A

DRAWING NUMBER: EC2015-1

SCALE - 1:25,000 @ A3

FINAL REPORT
FIGURES MAY 2015



Shoney (Seonaidh) Wind Limited

Inyanda Roodeplaat Wind Farm

FIGURE 6

Verreaux's and Martial Eagle Nest Locations

KEY:

- 55-turbine layout

Eagle nest sites

- Martial Eagle (estimated)
- Verreaux's Eagle
- Verreaux's old site

ECOLOGY CONSULTING

N

0 0.5 1 2 3 4 Kilometres

N/A N/A

EC-2015-1

SCALE - 1:75,000 @ A3

ORNITHOLOGICAL ASSESSMENT REVIEW

The rationale as to the extent of the breeding eagle survey area was unclear in the draft report but further correspondence has confirmed that it covered all of the areas that were considered by the surveyors could feasibly contain breeding pairs of eagles and other raptors that could be affected by the development. As a result, this coverage for the breeding eagle survey appears to be satisfactory, so information is available on locations of all of the relevant nests that could be affected by the WEF.

A further issue with regard to the breeding eagle data relates to the uncertainty over the status of Martial Eagle in the area. In the Jenkins report it is stated that breeding by this species within the survey area was likely but unconfirmed. Jon Smallie states incorrectly in his assessment report that a nest site location was confirmed but further communication with Andrew Jenkins has established that this was not the case (in his email of 21/11/14 to Hylton Newcombe). That mistake is still present in Smallie's updated report. A pair of Martial Eagles was observed in this area, behaving as if they had active nest with young, so it was likely that there was a nest in this vicinity, but the specific nest location was not identified and no nest was actually seen. In terms of the assessment though, the behaviour of the birds observed was indicative of birds breeding in this vicinity.

Further information obtained in consultation with Adri Barkhuysen indicated that he had seen a Martial Eagle pairs displaying in two locations in the area; (1) a small kloof west of Guntia and (2) on Nico Dorfling's farm, west of Tygerhoek and north of the main gravel road. Neither of these areas are within 5km of any of the proposed wind turbine locations. Barkhuysen also provided further background on this species in this region: Martial eagle tend to use the grass landscapes of the tops of the mountain, but he noted that he has never seen this species flying in mist during cold fronts (though he has observed this behaviour by Verreaux's Eagle). No specific data are available to provide any further information on the use of the probable breeding site located by Jenkins in 2014.

In conclusion with regard to breeding birds, there are up to six breeding pairs of Verreaux's Eagle and probably a single pair of Martial Eagles within the survey area that require consideration in the ornithological impact assessment. There have been errors in the plotting of some of the nest sites used by those birds and in the reporting of the status of the Martial Eagle, but none of these make any material differences to the assessment process (now that the nest locations have been confirmed). There are adequate baseline data on the locations of the key species nesting in the vicinity of the wind farm for the purposes of the assessment.

SECTION 3

REVIEW OF DRAFT ORNITHOLOGICAL ASSESSMENT

SECTION 3 – REVIEW OF DRAFT ORNITHOLOGICAL ASSESSMENT

Jon Smallie of Wildskies Ecological Services has produced a draft "*Avifaunal Impact Assessment*" dated November 2014 and an updated version in February 2015. The purpose of this section of the report is to provide a review of that document, including the assessment methodology, the results of the assessment and the conclusions reached, and the effectiveness of the mitigation proposed.

The assessment was described as being made on an approximate 48-turbine layout, though the report Figures all show a 55-turbine layout. Note is made of potential effects of the grid connection though most if the impact zone of that aspect of the project falls outside the site survey area. Several important species were identified that could be affected by the proposed overhead power line, but no survey effort has been directed at that area despite this issue being raised (as the line would cross suitable habitat for several species that could be vulnerable to collision with overhead lines, notably bustards and blue crane. It is understood through consultation with SRK that there would be a requirement to assess the effects of the grid connection as well as the wind farm itself. This could have been readily surveyed by extending the vehicle transects. One of these species, Ludwig's Bustard, was observed during my site visit (on open habitat approximately 1km north-east from the proposed site compound area).

Use of Literature

There is limited use of the literature, both local (for example with regard to Verreaux's Eagle) and international. No mention is made, for example, of recent success applying mitigation at wind farm sites with large raptors in southern Europe (Lucas et al 2012, Marques et al. 2014). There is very limited quantitative information on the actual effects of wind farms on similar species to those at Inyanda Roodeplaat. As a result the ornithological assessment is less robust and less well-informed that it might otherwise have been.

Desk Study

The results of the desk study could have been more clearly presented. The key point from that desk study appears to be a lack of information from the site (the BLSA sensitivity map indicates no recent data from the atlas grid squares in which most of site falls, for example). Local eagle expert Adri Barkhuysen undertook the 2013 eagle survey and also has longer-term experience in the region, and further longer-term information from him, particularly on eagle nest sites, would have made a useful addition to the assessment.

Survey Methodology

The general approach has been to adopt the BLSA/EWT birds and wind farm survey guidance (though these have not been fully implemented, particularly with regard to VP survey coverage of the WEF which is well below the guidance value of 75%). The issues in relation to the baseline data are discussed in detail in Section 2 above and are not repeated here.

In Section 2.6 Smallie recognises the limitations of his own survey methods, much of which should perhaps have been addressed during the surveys – and acted upon - rather than afterwards. The whole tone of the discussion of the limitations includes several statements that appear to question the credibility of the whole assessment, with reference to endless questions and acknowledgement of the inexperience of the assessment team.

The survey methodology section as a whole would have benefitted from the inclusion of a clear statement on which target species are covered by which surveys.

Access issues were cited to explain poor coverage of the eastern part of the wind farm, though that area was included in the Jenkins surveys in 2014. It is stated that in the assessment report that "*It is believed that since the habitat and topography on site is uniform between the eastern and western parts of the site, extrapolation of results to the inaccessible portions of the site will be acceptable*", but no clear evidence is provided to support this (e.g. habitat/topographical analysis). Such analysis could significantly strengthen this argument.

With regard to the incidental observations, it is unclear how these data were used in the assessment given their anecdotal nature. Indeed it is stated in 3.7 that "*Care must be taken not to attach too much importance to these sightings as they are not the product of systematic sampling and various biases exist in the data*".

The conclusion is reached that the density of Verreaux's Eagle is high but little supporting evidence is given. In particular here it would be useful to see how the area's breeding density compares with that elsewhere.

The vantage point (VP) survey methodology appeared initially on paper to be appropriate and in line with guidance, with a 2km viewing distance, observations spread through day, 12 hours surveys from each VP over each of four visits through the year, flight heights directly estimated and methodology following Jenkins et al. (2012). However, as discussed in Section 2 above, the examination of the actual field data do not fully support this position. It would appear that a 2km viewing distance was not fully achieved, and that the VP coverage did not meet the 75% guidance stipulation.

The assessment presents an approach to collision risk assessment that Smallie appears to have developed himself. This does not relate to widely used best practice, which would usually adopt a more quantitative approach to the risk assessment through collision modelling. Smallie's method identifies higher risk areas on the basis of key species flight activity at risk height and sensitivity of the species involved. However it is unclear as to why more quantitative approach was not adopted, which would have allowed more informative assessment of collision risk to be undertaken. The inclusion of both conservation status and flight behaviour within this part of analysis also obscures actual flight activity at rotor height.

Reference Sites (2.9)

It is stated that a suitable control site has been identified to the east of the wind farm site (presumably the data from VP4 overlooking the Holbak Verreaux's Eagle nest). However a control site should be similar in nature to the wind farm if it is to be the basis for comparison in the future. This does not appear to be the case given its proximity to the eagle nest and considerably lower elevation than the wind farm site. The site visit has further confirmed this – the terrain and habitat around this VP is not the same as that of the WEF, being on lower less exposed ground than the WEF as well as being in close proximity to an active eagle nest. It has provided some very useful information about how Verreaux's Eagles use the area around an active nest site (albeit not from an ideal VP as much of the range in proximity to the nest was obscured from view by a ridgeline) but it has not provided data that could in any way be considered a control in scientific terms.

Impact Zone (3.1)

The potential impact zone of the wind farm was taken somewhat arbitrarily as 2km around the site. This needs better justification, reference to literature and clarification of potential impacts in relation to distance from wind farm. Different impacts will have different impact zones (e.g. disturbance during construction is likely to affect a larger area than disturbance during operation). Despite this being raised in an early draft of my report it has still not been addressed in Smallie's update report.

Description of Study Area (3.2)

It is surprising that no mention is made of the other ecological work that has been undertaken for the proposal, which gives rather more detail on the habitats present. The ornithology report would benefit from cross-referencing to the ecology report. It should also include consideration of the Verreaux's Eagle's likely key prey species in this area, Rock Hyrax.

Target species list (3.3)

The process of determining the target species list is described at length and includes the species considered to be of 'most concern', but it is not clear how these were determined. How for example do the lark and pipit qualify for inclusion? It is stated that target species are "those which are believed to be most at risk of the proposed facility, and also of conservation concern" but larks and pipits - both small passerines - would not be likely to be at risk (SNH 2014).

Table 1 lists only Verreaux's and Martial Eagle as breeding, but presumably many of the other species were breeding too. The status of Martial Eagle should be consistent with the field data, which indicated 'probable' not 'confirmed' breeding.

Counts of large terrestrial species and raptors (3.5)

The final sentence in this section is another example of a statement that appears to question the validity of the data, "*The hilly topography means that visibility of anything other than raptors high in the air is reasonably poor, and the drivers' attention is taken up by the poor road quality, resulting in only one effective observer*. "

Focal Sites (3.6)

This section would benefit from an initial explanation as to how the five sites surveyed in 2013 were already known, i.e. reference to other previous surveys in the area.

The Martial Eagle breeding location in 2014 should be more clearly explained given the actual results from that survey (i.e. probable breeding birds located but not an actual confirmed nest site). Similarly Table 5 should report exactly what was observed.

Table 6 shows no flights recorded above rotor height, a surprising result given the species present. It was also not in line with what I observed during my site visit, when several Verreaux's Eagles were seen flying at heights well above rotor height. Perhaps it may have been a case of a conservative assumption that all flights above 25m were considered to be at rotor height? The paragraph following Table 6 is of concern, that it is "*Difficult to interpret data and understand risk*." This is precisely why a more quantitative approach to collision risk is more informative and useful.

Whilst there may be uncertainty as to the precise proportion of flights at rotor height and there may have been an over-estimate of this value, it is considered that such a precautionary approach is appropriate in the topography of the wind farm site (where steep slopes makes estimation of flight height challenging).

Figure 8 notes higher Verreaux's Eagle activity at this site that has been recorded at two other wind farm sites, but it is not clear exactly what data are being compared here. It would appear to include data from VP4 for Inyanda Roodeplaat, which would not be a valid comparison in relation to the wind farm and the risk of impact. It should use only flights within the risk zones of the wind farms for any meaningful comparison. This needs clarification and re-presentation of the results.

It would have been useful to have included analysis of Verreaux's Eagle flight activity in relation to distance from the nest using the VP4 data, as that would have informed the recommended buffer zones (enabling the relationship between distance from an eagle nest and flight activity to be explored).

The criteria for inclusion in Tables 6 and 7 is unclear. Some species have been included in both Tables, e.g. black harrier and booted eagle, and it is unclear what is meant by 'site'. This summary appears to include the whole survey area, including VP4 (which is some distance from the WEF and outside its potential impact zone). It is not clear whether the numbers in the Table represent mean flights per hour or mean time observed per hour. The apparent lack of separation out of VP4 data makes eagle activity within the wind farm site appear much higher than it actually was.

Spatial Analysis

Better justification should have been given as to why the spatial assessment was only undertaken for Verreaux's and Martial Eagle.

Recommendations are made for deleting turbines, but no attempt is made to quantify the benefits of doing this. It would be very useful to see what proportion of the risk would be removed if the recommendations were followed. The high risk areas are clearly clustered around the vantage points, with very few flights recorded more than 1km from VP within the WEF (see Section 3 above for further discussion of this issue). These recommendations for dropping turbines do not appear to have taken this into account and are therefore fundamentally flawed. Jon Smallie has now accepted that the effective viewing distance was much less than his stated 2km, acknowledging this issue but his update draft report has not addressed this.

In the first bullet point on page 51 it is stated that all turbines are in a high risk area. However it is unclear how such a conclusion has been reached and this does not seem to match up to the flight activity data (which show extensive areas of low bird activity). The VP data in particular indicate much of the wind farm was within an area little-used by the eagles.

The author seems to suggest that the only adequate baseline would be obtained by using satellite/GPS tagging. This is simply not the case. Whilst such studies could provide very useful background data, proper vantage point watches covering the site would have provided such data. The reasons for the lack of wider coverage are unconvincing, particularly given increased access to the eastern part of site for the eagle surveys in 2014. My site visit confirmed that this eastern track could be driven in a 4x4 vehicle. Jon Smallie stated verbally that would have taken too long, as would walking to a VP in that area. No attempt appears to have been made however to source an appropriate vehicle that could have facilitated survey of that area. This is very important to the quality of the baseline data as it has resulted in a large part of the wind farm (including that part closest to the Holbak Verreaux's Eagle nest site) being completely unsurveyed.

The reporting of the SNH collision model contains a further factual error. The 99% avoidance rate quoted as a 'default' is not correct – the default value for most species is 98% (see Urquhart 2010). The author states that he considers that SNH collision modelling "*would have little value*" yet does not offer any alternative quantification of collision risk (beyond mapping flight activity). This goes in the face of most current guidance worldwide, where is has been demonstrated widely that collision risk can be quantified in such a way that it can be a useful and informative tool in the assessment process. Quantifying collision risk is an achievable objective and is an important part of an assessment.

Assessment

The author states that a risk matrix has been used, but only presents an outline equation: "*Risk of interaction = Probability of interaction x Severity of interaction*." This produces what is termed a 'probability score' of 1-5 and a severity score of 1-3, which are multiplied together. All possible effects have been summarised in a single probability score for each species, rather than making a specific assessment of each of the possible effects. It is very difficult to see how these probability scores have been determined, and as a result the assessment methodology is not transparent or demonstrably objective.

The specific impacts are addressed in Section 5 of the draft assessment, but little reasoning is given for the conclusions reached, resulting in the assessment overall appearing subjective. The term 'significance' is used but no explanation is given as to how judgments are made and this doesn't seem to refer back to the previous assessment of risk of interaction (which was a general score for each species). It would be good practice to demonstrate transparently and objectively how significance has been assessed, for example setting impacts against the local/regional population levels and conservation status.

The literature regarding the quantitative aspects of collision risk is very limited (p.59).

There is very little discussion of prey abundance/availability on site and on surrounding land, something that would be expected to be very important to the local eagle ecology.

No wider context is provided of the densities of key species recorded.

Wider consideration of the ecology of key species would have been useful, e.g. does Martial Eagle ecology explain the low numbers of flights observed over the wind farm site even though it was probably nesting within the wider survey area?

Mitigation and Buffer Zones

It is stated in Table 9 that "*up to 60% of eagle flight activity will be within the identified buffers and hence safe from collision if no turbines are built in these areas. However, this statement is based on speculation, and incomplete understanding of the birds' behavior on this site*." If such a statement is so speculative then it should have no place in the main assessment summary Table. These numbers appear completely arbitrary and without any scientific basis (as do those for the anticipated benefits from the other mitigation). Better analysis of the VP survey data could have assisted in addressing this question and making a more informed assessment.

In relation to collision risk an important point is made in Table 9 that risky eagle flight activity may occur away from the nest site, referencing Watson (2010). However again Smallie appears to have ignored his own baseline data. If such flights did take place further from the nest (and potentially within the wind farm) they would have been very likely detected during the surveys from VP1-3 (which actually appeared to show only low eagle flight activity within the wind farm).

In 6.1 it is noted that the BLSA wind farm sensitivity mapping shows that the site is in only a medium sensitivity region, but no comment appears to be made relating this to the author's own conclusions that any wind farm at this site would be unacceptable. It should be made more explicitly clear that the higher sensitivity grid squares in this area from the BLSA mapping are data deficient (with that sensitivity determined from original nearly 20-year old SB1 data not the more recent surveys). It is not clear why this topic has been introduced here rather than in the introductory section. As Smallie quite rightly points out, "*Exercises such as this map will certainly be over ruled by actual data collected by pre-construction monitoring on site*". It is therefore of limited use in the context of the Inyanda Roodeplaat wind farm.

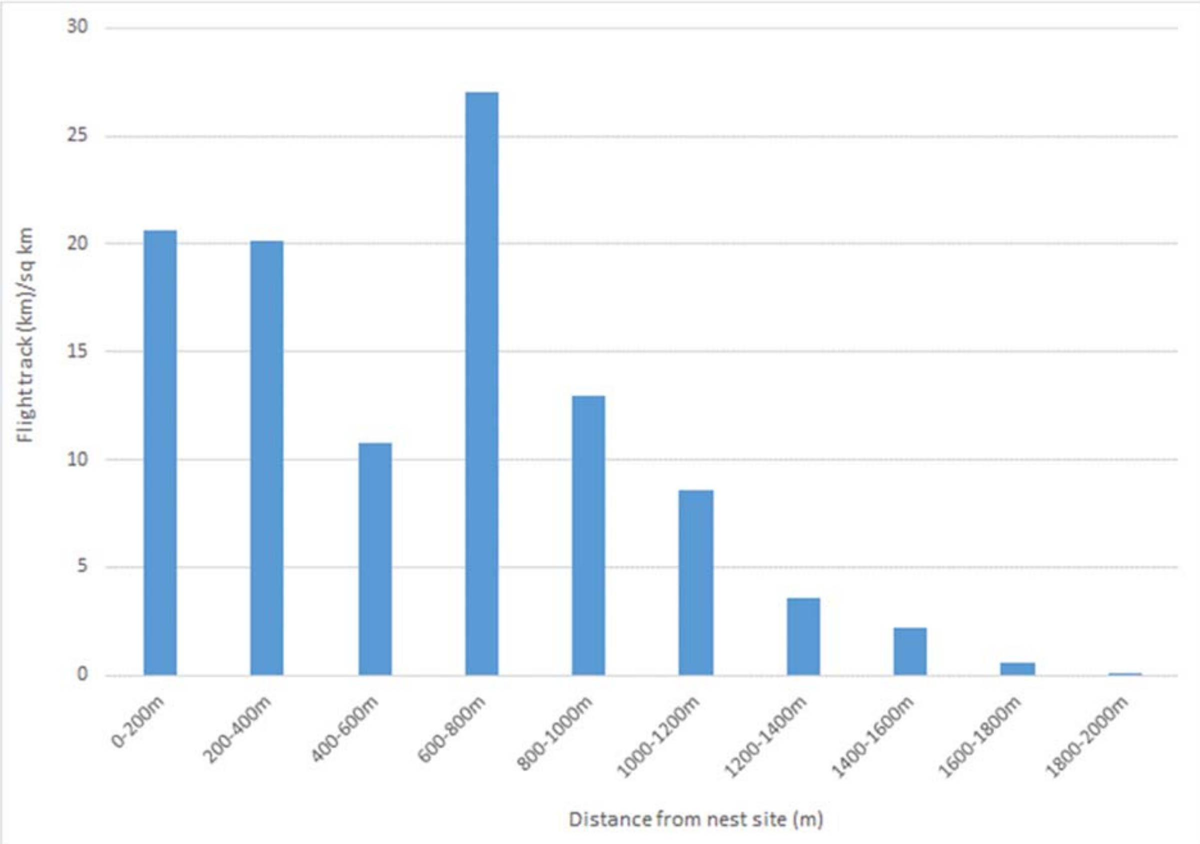
The discussion of buffers zones would be improved if their purpose could be clarified. They have the potential to reduce collision risk, to avoid disturbance to nest during construction/operation and to reduce the impact of displacement effects. Lumping all protective buffers together is misleading as they serve a range of purposes that may need different sized buffers.

The recommendations made with regard to design mitigation are to apply buffer zones around active eagle nests; 2km for Verreaux's Eagle and 2.5km Martial Eagle. These distance are rather less than those recommended by Jenkins in his report on the 2014 surveys (2.5km and 5km respectively). Smallie states in his report that his distances are based on basis of '*informal professional judgment*' and on a recent US Fish and Wildlife Service (2013) publication. He states that "*the US Fish & Wildlife Service (2013), recommended a buffer radius equal to half the mean inter nest distance for the species in the area*" and this method is used to justify the 2km recommendation for Verreaux's Eagle. There seems to be a confusion, however, over buffer size to reduce impacts and territory size. The USFWS publication actually states that "*One-half the mean inter-nest distance has been used as a coarse approximation for the territory boundary*" and that "*We recommend using this distance to delineate territories and associated breeding eagles at risk of mortality or disturbance*." It is therefore an approximation to assist in territory delineation not a buffer zone to mitigate any impacts.

Smallie draws attention to the fact that several of the proposed turbines are within 2km of the Perdehoek Verreaux's Eagle nest site, i.e. within the area that he had recommended should be free from turbines. However all of these turbines were within the viewing range of VP3, where little flight activity was noted. Smallie himself did not make any specific recommendations for turbine removal in this area. Whilst viewing of the part of this area that lies 1-2km from VP3 is likely to have been made less effective through the use of the naked eye for scanning (the VP looks down over this area so much of the viewing area would have been against the ground), viewing within 1km of the VP should have been clear for birds against both the sky and the ground. The baseline data show clearly and unequivocally that Verreaux's Eagle use of the zone within 1km of the proposed turbines in this area was minimal (with only five flights recorded in total in 144 hours of VP surveys over a whole year– see Figure 1).

The whole question of the appropriate extent of eagle nest buffer zones is best addressed by using the actual field data to determine these distances, so I used the data from VP4 to examine the relationship between eagle flight activity and distance from the nest (to inform the optimal buffer size). Flight activity was calculated for each 200m band from the Verreaux's Eagle nest site used in 2013 up to 2km, and standardised for the area of each buffer (expressed as flight length per unit area). The results are summarised in Figure 7, which shows the flight length per km^2 for each 200m band. This Figure illustrates the higher concentration of eagle flights around the nest, with 86% of flight tracks recorded within 1km and 98% within 1.5km. This would suggest that 1.5km would make an appropriate buffer from wind turbines to substantially reduce eagle collision risk (as that risk is likely to be proportional to flight activity), and that the benefit of increasing this buffer to 2km would be minimal.

Figure 7. Verreaux's Eagle flight activity in relation to distance from the active nest site at Holbak (VP 4).



The extent of appropriate wind turbine-free buffers is an issue that has been raised at other wind farm sites, including within South Africa. At the Witberg site in the Western Cape, buffers of 2.5km from Martial Eagle and 1.5km from Verreaux's Eagle were recommended primarily on the basis of local expert opinion (Percival 2013). Further analysis of local vantage point survey data at that site supported this distance for Verreaux's Eagle. Flight activity of this species at Witberg 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. Given this and the results of the analysis of the Inyanda Roodeplaat data it is recommended therefore that the same buffers as used at Witberg be applied here as well, i.e. 2.5km for Martial Eagle and 1.5km for Verreaux's Eagle.

Applying a 2.5km buffer from the estimated position of the Martial Eagle nest site location would include the locations of two proposed turbines, but there was no evidence from the VP surveys that those turbines would contribute disproportionately to the collision risk for that species. It could therefore be argued that any further removal of turbines for this species would be unnecessary given its very low flight activity over the site. However given the limitations of the VP viewing distances identified it is considered that it would be a better, more precautionary, approach to avoid locating any turbines within this 2.5km buffer.

Applying a 1.5km around all of the recorded Verreaux's Eagle sites would include a single proposed wind turbine location, the one closest to the Perdehoek nest. That turbine was within the full visibility zone of VP3 but little flight activity was noted there. However, as for the Martial Eagle, given the limitations of the VP viewing distances identified it is considered that it would be a better, more precautionary, approach to avoid locating any turbines in this 1.5km buffer.

The collision risk index assessment in section 6.2.2 of the Smallie report concludes that "*based on the collision risk index calculated to date, we would identify the top of the main mountain and the tops of each of the north-south spurs as sensitive areas. This would eliminate almost all current turbine positions*". However this does not seem to be in agreement with the baseline data, which show clear areas of higher and lower flight activity (and hence collision risk). For Verreaux's Eagle flight activity recorded within the WEF was clearly much lower than the activity observed at VP4 (outside the WEF). There does not appear to have been an objective assessment of the actual risk but rather just a jump to the conclusion that Smallie considers the whole scheme unacceptable. This argument is developed further by Smallie with somewhat emotive and subjective conclusions regarding the "*holistic risk*" of the wind farm.

Overall this assessment is lacking in objective detail. No attempt has been made to assess the context of any additional mortality in a population context. There is no detailed assessment of disturbance or habitat loss, no quantitative collision risk modelling to predict the numbers of collisions that could occur and no test of the buffer size recommendations (which indeed contradict the latter recommendations that all of the site could not accommodate a wind farm). The assessment needs to make more use of the wider literature/international experience of bird-wind farm interactions, and better identify potential mitigation opportunities.

SECTION 4

LITERATURE REVIEW: WIND TURBINES AND RAPTORS

SECTION 4 – LITERATURE REVIEW: WIND TURBINES AND RAPTORS

The key ornithological issue with the Inyanda Roodeplaat 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 Inyanda Roodeplaat 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 Inyanda Roodeplaat 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, Lucas et al. 2012). Vultures also have a high wind loading, reducing their maneuverability which also increases their vulnerability to collision (Janss 2000, Barrios and Rodríguez, 2004; Lucas et al., 2008). 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).

Collision risk of raptors has been shown to be affected by wind conditions (Johnston et al., 2014). That study found that golden eagles migrating over a wind farm in the Rocky Mountains experienced lower collision risk with increased wind speed and increased risk under head- and tailwinds when compared with crosswinds.

In wind farm sites in the UK, with similar large raptor flight densities to Inyanda Roodeplaat, 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 collisions 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, and a high wing loading that reduces their maneuverability
- 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).

The mitigation of collision risk has been recently reviewed by Marques et al (2014). This publication outlined a range of measures that have been implemented at existing wind farms in order to reduce collision risk. It includes details of several highly successful schemes, including:

- *Turbine shutdown on demand* - Lucas et al. (2012) showed that wind turbine shutdown on demand halved Griffon vulture fatalities in Andalusia, Spain, with only a marginal (0.07%) reduction in energy production. This study used human observers but automated (radar and video-based) systems are also now becoming available (Collier et al. 2011; Desholm et al. 2006).

- *Restriction of turbine operation* – this involves avoiding operation of the turbines at key risk times. This has been very effective for bats (Arnett et al. 2010), where reducing turbine operation during periods of low wind speeds reduced bat mortality by 44% - 93%, with marginal annual power loss (<1% of total annual output). For birds (including at the Inyanda Roodeplaat site) it is less likely to be such a useful tool as defining the higher risk periods is more difficult and it is unlikely that such a large reduction would be achievable without a much greater loss in power output.
- *Habitat management* – these schemes are usually implemented to reduce the attractiveness of the wind farm site for foraging (e.g. removal of carcasses for carrion feeding species) whilst at the same time increasing food availability elsewhere (to draw birds away from the wind farm and at the same time offset lost foraging opportunity) (Walker et al. 2005).
- *Increasing turbine visibility* – laboratory experiments have shown this to be a potentially effective tool but there have not yet been any field trials that have demonstrated a major benefit of such measures. Its applicability remains to be proven.
- *Deterrents* – bioacoustic or other scaring devices might have the potential to deter birds from flying in close proximity to wind turbines. Smith et al. (2011) showed that use of an acoustic deterrent (Long Range Acoustic Device) elicited strong reactions from 60% of Griffon vultures but its efficacy depended on the distance from the bird, altitude and flock size. Deterrents also have the potential to be activated by automated real-time surveillance systems as an initial mitigation step and prior to blade curtailment (May et al., 2012; Smith et al., 2011). A possible problem with this mitigation though, as noted by Marques et al. (2014), is that the deterrent may have an unpredictable effect on the flight path and may not always deflect the bird in the desired direction.
- *Compensation* – these include measures to deliver a wider benefit to the populations that could be affected by the wind farm, including habitat expansion, creation or restoration, predator control and supplementary feeding.

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, though Fielding and Haworth (2013) found evidence of displacement of golden eagle up to 500m. Displacement effects have also been reported for white-tailed eagles at Smøla (May et al. 2013). Campedelli et al (2013) found significant reductions in a range of raptor species at a wind farm in Italy. Though disturbance would reduce 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.

The best way to mitigate any such losses would be through the provision of alternative resources nearby (but outside the potential impact zone of the wind farm). Such measures have been successfully implemented at several wind farms, including for golden eagles (Walker et al. 2005).

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 Inyanda Roodeplaat 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 5

COLLISION RISK MODELLING: METHODOLOGY

SECTION 5 - COLLISION RISK MODELLING: METHODOLOGY

The collision risk modelling set out in this report adopts from the principle of making the best use of the available data to inform the assessment, though has had to also take into account the considerable limitations of the those baseline data.

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

The CRM was carried out on all of the four key raptor species of concern that were observed flying within the collision risk zone at rotor height; Verreaux's Eagle, Booted Eagle, Martial Eagle and Black Harrier.

Additional Data for Collision Modelling: 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 four key species (Golden Eagle for Verreaux’s Eagle, the mean of all of the available *Aquila* eagle species for Martial Eagle, the mean of all of the available *Buteo* species for the smaller Booted Eagle and the mean of all *Circus* harrier species for Black Harrier). The data used in the collision risk modelling are shown in Table 2.

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

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

Wind Farm Technical Data

The collision modelling requires a range of input data on the wind turbine specifications, which were provided by Afri-Coast Engineers Pty and the turbine manufacturers (Table 3). This modelling has taken a reasonable worst-case approach, running the model for the turbine likely to give the highest collision risk of the options being considered. The model was initially run on a 55-turbine layout (as used by Smallie for his assessment), and a further update has modelled a 48-turbine alternative (see Figures 18 and 19).

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

Specification	Value used in initial 55-turbine collision risk modelling	Value used in updated 48-turbine collision risk modelling
Number of turbines	55	48
Hub height	100m	85m
Rotor diameter	125m	130m
Height to blade tip	162.5m	150m
Minimum height of blade above ground	32.6m	20m
Rotational speed (variable – mean of range used)	12.4 rpm	12.2 rpm
Blade maximum chord	3.28m	4.2m
Blade pitch (variable – mean value used)	6°	7.5°
Turbine operation time (when not constrained by high/low wind speed or maintenance activity)	90%	90%

The same precautionary assumption has been made for this collision modelling as made by Smallie in his assessment report, i.e. that all flights recorded at 30m and above were considered as being at rotor height.

Study Area

The main collision risk zone for the 55-turbine layout was defined, as per Band et al (2007) and SNH guidance (Whitfield et al. 2010) as a 500m zone around the proposed wind turbine locations (Figure 5). The same process was used to define the collision zone for the alternative 48-turbine layout.

The survey methodology used for the VP flight activity surveys used scanning only by naked eye, resulting in lower detectability of birds particularly when observed flying against the ground. An initial run of the collision modelling was carried out assuming only a 1km viewing distance from the site VPs. However observations made during the site visit indicated that whilst a 1km detection distance is reasonable for birds viewed against the ground, eagles could be observed at up to 2km, even by naked eye, when seen against the sky. The effective study area has therefore been defined taking this into account, and is shown in Figure 5. This meant that 28 of the 55 proposed turbine location could be viewed at rotor height from VPs 1-3. It had to be assumed that these 28 turbines were representative of the whole wind farm in order to estimate collision risk for the whole wind farm, scaling up the predicted collision risk to 55 turbines (and the alternative 48 turbines, of which 22 were within the viewing zone), and making best use of the available data.

The question of whether the 28 turbines of the 55-turbine layout that were fully viewed from the VPs were representative of the whole wind farm was tested by comparing (a) the distances of the turbines from the nearest Verreaux's Eagle nest site, (b) the elevation of the turbines and (c) the habitats in which the turbines would be located (based on the Mucina and Rutherford, 2006, classification used by Jon Smallie in his report). These analyses did indicate that there were some ecological differences between the viewed and unviewed turbines that require consideration. The viewed turbines were statistically significantly closer to the nearest Verreaux's Eagle nest than the unviewed ones (Mann-Whitney test $Z=3.3$, $p=0.001$). The median closest nest distance was 3.0km for the viewed turbines and 3.8km for the unviewed turbines. The viewed turbines also had a statistically significantly higher elevation than the unviewed ones (Mann-Whitney test $Z=-3.8$, $p<0.001$). The median elevation was 986m for the viewed turbines and 916m for the unviewed turbines. Using the Mucina and Rutherford (2006) habitat classification there was little difference between the viewed and unviewed turbines. Six of the 28 viewed turbines (21%) were located in Kouga Sandstone Fynbos with the remainder in Kouga Grassy Sandstone Fynbos. In comparison 7 of the 27 unviewed turbines (26%) were in in Kouga Sandstone Fynbos (again with the remainder in Kouga Grassy Sandstone Fynbos).

As the viewed turbines were closer to the Verreaux's Eagle nest sites than the unviewed ones, more Verreaux's Eagle flight activity would be expected than at the more distance unviewed turbines. With regard to elevation, Verreaux's Eagle activity would be expected to be greater at lower elevation from the overall results of the VP survey data, so that could mean that overall flight activity was underestimated as a result of the higher elevation of the viewed turbines. However in combination with the fact that the unviewed turbines were further from the Verreaux's Eagle nests, it is considered that extrapolation of the data from the viewed turbines is unlikely to have introduced any significant bias into the estimate of overall flight activity.

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).

There is a lack of specific avoidance rate data from South Africa and on the species of concern at Inyanda Roodeplaat. As collision avoidance rates are not yet known for the species of concern, suitable overseas species have been used as proxies. The selection of appropriate rates 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. Given that the Inyanda Roodeplaat eagles occur at a much lower density (approximately 2.4/100km^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 Verreaux's Eagle at Inyanda Roodeplaat.

SECTION 6

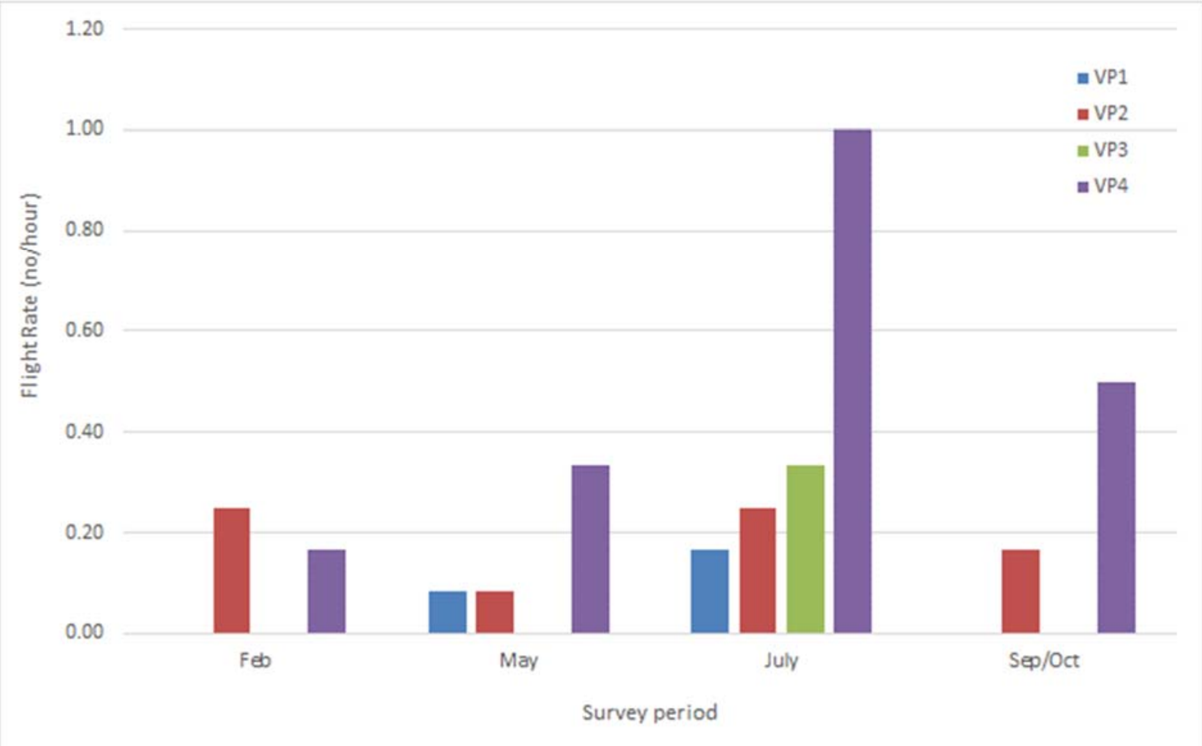
KEY SPECIES FLIGHT ACTIVITY

SECTION 6 - KEY SPECIES FLIGHT ACTIVITY

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

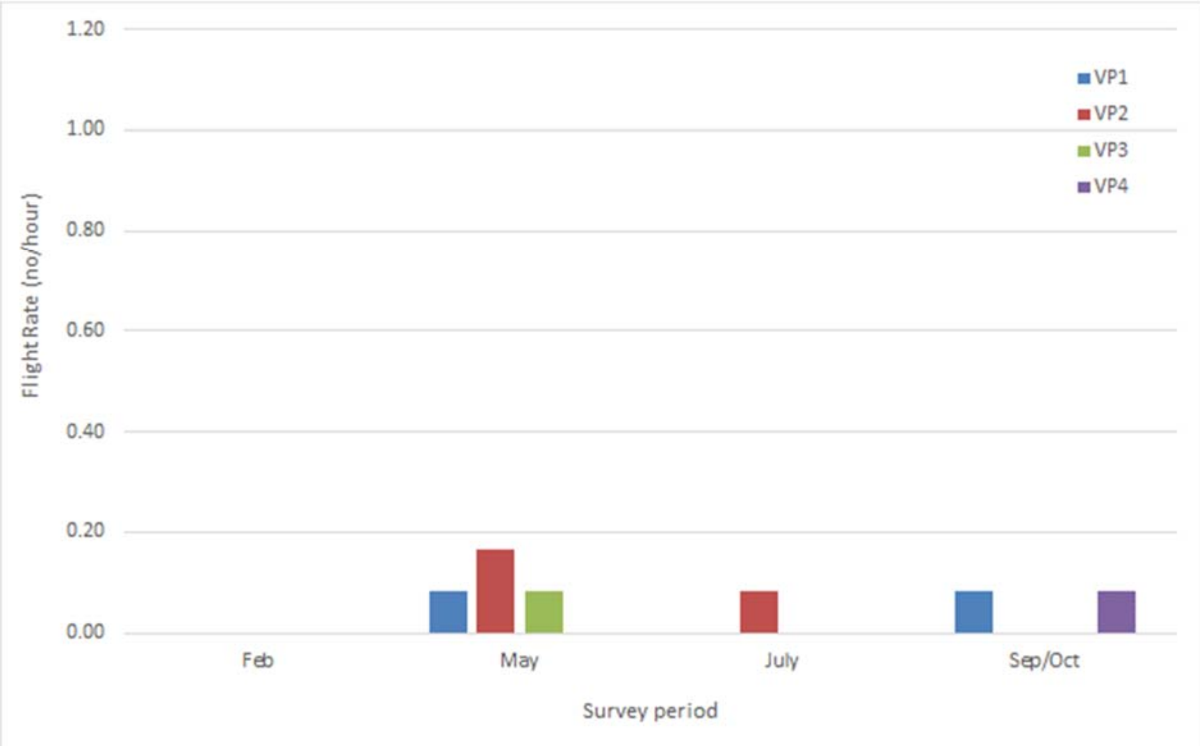
The flight rates (number of bird flights per hour of vantage point survey) from each vantage point in each month are summarised in Figures 8-11. **Verreaux's Eagle** (Figure 8) was much the most frequently recorded of the four key species, being most abundant July. It was seen from all of the vantage points, much most frequently from VP4 (which overlooks an active nest site outside the WEF).

Figure 8. Verreaux's Eagle flight rates observed from each of the four vantage points in each survey period.



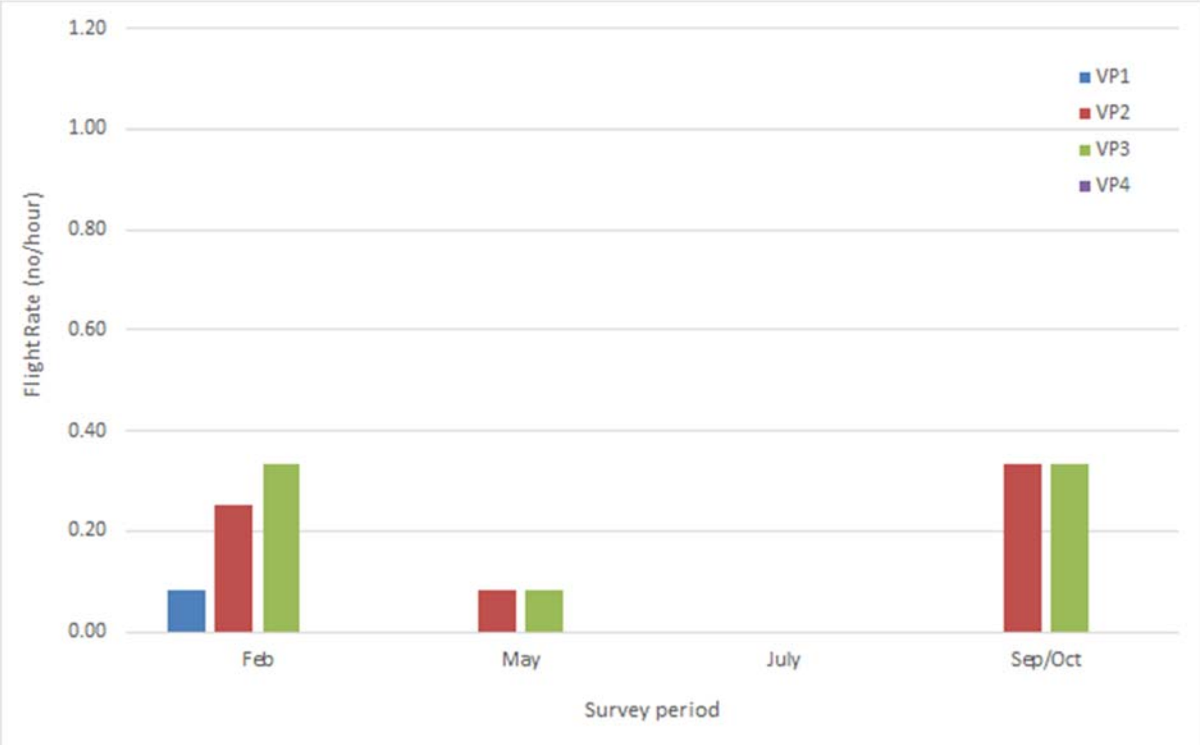
Martial Eagle (Figure 9) was only seen occasionally during the vantage point surveys (only seven flights in total) with no concentration of activity at any of the four VPs It was most frequent in May. There were no sightings at all during the February VP surveys.

Figure 9. Martial Eagle flight rates observed from each of the four vantage points in each survey period.



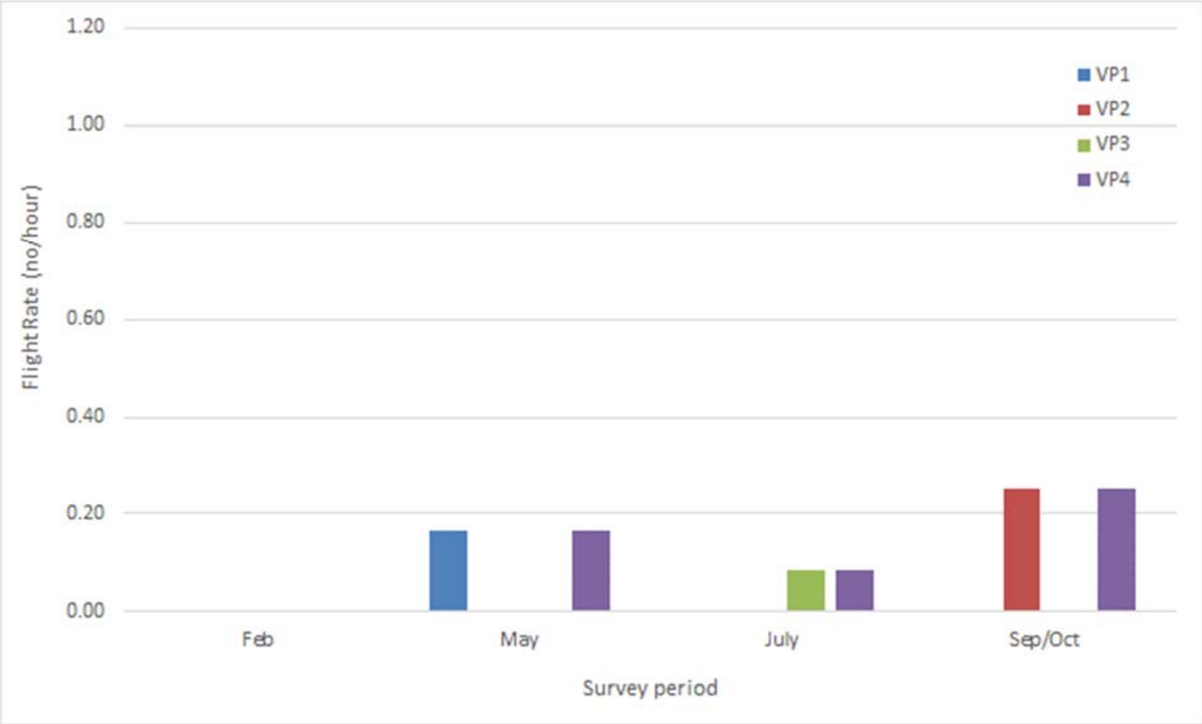
Booted Eagle (Figure 10) was also only seen in low numbers from the vantage points within the WEF (VP1-3), with peak flights recorded in February and September. There were no sightings at all during the July VP surveys, and none from VP4.

Figure 10. Booted Eagle flight rates observed from each of the four vantage points in each survey period.



Black Harrier (Figure 11) was recorded from all of the VPs during the vantage point surveys, but only infrequently. Most sightings were in Sep/Oct.

Figure 11. Black Harrier flight rates observed from each of the four vantage points in each survey period.



The flight activity of the key target species observed within the collision risk zones (the wind farm plus a 500m buffer, Whitfield et al. 2010) during the vantage point surveys for each of the two modelled layouts is summarised in Table 4. It should be noted that these occupancy rates presented relate to the observed part of the collision zone within 2km of the three vantage points.

Of the key raptor target raptor species seen flying through the collision risk zone at rotor height (Verreaux's Eagle, Martial Eagle, Booted Eagle and Black Harrier), Martial Eagle, Booted Eagle and Black Harrier were all 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 July and September/October.

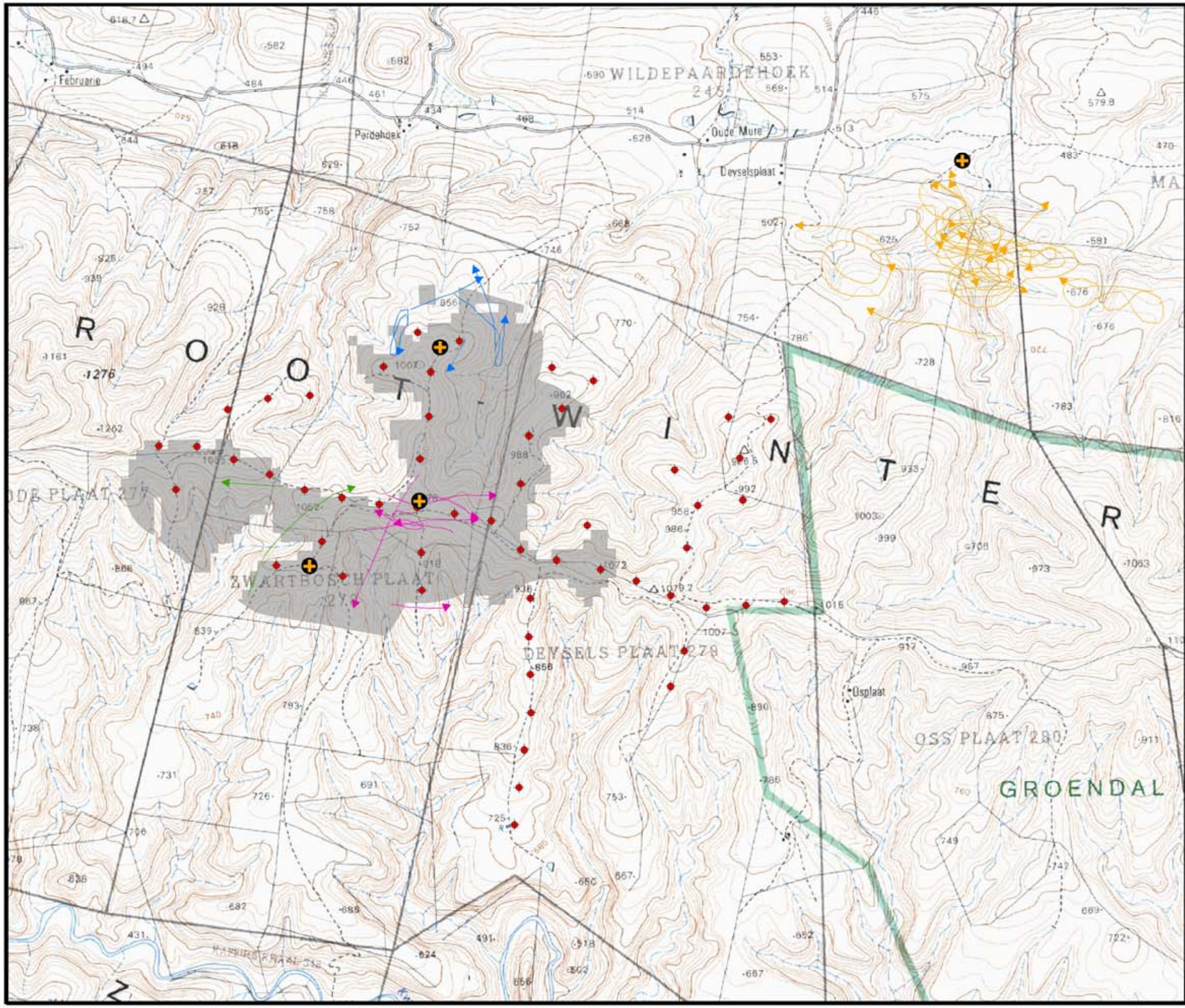
Table 4a. Occupancy rates (% observation time present) of key target species within the 55-turbine layout potential collision risk zone (wind farm plus 500m buffer), based on the area that could be effectively viewed from VPs 1-3 (see Figure 5).

Species	February	May	July	September/ October	OVERALL RATE
Verreaux's Eagle	0.269%	0.091%	1.173%	1.641%	0.793%
Martial Eagle	0%	0.151%	0.116%	0.177%	0.111%
Booted Eagle	0.176%	0%	0%	0%	0.044%
Black Harrier	0%	0%	0%	0.926%	0.232%

Table 4b. Occupancy rates (% observation time present) of key target species within the alternative 48-turbine layout potential collision risk zone (wind farm plus 500m buffer), based on the area that could be effectively viewed from VPs 1-3 (see Figure 5).

Species	February	May	July	September/ October	OVERALL RATE
Verreaux's Eagle	0.269%	0.082%	1.161%	1.623%	0.784%
Martial Eagle	0%	0.148%	0.116%	0.177%	0.110%
Booted Eagle	0.200%	0%	0%	0%	0.050%
Black Harrier	0%	0%	0%	0.926%	0.232%

Flight lines in relation to the 55-turbine collision risk zone and the effective viewing area from VPs 1-3 are shown in Figures 12-15 for Verreaux's Eagle, Martial Eagle, Booted Eagle and Black Harrier respectively.



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Inyanda Roodeplaat Wind Farm

FIGURE 12

Verreaux's Eagle flight lines 2013-14 and collision risk zone effective viewing area

KEY:

- Vantage_points
- Proposed wind turbines

Verreaux's Eagle Flight Lines

- VP1
- VP2
- VP3
- VP4
- Collision zone effective viewing area

ECOLOGY CONSULTING

N

Base map from Chief Directorate National Geo-spatial Information of South Africa: reprojected and collar-cropped for seamless mosaic by MadMappers.com

N/A N/A

Kilometers

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SCALE - 1:35,000 @ A3

ORNITHOLOGICAL ASSESSMENT REVIEW FIGURES MAY 2015

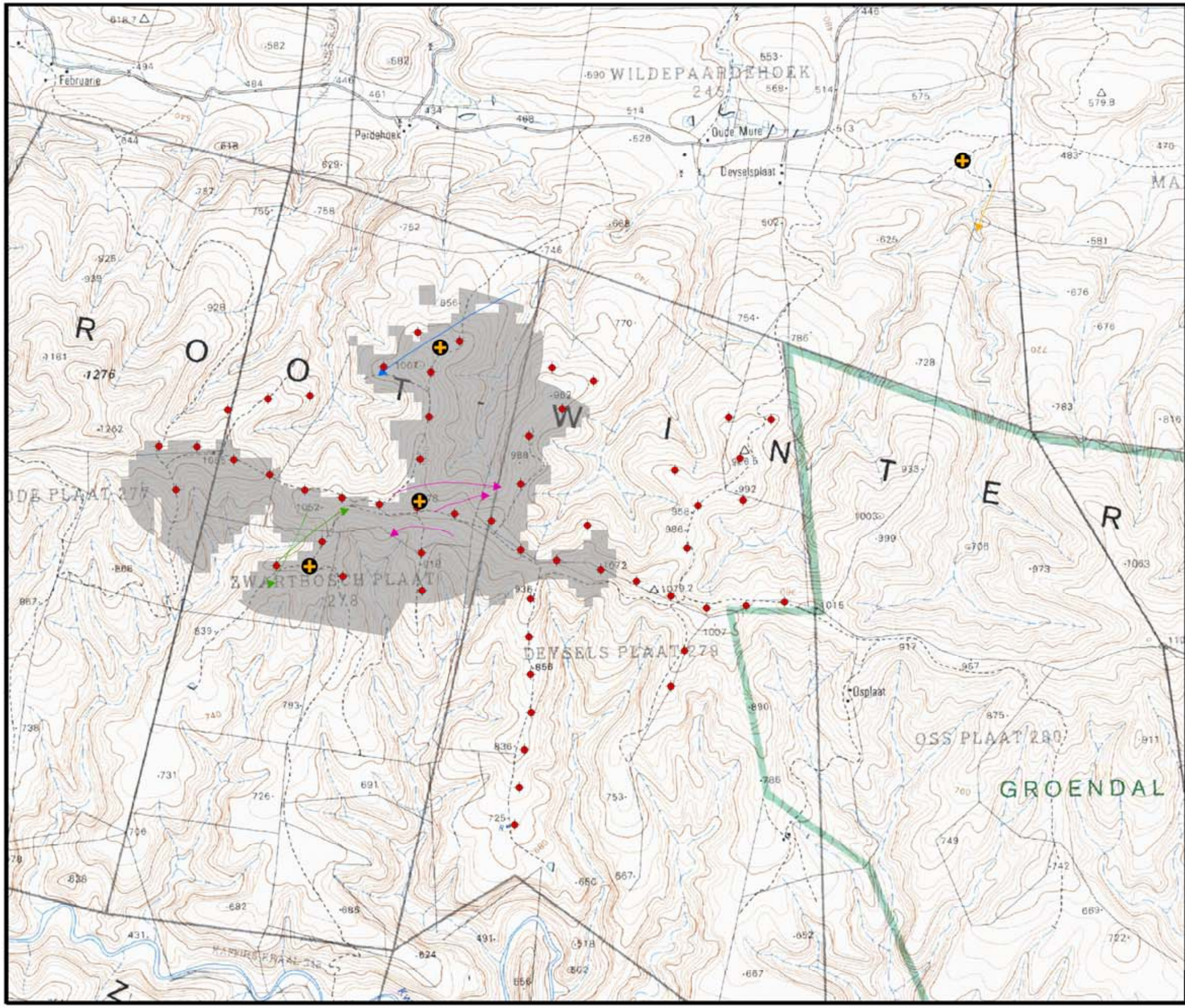

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FIGURE 13

Martial Eagle flight lines 2013-14 and collision risk zone effective viewing area

KEY:

- Vantage_points
- Proposed wind turbines

Martial Eagle Flight Lines

- VP1
- VP2
- VP3
- VP4
- Collision zone effective viewing area

ECOLOGY CONSULTING

N

Base map from Chief Directorate National Geo-spatial Information of South Africa: reprojected and collar-cropped for seamless mosaic by MadMappers.com

N/A | N/A

Kilometers
0 0.25 0.5 1 1.5 2

SCALE - 1:35,000 @ A3

ORNITHOLOGICAL ASSESSMENT REVIEW FIGURES MAY 2015

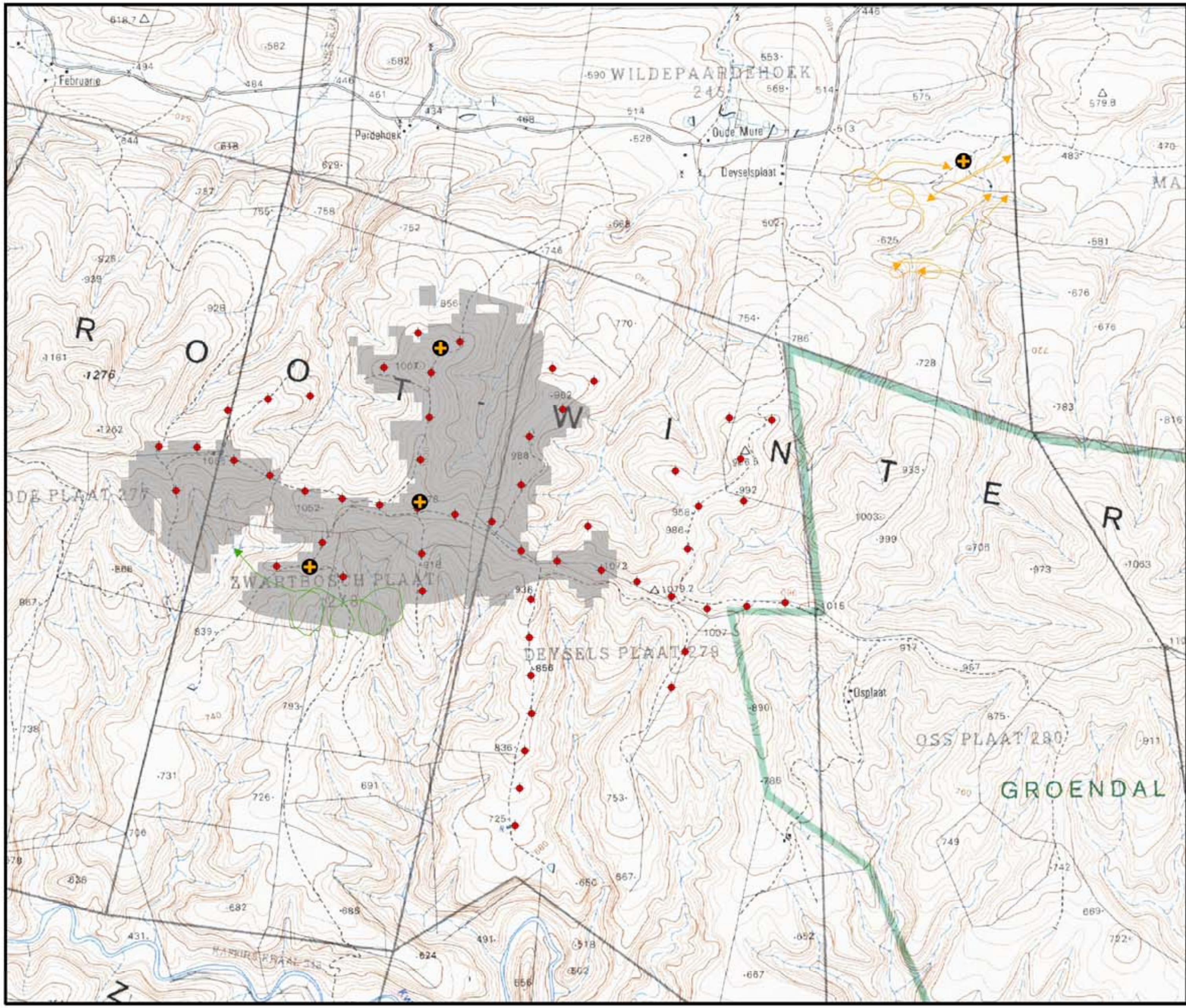

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FIGURE 14

Booted Eagle flight lines 2013-14 and collision risk zone effective viewing area

KEY:

- Vantage_points
- Proposed wind turbines

Booted Eagle Flight Lines

- VP1
- VP2
- VP3
- VP4
- Collision zone effective viewing area

ECOLOGY CONSULTING

N

Base map from Chief Directorate National Geo-spatial Information of South Africa: reprojected and collar-cropped for seamless mosaic by MadMappers.com

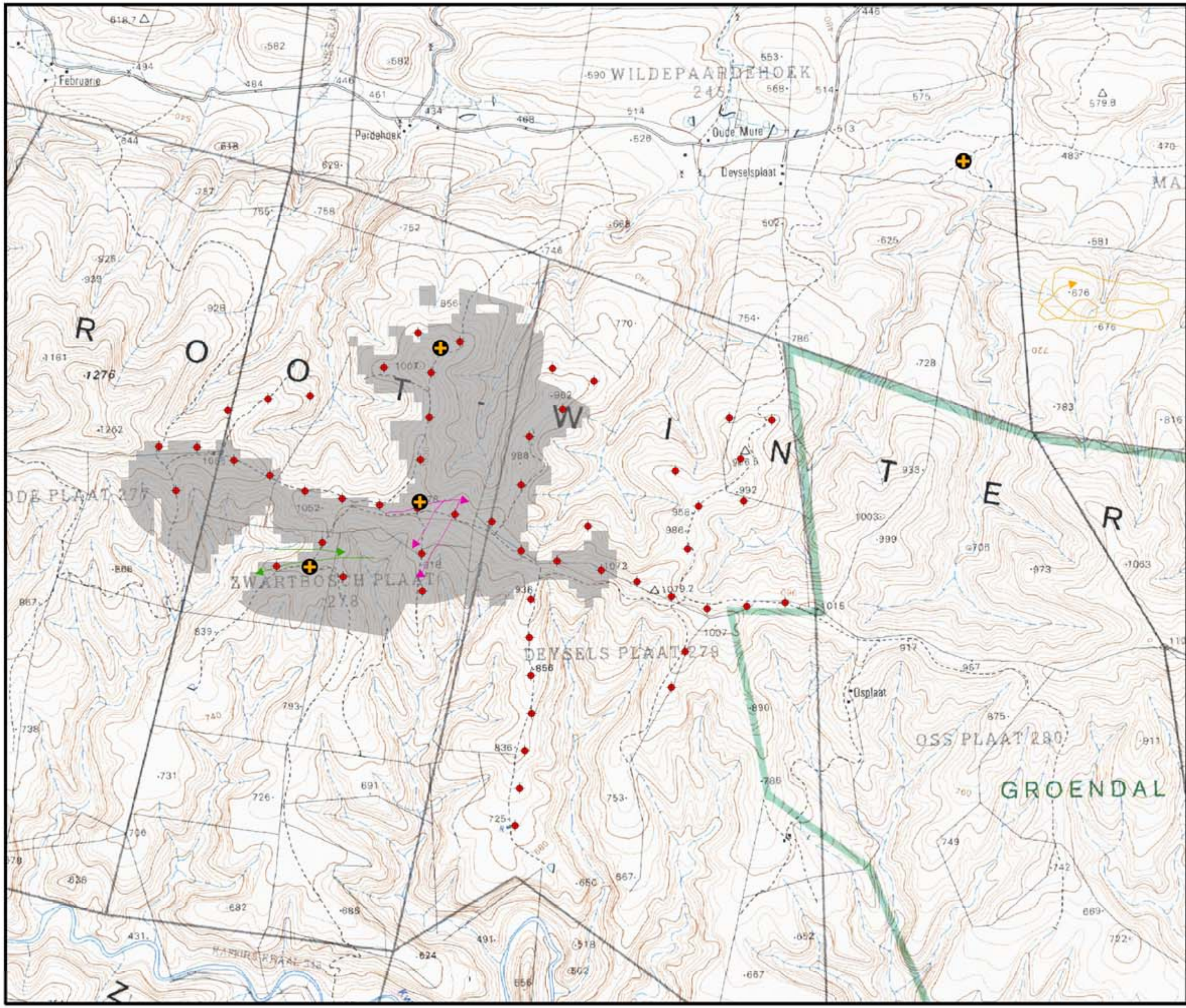
N/A | N/A

Kilometers

0 0.25 0.5 1 1.5 2

SCALE - 1:35,000 @ A3

ORNITHOLOGICAL ASSESSMENT REVIEW FIGURES MAY 2015



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Inyanda Roodeplaat Wind Farm

FIGURE 15

Black Harrier flight lines 2013-14 and collision risk zone effective viewing area

KEY:

- Vantage_points
- Proposed wind turbines

Black Harrier Flight Lines

- VP1
- VP2
- VP3
- VP4
- Collision zone effective viewing area

ECOLOGY CONSULTING

N

Base map from Chief Directorate National Geo-spatial Information of South Africa: reprojected and collar-cropped for seamless mosaic by MadMappers.com

N/A	N/A

Kilometers

0 0.25 0.5 1 1.5 2

SCALE - 1:35,000 @ A3

ORNITHOLOGICAL ASSESSMENT REVIEW FIGURES MAY 2015

SECTION 7

COLLISON MODELLING RESULTS

SECTION 7 – COLLISION MODELLING RESULTS

Table 5 summarises the results of the collision risk modelling for the proposed 55-turbine layout and the alternative 48-turbine layout for each of the four key species. 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. SNH has recommended the use of 99% avoidance rate for harriers, so that value is the primary one used for Black Harriers.

Table 5a. Collision risk modelling predictions for the Inyanda Roodeplaat wind farm 55-turbine layout, 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**			
Avoidance Rate	**95%**	**98%**	**99%**	**99.5%**
Verreaux's Eagle	4.23	**1.69**	0.85	0.42
Martial Eagle	0.52	**0.21**	0.10	0.05
Booted Eagle	0.17	**0.07**	0.03	0.02
Black Harrier	0.79	0.32	**0.16**	0.08

Table 5b. Collision risk modelling predictions for the Inyanda Roodeplaat wind farm 55-turbine layout, 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**			
Avoidance Rate	**95%**	**98%**	**99%**	**99.5%**
Verreaux's Eagle	4.35	**1.74**	0.87	0.44
Martial Eagle	0.54	**0.22**	0.11	0.05
Booted Eagle	0.20	**0.08**	0.04	0.02
Black Harrier	0.85	0.34	**0.17**	0.08

The overall collision risk was slightly higher for the alternative 48-turbine layout, even though it had a lower number of turbines than the 55-turbine layout. This was a result of a combination of a larger turbine rotor swept area, wider blade and lower height of the rotor above the ground.

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 6) of the receptors present in the study area, then determines the magnitude of the possible effect on those receptors (as described in Table 7).

Table 6. 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 7. 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 8).

Table 8. 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 Inyanda Roodeplaat

In the context of the Inyanda Roodeplaat site, the predicted collision mortality has been set against the regional background mortality for each of the four key species at risk of collision. The population data used in this analysis are summarised in Table 9. The region has been taken as the Karoo biome (Mucina and Rutherford 2006, and with reference to the WWF Karoo eco-region).

Table 9. 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)
Martial Eagle	300 pairs	7%	20%	0.6	5	150
Booted Eagle	700 pairs	10%	20%	1.0	3	500
Black Harrier	150 pairs	20%	50%	1.9	2	330

A conservative estimate of 600 pairs of Verreaux's Eagle for the Karoo escarpment (Roggeveld, Nuweveld, Sneeuberge and Winterberge) plus a further 100 pairs for the smaller inselbergs outside of the main mountain ranges was produced by Rob Simmons for the Witberg wind farm project (Percival 2013). 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 Inyanda Roodeplaat 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 10 shows the predicted collision risk and associated impact significance for each of the four species in the context of their background mortality and the % increase over the baseline that each risk represents, for each of the two 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 related to adult birds.

Table 10a. Collision risk for Verreaux's Eagle, Martial Eagle, Booted Eagle and Black Harrier and the increases that these represent over baseline mortality, for the proposed 55-turbine layout.

Species	Precautionary avoidance rate	Predicted collision risk	% increase over baseline mortality	Magnitude of effect	Likely significant effect?
Verreaux's Eagle	98%	1.69	1.80%	Low	Possible, but could be mitigated
Martial Eagle	98%	0.21	0.14%	Negligible	No
Booted Eagle	98%	0.07	0.01%	Negligible	No
Black Harrier	99%	0.16	0.05%	Negligible	No

Table 10b. Collision risk for Verreaux's Eagle, Martial Eagle, Booted Eagle and Black Harrier and the increases that these represent over baseline mortality, for the alternative 48-turbine layout.

Species	Precautionary avoidance rate	Predicted collision risk	% increase over baseline mortality	Magnitude of effect	Likely significant effect?
Verreaux's Eagle	98%	1.74	1.85%	Low	Possible, but could be mitigated
Martial Eagle	98%	0.22	0.15%	Negligible	No
Booted Eagle	98%	0.08	0.02%	Negligible	No
Black Harrier	99%	0.17	0.05%	Negligible	No

For Martial Eagle, Booted Eagle and Black Harrier 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 55-turbine layout of 1.7 collisions per year was assessed as a low magnitude effect, which would be considered to be of low significance on a high sensitivity species, and hence strictly not a significant impact applying the assessment methodology described in Tables 6-8 above. However it is above the 1% increase in the baseline mortality, and therefore requires careful consideration as to whether on the information currently available a significant effect on Verreaux's Eagle can be ruled out.

The results of the modelling for the alternative 48-turbine layout showed that the difference between that and the 55-turbine layout was negligible in terms of collision risk, and did not make any material difference to the conclusions reached in the assessment.

It is recommended that mitigation measures should be implemented to reduce the collision risk, especially given the uncertainties attached to the baseline data currently available.

Lastly, it should be noted that the collision risk results presented here are from a precautionary assessment, not the most likely outcome. As such it sets out the maximum collision mortality that could reasonably be expected to occur. The analysis has adopted a precautionary approach, including:

- Use of a precautionary 98% avoidance rate rather than the more evidence-based 99% for the closely related Golden Eagle;
- 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.
- Assuming no overlap of viewing between VPs.
- Assuming visibility limited to 1km from each of the three VPs in the WEF when viewing against the ground (and 2km when viewing against the sky).

SECTION 9

RECOMMENDATIONS FOR AVOIDANCE AND MITIGATION OF THE IMPACTS, AND FOR POST-CONSTRUCTION MONITORING

SECTION 9 – RECOMMENDATIONS FOR AVOIDANCE AND MITIGATION OF THE IMPACTS, AND FOR POST-CONSTRUCTION MONITORING

Design Mitigation

It is usual practice when designing a wind farm to use the baseline ornithological data to inform that design to minimize any ornithological impacts. However for the Inyanda Roodeplaat WEF the limited coverage of the vantage point surveys of bird flight activity within/around the wind farm makes that task currently very difficult.

One criterion that can still be used to inform the site design is the distance from known eagle nest sites. For most species it would be expected that flight activity (and hence collision risk) would be higher in closer proximity to nest sites, so leaving a turbine-free buffer around nest sites should reduce collision impacts. At the same time it should also remove any disturbance impacts on eagles at the nest, and reduce any displacement of birds from more important (closer to the nest site) foraging areas.

The optimal extent of buffer zones for each of the two eagle species recorded breeding in the survey area (Verreaux's Eagle and Martial Eagle) has been discussed in detail above, where it was concluded, on the basis of field data from the site and expert opinion from other wind farms developments, that a 2.5km buffer for Martial Eagle and a 1.5km buffer for Verreaux's Eagle should be applied.

Operational Mitigation

Jon Smallie was dismissive of operational mitigation at this site, stating that "*the position and nature of the Inyanda Roodeplaat site does not allow for effective mitigation at either of these levels*" [the 'levels' being the entire facility and individual turbines]. However the Smallie report and assessment does not appear to have fully considered all of the available mitigation options. A recent review of wind farm mitigation for birds discussed in Section 4 of this report sets out possible options, including (a) specific turbine shutdown on demand when risk of collision is imminent, (b) wider restriction of turbine operation in certain seasons/times of days associated with higher risks, (c) habitat management, (d) increasing turbine visibility, (e) use of deterrents and (f) compensation.

Of these, (b), (d) and (e) are considered unlikely to provide a deliverable solution at Inyanda Roodeplaat. With regards to (b), there are not any specific periods/seasons to which risk is restricted, so an economically viable scheme would be unlikely. Options (d) and (e) are not widely proven techniques and still in the developmental phase, so could not currently be relied upon. Each of the other three are discussed below:

- *Turbine shutdown on demand*

Curtailment of the operation of wind turbines could potentially be a useful mitigation measure to reduce collision risk, but is often uneconomic. Recent developments of schemes that have very limited shutdown over short periods has made the implementation of such schemes more viable, and there are now several in operation globally (mainly in southern Europe). These rely either on direct human observers at key risk periods and/or automated detection systems based on radar or video monitoring. Given the uncertainties with the baseline data obtained at Inyanda Roodeplaat such a system should be considered to provide a back-up response should the number of collisions actually approach the worst-case predictions.

- *Habitat Management (on-site)*

The raptor food resource must not become more attractive within the wind farm site, drawing foraging birds into the site, as this would increase collision risk. For instance, during access track construction, there may be periods of time where imported or excavated aggregate is stockpiled forming potentially attractive habitat for rock 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 should 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.

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.

- *Habitat management (off-site)*

A management programme should be implemented within the Verreaux's Eagle nest buffers to enhance the food resources away from the wind farm, and hence reduce eagle flight activity within the wind farm. 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.).

The wind farm landowner has also expressed willingness for his whole landholding (16,000 ha) to be put into stewardship. This has the potential to include management measures that could improve raptor prey populations and habitat over a large area that, if managed appropriately, could deliver a net gain to the local raptor populations. It is recommended that a specific management plan should be drawn up and implemented to integrate the ecological requirements of the local raptors into the management of this area.

Pre-Construction Monitoring

The monitoring programme for the wind farm should include continuation of the pre-construction baseline surveys (raptor surveys and vantage point surveys), but using an improved survey methodology to increase detection distance and a better spread of vantage points to cover the whole site, to compare bird distribution, abundance and behaviour before and after construction, and a programme to monitor the actual collisions that occur. A further year of pre-construction survey is recommended to provide a more robust baseline, using fully trained and experienced observers and with full quality assurance management.

Post-Construction Monitoring

Post-construction bird monitoring should be undertaken to better understand the impacts that actually occur and inform future wind farm design. Though not strictly mitigation, it does have the potential to make a significant contribution to the understanding of bird-wind farm interactions in this area and specifically about the key species at risk at this site, Verreaux's Eagle.

The operational phase 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 70m 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.

A programme of tagging Verreaux's Eagle is also recommended to provide further information on how this species how this species behaves in and around wind farms. Sample individuals (ideally young and adult birds) from the local population should be tagged with GPS/satellite tags to enable their detailed movement patterns to be determined. The VP surveys provide data on the use of the wind farm site but the tagging would provide more comprehensive data on how these birds are using their whole ranges and on how they respond to the presence of the wind turbines. Data from such a study could also be used to inform range modelling for this species (similar to that undertaken for the golden eagle in the UK, McLeod et al 2002, which has been widely applied to better assess the effects of wind farms on this species). Funding of a project that combines tagging and range modelling could make a significant contribution to the future conservation management of this species.

SECTION 10

ORNITHOLOGICAL ASSESSMENT UPDATE

SECTION 10 – ORNITHOLOGICAL ASSESSMENT UPDATE

The purpose of this section is not to undertake a full ornithological assessment but rather to bring together the information from the work undertaken for this report to assist in informing the overall assessment. The key ornithological issues at this site are collision risk and disturbance/displacement to raptors, particularly Verreaux's Eagle.

Collision Risk

The previous assessment of collision risk undertaken by Jon Smallie concluded that a significant impact on Verreaux's Eagle could not be ruled out, but that assessment was largely qualitative and did not assess the mortality in the context of the regional population. Considerable problems have been identified with the baseline data, particularly those relating to bird flight activity over the site, but best use has been made of those data (taking a precautionary approach to dealing with uncertainties). A quantitative collision risk assessment has shown that the previous conclusion may not be correct and that the level of risk may not be significant. Notwithstanding this (and to account for issues in the baseline data), mitigation measures are recommended to ensure that no significant collision impacts occur, including on- and off-site habitat management, and development of a back-up turbine shutdown on demand system. Previous conclusions in the Smallie report that suggest that such measures would be ineffective are not supported by recent studies of mitigation for raptors at existing wind farms.

Disturbance/Displacement

The implementation of the recommended buffers from known eagle nest sites that were put in place primarily to reduce collision risk (1.5km for Verreaux's Eagle and 2.5km for Martial Eagle), also removes possibility of disturbance to these eagle nest sites. The main residual disturbance issue would therefore be the loss of foraging habitat around the wind farm as a result of displacement. From experience at existing wind farms, birds are likely to avoid the close proximity of the wind turbines. There is uncertainty as to the precise extent of such an effect, but would be reasonable in the assessment to assume that it could occur. Given results from post-construction studies of other raptor species, particularly golden eagle (e.g. Walker et al. 2005), it has been considered that these raptors at this site might have reduced flight activity within 500m of the wind farm (as a reasonable worst case). Though this effect was recognised in the draft assessment as an impact, no quantitative assessment of it was made.

There are two key raptor species using the wind farm site and breeding within the survey area, Verreaux's Eagle and Martial Eagle. These are considered to be the only two species that could possibly be significantly affected by displacement. In order to inform the assessment, range analyses have been carried out for these two species, following the process set out by McGrady et al (1997) developed for golden eagle:

1. *Determination of range centre* – taken as the active nest location for both species. Where more than one nest location was known for a territory the one closest to the wind farm was used (as a worst case). Where the precise nest location had not been determined the best estimate was used.
2. *Determination of territory boundaries with neighboring eagles* – (i) draw a straight line joining the two range centres, (ii) find a point on this line half-way between centres, (iii) draw a line through the half-way point at right angles to the first line.

3. *Determination of territory boundaries without neighbouring eagles* – draw a curved line at 2.9 km (Verreaux's Eagle) or 9.4km (Martial Eagle) radius from the range centre to connect adjacent boundary lines drawn in Step 2. These distances were derived from reported territory sizes for these species (26km^2 for Verreaux's Eagle, from Davies 1994, and 280km^2 for Martial Eagle (Brown 1991).

There is likely to be further altitude constraint on both eagle species' ranges, but both species have been recorded across the full altitudinal range of the Inyanda Roodeplaat survey area, so it was not considered appropriate to include any such constraint at this site. Observed flight data (Figure 12) would suggest though that there is more Verreaux's Eagle flight activity within the lower altitude parts of the survey area, where the eagle nest sites were located, rather than over the higher ground where the wind farm would be sited.

Range loss was predicted by overlaying a 500m and a 250m buffer around the proposed wind turbines onto the estimated ranges and measuring the percentage of each range that could be lost through displacement. The results of this range analysis are mapped in Figure 16 (for Verreaux's Eagle) and Figure 17 (for Martial Eagle) and summarised in Table 11a. This analysis was repeated for an alternative 48-turbine layout and the results for that analysis are shown in Figure 18 (for Verreaux's Eagle) and Figure 19 (for Martial Eagle), and summarised in Table 11b.

For Verreaux's Eagle, there would be no range loss for the Tygerberg, Tiptree and Guntia territories, and only a very small loss from the February territory for the 55-turbine layout (and none for that range for the 48-tutbine layout). There would be a 4.7% loss from the Holbak territory and a 25.4% loss from the Perdehoek territory if there were complete displacement to 500m for the 55-turbine layout, and 5.0% and 21.4% losses for those two ranges respectively for that scenario for the alternative 48-turbine layout. The differences between the two proposed layouts were small, with a slightly higher loss to the Holbak range but a reduced loss to the Perdehoek range from the 48-turbine scheme.

For Martial Eagle, there would be a 7.4% loss from the single territory within the survey area for complete displacement to 500m for the 55-turbine layout, and a 6.8% loss for the same scenario for the alternative 48-turbine layout.

Table 11a. Predicted Verreaux's Eagle and Martial Eagle range loss for the proposed 55-turbine wind farm, assuming complete displacement of both species to 500m from turbines.

Species	Range	Area of range within 250m of proposed turbines (km^2)	% range loss if displaced 250m from turbines	Area of range within 500m of proposed turbines (km^2)	% range loss if displaced 500m from turbines
Verreaux's Eagle	February	0	0%	0.005	0.03%
	Perdehoek	2.80	12.0%	5.95	25.4%
	Holbak	0.58	2.2%	1.24	4.7%
	Tygerberg	0	0%	0	0%
	Guntia	0	0%	0	0%
	Tiptree (new 2014)	0	0%	0	0%
Martial Eagle	New 2014	9.72	3.5%	20.5	7.4%

Table 11b. Predicted Verreaux's Eagle and Martial Eagle range loss for the alternative 48-turbine wind farm, assuming complete displacement of both species to 500m from turbines.

Species	Range	Area of range within 250m of proposed turbines (km²)	% range loss if displaced 250m from turbines	Area of range within 500m of proposed turbines (km²)	% range loss if displaced 500m from turbines
Verreaux's Eagle	February	0	0%	0	0%
	Perdehoek	2.21	9.4%	5.01	21.4%
	Holbak	0.60	2.3%	1.32	5.0%
	Tygerberg	0	0%	0	0%
	Guntia	0	0%	0	0%
	Tiptree (new 2014)	0	0%	0	0%
Martial Eagle	New 2014	8.28	3.0%	19.0	6.8%

The magnitude of these disturbance impacts (and hence significance of effect) relates to the ecological consequences of any range loss. Ranges of golden eagles have been reported as being abandoned following a 40% loss of habitat (Watson et al. 1987) and reduced productivity associated with a 10-15% loss (Whitfield et al. 2001), though not in all cases and the effects of habitat loss generally can be complex. For a heavily constrained range (for example by a close neighbour or reduced availability of suitable habitat in the wider area), any additional loss is likely to be more ecologically important that an unconstrained range (Whitfield et al. 2001, 2007).

Focussing on the two specific Verreaux's Eagle territories that would be most affected, the area within the *Holbak* territory that would be affected is on the south-western edge of the range, on higher ground 2-3km from the closest nest site. Given the relative low use of the higher ground observed during the VP surveys and the wide availability of alternative foraging areas of similar habitat and elevation close nearby, the predicted 4.7% loss (or 5.0% for the alternative 48-turbine layout) is not considered to be significant. This conclusion is reinforced when the benefits of the proposed mitigation measures discussed above area also implemented.

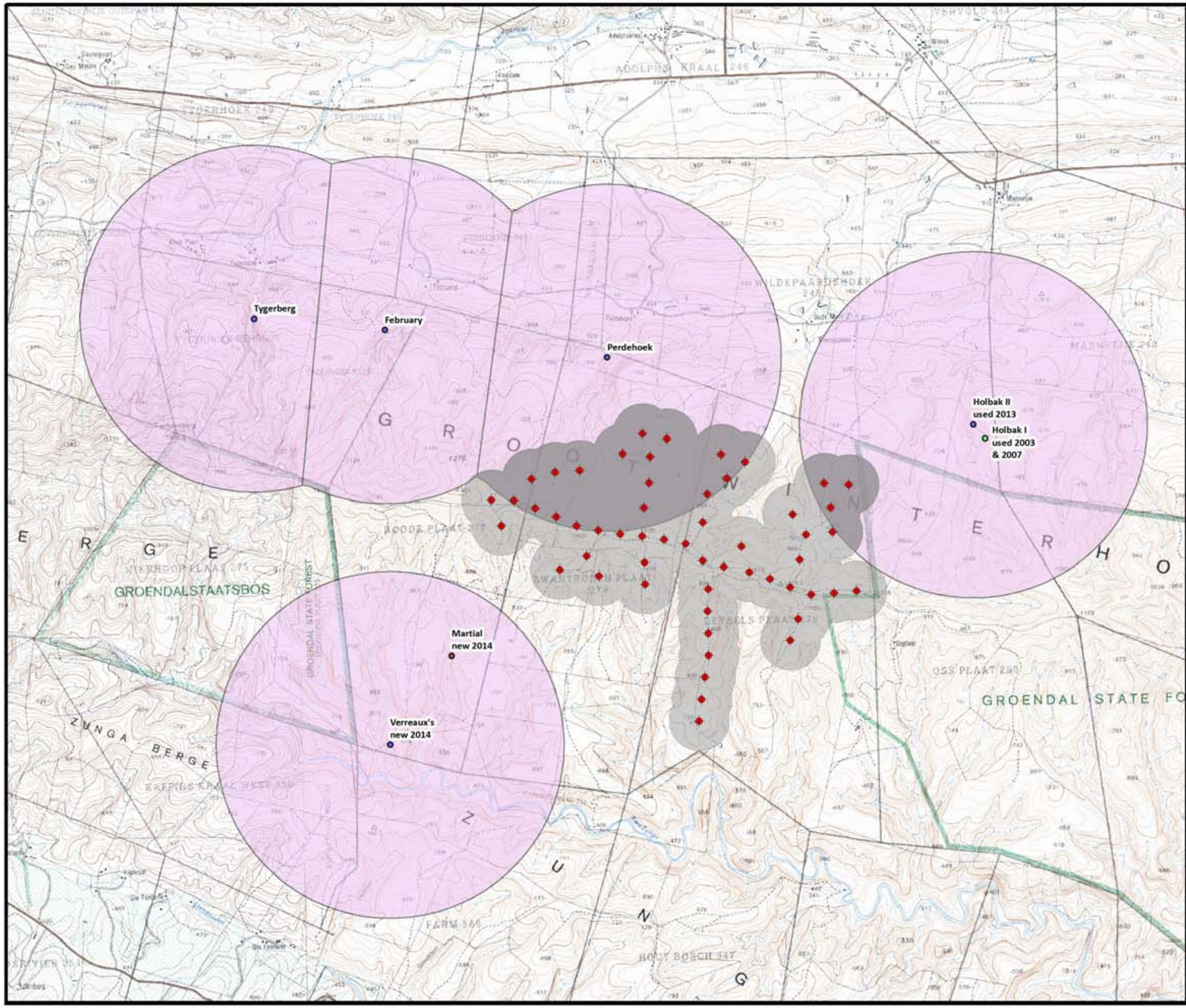
The predicted loss to the *Perdehoek* territory is much the greatest of the displacement impacts on Verreaux's Eagle, with 25% of that range falling within 500m of the proposed wind turbine locations (and 21% for the alternative 48-turbine layout). This is below the 40% threshold at which golden eagle range abandonment occurred, but could still be a substantial loss. There is also limited possibility for this territory to expand as it is bordered to the east and west by other eagle territories. The vantage point surveys (from VP1-3) did cover most of this area, however, and did not indicate that it formed an important part of the range, suggesting that the actual impact may be somewhat reduced. It will though still be important to ensure that the recommended mitigation measures discussed above (particularly the off-site habitat management) are implemented to avoid any significant impact on this territory.

Martial Eagles have much larger ranges than Verreaux's Eagles, so would be predicted to be less vulnerable to range loss. The whole of the wind turbine 500m buffer lies with the Martial Eagle range that overlaps the survey area, but even so this would constitute a loss of only 7.4% of the birds' range (and 6.8% for the alternative 48-turbine layout). Given that this range is largely unconstrained, such a loss would not be considered significant (especially as this species would also benefit from off-site habitat management).

In conclusion, both collision and disturbance impacts on Verreaux's Eagle have the potential to be significant, but mitigation measures have the potential to enable these to be managed so that they remain below the significance threshold. A phased implementation of such measures is proposed:

1. Further year's pre-construction surveys to provide additional baseline to inform and fine-tune the required measures.
2. Implementation of on-site and off-site habitat management prior to construction
3. Post-construction monitoring to determine the actual effects of the wind farm and inform the habitat management measures
4. Develop a back-up plan for turbine shutdown on demand (though further baseline data and assessment based on those data may show that such a scheme is unnecessary).

In addition funding of a project that combines tagging and range modelling could make a significant contribution to the future conservation management of Verreaux's Eagle.



Shoney (Seonaidh) Wind Limited

Inyanda Roodeplaat Wind Farm

FIGURE 16

Verreaux's Eagle Estimated Ranges and Predicted Loss

KEY:

- 55-turbine layout

Species

- Martial Eagle
- Verreaux's Eagle
- Verreaux's old site
- 55-turbine 500m Buffer
- Verreaux's Eagle Estimated Ranges
- Estimated Range Loss

ECOLOGY CONSULTING

N

0 0.4 0.8 1.6 2.4 3.2 Kilometres

N/A N/A

EC-2015-1

SCALE - 1:60,000 @ A3

ORNITHOLOGICAL ASSESSMENT REVIEW

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FIGURE 17

Martial Eagle Estimated Range and Predicted Loss

KEY:

- 55-turbine layout

Eagle Nest Site

- Martial Eagle
- 55-turbine 500m Buffer
- Martial Eagle Estimated Range

ECOLOGY CONSULTING

N

0 0.5 1 2 3 4 Kilometres

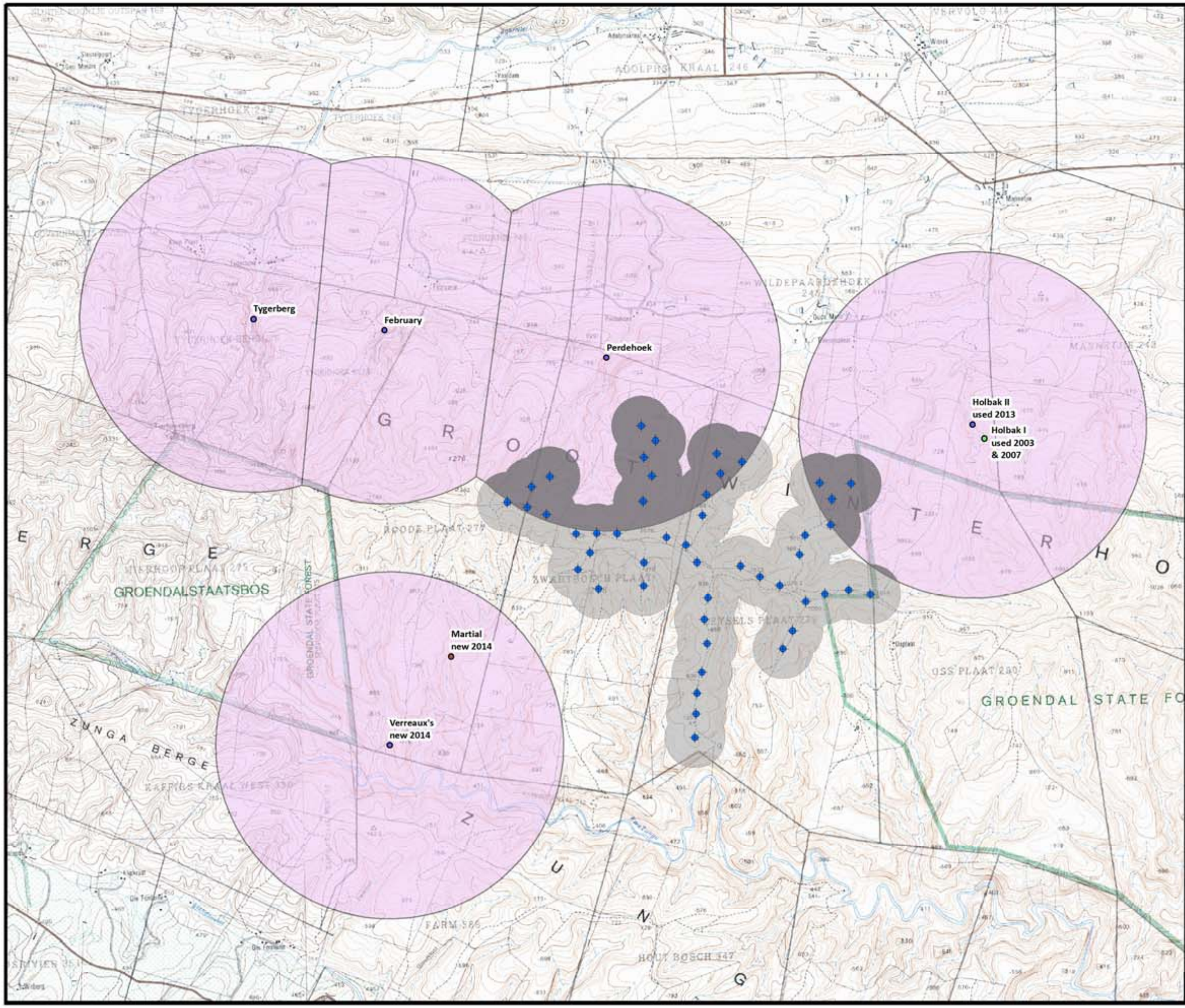
N/A

N/A

EC-2015-1

SCALE - 1:75,000 @ A3

ORNITHOLOGICAL ASSESSMENT REVIEW



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Inyanda Roodeplaat Wind Farm

FIGURE 18

Verreaux's Eagle Estimated Ranges and Predicted Loss (alternative 48-turbine layout)

KEY:

48-turbine layout

Species

Martial Eagle

Verreaux's Eagle

Verreaux's old site

48-turbine 500m Buffer

Estimated Range Loss (500m)

Verreaux's Eagle Estimated Ranges

ECOLOGY CONSULTING

N

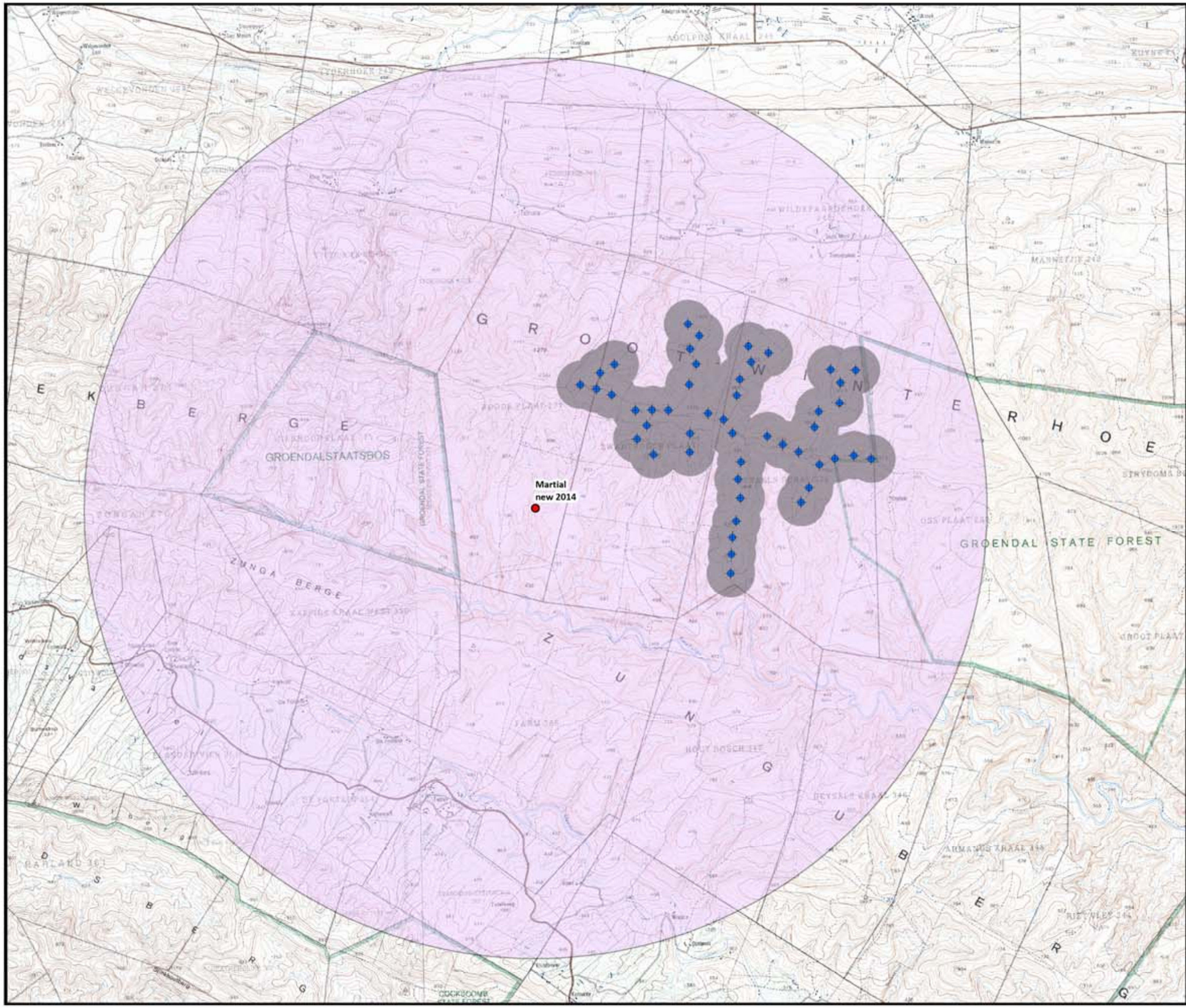
0 0.4 0.8 1.6 2.4 3.2 Kilometres

N/A | N/A

EC-2015-1

SCALE - 1:60,000 @ A3

ORNITHOLOGICAL ASSESSMENT REVIEW



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Inyanda Roodeplaat Wind Farm

FIGURE 19

Martial Eagle Estimated Range and Predicted Loss (alternative 48-turbine layout)

KEY:

- 48-turbine layout

Eagle Nest Site

- Martial Eagle
- 48-turbine 500m Buffer
- Martial Eagle Estimated Range

ECOLOGY CONSULTING

N

0 0.5 1 2 3 4 Kilometres

N/A	N/A

EC-2015-1

SCALE - 1:75,000 @ A3

ORNITHOLOGICAL ASSESSMENT REVIEW

SECTION 11

REFERENCES

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

(B) STATEMENT OF INDEPENDENCE FROM AFRI-COAST ENGINEERS AND THE INYANDA ROODEPLAAT 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 350 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 Afri-Coast Engineers and the Inyanda Roodeplaat WEF

Dr Steve Percival is independent from Afri-Coast Engineers and the Inyanda Roodeplaat WEF.

APPENDIX 2- COLLISON RISK MODELLLING

APPENDIX 2. COLLISION RISK MODELLING RESULTS FOR THE PROPOSED 55-TURBINE LAYOUT

This Appendix sets out the collision risk modelling that has been undertaken to support the ornithological assessment of the Inyanda Roodeplaat wind farm.

Firstly the standard Band model spreadsheets are presented for each species modelled in turn. These provide the information used to calculate the risk that individuals of each species would face if they flew through the Inyanda Roodeplaat wind farm rotor swept area. For the first species, for example, Verreaux's Eagle, this gives an overall 8.3% chance of collision.

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Verreaux's 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	5.87	25.27	1.00	0.00125	24.88	1.00	0.00125
Wingspan	2.4	m	0.075	0.575	1.96	8.56	0.45	0.00334	8.16	0.43	0.00319
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.17	5.74	0.30	0.00374	5.26	0.27	0.00342
			0.175	0.860	0.84	4.66	0.24	0.00425	4.07	0.21	0.00371
Bird speed	11.9	m/sec	0.225	0.994	0.65	4.02	0.21	0.00471	3.34	0.17	0.00391
RotorDiam	125	m	0.275	0.947	0.53	3.25	0.17	0.00466	2.60	0.14	0.00373
RotationPeriod	4.84	sec	0.325	0.899	0.45	2.71	0.14	0.00460	2.10	0.11	0.00355
			0.375	0.851	0.39	2.32	0.12	0.00453	1.73	0.09	0.00338
			0.425	0.804	0.35	2.06	0.11	0.00456	1.51	0.08	0.00334
			0.475	0.756	0.31	1.90	0.10	0.00470	1.38	0.07	0.00342
Bird aspect ratioo: β	0.37		0.525	0.708	0.28	1.77	0.09	0.00484	1.28	0.07	0.00351
			0.575	0.660	0.26	1.66	0.09	0.00496	1.20	0.06	0.00360
			0.625	0.613	0.23	1.56	0.08	0.00508	1.14	0.06	0.00371
			0.675	0.565	0.22	1.47	0.08	0.00518	1.09	0.06	0.00382
			0.725	0.517	0.20	1.40	0.07	0.00528	1.04	0.05	0.00394
			0.775	0.470	0.19	1.33	0.07	0.00537	1.01	0.05	0.00407
			0.825	0.422	0.18	1.27	0.07	0.00546	0.98	0.05	0.00421
			0.875	0.374	0.17	1.21	0.06	0.00553	0.96	0.05	0.00436
			0.925	0.327	0.16	1.16	0.06	0.00559	0.94	0.05	0.00452
			0.975	0.279	0.15	1.11	0.06	0.00565	0.92	0.05	0.00468
				Overall p(collision) =			**Upwind**	**9.3%**		**Downwind**	**7.3%**
								Average	**8.3%**		

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	5.67	17.80	0.96	0.00120	17.41	0.94	0.00117
Wingspan	1.23	m	0.075	0.575	1.89	6.06	0.33	0.00245	5.67	0.31	0.00229
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.13	4.23	0.23	0.00285	3.75	0.20	0.00253
			0.175	0.860	0.81	3.56	0.19	0.00336	2.97	0.16	0.00280
Bird speed	11.5	m/sec	0.225	0.994	0.63	3.16	0.17	0.00383	2.48	0.13	0.00300
RotorDiam	125	m	0.275	0.947	0.52	2.55	0.14	0.00378	1.90	0.10	0.00282
RotationPeriod	4.84	sec	0.325	0.899	0.44	2.12	0.11	0.00372	1.51	0.08	0.00264
			0.375	0.851	0.38	1.84	0.10	0.00372	1.26	0.07	0.00254
			0.425	0.804	0.33	1.65	0.09	0.00378	1.10	0.06	0.00252
			0.475	0.756	0.30	1.49	0.08	0.00383	0.98	0.05	0.00250
Bird aspect ratioo: β	0.41		0.525	0.708	0.27	1.37	0.07	0.00387	0.88	0.05	0.00249
			0.575	0.660	0.25	1.26	0.07	0.00390	0.80	0.04	0.00249
			0.625	0.613	0.23	1.16	0.06	0.00392	0.74	0.04	0.00250
			0.675	0.565	0.21	1.08	0.06	0.00393	0.69	0.04	0.00252
			0.725	0.517	0.20	1.01	0.05	0.00394	0.65	0.04	0.00255
			0.775	0.470	0.18	0.94	0.05	0.00393	0.62	0.03	0.00259
			0.825	0.422	0.17	0.88	0.05	0.00392	0.59	0.03	0.00263
			0.875	0.374	0.16	0.83	0.04	0.00390	0.57	0.03	0.00269
			0.925	0.327	0.15	0.78	0.04	0.00387	0.55	0.03	0.00275
			0.975	0.279	0.15	0.73	0.04	0.00383	0.54	0.03	0.00282
				Overall p(collision) =			**Upwind**	**7.2%**		**Downwind**	**5.1%**
								Average	**6.1%**		

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	5.13	20.83	1.00	0.00125	20.44	1.00	0.00125
Wingspan	2.15	m	0.075	0.575	1.71	7.08	0.42	0.00316	6.68	0.40	0.00299
F: Flapping (0) or gliding (+1)	0		0.125	0.702	1.03	4.79	0.29	0.00357	4.31	0.26	0.00321
			0.175	0.860	0.73	3.92	0.23	0.00409	3.33	0.20	0.00348
Bird speed	10.4	m/sec	0.225	0.994	0.57	3.41	0.20	0.00458	2.73	0.16	0.00366
RotorDiam	125	m	0.275	0.947	0.47	2.77	0.16	0.00453	2.12	0.13	0.00347
RotationPeriod	4.84	sec	0.325	0.899	0.39	2.31	0.14	0.00448	1.70	0.10	0.00329
			0.375	0.851	0.34	2.05	0.12	0.00458	1.47	0.09	0.00328
			0.425	0.804	0.30	1.88	0.11	0.00475	1.32	0.08	0.00336
			0.475	0.756	0.27	1.73	0.10	0.00491	1.22	0.07	0.00344
Bird aspect ratioo: β	0.38		0.525	0.708	0.24	1.62	0.10	0.00506	1.13	0.07	0.00354
			0.575	0.660	0.22	1.52	0.09	0.00520	1.06	0.06	0.00365
			0.625	0.613	0.21	1.43	0.09	0.00533	1.01	0.06	0.00376
			0.675	0.565	0.19	1.35	0.08	0.00545	0.97	0.06	0.00389
			0.725	0.517	0.18	1.29	0.08	0.00556	0.93	0.06	0.00402
			0.775	0.470	0.17	1.22	0.07	0.00566	0.90	0.05	0.00417
			0.825	0.422	0.16	1.17	0.07	0.00575	0.88	0.05	0.00432
			0.875	0.374	0.15	1.12	0.07	0.00583	0.86	0.05	0.00449
			0.925	0.327	0.14	1.07	0.06	0.00590	0.85	0.05	0.00466
			0.975	0.279	0.13	1.03	0.06	0.00596	0.83	0.05	0.00485
				Overall p(collision) =			**Upwind**	**9.6%**		**Downwind**	**7.3%**
								Average	**8.4%**		

CALCULATION OF COLLISION RISK FOR BIRD PASSING THROUGH ROTOR AREA											
Black Harrier											
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	0.51	m	0.025	0.575	4.78	13.95	0.89	0.00111	13.55	0.87	0.00108
Wingspan	1.00	m	0.075	0.575	1.59	4.78	0.31	0.00229	4.39	0.28	0.00210
F: Flapping (0) or gliding (+1)	0		0.125	0.702	0.96	3.38	0.22	0.00270	2.90	0.19	0.00232
			0.175	0.860	0.68	2.89	0.18	0.00324	2.30	0.15	0.00258
Bird speed	9.7	m/sec	0.225	0.994	0.53	2.60	0.17	0.00373	1.91	0.12	0.00275
RotorDiam	125	m	0.275	0.947	0.43	2.18	0.14	0.00383	1.53	0.10	0.00269
RotationPeriod	4.84	sec	0.325	0.899	0.37	1.90	0.12	0.00394	1.28	0.08	0.00266
			0.375	0.851	0.32	1.69	0.11	0.00404	1.10	0.07	0.00264
			0.425	0.804	0.28	1.52	0.10	0.00414	0.97	0.06	0.00264
			0.475	0.756	0.25	1.39	0.09	0.00422	0.87	0.06	0.00265
Bird aspect ratioo: β	0.51		0.525	0.708	0.23	1.28	0.08	0.00429	0.79	0.05	0.00266
			0.575	0.660	0.21	1.18	0.08	0.00435	0.73	0.05	0.00269
			0.625	0.613	0.19	1.10	0.07	0.00440	0.68	0.04	0.00273
			0.675	0.565	0.18	1.03	0.07	0.00444	0.64	0.04	0.00277
			0.725	0.517	0.16	0.97	0.06	0.00447	0.61	0.04	0.00283
			0.775	0.470	0.15	0.91	0.06	0.00449	0.59	0.04	0.00290
			0.825	0.422	0.14	0.85	0.05	0.00450	0.56	0.04	0.00298
			0.875	0.374	0.14	0.81	0.05	0.00450	0.55	0.04	0.00307
			0.925	0.327	0.13	0.76	0.05	0.00449	0.54	0.03	0.00317
			0.975	0.279	0.12	0.72	0.05	0.00447	0.53	0.03	0.00328
				Overall p(collision) =			**Upwind**	**7.8%**		**Downwind**	**5.3%**
								Average	**6.5%**		

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

All 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).

Section 1 of the Table gives the survey effort (number of hours observation) from each VP for each season.

The numbers of minutes of flight of each key species within the collision risk zone are summarised in Section 2, and those are converted to occupancy rates (the proportion of the observation time during which birds were present in the risk zone) in Section 3, which feed into the final section of the modelling.

Section 4 of the Table shows the hours of daylight per day and in total for each month (calculated using Band 2012).

INYANDA ROODEPLAAT COLLISION RISK MODELLING DATA INPUT: BIRD USAGE												
1. Hours observation												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VP1	0	12.0	0	0	12.0	0	12.0	0	12.0	0	0	0.0
VP2	0	12.0	0	0	12.0	0	12.0	0	12.0	0	0	0.0
VP3	0	12.0	0	0	12.0	0	12.0	0	12.0	0	0	0.0
2. Bird occupancy of collision zone (minutes)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Verreaux's Eagle		1.9			0.7		8.4		11.8			
Black Harrier		0.0			0.0		0.0		6.7			
Martial Eagle		0.0			1.1		0.8		1.3			
Booted Eagle		1.3			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
Verreaux's Eagle		0.269%			0.091%		1.173%		1.641%			
Black Harrier		0.000%			0.000%		0.000%		0.926%			
Martial Eagle		0.000%			0.151%		0.116%		0.177%			
Booted Eagle		0.176%			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	14.4	14.6	12.0	12.7	10.9	10.4	10.6	10.1	11.2	11.5	13.3	13.4
Mean nocturnal hours	9.6	9.4	12.0	11.3	13.1	13.6	13.4	13.9	12.8	12.5	10.7	10.6
No days birds present	31	30	31	30	31	31	28	31	30	31	30	31
Total hours day	445	438	373	382	338	322	298	314	337	356	400	416
Total hours day&night	744	744	672	744	720	744	720	744	744	720	744	720

The remaining Table in this Appendix show the results of the non-direct (variable) flight models for each of the four key species (Verreaux's Eagle, Black Harrier, Martial Eagle and Booted Eagle).

INYANDA ROODEPLAAT WIND FARM BAND ET AL 2007 COLLISION MODEL (OCCUPANCY)				
	Verreaux's Eagle	**Black Harrier**	**Martial Eagle**	**Booted Eagle**
Collision Zone Area (ha)	719	719	719	719
Hub Ht	100	100	100	100
Rotor diameter	125	125	125	125
Upper rotor ht	162.5	162.5	162.5	162.5
Lower rotor ht	37.5	37.5	37.5	37.5
Percentage of observation time seen flying in collision zone	**0.793%**	**0.232%**	**0.111%**	**0.044%**
Proportion of observation time seen flying at rotor height [only flights at rotor height included]	100%	100%	100%	100%
Adjusted proportion of observation time seen flying at rotor height	0.793%	0.232%	0.111%	0.044%
Season length	365	365	365	365
Activity per day	12.1	12.1	12.1	12.1
Total flight activity in collision zone at rotor ht	35.036	10.229	4.900	1.946
Flight risk volume	8.988E+08	8.988E+08	8.988E+08	8.988E+08
No Turbines	**28**	**28**	**28**	**28**
Rotor radius	**62.5**	**62.5**	**62.5**	**62.5**
Rotor depth	**3.28**	**3.28**	**3.28**	**3.28**
Bird length	**0.88**	**0.51**	**0.81**	**0.5**
Swept volume	1429425	1302288	1405372	1298852
Bird occupancy of swept volume	200.60	53.36	27.58	10.12
Bird speed	**11.9**	**9.7**	**10.4**	**11.5**
Rotor transit time	0.350	0.391	0.393	0.329
No of rotor transits	573.8	136.6	70.1	30.8
Turbine downtime	10%	10%	10%	10%
Band collision rate	8.3%	6.5%	8.4%	6.1%
Non-avoid collisions	43.0	8.0	5.3	1.7
Avoidance rate	98%	98%	98%	98%
Collision prediction (28 observed turbines)	**0.860**	**0.161**	**0.106**	**0.034**
Total collisions (55 TURBINES)	**1.69**	**0.32**	**0.21**	**0.07**