Pre-construction Avian Basic Assessment for the proposed ZONNEQUA Wind Farm, Kleinzee, Northern Cape

May 2017 to February 2018

Prepared for:

genesis eco-energy DEVELOPMENTS

ATLANTIC ENERGY PARTNERS

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1 SUMMARY

Genesis Zonnequa Wind (Pty) Limited have proposed the development of a wind energy facility (WEF) in the Renewable Energy Zone (REDZ 8) near Kleinzee, South Africa, part of the arid Namaqualand Strandveld. Potential threats to the priority avifauna were monitored over 12 months as dictated by the DEA and Birds and Renewable Energy Group. Kleinzee lies in the Succulent Karoo Biome of the Northern Cape and this report details the number of priority species (including all threatened and collision-prone birds) and their Passage Rates through the 44.2-km^2 area proposed for the development in spring, summer, autumn and winter seasons. We then quantify and predict possible threats, and map high risk and low risk areas to reduce future impacts.

The possible impacts for any wind farm include:

- Displacement and avoidance of nationally important species by the turbines;
- Loss of habitat for such species due to direct habitat destruction under the turbines;
- Disturbance during construction;
- Mortality arising from birds impacting the moving turbine blades or associated infrastructure.

The impact zone of the proposed WEF site lies within the coastal area of the Succulent Karoo biome. Dry and uniform grazed habitats within this undulating area allows a small suite of arid-adapted and nomadic species to exist. Up-to-date (SABAP2) bird atlas data of the broader region indicates that the area proposed for the development supports a low diversity of 48 bird species. Our own records, focussed on the wind farm site in a particularly dry period, found only 45 species in 12 months of monitoring. Allowance is made for this based on our experience of bird diversity and abundance in arid areas to give a more realistic assessment of avian diversity at other times. More birds (31.3 per kilometre) and a higher species richness (26) were present in spring (August), which is more than any other month. This included 7 collision-prone species of which 3 were red-listed: Ludwig's Bustard *Neotis ludwigii* (ranked 10th in the top 100), Kori Bustard *Ardeotis kori* (ranked 37th) and Secretarybird *Sagittarius serpentarius* (ranked 12th).

In the broader area around the proposed wind farm covered by bird atlas cards, 9 collision-prone species were recorded and the wind farm may thus impact these birds negatively. Turbines that kill, on average, 4.11 birds per turbine per year in South Africa, particularly raptors (Ralston-Paton et al. 2017) may, therefore, impact the raptors and bustards that frequent the site. Fortunately, both the annual passage rate of the collision-prone species on the WEF (0.36 birds per hour), and the Red Data birds alone (0.09 birds per hour) was so low, that the probability of impacts and avoidance are also likely to be low.

Several priority species flew at the blade-swept heights of 55-205-m of the proposed turbines, with the Secretarybird (42%), Black-chested Snake Eagle (59%), Booted Eagle (65%), and Jackal Buzzard (85%) all recorded frequently at these risky heights.

One area of high-risk and three areas of medium-risk were found on the proposed wind farm. The high-risk area identified is located within the southern section of the site where an inactive Secretarybird nest site was located. We never observed this nest being used and it was thus the least used nest area of a pair/individual present on the adjacent Namas property. Because the Namas (also inactive) nest has been buffered, the 1-km buffer here is not necessary because it's the least likely to be used. We recommend moving this structure outside the WEF area as a further precaution. This idea has gained the green light from Birdlife South Africa following discussions because (i) Secretarybirds often move sites when their nests disintegrate every ~3 years or so and (ii) this nest structure has never been used. The medium risk areas (where one Red Data species and one other priority species overlap) are recommended for development but only with the implementation of appropriate mitigation. We recommend:

- a black- or UV-painted blade for all turbines in medium risk areas to reduce possible raptor mortalities;
- that construction and post-construction monitoring takes place to ensure that any wind-farm-related fatalities are documented and addressed immediately.

The cumulative impacts of three other proposed renewable energy facilities within 30-km of the Zonnequa Wind Farm were assessed, and a maximum of 1084 bird fatalities are estimated annually from these proposed facilities. Approximately 78 of these are estimated to be priority Red Data raptors per year. However, given the very low occurrence and Passage Rates this is likely to be an over-estimate. It is also unlikely that all the proposed facilities will be developed, further reducing the likely cumulative impacts.

Because this is a medium impact site for birds we recommend that, with the mitigations above considered, development be allowed to proceed with a full 12-24 months post construction monitoring programme in place. This should be undertaken by competent ornithologists familiar with the area's threatened species to monitor fatalities or problems in the construction and post-construction phases. Solutions and alternatives can then be suggested and implemented if challenges arise.

1.1 Consultant's Declaration of Independence

Birds & Bats Unlimited are independent consultants to Genesis Zonnequa Wind (Pty) Limited. They have no business interest - financial, personal or other - in the activity, application or appeal other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of the specialists performing such work.

Qualifications of Specialist Consultant

Birds & Bats Unlimited (www.birds-and-bats-unlimited.com/) were approached to undertake the specialist avifaunal assessment for the pre-construction phase of the proposed Zonnequa Wind Farm near Kleinzee. Dr Rob Simmons is an ornithologist, with 35 years' experience in avian research and impact assessment work. He has published over 100 peer-reviewed papers and 2 books, (see www.fitzpatrick.uct.ac.za/fitz/staff/research/simmons for details). More than 60 projects and assessments over 23 habitats have been undertaken throughout Namibia, (where he was the State Ornithologist for 14 years), Angola, Lesotho and South Africa. He also undertakes long-term research on threatened species (raptors, vultures, flamingos and terns) and the impacts of predatory domestic cats on biodiversity around Cape Town, at the FitzPatrick Institute, UCT where he has been an Honorary Research Associate for 16 years.

Marlei Martins, co-director of Birds & Bats Unlimited, has over 7 years' consultancy experience in avian wind farm impacts as well as 20 years in environmental issues and rehabilitation. She has been employed by several consultancy companies throughout South Africa because of her expertise in this field. She has published papers on her observations, including a new species of raptor to South Africa (http://www.birds-and-bats-unlimited.com/).

2 TERMS OF REFERENCE

The terms of reference for the final Pre-construction Avian Assessment Report, based on the EIA regulations, are as follows:

- To provide a list of the occurrence and passage rates of priority species, particularly the priority Red Data and collision-prone species [CPS], at the proposed Zonnequa Wind Farm;

- To estimate the density of smaller passerine species in the WEF and compare that with those found in the Control area;
- To provide details of any medium- and high-risk avian areas within the WEF, based on the occurrence of priority species found throughout the year;
- To provide a semi-quantitative assessment of impacts, before and after the proposed mitigations;
- To provide recommendations for mitigating the possible impacts identified;
- To provide an assessment of the Cumulative Impacts for other authorised renewable energy facilities with a current Environmental Authorization within 30-km to determine possible wide-scale mortalities or displacement;
- To provide an Environmental Management Plan to implement during-construction and post-construction monitoring and to ensure that the recommended mitigations are implemented to reduce potential impacts to the priority avifauna of the area.

2.1 Need for Proposed Avian Assessment

Birds are known to be impacted directly and indirectly by wind farms world-wide, both onshore and offshore (Langston 2006), and the Department of Environmental Affairs (DEA) mandates that all proposed wind farms require 12-months of avian pre-construction monitoring to determine the abundance and diversity of collision-prone species, particularly threatened red data species, which are at risk, and the impacts. Mitigations and alternatives must be provided at the conclusion of such reports, and they are guided in these recommendations by the Birds and Renewable Energy Specialist Group (BARESG). This advisory group produced monitoring guidelines for birds and wind farms (Jenkins et al. 2014). This study arises from this need for 12-months monitoring, and we follow the BARESG guidelines throughout.

3 BACKGROUND

Genesis Zonnequa Wind (Pty) Limited has proposed a wind energy facility (WEF) in the Renewable Energy Zone (REDZ 8) near Kleinzee, South Africa in the arid Namaqualand Strandveld. The wind farm will be sited on slightly raised ground on portion 1 of the farm Zonnekwa 328 and the remaining extent of the farm Zonnekwa 326, 22.5-km south-east of Kleinzee. A wind mast is situated on the adjacent Namas farm at S 29°50'49" E 17°11'39" in heavily grazed sandy substrate.

The wind farm was designed to generate 140MW of power, initially, from 70, 2.5MW turbines of 80-m hub height. However, in March 2018 advances in renewable energy technology allowed the possibility of fewer turbines with the following combinations:

- 47 turbines, of 3.0MW each;
- 36 turbines of 4MW each; or
- 34 turbines of 4.2MW each (D Peinke pers. comm.).

All designs have hub heights of up to 130m, with blades (rotors) of 75m, giving a rotor diameter of 150m. These are important considerations for birds because taller turbines are predicted to cause a greater impact to birds than shorter turbines (see details below). This can be offset by having fewer turbines.

Pre-construction monitoring has been undertaken for the Zonnequa Wind Farm in line with the international best-practice guidelines of the Birds and Renewable Energy Specialist Group (BARESG) (Jenkins et al. 2014). These call for four seasons' monitoring over 12-months across the proposed site and a Control site to be simultaneously monitored over the same period. This allows us to determine the effect that turbines may have on birds after construction, independent of natural fluctuations due to other causes. Passage rates (number of collision-prone birds [CPB] per hour) through both areas are highlighted to determine the risk to CPB.

4 STUDY METHODOLOGY

The avian monitoring reported here covered 12-months as dictated by the DEA and Birdlife South Africa. Priority species, defined as the top 100 collision-prone species (CPS) and red-listed species that pass through the 44.2-km^2 area, were documented in winter (May 2017), spring (August 2017), summer (November 2017) and autumn (February 2018), to help quantify, predict and reduce future impacts. This covers all the bird-active months for migrants and residents. We report on (i) the density of smaller resident species in the wind farm site; (ii) the presence and passage rates of all larger CPS passing through the wind farm site (and the Control area) from Vantage Point (VP) surveys; and (iii) breeding species throughout the area. We conclude by identifying the impacts and the high- and medium-risk sensitivity areas within the WEF, based on the presence and number of CPS using the area. The possible Cumulative impacts were also provided, as required by the DEA.

All bird transects took place in the morning (bird-active) hours. Each 1-km transect was walked slowly over a 25- to 50-minute duration, depending on terrain and number of birds present. One survey was walked in each of the areas proposed for turbines (i.e. WEF areas) in each season, with another 1-km transect in the Control area north of the WEF. These transects cover the main habitat type present (e.g. heavily grazed Succulent Karoo and Nama Karoo scrub), including ridges and valleys. All VPs and transects are shown in Figure 1. All species were identified where possible, and the number of individual birds and the perpendicular distance to them was recorded with a Leica Laser Rangemaster 1600. This allows an estimate of the density (birds per unit area and kilometre) and the species richness in each area. We, simultaneously, recorded all large birds (mainly raptors and bustards) and noted and recorded the position of any large active nests found in the study area.

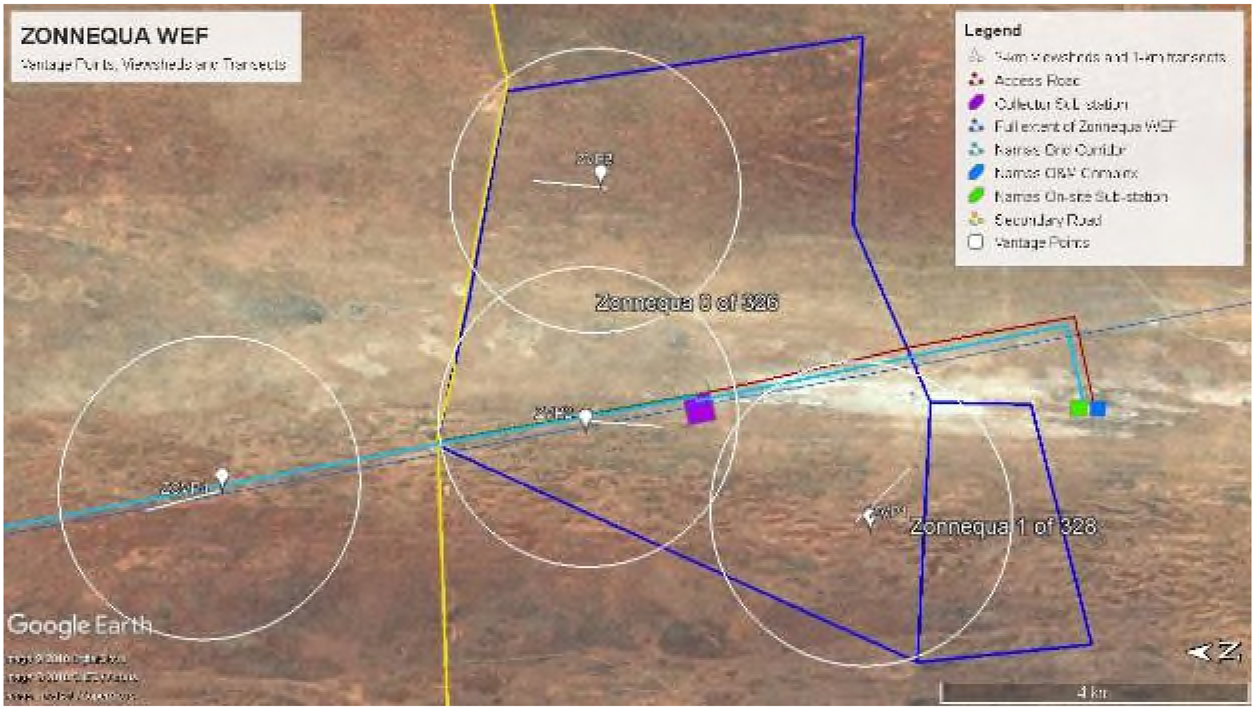

Figure 1: The 44.2-km^2 extent of the proposed Zonnequa Wind Farm showing the boundary of the site (blue polygon), the VP viewsheds of 2-km radius (white circles) and the 1-km transects in the WEF (white lines). A Control area with equivalent habitat and land-use was chosen to the north (left) and surveyed simultaneously. North is to the left.

Vantage Point (VP) monitoring is the most important aspect of such site surveys (BARESG 2015). They comprised 6-hours observations for each VP on two separate days, for a total of 12-hours to record passage rates of the larger CPB (i.e. large raptors and bustards) from equally-spaced vantage points throughout the WEF and Control areas. These were undertaken from hills and other raised points, and allowed uninterrupted views of about 2-km. At 2-km it becomes more difficult to identify each species and their positions, but the presence and identity of larger birds is still possible over these distances with 8.5x or 10x Swarovski binoculars. The VPs were sited to cover the entire study area equally. For areas where the viewshed was obstructed we undertook additional observations from a second VP in those obstructed areas. For identified birds, their flight height and behaviour was estimated every 15-seconds and recorded directly onto laminated Google Earth maps in the field, and then transferred to a digital Google Earth image of the area. These are combined and presented here for May 2017 to February 2018 (Figures 5-8). Flight height is a difficult parameter to measure but we used the presence of the 99-m wind mast on the adjacent property and our previous expertise with estimating height in a drone experiment in similar terrain in which our average error was about 10 m (Figure 2).

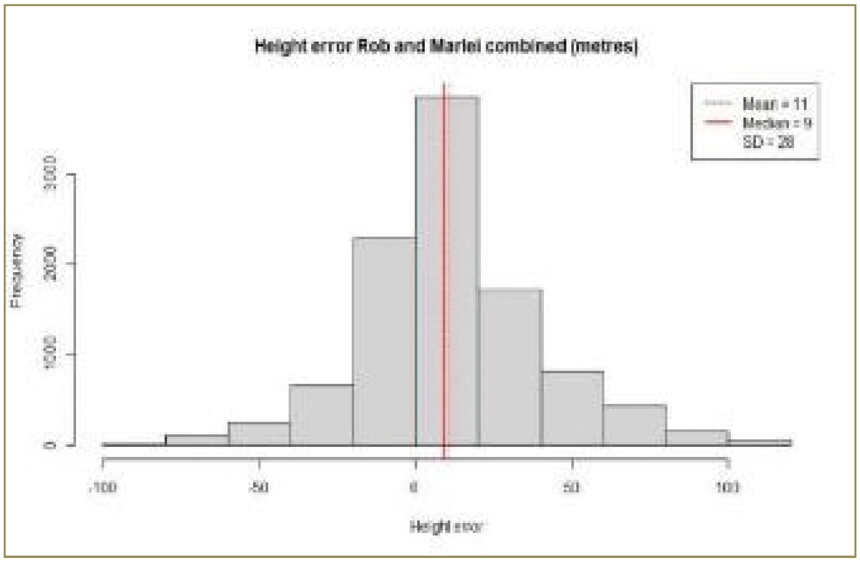

Figure 2: The error in estimating height of a GPS-fitted drone under field conditions by M Martins and R Simmons, based on over 3000 observations at a west-coast site. The median error was under 10m. Unpubl. data of F Cervantes-Peralta.

4.1 Data Sources Used

The following data sources and reports were consulted in the compilation of this report:

- Data on the biology (Hockey et al 2005), distribution (Harrison et al. 1997) and conservation status (Taylor et al. 2015) of South African birds was consulted. Up-to-date data were extracted from the Southern African Bird Atlas Projects (SABAP) which were obtained from the Animal Demography Unit website (http://sabap2.adu.org.za/index.php) for the relevant "pentads" of 5' x 5' (from SABAP 2: Appendix 1). From these data, we compiled a list of the avifauna likely to occur within the impact zone of the proposed WEF. These data were augmented and constantly updated from our four visits over the period May 2017 to February 2018;
- The ranking of collision-prone species (CPS) is drawn from the updated BARESG tabulation of 2014. We consider only the Top 100 collision-prone species as priority species. This reduces the spurious

introduction of species that may be influenced by the wind farm but have a low conservation status. This was sourced from the Birdlife South Africa website at www.birdlife.org.za/conservation/terrestrial-bird-conservation/birds-and-renewable-energy Among these CPS are Red Data species that require special attention;

- Red Data species conservation status, and the Red Data classification in South Africa, was sourced from Taylor et al. (2015);
- Important Bird Area (IBA) data were collated from Barnes (1998) and the updated layers provided by D Marnewick (Birdlife SA) and available at http://www.birdlife.org.za/conservation/important-bird-areas/documents-and-downloads

4.2 Limitations and Assumptions

Inaccuracies in the above sources of information can limit this study. The SABAP1 national data set is now over 20-years old (Harrison et al. 1997) and it is likely that bird distributions have since altered under the effects of climate change in South Africa (Simmons et al. 2004). Therefore, we have used only the more recent SABAP2 data set. This has a higher spatial resolution and is up to date (2007 to 2017). There were 37 full-protocol cards in the pentads that cover the wind farm site and together they help to give a picture of the overall species richness, that single site visits would not achieve.

Any site visits to record birds, even over a 12-month period, may not provide a complete picture of all species likely to occur in an arid region. Rainfall is the chief limiting factor as it dictates if birds occur, species diversity and when, and if they breed (Lloyd 1999, Dean 2004, Seymour et al. 2015). Rainfall was scarce throughout most visits to the site, and this may reduce the overall numbers and diversity of birds occurring. We used our experience from years of surveying bird communities in arid areas (Seymour et al. 2015) to extrapolate more normal diversity measures and thus impacts at times of typical rainfall.

5 BRIEF REVIEW OF AVIAN-WIND FARM IMPACTS

Birds are known to be impacted directly and indirectly by wind farms, both onshore and offshore worldwide. But which birds are susceptible and why? And what mitigation measures have been tried to reduce the impacts?

5.1 Interactions between birds and wind farms

The main avian impacts, according to a position paper on the subject by Birdlife SA (http://www.birdlife.org.za/conservation/terrestrial-bird-conservation/birds-and-renewable-energy) are:

- displacement of nationally important species from their habitats,
- loss of habitats for such species,
- disturbance during construction and operation of the facility,
- collision with the turbine blades or associated infrastructure.

Several literature reviews (Kingsley & Whittam 2005, Drewitt & Langston 2006, Kuvlevsky et al. 2007, Stewart et al. 2007, Drewitt & Langston 2008, Loss et al. 2013) have summarised all sources of information in the field of wind energy facilities. The number of longer-term analyses of the effects of wind energy facilities on birds is increasing, but most research in this field rarely sees the light of day (Madders & Whitfield 2006, Stewart et al. 2007). Available information originates from short-term studies from the United Kingdom, the United States of America and, more recently, longer-term studies from Spain, where wind power generation is well established.

Concern about the impacts of wind facilities on birds arose in the 1980s when numerous raptor mortalities were detected in California (Altamont Pass, USA) and at Tarifa (Spain). Mortalities at these sites focused attention on the impact of wind energy facilities on birds, and subsequently much monitoring has been done at a wide variety of wind energy facility sites. More recently, there has been additional concern about the degree to which birds avoid, or are excluded from, the areas occupied by wind energy facilities - either because of the action of the turbine blades or because of the noise they generate - and hence, suffer a loss of habitat (Stewart et al. 2007, Devereaux et al. 2008. Pearce-Higgins et al. 2009).

- Most studies suggest low numbers of bird fatalities at wind energy facilities numbering tens to hundreds of birds per year (Kingsley & Whittam 2005).
- Observed mortality caused by wind energy facilities is also very low compared to other existing sources of anthropogenic avian mortality (Crockford 1992, Colson & associates 1995, Gill et al. 1996, and Erickson et al. 2001, Sovacool 2009, 2013).
- Population declines due to climate change and fossil fuels is estimated at 14.5 million birds annually, whereas wind energy facilities killed about 20 000 -234 000 birds annually in the USA (Sovacool 2013, Loss et al. 2013). See Benefits of Wind farms (5.2) below.

- In South Africa, with 22 operational wind farms by the end of 2017, and an average of 36.8 turbines per farm (Ralston et al. 2017), the projected mortality, at 4.1 bird fatalities per turbine per year is estimated to be much lower 3310 birds per year.

5.1.1 Collisions with turbines

COLLISION RATES

Avian mortality rates at wind energy facilities are compared in terms of a common unit: mortalities/turbine/year, or mortalities MW^{-1}year^{-1} (Smallwood & Thelander 2008). Where possible, measured collision rates should allow for

(i) the proportion of actual casualties which are detected by observers (searcher efficiency); and

(ii) the rate at which carcasses are removed by scavengers (scavenger removal rate, important in an African landscape).

(iii) Although collision rates may appear relatively low in many instances, cumulative effects over time, especially when applied to large, long-lived, slow-reproducing and/or threatened species (many of which are collision-prone) may be of considerable conservation significance.

The National Wind Co-ordinating Committee (2004) estimated

- that 2.3 birds are killed per turbine per year in the USA outside California – correcting for searcher efficiency and scavenger rates;
- This index ranges from 0.63 birds per turbine per year in Oregon to as high as 10 birds per turbine per year in Tennessee (NWCC 2004), illustrating the wide variance in mortality rates between sites.

At Altamont Pass, California, Curry & Kerlinger (2000) found

- only 13% of more than 5000 turbines were responsible for all Golden Eagle *Aquila chrysaetos* and Red-tailed Hawk *Buteo jamaicensis* collisions.
- Total casualty estimates for Altamont run to >1000 raptors, and nearly 3000 birds killed in turbine collisions annually (Smallwood & Thelander 2008). This large figure includes >60 Golden Eagles at a mean rate of 2-4 mortalities per MW per year;
- At the Tarifa and Navarre wind energy facility sites on the Straits of Gibraltar, southern Spain, about 0.04-0.08 birds are killed per turbine per year (Janss 2000a, de Lucas et al. 2008);

- relatively high collision rates are recorded for threatened raptors such as the Griffon Vulture *Gyps fulvus*;
- At the same sites, collisions have also been found to be non-randomly distributed, with >50% of the vulture casualties at Tarifa being killed by only 15% of the turbine array (Acha 1997);
- Collision rates from other European sites are equally variable, with certain locations sporadically problematic (Everaert 2003). Migration highways, and other areas where birds funnel through a bottleneck, are areas which should be avoided;
- In a recent review from the USA, Loss et al. (2013) estimated that an average of 234 000 birds are killed by wind turbines annually;
- Variation was apparent across the USA from 7.85 bird fatalities/turbine/year in California to 1.61 birds/turbine/year in the (central) Great Plains. The average from over 44000 turbines was 5.25 birds per turbine per year.

In South Africa,

- We, too, found that a fraction of the22% of 60 turbines killed 69% of raptors at a wind farm in the Eastern Cape (Simmons and Martins 2017);
- Fatality estimates after 1-2 years of monitoring at eight wind farms (Ralston et al. 2017) suggest 4.11 mortalities/turbine/year (corrected for searcher efficiency and scavenger removals). The identity of these wind farms is not known – data were provided anonymously – so exact comparisons with respect to the habitats impacted, is unknown.
- Broad-scale comparisons are possible because the eight farms cover the Fynbos and Karoo biomes and are, therefore, applicable to the comparisons given below. It should be noted that most are in higher rainfall sites and may thus give slightly inflated figures for mortality rates.
- Of concern, the majority of deaths were raptors (36% of 155 mortalities). This total includes Red Data raptor species including Martial Eagles *Polemaetus bellicosus*, Verreaux's Eagles *Aquila verreauxii* and Black Harriers *Circus maurus* (Smallie 2015, Simmons & Martins 2016, unpubl data), and a Secretarybird *Sagittarius serpentarius.*

CAUSES OF COLLISION

Multiple factors influence the number of birds killed at wind energy facilities. These can be classified into three broad groupings:

- avian variables (some birds, especially raptors are more prone to collision than others);
- location variables (wind farms placed on migration routes, in pristine vegetation or near roosts or nests will attract more fatalities than others);
- facility-related variables (farms with more turbines, more lighting, or lattice towers may attract more fatalities).

Two studies have shown a direct relationship between the abundance of birds in an area and the number of collisions (Everaert 2003, Smallwood et al. 2009), and it is logical to assume that the more birds flying through an array of turbines, the higher the chances of a collision occurring. However, this is not found in all studies: de Lucas et al. (2008), found instead a closer relationship with individual species abundance (vultures) and fatalities, not all birds. In South Africa, we found that raptor abundance and fatalities were significantly related at an Eastern Cape wind farm (Figure 3).

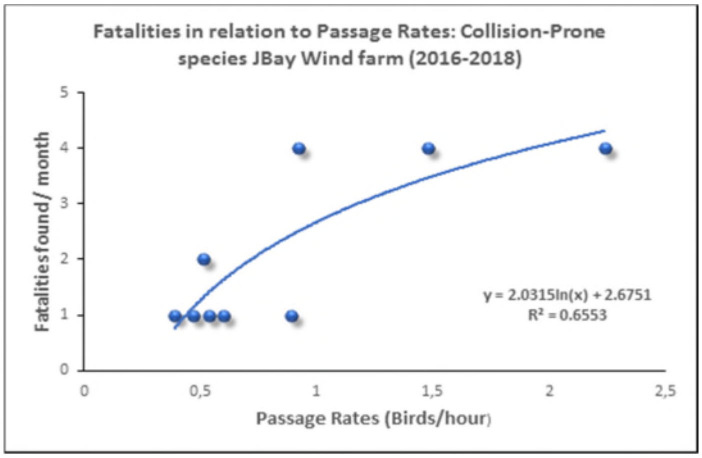

Figure 3: Raptor fatalities in relation to the Passage Rates (bird flights/h) of all raptors in 2-month sampling periods in an Eastern Cape wind farm over 2 years (Simmons, Martins, Smallie and MacEwan unpubl data).

The identity of the species present in the area is also important as some birds are more vulnerable to collision than others, featuring disproportionately frequently in collision surveys (Drewitt & Langston 2006, 2008, de Lucas et al. 2008).

- Buzzards or hawks (*Buteo* species) are the most impacted collision-prone species in both South Africa (S. Ralston unpubl data) and the USA (P. Kolgar unpubl data) (Figure 4);
- Kestrels are the second most impacted species in South Africa, but owls are globally (Figure 4).

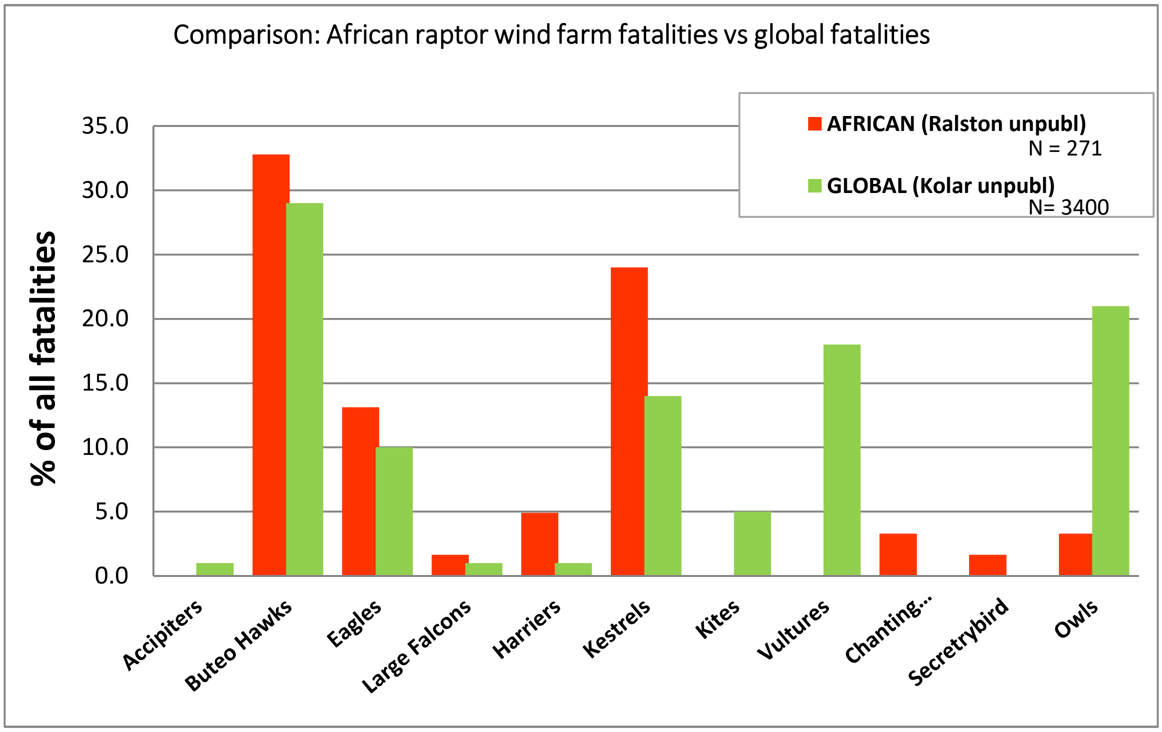

Figure 4: A comparison of the most collision-prone species in South Africa (orange) relative to global averages (green) from unpublished data of S Ralston (BLSA) and P. Kolar (USA). Buzzards top the list in all areas, but kestrels followed by eagles are dominant fatalities in South Africa, while owls and vultures top the list elsewhere.

Species-specific variation in behaviour, such as foraging, commuting or courting, also affect susceptibility to collision (Barrios & Rodríguez 2004, Smallwood et al. 2009). There may also be seasonal and temporal differences in behaviour, for example breeding males displaying or food-carrying may be particularly at risk (Simmons 2011, Simmons & Martins 2017).

In 2016, observations in South Africa indicated that

- breeding males are particularly susceptible to impacts. This includes both Martial Eagles and Black Harriers flying frequently at rotor-swept height in South Africa.
- Given that these birds were providing food for females and young at the time, there are **hidden costs** to the fatalities beyond the loss of the individual birds – i.e. the loss of the next generation because breeding females cannot rear a brood alone, as evidenced there (Simmons & Martins 2017).

Landscape features often channel birds towards a certain area and, in the case of raptors, influence their flight and foraging behaviour. Ridges and steep slopes are important factors in determining the extent to which an area is used by gliding and soaring birds (Barrios & Rodríguez 2004). Golden Eagles *Aquila chrysaetos* fly higher (> 250-m) over flat terrain and low hills where thermals occur, than over steep slopes (~150-m) where orographic winds give them lift (Katzner et al. 2012). Migratory eagles tended to fly higher over all land forms (135-341-m) than resident birds (63-83-m). This suggests that wind farms placed on top of steep slopes are more likely to impact eagles than those on flat terrain, and resident birds are more likely to be impacted (flying within the rotor-swept area) than migrants.

- High densities of prey will attract raptors, increasing the time spent hunting, and reducing vigilance.
- Poor weather affects visibility, with birds flying lower during strong headwinds (Hanowski & Hawrot 2000, Richardson 2000) so when the turbines are functioning at maximum speed, birds are likely to be flying at their lowest – increasing collision risk (Drewitt & Langston 2006, 2008).

Larger wind energy facilities, with more than 100 turbines, are almost, by definition, more likely to incur increased bird casualties (Kingsley & Whittam 2005), and turbine size may be proportional to collision risk – with taller turbines associated with higher mortality rates in most instances (e.g. de Lucas et al. 2009, Loss et al. 2013, Thaxter et al. 2007).

With newer technology, fewer, larger turbines are needed to generate the same amount of power, which may result in fewer collisions per Megawatt produced (Erickson et al. 1999, Thaxgter et al. 2007). Certain tower structures, and particularly the old-fashioned lattice designs, present many potential perches for birds, increasing the likelihood of collisions as birds land or leave these sites. This problem has, largely, been solved with more modern, tubular tower designs (Drewitt & Langston 2006, 2008).

However, Loss et al. (2013) undertook a meta-analysis of all wind farms and associated fatalities in the USA and found a strong correlation **of increasing hub height or blade length with increased impacts to birds**. Thus, taller turbines appear to be riskier for birds. We have added to that dataset with eight studies from South Africa and found that the relationship still holds (Figure 3).

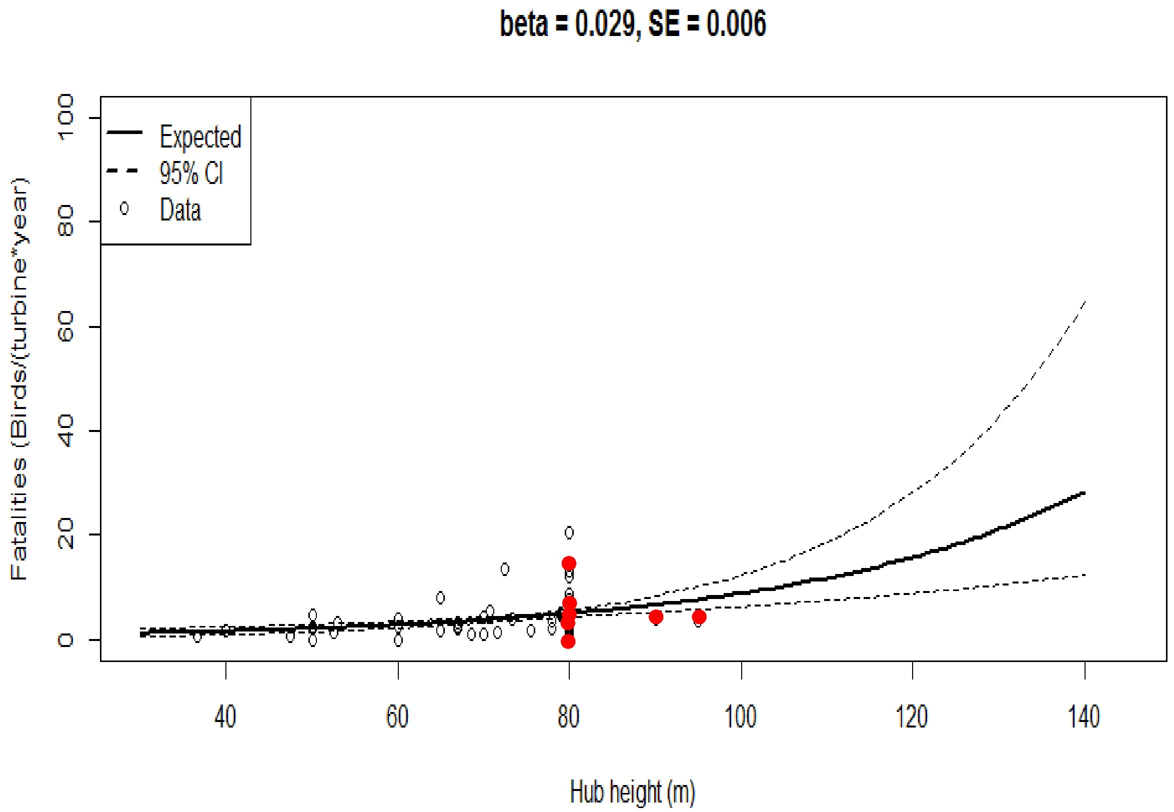

Figure 3: Modelled data combining avian fatalities from the USA (Loss et al. 2013) and from South Africa (Ralston-Paton et al. 2017, = red dots) and their relationship with hub height. The South African data (n=8 farms) include two farms with hub heights of 90-m and 95-m. The combined data and 95% confidence limits predict that 16 birds (95% CI = 9, 28) will be killed on average per year for 120-m-high turbines and 28 (95% CI = 12, 65) birds on average for 140-m-high turbines. Given that the average number of birds killed for the typical 80-m turbines was 5.40 and it increased to 16 fatalities at 120-m, the increase in fatalities is forecast to be 2.9-fold if turbines are increased from 80 to 120-m. Note that this is a statistical forecast and is not based on empirical data. From Simmons, Cervantes-Peralta, Erni, Martins & Loss (2017).

Illumination of turbines and other infrastructure often increases collision risk (Winkelman 1995, Erickson et al. 2001), either because birds move long distances at night and navigate using the stars, mistaking lights for stars (Kemper 1964), or because lights attract insects, which in turn attract foraging birds. Changing constant lighting to flashing lighting has been shown to reduce nocturnal collision rates (Richardson 2000, APLIC 1994, Jaroslow 1979, Weir 1976) and changing flood-lighting from white to red (or green) can affect an 80% reduction in mortality rates (Weir 1976).

Spacing between turbines at a wind facility can also affect the number of collisions. Some authors have suggested that paths need to be left between turbines so that birds can move through unscathed.

Alternatively, those turbines known to kill more birds can be temporarily taken out of service (e.g. during migration or breeding). For optimal wind generation, relatively large spaces are required between turbines to avoid wake and turbulence effects.

COLLISION PRONE BIRDS

Collision prone birds (CPBs) generally include:

- large species, or those with high wing-loading (i.e. the ratio of body weight to wing surface area), and with low manoeuvrability (cranes, bustards, vultures, gamebirds, waterfowl, falcons);
- species which fly at high speed (gamebirds, pigeons and sandgrouse, swifts, falcons);
- species which are distracted in flight – predators, or species with aerial displays (many raptors, aerial insectivores, some open country passerines);
- species which habitually fly in low light conditions (flamingos);
- species with narrow field, or no, binocular vision (cranes and bustards) (Drewitt & Langston 2006, 2008, Jenkins et al. 2010, Martin & Shaw 2010).

To these we can add those species that more frequently fly at rotor swept height (e.g. buzzards and eagles) and are more likely to impact turbines (Simmons & Martins unpubl data).

Recent studies by Martin & Shaw (2010) indicate that, particularly, collision-prone species such as bustards and cranes do not see ahead of them due to skull morphology and have a blind region that prevents them from seeing directly ahead. This is one reason why they hit overhead lines so regularly (Shaw et al. 2015).

These traits confer high levels of susceptibility, which may be compounded by high levels of exposure to man-made obstacles such as wind turbines or towers (Jenkins et al. 2010). Exposure is greatest in (i) highly aerial species; (ii) species that make regular and/or long-distance movements (migrants or any species with widely-separated resources – food, water, roost and nest sites); and (iii) species that fly in flocks (increasing the chances of incurring multiple fatalities in single collision incidents). Soaring species may be particularly prone to colliding with turbines where this infrastructure is placed along ridges, because the turbines exploit the same updrafts favoured by such birds – vultures, storks, cranes, and most raptors (Erickson et al. 2001, Kerlinger & Dowdell 2003, Drewitt & Langston 2006, 2008, Jenkins et al. 2010, Katzner et al. 2012).

MITIGATING COLLISION RISK

One direct way to reduce the risk of birds colliding with turbine blades is to render the blades more conspicuous. Blade conspicuousness is compromised by a phenomenon known as ‘motion smear’ or retinal blur, in which rapidly moving objects become less visible the closer they are to the eye (McIsaac 2001, Hodos 2002). The retinal image can only be processed up to a certain speed, after which the image cannot be perceived. This effect is magnified in low light conditions, so slow blade rotation may be difficult for birds to see.

Laboratory-based studies of visual acuity in raptors have determined that

- visual acuity in kestrels is superior when objects are viewed at a distance, suggesting that the birds may view nearby objects with one visual field, and objects further away with another;
- moderate motion of the visual stimulus significantly influences acuity, and kestrels may be unable to resolve all portions of an object such as a rotating turbine blade because of motion smear, especially under low light conditions;
- this deficiency can be addressed by patterning the blade surface in a way which maximizes the time between successive stimulations of the same retinal region; and
- the cheapest, and most visible, blade pattern for this purpose, effective across a variety of backgrounds, is a **single black blade** in amongst white blades (McIsaac 2001, Hodos 2002, Stokke et al. 2017).

Hence marking blades may be an important means to reduce collision rates by making them as conspicuous as possible under poor visual conditions, particularly at facilities where raptors are known to be collision casualties. While CAA regulations stipulate white towers and turbine blades this could be avoided by using UV paint that is visible to birds but not to pilots. Norwegian CAA have already accepted that black-painted blades are acceptable. **Marking turbine rotors** in this way, has been tested recently with a clever experiment in Norway where turbines were killing large numbers of White-tailed Eagles *Haliaetus albicilla* and other ground-dwelling species. By painting one turbine blade black,

- researchers at the Norwegian Institute of Nature Research reduced the incidence of overall bird fatalities by 71% relative to unpainted controls (Stokke et al. 2017).
- More impressive was the fact that no further eagle mortalities were recorded over the 2-year period that the experiment ran, relative to unpainted controls (R May in litt. February 2018).

All other collision mitigation options operate indirectly, by reducing the frequency with which collision prone species are exposed to collision risk. This is achieved mainly by: (i) siting farms and individual turbines away from areas of high density or groupings, regular commuting or slope-soaring regions; (ii) using low-risk turbine designs and configurations, discouraging birds from perching on turbine towers or blades, and allowing sufficient space for commuting birds to fly through the turbine strings; and (iii) carefully monitoring collision incidence, and being prepared to shut-down problem turbines at particular times or under particular conditions (e.g. breeding, or increased migration activity).

Figure 4: A single black-painted blade on turbines on the island of Smøla, Norway. This simple mitigation reduced eagle fatalities by 100% relative to unpainted controls. Civil Aviation Authorities in Norway permitted this new mitigation technique, setting a precedent for other aviation authorities in the world (from Stokke et al. 2017).

5.1.2 Habitat loss – destruction, disturbance and displacement

While the final footprint of most wind farms is likely to be relatively small, the construction phase of development incurs quite extensive temporary or permanent destruction of habitat. This may be of lasting significance where wind energy facility sites coincide with critical areas for restricted range, endemic and/or threatened species. Similarly, construction, and maintenance activities are likely to cause some disturbance to birds in the general surrounds, and especially of shy and/or ground-nesting species resident in the area. Mitigation of such effects requires that best-practice principles be rigorously applied – that sites are selected to avoid the destruction of key habitats, and construction and final footprints, as well as sources of disturbance of key species, must be minimised.

Some studies have shown significant decreases in the numbers of birds in areas where wind energy facilities occur, as a result of avoidance due to noise or movement of the turbines (e.g. Larsen & Guillemette 2007). Others have shown decreases attributed to a combination of collision casualties and avoidance, or exclusion from the impact zone of the facility (Stewart et al. 2007). Such displacement effects are probably more relevant in situations where wind energy facilities are built in natural habitat (Pearce-Higgins et al. 2009, Madders & Whitfield 2006) than in modified environments such as farmland (Devereaux et al. 2008).

5.1.3 Impacts of associated infrastructure

Infrastructure commonly associated with wind farms can often be more detrimental to birds than the turbines themselves. The construction and maintenance of substations, servitudes and roadways cause both temporary and permanent habitat destruction and disturbance.

5.2 Benefits of wind farms

While this review focuses on the negative impacts of wind farming, and reducing those impacts to birds, it is important to give the positive side of such energy production. As a green, sustainable form of energy production, with no green-house gas emissions, wind farms have huge benefits over traditional fossil-fuel or nuclear energy production. At present over 80% of South Africa's energy is derived from coal, oil or gas that increases South Africa's carbon-footprint. From an environmental point of view, wind farms create sustainable energy, do not emit green-house gases, and can be built on otherwise productive land without altering the land-use practises. They are one of the most cost-effective sources of energy and provide energy at night when other renewable energy sources are dormant (https://energy.gov/eere/wind/advantages-and-challenges-wind-energy).

The impacts to the environment, while highlighted by environmentalists, are relatively negligible when compared with other forms of energy that we take for granted in our homes. Most of South Africa's energy is produced by coal-fired power stations (69%), crude oil (15%) or natural gas (~3%). Renewables accounted for ~0.2% of all energy production in 2012 (www.zapmeta.co.za/wiki/page/Energy_in_South_Africa). This will have increased since 2012 when these statistics where compiled.

An attempt was made to determine the impact on birds of these various forms of energy production to contextualize the impacts reported from wind farms (Sovacool 2009). His paper summarised the impacts as follows:

"For wind turbines, the risk appears to be greatest to birds striking towers or turbine blades and for bats suffering barotrauma. For fossil-fuelled power stations, the most significant fatalities come from climate change, which is altering weather patterns and destroying habitats that birds depend on. For nuclear power plants, the risk is almost equally spread across hazardous pollution at uranium mine sites and collisions with draft cooling structures. Yet, taken together, fossil-fuelled facilities are about 17 times more dangerous to birds on a per GWh basis than wind and nuclear power stations. In absolute terms, wind turbines may have killed about 20 000 birds [in the USA: Sovacool 2013] in 2006 but fossil-fuelled stations killed 14.5 million and nuclear power plants 327,000 birds." (Sovacool 2009, p2246).

Sovacools' (2013) revised conclusion of 20 000 birds killed at wind farms annually in the USA was revised again by Loss et al. (2013), to 234 000 birds killed annually by American wind farms by non-lattice tower turbines. This revised estimate is still 62-fold lower than the estimated 14.5 million fatalities caused by fossil-fuel powered energy. In a southern African or African context, this means that moving away from our heavy reliance on coal, to one based on renewable energies, could reduce the impact on birds at least 60-fold. If even a small proportion of these birds in southern Africa are threatened red-listed species (and climate change may be affecting these red-listed species more than other – more common – species: Simmons et al. 2004), then the threats to these species are likely to be reduced. Thus, while this report details the negative impacts to birds at wind farm sites, the goal of turning away from fossil-fuel dependence through wind (and solar) energy is a positive move for South Africa, which lies 19th in the world of CO_2 producers (Olivier et al. 2014) and should be encouraged.

6 STUDY AREA AND HABITAT

The 44.2-km^2 study area occurs on Portion 1 of Zonnekwa 328 with an extent of 5.96 km^2 and the Remainder of the Farm Zonnekwa 326 covering 38.3km^2 in the Nama Karoo biome. Both farms are owned by Johanna Beatrix Van Dyk and the centre of the site is located at S29°47'16.07" E 17°14'45.49". The land undulates from 214 m asl in the north-east to 210 m asl in the south-west with a valley and a farm access road in the centre. It is primarily deep sand with calcrete outcrops in some areas. Land-use is predominantly sheep grazing.

6.1 Vegetation of the study area

The study area occurs at the north-west end of the Nama Karoo biome (Mucina and Rutherford 2006, p264) and is designated as Namaqualand Strandveld. It is dominated by low species-rich shrubland (Photo 1-3) of erect and creeping succulents on nutrient-poor sand and heavily grazed in places. The sheep are moved off the land in the summer when temperatures increase, and rainfall decreases.

The study area experiences winter rainfall averaging a low 112-mm per annum, with high variability. Most falls in June-July-August (winter). In our 12-month visit little rain had fallen and by the summer and autumn visits the veld was dry and moribund. While this will reduce avian diversity indices (Seymour et al. 2015), we have used our experience at other wind farms in the area to account for this in more typical years. Maximum day time temperatures average about 10-20°C from winter to summer. Minimum temperatures average ~7-15°C. Minimum night-time temperatures rarely dip below zero for the winter months (Mucina & Rutherford 2006).

Photos 1-3: Coastal shrubs, bulbs and other plants found on the Zonnequa site during our site visits.

6.2 Avian microhabitats

Bird habitat in the region consists of fairly uniform vegetation type of coastal shrubs and succulent plants (Photos 4-5). The vegetation includes succulent shrubs such as *Tertragonia, Cephalophyllum* and *Didelta* succulent shrub and non-succulents such as *Eriocephalus, Pteronia* and *Salvia*. There are a few alien trees on site (Eucalyptus), found around the farmsteads, and some farm dams and water points for sheep. Few grasses are found, making the lark species diversity rather slim within the site, providing some perch sites for raptors but no nesting sites.

Photos 4-5: Raptors were the main species seen on site, including this pair of Red Data Secretarybird *Sagittarius serpentarius* (top right) and the Least Concern Booted Eagle *Aquila pennatus* (left). The former performed display flights in the study site.

7 RESULTS

7.1 Species diversity

Over the course of 12-months we recorded only 45 avian species in the WEF site in our four equally-spaced site visits over the year. This is a very low total compared with other arid areas in the Northern and Western Capes that we have sampled. Species richness varied over the seasons with higher totals recorded in Spring (26 species) and the lowest in summer (12 species: Table 1). All were typical residents of the arid Karoo landscape including chats, prinias, cisticolas, titbabblers, warblers, flycatchers, Karoo Larks and Tits (photos 6 and 7).

Photos 6-7: From left - the ubiquitous Karoo Lark *Calendulauda albescens* and a Grey Tit *Parus afer*

Small aerial species which may be affected by a new wind farm included the occasional hirundines such as Rock Martin *Ptyonoprogne fuligula* and flocks of up to 90 swifts including Alpine *Tachymarptis melba*, Little *Apus affinis* and Common Swifts *A. apus* that were recorded foraging over the study site. The average number of species per kilometre was higher in the WEF (7.5 species per km) than in the Control site (4.5 species per km) (Table 1). Similarly, the average number of individual birds per kilometre found in the WEF (21.3 birds per km) was higher than in the Control (10.0 birds per km). Bird abundance indices were higher in the spring (August) than any other month (Table 1). Bird species richness on site stayed relatively constant throughout the year but reduced as the drought intensified in autumn (February).

Table 1: Summary of bird species richness and number of birds/km recorded in 1 km transects in the proposed WEF and Control areas, from May 2017 through Feb 2018. Overall means are given in bold.

1-km Transects in WEF Site	SPECIES per km					BIRDS per km				
(region of the WEF)	May	Aug	Nov	Feb	MEAN	May	Aug	Nov	Feb	MEAN
Transect ZT1 (centrally placed at VP1)	6	9	8	8	7.8	19	22	22	30	23.3
Transect ZT2 (centrally placed at VP2)	6	9	10	6	7.8	12	39	28	12	22.8
Transect ZT3 (centrally placed at VP3)	5	11	9	3	7.0	17	33	17	5	18.0
Means	5.7	9.7	9.0	5.7	**7.5 Species/km**	16.0	31.3	22.3	15.7	**21.3 Birds/km**
Seasonal occurrence of all species:	25.0	26.0	22.0	12.0						
Overall totals	45 Species in WEF/Control									

1-km Transects in Control Site	SPECIES per km					BIRDS per km				
	May	Aug	Nov	Feb	MEAN	May	Aug	Nov	Feb	MEAN
Transect ZT1 (centrally placed at VP1)	4.0	10.0	2.0	2.0	4.5	4.0	25.0	3.0	8.0	10.0
Means	4.0	10.0	2.0	2.0	**4.5 Species/km**	4.0	25.0	3.0	8.0	**10.0 Birds/km**
Seasonal occurrence of all species:	**25.0**	**26.0**	**22.0**	**12.0**						

Overall totals	45 Species in WEF/ Control

How might the drought have influenced these abundance and diversity indices? We used data collected in 2014 at the Kleinzee 300 (Eskom) site (20 km west of Zonnequa) for comparison when rainfall was more typical. There, in 12 months monitoring, species richness was 40% higher and totalled 63 species (45 species at Zonnequa). Average birds per km was 74% higher at 37.1 (21.3 birds per km at Zonnequa), and the average number of species per km was 43% higher at 10.7 (7.5 species per km at Zonnequa). Below we show that 9 collision-prone species were recorded at Zonnequa in drought conditions, while at Kleinzee 300 (in similar sheep-grazed habitat under normal rain conditions), 14 CPSs were recorded. This is 56% higher in typical rainfall. Thus, all avian indices were between 40% and 74% higher during more normal rainfall conditions.

7.2 Collision-prone and red-listed species

Among the 48-species recorded on the 37 SABAP bird atlas cards for this region (May 2013-February 2018) were 8 collision-prone species (CPS). We recorded nine collision-prone species from our Vantage Point surveys (Kori Bustards *Neotis ludwigii* were missed by the SABAP data set) over the course of the year (Table 2). These included three Red Data species (Ludwig's and Kori Bustards and Secretarybird). The Ludwig's Bustards were recorded in August and November, as was the Kori Bustard. The Secretarybirds were only recorded in August 2017 when a pair were observed in flight together over the Zonnequa Wind Farm (photo 4-5). A red-listed Lanner Falcon was also seen as an incidental in May 2017, but not seen again.

A pair of Secretarybirds were observed from two Vantage Points (VP1 and 2). The pair landed south of VP1 and one bird displayed with wings up, suggesting a breeding display (Dean and Simmons 2005). During routine transects and travelling to the VPs we discovered a freshly built nest at S29°48'25" E17°13'57" (photo 8), close to the area the birds were seen to land and display. Despite further observations on site, we never saw this nest used at any time, either for roosting or breeding. Secretarybirds made use of several areas within the proposed WEF.

Photo 8: A freshly built Secretarybird nest found 300 m from VP1 in December 2017. The nest was probably constructed between our two site visits in August and December 2017 at S29°48'25" E17°13'57". No birds were recorded using it during any site visits but preferred an inactive nest site for roosting on the adjacent Namas Wind Farm, near the wind mast. It is the latter "wind mast nest" that may need mitigation, and this unused nest, does not require mitigation. As a precaution, we suggest this structure is moved to another site on Zonnequa where breeding activity was reported several years previously by the farmer.

Table 2. Red-listed bird species (in red) and collision-prone species recorded on 37 cards by SABAP2 in four pentads that cover the Zonnequa site (Appendix 2). Shaded species were recorded over the WEF site during our four site visits (total 16 field-days) from May 2017 to February 2018. Reporting Rate from SABAP2 is given in brackets. Kori Bustard, were only recorded by us.

					Susceptibility to:
Common Name	**Scientific Name**	**Red-list status**	**Reporting Rate ***	**Collision (Rank **)**	**Disturbance**
Ludwig's Bustard	*Neotis ludwigii*	**Endangered**	**3/16 = 19% (11%)**	**10**	**Medium**
Secretarybird	*Sagittarius serpentarius*	**Vulnerable**	**2/16 = 13% (5%)**	**12**	**High**
Lanner Falcon	*Falco biarmicus*	**Vulnerable**	**1/16 = 6% (3%)**	**22**	**Medium**
Kori Bustard	*Ardeotis kori*	**Near Threatened**	**2/16 = 13% (0%)**	**37**	**High**
Southern Black Korhaan	*Afrotis afra*	-	**1/16 = 6% (8%)**	**35**	**Low**
Booted Eagle	*Aquila pennatus*	-	**3/16=19% (11%)**	**55**	**Medium**
Black-chested Snake Eagle	*Circaetus cinerescens*	-	**2/16 = 13% (8%)**	**56**	**Medium**
Pale Chanting Goshawk	*Melierax canorus*	-	**8/16 = 50% (22%)**	**73**	**Low**
Greater Kestrel	*Falco rupicolloides*		**3/16 = 19% (16%)**	**97**	**low**

* Reporting rate is a measure of the likelihood of occurrence and is based on the number of times seen in 20 days field work over 4 seasons. We compare this with the number of times it was recorded/in 37 atlas cards (on SABAP2 cards)

** Collision rank derived from the BAWSESG 2014 guidelines. Smaller numbers denote higher collision-risk.

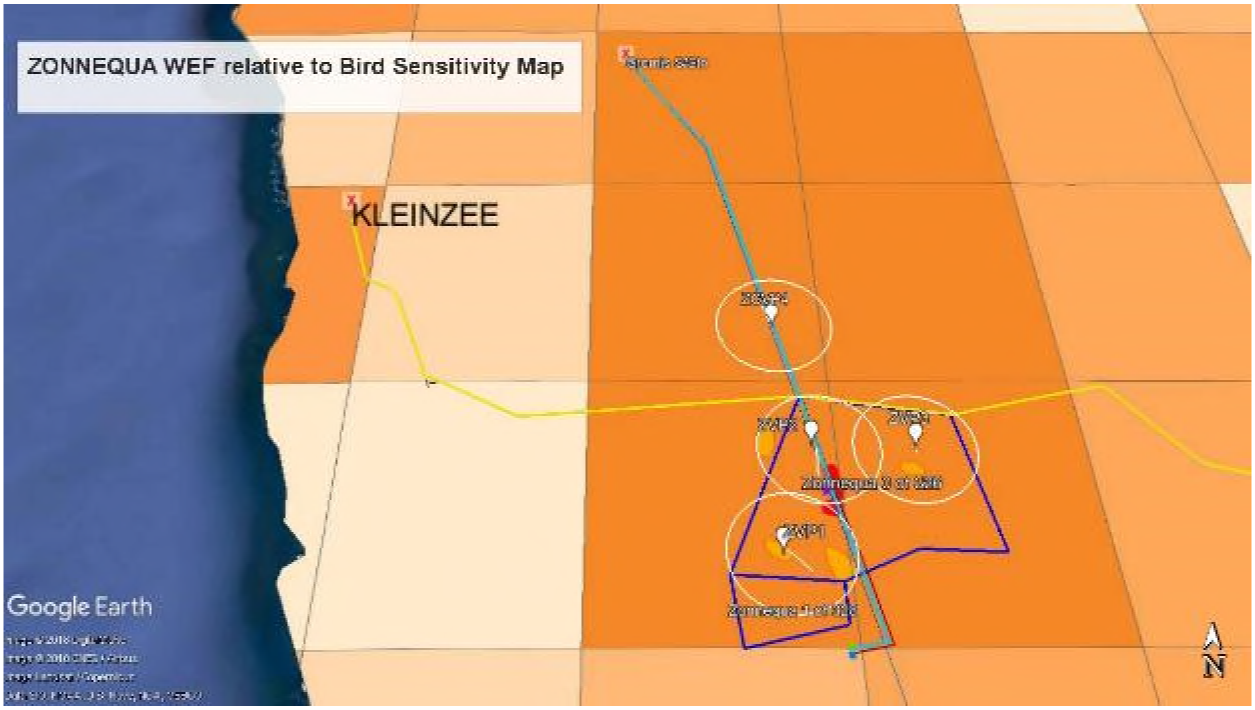

Figure 5: The Zonnequa WEF site in relation to the national bird sensitivity map of Birdlife South Africa. Light squares depict low-bird sensitivity (score ~50-100) and darker squares higher bird sensitivity (scores 800-1000). The entire Zonnequa WEF site lies in an area of medium bird sensitivity (scored 601). For details see: http://www.birdlife.org.za/conservation/terrestrial-bird-conservation/birds-and-renewable-energy/wind-farm-map

7.2.1 Passage Rates of collision-prone species (CPSs)

By observing from three Vantage Points (VPs) over the airspace above the proposed WEF (Figure 1), we calculated the frequency with which the 9 collision-prone species on site (Table 1) traversed the wind farm in 144-hours of field observations. We recorded 52 individual flights of the 8 species of CPB in the 144-hours over one year, giving a low Passage Rate of 0.36 birds per hour (Table 3).

By comparison at the Kleinzee 300 site, under more typical rainfall conditions in 2014, Passage Rates averaged 0.54 collision-prone birds, 50% higher than during the drought conditions experienced in 2017-2018 on the Zonnequa site (Simmons and Martins 2014).

Table 3. Passage Rates of all (9) collision-prone species recorded in the WEF site over all seasons in 2017-2018. Red Data species (3) are included and their combined passage rate was very low at 0.36 birds per hour.

Summary of Passage Rates for all seasons and all collision-prone birds at Zonnequa WEF		
Passage rate:	**Season**	**Collision-prone species**
WEF 36.0 hr 3 birds 0.08 birds / hr	February 2018	Black-chested Snake Eagle, S Black Korhaan
WEF 36.0 hr 25 birds 0.69 birds / hr	November 2017	Pale Chanting Goshawk, Greater Kestrel, Booted Eagle, Ludwig's Bustard
WEF 36.0 hr 22 birds 0.33 birds / hr	August 2017	Pale Chanting Goshawk, Greater Kestrel, Booted Eagle, Ludwig's Bustard, Kori Bustard, Secretarybird
WEF 36.0 hr 2 birds 0.06 birds / hr	May 2017	Pale chanting Goshawk,
Summary: 144 h 52 birds 0.36 birds / hr	**4 seasons**	**8 species of Collision-prone birds**

Table 4. Passage Rates of all (5) collision-prone species recorded in the Control site over all seasons in 2017-2018. Red Data species (1) are included and their combined passage rate was also low at 0.29 birds per hour.

Summary of Passage Rates for all seasons and all collision-prone birds at Zonnequa Control		
Passage rate:	**Season**	**Collision-prone species**
Control 12.00 hr 0 birds 0.00 birds / hr	February 2018	None
Control 12.00 hr 7 birds 0.58 birds / hr	November 2017	Booted Eagle, Jackal Buzzard, Pale chanting Goshawk, Kori Bustard
Control 12.00 hr 7 birds 0.58 birds / hr	August 2017	Booted Eagle, Jackal Buzzard, Pale chanting Goshawk, Black-chested Snake Eagle
Control 12.00 hr 0 birds 0.00 birds / hr	May 2017	None
Summary 48 hours 14 birds 0.29 birds / hr	**4 seasons**	**5 species of collision-prone birds**

In the Control area, we recorded only 14 flights of 4 species of CPBs in 48-hours over the year, giving a similarly low Passage Rate of 0.29 birds per hour (Table 4).

For the priority Red Data species alone (comprising the Secretarybird and Kori and Ludwig's Bustards) the Passage Rates were very low, averaging just 0.09 birds per hour in the WEF and 0.02 birds per hour in the Control site. Thus, while three Red Data species were present on site, their Passage Rates (Table 5) and their likelihood of occurrence (Table 1) were both low, making risk of collision unlikely. These data were collected at time of drought (reducing the passage rates by an estimated 50%) and this must be taken into account in the scoring of impacts below.

Table 5. Passage Rates of the three Red Data collision-prone species recorded in the Zonnequa WEF site over all seasons in 2017-2018. The Red Data species combined passage rate was very low at 0.09 birds per hour.

WEF - Month	**Hours**	**No. of Collision-prone Red Data birds**	**Passage Rate (birds/h) Red Data birds**	**Season**
May 2017	36.0	0	0.00	Spring
August 2017	36.0	1	0.03	Summer
November 2017	36.0	12	0.33	Autumn
February 2018	36.0	0	0.00	Winter
TOTALS	**144.0**	**13**	**0.09**	**All seasons**
Control - Month	**Hours**	**No. of Collision-prone Red Data birds**	**Passage Rate (birds/h) Red Data birds**	**Season**
May 2017	12.0	0	0.00	Spring
August 2017	12.0	0	0.00	Summer
November 2017	12.0	1	0.08	Autumn
February 2018	12.0	0	0.00	Winter
TOTALS	**48.0**	**1**	**0.02**	**All seasons**

7.2.2 Flying heights and risk

Flying heights are possibly a better estimate than Passage Rate of the risk that the collision-prone species face on site (Whitfield & Madders 2006, Band et al. 2007). This arises because any species spending large proportions of time at rotor-swept heights of 55-205-m (up to130-m hub height with up to 75-m blades) is more likely to be at risk of being hit by turbine blades, than if it is simply passing through the site at low (or high) altitudes (Smallwood et al. 2009). By recording flight height every 15-seconds for focal birds, we assessed the proportion of time spent in the rotor-swept zone by all Red Data species, as a gauge of risk.

Of the three Red Data species recorded, the Secretarybird flew most often within the blade-swept area (BSA) at 42% of all occasions. This surprisingly high figure for a largely terrestrial bird is mirrored by recent data from an Eastern Cape wind farm where Secretarybirds were recorded at similar Blade Swept Height (58-203 m), 85% of the time when in flight (Martins & Simmons unpubl data). However, further analysis from the same wind farm indicates that in over 300 h of observation when Secretarybirds were known to be on site, they flew less than 0.2% of the time (Simmons and Martins unpubl data), confirming their terrestrial life style (Dean and Simmons 2005). This may explain their very low frequency in wind farm fatality estimates as they are recorded only once in over 200 raptors deaths (S Ralston pers. comm.).

The rarely seen Kori Bustard was never observed at risky heights (Table 6). If Ludwig's Bustards occurred in the wind farm site, they would suffer a low risk as they spent 16% of their time at blade height.

Table 6: Flying heights of all collision-prone species observed in the proposed Zonnequa Wind farm recorded every fifteen seconds. Data were collected throughout the year – May, August, November 2017 and February 2018 from focal birds. The blade-swept zone was taken to be 58 m to 203 m for proposed turbines of up to 130m hub height.

Species	Flight heights	Number of observations	Proportion of observations in blade-swept area
Ludwig's Bustard **N= 38**	1-55 m	32	84%
	55-205 m [blade-swept zone]	**6**	**16%**
	205+ m	0	0%
Kori Bustard **N = 14**	1 -55 m	14	100%
	55-205 m [blade-swept zone]	**0**	**0%**
	205+ m	0	0%
Secretarybird **N = 64**	1 -55 m	37	58%
	55-205 m [blade-swept zone]	**27**	**42%**
	205+ m	0	0%
Booted Eagle **N = 368**	1 -55 m	106	29%
	55-205 m [blade-swept zone]	**240**	**65%**
	205+ m	22	6%
Jackal Buzzard **N = 20**	1 -55 m	3	15%
	55-205 m [blade-swept zone]	**17**	**85%**
	205+ m	0	0%
Pale chanting Goshawk **N = 52**	1 -55 m	40	77%
	55-205 m [blade-swept zone]	**12**	**23%**
	205+ m	0	0%
Greater Kestrel **N = 47**	1 -55 m	42	89%
	55-205 m [blade-swept zone]	**5**	**11%**
	205+ m	0	0%
Black-chested Snake Eagle **N = 76**	1 -55 m	31	41%
	55-205 m [blade-swept zone]	**45**	**59%**
	205+ m	0	0%
Southern Black Korhaan **N = 7**	1 -55 m	7	100%
	55-205 m [blade-swept zone]	**0**	**0%**
	205+ m	0	0%

Six other collision-prone species (CPS) were recorded and of these the Jackal Buzzard (85%), Booted Eagle (65%) and Black-chested Snake Eagle (57%) were the species most often recorded within the BSA (Table 6). All are, therefore, at risk from turbines built within this wind farm in the areas where they occur. The other three species of CPS were less often recorded flying at the risky heights of 55 – 205 m (Table 6).

In summary, the Red Data Secretarybird, and particularly the Jackal Buzzard, Booted Eagles and Black-chested Snake Eagles would all face some risks in a wind farm environment as they were all recorded flying at risky heights more than 40% of the time. The Secretarybirds terrestrial life style however, means they are rarely in this air space and face a low-level risk of impacts.

All flight tracks of all collision-prone species in the proposed Zonnequa WEF are shown in Figures 5-8. Areas where two or more of the Red Data species overlap are designated as medium- or high-risk areas where turbine development is not recommended.

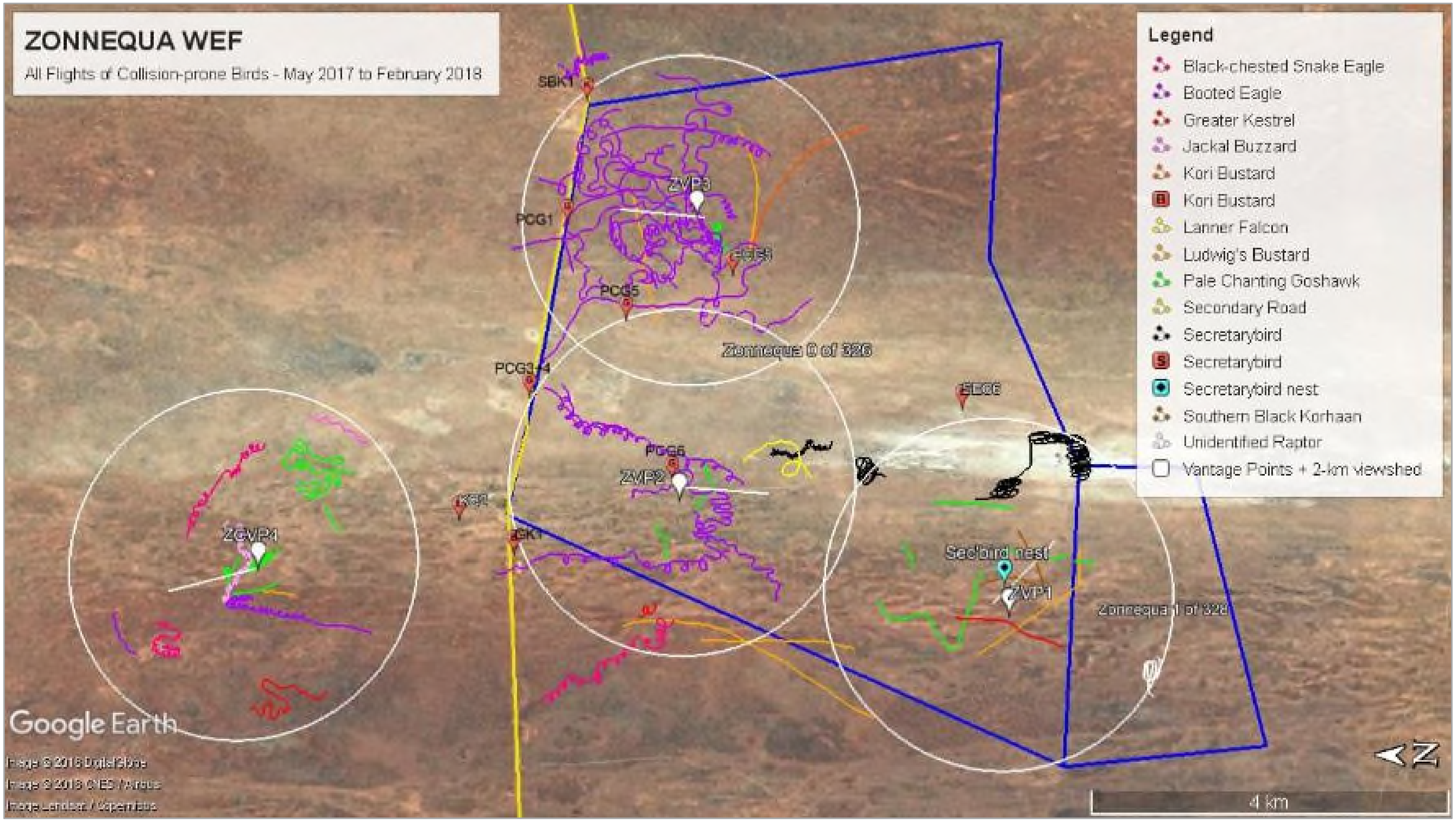

Figure 5: All flights of collision-prone bird across all VPs on the proposed Zonnequa Wind Farm from May 2017 to February 2018. Our VPs (= white pins) and their 2-km viewsheds (=white circles) are shown. Three Red Data species - Secretarybird (=black line), and Ludwig's and Kori Bustards (= orange lines) were found on site. Non- threatened CPS included several Pale Chanting Goshawks (=PCG, green lines), Greater Kestrels (=red lines), Southern Black Korhaan (=brown lines), Black-chested Snake Eagle (=magenta line) and Jackal Buzzards (=mauve line) were apparent across the site. A Lanner Falcon (=yellow line) was recorded as an incidental, but did not occur in timed VP observations.

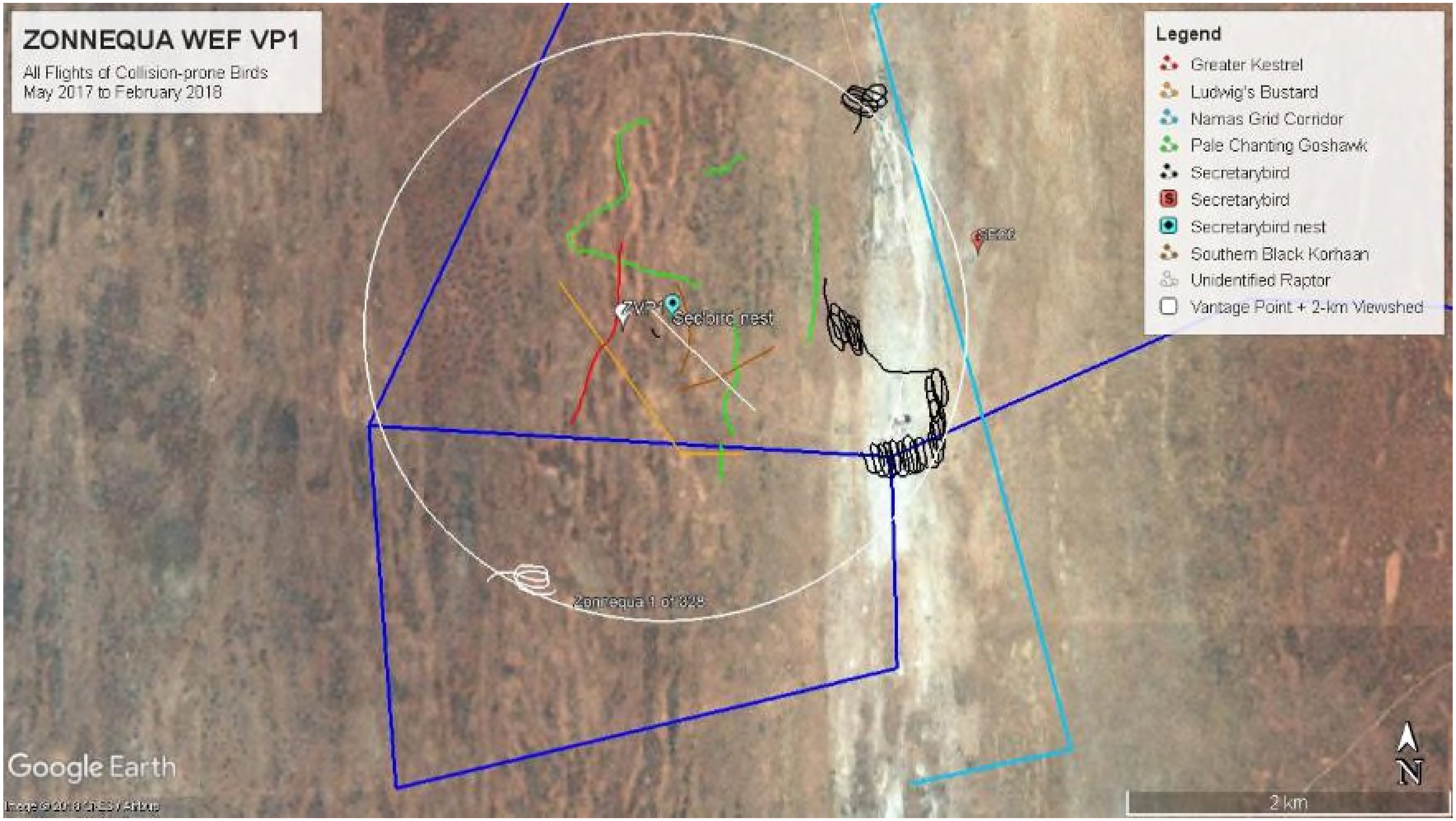

Figure 6: Flight paths of all collision-prone species passing through VP1 (=white pin) during our monitoring from May 2017 – February 2018. Red Data Secretarybirds (= black lines and blue pin), and Ludwig's Bustards (=orange line) were the main priority species here. Pale Chanting Goshawks (=green lines), Greater Kestrel (= red line) and a Southern Black Korhaan (=brown line) were three other collision-prone species found here.

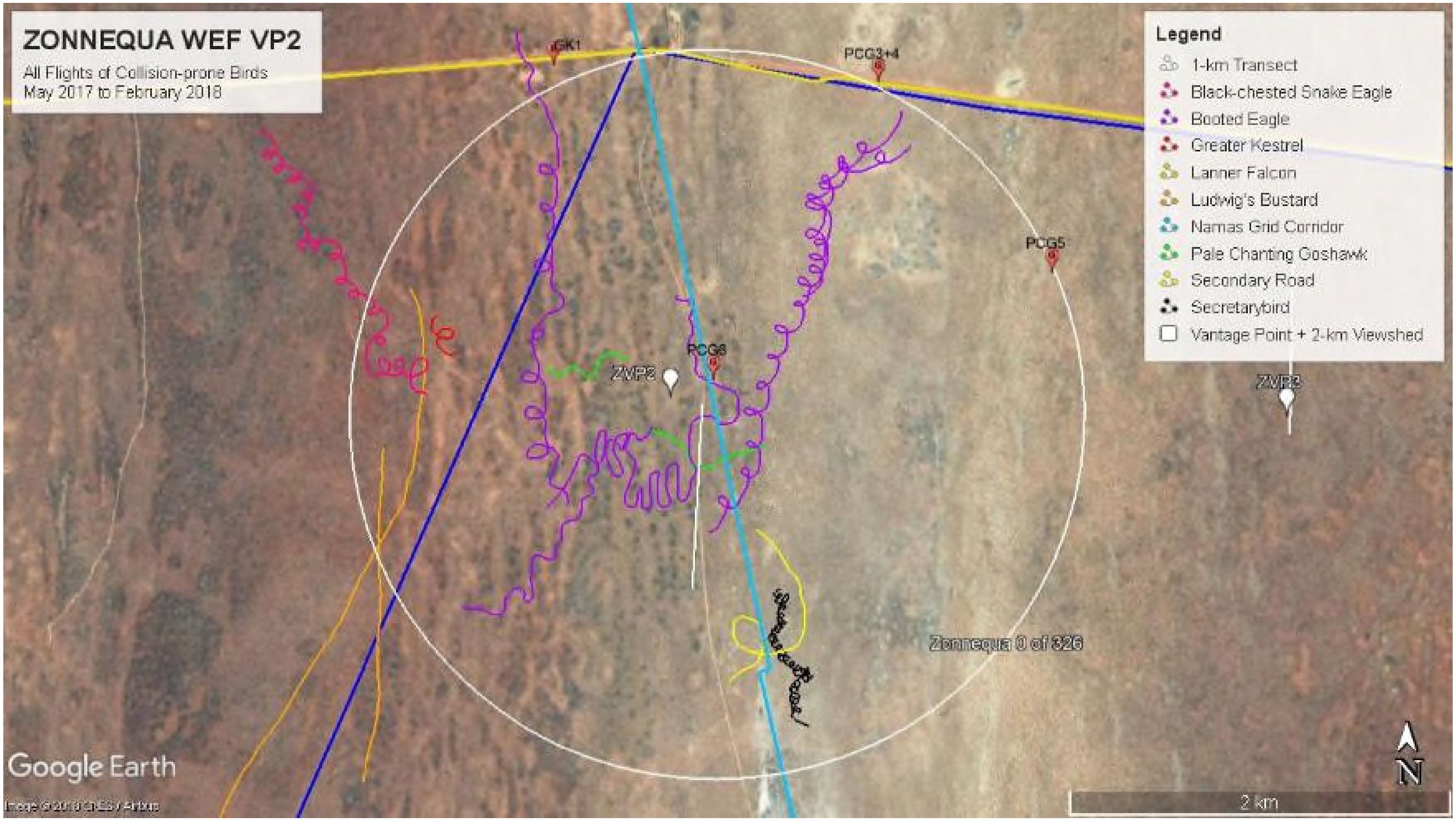

Figure 7: Flight paths of all collision-prone species passing through VP2 (=white pin) view shed (= white circle) during our monitoring from May 2017 – February 2018. A pair of Red Data Secretarybirds (=black line) a Ludwig's Bustard (=orange lines) and a brief appearance of a Lanner Falcon (=yellow line), were the main Red Data species recorded here. Booted Eagles (=purple lines), Pale Chanting Goshawks (=green line) and Black-chested Snake Eagle (=magenta line) comprised the other CPS recorded here.

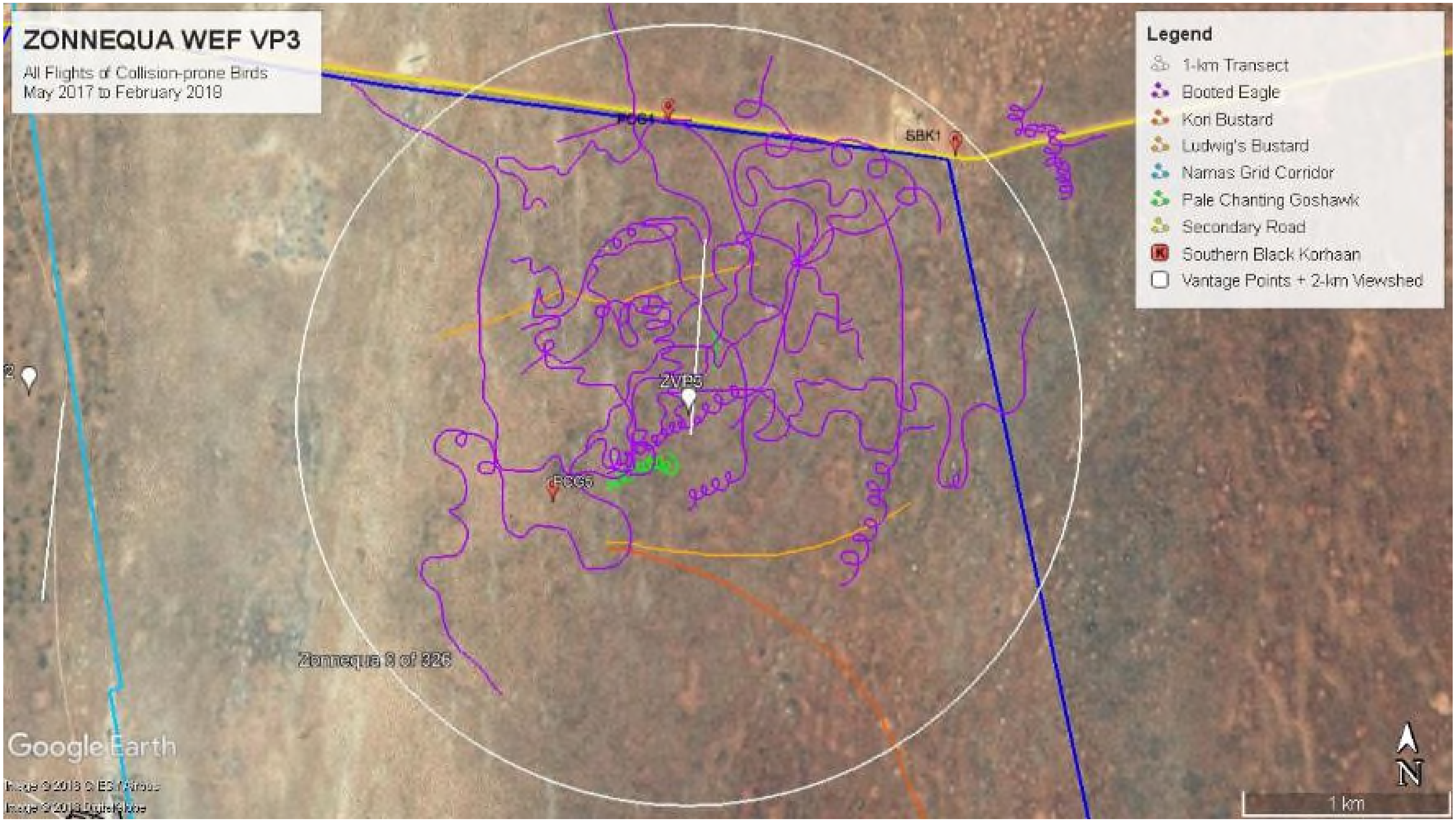

Figure 8: Flight paths of all collision-prone species passing through VP3 (=white pin) view shed (= white circle) during our monitoring from May 2017 – February 2018. One Red Data Kori bustard and two Ludwig's Bustards (=orange lines) were recorded here. The most frequently recorded priority species was a pair of Booted Eagle (=purple lines), and a few Pale Chanting Goshawks (=green line).

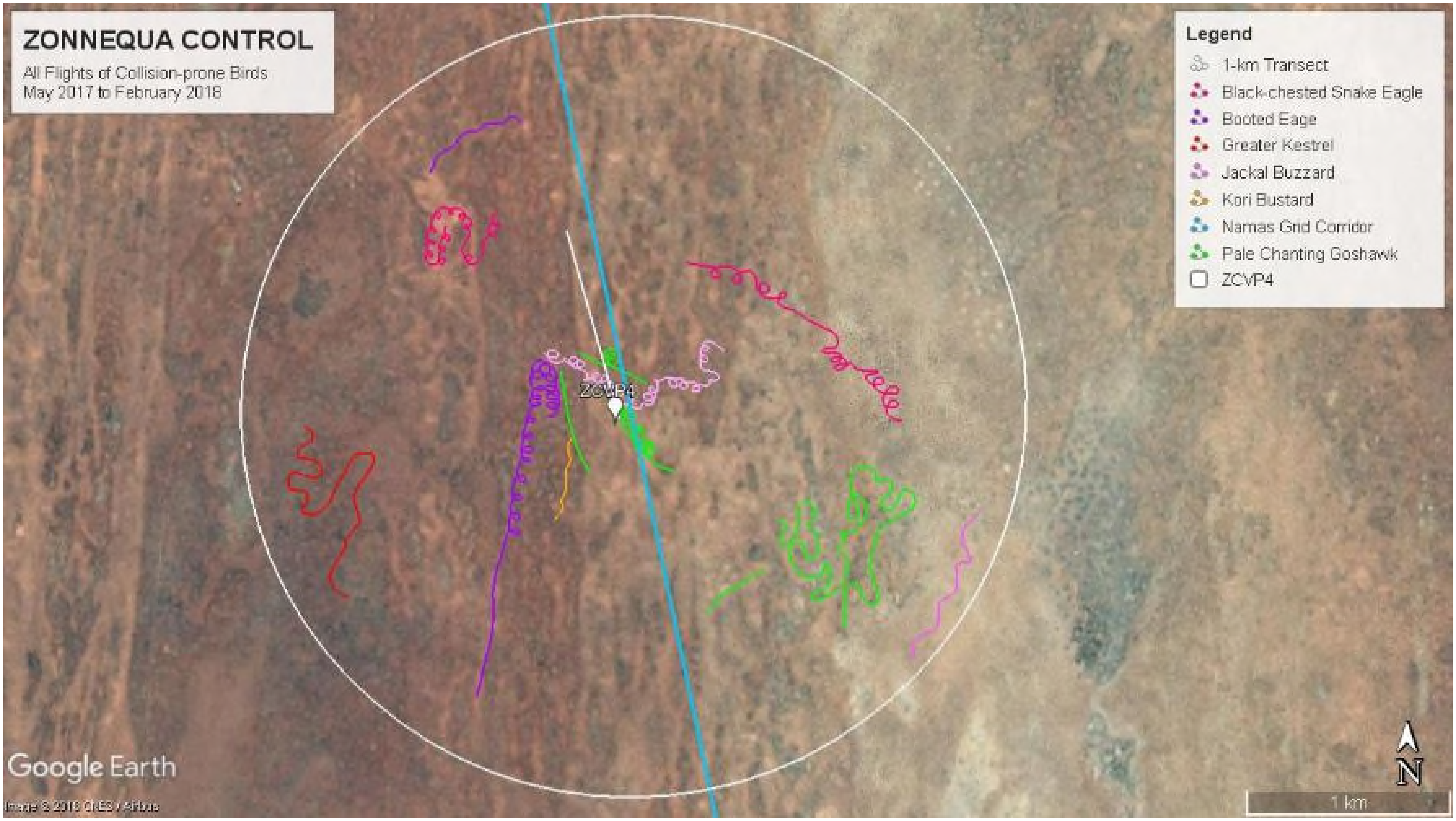

Figure 9: Flight paths of all collision-prone species passing through the Control site (VP4) (=white pin) north of the WEF, during our monitoring from May 2017 – February 2018. A Red Data Kori Bustard (=orange line), was the only Red Data species recorded here. The other priority species comprised Booted Eagle (= purple lines), Pale Chanting Goshawks (=green lines),a Greater Kestrel (=red line), and a Black-chested Snake Eagle (=magenta line).

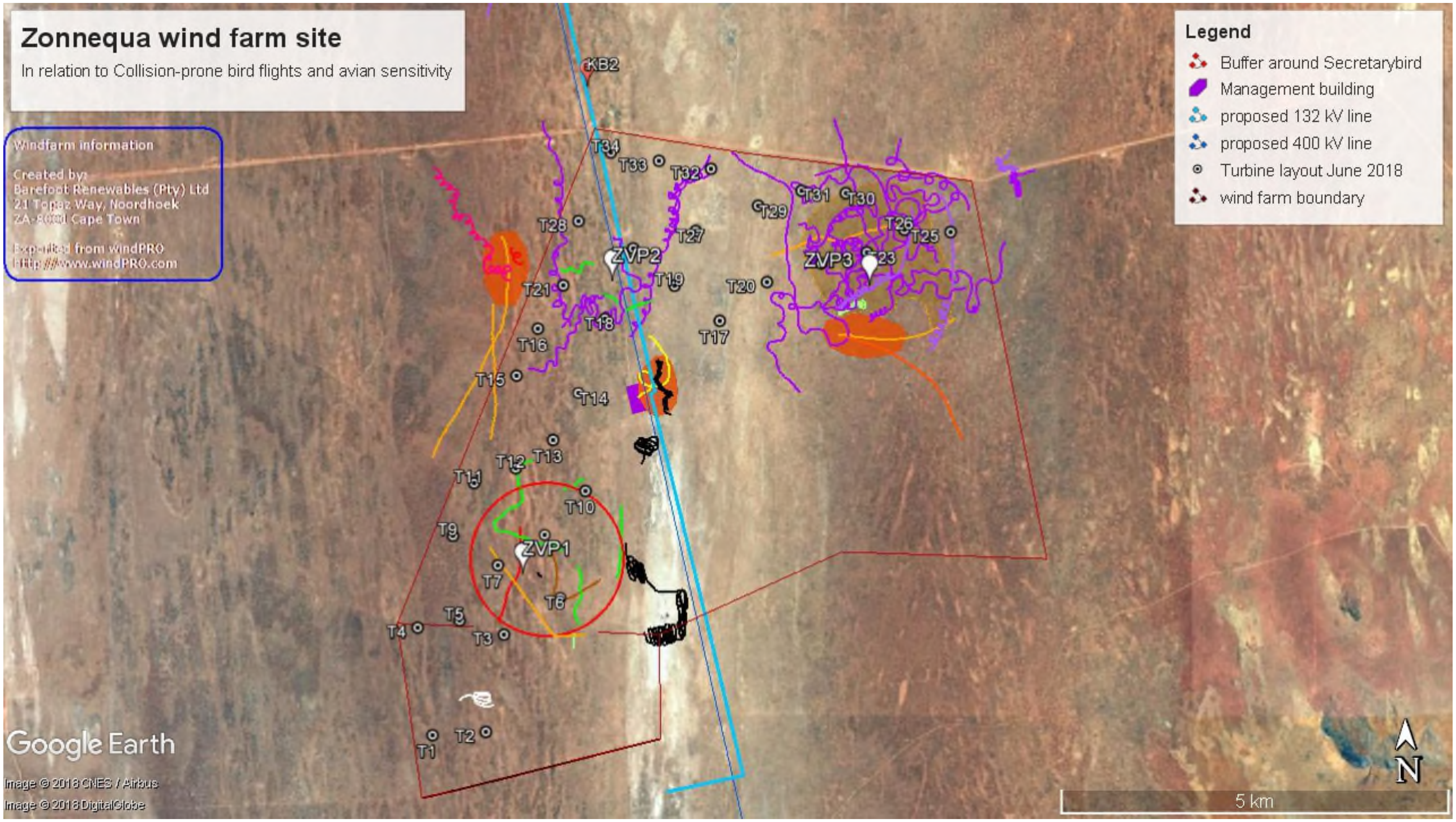

Figure 10: High risk and medium risk areas identified in the Zonnequa Wind Farm site based on flight data from May 2017 to February 2018. The red circle indicates the only high-risk area identified – an inactive Secretarybird nest with a 1-km buffer around it. **Because this pair is likely the same as the pair recorded on Namas wind farm site and the nest there is more frequently used, this buffer falls away (see caveat below).** Three medium risk areas are identified (= deep orange), encompassing 1 Red Data species and 1 or more CPSs. One medium-low risk area is also shown (= light orange) due to the high density of Booted Eagle flights centred on VP3 (right).

The risk areas identified on Figure 10 encompassed the following areas:

High risk (red circle) – Secretarybird (inactive) nest close to VP1 at S29°48'23.7" E17°13'57.5" (with a 1-km buffer). This inactive nest may be the alternative site of the bird at the Namas wind mast;.

Caveat: It is our opinion that the two inactive Secretarybird nests – one on Zonnequa Wind Farm and one on the adjacent Namas Wind Farm – are alternate sites of the same pair.

- The two inactive nests are 11-km apart and only two birds were seen at any one time during successive (back-to-back) observations on the two sites over 12 months.
- In August 2017 when display and aerial flights by a pair on the Zonnequa Wind Farm peaked, there was no activity on the Namas Wind Farm two to six days later.

Because this pair is likely the same as the pair recorded on Namas wind farm site and the nest there is more frequently used, this buffer falls away. As a precautionary measure, we suggest the nest structure is moved and placed near the only known breeding site reported just off site by the farmer (A. Engelbrecht pers. comm.) This is to encourage the birds to use the alternative nest. This will free up space for development, but it must be done with due consideration.

This plan and the reasons behind it were discussed by email and phone with Birdlife South Africa (S Ralston pers. comm.) and the EAP Savannah Environmental (K Jodas pers. comm.);

- Birdlife South Africa agreed that given that Secretarybirds often change their nest sites ~every 3 years" because their nests disintegrate into the top of the bushes they choose (Dr M Whitecross unpubl data), and
- Because this nest structure has never been used for breeding or roosting, that the nest structure can be moved as a precautionary measure to reduce the chance of the Secretarybirds moving into the centre of the wind farm to breed.

- **Medium risk** (deep orange) – three such areas are identified based on the overlap of one Red Data species and at least one other collision-prone species;
  - Area 1 near proposed operations and management building where Lanner Falcon and Secretarybirds present;
  - Area 2 west of VP2 (and possibly outside the site boundary);
  - Area 3 south of VP3, where two species of Red Data bustards were recorded;
  - These areas may be used for construction but mitigation for turbines must be enacted (see below);

- **Medium-Low risk** (light orange) – One large area encompassing multiple flights by collision-prone Booted Eagles. This area is not designated Medium risk because only one Collision-prone species was present in this area, not two species. However, the Passage Rate of this species alone in November 2017 was 0.5 birds per hour, a medium-high rate for a single species. This species also flies frequently on the wing and was recorded at Blade-Swept Height 65% of the time and is thus at considerable risk from turbines in the area (Table 6). Thus, turbines here require mitigation if more than one collision-prone bird per year is killed by the turbines.

7.3 Level of risk and recommended mitigation

All of these risk areas are designed to highlight areas where disturbance by construction or operation of priority species must be minimised or avoided. The level of risk signifies the level of mitigation. This varies from no construction recommended in the High-Risk areas, to turbines constructed with mitigation measures as they are built within the Medium-Risk areas. In the Medium-low risk areas, turbines may be constructed without mitigation but if more than one collision-prone bird per year is killed by the turbines then mitigation must be enacted. All are designed to reduce the possibility of direct impacts for priority species to a minimum. This applies to construction of roads, turbines or associated infrastructure.

8 QUANTIFYING THE IMPACTS

Below, we semi-quantify the impacts and evaluate the advantages of various forms of mitigation to reduce expected impacts.

Nature: The impact of the proposed WEF area will generally be negative for birds given the certainty that: (i) ~44.2-km^2 of habitat will be transformed and the associated habitat potentially fragmented; and (ii) birds may be killed directly if they fly into the wind turbines.

The Extent (**E**, from 1-5) of the impact will be local within the 44.2-km^2 area = (1).

The Duration (**D**, from 1-5) will be long-term (4) for the lifetime of the WEF. This is so for all collision-prone species.

The Magnitude (**M**, from 0-10) of the WEF area is expected to cause a medium impact (5) for the raptors.

The Probability of occurrence (**P**, from 1-5) of the raptors (Secretarybird) and bustards having some sort of interaction with the WEF site is ranked as probable (4) because of their passage rates and occurrence on the proposed wind farm identified in this assessment. This was justified above for Secretarybirds which frequently fly at risk (42% and 85% in our two studies).

The Significance S, [calculated as S = (E+D+M)P], is as follows (Table 7) for the species identified as at risk in the wind farm site.

The scale varies from:

- 0 (no significance), to
- < 30 Low (this impact would not have a direct influence on the decision to develop in the area), to
- 30-60 (the impact could influence the decision to develop in the area unless it is effectively mitigated), to
- >60 (the impact must have an influence on the decision process to develop in the area).

Table 7. A quantification of impacts to the three, main, collision-prone Red Data species and other priority raptors likely to be impacted by the **proposed Zonnequa WEF.**

WEF development site

Nature: Negative due to direct impact fatalities, disturbance and loss of foraging habitat around the WEF site for the Red-listed bird groups identified as at risk above.

- The Red Data Secretarybirds, Lanner Falcon, and the two eagles (Black-chested Snake and Booted) are collectively summed under Raptors (**RA**) and are likely to be impacted as well as the nomadic Kori and Ludwig's Bustard (**BS**).

	Without mitigation	**With mitigation**
Extent	**1**	**1**
Duration	**4**	**4**
Magnitude	**5 (RA) 4 (BS)**	**4 (RA) 3 (BS)**
Probability	**4 (RA) 4 (BS)**	**3 (RA) 3 (BS)**
Significance (E+D+M)P	**40 (RA) 36 (BS) (medium) (medium)**	**27 (RA) 24 (BS) (low) (low)**
Status (+ve or –ve)	Negative	Negative
Reversibility	Yes, if mitigation is implemented in medium risk areas	Yes
Irreplaceable loss of species?	No, Secretarybirds populations are relatively low here (not core habitat). Ludwig's Bustards are nomadic visitors to this area.	
Can impacts be mitigated?	Yes	Yes.

Mitigation for WEF site:

The mitigation for birds around the Zonnequa WEF site are as follows:

- position the turbines away from risk areas of high aerial traffic or nests of collision-prone species;
- if birds impact the turbines then paint a single blade black for those select turbines known to kill most birds to reduce impacts for eagles and other raptors (Stokke et al. 2017);
- selective feathering or stopping of turbines can be implemented during high-use seasons or times in the day for turbines that continue to kill unsustainable numbers of raptors
- As a precautionary measure move the Secretarybird nest-structure to the last known breeding area to the east;
- if raptors continue to be attracted into the site then habitat can be manipulated to reduce the attractiveness (from a prey point of view) for the raptors. Reducing the food resources will reduce raptor use of the area. This can be achieved by increasing the stocking density of sheep or goats on the farm;

One of the mitigations above (black-blade mitigations) is dependent upon knowing which turbines are responsible for most deaths. Thus, we recommended that: Genesis Zonnequa Wind (Pty) Ltd implement 12-24 months post-construction monitoring to assess the mortality of birds in the wind farm, through direct observation and carcass searches. This will assist in determining where individual turbine-specific mitigation measures are required to be implemented.

Residual impacts:

After mitigation, direct mortality through collision, or area avoidance, by the species identified above may still occur and further research and mitigation measures should be suggested. This can only be undertaken in conjunction with a systematic monitoring programme.

8.1 Cumulative Impacts

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

Thus, in this context, cumulative impacts are those that will impact the general avian communities in and around the Zonnequa Wind Farm development, mainly by other wind and solar farms and associated infrastructure in the Nama Karoo. This will happen via the same factors identified here viz: collision, avoidance and displacement. As a starting point, the number of renewable energy developments around the region within a 30-km radius of the site needs to be determined, and secondly, to know their impact on avifauna.

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

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

Six renewable energy developments are currently on record with the DEA (Table 9), but only one (Eskom) has an Environmental Authorization. Five of the six are wind farms (Figure 12), and the sixth is a solar photo-voltaic (PV) sites. The combined energy output of the six sites is projected to be 645MW. Project Blue 1 is of unknown energy output.

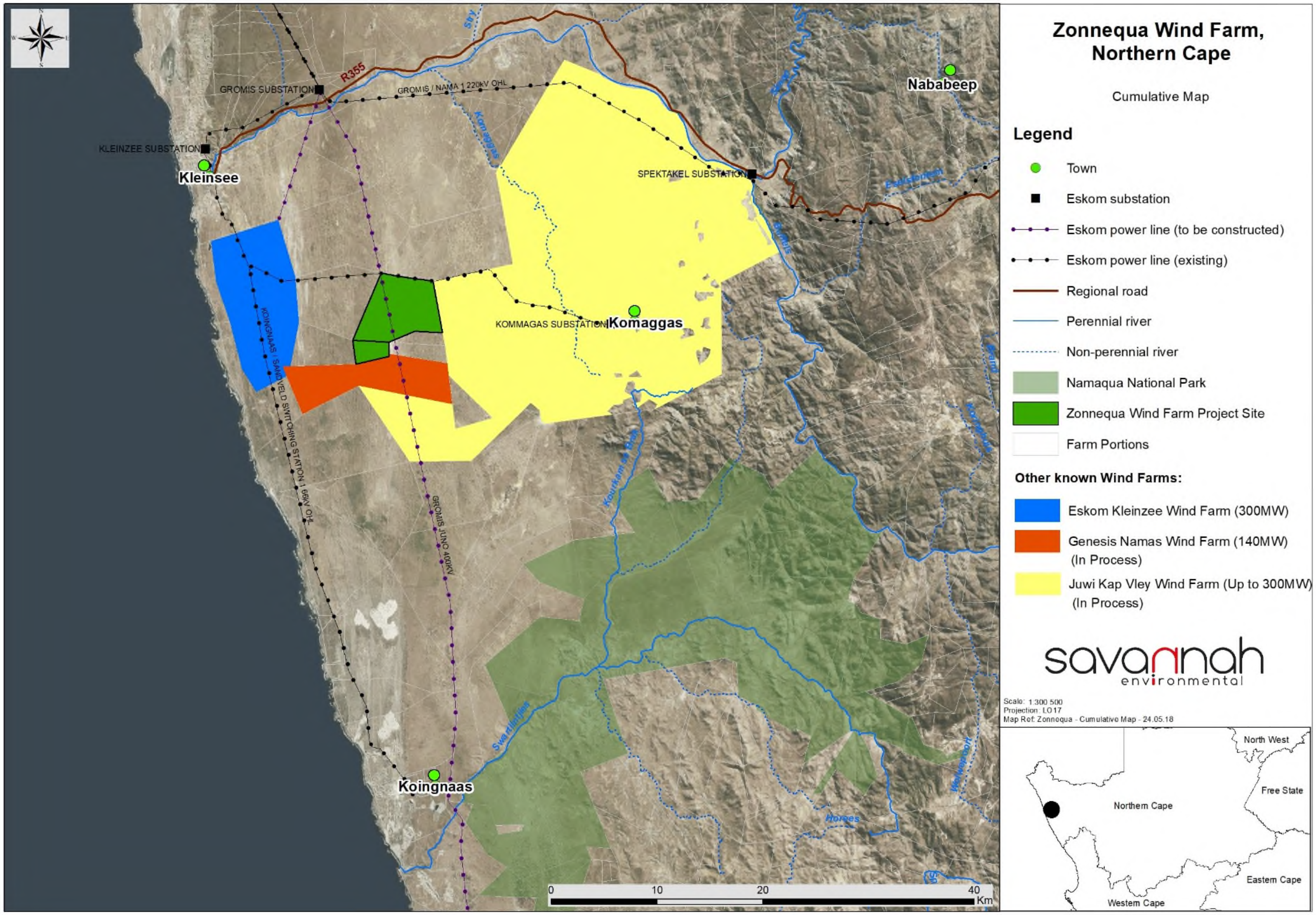

Figure 12: All proposed renewable energy (RE) developments within a 30-km radius of the Zonnequa wind farm. Three proposed RE sites are shown within 30-km – the Eskom Kleinsee 300 site (blue), the Genesis Namas site (brown) and the Juwi Kap Vley wind farm (yellow). The project Blue (Diamond) winds, within the 30 km radius, north of the Gromis substation has a lapsed EA, and is not shown.

Table 9: All renewable energy projects within a 30-km radius of the Zonnequa WEF, and their approval status with the DEA. Source: Savannah Environmental updated from http://egis.environment.gov.za/frontpage. aspx?m=27 DEA first quarter 2018.

	Project Title	**Distance from Zonnequa**	**Technology**	**Megawatts**	**Current Status**
1	Genesis Namas	1.0 km	Wind	140 MW	In Process
2	Juwi Kap Vlei	5.0 km	Wind	140 MW	In process
3	Eskom Kleinsee K300	7.0 km	Wind	300 MW	Approved
Totals: 3 wind farms 580 MW					

We searched for data to populate the Cumulative Impacts table from published and unpublished studies and theses. We sourced data from (i) post-construction wind farm data from avian assessments summarised by Birdlife South Africa from 1-2 years' post-construction monitoring (Ralston et al. 2017) (Table 8), and (ii) data from two unpublished MSc theses (Visser 2016, Jeal 2017).

The national review of post-construction data (Table 8), indicates that South African wind farms kill about 4.1 birds per turbine per year, similar to the international mean of about 5.25 birds per turbine per year (see Review (Point 5) above). Of some concern is that 36% of the fatalities recorded are raptors (Table 8). The equivalent number of fatalities per Megawatt lies between 1.87 and 5.5 birds per MW per year (Ralston et al. 2017). Note that using the median levels of mortality may give a slightly inflated figure because many early wind farms in South Africa did not have stringent mitigation measures, appropriate buffers and sensitive siting of turbines. Moreover, as a lower rainfall site (averaging 112 mm per annum) area, the avian abundance and diversity values are likely to be lower (Seymour et al. 2015) than higher rainfall sites, thus fatalities are also likely to be lower. Therefore, the lower end of the range reported by Ralston et al. (2017) is used here (1.87 mortalities/MW/yr).

For the number of fatalities (i.e. based on the MW of power to be produced within a 30 km radius is as follows:

- 580 MW x 1.87 fatalities per MW per year = 1084 (all) birds per year.
- If 36% of these are likely to be raptors (Table 10), then 390 raptor fatalities are predicted per year.
- If ~20% of these raptors are Red Data species (Ralston et al. 2017) then the cumulative impact is estimated to be 78 threatened raptors killed annually by the three wind farms.

Note that these are likely to be liberal estimates for the possible fatalities. First, the Passage Rates for raptors and bustards through this area when typically dry conditions occur is very low. Second, the fatality rates derived from Ralston et al (2017) were from areas with higher raptor concentrations (Eastern Cape, wet Western Cape sites) than here in the arid far-west. Thus, they may over-estimate the possible fatalities.

High (99%) avoidance rates are known for raptors around wind farms (Madders & Whitfield 2006). Thus, it is likely these figures are inflated fatality estimates.

Table 10: Summary of all birds and Red Data raptors killed at six wind farms in South Africa from 2014–2016. From Birdlife South Africa (Ralston et al. 2017). The identity of the wind farms was kept anonymous as a condition for the use of the data.

Wind farms	Turbines	Months monitored	Avian fatalities	Adjusted mortality rate*
6	46, 9, 41, 40, 60, 32	69	309	4.1 birds.turbine^{-1}year^{-1}
Main groups		Proportion of all avian fatalities		Ranking
Raptors (small-medium)		**33%**		1
Others/unknown		16%		2
Swifts, swallow and martins		14%		3
Passerine (small perching birds)		14%		3
Waders and wetland birds		10%		5
Raptors (eagles)		**3%**		6
Red Data raptors as a proportion of all raptors killed		12/61 = 19.7%		

Table 11: Cumulative impacts of the Zonnequa Wind Farm in the Nama Karoo, relative to 3 other potential wind and solar energy facilities within 30-km of the site.

Nature: The impact of the wind energy facilities proposed in the coastal Nama Karoo is expected to be negative and arise from disturbance, displacement and collision for birds around the wind turbines. The associated infrastructure may also affect species in the form of new roads and substations.

The direct potential impact of the 3 wind farms (Table 9) was gauged using data recently released by Birdlife South Africa for fatalities at 8 wind farms in South Africa (Ralston et al. 2017).

About 4.1 birds per turbine per year, or ~3.7 birds per MW per year are killed annually. We have used the lower mortality rate of 1.87 birds/MW/yr because dry areas will have lower species richness and abundance than more mesic areas.

If a total of 580MW is produced then 1084 birds per year may be killed of which 390 are expected to be raptors and 78 of these are estimated to be red data raptors.

These estimates are likely over-estimates given the very low passage rates recorded in this study area, and it is expected that probably 10% of this figure to be closer to reality in typical rainfall years. Thus, the likely impact varies from medium without mitigation. Careful mitigation can reduce this to low levels.

	Contribution of Proposed Zonnequa wind farm project*	**Cumulative Impact Of all projects within 30 km**
Extent	Low (1)	Low (1)
Duration	Long-term (4)	Long-term (4)
Magnitude	Moderate (7)	High (8)
Probability	Probable (3)	Probable (3)
Significance	**Medium (36)**	**Medium (39)**
Status (positive/negative)	Negative	Negative
Reversibility	Medium	Medium
Loss of resources/species?	Likely	Unlikely
Can impacts be mitigated?	Probably, Yes	Unknown

Confidence in findings:

Medium-Low: the mortality data released by Birdlife South Africa allows for the estimation of the probable mortality, but they may over-estimate avian mortality rates in the dry conditions typical in the western part of South Africa. Passage Rates and occurrence of Collision-prone species are typically low when annual rainfall is low, and mortality is thus expected to be minimal at such times. The mitigation measures suggested to avoid major raptor fatalities is unknown for each wind farm. Without mitigation measures (i.e. the avoidance of high-use and high-risk areas) the chances of mortality will increase greatly.

Mitigation:

Reducing avian impacts at wind energy facilities is in its infancy in South Africa. Recommended measures include:

- avoiding all migration routes and major flyways in the placement of such facilities;
- avoiding all nest areas and foraging/roosting areas of Red Data species in the siting of said facilities;
- employ radar or video detection of collision-prone birds and audible or visual deterrence to deter birds from approaching close to the turbines;
- painting one turbine blade black and selective stopping of turbines should be tested for efficacy;
- introduce livestock into the area to reduce the attractiveness of the habitat to raptors through increased grazing pressure, thereby reducing prey populations.

**With mitigation*

9 ENVIRONMENTAL MANAGEMENT PLAN

Given the possible impact of the proposed Zonnequa Wind farm development, the overall impact on avifaunal species requires systematic monitoring at both the construction and post-construction phases. This is a recommendation of the BARESG guidelines (Jenkins et al. 2015).

The guidelines suggest an adaptive and systematic monitoring of bird displacement (comparing avian densities before and after construction, particularly for priority collision-prone and red data species) and particularly the monitoring of all turbine-related fatalities. The latter must take account of biases introduced by scavengers removing carcasses and observers failing to detect bird remains below the turbines.

The monitoring should include the following (as per BARESG guidelines):

- Post-construction monitoring should be started as the facility becomes operational, bearing in mind that the effects of the wind farm facility may change over time;
- Monitoring should be undertaken by trained observers, willing to cover 4-5 turbines per day in all weathers and over-seen by an ornithologist competent to determine species identification and a manager to collate and analyse each year's data;
- Post-construction monitoring can be divided into two categories: a) quantifying bird numbers and movements (replicating baseline data collection), and b) estimating bird mortalities;
- Estimating bird fatality rates includes: a) estimation of searcher efficiency and scavenger removal rates, b) carcass searches, and c) data analysis incorporating systematically collected data from (a) and (b);
- A minimum of 30-40% of the wind farm footprint should be methodically searched for fatalities, throughout the year, with a search interval informed by scavenger removal trials and objective monitoring. Any evidence of mortalities or injuries within the remaining area should be recorded and included in reports as incidental finds;
- The search area should be defined and consistently applied throughout monitoring;
- Observed mortality rates must be adjusted to account for searcher efficiency (which could change seasonally depending on vegetative condition of the site), scavenger removal and the proportion of the facility covered by the monitoring effort. Some of these factors may change seasonally due to the breeding season of scavengers and whether visibility of the survey area changes through the year;
- The duration and scope of post-construction monitoring should be informed by the outcomes of the previous year's monitoring, and reviewed annually;
- Post-construction monitoring of bird abundance and movements and fatality surveys should span 2-3 years to take inter-annual variation into account; and
- If significant problems are found or suspected, the post-construction monitoring should continue in conjunction with adaptive management and mitigations, taking into account the risks related to the particular site and species involved.

An assessment guided by these principles is required not only to enact and experiment with different mitigation measures where significant mortality occurs, but to allow data to be collected that will benefit the avifauna at other renewable energy farms. This is also important for a study of cumulative avian impacts for the increasing number of wind farms planned for South Africa’s Northern and Eastern Capes.

Management interventions: Where avian fatalities are found to occur (i) to red-data species, or (ii) at unacceptably high levels, to priority species, then the mitigation measures detailed above, should be brought into play. Thus, experiments for example with bird deterrent techniques such as black-painted blade mitigation (successfully used to prevent eagle collisions in Norway: Stokke at el. 2017) or an equivalent such as UV-reflective painting of one blade should be undertaken without delay to reduce fatality rates. The results of these experiments should also be publicized so that other wind farms, with similar issues, can be informed.

We would encourage the developers to release the results of the annual monitoring to Birdlife South Africa such that South Africa-wide fatality and displacement results to be collated and assessed. Only in this way will the cumulative impacts assessments, currently crudely estimated, be refined, region by region.

10 CONCLUSIONS AND RECOMMENDATIONS

This year-long survey provides a comprehensive understanding of the avian species present in the Zonnequa Wind Farm prior to construction. The presence of some nine priority species, including Red Data species (Ludwig’s Bustard, Kori Bustard, Secretarybird) means the site is medium-rich in threatened species. Despite this, the Passage Rates were very low: for the Red Data species on the WEF site Passage Rates were 0.09 bird per hour and were low for all 9 collision-prone species combined (0.36 birds per hour). This suggests a relatively low risk to any birds on site. We also believe that this may have arisen from the very dry conditions present in western South Africa in 2017-2018 this may become the norm under climate change as it is part of a long-term decline apparent since the 1940s of a decrease in rainfall. This amounts to a decline of 17mm per year every decade (www.news24.com/SouthAfrica/News/how-severe-is-cape-towns-drought-a-detailed-look-at-the-data-20180123). While avian passage rates are expected to be higher during more typical rainfall, research in arid areas indicates that avian diversity and avian populations decline as mean annual rainfall declines over large areas (Seymour et al. 2015).

Nevertheless, one area of high-risk and three areas of medium risk were identified on the proposed site.

The high risk was associated with an inactive nest of a resident Red Data Secretarybird. If a pair occurs and breeds they may be impacted if turbines are constructed. As a precautionary measure we propose moving the structure to an area to the east where the only the only breeding took place several years previously. The idea has gained the green light from Birdlife South Africa because (i) Secretarybirds often move sites when their nests disintegrate every 3 years or so (M. Whitecross unpubl data) and (ii) this nest structure has never been used.

Three medium-risk areas, encompassing the flights of one Red Data species and at least one other priority species, were also located. We recommend that:

- development can proceed in these medium risk areas with the implementation of appropriate mitigation measures with the construction of the turbines;
- **we strongly recommend the use of the successful black-painted blade mitigation (or UV-painted equivalent) known to reduce eagle mortalities 100% at one other overseas wind farm;**
- In the medium-low risk area in the east of the site (where high rates of Booted Eagle activity occurred), development can occur, but mitigations must be enacted if more than one mortality of a collision-prone species occurs per month at the turbines involved.

By implementing these measures to mitigate possible impacts for these collision-prone Red Data species, risks and mortality can be reduced to acceptable levels.

We define **acceptable levels** as less than one raptor fatality every 2 month across the entire wind farm site. Or not more than one red data raptor per year across the wind farm. If more than these levels are found, with the current level of mitigation implemented, then additional mitigation measures as itemised in Table 7 (for the wind farm) must be implemented.

Cumulative impacts are greater for the 3 proposed wind farms within 30-km of the Zonnequa Wind Farm site, and we estimate that in high rainfall years hundreds of fatalities (all bird species) may occur annually based on average South African fatality rates. The proportion of threatened species is estimated at 78 red data raptors (Table 11) cumulatively killed annually in typical rainfall years. Low Passage Rates of raptors in dry conditions and in this over-grazed landscape suggests that this figure is over-inflated and that fatalities may be only 10% of this figure.

In our view, and from research on bird populations in arid areas (Seymour et al. 2015), low rainfall sites will have fewer species and a lower abundance of those species. Given the expected reduction in rainfall projected under climate change over the next 18-47 years in the Northern Cape http://www.weathersa.co.za/images/SAWS_CC_REFERENCE_ATLAS_PAGES.pdf and its expected negative effect on South African bird populations (Simmons et al. 2004) the Passage Rates recorded here are, on average, unlikely to be much higher than recorded in 2017-2018, and the impact on the avifauna of the area will be at acceptable levels to allow development to proceed with the recommended mitigations.

This must be accompanied by a full 12-24 months of systematic post-construction monitoring in place by competent ornithologists familiar with the area and locating Secretarybirds. This will determine the efficacy of the mitigations and provide input to any further mitigations required if problems arise on site.

We also suggest that further reducing the attractiveness of the site for raptors through the continued intense livestock farming, will assist in reducing future impacts. At present the land-owners here farm with sheep year-round, supplementing them in the dry months, while other more affluent farmers move their sheep away in hot dry summer months. This land use should be continued.

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2 April 2018
Revised : 13 April 2018; 2nd revision: 27 June 2018 3rd revision: 22 Aug 2018; 4th revision 17 Sept 2018

APPENDIX 1

All Bird species recorded on SABAP2 bird atlas cards in the pentads (2945_1710, 2950_1710, 2945_1715, 2950_1715) surrounding the Zonnequa wind farm. N = 37 cards from June 2013 to March 2018 for the WEF and control sites. Ordered in terms of descending reporting rate.

SABAP species 37 cards	**Full protocol**	
June 2013 - March 2018	Rep Rate (%)	n
Scrub-robin, Karoo	37.8	14
Prinia, Karoo	35.1	13
Lark, Karoo	32.4	12
Flycatcher, Chat	29.7	11
Crow, Pied	27.0	10
Crow, Cape	27.0	10
Cisticola, Grey-backed	27.0	10
Lark, Karoo Long-billed	24.3	9
Sunbird, Southern Double-collared	24.3	9
Goshawk, Southern Pale Chanting	21.6	8
Warbler, Rufous-eared	21.6	8
Canary, Yellow	18.9	7
Martin, Rock	18.9	7
Kestrel, Greater	16.2	6
Bokmakierie,	13.5	5
Crombec, Long-billed	13.5	5
Bustard, Ludwig's	10.8	4

Tit-babbler, Layard's	10.8	4
Lark, Spike-heeled	10.8	4
Swift, Little	10.8	4
Eagle, Booted	10.8	4
Swallow, Barn	10.8	4
Sparrow, Cape	10.8	4
Swift, Alpine	8.1	3
Sunbird, Malachite	8.1	3
Korhaan, Southern Black	8.1	3
Penduline-tit, Cape	8.1	3
Snake-eagle, Black-chested	8.1	3
Secretarybird	5.4	2
Wheatear, Capped	5.4	2
Fiscal, Common (Southern)	5.4	2
Bee-eater, European	5.4	2
Canary, White-throated	5.4	2
Chat, Familiar	5.4	2
Lark, Cape Long-billed	5.4	2
Chat, Anteating	5.4	2
Sandgrouse, Namaqua	5.4	2
Falcon, Lanner	2.7	1
Swift, Common	2.7	1
Thick-knee, Spotted	2.7	1
Turtle-dove, Cape	2.7	1
Tit, Grey	2.7	1
Lark, Red-capped	2.7	1
Bulbul, Cape	2.7	1
Kestrel, Rock	2.7	1
Swallow, White-throated	2.7	1
Stonechat, African	2.7	1
Lapwing, Crowned	2.7	1
48 species recorded		
8 Collision-prone species		
3 Red Data species		

APPENDIX 2

ALL COLLISION-PRONE BIRD SPECIES RECORDED IN THE PROPOSED ZONNEQUA WIND FARM FROM MAY 2013 TO FEBRUARY 2018.

ZONNEQUA WEF Passage Rates – May 2017

Date	Time	Obs period	Hrs	VP	No	Species	Height	Seconds	Ref on Map
29/05/2017		08h30-14h30	6.00	**ZVP1**		**No Birds**		-	
31/05/2017		11h55-17h55	6.00	**ZVP1**		**No Birds**		-	
29/05/2017		08h53-14h53	6.00	**ZVP2**		**No Birds**			
31/05/2017		12h00-18h00	6.00	**ZVP2**		**No Birds**		-	
30/05/2017		08h00-14h00	6.00	**ZVP3**	1	Pale Chanting Goshawk	0m perched	0	PCG1
01/06/2017	12h20	12h00-18h00	6.00	**ZVP3**	1	Pale Chanting Goshawk	0m perched	0	PCG2
			36.00	**Hrs**	**2**	**Birds**			
WEF	**Passage rate:**		**36.00**	**Hr**	**2**	**0.06**	**Birds / hr**		
Red Data	**Passage rate:**		**36.00**	**Hr**	**0**	**0.00**	**Birds / hr**		**May 2017**

ZONNEQUA WEF Passage Rates – August 2017

Date	Time	Obs period	Hrs	VP	No	Species	Age	Sex	Height	Seconds
28/8/2017	8h39	8h15-14h15	6.00	**ZVP1**	1	**Ludwig's Bustard**	Ad	Unkn	15,20,10,20,25,25	75
29/8/2017	11:07	10h40-16h40	6.00	**ZVP1**	1	Unidentified raptor	Unkn	Unkn	130,140,140	40
	12:01				2	**Secretarybird**	Ad	M/F	60,60,80,80,80,60	85
	12:26				2	**Secretarybird**	Ad	M/F	0m	54
	13:01				1	**Secretarybird**	Ad	Unkn	50,50,50,80,100,100,100,120, 130,140,140, 150,160,160,170,170,150,150 ,150,150,170,170,170,170	346
					1	Pale Chanting Goshawk	Imm	Unkn	5,5,5	42
28/8/2017	8:46	7h45-13h45	6.00	**ZVP2**	1	**Ludwig's Bustard**	Ad	Unkn	10,10,8,12,12,12	80
	12:55				1	Pale Chanting Goshawk	Ad	Unkn	15,8,0	40
29/8/2017	10:55	10h15-16h15	6.00	**ZVP2**	**1**	**Ludwig's Bustard**	Ad	Unkn	30,30,30,30,35,35,50,50,55,55,60,70,65,60,65,60	225
	10:55				1	Greater Kestrel	Ad	Unkn	25,25,25	30
	11:58				1	**Secretarybird**	Ad	F	10,10,20,25,10,10,10,15,20,20,30,30,35,40,40,40,40,20	270
	11:59				1	**Secretarybird**	Ad	M	50,40,10,10,15,20,30,30,35,40,40,40,40,20	210
30/8/2017		7h30-13h30	6.00	**ZVP3**		No Birds				
31/8/2017	11:00	11h00-17h30	6.00	**ZVP3**	1	**Ludwig's Bustard**	Ad	Unkn	7,7,7,5,2	60
					1	**Kori Bustard**	Ad	Unkn	7,7,7,10,15,20,25,30,35,5	135
	12:55				2	Pale Chanting Goshawk	Ad	M/F	45,45,60,60,60,65,70	90

	12:55				1	Booted Eagle	Ad	Unkn	50,50,60,65,70,80,85,80,80,100,110,110,110,105,150,150,150,100,100,105,110	300
					1	Booted Eagle	Ad	Unkn	40,50,50,70,95,110,110,120,130,100,110,115,130,130,130,130,130	240
	14:11				1	Booted Eagle	Ad	Unkn	20,40,50,60,85,95,100,100,100,40,10,0	150
	14:13				1	Booted Eagle	Ad	Unkn	15,20,30,40,45,35,35,30,30,30,25,29,40,50,50,40,59,50,50,30,10	285
WEF	**Passage rate:**		**36.0**	**Hr**	**22**	**0.61**	**Birds / hr**			
Red Data	**Passage rate:**		**36.0**	**Hr**	**12**	**0.33**	**Birds / hr**		**August 2017**	

ZONNEQUA WEF Passage Rates – November 2017

Date	Time	Obs period	Hrs	VP	No	Species	Age	Sex	Height	Seconds
26/11/2017	11:29	8h15-14h15	6.00	**ZVP1**	1	Greater Kestrel	Ad	U	20,40,40,40,40,40,45,45,40,43,15,20,15,20,25,25,20,30,5,15,20,5,5,13,17,10,10,7,10,10,20,5,5,12,5	510
	12:49				1	Pale Chanting Goshawk	Ad	U	35,35,35	30
27/11/2017	11:05	11:00-17:00	6.00	**ZVP1**	1	Pale Chanting Goshawk	Ad	U		62
	15:28				1	Pale Chanting Goshawk	Ad	U		27
	16:19				1	Pale Chanting Goshawk	Ad	U		42
26/11/2017	8:19	8h45-14h45	6.00	**ZVP2**	1	Pale Chanting Goshawk	Ad	U	30,30,20,10	44
	11:27				1	Booted Eagle	Ad	U	60,60,80,80,100,120,140,140,150,160	136
	13:06				1	Booted Eagle	Ad	U	5,5,5,10,15,80,50,60,80,100,100,100,120,120,120,150,180,180,200,240,240,260,300,300,320,320,280,260,220,180,160,140	482
27/11/2017	10:28	10h30-16h30	6.00	**ZVP2**	**1**	Booted Eagle	Ad	U	20,30,35,40,40	60
	12:45				**1**	Booted Eagle	Ad	U	70,75,90,95,90,90,90,90,100,110,110,120,130,130,130,130,130,130,150,160,190,190	315
	12:49				**1**	Booted Eagle	Ad	U	135,135,135,145,160,180,200,210,230,260	135
24/11/2017	8:19	8h15-14h15	6.00	**ZVP3**	1	**Ludwig's Bustard**	Ad	U	20,20,20,10,10	56
	8:44				2	Booted Eagle (pale)			15,30,40,70,80,100,120,140,100,160,180,200,200,200,200,220,220,220,220,220,240,240	197
	9:16				1	Booted Eagle (pale)	Ad	U	40,40,60,60,50,40	76

	10:23				1	Booted Eagle (pale)	Ad	U	80,80,100,120,100	59
	10:51				1	Booted Eagle (dark)	Ad	U	70,70,70,80,80,80,100,100,100,80,80,80,120,120,120,160,160,200,200,200,240,200,200,180,180,150,150,130,130,120,100,90,90	482
	10:56				1	Booted Eagle (pale)	Ad	U	80,80,90,100,80,70,50,50	107
	11:55				1	Booted Eagle (pale)	Ad	U	180,180,180,180,160,160,150,150,150,130,130,130,120,120,100,100,100,80,80,70,60,60,50,50,50	362
	12:13				1	Booted Eagle (pale)	Ad	U	20,20,30,40,50,30,40,40,80,80,30,20,20	183
	12:26				1	Booted Eagle (pale)	Ad	U	50,50,30,30,30,40,50,70,70,100,100,100,80,80,60,60,40	237
	12:50				1	Booted Eagle (pale)	Ad	U	70,70,80,80,100,100,100,90,90,80	131
	14:05				1	Booted Eagle (pale)	Ad	U	50,50,60,60,80,80,90,90,100,100,100,80,80,60,50,50,50	236
25/11/2017	11:15	9:20-15:20	6.00	**ZVP3**	1	Booted Eagle (pale)	Ad	U	40,45,45,45,50,55,65,75,80,85,90,105,120,115,110,120,130,130,125,125,135,140,150,155,155,150,145,140,145,160,150,145,145,135,120,120,120	555
	13:14				1	Booted Eagle (pale)	Ad	U	70,75,75,80,85,80,75,75,75,80,80,75	180
WEF	**Passage rate:**		**36.0 hr**		**25**	**0.69**	**Birds / hr**			
Red Data	**Passage rate:**		**36.0 hr**		**1**	**0.03**	**Birds / hr**		**November 2017**	

ZONNEQUA WEF Passage Rates – February 2017

Date	Time	Obs period	Hrs	VP	No	Species	Age	Sex	Height	Seconds
2018/02/28	7:11	7h10-14h10	7.00	**ZVP1**	1	Southern Black Korhaan	A	M	5;7;7;7	45
	7:44				1	Southern Black Korhaan	A	M	10;10;10	30
2018/03/01		8h00-13h00	5.00	**ZVP1**		No birds			-	
2018/02/28		7h30-14h30	7.00	**ZVP2**		No birds			-	
2018/03/01	10:40	7h10-12h10	5.00	**ZVP2**	**1**	**Black-chested Snake Eagle**			20,25,30,90,110,125,130,130,130,110,110,110,110,20,down,down,35,35,40,40,40,45,45,50,50,55,60,65,70,70,70,80,85,105,105	510
2018/02/26		8h00-12h00	4.00	**ZVP3**		No birds			-	
2018/02/27		7h00-15h00	8.00	**ZVP3**		No birds			-	
WEF	**Passage rate:**	**36.0**	**Hr**	**3**		**0.08**	**Birds / hr**			
Red Data	**Passage rate:**	**36.0**	**Hr**	**0**		**0.00**	**Birds / hr**		**February 2018**	

Photo 9: Small bird diversity was low throughout the study year but one of the most common species was the Cape Long-billed Lark that was heard throughout the year, seemingly unaffected by the drought conditions