Avifaunal pre-construction monitoring at the proposed Mainstream Loeriesfontein 2 and Khobab Wind Energy Facilities

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Chris has seventeen years' experience in the management of wildlife interactions with electricity infrastructure. He was head of the Eskom-Endangered Wildlife Trust (EWT) Strategic Partnership from 1996 to 2007, which has received international acclaim as a model of co-operative management between industry and natural resource conservation. He is an acknowledged global expert in this field and has worked in South Africa, Namibia, Botswana, Lesotho, New Zealand, Texas, New Mexico and Florida. Chris also has extensive project management experience and has received several management awards from Eskom for his work in the Eskom-EWT Strategic Partnership. He is the author of 15 academic papers (some with co-authors), co-author of two book chapters and several research reports. He has been involved as ornithological consultant in more than 100 power line and 25 wind generation projects. Chris is also co-author of the Best Practice for Avian Monitoring and Impact Mitigation at Wind Development Sites in Southern Africa, which is currently (2013) accepted as the industry standard. Chris also works outside the electricity industry and had done a wide range of bird impact assessment studies associated with various residential and industrial developments.

Albert Froneman (Pr.Sci.Nat)

Albert has an M. Sc. in Conservation Biology from the University of Cape Town, and started his career in the natural sciences as a Geographic Information Systems (GIS) specialist at Council for Scientific and Industrial Research (CSIR). He is a registered Professional Natural Scientist in the field of zoological science with the South African Council of Natural Scientific Professionals (SACNASP). In 1998, he joined the Endangered Wildlife Trust where he headed up the Airports Company South Africa – EWT Strategic Partnership, a position he held until he resigned in 2008 to work as a private ornithological consultant. Albert's specialist field is the management of wildlife, especially bird related hazards at airports. His expertise is recognized internationally; in 2005 he was elected as Vice Chairman of the International Bird Strike Committee. Since 2010, Albert has worked closely with Chris van Rooyen in developing a protocol for pre-construction monitoring at wind energy facilities, and they are currently jointly coordinating pre-construction monitoring programmes at several wind farm facilities. Albert also works outside the electricity industry and had done a wide range of bird impact assessment studies associated with various residential and industrial developments.

Nico Laubscher

Nico holds a D.Sc. from the University of Potchefstroom and was head of the Statistics Division, National Research Institute for Mathematical Sciences of the CSIR from 1959 – 1975. He retired in 1989 as head of the Centre for Statistical Consultation at the University of Stellenbosch. Nico held several offices, including President of the South African Statistical Association, and editor of the South African Statistical Journal. Nico has 56 years' experience in statistical analysis and data science applications, including specialisation in model building with massive data sets, designing of experiments for process improvement and analysis of data so obtained, and statistical process control. He also has published peer reviewed papers in several leading statistical journals, including *Annals of Mathematical Statistics, American Statistical Journal, Technometrics* and *The American Statistician.* He currently operates as a private statistical consultant to industry and academia.

Executive summary

This report presents the findings of a pre-construction avifaunal monitoring programme which was implemented at the proposed Mainstream Loeriesfontein 2 and Khobab wind energy facilities approximately 60km north of the town of Loeriesfontein in Bushmanland in the Northern Cape Province during the course of 2012 and 2013. At this stage, it is estimated that the proposed project will encompass the installation of a number of wind turbine generators and their associated components in order to generate electricity that is to be fed into the existing Eskom distribution and/or transmission lines that cross or are located nearby the proposed site. The project also has a solar component, but that is not covered by the terms of reference of this report. The scope of this report is restricted to the Loeriesfontein 2 and Khobab developments which consist of 62 and 61 proposed turbines respectively (n = 123), collectively referred to as “the turbine site”. The turbines will have a hub height of 99.5m, a rotor span of 108m, a minimum tip height of 45.5m and a maximum tip height of 153.5m. It should be noted that the lay-out originally included an additional 35 turbines which were located north of the current Loeriesfontein 2 lay-out. However, these turbines were removed before the monitoring commenced, on the basis that they might constitute a collision risk to flamingos which could potentially be present at a large pan north-west of the proposed Loeriesfontein 2 development.

The following is a summary of the findings of the pre-construction monitoring programme:

DISPLACEMENT

- With an overall species count of 35, of which 8 are priority species, the turbine site supports a relatively low diversity of avifauna, which is to be expected in an arid area like Bushmanland.
- The abundance of priority species at the turbine site is also generally low, with 1.09 birds/km recorded on drive transects for all the priority species combined, and 4.27 birds/km recorded on walk transects.
- The turbine site is clearly important for Red Lark, with 1.59 birds/km recorded during walk transects.
- Ludwig’s Bustard also occurs regularly at the turbine site with 0.53 birds/km reported during drive transects, and 0.34 birds/km reported during walk transects.
- Karoo Korhaan is also relatively abundant with 0.18 birds/km reported during drive transects, and 1.20 birds/km during walk transects.

- Northern Black Korhaan occurs sparsely at the turbine site with 0.26 birds/km reported during walk transects.
- Sclater's Lark was also reported only at the turbine site during transect counts (0.78 birds/km during walk transects).
- If displacement of Red Lark and (to a lesser extent) Sclater's Lark happens due to the construction and operation of the wind farm, the cumulative impact of several wind farms may constitute a significant impact, as both species are Red Data range restricted endemics. However, based on the existing information on the displacement of passerines by wind farms, it is unlikely that these species will be displaced, but it can only be confirmed once post-construction monitoring is implemented.
- Based on the data currently available, none of the priority species recorded at the site is likely to be permanently displaced by the operations of the wind farm, although this will have to be confirmed during post – construction monitoring, especially for Ludwig's Bustard. From a potential displacement perspective no relocation of turbine positions is currently required.

COLLISIONS

- From a statistical perspective, it would seem that the survey effort was sufficient to produce a reasonably reliable set of data to draw conclusions from.
- The passage rate during the survey periods for priority species flying at approximate rotor height was low at 0.57 birds/hour.
- Based on the site specific collision risk rating, Ludwig's Bustard is the species most likely to collide with the turbines, although the estimated annual mortality rate is still low, i.e. <1 birds per year.
- The estimated annual mortality rate for priority species as a whole is <1 birds/year.
- Based on the data currently available, and specifically the low estimated annual collision mortality for priority species, no relocation of turbine positions is currently required.
- An issue that remains uncertain is whether there will be a collision risk for Lesser and Greater Flamingos associated with the pan which is situated approximately 2.5km to the northwest from the closest proposed turbine position, although this risk has already been significantly reduced through the removal of 35 intended turbines to the north of the current turbine lay-out to lessen the risk of flamingo collisions. The situation would have to be closely monitored during operation through post-construction monitoring to establish if flamingos are indeed at risk, and appropriate mitigation implemented if need be.

Based on the results of the monitoring to date, no relocation of specific turbines is currently recommended.

The following management actions are recommended:

DISPLACEMENT

- Formal monitoring should be resumed once the turbines have been constructed, as per best practice guidelines (Jenkins *et al.* 2011). The purpose of this would be to establish if displacement of priority species has occurred and to what extent. The exact time when post-construction monitoring should commence, will depend on the construction schedule, and will be agreed upon with the developer once these timelines have been finalised.
- The duration of the post-construction monitoring would need to be for at least an equivalent period to the pre-construction monitoring (four seasons); and ideally for at least three years thereafter. Thereafter the need for additional monitoring will be determined and agreed to with the developer..
- Construction activity should be restricted to the immediate footprint of the infrastructure, and in particular to the proposed road network. Access to the remainder of the site should be prohibited to prevent unnecessary disturbance of priority species.

COLLISIONS

- Formal monitoring should be resumed once the turbines have been constructed, as per best practice guidelines (Jenkins *et al.* 2011) (see previous section Displacement). The duration of the post-construction monitoring would need to be for at least an equivalent period to the pre-construction monitoring (four seasons); and ideally for at least three years thereafter. Thereafter the need for additional monitoring will be determined and agreed to with the developer. The purpose of this would be (a) to establish if displacement of priority species has occurred and to what extent through the altering of flight patterns post-construction, and (b) to search for carcasses at turbines.
- The environmental management plan should provide for the on-going inputs of a suitable experienced ornithological consultant to oversee the post-construction monitoring and assist with the on-going management of bird impacts that may emerge as the post-construction monitoring programme progresses. Depending on the results of the carcass searches, a range of mitigation measures will have to be considered if mortality levels turn out to be significant. If flamingo mortality is recorded, depending on the severity of the problem, appropriate measures to record nocturnal flight movement would need to be implemented.

Contents

1. Introduction

This report presents the findings of a pre-construction avifaunal monitoring programme which was implemented at the proposed Mainstream Loeriesfontein 2 and Khobab wind energy facilities approximately 60km north of the town of Loeriesfontein in Bushmanland in the Northern Cape Province during the course of 2012 and 2013. At this stage, it is estimated that the proposed project will encompass the installation of a number of wind turbine generators and their associated components in order to generate electricity that is to be fed into the existing Eskom distribution and/or transmission lines that cross or are located nearby the proposed site. The project also has a solar component, but that is not covered by the terms of reference of this report. The scope of this report is restricted to the Loeriesfontein 2 and Khobab developments which consist of 62 and 61 proposed turbines respectively (n = 123), collectively referred to as "the turbine site". The turbines will have a hub height of 99.5m, a rotor span of 108m, a minimum tip height of 45.5m and a maximum tip height of 153.5m. It should be noted that the lay-out originally included an additional 35 turbines which were located north of the current Loeriesfontein 2 lay-out. However, these turbines were removed before the monitoring commenced, on the basis that they might constitute a collision risk to flamingos which could potentially be present at a large pan north-west of the proposed Loeriesfontein 2 development.

The pre-construction monitoring protocol was designed in accordance with the *"Best practice guidelines for avian monitoring and impact mitigation at proposed wind energy development sites in southern Africa"* (Jenkins *et al.* 2011) which was published by the Endangered Wildlife Trust (EWT) and BirdLife South Africa (BLSA) in March 2011, and subsequently revised in August 2011 and July 2012. The investigation of potential impacts on birds caused by wind farms is a relatively new field of study in South Africa, and has only been the focus of much attention since mid-2010. The concept of wind energy suddenly and rapidly gained momentum in South Africa in the latter part of 2010, resulting in a plethora of proposed wind farm applications which caught the ornithological community somewhat off-guard. The pace of new developments is such that both developers and specialist ornithological consultants struggled (and are still struggling) to come to grips with the enormity of the task ahead, namely to ensure that scientifically robust studies are implemented at all proposed development sites to assess the potential impact on avifauna. The basic approach of this study is to present findings and recommendations based on the knowledge which is currently available in a South African context, while acknowledging that there is still much to learn in this field. As the results of pre-and post-construction monitoring programmes which are currently being implemented become available, those results will be applied to future developments in order to predict with increasing confidence what the likely impact of a particular wind farm development will be on avifauna.

2. Terms of reference

The terms of reference for the avifaunal pre-construction monitoring programme were as follows:

- To establish which species regularly occur at the development site;
- To gather baseline data on the diversity of avifauna and specifically abundance of priority species within the development area to measure potential **displacement** due to the construction and operation of the wind farm. This is primarily done through transect surveys (see 4.1 below).
- To record flight behaviour of priority species to assess the risk of potential mortality due to **collision** with the turbines. This is primarily done through vantage point counts (see 4.2 below).

3. Assumptions and limitations

The basic assumption is that the sources of information used are reliable enough to allow for meaningful interpretation. However, it must be noted that there are certain limitations:

- It is inevitable that observations at vantage points are biased towards those species that are more visible (i.e. larger species), and flights that are closer to the observer. It must therefore be accepted that both the accuracy and frequency of observations decrease with distance from the observer. It should also be noted that the survey method i.e. an observer using binoculars is inherently not very accurate when it comes to judging flight height, therefore flight height should be seen as an approximation only.
- The best practice guidelines state that “monitoring data also should be collected over at least a 12 month period (at both WEF and control sites), and include sample counts representative of the full spectrum of prevailing environmental conditions likely to occur on each site in a year”. Whereas the sampling periods in this study aim to be broadly representative of seasonal environmental

conditions which prevailed during the monitoring period, it must be borne in mind that environmental conditions may vary significantly on an annual basis, especially in an arid environment like Bushmanland. Furthermore, it is not always practically possible to schedule monitoring to coincide with the full spectrum of environmental conditions, due to practical constraints.

- In circumstances where there is uncertainty and the precautionary principle may be relevant, evidence, expert opinion, best practice guidance and professional judgment were applied.
- For purposes of monitoring, priority species were defined as species included on the list of priority species of the Avian Wind Farm Sensitivity Map of South Africa compiled by Birdlife South Africa (Retief *et al.* 2012).

4. Methods

Data were gathered in four sampling seasons at the turbine site and a control site. The seasons are defined as follows:

- Spring: Mid-August to Mid – November.
- Summer: Mid - November to Mid - March.
- Autumn: Mid - March to Mid-May
- Winter: Mid-May to Mid-August

Monitoring was implemented during the following periods:

- Spring: 18 – 22 September 2012, 09 – 13 September 2013
- Summer: 17 - 23 December 2012
- Autumn: 15 – 19 April 2013
- Winter: 03 – 15 June 2013

4.1 Transects, point counts and vantage points

The monitoring protocol for the site is designed according to the latest version (2012) of *Jenkins A R; Van Rooyen C S; Smallie J J; Anderson M D & Smit H A. 2011. Best practice guidelines for avian monitoring and impact mitigation at proposed wind energy development sites in southern Africa. Endangered Wildlife Trust and Birdlife South Africa.*

The monitoring was conducted by three field monitors.

Monitoring was conducted in the following manner:

- Drive transects totalling 24.3km were identified (11.5km on the Phase 2 site and 12.8km on the Phase 3 site) within the proposed turbine area, and one drive transect in the control site with a total length of 7km.
- Two observers travelling slowly (± 10km/h) in a vehicle records all priority species on both sides of the transect. The observers stop at regular intervals (every 500 m) to scan the environment with binoculars. Transects were counted three times per seasonal sampling session.
- In addition, four walk transects of 1km were identified (two at phase 2 and two at phase 3), and one at the control site. All birds were recorded during walk transects, not only priority species.
- The following variables were recorded:
    - Species;
    - Number of birds;
    - Date;
    - Start time and end time;
    - Distance from transect (0-50 m, 50-100 m, >100 m);
    - Wind direction;
    - Wind strength (calm; moderate; strong);
    - Weather (sunny; cloudy; partly cloudy; rain; mist);
    - Temperature (cold; mild; warm; hot);
    - Behaviour (flushed; flying-display; perched; perched-calling; perched-hunting; flying-foraging; flying-commute; foraging on the ground); and

- Co-ordinates (priority species only).

- Six vantage points (VPs) were selected (three on the Phase 2 site and three on the Phase 3 site) from which the majority of the proposed turbine area could be observed (the "VP area"), to record the flight altitude and patterns of priority species. The following variables were recorded:
    - Species;
    - Number of birds;
    - Date;
    - Start time and end time;
    - Wind direction;
    - Wind strength (estimated Beaufort scale 1-7);
    - Weather (sunny; cloudy; partly cloudy; rain; mist);
    - Temperature (cold; mild; warm; hot);
    - Flight altitude (high i.e. >150 m; medium i.e. 50-150 m; low i.e. <50 m);
    - Flight mode (soar; flap; glide ; kite; hover); and
    - Flight duration (in 15 second-intervals).

The aim with drive transects was primarily to record large priority species (i.e. raptors and large terrestrial species), while walk transects were primarily aimed at recording small passerines. The objective of the transect monitoring was to gather baseline data on the use of the site by birds in order to measure potential displacement by the wind farm activities. The objective of vantage point counts was to measure the potential collision risk with the turbines.

On 01 July 2013, a new proposed lay-out for Phase 3 was communicated to the authors by Mainstream, which substantially reduced the turbine area for phase 3. This resulted in the walk transects that had been surveyed to date now falling somewhat outside the proposed turbine area. However, due to the uniformity of the habitat, this should not materially affect the accuracy of the outcomes, as the same suite of species is expected to occur in areas immediately adjacent to the turbine area.

Figure 1 shows the location of the VPs, transects and proposed turbine lay-out. Figure 2 shows the location of the control site.

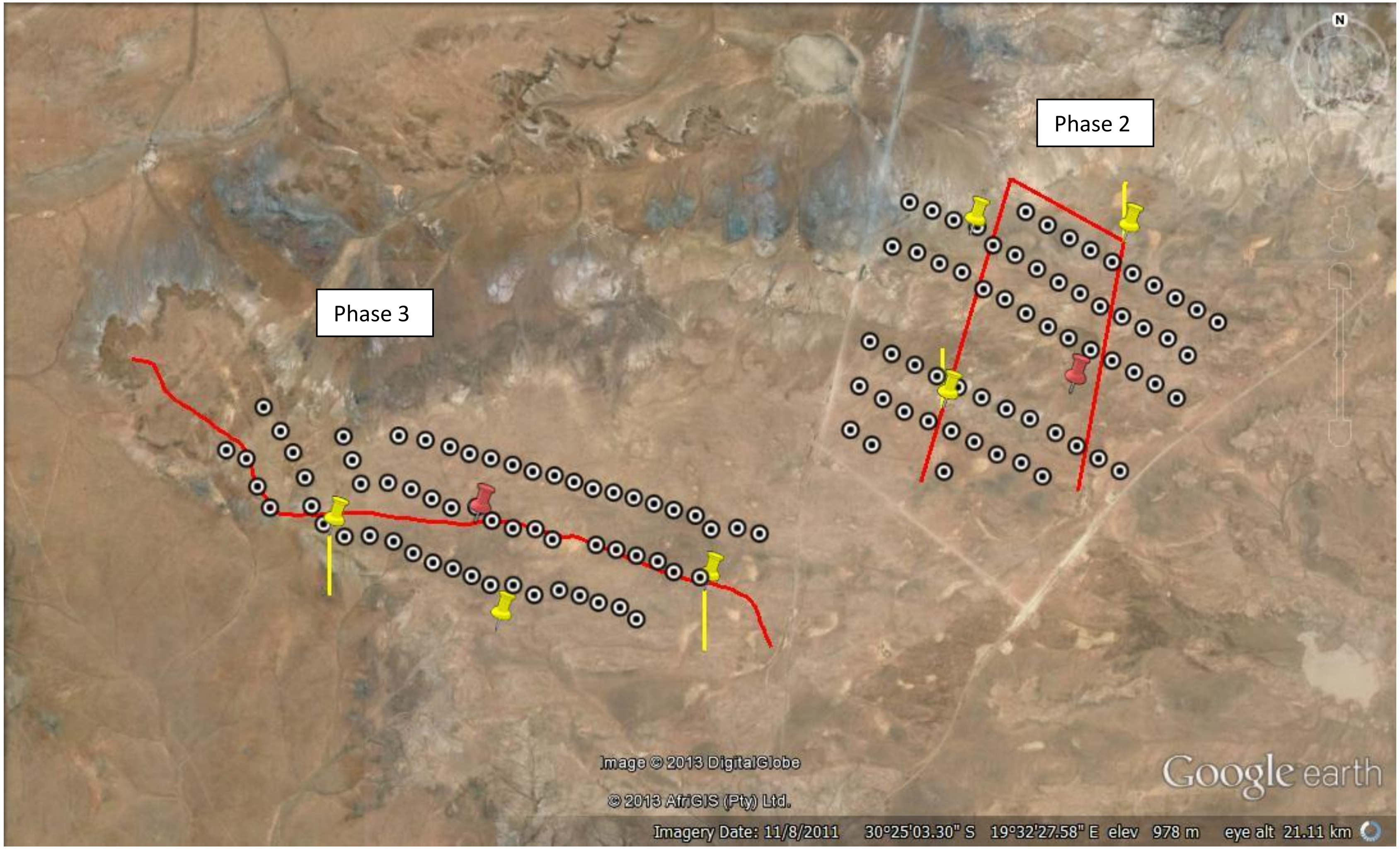

Figure 1: Loeriesfontein phase 2 and 3 turbine site indicating the turbine site drive transects (red line), turbine vantage points (VPs) (yellow placemarks), walk transects (yellow lines), turbine positions (circles) and focal points (red placemarks).

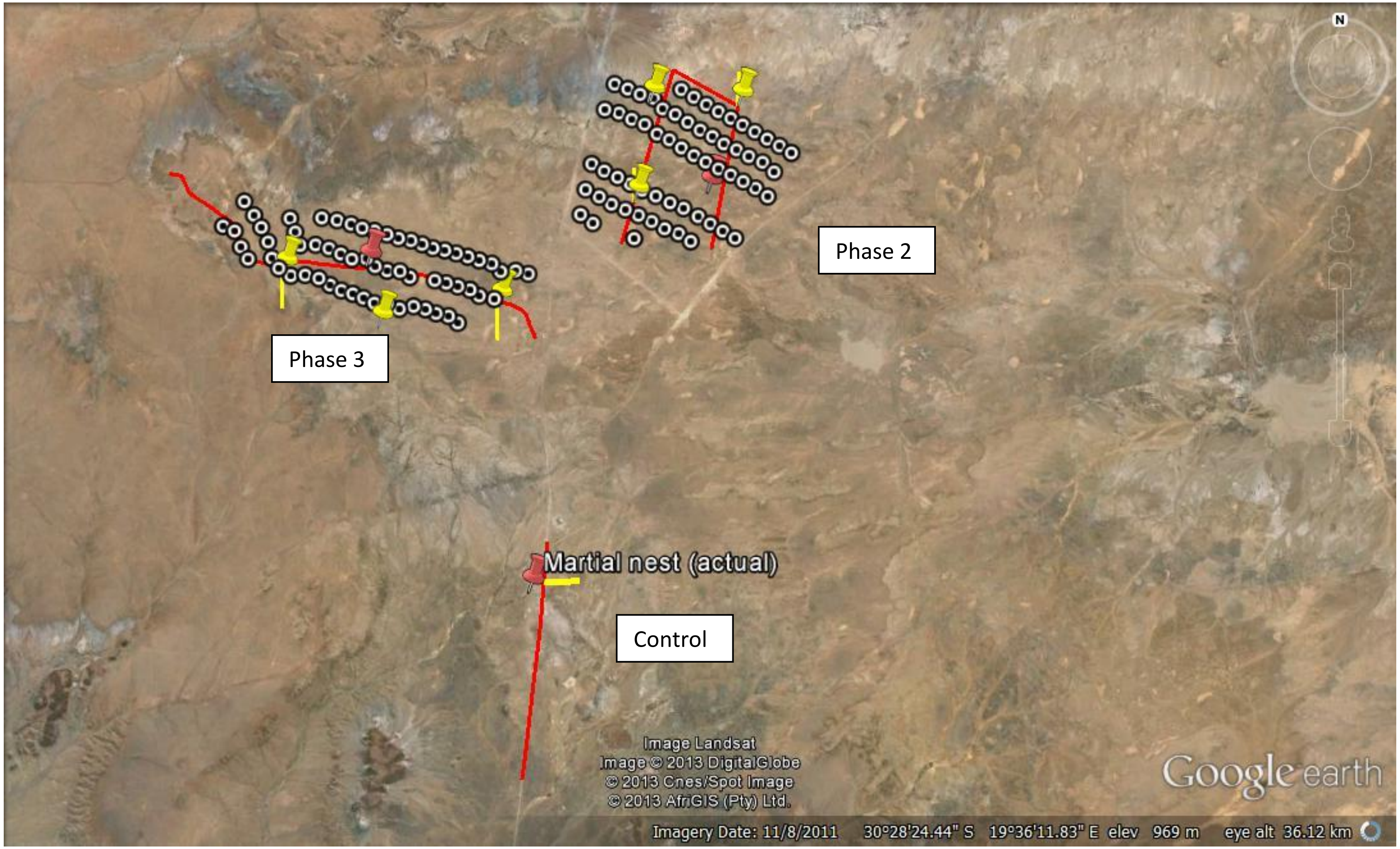

Figure 2: Loeriesfontein site indicating the location of the control drive transect (red line), control walk transect (yellow line) and focal point (red placemark).

4.2 Focal point counts

Two water reservoirs providing permanent water (30°24'46.29"S 19°36'19.76"E and 30°25'56.06"S 19°30'7.04"E) were identified as focal points for bird activity, as permanent water always acts as a draw card for birds in arid areas. A Martial Eagle nest (30°31'3.24"S 19°33'3.81"E) on a transmission line at the control site was also identified as a focal point and monitored. Focal points were surveyed once during each sampling season.

Figures 1 and 2 indicate the position of the focal points.

4.3 Habitat classification

The habitat at both the turbine site and the control site is very uniform, and consists of Bushmanland Basin Shrubland (Mucina & Rutherford 2006). Bushmanland Basin Shrubland consists of dwarf shrubland dominated by a mixture of low, sturdy and spiny (and sometimes also succulent) shrubs (*Rhigozum, Salsola, Pentzia, Eriocephalus*), 'white' grasses (Stipagrostis) and in years of high rainfall also abundant annual flowering plants such as species of *Gazania* and *Leysera*. The study area is extremely arid with a mean annual rainfall of 220mm over the past 11 years, with peak rainfall between April and August (South African Weather Service 2013). The proposed wind farm site is situated in an ecological transitional zone between the Nama Karoo and Succulent Karoo biomes (Harrison *et al*. 1997). In comparison with Succulent Karoo, the Nama Karoo has higher proportions of grass and tree cover. The ecotonal nature of the study area is apparent from the presence of typical avifauna of both Succulent and Nama Karoo at the wind farm site e.g. Karoo Eremomela *Eremomela gregalis* and Red Lark *Calendulauda burra*.

An important feature of the arid landscape where the proposed site is located is the presence of pans. Pans are endorheic wetlands having closed drainage systems; water usually flows in from small catchments but with no outflow from the pan basins themselves. They are typical of poorly drained, relatively flat and dry regions. Water loss is mainly through evaporation, sometimes resulting in saline conditions, especially in the most arid regions. Water depth is shallow (<3m), and flooding characteristically ephemeral (Harrison *et al*. 1997). Although the site itself does not contain any significant pans, there is a pan situated approximately 2.5km in a north-westerly direction from the nearest turbine position (see Figure 3 below). When this pans holds water (which is only likely after exceptional rainfall events), waterbird movement to and fro from the pan is possible, including Greater Flamingo *Phoenicopterus roseus* and Lesser Flamingo *Phoenicopterus minor*. Some of that movement might take place over the proposed wind farm site.

Figure 3: The location of a pan relative to the turbine site.

5. Results

5.1 Transects, incidental sightings and focal point surveys

5.1.1 Transects, point counts and incidental sightings

The study area was surveyed 12 times, three times per season. A total of 1 868 birds were recorded at the turbine site, of which 419 were priority species and 1 449 non-priority species, belonging to 35 species (8 priority species and 27 non-priority species). At the control site, a total of 274 birds were recorded, of which 77 were priority species and 197 non-priority species, belonging to 25 species (8 priority species and 17 non-priority species). Five priority species were recorded as incidental sightings, and 9 priority species during vantage point counts (see Table 1 for a consolidated list of priority species from all survey sources, and Appendix 1 for a consolidated list of all species recorded).

An Index of Kilometric Abundance (IKA = birds/km) was calculated for each priority species, and also for all priority species combined. This was done separately for drive transects and walk transects (see Figures 4 and 5 below).

Table 1: Consolidated list of priority species recorded at the turbine and control site from all data sources

Species	Scientific name	Transects		Focal points		Vantage points	Incidental sightings
		Turbine	Control	Turbine	Control	Turbine	Turbine
Martial Eagle	*Polemaetus bellicosus*		x		x		
Sclater's Lark	*Spizocorys sclateri*	x		x		x	
Ludwig's Bustard	*Neotis ludwigii*	x	x	x		x	x
Southern Pale Chanting Goshawk	*Melierax canorus*	x	x	x		x	x
Greater Kestrel	*Falco rupicoloides*	x	x	x		x	x
Spotted Eagle-Owl	*Bubo africanus*					x	
Red Lark	*Calendulauda burra*	x				x	x
Karoo Korhaan	*Eupodotis vigorsii*	x	x			x	x
Lanner Falcon	*Falco biarmicus*	x	x	x			
Black-chested Snake-Eagle	*Circaetus pectoralis*		x				
Jackal Buzzard	*Buteo rufofuscus*			x		x	
Kori Bustard	*Ardeotis kori*		x				
Northern Black Korhaan	*Afrotis afraoides*	x					

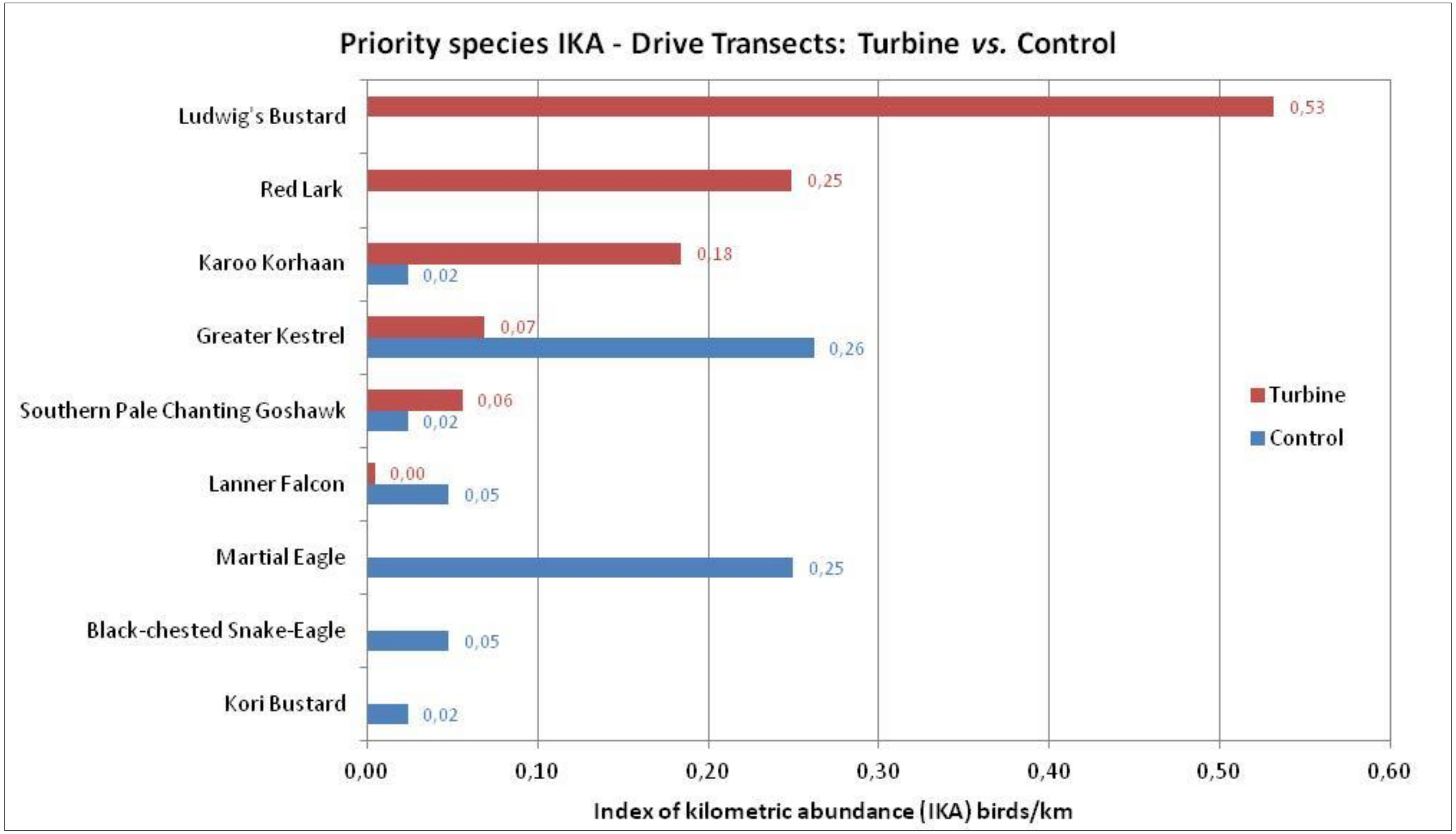

Figure 4: Priority species recorded at the turbine and control site through drive transect surveys

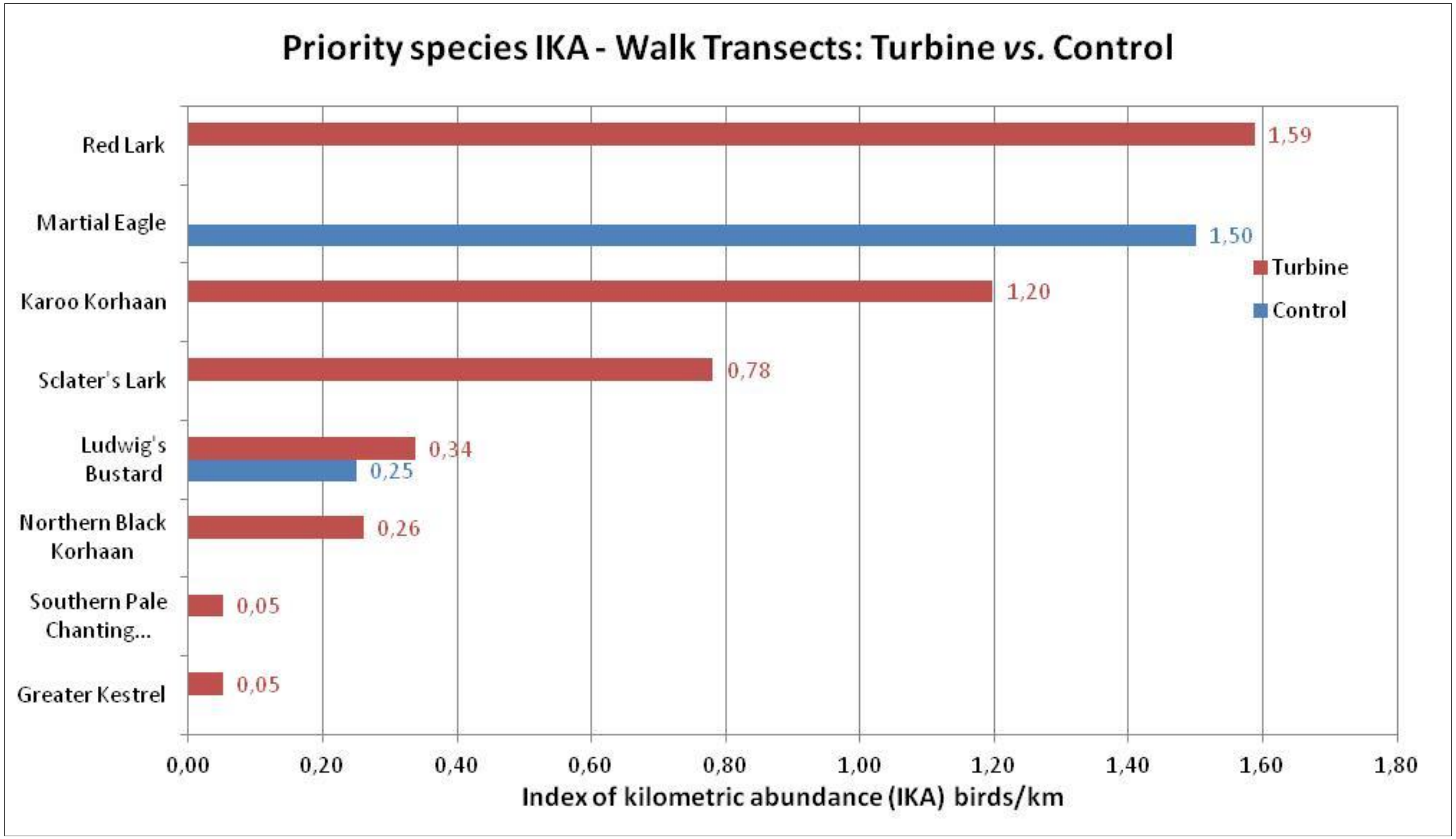

Figure 5: Priority species recorded at the turbine and control site through walk transect surveys

The spatial distribution of recorded priority species is indicated in Figures 6-8 below.

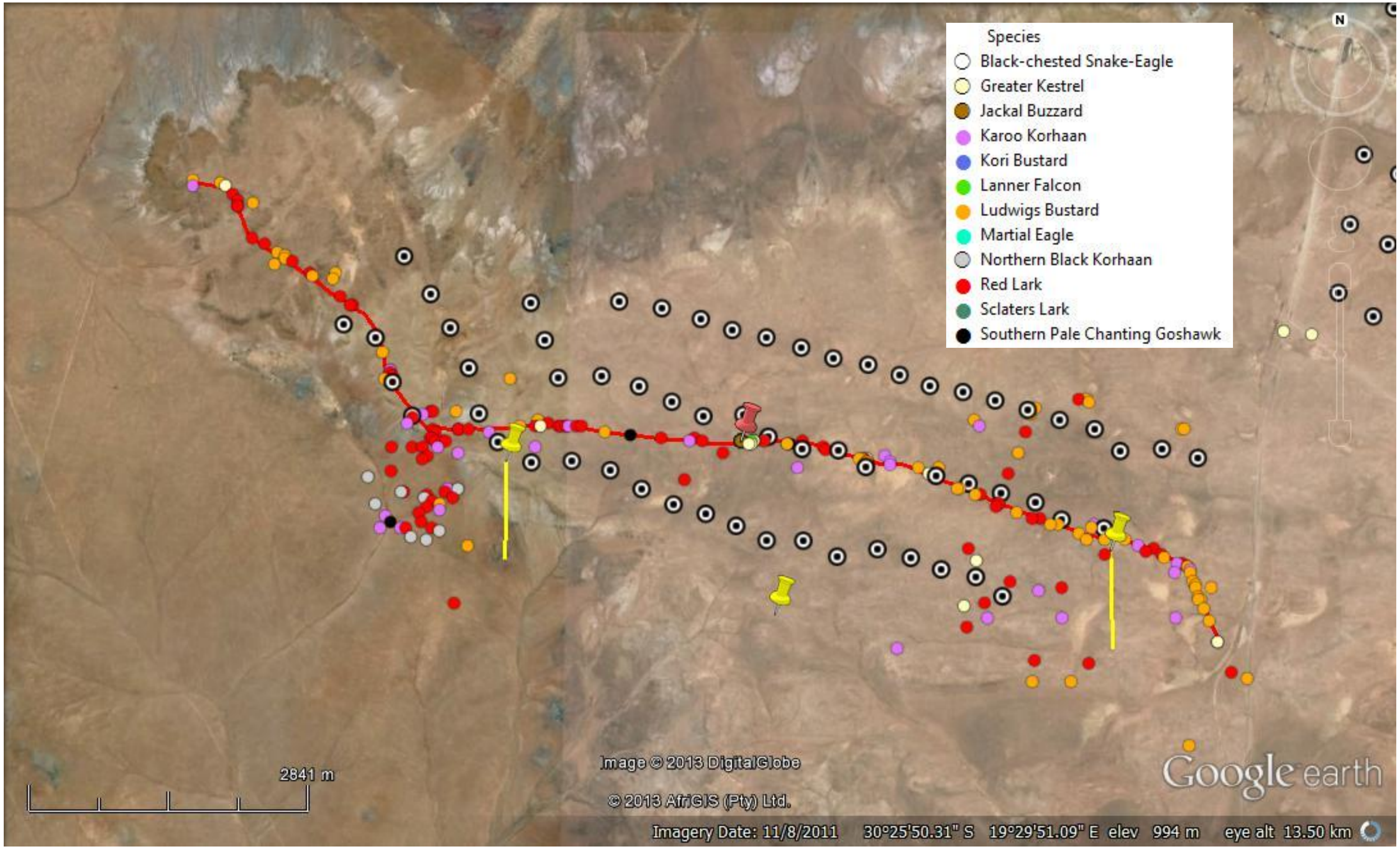

Figure 6: Spatial distribution of sightings of priority species at the phase 3 turbine site (includes incidental sightings).

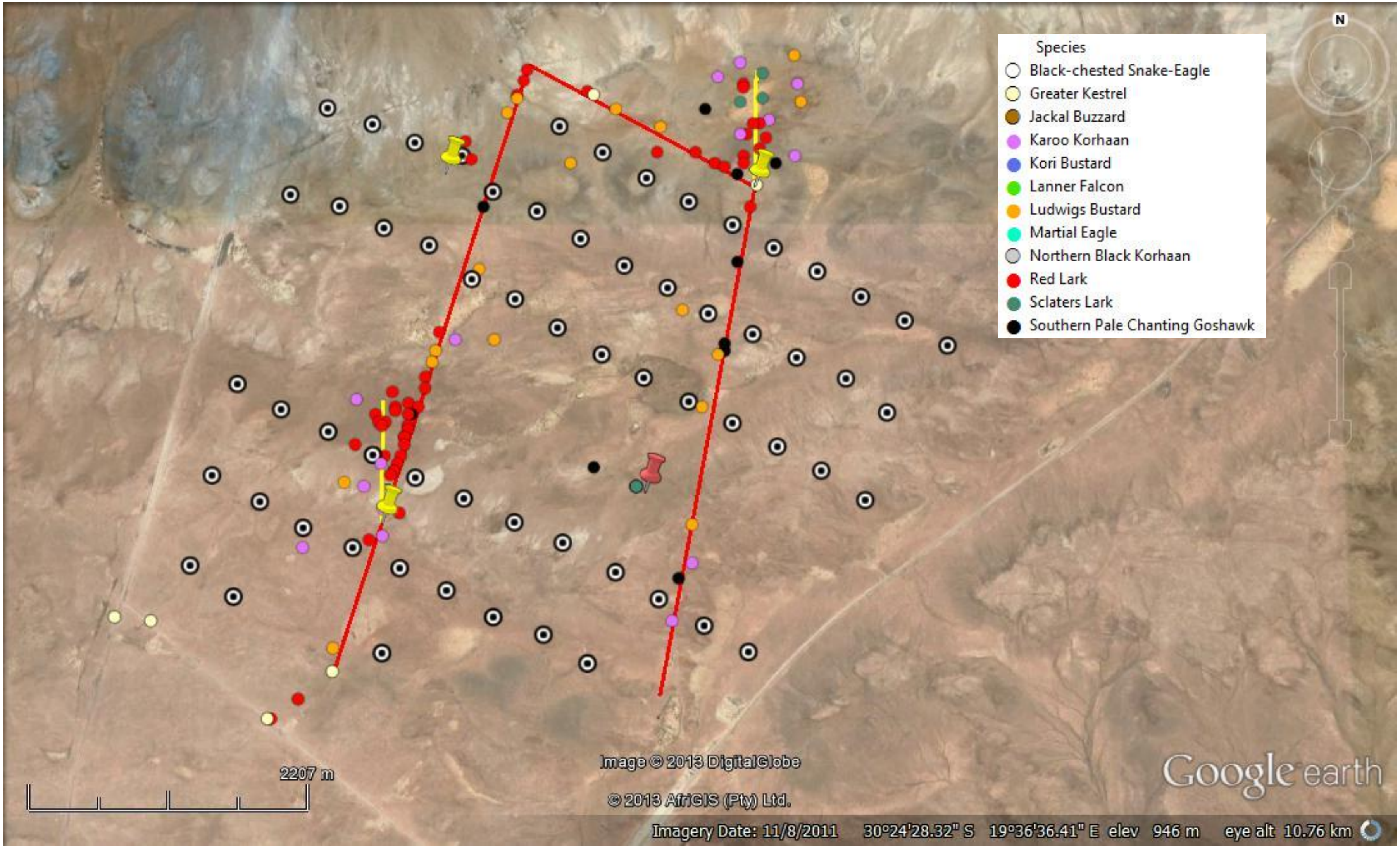

Figure 7: Spatial distribution of sightings of priority species at the phase 2 turbine site (includes incidental sightings).

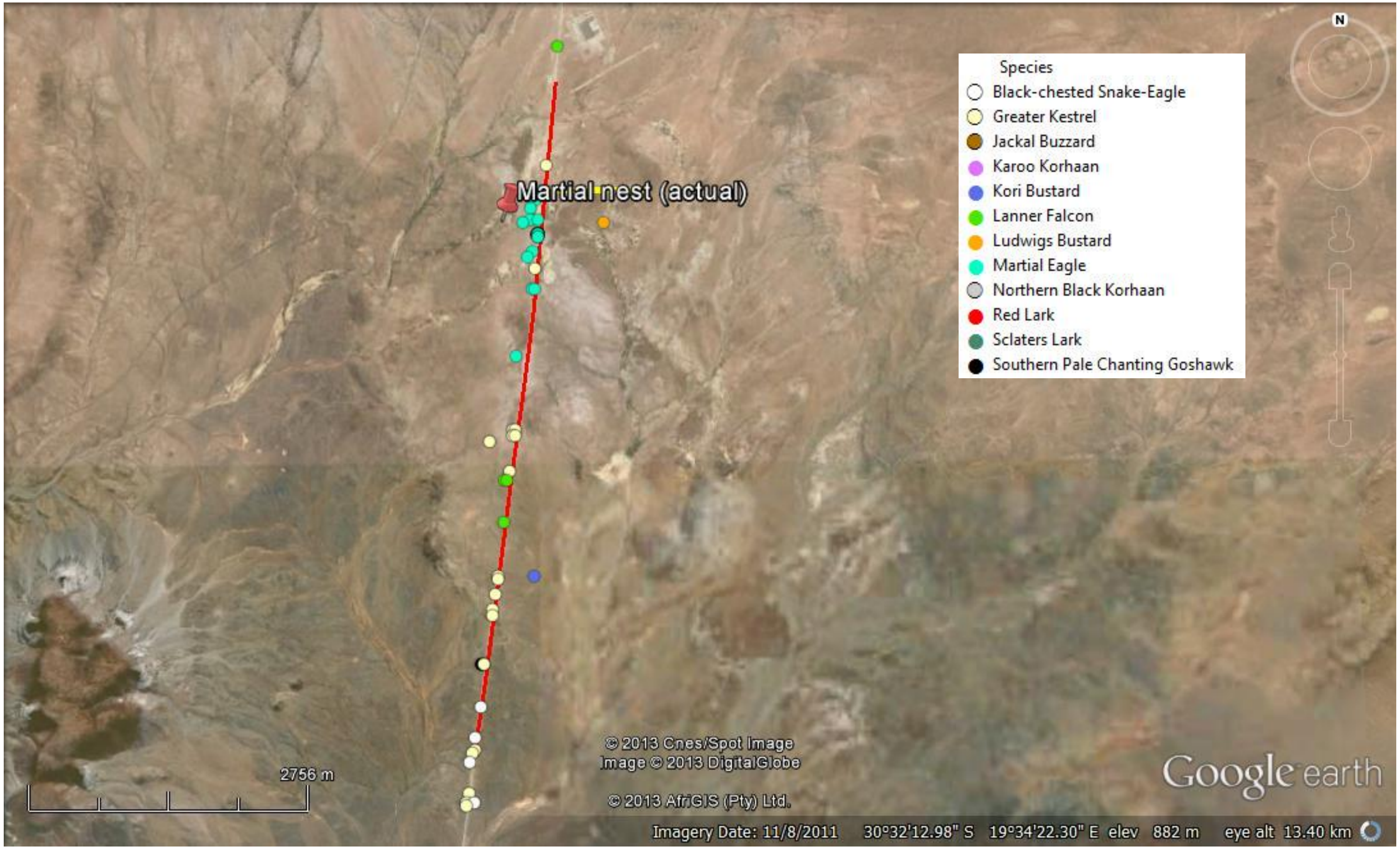

Figure 8: Spatial distribution of sightings of priority species at the control site (includes incidental sightings).

5.1.2 *Focal points*

A total of 40 hours were spent surveying the focal points (water reservoirs) at the turbine site over four seasons. Priority species that were recorded at the focal points are Lanner Falcon, Greater Kestrel, Jackal Buzzard, Southern Pale Chanting Goshawk and Sclater's Lark. Ludwig's Bustard were recorded flying in the vicinity of the focal points. The Martial Eagle nest at the control site was surveyed for a total of 25 hours over four seasons. One adult was recorded perching around and on the nest in September 2012. In December 2012 a juvenile eagle (probably the 2012 chick) was recorded several times perching on the transmission tower where the nest is situated. In April 2013 the female was recorded sitting on the nest continuously. In June 2013 the female was recorded feeding a small chick. In September 2013, the recently fledged juvenile eagle was recorded in the vicinity of the nest together with both adults, indicating that they have bred successfully. It would seem therefore that the pair bred successfully in 2012 and 2013.

5.2 Vantage point observations

Nine priority species were recorded during VP watches. A total of 288 hours of vantage point watches (12 hours per season per vantage point) was completed in order to record flight patterns of priority species at the site. In the four seasonal sampling periods, priority species were recorded flying over the VP area for a total of 2 hours, 30 minutes and 15 seconds. A total of 193 individual flights were recorded. Of these, 23 (11.91%) flights were at high altitude (above rotor height), 50 (25.9%) were at medium altitude (i.e. approximately within rotor height) and 120 (62.17%) were at a low altitude (below rotor height). The passage rate for priority species over the VP area (all flight heights) was 0.57 birds/hour[1]. See Figure 9 below for the duration of flights within the VP area for each species, at each height class[2].

For purposes of flight analyses, priority species recorded during VP watches at the site were classified in two classes:

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[1] For calculating the passage rate, a distinction was drawn between passages and flights. A passage may consist of several flights e.g. every time a bird changes height or mode of flight; this was recorded as an individual flight, although it still forms part of the same passage.

[2] Flight duration was calculated by multiplying the flight time with the number of individuals in the flight e.g. if the flight time was 30 seconds and it contained two individuals, the flight duration was 30 seconds x 2 = 60 seconds.

- Terrestrial species: Birds that spend most of the time foraging on the ground. They do not fly often and then generally short distances at low to medium altitude, usually powered flight. Some larger species undertake longer distance flights at higher altitudes, when commuting between foraging and roosting areas. At the wind farm site, korhaans, bustards and larks were included in this category. Although not a terrestrial species, in this instance, Spotted Eagle-Owl was also included in this category as the usual manner of flight closely resembles a terrestrial species.
- Soaring species: Species that spend a significant time on the wing in a variety of flight modes including soaring, kiting, hovering and gliding at medium to high altitudes. At the wind farm site, the raptor species (except owls) that were recorded during VP watches were included in this class.

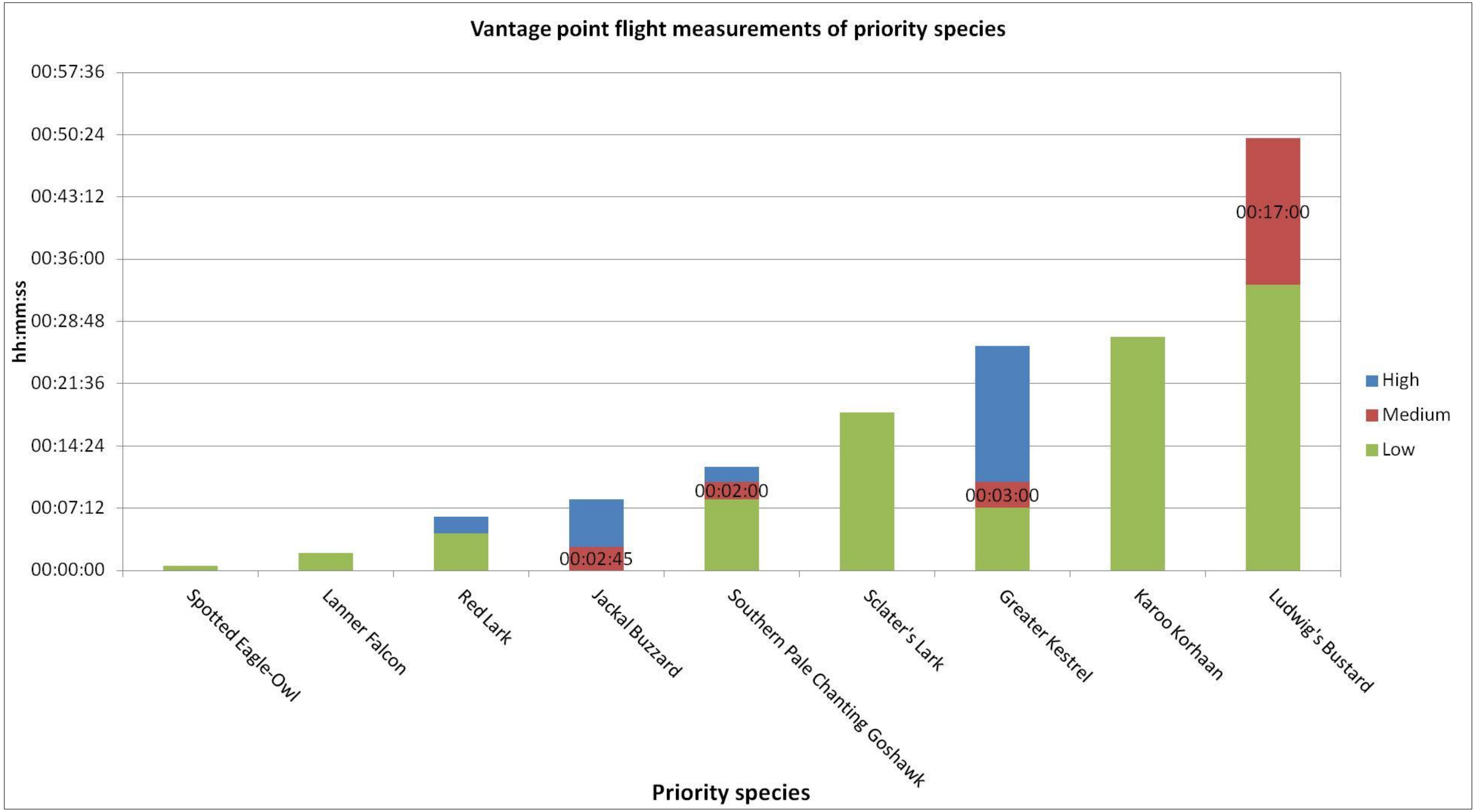

Figure 9: Flight duration and heights recorded for priority species (Y axis = hours: minutes: seconds). Duration (hours: minutes: seconds) of medium height flights indicated on the red section of the bars.

5.2.1 Site specific collision risk rating

A site specific collisions risk rating for each priority species recorded during VP watches was calculated to give an indication of the likelihood of an individual of the specific species to collide with the turbines at this site. This was calculated taking into account the following factors:

- The duration of medium height flights;
- the susceptibility to collisions, based on morphology (size) and behaviour (soaring, predatory, ranging behaviour, flocking behaviour, night flying, aerial display and habitat preference) using the ratings for priority species in the Avian Wind Farm Sensitivity Map of South Africa (Retief *et al*. 2012); and
- the number of planned turbines.

This was done in order to gain some understanding of which species are likely to be most at risk of collision. The formula used is as follows[3]:

Duration of medium height flights in decimal hours x collision susceptibility calculated as the sum of morphology and behaviour ratings x number of planned turbines ÷100.

The results are displayed in Table 3 and Figure 10 below.

[3] It is important to note that the formula does not incorporate avoidance behaviour. This may differ between species and may have a significant impact on the size of the risk associated with a specific species. It is generally assumed that 95-98% of birds will successfully avoid the turbines (SNH 2010).

Table 3: Site specific collision risk rating for all priority species recorded during VP watches.

Species	Duration of flights (hour)	Collision rating	# turbines	Risk rating
Lanner Falcon	0.00	85.00	123	0.00
Spotted Eagle-Owl	0.00	55.00	123	0.00
Sclater's Lark	0.00	45.00	123	0.00
Red Lark	0.00	35.00	123	0.00
Karoo Korhaan	0.00	60.00	123	0.00
Southern Pale Chanting Goshawk	0.03	65.00	123	2.67
Jackal Buzzard	0.05	95.00	123	5.36
Greater Kestrel	0.25	52.00	123	15.99
Ludwig's Bustard	0.81	80.00	123	79.95
Average	*0.13*	*63.56*	*123*	*9.92*

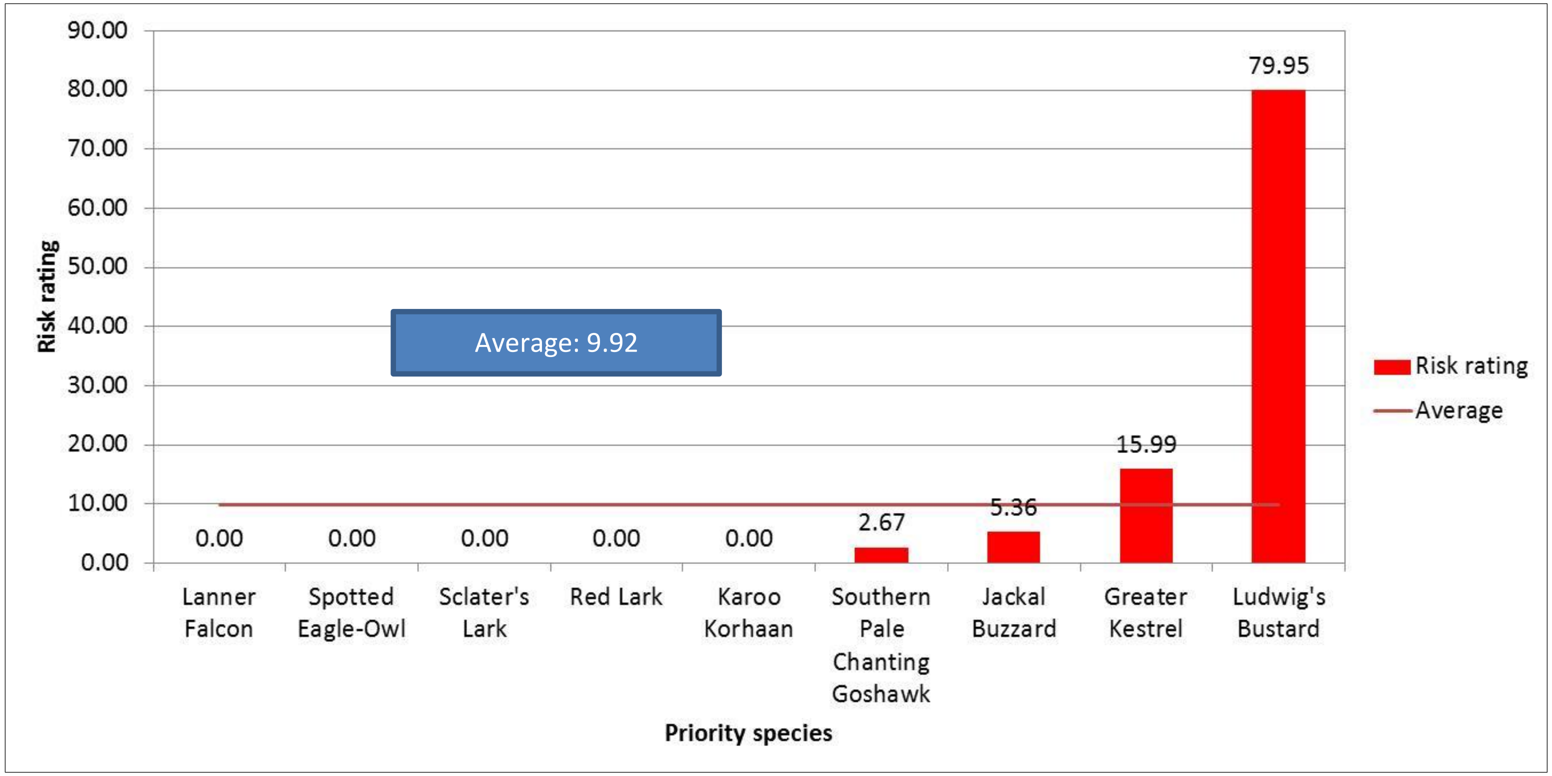

Figure 10: Site specific collision risk rating for priority species.

5.2.2 Collision risk modelling

In order to arrive at an estimate of collision mortality for priority species per year, an elementary collision risk model (CRM) was designed and applied to the data gathered during the VP watches. CMRs are not very accurate because of the many assumptions that need to be built into the models. Furthermore, to arrive at accurate estimates; large datasets are required which means that the monitoring effort often falls short of the required standard. However, despite these shortcomings, it can be useful to attempt to quantify the mortality, provided the very real shortcomings are kept in mind in the interpretation of the results. This is especially so if statistical analysis of the flight data finds that the sample size is adequate and representative of actual flight behaviour in the survey area (see 5.2.3 below).

In order to calculate to number of estimated mortalities for the total VP watch period (*mT*), the following formula was applied:

mT = [n x r x a x(d÷T)]

- *n* = number of individual birds recorded during the total VP observation time at rotor height.
- *r* = the percentage that the potential lethal area (PLA) comprises of the total VP survey area. The total region in the survey area that carries potential risk to birds entering it (the potential risk area, PRA) is assumed to be the cylindrical aerial space enclosing the survey area of every VP at the height of the rotors, starting at the rotor's lower point from ground level and extending vertically to its highest point. Thus the height of this vertical cylinder is the diameter of the rotor blade circle (h = 108m) and its diameter is taken to be a suitable distance covering the survey area of any VP. It is taken to be d = 4km in this case. The volume of the aerial space in the survey area that carries potential risk is thus $\frac{1}{4}\pi d^2 h$ = 1.3572 km^3. Since there are six VPs this volume is multiplied by six to PRA = 8.1432 km^3. The PLA is assumed to be the aerial volume where a bird could potentially collide with a rotor, and is assumed to be a sphere with a diameter of 108m around the rotor (PLA = 0.000659584 km^3). This is multiplied by the number of turbines in the total VP survey area (93 turbines[4]), which comes to 0.0613335 km^3. The PLA as a percentage of the PRA is r = 0.75%.
- *a* = estimated avoidance rate which takes account of the fact that many birds may either avoid the wind farm entirely as a consequence of being displaced (changes in the habitat or prey base, the presence of turbines and associated activities, or other factors may dissuade birds from using the area), or fly high or low so that their flight does not pass through the turbines, or perform 'emergency' manoeuvres to avoid a moving turbine blade. Avoidance rates are expressed as a percentage, e.g. 98% means that 98%

[4] The total VP area encompassed 93 of the 123 turbines (76% of the turbines)

of birds are expected to avoid the turbine(s), or conversely, only 2% is expected to collide with the turbines. The result is used to estimate the number of collisions, either on a yearly basis, or over the lifetime of the wind farm. Unfortunately avoidance rates for priority species in South Africa have not been reliably established. It was therefore decided to use the default of 98% recommended by the Scottish Natural Heritage (SNH 2010).

- *d* = flight duration i.e. the total time that these individual birds were present at rotor height in the VP survey area. Flight duration was calculated by multiplying the flight time with the number of individuals in the flight e.g. if the flight time was 30 seconds and it contained two individuals, the flight duration was 30 seconds x 2 = 60 seconds. Flight duration is expressed in decimal hours e.g. 60 seconds = 0.016 decimal hours.
- *T* = total VP observation time

In order to calculate the estimated turbine operating hours per year (*O*) the following formula was used:

O = [(24 x 365) x c]

- *c* = capacity factor i.e. the percentage of time which a wind turbine is expected to be operating

In order to calculate the number of daylight turbine operating hours per year (*Oo*), assuming that the birds only fly during daylight hours, the following formula was used:

Oo = O x (h÷24)

- *h = the average daylight hours per day over a period of a year:* The actual daylight hours per day for Loeriesfontein at gps location 30°27'15.11"S / 19°34'42.17"E was computed by Professor Niko Sauer (University of Pretoria, personal communication) as 12.10398 decimal hours per day.

The estimated mortality per year (mA) was calculated as follows:

mA = [(mT ÷T) x Oo] x f

- *f = Correction factor for estimated observer bias:* It is inevitable that flights that are closer to the observer will be recorded more easily than those far from the observer. To compensate for this, the calculated mortality/year was multiplied with a correction factor to address this bias. For purposes of the calculation, it was estimated that 100% of flights of large birds (e.g. eagles and bustards) were recorded within a 2km radius around the VP, therefore a correction factor of 1 was applied in these instances. For medium sized birds, such as Greater Kestrel and Southern Pale Chanting Goshawk, it was assumed that 100% of flights within a 1km radius around the VP was recorded, which necessitates a correction factor of 4, as the volume of sky in a VP area with a 1 km radius is only 25% of the volume of a VP area with a 2km radius. For small birds (larks) it was assumed that all flights within a 300m radius around the VP was recorded, which necessitates a correction factor of 50 as the volume of sky in a VP area with a 300m radius is only 2% of the volume of a VP area with a 2km radius.

The following assumptions were made which also affects the accuracy of the predicted collision rates:

- The flights are randomly distributed across the VP area;
- A bird will always be killed if it enters a potentially lethal zone;
- Environmental conditions (i.e. bird flight activity) will remain broadly similar each year.

Table 4 below gives the estimated annual mortality rates arrived at for priority species recorded at medium height over the VP areas, using the above CRM:

Table 4: Estimated annual mortality rates for all priority species recorded during VP watches.

Priority species	Estimated mortality rate
Southern Pale Chanting Goshawk	<1 birds/year
Jackal Buzzard	<1 birds/year
Greater Kestrel	<1 birds/year
Ludwig's Bustard	<1 birds/year
All priority species	<1 birds/year

It must again be stressed that these estimates are at best crude, and should only be taken as broad indicators, given the many assumptions built into the calculations.

5.2.3 Sample size and representativeness of flight data

Fifty-three flights and 65 individual soaring birds were counted during the 144 watch periods, leading to an estimated average of 0.37 ± 0.24 flights and 0.45 ± 0.31 individuals (approximately 95% confidence) per 2 hour watch period respectively. Sixty-nine flights and 128 individual terrestrial birds were counted during the 144 watch periods, leading to estimated averages of 0.48 ± 0.15 for flights and 0.89 ± 0.31 for individuals (approximately 95% confidence) per 2h watch period. The overall variability over all seasons (standard deviation over all survey periods) for both soarers and terrestrials varies between 0.9 and 1.9. The question that requires investigation from a statistical viewpoint is the extent to which the data obtained are representative of the actual flight activity of priority species during VP watches, which in turn affects the reliability of the estimated annual collision rate (see 5.2.2 above).

The standard deviations are a measure of the variability that exists in the counts observed. The variability of the counts is visualised for individual counts in Figures 11 (soaring individuals) and 12 (terrestrial individuals).

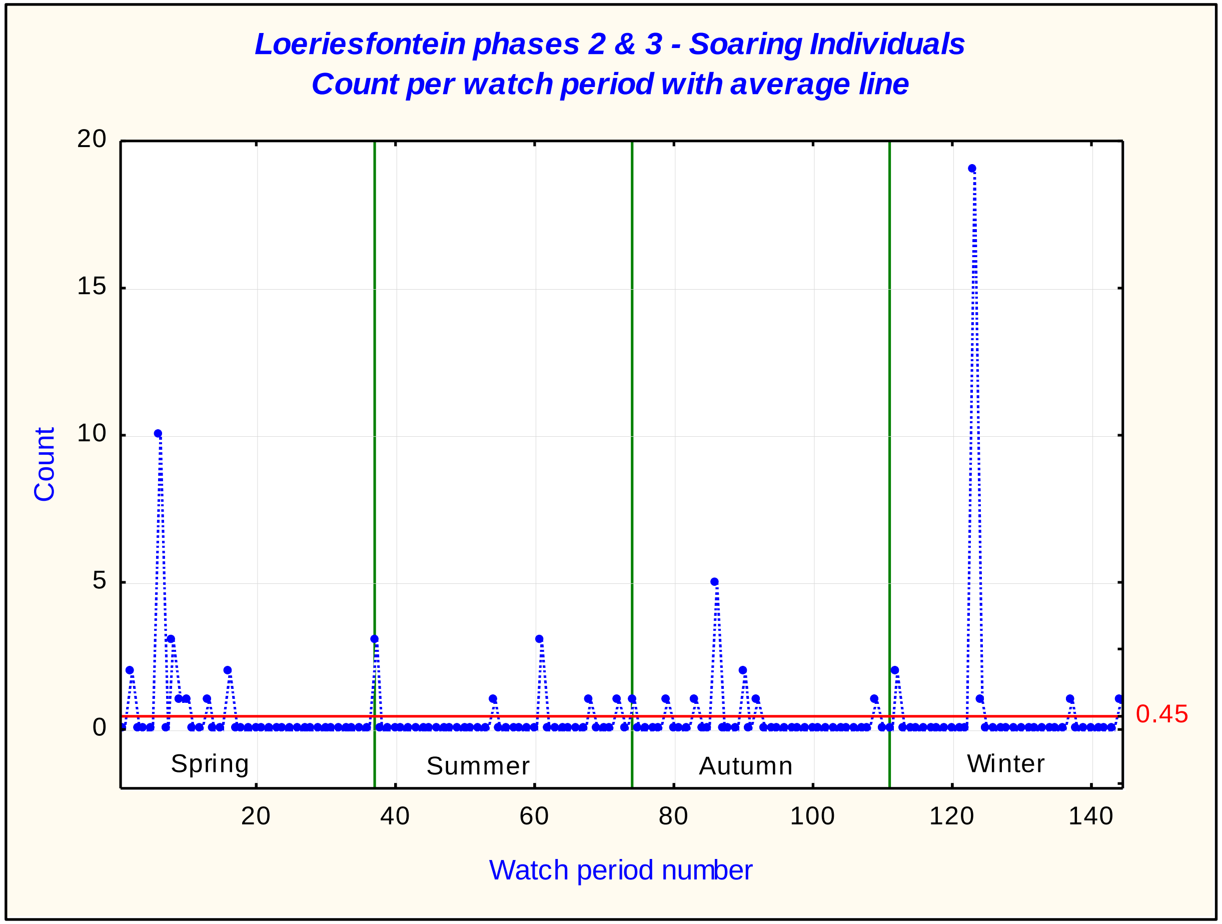

Figure 11: Soaring birds: sequential time plot of individual soaring bird counts.

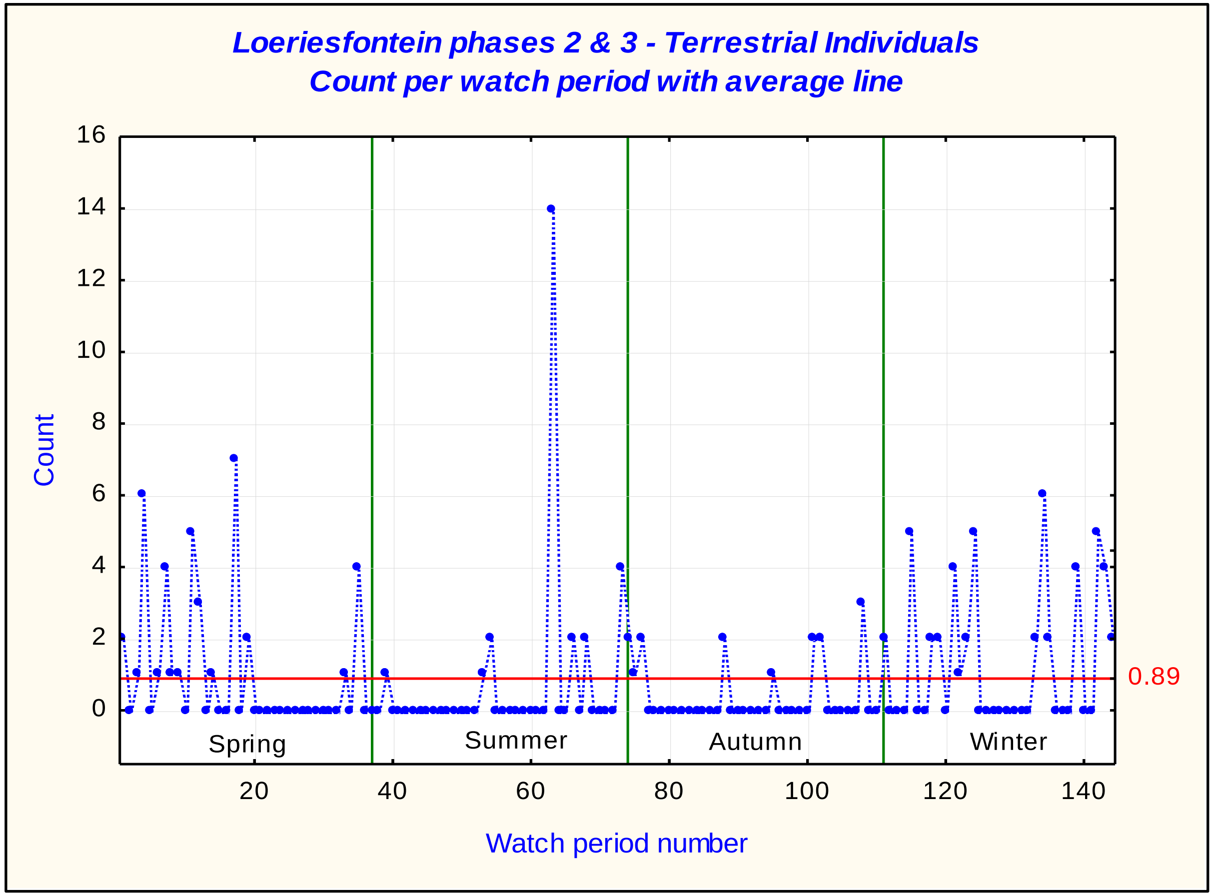

Figure 12: Terrestrial birds: sequential time plot of individual terrestrial bird counts.

As may be seen from Figures 11 and 12 many consecutive watch periods existed where no birds were observed. Thus, judging if the observations gathered are representative and a true reflection of the actual number of birds in the survey area, require some further investigation.

The question is: how many watch periods (*n*) must be sampled in order to be 95% certain of obtaining an estimate of the mean that is within a precision of "*d*" units (counts) from the true mean value, i.e. to say with 95% certainty that the true mean count per observation period lies in an interval of $\bar{x} \pm d$ where $\bar{x}$ is the sample estimate of the true mean value. Due to the relatively small number of birds observed it is suggested that the average number of birds in this survey should be estimated to within a value of *±0.5* per *2* hour watch period (i.e. *d = 0.5*). As is to be expected, the smaller *d* (i.e. the higher the precision) the larger the sample size must be.

A practical approximation to an appropriate sample size for that purpose may be obtained from the formula:

(*1*) $$n = (s * t_{\alpha/2}(n-1) / d)^2 ,$$

Where $t_{\alpha/2}(n-1)$ is the upper $\alpha/2$ = 2.5% point of Student's t distribution with $n - 1$ degrees of freedom and s is an estimate of the true standard deviation of the counts (see Zar, 2010, page 115).

As already mentioned a standard deviation estimated at about s ≈ 2 seems to be somewhat conservative. If this is accepted as reasonable, together with *d = 0.5*, the solution of equation (1) is *n ≈ 64*. It is thus believed that the available sample size of *n = 144* obtained over all four seasons is sufficient to provide reasonable estimates of the overall mean values with an approximate 95% precision. It has to be realised that these computations are based on certain assumptions (e.g. normality of the counts distribution) that are probably not met. However, it at least provides some indication.

The data may also be used to gain further insight into the representativeness and stability of the counting process. As the data are gathered watch period by watch period an improved estimate of the average number of birds that occurs in the area will be achieved. As more data are gathered the more accurate the estimate will become. The issue is to determine if the updated average count begins to stabilise towards the end (or even perhaps before the end) of the survey (and thus the conclusion that a representative sample has been achieved).

To achieve this, the average number of flights (as well as individual birds) is computed from all preceding data as the data become available in consecutive watch periods (and day after day). This updated average is expected to vary to a large extent in the initial stages of sampling and to stabilise as it is based on more data. Since the counts vary (in principle) substantially over the seasons (especially for individual counts) the updated averages are determined separately for each season.

Figure 13 plots these updated averages for soaring birds (the number of flights as well as a count of the total number of individual birds). Figure 14 does the same for terrestrial birds. If the graph consists of a single (red) line it means that the number of flights and individual counts are the same.

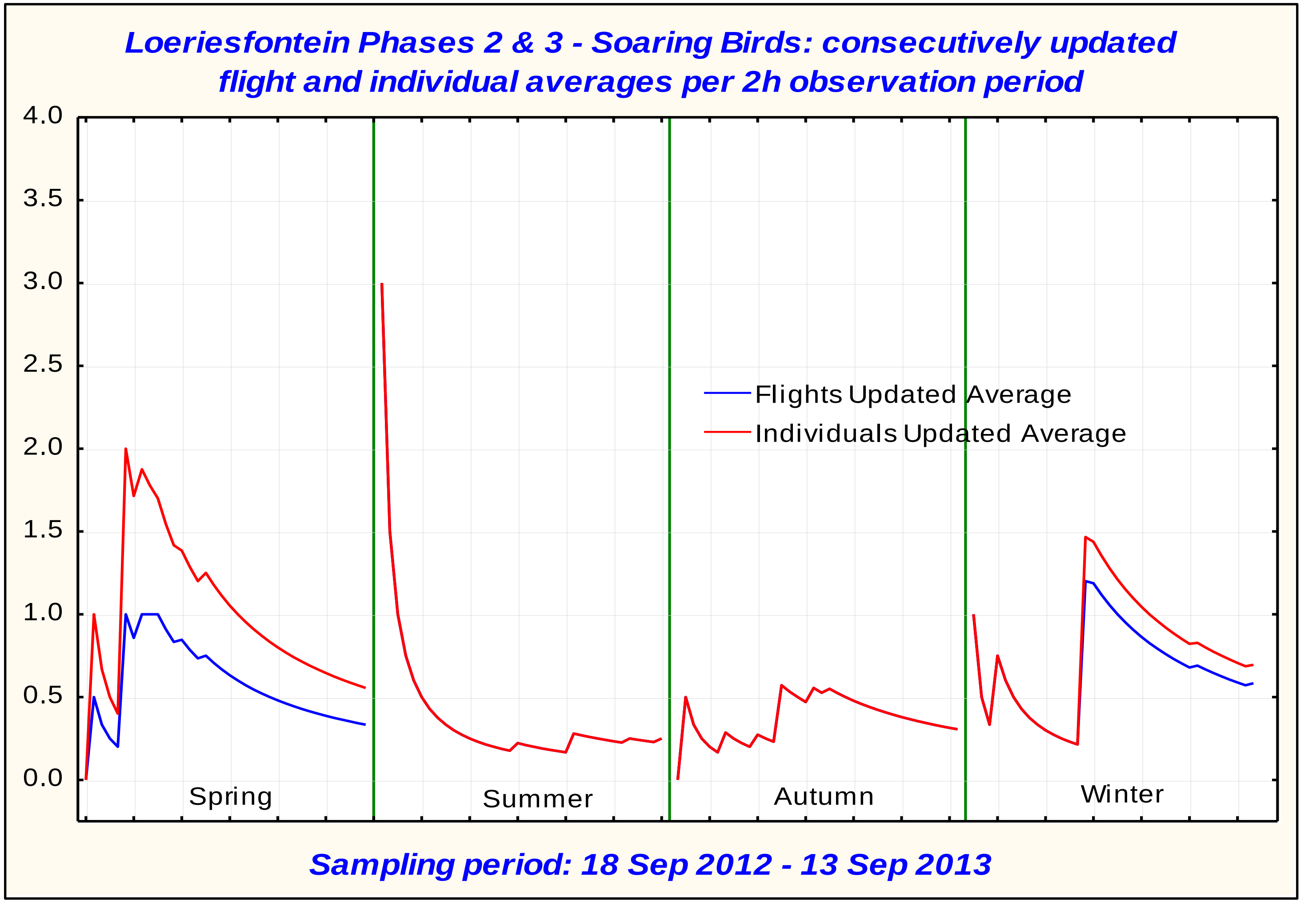

Figure 13: Soaring birds: updated average for *Flight* and *Individual* counts.

Figure 14 shows that the only differences in the counts between flights and individuals for soaring bird counts were seen in spring and in winter. The day to day updated averages have stabilised well for both flights and for individuals. Further sampling is not believed to improve the overall estimates of the averages for soaring birds in a substantial way.

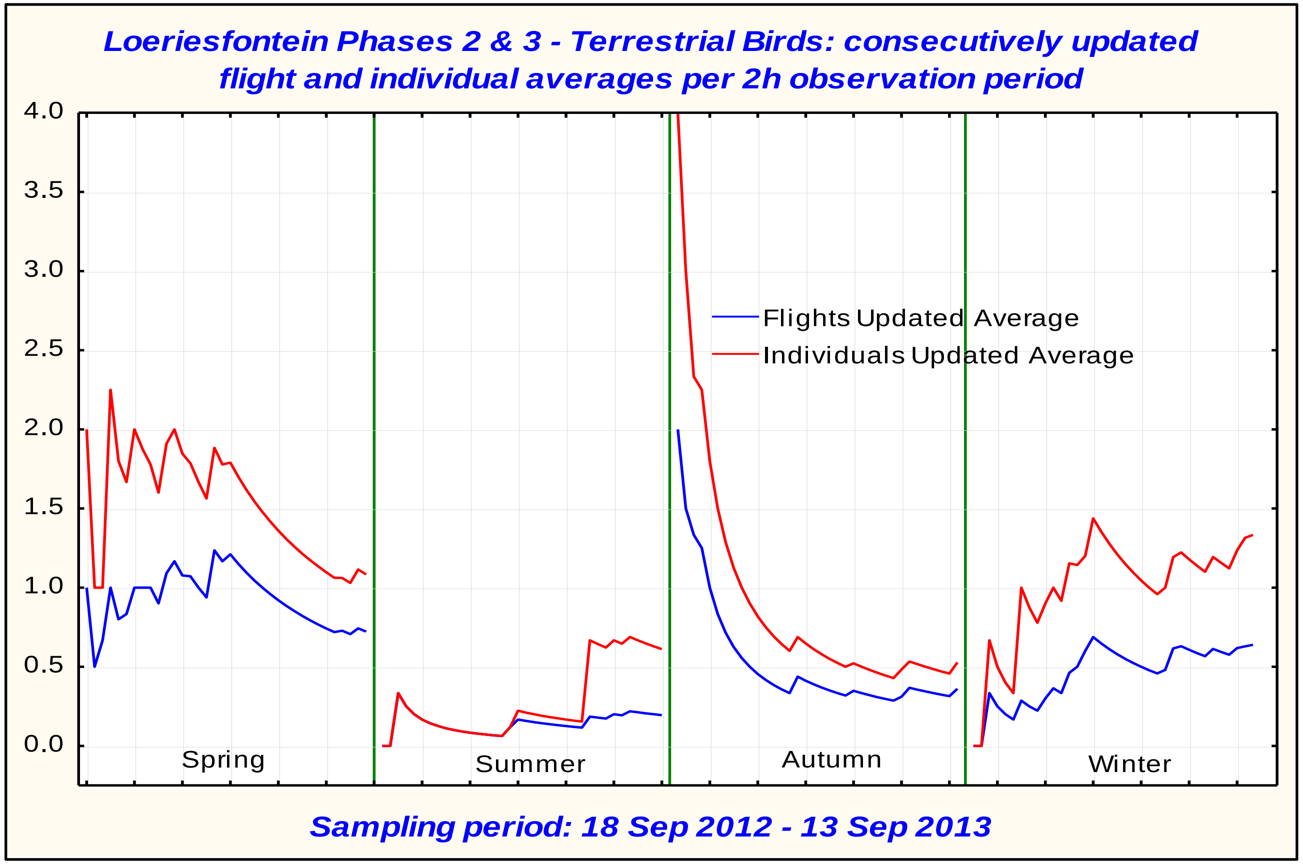

Figure 14: Terrestrial birds: updated average for *Flight* and *Individual* counts.

Figure 14 confirms that the survey also has gathered sufficient information to be able to say, also for terrestrial birds, that the data represent the true situation fairly well. An estimate of the average number of terrestrial birds (flights or individuals) is not likely to be improved by further sampling.

In conclusion it can be stated that the computations and the way the data were exhibited in the tables and graphs in this report show that the survey may be taken to be statistically representative of the soaring and terrestrial priority species of birds that occur in the area.

See Appendix 2 for a detailed explanation of the statistical methods.

Another issue that needs to be investigated is whether the sampling happened during typical rainfall conditions. The Karoo is a rain driven ecosystem, and climatic conditions may vary substantially from year to year, due to the potential unpredictability of rainfall patterns. This may in turn affect the annual variety and abundance of birds at the study area (Harrison *et al.* 1997). In order to assess whether the sampling periods were representative of typical rainfall conditions in the study area, the annual rainfall figures for Loeriesfontein for the period 2003 – 2013 (11 years) was obtained from the South African Weather Services (see Figure 15 below). This indicates that 2012 and 2013 when the sampling took place, were slightly above average rainfall years.

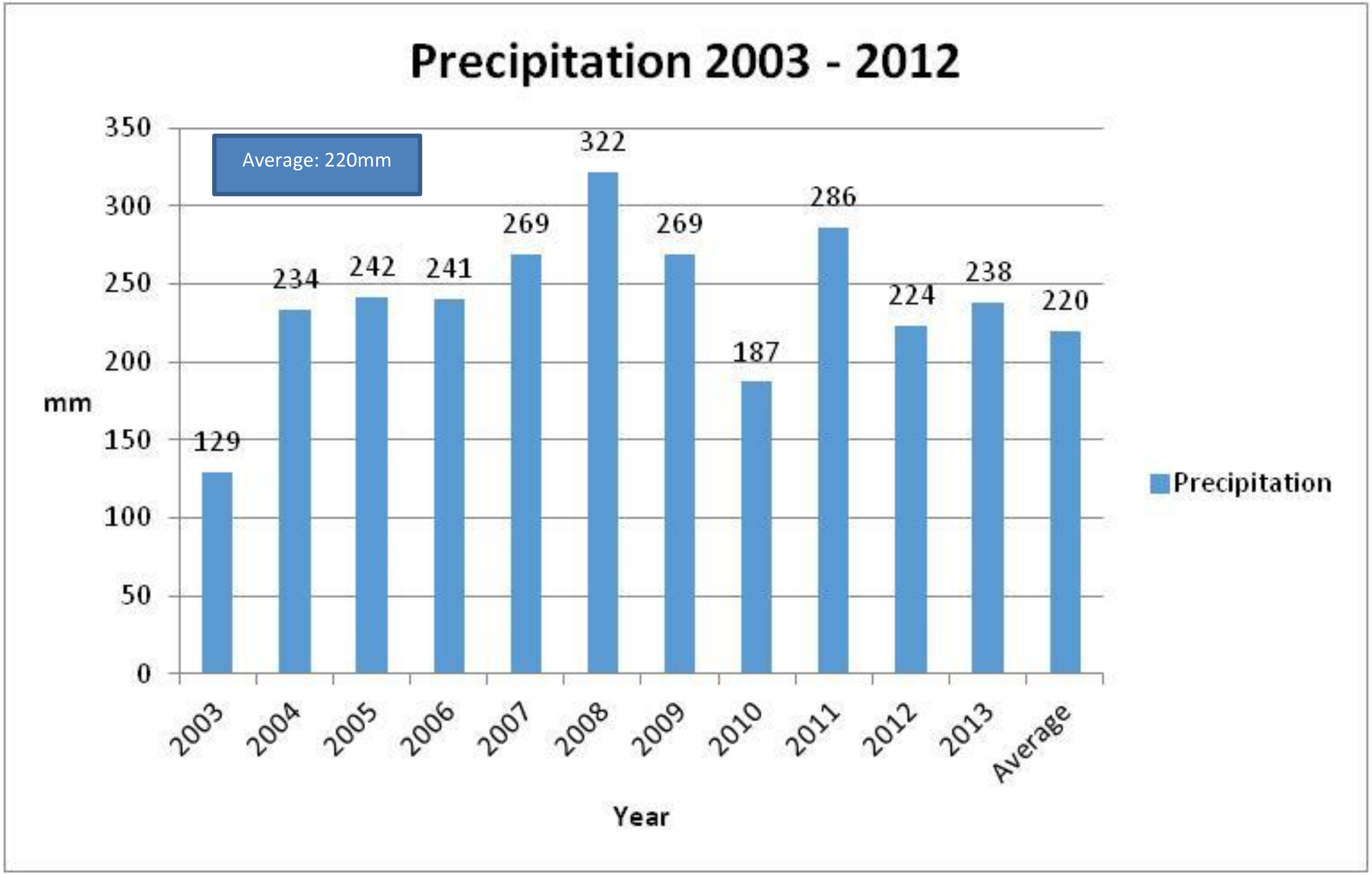

Figure 15: Annual precipitation figures for Loeriesfontein 2003 – 2013 (South African Weather Service).

5.3 Spatial distribution of flights over the turbine area

Flight maps were prepared, indicating the spatial distribution of passages containing medium height priority species flights observed from the various vantage points (see Figures 16-19 below). This was done by overlaying a 100m x 100m grid over the survey area. Each grid cell was then given a weighting score taking into account the duration and distance of individual flight lines through a grid cell and the number of individual birds associated with each flight crossing the grid cell. It is important to interpret these maps bearing in mind the amount of time that each species spent at medium height i.e. the “High” category on the map for Ludwig’s Bustard is not equivalent to the “High” category on the map for Greater Kestrel, as the flight duration for Ludwig’s Bustard is much higher than the flight duration for Greater Kestrel (see Figure 10).

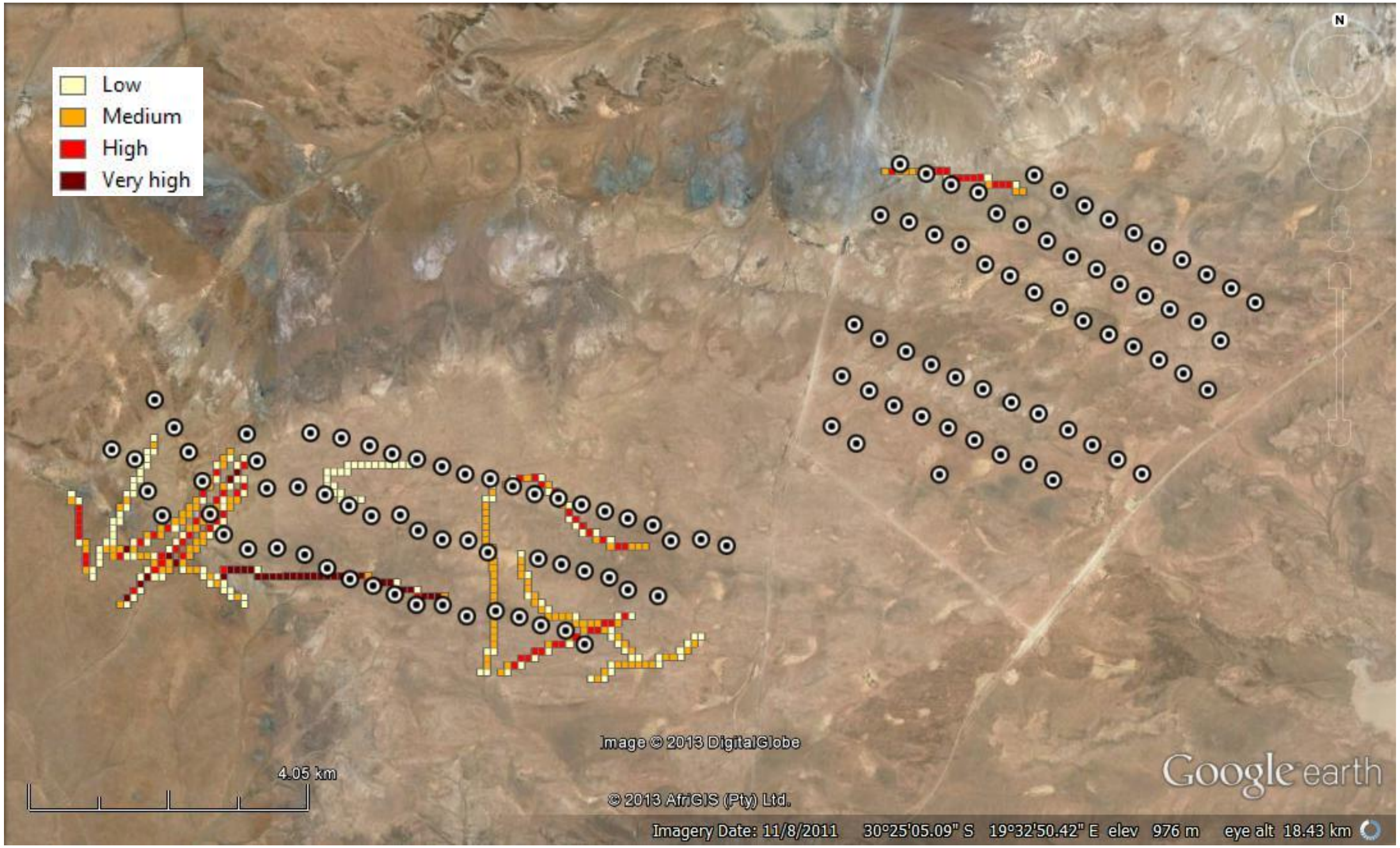

Figure 16: Spatial distribution of medium height flights for Ludwig's Bustard.

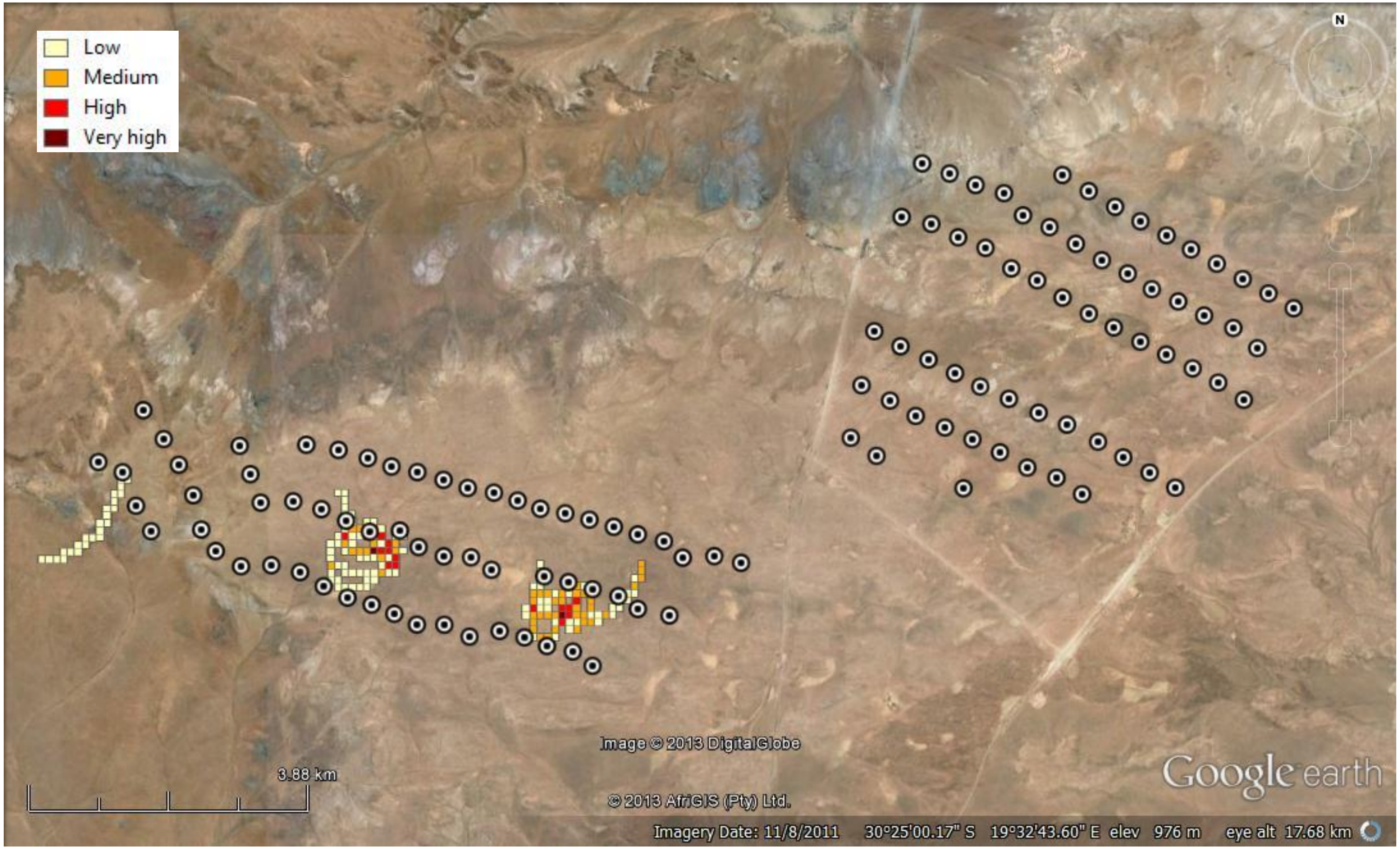

Figure17: Spatial distribution of medium height flights for Greater Kestrel.

Figure18: Spatial distribution of medium height flights for Jackal Buzzard.

Figure 19: Spatial distribution of medium height flights for Southern Pale Chanting Goshawk.

6. Discussion

6.1 Transects and focal points

With an overall species count of 35, of which 8 are priority species, the turbine site supports a relatively low diversity of avifauna, which is to be expected in an arid area like Bushmanland. The control site has an overall species count of 25 species of which 8 are priority species. Based on avifaunal numbers and diversity recorded, the turbine and control sites are broadly similar, although there are also notable exceptions e.g. Red Lark was not recorded at the control site, for reasons which are not immediately apparent.

The abundance of priority species at the turbine site is also generally low, with 1.09 birds/km recorded on drive transects for all the priority species combined, and 0.68 birds/km at the control site. For walk transects, the figures are 4.27 birds/km and 1.5 birds/km for the turbine site and control site respectively. An important difference in the priority species composition between the two sites is the high reporting rate for Martial Eagle at the control site (0.25 birds/km for drive transects and 0.42 birds/km for walk transects), which is a function of the breeding pair with an active nest on the transmission line running through the control site. The species was not recorded at the turbine site. The turbine site is clearly important for Red Lark, with 1.59 birds/km recorded during walk transects, while the species is somewhat inexplicably absent at the control site. Ludwig's Bustard also occurs regularly at the turbine site with 0.53 birds/km reported during drive transects, and 0.34 birds/km reported during walk transects. Karoo Korhaan is also relatively abundant with 0.18 birds/km reported during drive transects, and 1.20 birds/km during walk transects. Sclater's Lark was also reported only at the turbine site transect counts (0.78 birds/km during walk transects). If displacement of Red Lark and (to a lesser extent) Sclater's Lark happens due to the construction and operation of the wind farm, the cumulative impact of several wind farms in the area may constitute a significant impact, as both species are restricted range endemics, and are classified as Vulnerable and Near-Threatened respectively in the South African Red Data Book of Birds (Barnes 2000). However, there is evidence that passerines are less likely to be displaced by wind farms than large species (Farfán *et al.* 2009; Pierce- Higgins *et al.* 2012; Stevens *et al.* 2013) although it may happen in specific instances (Stevens *et al.* 2013).

The distribution of Martial Eagle, Lanner Falcon and Black-chested Snake-Eagle sightings is clearly related to utility structures (the latter species was recorded only at the control site), emphasising the importance of transmission lines and telephone poles for these and other raptors as hunting, perching and nesting substrate. The Martial Eagle nest on the transmission line at the control site is 8.11km away from the closest proposed turbine, therefore the construction activity associated with the turbines is not expected to interfere directly with the breeding activity of the birds. When the construction commences, there will be a lot of traffic on the main access road to the site, which runs 420m directly east of the nest at its closest point. However, it is assumed that the birds are used to traffic on the road, and as long as vehicle traffic is restricted strictly to the road, it should not interfere with the breeding activity. None of the recorded priority raptor species is expected to be displaced, although temporary displacement during the construction phase is likely.

Of the large terrestrial priority species that occur or is likely to occur on the site, Ludwig's Bustard are most likely to be affected by displacement. Bustards are very sensitive to disturbance, and will readily vacate an area due to the presence of human activity (pers. obs). It is however possible that the birds may return once the construction activity is finished (Camiña 2012). No evidence of any bustard display sites (leks) was found during any of the surveys. Karoo Korhaan was recorded regularly at the turbine site and at the control site, and Northern Black Korhaan sparsely at the turbine site. Temporary displacement of the species is likely during the construction phase, but numbers may recover afterwards. However, due to lack of precedents, this will only become evident once post - construction monitoring is implemented and such re-colonisation may only happen after a few years.

6.2 Vantage point observations

6.2.1 Representativeness of counts and sample size

The counts for both soaring and terrestrial species have stabilised relatively well at the end of the surveys for every season. It is thus believed that reasonably representative samples of flight activity have been obtained for all survey periods. Further sampling would not have succeeded in improving the estimates of the average number of birds meaningfully. It is thus believed that the available sample size of 144 sampling periods (288 observation hours) over all four seasons is sufficient to provide reasonable estimates of the overall mean values with an approximate 95% precision. It has to be realised that these computations are based on certain assumptions (e.g. normality of the count distribution) that are probably not met. However, it at least provides some indication.

6.2.2 Site specific risk rating, spatial distribution and estimated mortality rate

In general, very little flight activity was recorded during the VP watches, with an overall passage rate for priority species over the VP area (all flight heights) of 0.57 birds/hour. Based on the amount of time spent at turbine height and potential susceptibility to collisions, Ludwig's Bustard emerged overwhelmingly as the species with the highest collision risk score i.e. with a risk rating 6.92 times higher than the average risk rating for priority species. For some reason the priority species flight activity was much higher over the phase 3 turbine area than over the phase 2 turbine area, although the areas do not differ materially as far as habitat composition is concerned. Given the overall low level of flight activity at the site, the estimated annual mortality rate for priority species is low, <1 birds/year. It must be emphasised that this figure is speculative due to the many variables that need to be assumed, and should not be seen as definitive.

An issue that remains uncertain is whether there will be a collision risk for Lesser and Greater Flamingos associated with the pan which is situated approximately 2.5km from the closest proposed turbine position. No flamingos were recorded at the pan during the monitoring periods, because the pan was dry. However, a dead flamingo was recorded at the bat monitoring mast situated at 30°23'25.16"S 19°36'54.82"E just north of the current proposed Loeriesfontein 2 turbine area, in the area where 35 potential turbines were excluded from the development for fear of potential flamingo collisions., This may have been the result of a collision with the guy wires of the mast. Flamingos normally fly at night when undertaking long distance migrations, therefore the routine monitoring would not have picked up such nocturnal movements. The occurrence of flamingos on the pan is likely to be sporadic and linked to major rainfall events when the pan fills up with water (Hockey *et al.* 2005). The situation would have to be closely monitored during post-construction monitoring to establish if flamingos are indeed at risk, and appropriate mitigation implemented if need be.

7. Summary of findings

The following is a summary of the findings of the pre-construction monitoring programme:

DISPLACEMENT

- With an overall species count of 35, of which 8 are priority species, the turbine site supports a relatively low diversity of avifauna, which is to be expected in an arid area like Bushmanland.
- The abundance of priority species at the turbine site is also generally low, with 1.09 birds/km recorded on drive transects for all the priority species combined, and 4.27 birds/km recorded on walk transects.
- The turbine site is clearly important for Red Lark, with 1.59 birds/km recorded during walk transects.
- Ludwig's Bustard also occurs regularly at the turbine site with 0.53 birds/km reported during drive transects, and 0.34 birds/km reported during walk transects.
- Karoo Korhaan is also relatively abundant with 0.18 birds/km reported during drive transects, and 1.20 birds/km during walk transects.
- Northern Black Korhaan occurs sparsely at the turbine site with 0.26 birds/km reported during walk transects.
- Sclater's Lark was also reported only at the turbine site during transect counts (0.78 birds/km during walk transects).
- If displacement of Red Lark and (to a lesser extent) Sclater's Lark happens due to the construction and operation of the wind farm, the cumulative impact of several wind farms may constitute a significant impact, as both species are Red Data range restricted endemics. However, based on the existing information on the displacement of passerines by wind farms, it is unlikely that these species will be displaced, but it can only be confirmed once post-construction monitoring is implemented.
- Based on the data currently available, none of the priority species recorded at the site is likely to be permanently displaced by the operations of the wind farm, although this will have to be confirmed during post – construction monitoring, especially for Ludwig's Bustard. From a potential displacement perspective no relocation of turbine positions is currently required.

COLLISIONS

- From a statistical perspective, it would seem that the survey effort was sufficient to produce a reasonably reliable set of data to draw conclusions from.
- The passage rate during the survey periods for priority species flying at approximate rotor height was low at 0.57 birds/hour.
- Based on the site specific collision risk rating, Ludwig's Bustard is the species most likely to collide with the turbines, although the estimated annual mortality rate is still low, i.e. <1 birds per year.
- The estimated annual mortality rate for priority species as a whole is <1 birds/year.

- Based on the data currently available, and specifically the low estimated annual collision mortality for priority species, no relocation of turbine positions is currently required.
- An issue that remains uncertain is whether there will be a collision risk for Lesser and Greater Flamingos associated with the pan which is situated approximately 2.5km to the northwest from the closest proposed turbine position, although this risk has already been significantly reduced through the removal of 35 intended turbines to the north of the current turbine lay-out to lessen the risk of flamingo collisions. The situation would have to be closely monitored during operation through post-construction monitoring to establish if flamingos are indeed at risk, and appropriate mitigation implemented if need be.

8. Recommendations

Based on the results of the monitoring to date, no relocation of specific turbines is currently recommended.

The following management actions are recommended:

DISPLACEMENT

- Formal monitoring should be resumed once the turbines have been constructed, as per best practice guidelines (Jenkins *et al.* 2011). The purpose of this would be to establish if displacement of priority species has occurred and to what extent. The exact time when post-construction monitoring should commence, will depend on the construction schedule, and will be agreed upon with the developer once these timelines have been finalised.
- The duration of the post-construction monitoring would need to be for at least an equivalent period to the pre-construction monitoring (four seasons); and ideally for at least three years thereafter. Thereafter the need for additional monitoring will be determined and agreed to with the developer..
- Construction activity should be restricted to the immediate footprint of the infrastructure, and in particular to the proposed road network. Access to the remainder of the site should be prohibited to prevent unnecessary disturbance of priority species.

COLLISIONS

- Formal monitoring should be resumed once the turbines have been constructed, as per best practice guidelines (Jenkins *et al.* 2011) (see previous section Displacement). The duration of the post-construction monitoring would need to be for at least an equivalent period to the pre-construction monitoring (four seasons); and ideally for at least three years thereafter. Thereafter the need for additional monitoring will be determined and agreed to with the developer. The purpose of this would be (a) to establish if displacement of priority species has occurred and to what extent through the altering of flight patterns post-construction, and (b) to search for carcasses at turbines.
- The environmental management plan should provide for the on-going inputs of a suitable experienced ornithological consultant to oversee the post-construction monitoring and assist with the on-going management of bird impacts that may emerge as the post-construction monitoring programme progresses. Depending on the results of the carcass searches, a range of mitigation measures will have to be considered if mortality levels turn out to be significant. If flamingo mortality is recorded, depending on the severity of the problem, appropriate measures to record nocturnal flight movement would need to be implemented.

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Appendix 1: Species lists

Priority Species	
Black-chested Snake-Eagle	*Circaetus pectoralis*
Greater Kestrel	*Falco rupicoloides*
Jackal Buzzard	*Buteo rufofuscus*
Karoo Korhaan	*Eupodotis vigorsii*
Kori Bustard	*Ardeotis kori*
Lanner Falcon	*Falco biarmicus*
Ludwig's Bustard	*Neotis ludwigii*
Martial Eagle	*Polemaetus bellicosus*
Northern Black Korhaan	*Afrotis afraoides*
Red Lark	*Calendulauda burra*
Sclater's Lark	*Spizocorys sclateri*
Southern Pale Chanting Goshawk	*Melierax canorus*
Spotted Eagle-Owl	*Bubo africanus*
Non-Priority Species	
Barn Swallow	*Hirundo rustica*
Black-eared Sparrowlark	*Eremopterix australis*
Bokmakierie	*Telophorus zeylonus*
Cape Bunting	*Emberiza capensis*
Cape Penduline-Tit	*Anthoscopus minutus*
Cape Sparrow	*Passer melanurus*
Capped Wheatear	*Oenanthe pileata*
Chat Flycatcher	*Bradornis infuscatus*
Dusky Sunbird	*Cinnyris fuscus*
Fairy Flycatcher	*Stenostira scita*
Grey-backed Cisticola	*Cisticola subruficapilla*
Karoo Chat	*Cercomela schlegelii*
Karoo Eremomela	*Eremomela gregalis*
Karoo Long-billed Lark	*Certhilauda subcoronata*
Karoo Prinia	*Prinia maculosa*
Karoo Scrub-Robin	*Cercotrichas coryphoeus*
Large-billed Lark	*Galerida magnirostris*
Lark-like Bunting	*Emberiza impetuani*
Layard's Tit-Babbler	*Parisoma layardi*
Little Swift	*Apus affinis*
Namaqua Sandgrouse	*Pterocles namaqua*
Pied Crow	*Corvus albus*
Red-capped Lark	*Calandrella cinerea*
Rock Kestrel	*Falco rupicolus*
Rufous-eared Warbler	*Malcorus pectoralis*
Sickle-winged Chat	*Cercomela sinuata*
Spike-heeled Lark	*Chersomanes albofasciata*
Tractrac Chat	*Cercomela tractrac*

White-Throated Canary	*Crithagra albogularis*
Yellow Canary	*Crithagra flaviventris*
Yellow-bellied Eremomela	*Eremomela icteropygialis*
Yellow-billed Kite	*Milvus aegyptius*

Appendix 2: Statistical analysis

REPRESENTATIVENESS OF THE LOERIESFONTEIN PHASES 2 & 3 DATA

Prepared by Nico Laubscher

Introduction

The data on which this report is based are contained in the MS Excel file "*20131208_LoeriesF2&3_VP_Data_V2.xlsx*". This file contains records for each individual flight of birds that was recorded at each of three vantage points and for every two-hour watch period during the survey that was held for periods between 18 September 2012 and 13 September 2013.

There were 36 watch periods allocated to every season. The data representing Spring were obtained in two halves: the first from 18 – 21 September 2012 and the second from 9 – 13 September 2013. These were put together to represent Spring even though it was not gathered during that season of the same year. The 2013 Spring data were artificially labelled chronologically earlier than the 2012 Spring data for computational purposes even though it was taken a year later. It was representing an earlier part of the month of September than the 2012 data. This is reflected in the graphs of Figures 1 – 4 and in Tables B and C in the Appendix.

The question that is investigated from a statistical viewpoint in this report is the extent to which the data obtained are representative of the true occurrence of those birds identified as priority species in the area.

A count of the total number of individual birds observed during the survey as well as those flying at *Medium Height* are extracted, by species and presented in Table A in the *Appendix*.
The counts observed during consecutive watch periods, also identified by season and by vantage point, are listed separately for Soaring and Terrestrial birds in Tables B and C in the *Appendix* together with calculations of watch period by consecutive watch period updated average counts.

The computations were done using STATISTICA statistical software (see StatSoft Inc., 2013) and with routines developed for this purpose in "Statistica Visual Basic", the programming language of STATISTICA.

Average & variability of counts per watch

The descriptive statistics of average counts, standard deviations and 95% confidence intervals for the mean count per watch period for the data in each of the four seasons are computed from Tables B and C and these are listed in Tables 1 – 4.

Table 1. Soaring birds, Flights: average, SD and 95% lower and upper confidence limits for the number of Flights per watch period.

Season	Watch periods	Flights Count	Flights Avge	Flights Std.Dev.	Flights 95% LCL	Flights 95% UCL
Spring	36	12	0.3	0.9	0.0	0.6
Summer	36	9	0.3	0.7	0.0	0.5
Autumn	36	11	0.3	0.9	0	0.6
Winter	36	21	0.6	2.5	0	1.4
All Grps	144	53	0.4	1.5	0.1	0.6

Table 2. Soaring birds, Individuals: average, SD and 95% lower and upper confidence limits for the number of Individuals per watch period.

Season	Watch periods	Individs Count	Individs Avge	Individs Std.Dev.	Individs 95% LCL	Individs 95% UCL
Spring	36	20	0.6	1.8	0	1.2
Summer	36	9	0.3	0.7	0.0	0.5
Autumn	36	11	0.3	0.9	0	0.6
Winter	36	25	0.7	3.2	0	1.8
All Grps	144	65	0.5	1.9	0.1	0.8

Tables 1 and 2 show that 53 flights and 65 individual soaring birds were counted during the 144 watch periods, leading to an estimated average of 0.37 ± 0.24 flights and 0.45 ± 0.31 individuals (approximately 95% confidence) per 2h watch period respectively.

Table 3. Terrestrial birds, Flights: average, SD and 95% lower and upper confidence limits for the number of Flights per watch period.

Season	Watch periods	Flights Count	Flights Avge	Flights Std.Dev.	Flights 95% LCL	Flights 95% UCL
Spring	36	26	0.7	1.2	0.3	1.1
Summer	36	7	0.2	0.5	0.0	0.4
Autumn	36	13	0.4	0.7	0.1	0.6
Winter	36	23	0.6	0.9	0.3	1.0
All Grps	144	69	0.5	0.9	0.3	0.6

Table 4. Terrestrial birds, Individuals: average, SD and 95% lower and upper confidence limits for the number of Individuals per watch period.

Season	Watch periods	Individs Count	Individs Avge	Individs Std.Dev.	Individs 95% LCL	Individs 95% UCL
Spring	36	39	1.1	1.9	0.4	1.7
Summer	36	22	0.6	2.4	-0.2	1.4
Autumn	36	19	0.5	1.0	0.2	0.9
Winter	36	48	1.3	1.9	0.7	2.0
All Grps	144	128	0.9	1.9	0.6	1.2

Tables 3 and 4 show that 69 flights and 128 individual terrestrial birds were counted during the 144 watch periods, leading to estimated averages of 0.48 ± 0.15 for flights and 0.89 ± 0.31 for individuals (approximately 95% confidence) per 2h watch period.

The overall variability over all seasons (standard deviation over all survey periods) for both soarers and terrestrials varies between 0.9 and 1.9.

Sample size

The standard deviations are a measure of the variability that exists in the counts observed. The variability of the counts is visualised for individual counts in Figures 1 (Soaring individuals) and 2 (Terrestrial individuals).

Figure 1: Soaring birds: sequential time plot of individual soaring bird counts.

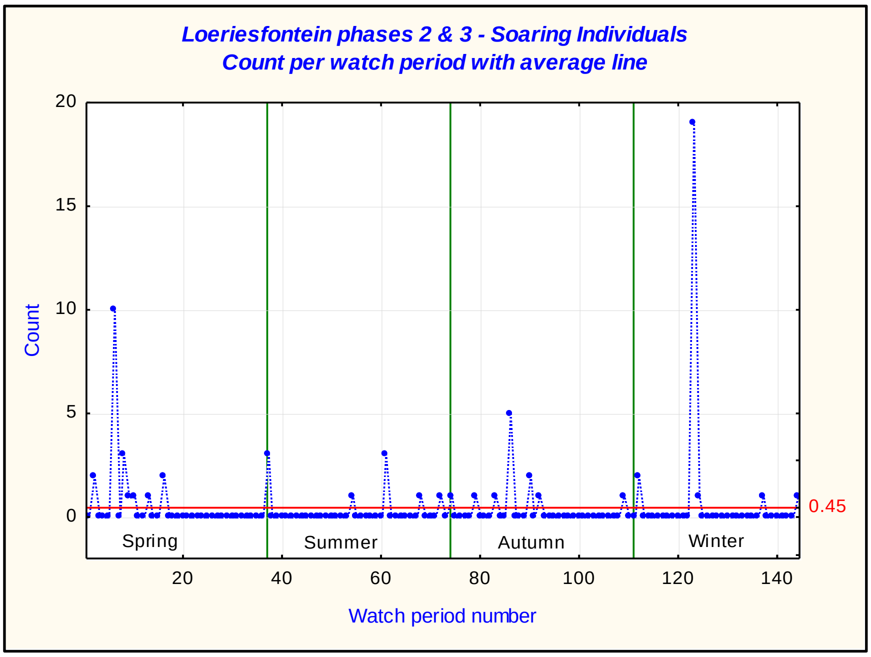
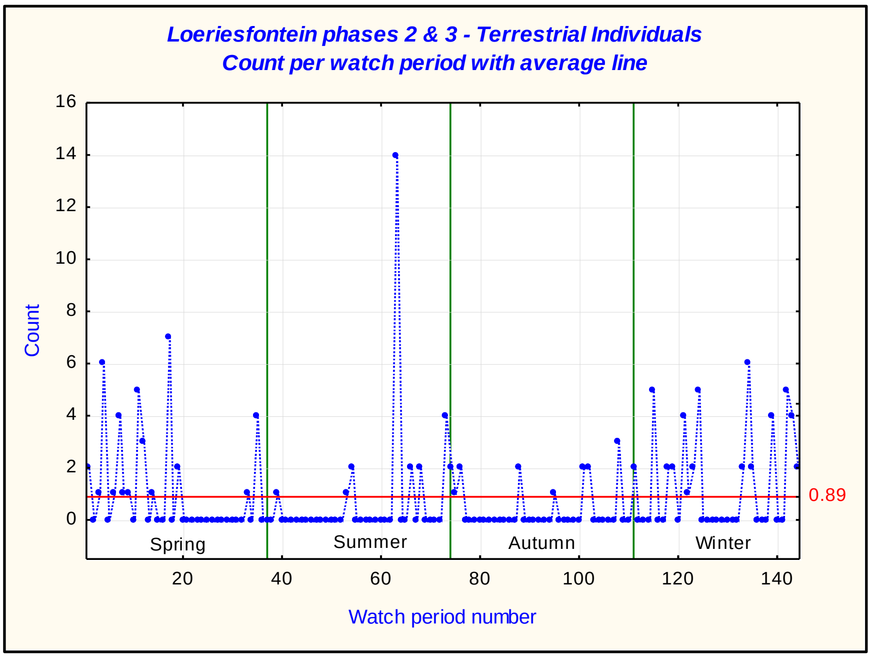


Figure 2: Terrestrial birds: sequential time plot of individual terrestrial bird counts.



As may be seen from Figures 1 and 2 many consecutive watch periods existed where no birds were observed. Thus, judging if the observations gathered are representative and a true reflection of the actual number of birds in the survey area, require some further insight.

The question is: how many watch periods (n) must be sampled in order to be 95% certain of obtaining an estimate of the mean that is within a precision of "*d*" units (counts) from the true mean value, i.e. to say with 95% certainty that the true mean count per observation period lies in an interval of $\bar{x} \pm d$ where $\bar{x}$ is the sample estimate of the true mean value. Due to the relatively small number of birds observed it is suggested that the average number of birds in this survey should be estimated to within a value of ± 0.5 per *2* hour watch period (i.e. $d = 0.5$). As is to be expected, the smaller d (i.e. the higher the precision) the larger the sample size must be.

A practical approximation to an appropriate sample size for that purpose may be obtained from the formula:

$$(1) \qquad n = (s * t_{\alpha/2}(n-1) / d)^2 ,$$

Where $t_{\alpha/2}(n-1)$ is the upper $\alpha/2$ = 2.5% point of Student's t distribution with $n - 1$ degrees of freedom and s is an estimate of the true standard deviation of the counts (see Zar, 2010, page 115).

As already mentioned a standard deviation estimated at about $s \approx 2$ seems to be somewhat conservative. If this is accepted as reasonable, together with $d = 0.5$, the solution of equation (1) is $n \approx 64$. It is thus believed that the available sample size of $n = 144$ obtained over all four seasons is sufficient to provide reasonable estimates of the overall mean values with an approximate 95% precision. It has to be realised that these computations are based on certain assumptions (e.g. normality of the counts distribution) that are probably not met. However, it at least provides some indication.

Stability and Representativeness

The data may also be used to gain further insight into the representativeness and stability of the counting process. As the data are gathered watch period by watch period an improved estimate of the average number of birds that occurs in the area will be achieved. As more data are gathered the more accurate the estimate will become. The issue is to determine if the updated average count begins to stabilise towards the end (or even perhaps before the end) of the survey (and thus the conclusion that a representative sample has been achieved).

To achieve this the average number of flights (as well as individual birds) are computed from all preceding data as the data become available in consecutive watch periods (and day after day). This updated average is expected to vary to a large extent in the initial stages of sampling and to stabilise as it is based on more data. Since the counts vary (in principle) substantially over the seasons (especially for individual counts) the updated averages are determined separately for each season and are listed in Tables B and C in the Appendix.

Figure 3 plots these updated averages for Soaring birds (the number of flights as well as a count of the total number of individual birds). Figure 4 does the same for Terrestrial birds. If the graph consists of a single (red) line it means that the number of flights and individual counts are the same.

Figure 3. Soaring birds: updated average for *Flight* and *Individual* counts.

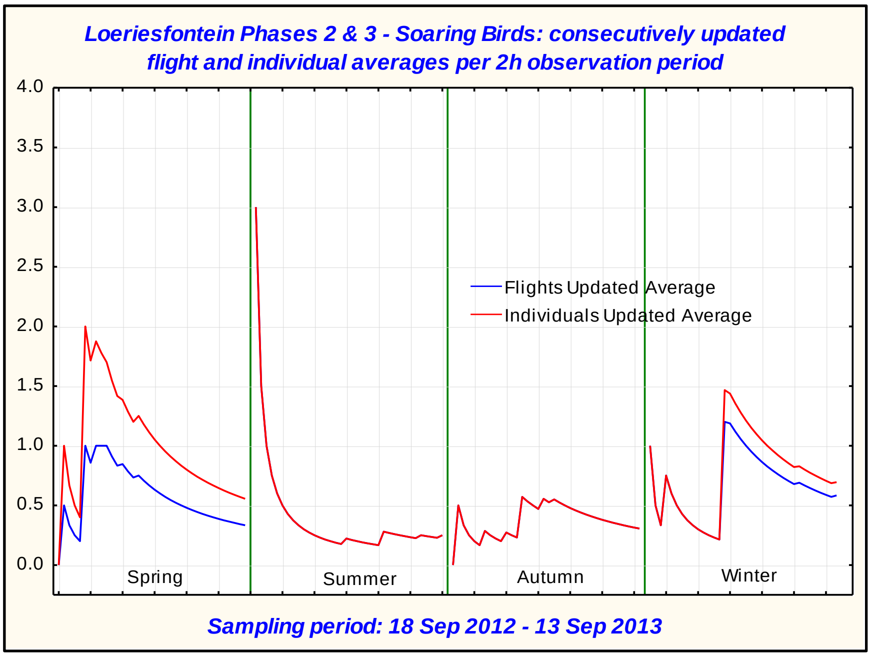


Figure *3* shows that the only differences in the counts between flights and individuals for soaring bird counts were seen in Spring and in Winter. The day to day updated averages have stabilised well for both flights and for individuals. Further sampling is not believed to improve the overall estimates of the averages for soaring birds in a substantial way.

Figure 4. Terrestrial birds: updated average for *Flight* and *Individual* counts.

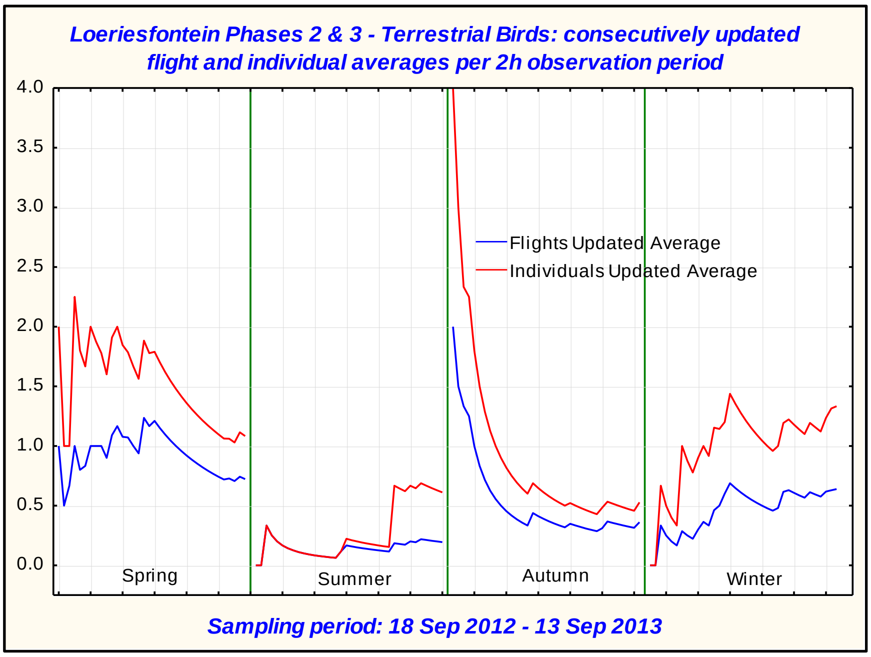


Figure 4 confirms that the survey also has gathered sufficient information to be able to say, also for terrestrial birds, that the data represent the true situation fairly well. An estimate of the average number of terrestrial birds (flights or individuals) is not likely to be improved by further sampling.

Conclusion

The computations and the way the data were exhibited in the tables and graphs in this report show that the survey may be taken to be statistically representative of the soaring and terrestrial priority species of birds that occur in the area.

References

StatSoft, Inc., (2013), STATISTICA (data analysis software system), Version 12. www.Statsoft.com.

Zar, J.H., (2010), *Biostatistical Analysis* (5th ed.), Prentice-Hall, Inc., Upper Saddle River: NJ 07458.

APPENDIX

Table A. Number of individual birds recorded during the survey as well as those flying at medium height.			
Species	**Flight Class**	**Individuals (all Counts)**	**Individuals at Medium Height**
Greater Kestrel	Soaring	47	17
Southern Pale Chanting Goshawk	Soaring	12	1
Jackal Buzzard	Soaring	5	2
Lanner Falcon	Soaring	1	0
Total count (soaring)		65	20
Ludwig's Bustard	Terrestrial	68	30
Karoo Korhaan	Terrestrial	24	0
Sclater's Lark	Terrestrial	22	0
Red Lark	Terrestrial	13	0
Spotted Eagle-Owl	Terrestrial	1	0
Total count (terrestrial)		128	30

Table B: ***Soaring Birds*: Flights and Individuals per watch period and by vantage point over time with updated averages per consecutive watch period.**

Date	Season	VP	Flights count	Flights Updated Avge	Individuals count	Individuals Updated Avge
2013-09-09	Spring	VP1	0.0	0.00	0.0	0.00
2013-09-09	Spring	VP2	1.0	0.50	2.0	1.00
2013-09-09	Spring	VP3	0.0	0.33	0.0	0.67
2013-09-09	Spring	VP1	0.0	0.25	0.0	0.50
2013-09-09	Spring	VP3	0.0	0.20	0.0	0.40
2013-09-09	Spring	VP2	5.0	1.00	10.0	2.00
2013-09-10	Spring	VP1	0.0	0.86	0.0	1.71
2013-09-10	Spring	VP2	2.0	1.00	3.0	1.88
2013-09-10	Spring	VP3	1.0	1.00	1.0	1.78
2013-09-10	Spring	VP2	1.0	1.00	1.0	1.70
2013-09-10	Spring	VP3	0.0	0.91	0.0	1.55
2013-09-10	Spring	VP3	0.0	0.83	0.0	1.42

2013-09-10	Spring	VP1	1.0	0.85	1.0	1.38
2013-09-12	Spring	VP2	0.0	0.79	0.0	1.29
2013-09-12	Spring	VP1	0.0	0.73	0.0	1.20
2013-09-13	Spring	VP2	1.0	0.75	2.0	1.25
2013-09-13	Spring	VP1	0.0	0.71	0.0	1.18
2013-09-13	Spring	VP3	0.0	0.67	0.0	1.11
2012-09-18	Spring	VP1	0.0	0.63	0.0	1.05
2012-09-18	Spring	VP2	0.0	0.60	0.0	1.00
2012-09-18	Spring	VP1	0.0	0.57	0.0	0.95
2012-09-18	Spring	VP2	0.0	0.55	0.0	0.91
2012-09-18	Spring	VP2	0.0	0.52	0.0	0.87
2012-09-18	Spring	VP3	0.0	0.50	0.0	0.83
2012-09-19	Spring	VP1	0.0	0.48	0.0	0.80
2012-09-19	Spring	VP3	0.0	0.46	0.0	0.77
2012-09-19	Spring	VP1	0.0	0.44	0.0	0.74
2012-09-19	Spring	VP3	0.0	0.43	0.0	0.71
2012-09-19	Spring	VP2	0.0	0.41	0.0	0.69
2012-09-20	Spring	VP3	0.0	0.40	0.0	0.67
2012-09-20	Spring	VP2	0.0	0.39	0.0	0.65
2012-09-20	Spring	VP3	0.0	0.38	0.0	0.63
2012-09-20	Spring	VP1	0.0	0.36	0.0	0.61
2012-09-21	Spring	VP2	0.0	0.35	0.0	0.59
2012-09-21	Spring	VP1	0.0	0.34	0.0	0.57
2012-09-21	Spring	VP3	0.0	0.33	0.0	0.56
2012-12-17	Summer	VP1	3.0	3.00	3.0	3.00
2012-12-17	Summer	VP3	0.0	1.50	0.0	1.50
2012-12-17	Summer	VP3	0.0	1.00	0.0	1.00
2012-12-17	Summer	VP2	0.0	0.75	0.0	0.75
2012-12-17	Summer	VP3	0.0	0.60	0.0	0.60
2012-12-17	Summer	VP2	0.0	0.50	0.0	0.50
2012-12-18	Summer	VP1	0.0	0.43	0.0	0.43
2012-12-18	Summer	VP3	0.0	0.38	0.0	0.38
2012-12-18	Summer	VP2	0.0	0.33	0.0	0.33
2012-12-18	Summer	VP1	0.0	0.30	0.0	0.30
2012-12-18	Summer	VP1	0.0	0.27	0.0	0.27
2012-12-18	Summer	VP2	0.0	0.25	0.0	0.25
2012-12-19	Summer	VP2	0.0	0.23	0.0	0.23

2012-12-19	Summer	VP1	0.0	0.21	0.0	0.21
2012-12-19	Summer	VP3	0.0	0.20	0.0	0.20
2012-12-20	Summer	VP2	0.0	0.19	0.0	0.19
2012-12-20	Summer	VP3	0.0	0.18	0.0	0.18
2012-12-20	Summer	VP2	1.0	0.22	1.0	0.22
2012-12-20	Summer	VP3	0.0	0.21	0.0	0.21
2012-12-20	Summer	VP1	0.0	0.20	0.0	0.20
2012-12-20	Summer	VP1	0.0	0.19	0.0	0.19
2012-12-20	Summer	VP2	0.0	0.18	0.0	0.18
2012-12-21	Summer	VP2	0.0	0.17	0.0	0.17
2012-12-21	Summer	VP3	0.0	0.17	0.0	0.17
2012-12-21	Summer	VP2	3.0	0.28	3.0	0.28
2012-12-21	Summer	VP3	0.0	0.27	0.0	0.27
2012-12-21	Summer	VP1	0.0	0.26	0.0	0.26
2012-12-21	Summer	VP3	0.0	0.25	0.0	0.25
2012-12-22	Summer	VP1	0.0	0.24	0.0	0.24
2012-12-22	Summer	VP3	0.0	0.23	0.0	0.23
2012-12-22	Summer	VP1	0.0	0.23	0.0	0.23
2012-12-23	Summer	VP1	1.0	0.25	1.0	0.25
2012-12-23	Summer	VP2	0.0	0.24	0.0	0.24
2012-12-23	Summer	VP1	0.0	0.24	0.0	0.24
2012-12-23	Summer	VP2	0.0	0.23	0.0	0.23
2012-12-23	Summer	VP3	1.0	0.25	1.0	0.25
2013-04-15	Autumn	VP1	0.0	0.00	0.0	0.00
2013-04-15	Autumn	VP2	1.0	0.50	1.0	0.50
2013-04-15	Autumn	VP3	0.0	0.33	0.0	0.33
2013-04-15	Autumn	VP1	0.0	0.25	0.0	0.25
2013-04-15	Autumn	VP2	0.0	0.20	0.0	0.20
2013-04-15	Autumn	VP3	0.0	0.17	0.0	0.17
2013-04-15	Autumn	VP3	1.0	0.29	1.0	0.29
2013-04-15	Autumn	VP1	0.0	0.25	0.0	0.25
2013-04-15	Autumn	VP2	0.0	0.22	0.0	0.22
2013-04-16	Autumn	VP3	0.0	0.20	0.0	0.20
2013-04-16	Autumn	VP1	1.0	0.27	1.0	0.27
2013-04-16	Autumn	VP2	0.0	0.25	0.0	0.25
2013-04-16	Autumn	VP3	0.0	0.23	0.0	0.23
2013-04-16	Autumn	VP1	5.0	0.57	5.0	0.57

2013-04-16	Autumn	VP2	0.0	0.53	0.0	0.53
2013-04-16	Autumn	VP1	0.0	0.50	0.0	0.50
2013-04-16	Autumn	VP3	0.0	0.47	0.0	0.47
2013-04-16	Autumn	VP2	2.0	0.56	2.0	0.56
2013-04-17	Autumn	VP1	0.0	0.53	0.0	0.53
2013-04-17	Autumn	VP2	1.0	0.55	1.0	0.55
2013-04-17	Autumn	VP3	0.0	0.52	0.0	0.52
2013-04-17	Autumn	VP1	0.0	0.50	0.0	0.50
2013-04-17	Autumn	VP3	0.0	0.48	0.0	0.48
2013-04-17	Autumn	VP2	0.0	0.46	0.0	0.46
2013-04-17	Autumn	VP3	0.0	0.44	0.0	0.44
2013-04-17	Autumn	VP1	0.0	0.42	0.0	0.42
2013-04-17	Autumn	VP2	0.0	0.41	0.0	0.41
2013-04-18	Autumn	VP1	0.0	0.39	0.0	0.39
2013-04-18	Autumn	VP2	0.0	0.38	0.0	0.38
2013-04-18	Autumn	VP3	0.0	0.37	0.0	0.37
2013-04-18	Autumn	VP1	0.0	0.35	0.0	0.35
2013-04-18	Autumn	VP3	0.0	0.34	0.0	0.34
2013-04-18	Autumn	VP2	0.0	0.33	0.0	0.33
2013-04-18	Autumn	VP1	0.0	0.32	0.0	0.32
2013-04-18	Autumn	VP2	0.0	0.31	0.0	0.31
2013-04-18	Autumn	VP3	0.0	0.31	0.0	0.31
2013-06-04	Winter	VP1	1.0	1.00	1.0	1.00
2013-06-04	Winter	VP3	0.0	0.50	0.0	0.50
2013-06-04	Winter	VP2	0.0	0.33	0.0	0.33
2013-06-04	Winter	VP1	2.0	0.75	2.0	0.75
2013-06-04	Winter	VP2	0.0	0.60	0.0	0.60
2013-06-04	Winter	VP3	0.0	0.50	0.0	0.50
2013-06-04	Winter	VP1	0.0	0.43	0.0	0.43
2013-06-04	Winter	VP2	0.0	0.38	0.0	0.38
2013-06-04	Winter	VP3	0.0	0.33	0.0	0.33
2013-06-05	Winter	VP1	0.0	0.30	0.0	0.30
2013-06-05	Winter	VP2	0.0	0.27	0.0	0.27
2013-06-05	Winter	VP3	0.0	0.25	0.0	0.25
2013-06-05	Winter	VP1	0.0	0.23	0.0	0.23
2013-06-05	Winter	VP2	0.0	0.21	0.0	0.21
2013-06-05	Winter	VP3	15.0	1.20	19.0	1.47

2013-06-05	Winter	VP2	1.0	1.19	1.0	1.44
2013-06-05	Winter	VP1	0.0	1.12	0.0	1.35
2013-06-05	Winter	VP3	0.0	1.06	0.0	1.28
2013-06-06	Winter	VP3	0.0	1.00	0.0	1.21
2013-06-06	Winter	VP1	0.0	0.95	0.0	1.15
2013-06-06	Winter	VP2	0.0	0.90	0.0	1.10
2013-06-06	Winter	VP1	0.0	0.86	0.0	1.05
2013-06-06	Winter	VP2	0.0	0.83	0.0	1.00
2013-06-06	Winter	VP3	0.0	0.79	0.0	0.96
2013-06-07	Winter	VP3	0.0	0.76	0.0	0.92
2013-06-07	Winter	VP1	0.0	0.73	0.0	0.88
2013-06-07	Winter	VP2	0.0	0.70	0.0	0.85
2013-06-07	Winter	VP1	0.0	0.68	0.0	0.82
2013-06-07	Winter	VP2	1.0	0.69	1.0	0.83
2013-06-07	Winter	VP3	0.0	0.67	0.0	0.80
2013-06-07	Winter	VP2	0.0	0.65	0.0	0.77
2013-06-07	Winter	VP3	0.0	0.63	0.0	0.75
2013-06-07	Winter	VP1	0.0	0.61	0.0	0.73
2013-06-10	Winter	VP1	0.0	0.59	0.0	0.71
2013-06-10	Winter	VP2	0.0	0.57	0.0	0.69
2013-06-10	Winter	VP3	1.0	0.58	1.0	0.69

Table C: ***Terrestrial Birds*: Flights and Individuals per watch period and by vantage point over time with updated averages per consecutive watch period.**

Date	Season	VP	Flights count	Flights Updated Avge	Individuals count	Individuals Updated Avge
2013-09-09	Spring	VP1	1.0	1.00	2.0	2.00
2013-09-09	Spring	VP2	0.0	0.50	0.0	1.00
2013-09-09	Spring	VP3	1.0	0.67	1.0	1.00
2013-09-09	Spring	VP1	2.0	1.00	6.0	2.25
2013-09-09	Spring	VP3	0.0	0.80	0.0	1.80
2013-09-09	Spring	VP2	1.0	0.83	1.0	1.67
2013-09-10	Spring	VP1	2.0	1.00	4.0	2.00
2013-09-10	Spring	VP2	1.0	1.00	1.0	1.88
2013-09-10	Spring	VP3	1.0	1.00	1.0	1.78
2013-09-10	Spring	VP2	0.0	0.90	0.0	1.60

2013-09-10	Spring	VP3	3.0	1.09	5.0	1.91
2013-09-10	Spring	VP3	2.0	1.17	3.0	2.00
2013-09-10	Spring	VP1	0.0	1.08	0.0	1.85
2013-09-12	Spring	VP2	1.0	1.07	1.0	1.79
2013-09-12	Spring	VP1	0.0	1.00	0.0	1.67
2013-09-13	Spring	VP2	0.0	0.94	0.0	1.56
2013-09-13	Spring	VP1	6.0	1.24	7.0	1.88
2013-09-13	Spring	VP3	0.0	1.17	0.0	1.78
2012-09-18	Spring	VP1	2.0	1.21	2.0	1.79
2012-09-18	Spring	VP2	0.0	1.15	0.0	1.70
2012-09-18	Spring	VP1	0.0	1.10	0.0	1.62
2012-09-18	Spring	VP2	0.0	1.05	0.0	1.55
2012-09-18	Spring	VP2	0.0	1.00	0.0	1.48
2012-09-18	Spring	VP3	0.0	0.96	0.0	1.42
2012-09-19	Spring	VP1	0.0	0.92	0.0	1.36
2012-09-19	Spring	VP3	0.0	0.88	0.0	1.31
2012-09-19	Spring	VP1	0.0	0.85	0.0	1.26
2012-09-19	Spring	VP3	0.0	0.82	0.0	1.21
2012-09-19	Spring	VP2	0.0	0.79	0.0	1.17
2012-09-20	Spring	VP3	0.0	0.77	0.0	1.13
2012-09-20	Spring	VP2	0.0	0.74	0.0	1.10
2012-09-20	Spring	VP3	0.0	0.72	0.0	1.06
2012-09-20	Spring	VP1	1.0	0.73	1.0	1.06
2012-09-21	Spring	VP2	0.0	0.71	0.0	1.03
2012-09-21	Spring	VP1	2.0	0.74	4.0	1.11
2012-09-21	Spring	VP3	0.0	0.72	0.0	1.08
2012-12-17	Summer	VP1	0.0	0.00	0.0	0.00
2012-12-17	Summer	VP3	0.0	0.00	0.0	0.00
2012-12-17	Summer	VP3	1.0	0.33	1.0	0.33
2012-12-17	Summer	VP2	0.0	0.25	0.0	0.25
2012-12-17	Summer	VP3	0.0	0.20	0.0	0.20
2012-12-17	Summer	VP2	0.0	0.17	0.0	0.17
2012-12-18	Summer	VP1	0.0	0.14	0.0	0.14
2012-12-18	Summer	VP3	0.0	0.13	0.0	0.13
2012-12-18	Summer	VP2	0.0	0.11	0.0	0.11
2012-12-18	Summer	VP1	0.0	0.10	0.0	0.10
2012-12-18	Summer	VP1	0.0	0.09	0.0	0.09

2012-12-18	Summer	VP2	0.0	0.08	0.0	0.08
2012-12-19	Summer	VP2	0.0	0.08	0.0	0.08
2012-12-19	Summer	VP1	0.0	0.07	0.0	0.07
2012-12-19	Summer	VP3	0.0	0.07	0.0	0.07
2012-12-20	Summer	VP2	0.0	0.06	0.0	0.06
2012-12-20	Summer	VP3	1.0	0.12	1.0	0.12
2012-12-20	Summer	VP2	1.0	0.17	2.0	0.22
2012-12-20	Summer	VP3	0.0	0.16	0.0	0.21
2012-12-20	Summer	VP1	0.0	0.15	0.0	0.20
2012-12-20	Summer	VP1	0.0	0.14	0.0	0.19
2012-12-20	Summer	VP2	0.0	0.14	0.0	0.18
2012-12-21	Summer	VP2	0.0	0.13	0.0	0.17
2012-12-21	Summer	VP3	0.0	0.13	0.0	0.17
2012-12-21	Summer	VP2	0.0	0.12	0.0	0.16
2012-12-21	Summer	VP3	0.0	0.12	0.0	0.15
2012-12-21	Summer	VP1	2.0	0.19	14.0	0.67
2012-12-21	Summer	VP3	0.0	0.18	0.0	0.64
2012-12-22	Summer	VP1	0.0	0.17	0.0	0.62
2012-12-22	Summer	VP3	1.0	0.20	2.0	0.67
2012-12-22	Summer	VP1	0.0	0.19	0.0	0.65
2012-12-23	Summer	VP1	1.0	0.22	2.0	0.69
2012-12-23	Summer	VP2	0.0	0.21	0.0	0.67
2012-12-23	Summer	VP1	0.0	0.21	0.0	0.65
2012-12-23	Summer	VP2	0.0	0.20	0.0	0.63
2012-12-23	Summer	VP3	0.0	0.19	0.0	0.61
2013-04-15	Autumn	VP1	2.0	2.00	4.0	4.00
2013-04-15	Autumn	VP2	1.0	1.50	2.0	3.00
2013-04-15	Autumn	VP3	1.0	1.33	1.0	2.33
2013-04-15	Autumn	VP1	1.0	1.25	2.0	2.25
2013-04-15	Autumn	VP2	0.0	1.00	0.0	1.80
2013-04-15	Autumn	VP3	0.0	0.83	0.0	1.50
2013-04-15	Autumn	VP3	0.0	0.71	0.0	1.29
2013-04-15	Autumn	VP1	0.0	0.63	0.0	1.13
2013-04-15	Autumn	VP2	0.0	0.56	0.0	1.00
2013-04-16	Autumn	VP3	0.0	0.50	0.0	0.90
2013-04-16	Autumn	VP1	0.0	0.45	0.0	0.82
2013-04-16	Autumn	VP2	0.0	0.42	0.0	0.75

2013-04-16	Autumn	VP3	0.0	0.38	0.0	0.69
2013-04-16	Autumn	VP1	0.0	0.36	0.0	0.64
2013-04-16	Autumn	VP2	0.0	0.33	0.0	0.60
2013-04-16	Autumn	VP1	2.0	0.44	2.0	0.69
2013-04-16	Autumn	VP3	0.0	0.41	0.0	0.65
2013-04-16	Autumn	VP2	0.0	0.39	0.0	0.61
2013-04-17	Autumn	VP1	0.0	0.37	0.0	0.58
2013-04-17	Autumn	VP2	0.0	0.35	0.0	0.55
2013-04-17	Autumn	VP3	0.0	0.33	0.0	0.52
2013-04-17	Autumn	VP1	0.0	0.32	0.0	0.50
2013-04-17	Autumn	VP3	1.0	0.35	1.0	0.52
2013-04-17	Autumn	VP2	0.0	0.33	0.0	0.50
2013-04-17	Autumn	VP3	0.0	0.32	0.0	0.48
2013-04-17	Autumn	VP1	0.0	0.31	0.0	0.46
2013-04-17	Autumn	VP2	0.0	0.30	0.0	0.44
2013-04-18	Autumn	VP1	0.0	0.29	0.0	0.43
2013-04-18	Autumn	VP2	1.0	0.31	2.0	0.48
2013-04-18	Autumn	VP3	2.0	0.37	2.0	0.53
2013-04-18	Autumn	VP1	0.0	0.35	0.0	0.52
2013-04-18	Autumn	VP3	0.0	0.34	0.0	0.50
2013-04-18	Autumn	VP2	0.0	0.33	0.0	0.48
2013-04-18	Autumn	VP1	0.0	0.32	0.0	0.47
2013-04-18	Autumn	VP2	0.0	0.31	0.0	0.46
2013-04-18	Autumn	VP3	2.0	0.36	3.0	0.53
2013-06-04	Winter	VP1	0.0	0.00	0.0	0.00
2013-06-04	Winter	VP3	0.0	0.00	0.0	0.00
2013-06-04	Winter	VP2	1.0	0.33	2.0	0.67
2013-06-04	Winter	VP1	0.0	0.25	0.0	0.50
2013-06-04	Winter	VP2	0.0	0.20	0.0	0.40
2013-06-04	Winter	VP3	0.0	0.17	0.0	0.33
2013-06-04	Winter	VP1	1.0	0.29	5.0	1.00
2013-06-04	Winter	VP2	0.0	0.25	0.0	0.88
2013-06-04	Winter	VP3	0.0	0.22	0.0	0.78
2013-06-05	Winter	VP1	1.0	0.30	2.0	0.90
2013-06-05	Winter	VP2	1.0	0.36	2.0	1.00
2013-06-05	Winter	VP3	0.0	0.33	0.0	0.92
2013-06-05	Winter	VP1	2.0	0.46	4.0	1.15

2013-06-05	Winter	VP2	1.0	0.50	1.0	1.14
2013-06-05	Winter	VP3	2.0	0.60	2.0	1.20
2013-06-05	Winter	VP2	2.0	0.69	5.0	1.44
2013-06-05	Winter	VP1	0.0	0.65	0.0	1.35
2013-06-05	Winter	VP3	0.0	0.61	0.0	1.28
2013-06-06	Winter	VP3	0.0	0.58	0.0	1.21
2013-06-06	Winter	VP1	0.0	0.55	0.0	1.15
2013-06-06	Winter	VP2	0.0	0.52	0.0	1.10
2013-06-06	Winter	VP1	0.0	0.50	0.0	1.05
2013-06-06	Winter	VP2	0.0	0.48	0.0	1.00
2013-06-06	Winter	VP3	0.0	0.46	0.0	0.96
2013-06-07	Winter	VP3	1.0	0.48	2.0	1.00
2013-06-07	Winter	VP1	4.0	0.62	6.0	1.19
2013-06-07	Winter	VP2	1.0	0.63	2.0	1.22
2013-06-07	Winter	VP1	0.0	0.61	0.0	1.18
2013-06-07	Winter	VP2	0.0	0.59	0.0	1.14
2013-06-07	Winter	VP3	0.0	0.57	0.0	1.10
2013-06-07	Winter	VP2	2.0	0.61	4.0	1.19
2013-06-07	Winter	VP3	0.0	0.59	0.0	1.16
2013-06-07	Winter	VP1	0.0	0.58	0.0	1.12
2013-06-10	Winter	VP1	2.0	0.62	5.0	1.24
2013-06-10	Winter	VP2	1.0	0.63	4.0	1.31
2013-06-10	Winter	VP3	1.0	0.64	2.0	1.33