Avifaunal pre-construction monitoring at the proposed Mainstream Noupoort Wind Energy Facility

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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 (2012) 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

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). 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 he is currently jointly coordinating pre-construction monitoring programmes at 11 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 Noupoort Wind Energy Facility near the town of Noupoort in the Northern Cape Province in the course of 2011 and 2012.
The following is a summary of the findings of the pre-construction monitoring programme:

<u>DISPLACEMENT</u>

- With an overall species count of 68, of which 11 species are priority species, the turbine site supports a relatively low diversity of avifauna, which is to be expected in this arid environment. The control site has a comparable overall species count of 77 species of which 13 are priority species, which is broadly similar to the turbine site.
- Priority species site specific abundance: Based on numbers counted, Lesser Kestrel (summer only), Grey-winged Francolin and Blue Crane are most commonly recorded at the turbine site, with Lesser Kestrel overwhelmingly the most abundant priority species. Other priority species irregularly observed were mostly raptors i.e. Steppe Buzzard, Jackal Buzzard, Amur Falcon (in association with Lesser Kestrel), Lanner Falcon, Martial Eagle and African Harrier Hawk. Ludwig's Bustard was recorded once only, and Melodious Lark was recorded in low numbers in spring and autumn.
- As far as habitat preferences are concerned, the habitat indices for all species (using the data from walk transects only) indicate that relative to the available habitat, overall species diversity at the turbine site is highest in wetlands, followed by Grassy Karoo, with no species recorded during walk transects in agricultural habitat.
- From an abundance perspective, relative to the amount of available habitat at the site, individual birds were most commonly recorded in wetland habitat, followed by Grassy Karoo, with no birds recorded in agriculture.
- The species specific indices for the three most recorded priority species (combining the data from walk transects and drive transects), indicate that Lesser Kestrel, Grey-winged Francolin and Blue Crane all prefer Grassy Karoo at the turbine site.
- As far as the spatial distribution of records of the priority species at the turbine site is concerned, Blue Cranes records are clearly clustered around the breeding area of the pair of Blue Cranes. Grey-winged Francolin occurs all over the site with no specific spatial pattern evident. Lesser Kestrel records seem to be concentrated in the western and central sections of the site.
- Only one nest of priority species (Blue Crane) was discovered, although Grey-winged Francolin probably breeds on the site too.

<u>COLLISIONS</u>

- In general, it would seem that the survey effort was sufficient to produce a reasonably reliable set of data to draw conclusions from.
- Based on the site specific rating, Lesser Kestrels are overwhelmingly the species most at risk of collision.

- Collision risk at the site is most prevalent for Lesser Kestrels, on average, in summer in warm temperatures, when the wind direction is south to south--easterly and when the wind strength is at a moderate breeze.
- An unpredictable factor that potentially exacerbates the risk of collision for Lesser Kestrels is the availability of food sources, which may concentrate flight activity in a specific area.
- No detailed association analyses were conducted for terrestrial species due to the small number of records, indicating a low risk of collisions due to very low flight activity.

RECOMMENDATIONS

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

The following management actions are recommended:

<u>DISPLACEMENT</u>

- 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 Mainstream 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), thereafter the need for additional monitoring will be determined and agreed to with Mainstream, based on the results of the first year of post-construction monitoring.
- A 500m buffer has already been implemented in the lay-out to accommodate the Blue Cranes that are breeding on the site. This should be strictly enforced as a no turbine zone for the duration of the project. In addition, no access roads should be constructed within that zone.

<u>COLLISIONS</u>

- 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 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.

Contents

1. Introduction

This report presents the findings of a pre-construction avifaunal monitoring programme which was implemented at the proposed Mainstream Noupoort Wind Energy Facility near the town of Noupoort in the Northern Cape Province during the course of 2011 and 2012. Mainstream Renewable Power South Africa ("Mainstream") is a South African-based independent power producer that designs, builds, finances, owns and operates energy projects in South and Southern Africa. It is envisaged that a maximum of 83 wind turbines are to be developed over time with a cumulative generation capacity of approximately 188 megawatts. Currently, the Eskom grid can only accommodate 35 turbines totalling approximately 80 megawatts, which will be the initial phase of the project. The wind turbines will have a hub height of between 80 to 120m and a rotor diameter of 87 to 120m.

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 new field of study in South Africa, and has only been the focus of much attention since the middle of 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. At present it has to be acknowledged that there is much to be learnt and this situation is likely to continue for some time.

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.
- 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. Furthermore, it is not always practically possible to schedule monitoring to coincide with the full spectrum of environmental conditions, due to practical constraints such as the availability of monitors and adverse weather conditions. It is hoped that a reasonable compromise was reached in this instance between representativeness and what turned out to be practically achievable.
- In circumstances where there is uncertainty and the precautionary principle may be relevant, evidence, expert opinion, best practice guidance and professional judgment was 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 (Retief *et al* 2012).

4. Methods

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

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

Actual monitoring happened during the following periods:

- Spring: October 2011
- Summer: February 2012
- Autumn: May 2012
- Winter: August 2012

4.1 Transects and point counts

The monitoring was conducted at the proposed turbine site and a control site by two field monitors. Monitoring is conducted in the following manner:

<u>Spring and summer</u>

- Two drive transects were identified totalling 17.48km within the proposed turbine area, and one drive transect in the control site with a total length of 7.72km.
- Two observers travelling slowly (± 10km/h) in a vehicle recorded all priority species on both sides of the transect. This is referred to in the report as the "survey area", and comprises an approximate 750m buffer area on both sides of the transect.
- The observers stopped at regular intervals (every 500 m) to scan the environment with binoculars. The transects were counted three times per seasonal sampling session.
- In addition, four walk transects of 1km each were identified at the turbine site, and two 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 (estimated Beaufort scale);
- 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).

Autumn and winter

On 14 February 2012, a new proposed turbine lay-out of 83 turbines was communicated to the author by Sivest Environmental Consultants, who conducted the EIA for the project. In view of this, the transects for the remaining two sampling seasons (autumn and winter) were adapted to better cover the revised turbine area (total length of adapted transects 18.2km). On 05 February 2013 a third lay-out was communicated to the author by Mainstream, which is a reduced lay-out, comprising 35 turbines (see Figure 2).

4.2 Vantage point observations

Spring and summer

Three vantage points (VP points) were selected 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 (see Figure 3). A total of 12 hours of observations per vantage point per season was conducted. Observations were conducted in two hour watches at a time by a single observer, in three periods namely morning (starting just after sunrise), midday, and late afternoon (starting three hours before sunset). The following variables were recorded:

- Species;
- Number of birds;
- Date;
- Watch start time and end time;

- Wind direction[1];
- Wind strength (Beaufort scale[2]);
- Weather (sunny; cloudy; partly cloudy; rain; mist);
- Temperature (cold; mild; warm; hot[3]);
- Flight altitude (high i.e approx. >180m; medium i.e. approx. 40-180 m; low i.e. approx. <40 m);
- Flight mode (soar; flap; glide ; kite; hover); and
- Flight duration (in 15 second-intervals).

Autumn and winter

On 14 February 2012, a new proposed turbine lay-out of 83 turbines was communicated to the author by Sivest Environmental Consultants, who is conducting the EIA for the project. In view of this, it was decided to change the location of the VPs to better cover the revised turbine area for the remaining two seasons (autumn and winter). Two VPs (VP2 and VP3) were terminated and a new VP (VP4) was created to better cover the proposed revised turbine area. On 05 February 2013 a third lay-out was communicated to the author by Mainstream, which is a reduced lay-out, comprising 35 turbines.

4.3 Focal point counts

Two focal points of potential significant avifaunal activity were identified namely a Blue Crane nest (31°10'241S 25°02'219E) at the turbine site, and a grassy area around a small temporary dam on the control site which according to the landowner also contained a breeding pair of Blue Cranes.

Figure 1 indicates the survey areas, habitat types, VP points and focal point.

4.4 Habitat classification

The following avifaunal habitat classes were identified at the turbine site and control site:

- Grassy Karoo: An ecological transition zone between Nama Karoo and grassland, primarily a dwarf shrub habitat, but with a high proportion of grass.

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[1] For statistical analysis, data from the wind measuring mast on the site was used as measured at 80m.

[2] See footnote 1

[3] See footnote 1

- Wetland: Present in drainage lines, and include farm dams.
- Agriculture: Irrigated crops, mostly lucerne.

Table 1: Habitat quantities in the turbine and control survey areas

	Turbine		Control	
	Hectares	**% of total survey area**	**Hectares**	**% of total survey area**
Grassy Karoo	3288	97%	1409	94%
Wetland	76	2%	47	3%
Agriculture	29	0.8%	45	3%

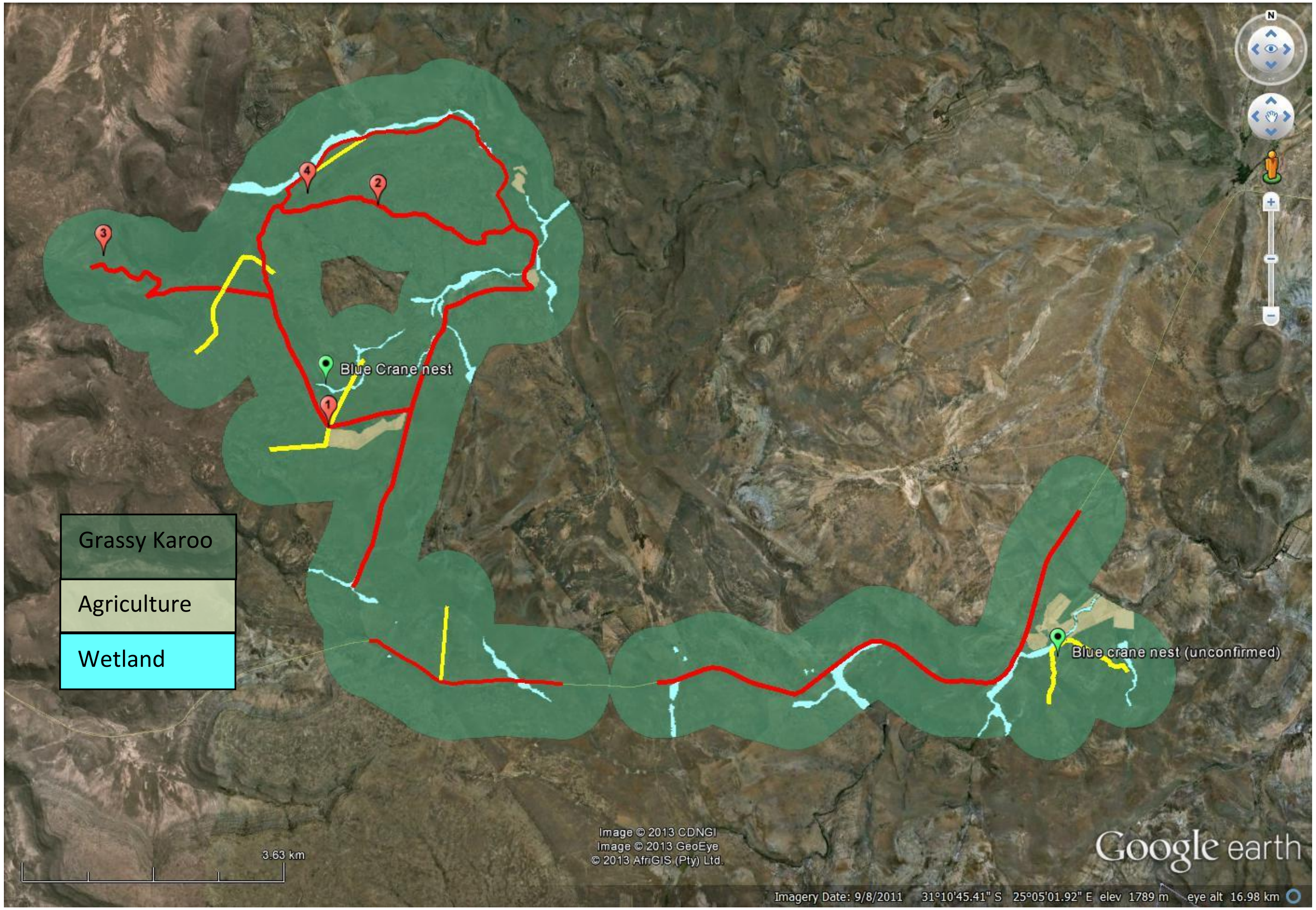

Figure 1: Habitat in the survey areas, with drive transects (red lines), walk transects (yellow lines), VPs (red placemarks) and focal points (green placemarks). The turbine survey area is on the left and control area is on the right (see Figure 2).

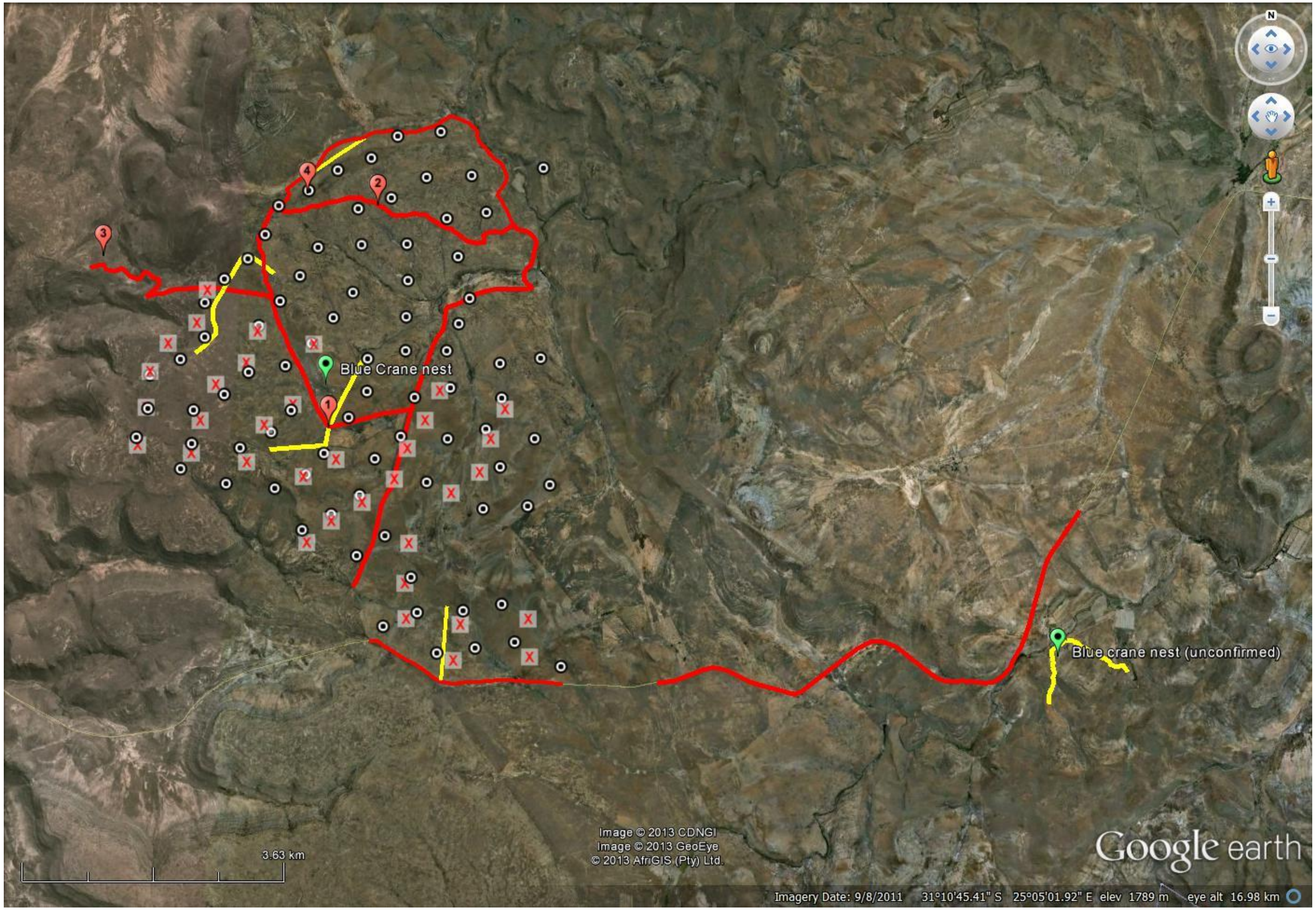

Figure 2: Turbine lay-out in the survey area, with drive transects (red lines), walk transects (yellow lines), VPs (red placemarks) and focal points (green placemarks). The dots show the 83 turbine lay-out (long term), and the crosses the 35 turbine lay-out (short term).

5. Results

5.1 Transects and focal point surveys

5.1.1 Transects (drive and walk)

The study area was surveyed 12 times, three times per season. A total of 1 782 birds were recorded at the turbine site, of which 602 were priority species and 1 170 non-priority species, belonging to 68 species. At the control site, a total of 1 456 birds were recorded, of which 180 were priority species and 1 276 non-priority species, belonging to 77 species (see Appendix 1). 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 3 and 4 below).

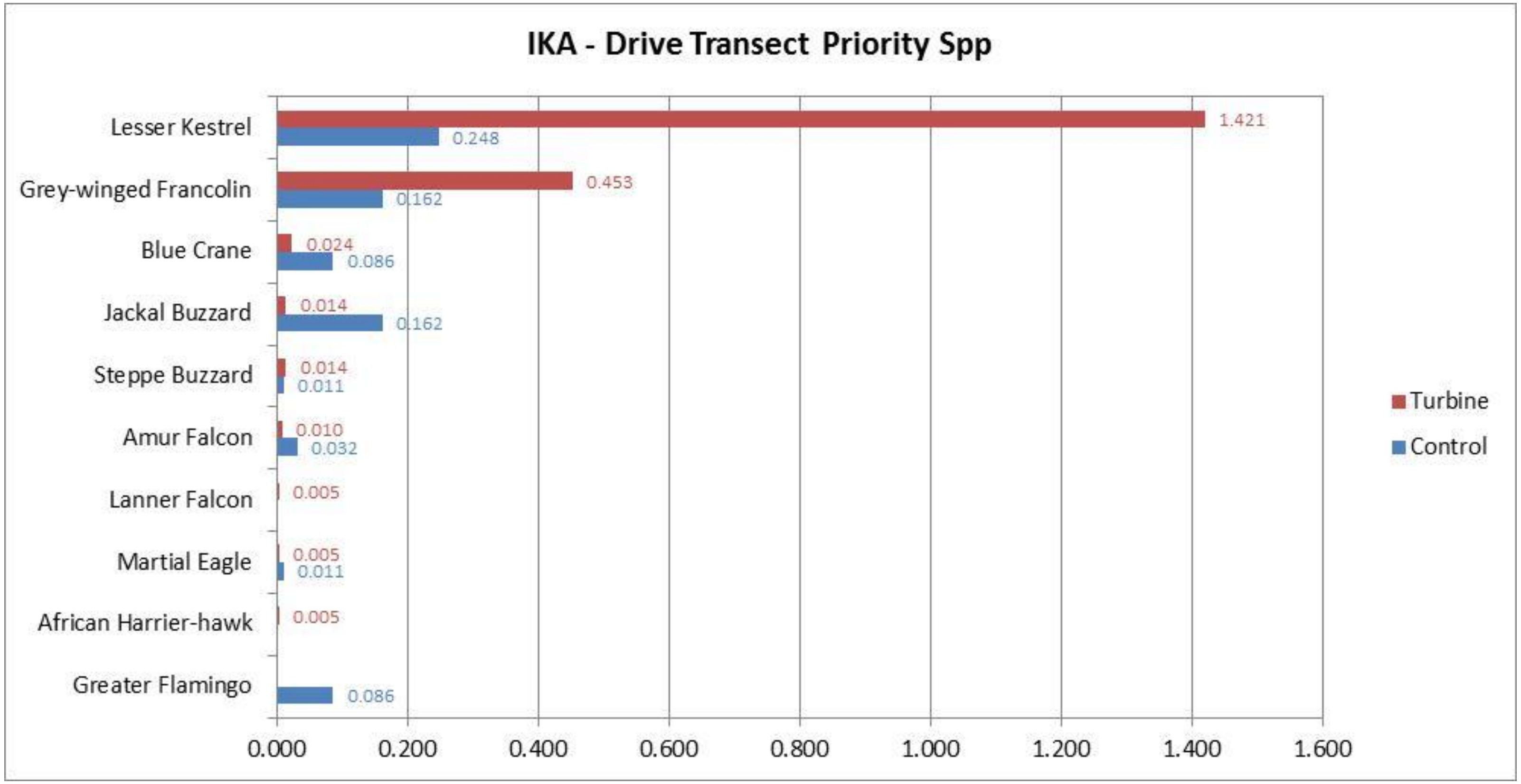

Figure 3: Priority species recorded at the turbine and control site through drive transect surveys

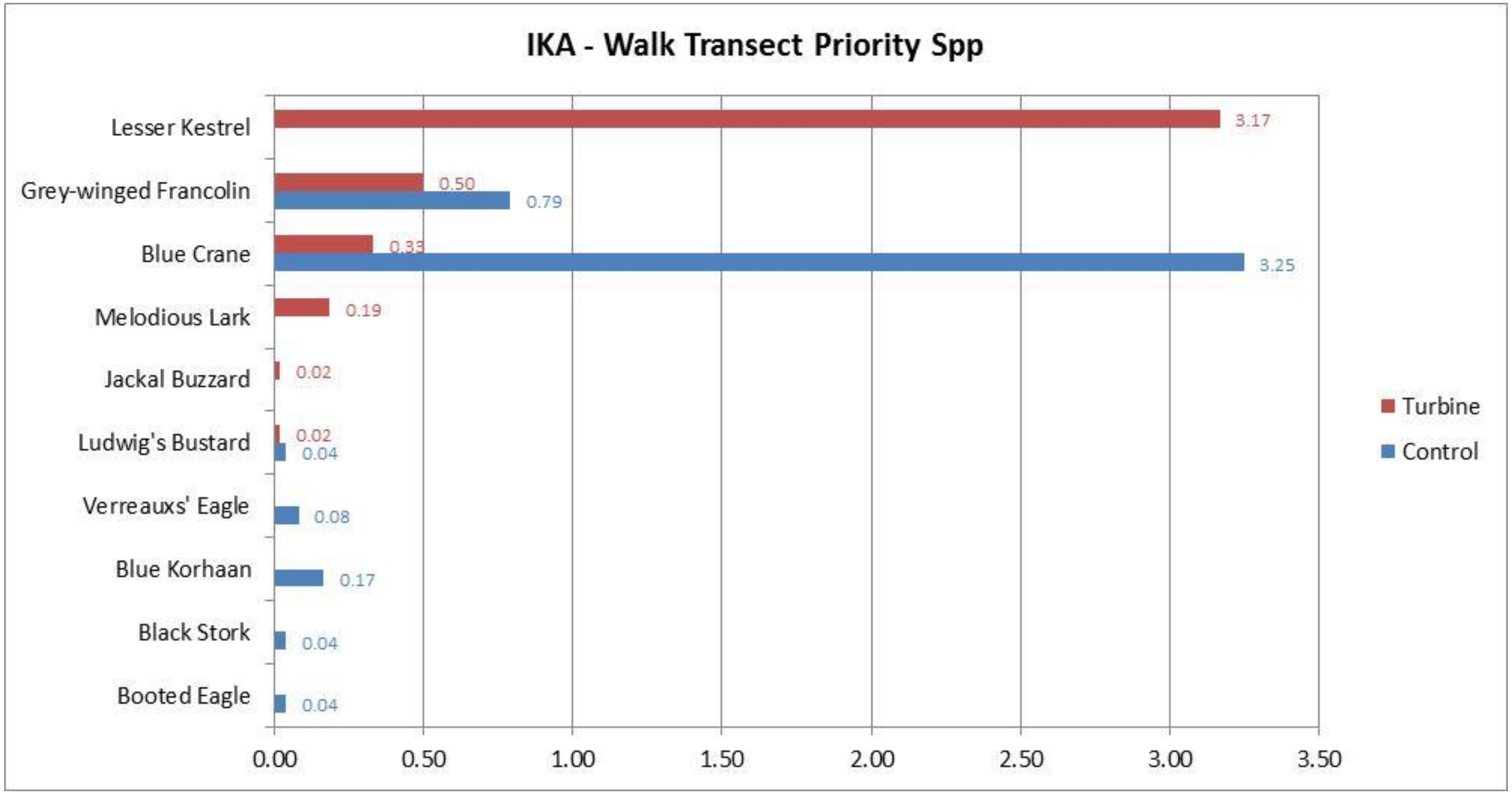

Figure 4: Priority species recorded at the turbine and control site through walk transect surveys

Using the walk transects, an indication of habitat preference for all birds was determined by calculating *a species diversity per habitat index* as the number of species recorded per unit area of habitat type ÷ habitat % of total area (see Figure 6 below). In addition a species *abundance per habitat index* is also calculated as the number of individuals recorded per unit area of habitat type ÷ habitat % of total area (see Figure 7 below). The former is needed to get an indication of which habitat type supports the greatest **variety of species** at the site, and the latter to get an indication of which habitat is likely to attract the **biggest number of species individuals**. The *species abundance per habitat index* was also calculated for the three most frequently recorded priority species at the turbine site and control site (Figures 8 and 9). Birds that were only observed as commuting over the site were excluded from this analysis.

The spatial distribution of sightings of the three priority species with the highest IKA at the turbine site, i.e. Lesser Kestrel, Grey-winged Francolin and Blue Crane, is indicated in Figure 5 below.

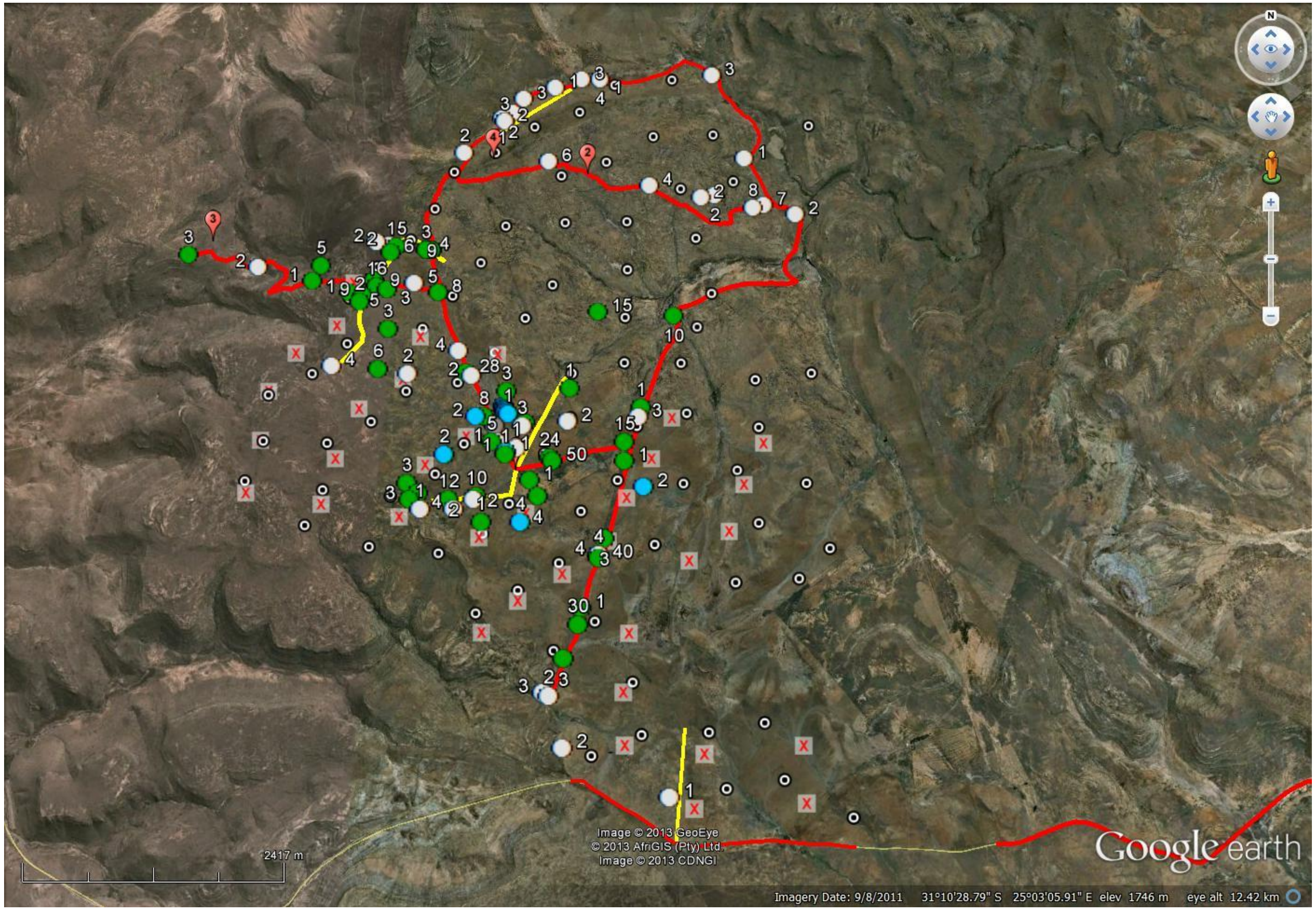

Figure 5: Spatial distribution of sightings of Lesser Kestrel (green dots), Grey-winged Francolin (white dots) and Blue Crane (blue dots) recorded during transect counts. Numbers of individuals are indicated next to the dot.

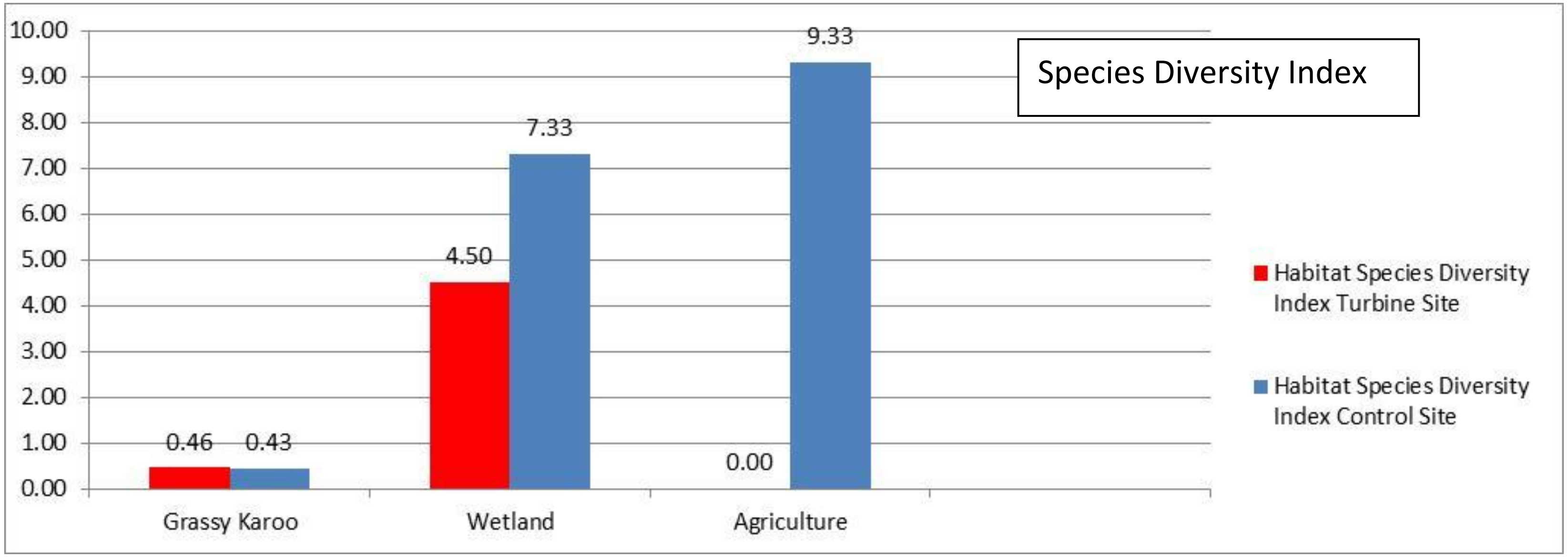

Figure 6: Species diversity per habitat index for both the turbine and control site

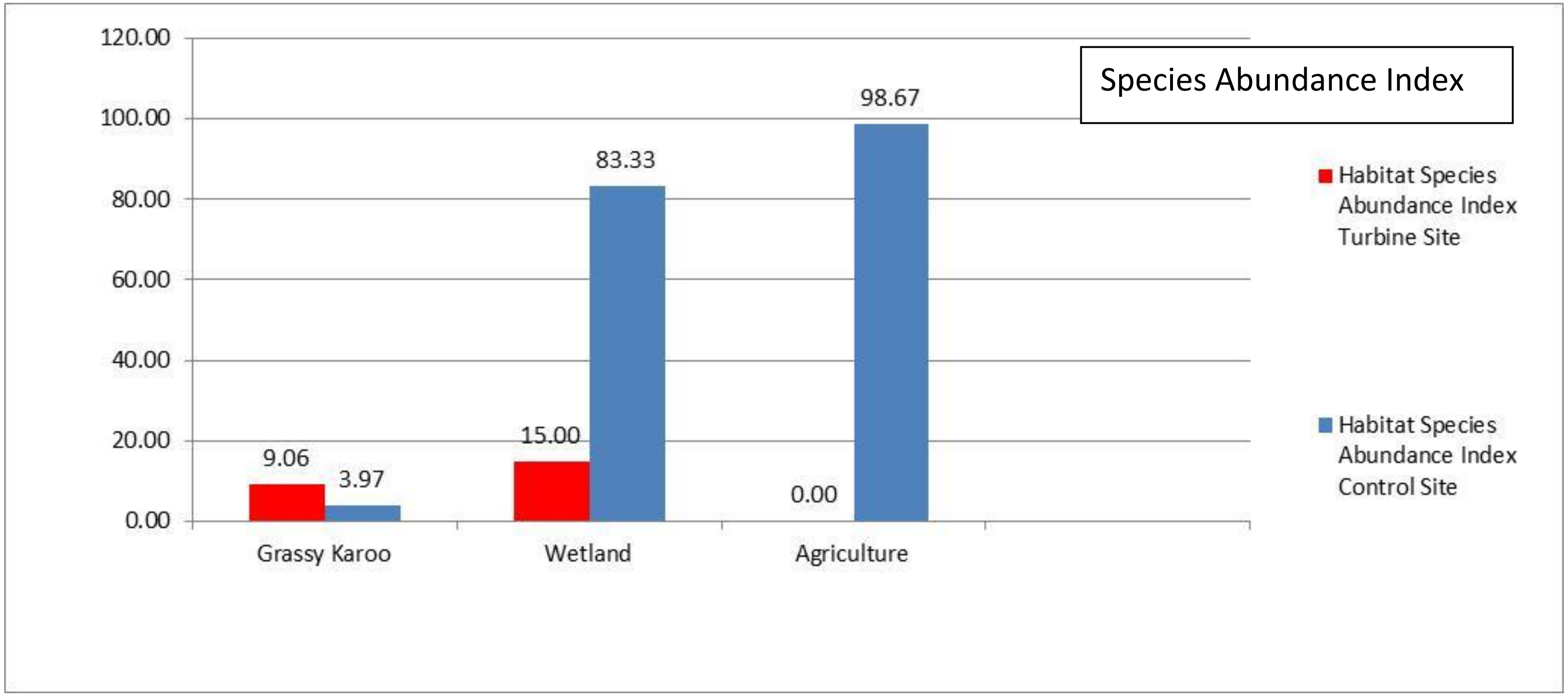

Figure 7: Species abundance per habitat index for both the turbine and control site

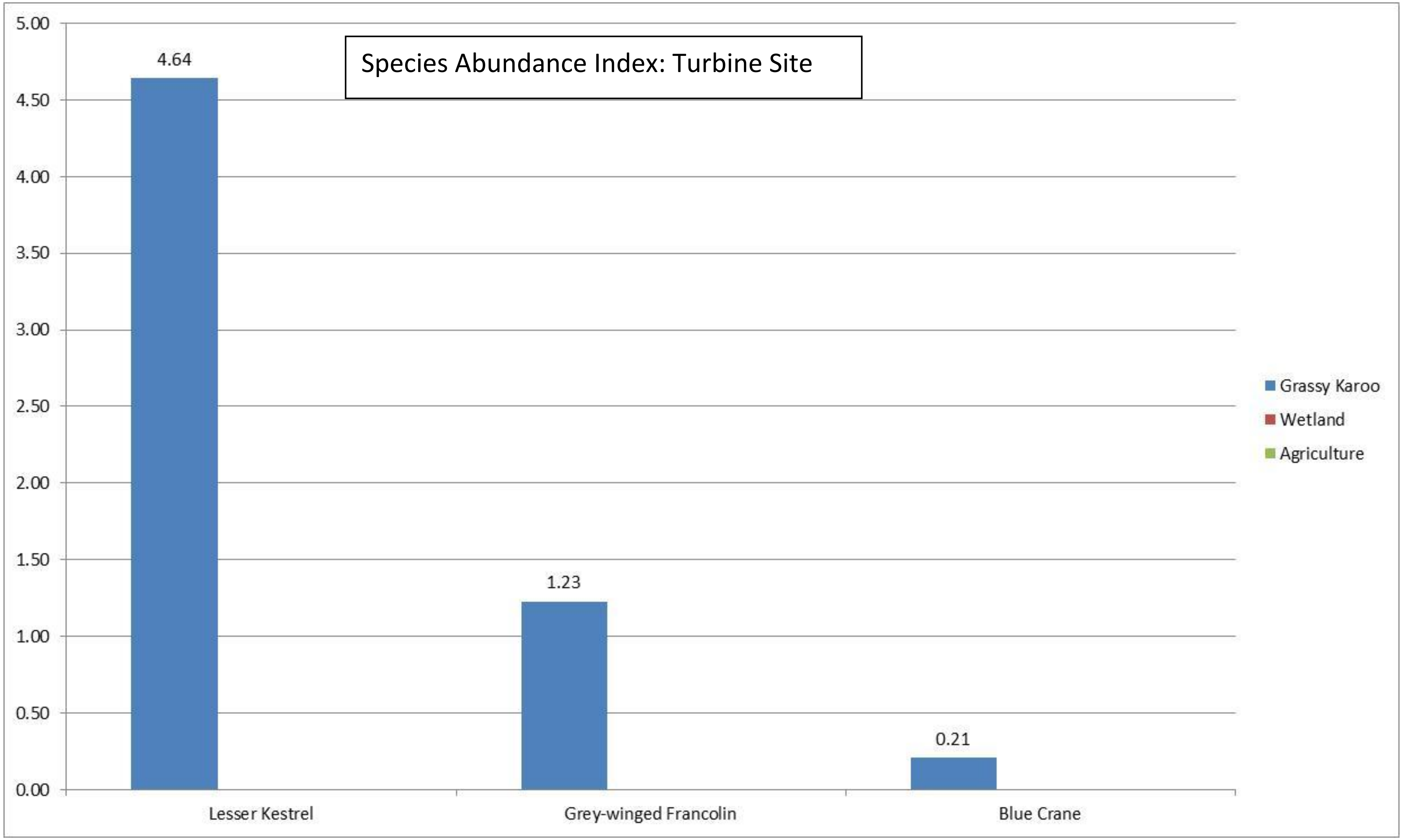

Figure 8: Species abundance per habitat index for the turbine site for the three most recorded priority species

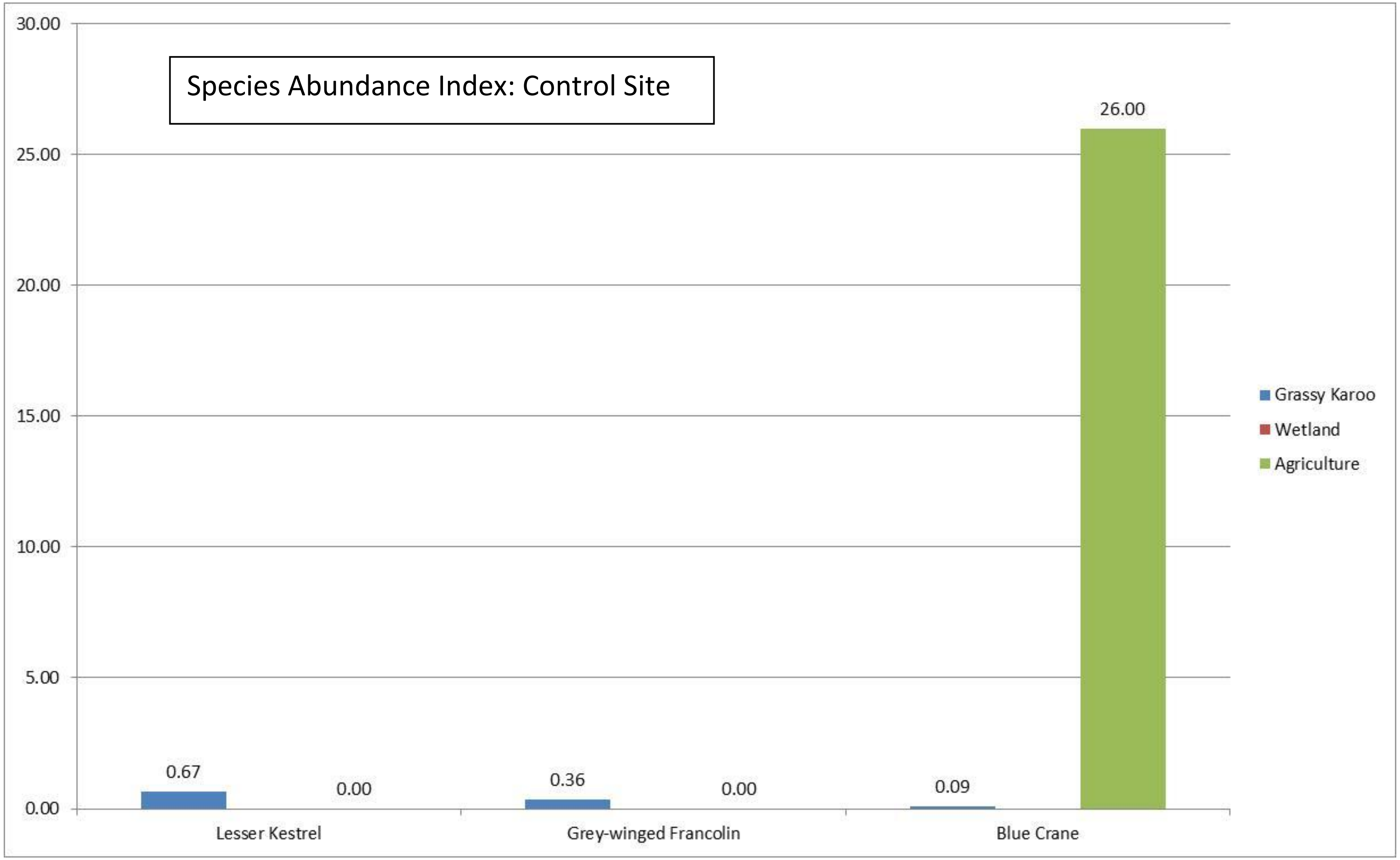

Figure 9: Species abundance per habitat index for the control site for the three most recorded priority species

5.2 Vantage point observations

A total of 120 hours of vantage point watches (12 hours per season per vantage point) was completed in order to record flight patterns of priority species. In the four seasonal sampling periods, priority species were recorded flying over the VP area for a total of 1 hour 57 minutes and 15 seconds. A total of 77 individual flights were recorded. Of these, 22 (29%) flights were at low altitude (below rotor height), 44 (57%) were at medium altitude (i.e. approximately within rotor height) and 10 (13%) were at a high altitude (above rotor height). The passage rate for priority species over the VP area (all flight heights) was 1.41 birds/hour[4]. The passage rate for medium height flights only was 1 bird/hour. See Figure 10 below for a breakdown of time spent by priority species at the various flight heights within the VP area.

For some of the analyses (see below), priority species with similar flight characteristics were grouped together in the following manner:

- Terrestrial species: Small to large 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 species undertake longer distance flights at higher altitudes, when commuting between foraging and roosting areas. At the wind farm site, larks, cranes, bustards, francolins and Secretarybirds are potentially included in this category.
- 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, these are mostly raptors, but potential soaring flights of Blue Cranes and Secretarybird are also included in this category.

[4] 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.

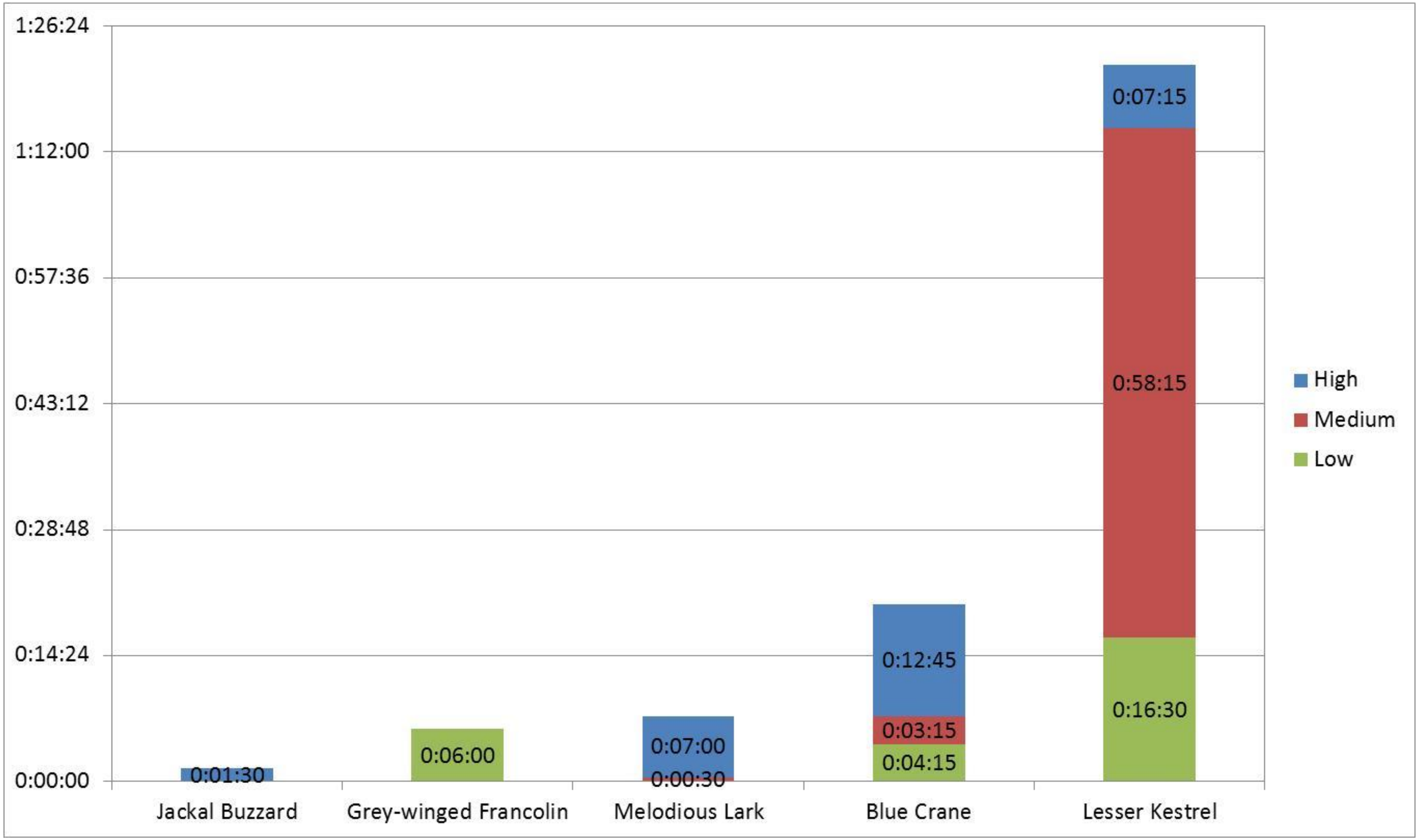

Figure 10: Flight times and heights recorded for priority species (Y axis = hours: minutes: seconds)

5.2.1 Site specific collision risk rating

A site specific collisions risk rating for each priority species recorded during VP watches was calculated taking into account the following factors:

- number of birds in every passage which contained medium height flights;
- 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 was as follows:

sum of birds per passage containing medium height flights x sum of duration of medium height flights in 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 2 and Figure 11 below.

Table 2: Site specific collision risk rating

Species	# birds	Duration of flights (hr)	Collision rating	# turbines	Risk rating
Blue Crane	6	0.054	80	83	22
Jackal Buzzard	0	0	95	83	0
Grey-winged Francolin	0	0	35	83	0
Lesser Kestrel	114	0.712	72	83	4851
Melodious Lark	1	0.008	40	83	0

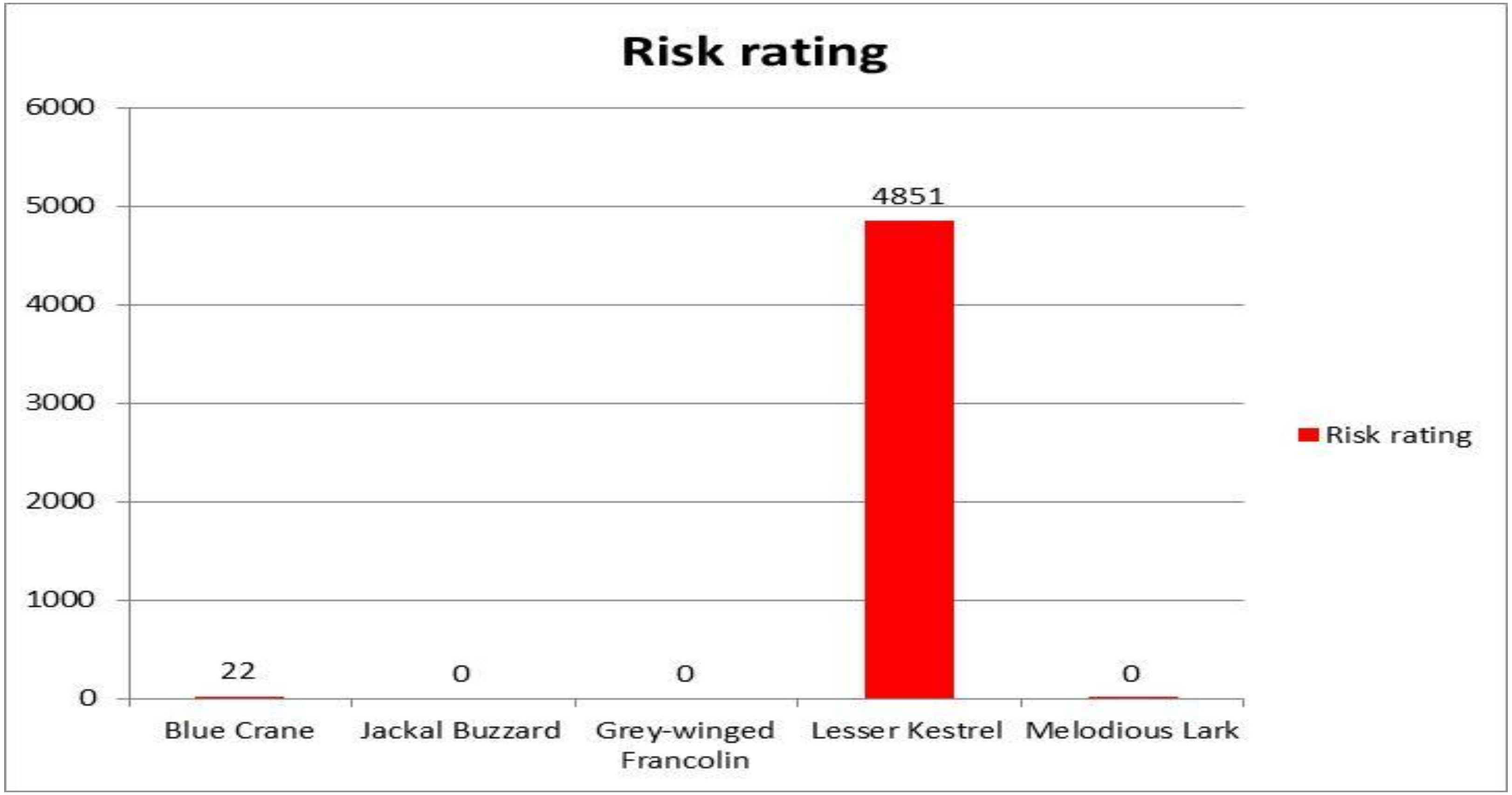

Figure 11: Site specific collision risk rating for priority species.

5.2.2 *Association between rotor height flights and environmental factors*

The potential association between rotor height (medium height) flights over the turbine area and a range of environmental factors was investigated to establish under what conditions and for what species the risk of collisions with the turbines will be highest:

- The potential correlation between medium height flights and **wind direction** was investigated. This was done to establish if wind direction plays a role in the extent of the collision risk i.e. if birds are more likely to fly at medium height over the turbine area when the wind is blowing from a specific direction. Actual wind direction data was obtained from the client for the periods when vantage point watches were performed[5].
- The potential correlation between medium height flights and **wind strength** was investigated. This was done to establish if wind strength plays a role in the extent of the collision risk i.e. if birds are more likely to fly at medium height over the turbine area when the wind is blowing at a specific strength. Wind strength data was obtained from the client for periods when vantage point watches were performed and transformed to classes using the Beaufort scale standard[6].
- The potential correlation between medium height flights and **temperature** was investigated. This was done to establish to what extent ambient temperature played a role in flight activity[7].
- Statistical process control charts were applied to consecutive daily counts to establish to what extent the data could be considered to be "in control". Daily running averages were also plotted against consecutive counting dates. This helped in the assessment of the stability of the counting process and thus to what extent the statistical inferences drawn from this dataset may be accepted as **representative of the true situation.**

5.2.2.1 Representativeness of flight data

As the data are gathered day after day an improved estimate of the number of birds that occurs in the area is achieved. As more data are gathered the more refined the estimate will become. The issue is to determine if the data at hand provide a fair representation of the true situation in the area, i.e. if the average begins to stabilise towards the end of the observation period (and hence a representative sample has been achieved).

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[5] Wind direction has the categories of the wind rose: *N, NW, W, SW, S, SE, E* and *NE*.

[6] The Beaufort scale classes (in m/s) are bounded as follows: 0≤Calm≤ 0.25, 0.25<Light Air ≤1.55, 1.15<Light Breeze≤3.35, 3.35<Gentle Breeze≤5.45, 5.45<Moderate Breeze≤7.95, 7.95<Fresh Breeze≤10.75, 10.75<Strong Breeze≤13.85,13.85<Near Gale≤17.15, 17.15< Gale≤ 20.75, Severe Gale > 20.75.

[7] Temperature into classes *Cold* (<= 10°C), *Mild* (> 10°C and <= 20°C), *Warm* (> 20°C and <= 30°C) and *Hot* (> 30°C).

The average number of flights (as well as that of individual birds recorded) is computed as the data become available watch period by watch period (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 may vary substantially due to differences in seasonal conditions, the updated averages were determined separately for each season.

Figure 12 plots these updated averages for the soaring bird species (the number of flights observed as well as a count of the total number of individual birds observed). Figure 13 is a similar representation for the terrestrial bird species.

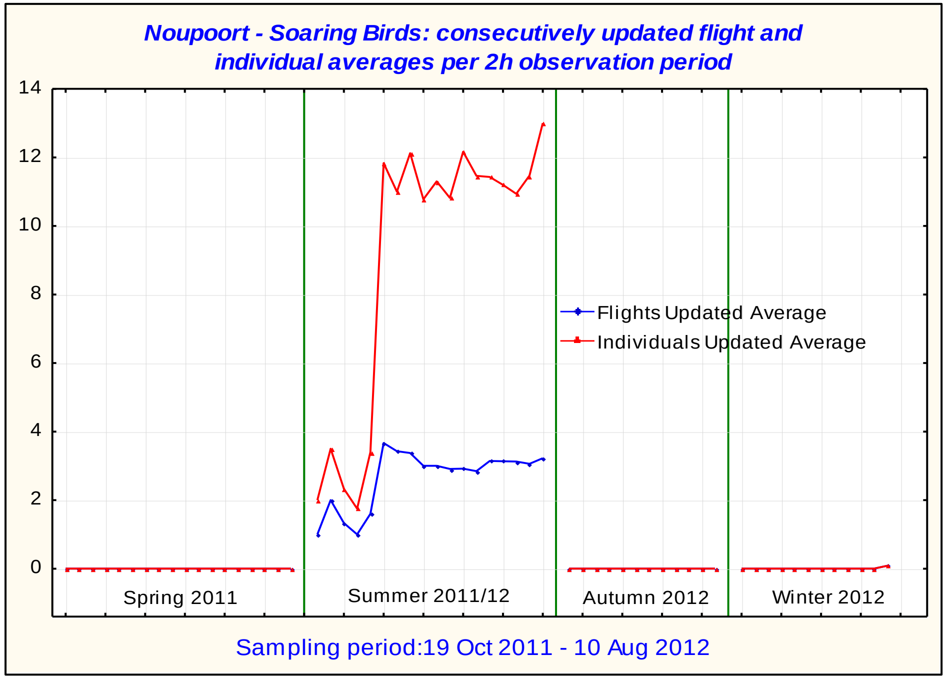

Figure 12: Soaring Birds: updated average number of *Flights* and *Individuals*

Figure 13 shows that practically no soaring birds were present during spring and autumn and the updated average shows a blip where a single soarer was recorded during the winter sampling. Figure 12 shows that the summer counts smoothed out horizontally quite well too. That alone may be taken as reasonable evidence that the summer data are representative of the true picture. It seems a reasonable conclusion that stability in counts has been obtained and that the available data provide a representative picture of the flight activity of the soaring avifauna over the turbine area during the seasonal sampling periods.

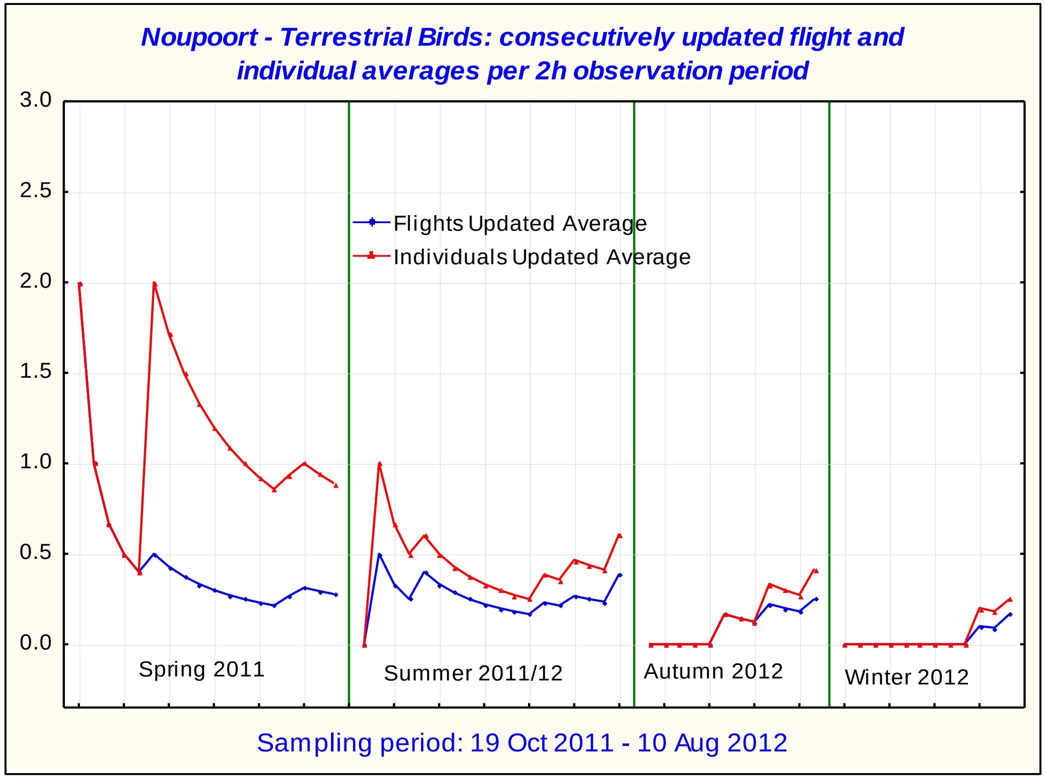

Figure 13: Terrestrial Birds: updated average number of *Flights* and *Individuals*.

Figure 13 shows that the updated averages for flight and individual counts for terrestrial birds are reasonably stable towards the end of each of the four seasons. Therefore stability is accepted to have been reached in the counts, specifically also because the variability for both flights and individual counts of terrestrial birds are much smaller than for soaring birds. Accordingly the data should provide a good representation of the terrestrial bird flight activity in the region

Appendix 2 provides an in-depth explanation of the statistical methods and analyses.

5.2.2.2 Association between rotor height flights and environmental factors

Flight height was categorised with values “Low”, “Medium” and “High”. For soaring birds only those records where *Medium* flight heights have been recorded were extracted from the database for analysis. All observation periods (VP watch periods) were divided into ten minute intervals (780 in all) and all flights occurring in each ten minute interval are listed in the database. The environmental factor measurements (*Temperature, Wind Direction* and *Wind Strength*) were made available within each of the ten minute intervals. The associations between counts for birds at *Medium* flight height and the factors *Temperature, Wind Direction* and *Wind Strength* were then considered.

Table 3 presents the average numerical values of the three environmental factors as well as some basic statistics, in particular the 95% confidence intervals for the average for medium height soaring birds. N = 29 flights of medium height soarers were recorded in the 780 ten minute observation periods. These 29 flights consisted of 184 individual birds. Of these, 182 were Lesser Kestrels and two were Blue Cranes. All of these were recorded in the summer sampling season with no sightings during spring, autumn and winter.

As far as the terrestrial birds are concerned only N = 3 flights consisting of a total of 5 birds were recorded. These sightings occurred, just as for the soaring birds, only in summer. In the light of the small number of relevant terrestrial birds it was considered advisable not to list basic statistics for this group as those may be misleading.

Table 3 lists the basic statistics for soaring birds. *Temperatures, Wind Directions* and *Wind Strength* statistics are listed for the 29 flights only. These are not weighted with the individual counts.

Table 3. Descriptive statistics for soaring birds. The quantitative measurements on the three environmental factors, including 95% upper (UCL) and lower (LCL) confidence limits for the mean. Only for the periods in which at least one bird was recorded.

Environmental factor	Soaring birds				
	N	Mean	95% LCL	95% UCL	Std. Dev.
Temp °C	29	22.8	21.3	24.3	3.9
Wind Direction	29	104	87	122	41.8
Wind Strength	29	6.7	6.1	7.2	1.5

From Table 3, as a rough guide, it can be said that the soaring birds i.e. effectively Lesser Kestrels were observed, on average, at *Warm* temperatures, when the *Wind Direction* was North-East to South-East and when the wind strength was at a *Moderate Breeze*.

5.3 Focal point counts

Two focal points of potential significant avifaunal activity were identified namely a Blue Crane nest at the turbine site, and a grassy area around a small temporary dam on the control site which according to the landowner also contained a breeding pair of Blue Cranes (see Figures 1 &2). The Blue Crane nest at the turbine site was discovered at the turbine site during the spring monitoring. The nest is situated at 31°10'241S 25°02'219E. During the summer monitoring period, it was established the cranes had bred successfully and two chicks were observed with the parents. As expected, no activity was observed after the breeding season autumn and winter monitoring periods.

During the spring monitoring period, a pair of Blue Cranes was recorded displaying at the control focal point. No further activity was recorded during subsequent monitoring periods.

5.4 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 14-16 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.

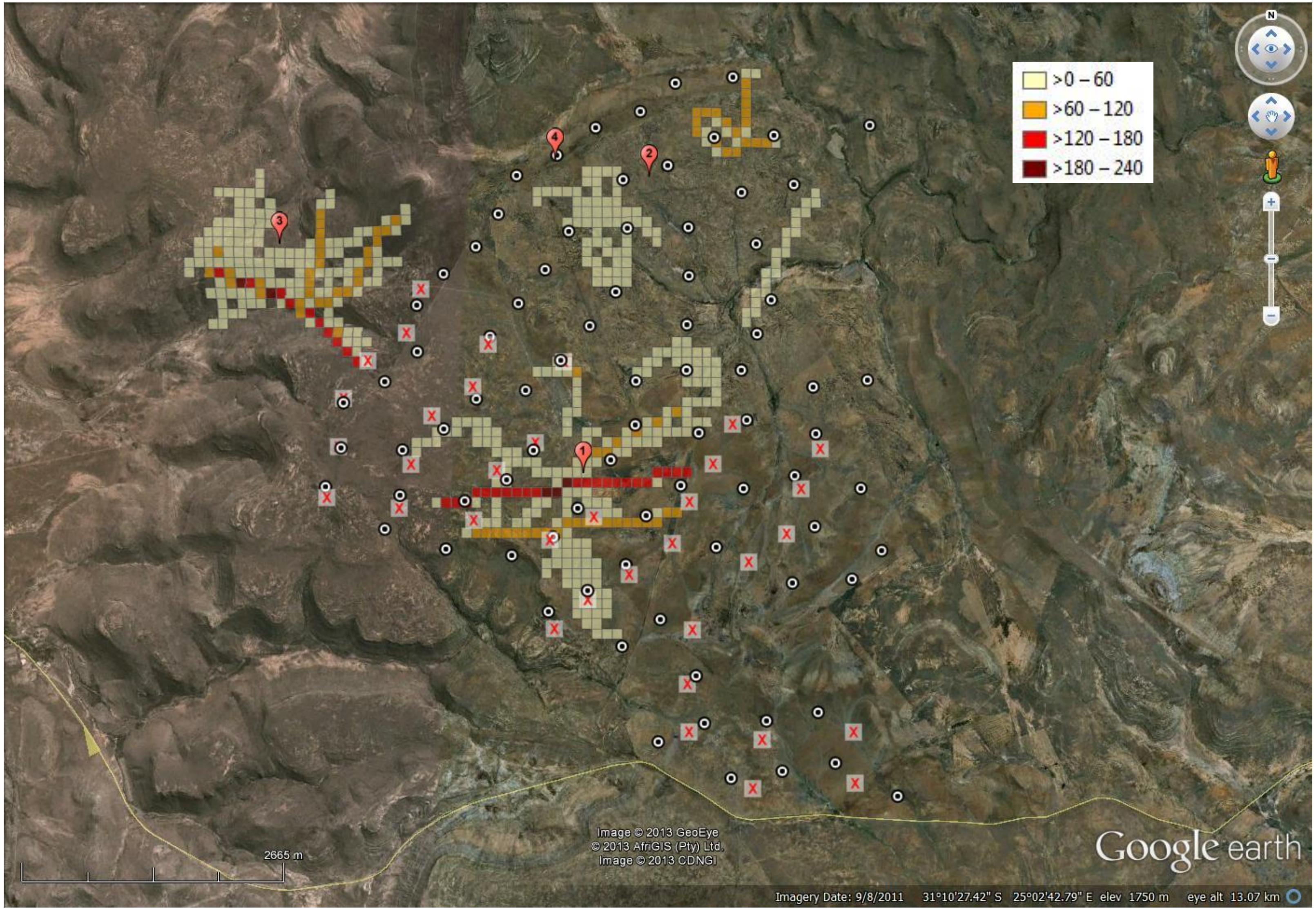

Figure 14: Spatial distribution of medium height flights for all priority species.

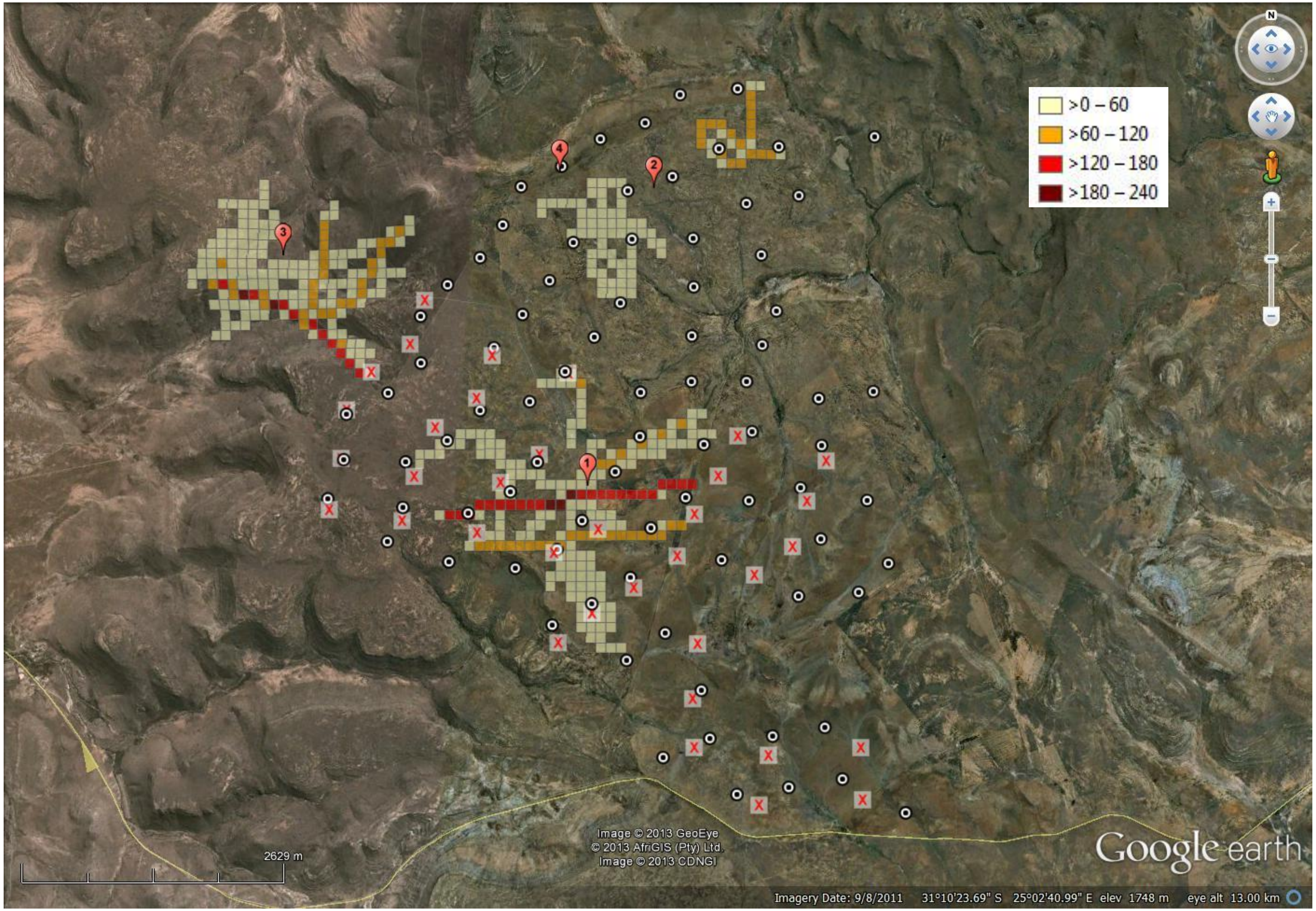

Figure15: Spatial distribution of medium height flights for all soaring priority species.

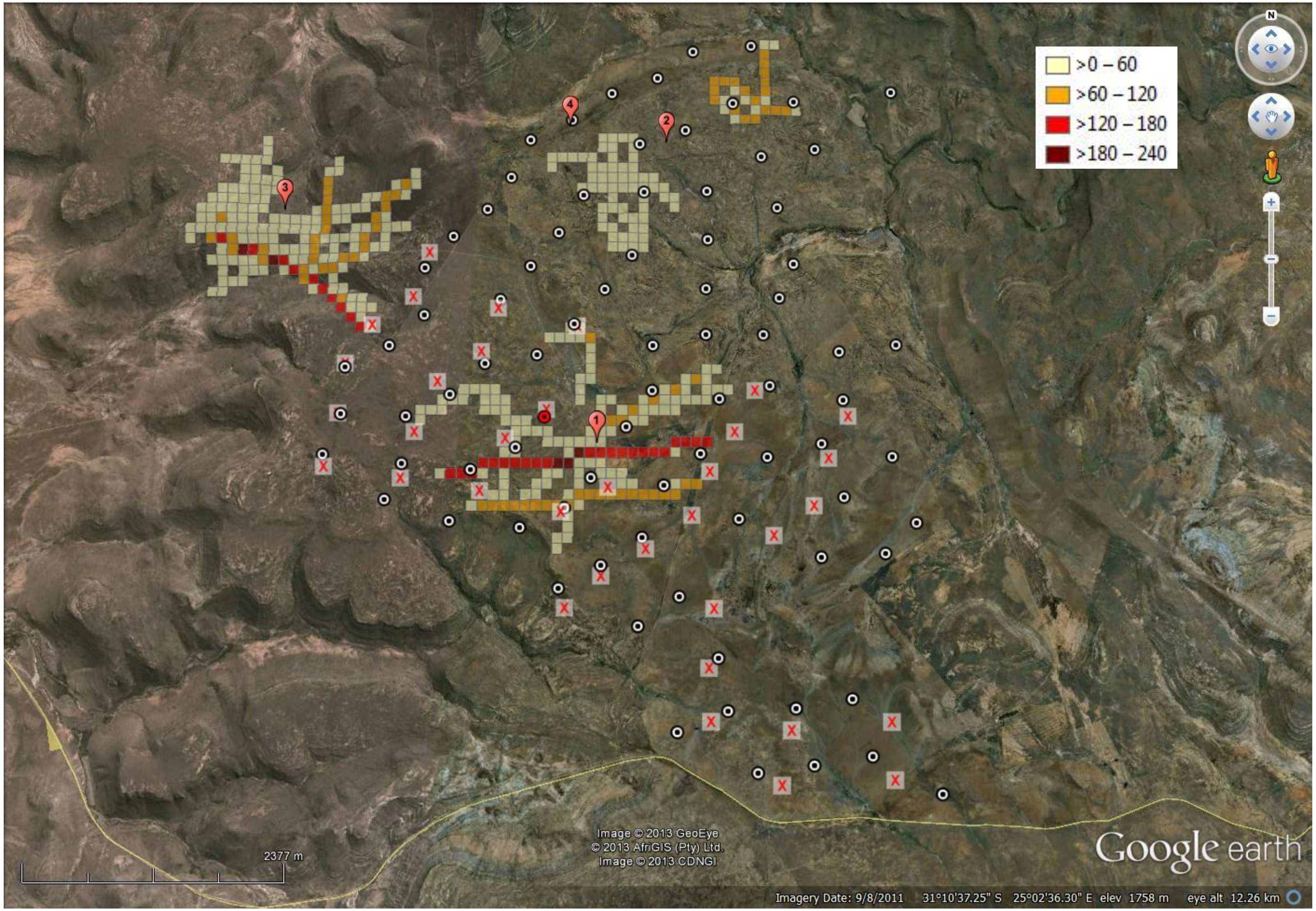

Figure 16: Spatial distribution of medium height flights for Lesser Kestrel.

6. Discussion

6.1 Transects and focal points

With an overall species count of 68, of which 11 species are priority species, the turbine site supports a relatively low diversity of avifauna, which is to be expected in this arid environment. The control site has a comparable overall species count of 77 species of which 13 are priority species, which is broadly similar to the turbine site. At the turbine site, both the drive transects and the walk transects produced the same order of abundance for priority species, namely Lesser Kestrel, Grey-winged Francolin and Blue Crane. Lesser Kestrel was overwhelmingly the most abundant priority species. At the control site, the drive transects produced a similar order of abundance to the turbine site, except that Jackal Buzzard was the third most recorded priority species, with Blue Crane in the fourth place. The walk transects produced a significantly different picture compared to the turbine site, with the following order of abundance: Blue Crane, Grey-winged Francolin and Blue Korhaan. The high IKA for Blue Cranes at the control site was largely due to a flock of 70 individuals which was recorded in an agricultural field during one of the winter walk transect surveys.

As far as habitat preferences are concerned, the habitat indices for all species (using the data from walk transects only) indicate that relative to the available habitat, overall species diversity at the turbine site is highest in wetlands, followed by Grassy Karoo, with no species recorded during walk transects in agricultural habitat. At the control site, the order of preference is somewhat different, with agriculture supporting the biggest species diversity, followed by wetland and Grassy Karoo, in that order. From an abundance perspective, relative to the amount of available habitat at the site, individual birds were most commonly recorded in wetland habitat, followed by Grassy Karoo, with no birds recorded in agriculture. At the control site, a different picture emerged, with individual birds most commonly recorded in agriculture, closely followed by wetlands and Grassy Karoo a distant third. The species specific indices for the three most recorded priority species (combining the data from walk transects and drive transects), indicate that Lesser Kestrel, Grey-winged Francolin and Blue Crane all prefer Grassy Karoo at the turbine site. At the control site, the same is the case with Lesser Kestrel and Grey-winged Francolin, but Blue Cranes show a strong preference for agriculture. The index for the control site was strongly influenced by the single flock of 70 birds in an agricultural field that was recorded during one of the winter walk transects. No Blue Cranes were recorded in agricultural habitat at the turbines site, which is somewhat surprising. It could however be a function of the small size of the available agricultural habitat at the turbine site, and/or the unpredictable spatial distribution of Blue Crane flocks during the winter (non-breeding) season.

As far as the spatial distribution of records of the priority species at the turbine site is concerned, Blue Cranes records are clearly clustered around the breeding area of the pair of Blue Cranes. Blue Cranes may be less prone to displacement than some other large terrestrial species (e.g. bustards), as they seem to have adapted well to anthropogenic disturbances and agriculture activity. The birds seem to co-exist without problems on farms with intensive agricultural operations in the Overberg region of the Western Cape (Young *et al.* 2003; pers. obs.).

However, even in areas such as the Overberg with extensive agricultural operations, Blue Cranes have been shown to select nesting sites that are were significantly further from buildings and farm tracks than were random sites (Bidwell 2004), indicating that buffer zones will be required around nest sites.

Grey-winged Francolin occurs all over the site with no specific spatial pattern evident. The potential long term displacement of Grey-winged Francolin is difficult to assess, again due to the lack of scientific precedents, and whether this species will successfully habituate and re-occupy suitable habitat post-construction (assuming displacement is likely during the construction phase) will only become clear with long term monitoring.

Lesser Kestrel records seem to be concentrated in the western and central sections of the site. No immediate explanation is evident for the Lesser Kestrel distribution patterns; the most likely explanation is that it may be linked to food sources. As far as raptors are concerned, the chances of displacement are low, based on research results elsewhere (Madders and Whitfield 2006). This trend also seems to be supported by the results of the limited post-construction monitoring conducted at the existing four turbines at the Darling Wind Farm (Van Rooyen 2011). It is therefore unlikely that Lesser Kestrels will be displaced in the long term.

6.2 Vantage point observations

6.1 Representativeness of counts

No soaring species were recorded during spring and autumn and only a single soaring species (a Jackal Buzzard) was recorded during the winter sampling effort. Practically all soaring flight activity was concentrated in summer, which consisted almost exclusively of Lesser Kestrel (a summer migrant), except for a few soaring flights of Blue Cranes. The updated average for soaring flights smoothed out well by the end of the summer sampling period, indicating that the picture for soaring flights is representative of the actual situation on the ground. The situation with individual counts (i.e. the number of birds present in every flight) is different. Here the counts vary widely with a number of outlier counts. In summer the largest count is 54 and second largest 27 (which itself is much larger than the rest). This indicates that the number of individual Lesser Kestrels engaging in aerial foraging at the site varies substantially and that a larger sample size would be required to obtain a representative sample. However, the updated average for soaring individuals has smoothed out horizontally quite well, even with sample size of 18 counts (see Figure 12). That alone may be taken as reasonable evidence that the summer data are representative of the true picture.

Figure 13 shows that the updated averages for flight and individual counts for terrestrial species are reasonably stable towards the end of each of the four seasons. Therefore stability is accepted to have been reached in the counts, specifically also because the variability for both flights and individual counts of terrestrial birds are much smaller than for soaring birds. Accordingly the data should provide a good representation of the terrestrial flight activity at the site. As expected, flight activity of terrestrial species (Blue Crane, Melodious Lark and

Grey-winged Francolin) is much less compared to soaring species, which points to a much lower risk of collision if based purely on the amount of time spent at rotor height (see Figure 10). Grey-winged Francolin was never recorded at rotor height.

6.2 Site specific risk rating, spatial distribution and association with temperature, wind direction and wind strength

Based on the site specific rating, Lesser Kestrels are overwhelmingly the species most at risk of collision.

The analysis revealed a statistically significant association between medium height flights for soaring species and **temperature**, with medium height flights associated mostly with warm temperatures. Flight activity is conspicuously less in cold and mild temperatures. This may be linked to the presence of thermals, which is associated with warmer temperatures. However, the influx of migratory Lesser Kestrel in summer, when temperatures are generally warmer, might be the decisive factor here, rather than a specific preference for warm temperatures. It may also be that their insect prey is more active during warm temperatures, triggering aerial foraging activity.

A statistically significant association for soaring species also emerged for **wind direction** and medium height flights, with flight activity almost absent in winds with a north to north-westerly orientation, and most prevalent in winds with a south to south-easterly orientation. This could most likely again be linked to the presence of Lesser Kestrels in summer i.e. when the prevailing wind orientation is south to south-east, which means that flight activity over the site is much reduced in winter.

Wind strength also emerged as statistically significant for soaring species (i.e. Lesser Kestrels), with medium height flights more prevalent in moderate breezes. This seems intuitively correct with Lesser Kestrels probably preferring moderate breezes to perform their characteristic hovering. Too little wind would probably require too much energy expenditure to maintain sustained hovering flight activity, and flight becomes difficult for a small raptor to control in gale and near gales.

A factor that most likely plays a role in the spatial distribution of flights is **availability of food sources**. The concentration of flight activity recorded for Lesser Kestrels in the western and central part of the study area is probably linked to the presence of their insect prey, and presents a potential avenue for further exploration during subsequent monitoring. The spatial distribution of flight activity recorded during VP watches correspond roughly with the location of sightings recorded during transect counts. Whether this spatial distribution is valid for the entire summer season when the birds are present can however not be stated with certainty, as this may vary in response to prey availability.

No detailed association analyses were conducted for terrestrial species due to the small number of records. That in itself is valuable information: since so few terrestrial species are expected to be present from a reasonable sample, it may be concluded that the risk of fatal collisions will be small.

In summary it can be said that collision risk at the site is most prevalent for Lesser Kestrels, on average, in warm temperatures, when the wind direction is south to south--easterly and when the wind strength is at a moderate breeze.

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 68, of which 11 species are priority species, the turbine site supports a relatively low diversity of avifauna, which is to be expected in this arid environment. The control site has a comparable overall species count of 77 species of which 13 are priority species, which is broadly similar to the turbine site.
- Priority species site specific abundance: Based on numbers counted, Lesser Kestrel (summer only), Grey-winged Francolin and Blue Crane are most commonly recorded at the turbine site, with Lesser Kestrel overwhelmingly the most abundant priority species. Other priority species irregularly observed were mostly raptors i.e. Steppe Buzzard, Jackal Buzzard, Amur Falcon (in association with Lesser Kestrel), Lanner Falcon, Martial Eagle and African Harrier Hawk. Ludwig's Bustard was recorded once only, and Melodious Lark was recorded in low numbers in spring and autumn.
- As far as habitat preferences are concerned, the habitat indices for all species (using the data from walk transects only) indicate that relative to the available habitat, overall species diversity at the turbine site is highest in wetlands, followed by Grassy Karoo, with no species recorded during walk transects in agricultural habitat.
- From an abundance perspective, relative to the amount of available habitat at the site, individual birds were most commonly recorded in wetland habitat, followed by Grassy Karoo, with no birds recorded in agriculture.
- The species specific indices for the three most recorded priority species (combining the data from walk transects and drive transects), indicate that Lesser Kestrel, Grey-winged Francolin and Blue Crane all prefer Grassy Karoo at the turbine site.
- As far as the spatial distribution of records of the priority species at the turbine site is concerned, Blue Cranes records are clearly clustered around the breeding area of the pair of Blue Cranes. Grey-winged Francolin occurs all over the site with no specific spatial pattern evident. Lesser Kestrel records seem to be concentrated in the western and central sections of the site.
- Only one nest of priority species (Blue Crane) was discovered, although Grey-winged Francolin probably breeds on the site too.

COLLISIONS

- In general, it would seem that the survey effort was sufficient to produce a reasonably reliable set of data to draw conclusions from.
- Based on the site specific rating, Lesser Kestrels are overwhelmingly the species most at risk of collision.
- Collision risk at the site is most prevalent for Lesser Kestrels, on average, in summer in warm temperatures, when the wind direction is south to south--easterly and when the wind strength is at a moderate breeze.
- An unpredictable factor that potentially exacerbates the risk of collision for Lesser Kestrels is the availability of food sources, which may concentrate flight activity in a specific area.
- No detailed association analyses were conducted for terrestrial species due to the small number of records, indicating a low risk of collisions due to very low flight activity.

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 Mainstream 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), thereafter the need for additional monitoring will be determined and agreed to with Mainstream, based on the results of the first year of post-construction monitoring.
- A 500m buffer has already been implemented in the lay-out to accommodate the Blue Cranes that are breeding on the site. This should be strictly enforced as a no turbine zone for the duration of the project. In addition, no access roads should be constructed within that zone.

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 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 specific turbines.

9. References

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Appendix 1: Species lists

TURBINE SITE	
African Black Swift	*Apus barbatus*
African Harrier-hawk	*Polyboroides typus*
African Pipit	*Anthus cinnamomeus*
African Quailfinch	*Ortygospiza fuscocrissa*
African Rock Pipit	*Anthus crenatus*
African Stonechat	*Saxicola torquatus*
Amur Falcon	*Falco amurensis*
Ant-eating Chat	*Myrmecocichla formicivora*
Barn Swallow	*Hirundo rustica*
Black-headed Canary	*Serinus alario*
Blue Crane	*Anthropoides paradiseus*
Bokmakierie	*Telophorus zeylonus*
Brown-throated Martin	*Riparia paludicola*
Buffy Pipit	*Anthus vaalensis*
Cape Bunting	*Emberiza capensis*
Cape Longclaw	*Macronyx capensis*
Cape Robin-Chat	*Cossypha caffra*
Cape Sparrow	*Passer melanurus*
Cape Turtle-Dove	*Streptopelia capicola*
Cape Wagtail	*Motacilla capensis*
Cloud Cisticola	*Cisticola textrix*
Common Fiscal	*Lanius collaris*
Common Quail	*Coturnix coturnix*
Common Waxbill	*Estrilda astrild*
Crowned Lapwing	*Vanellus coronatus*
Eastern Clapper Lark	*Mirafra fasciolata*
Familiar Chat	*Cercomela familiaris*
Greater Striped Swallow	*Hirundo cucullata*
Grey Heron	*Ardea cinerea*
Grey-backed Cisticola	*Cisticola subruficapilla*
Grey-winged Francolin	*Scleroptila africanus*
Hadeda Ibis	*Bostrychia hagedash*
Jackal Buzzard	*Buteo rufofuscus*
Karoo Prinia	*Prinia maculosa*
Karoo Scrub-Robin	*Cercotrichas coryphoeus*
Lanner Falcon	*Falco biarmicus*
Large-billed Lark	*Galerida magnirostris*
Layard's Tit-Babbler	*Parisoma layardi*
Lesser Kestrel	*Falco naumanni*

Levaillant's Cisticola	*Cisticola tinniens*
Little Swift	*Apus affinis*
Long-billed Pipit	*Anthus similis*
Ludwig's Bustard	*Neotis ludwigii*
Martial Eagle	*Polemaeetus bellicosus*
Melodious Lark	*Mirafra cheniana*
Mountain Wheatear	*Oenanthe monticola*
Neddicky	*Cisticola fulvicapilla*
Pale-winged Starling	*Onychognathus nabouroup*
Pied Crow	*Corvus albus*
Pied Starling	*Spreo bicolor*
Pin-tailed Whydah	*Vidua macroura*
Red-billed Quelea	*Anas erythrorhyncha*
Red-capped Lark	*Calandrella cinerea*
Rock Kestrel	*Falco rupicolus*
Rufous-eared Warbler	*Malcorus pectoralis*
Short-toed Rock-Thrush	*Monticola brevipes*
Sickle-winged Chat	*Cercomela sinuata*
Southern Masked-Weaver	*Ploceus velatus*
Southern Red Bishop	*Euplectes orix*
Speckled Pigeon	*Columba guinea*
Spike-heeled Lark	*Chersomanes albofasciata*
Spotted Thick-knee	*Burhinus capensis*
Steppe Buzzard	*Buteo vulpinus*
Three-banded Plover	*Charadrius tricollaris*
Wattled Starling	*Creatophora cinerea*
White-necked Raven	*Corvus albicollis*
Yellow Canary	*Crithagra flaviventris*
Yellow-bellied Eremomela	*Eremomela icteropygialis*
Yellow-billed Duck	*Anas undulata*

CONTROL SITE	
Acacia Pied Barbet	*Tricholaema leucomelas*
African Black Swift	*Apus barbatus*
African Pipit	*Anthus cinnamomeus*
African Quailfinch	*Ortygospiza fuscocrissa*
African Red-eyed Bulbul	*Pycnonotus nigricans*
African Rock Pipit	*Anthus crenatus*
African Sacred Ibis	*Threskiornis aethiopicus*
African Spoonbill	*Platalea alba*
African Stonechat	*Saxicola torquatus*
Amur Falcon	*Falco amurensis*
Ant-eating Chat	*Myrmecocichla formicivora*
Barn Swallow	*Hirundo rustica*
Black Stork	*Ciconia nigra*
Black-headed Canary	*Serinus alario*
Blacksmith Lapwing	*Vanellus armatus*
Blue Crane	*Anthropoides paradiseus*
Blue Korhaan	*Eupodotis caerulescens*
Bokmakierie	*Telophorus zeylonus*
Booted Eagle	*Aquila pennatus*
Brown-throated Martin	*Riparia paludicola*
Buffy Pipit	*Anthus vaalensis*
Cape Bunting	*Emberiza capensis*
Cape Canary	*Serinus canicollis*
Cape Longclaw	*Macronyx capensis*
Cape Robin-Chat	*Cossypha caffra*
Cape Sparrow	*Passer melanurus*
Cape Turtle-Dove	*Streptopelia capicola*
Cape Wagtail	*Motacilla capensis*
Cape White-eye	*Zosterops pallidus*
Common Fiscal	*Lanius collaris*
Common Waxbill	*Estrilda astrild*
Crowned Lapwing	*Vanellus coronatus*
Diderick Cuckoo	*Chrysococcyx caprius*
Eastern Clapper Lark	*Mirafra fasciolata*
Egyptian Goose	*Alopochen aegyptiacus*
Familiar Chat	*Cercomela familiaris*
Fiscal Flycatcher	*Sigelus silens*
Greater Flamingo	*Phoenicopterus ruber*
Greater Striped Swallow	*Hirundo cucullata*
Grey Heron	*Ardea cinerea*
Grey-backed Cisticola	*Cisticola subruficapilla*

Grey-winged Francolin	*Scleroptila africanus*
Ground Woodpecker	*Geocolaptes olivaceus*
Hadeda Ibis	*Bostrychia hagedash*
Hamerkop	*Scopus umbretta*
Helmeted Guineafowl	*Numida meleagris*
Jackal Buzzard	*Buteo rufofuscus*
Karoo Prinia	*Prinia maculosa*
Karoo Scrub-Robin	*Cercotrichas coryphoeus*
Large-billed Lark	*Galerida magnirostris*
Laughing Dove	*Spilopelia senegalensis*
Layard's Tit-Babbler	*Parisoma layardi*
Lesser Kestrel	*Falco naumanni*
Long-billed Pipit	*Anthus similis*
Ludwig's Bustard	*Neotis ludwigii*
Martial Eagle	*Polemaeetus bellicosus*
Neddicky	*Cisticola fulvicapilla*
Pied Crow	*Corvus albus*
Pied Starling	*Spreo bicolor*
Red-billed Quelea	*Anas erythrorhyncha*
Red-eyed Dove	*Streptopelia semitorquata*
Rufous-eared Warbler	*Malcorus pectoralis*
Sickle-winged Chat	*Cercomela sinuata*
South African Shelduck	*Tadorna cana*
Southern Masked-Weaver	*Ploceus velatus*
Southern Red Bishop	*Euplectes orix*
Speckled Pigeon	*Columba guinea*
Speckled Mousebird	*Colius striatus*
Spike-heeled Lark	*Chersomanes albofasciata*
Spotted Thick-knee	*Burhinus capensis*
Spur-winged Goose	*Plectropterus gambensis*
Steppe Buzzard	*Buteo vulpinus*
Verreaux’s Eagle	*Aquila verreauxi*
Three-banded Plover	*Charadrius tricollaris*
White-backed Mousebird	*Colius colius*
White-necked Raven	*Corvus albicollis*
White-rumped Swift	*Apus caffer*
Yellow Canary	*Crithagra flaviventris*

Species composition: Turbine site				
All Species	68			
Priority Species (Jan '12)	11			
Non-Priority Species	57			
		Number of replications	12	
Total count	Total	Mean	StDev	StErr
Drive transects	409	34.08	62.25	17.97
Walk transects	1373	114.42	73.79	21.30
Drive transects				
Priority Spp	Total	Mean	StDev	StErr
African Harrier-hawk	1	0.08	0.29	0.08
Amur Falcon	2	0.17	0.58	0.17
Blue Crane	5	0.42	0.79	0.23
Grey-winged Francolin	95	7.92	8.98	2.59
Jackal Buzzard	3	0.25	0.87	0.25
Lanner Falcon	1	0.08	0.29	0.08
Lesser Kestrel	298	24.83	54.85	15.83
Martial Eagle	1	0.08	0.29	0.08
Steppe Buzzard	3	0.25	0.45	0.13
Grand Total:	409	34.08	62.25	17.97
Walk transects				
Priority species	Total	Mean	StDev	StErr
Blue Crane	16	1.33	2.31	0.67
Grey-winged Francolin	24	2.00	2.59	0.75
Jackal Buzzard	1	0.08	0.29	0.08
Lesser Kestrel	152	12.67	24.77	7.15
Ludwig's Bustard	1	0.08	0.29	0.08
Melodious Lark	9	0.75	1.76	0.51
Priority species Sub Total:	203	16.92	26.63	7.69
Non-priority species	Total	Mean	StDev	StErr
African Black Swift	20	1.67	5.77	1.67
African Pipit	4	0.33	1.15	0.33
African Quailfinch	5	0.42	1.00	0.29
African Rock Pipit	7	0.58	0.79	0.23
African Stonechat	18	1.50	1.45	0.42
Ant-eating Chat	37	3.08	4.48	1.29
Barn Swallow	101	8.42	18.35	5.30
Black-headed Canary	17	1.42	2.91	0.84
Bokmakierie	55	4.58	4.34	1.25
Brown-throated Martin	1	0.08	0.29	0.08
Buffy Pipit	1	0.08	0.29	0.08
Cape Bunting	48	4.00	2.73	0.79
Cape Longclaw	53	4.42	3.87	1.12
Cape Robin-chat	2	0.17	0.58	0.17
Cape Turtle-dove	1	0.08	0.29	0.08
Cape Wagtail	11	0.92	1.24	0.36
Cloud Cisticola	36	3.00	3.74	1.08

Common Fiscal	4	0.33	0.49	0.14
Common Quail	16	1.33	2.90	0.84
Common Waxbill	16	1.33	2.74	0.79
Crowned Lapwing	17	1.42	2.35	0.68
Eastern Clapper Lark	127	10.58	6.86	1.98
Familiar Chat	1	0.08	0.29	0.08
Greater Striped Swallow	33	2.75	3.19	0.92
Grey Heron	1	0.08	0.29	0.08
Grey-backed Cisticola	65	5.42	3.60	1.04
Hadeda Ibis	1	0.08	0.29	0.08
Karoo Prinia	2	0.17	0.39	0.11
Karoo Scrub-robin	17	1.42	1.31	0.38
Large-billed Lark	47	3.92	2.15	0.62
Layard's Tit-Babbler	6	0.50	0.90	0.26
Levaillant's Cisticola	3	0.25	0.87	0.25
Little Swift	1	0.08	0.29	0.08
Long-billed Pipit	13	1.08	1.31	0.38
Mountain Wheatear	8	0.67	1.61	0.47
Neddicky	1	0.08	0.29	0.08
Pale-winged Starling	7	0.58	1.38	0.40
Pied Crow	11	0.92	1.08	0.31
Pied Starling	50	4.17	7.81	2.26
Pin-tailed Whydah	4	0.33	0.78	0.22
Red-billed Quelea	40	3.33	11.55	3.33
Red-capped lark	46	3.83	5.81	1.68
Rock Kestrel	1	0.08	0.29	0.08
Rufous-eared Warbler	17	1.42	2.11	0.61
Short-toed Rock-Thrush	1	0.08	0.29	0.08
Sickle-winged Chat	9	0.75	1.22	0.35
Southern Masked-weaver	6	0.50	1.45	0.42
Southern Red Bishop	74	6.17	17.30	4.99
Speckled Pigeon	5	0.42	1.44	0.42
Spike-heeled Lark	25	2.08	2.39	0.69
Spotted Thick-knee	2	0.17	0.39	0.11
Three-banded Plover	2	0.17	0.58	0.17
Wattled Starling	20	1.67	5.77	1.67
White-necked Raven	1	0.08	0.29	0.08
Yellow Canary	48	4.00	5.17	1.49
Yellow-bellied Eremomela	3	0.25	0.87	0.25
Yellow-billed Duck	2	0.17	0.58	0.17
Non-priority species Sub Total:	1170	97.50	52.46	15.14
Walk transects Grand Total:	1373	114.42	73.79	21.30

Species composition: Control site				
All Species	77			
Priority Species (Jan '12)	13			
Non-Priority Species	64			
		Number of replications	12	
Total count	Total	Mean	StDev	StErr
Drive transect	74	6.17	10.37	2.99
Walk transects	1382	115.17	26.74	7.72
Drive transects				
Priority Spp	Total	Mean	StDev	StErr
Amur Falcon	3	0.25	0.87	0.25
Blue Crane	8	0.67	1.56	0.45
Greater Flamingo	8	0.67	2.31	0.67
Grey-winged Francolin	15	1.25	2.14	0.62
Jackal Buzzard	15	1.25	1.14	0.33
Lesser Kestrel	23	1.92	5.73	1.65
Martial Eagle	1	0.08	0.29	0.08
Steppe Buzzard	1	0.08	0.29	0.08
Grand Total:	74	6.17	10.37	2.99
Walk transects				
Priority species	Total	Mean	StDev	StErr
Black Stork	1	0.08	0.29	0.08
Blue Crane	78	6.50	20.06	5.79
Blue Korhaan	4	0.33	0.78	0.22
Booted Eagle	1	0.08	0.29	0.08
Grey-winged Francolin	19	1.58	2.50	0.72
Ludwig's Bustard	1	0.08	0.29	0.08
Verreauxs' Eagle	2	0.17	0.58	0.17
Priority species Sub Total:	106	8.83	19.90	5.75
Non-priority species	Total	Mean	StDev	StErr
Acacia Pied Barbet	2	0.17	0.58	0.17
African Black Swift	12	1.00	3.46	1.00
African Pipit	2	0.17	0.58	0.17
African Quailfinch	2	0.17	0.58	0.17
African Red-eyed Bulbul	19	1.58	2.19	0.63
African Rock Pipit	4	0.33	0.65	0.19
African Sacred Ibis	26	2.17	3.69	1.06
African Spoonbill	2	0.17	0.58	0.17
African Stonechat	1	0.08	0.29	0.08
Ant-eating Chat	26	2.17	2.72	0.79
Barn Swallow	53	4.42	10.58	3.05
Black-headed Canary	10	0.83	1.40	0.41
Blacksmith Lapwing	1	0.08	0.29	0.08
Bokmakierie	51	4.25	2.56	0.74
Brown-throated Martin	2	0.17	0.39	0.11
Buffy Pipit	1	0.08	0.29	0.08
Cape Bunting	15	1.25	0.87	0.25
Cape Canary	2	0.17	0.58	0.17
Cape Longclaw	9	0.75	1.29	0.37

Cape Robin-chat	13	1.08	1.16	0.34
Cape Sparrow	84	7.00	8.32	2.40
Cape Turtle-dove	25	2.08	2.07	0.60
Cape Wagtail	5	0.42	0.90	0.26
Cape White-eye	3	0.25	0.87	0.25
Common Fiscal	9	0.75	0.97	0.28
Common Waxbill	10	0.83	1.80	0.52
Crowned Lapwing	6	0.50	1.24	0.36
Diderick Cuckoo	3	0.25	0.62	0.18
Eastern Clapper Lark	31	2.58	2.84	0.82
Egyptian Goose	3	0.25	0.87	0.25
Familiar Chat	4	0.33	0.89	0.26
Fiscal Flycatcher	2	0.17	0.58	0.17
Greater Striped Swallow	30	2.50	3.00	0.87
Grey Heron	1	0.08	0.29	0.08
Grey-backed Cisticola	46	3.83	2.69	0.78
Ground Woodpecker	3	0.25	0.62	0.18
Hadeda Ibis	28	2.33	2.31	0.67
Hamerkop	4	0.33	0.49	0.14
Helmeted Guineafowl	96	8.00	18.18	5.25
Karoo prinia	13	1.08	0.67	0.19
Karoo Scrub-robin	41	3.42	2.68	0.77
Large-billed Lark	4	0.33	0.78	0.22
Laughing Dove	7	0.58	0.79	0.23
Layard's Tit-Babbler	2	0.17	0.39	0.11
Long-billed Pipit	4	0.33	0.65	0.19
Neddicky	14	1.17	1.27	0.37
Pied Crow	7	0.58	0.79	0.23
Pied Starling	306	25.50	20.02	5.78
Red-billed Quelea	30	2.50	8.66	2.50
Red-eyed Dove	12	1.00	1.21	0.35
Rufous-eared Warbler	15	1.25	1.82	0.52
Sickle-winged Chat	5	0.42	0.67	0.19
South African Shelduck	2	0.17	0.58	0.17
Southern Masked-Weaver	99	8.25	5.43	1.57
Southern Red Bishop	12	1.00	2.37	0.69
Speckled Mousebird	1	0.08	0.29	0.08
Speckled Pigeon	2	0.17	0.58	0.17
Spike-heeled Lark	26	2.17	2.37	0.68
Spotted Thick-knee	1	0.08	0.29	0.08
Spur-winged Goose	3	0.25	0.87	0.25
White-backed Mousebird	6	0.50	1.73	0.50
White-necked Raven	1	0.08	0.29	0.08
White-rumped Swift	2	0.17	0.58	0.17
Yellow Canary	15	1.25	2.99	0.86
Non-priority species Sub Total:	1276	106.33	36.16	10.44
Walk transects Grand Total:	1382	115.17	26.74	7.72

Appendix 2: Statistical methods

IndusStat Pro

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STATISTICAL ANALYSIS OF THE NOUPOORT SURVEY DATA

Prepared by Nico Laubscher

Data Source and Basic Statistics

The data on which this report is based are contained in the MS Excel file "*Noupoort_VP_10min_data_03122012_v1.xlsx*". It contains two datasets: one for observations recorded in 120 minute observation periods at different sampling vantage points and another is the same data reorganized but only for flights at medium height and reported in 10 minute intervals within the 120 minute slots. The survey was done from 19 October 2011 to 10 August 2012. The environmental data of Temperature, Wind Direction and Wind Strength are integrated in the second dataset.

The counts observed during each two hour watch period at each of the vantage points (VP1 – VP4) for two flight classes of birds (Soaring and Terrestrial), extracted from the raw database, are listed in Tables A and B in the Appendix. The number of *Flights* as well as the number of individual birds (*Individuals*) for the two categories are presented in these tables, together with additional calculations.

The descriptive statistics of average counts, standard deviations and 95% confidence intervals for the mean values (for Flights and for Individual counts) are listed in Tables 1 and 2 for each of the four seasons. LCL = Lower confidence limit, UCL = Upper confidence limit.

Table 1. **Soaring birds, Flights (and Individual counts in brackets): average, SD and 95% confidence limits for the average number per 2h watch period.**

Season	Obs periods	Number Counted	Avge	Std.Dev.	95% LCL	95% UCL
Spring 2011	18	0 (0)	0 (0)	0 (0)		
Summer 2012	18	58 (234)	3.22 (13.00)	3.26 (14.60)	1.60 (5.74)	4.85 (20.26)
Autumn 2012	12	0 (0)	0 (0)	0 (0)		
Winter 2012	12	1 (1)	0.08 (0.08)	0.29 (0.29)	0.00 (0.00)	0.27 (0.27)
All Grps	60	59 (235)	0.98 (3.92)	2.30 (9.879)	0.39 (1.37)	1.58 (6.47)

Table 2. **Terrestrial birds, Flights (and Individual counts in brackets): average, SD and 95% confidence limits for the average number per 2h watch period.**

Season	Obs periods	Number Counted	Avge	Std.Dev.	95% LCL	95% UCL
Spring 2011	18	5 (16)	0.28 (0.89)	0.57 (2.40)	0. 00 (0.00)	0.56 (2.08)
Summer 2012	18	7 (11)	0.39 (0.61)	0.78 (1.14)	0. 00 (0.04)	0.78 (1.18)
Autumn 2012	12	3 (5)	0.25 (0.42)	0.45 (0.79)	0. 00 (0.00)	0.54 (0.92)
Winter 2012	12	2 (3)	0.17 (0.25)	0.39 (0.62)	0. 00 (0.00)	0.41 (0.64)
All Grps	60	17 (35)	0.28 (0.58)	0.58 (1.51)	0.13 (0.19)	0.43 (0.97)

Stability and Representativeness

As the data are gathered day by day an improved estimate of the number of birds that occurs in the area is achieved. As more data are gathered the more refined the estimate will become. The issue is to determine if the data at hand provide a fair representation of the true counts in the area, i.e. if the average begins to stabilise towards the end of the observation period (and hence a representative sample has been achieved).

The average number of flights (as well as that of individual birds recorded) are computed as the data become available watch period by watch period (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 were determined separately for each season.
Figure 1 plots these updated averages for Soaring birds (the number of flights as well as a count of the total number of individual birds observed). Figure 2 does the same for the Terrestrial birds.

Figure 2. **Soaring Birds: updated average number of *Flights* and *Individuals***

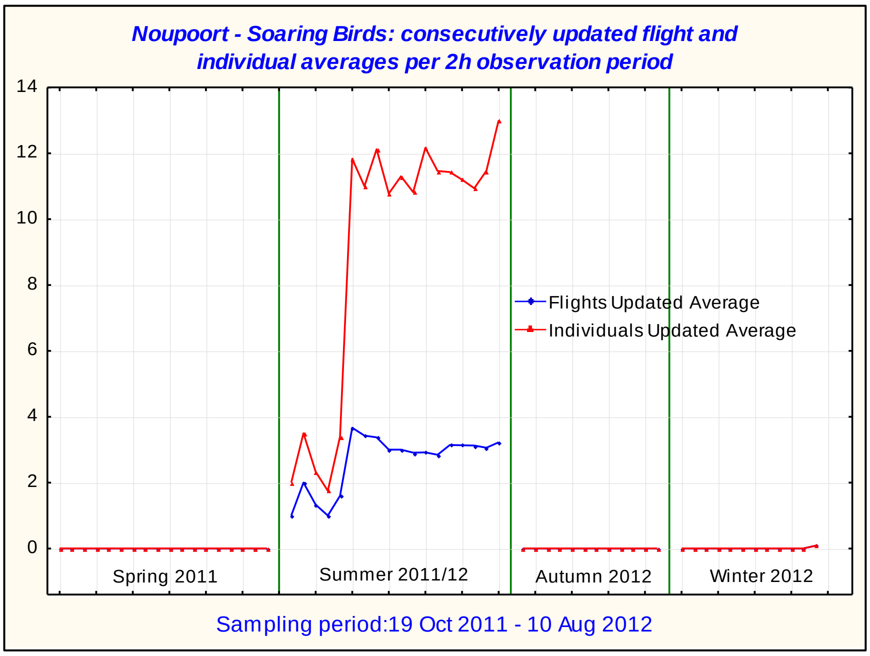


Figure 1 shows that practically no soaring birds were present during Spring and Autumn and the updated average shows a blip where a single soarer was recorded during the Winter sampling. Each of the seasons were sampled for either 12 or 18 observation periods (of 2h). With such a constant recording the standard deviation may be taken to be very small (see Table 1).

An approximation to the number of sampling periods that is required to yield an estimate of the mean that is within a precision of "*e*" units of the true mean (with 95% certainty) is given by the formula (see Berenson & Levine, 1996):

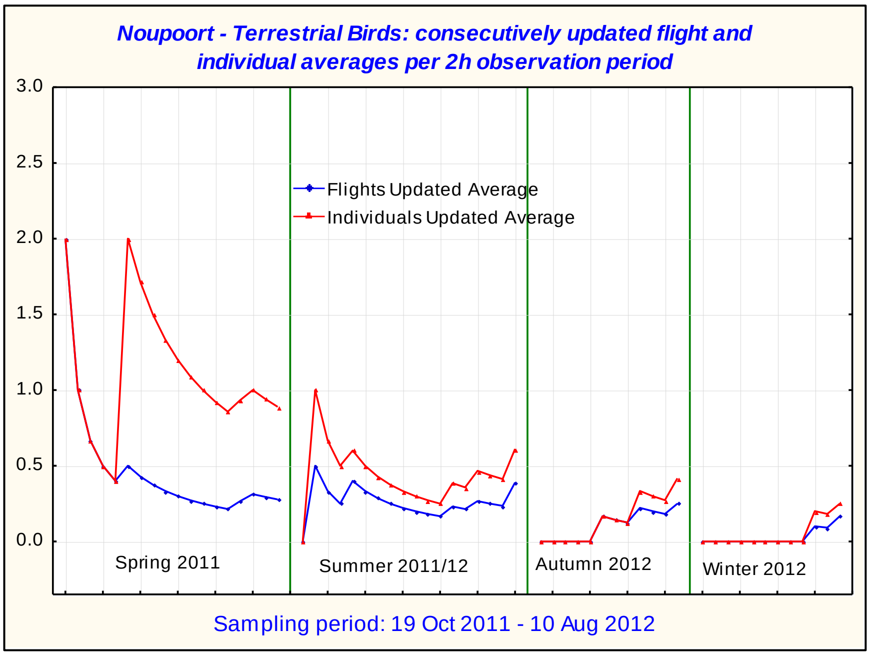
$$n \approx (1.96s / e)^2 .$$

The estimate, *s*, for σ (the true standard deviation) is taken from the available data and since the majority of birds were recorded in Summer, the Summer data are used to compute an estimate of the sample size. For the Summer soaring flights the standard deviation is much inflated by the outlier of 14 which is 2 times as large as the second largest count. If that is ignored, the standard deviation estimated by using the moving range estimator (see Montgomery, 2005, p. 232) and correcting for bias is $s \approx 1.94$. If $e = 1$, this leads to n ≈ 15. The 18 samples obtained thus seem to provide a good representative sample.

The situation with soaring flights for individual counts is different. Here the counts vary widely with a number of outlier counts. In Summer the largest count is 54 and second largest 27 (which itself is much larger than the rest). If these two counts are ignored, the moving range estimator is s = 7.6 (which is 1.9 times smaller than the usual standard deviation). Using the above sample size formula with e = 1 the approximate sample size is n ≈ 222. This is clearly unattainable in practice. However, Figure 1 shows that the updated average for soaring individuals has smoothed out horizontally quite well, even with n = 18. That alone may be taken as reasonable evidence that the Summer data are representative of the true picture.

Figure 2 shows that the updated averages for flight and individual counts for terrestrial birds are reasonably stable towards the end of each of the four seasons.

Figure 2. Terrestrial Birds: updated average number of *Flights* and *Individuals*.



Therefore stability is accepted to have been reached in the counts, specifically also because the variability for both flights and individual counts of terrestrial birds are much smaller than for soaring birds. Accordingly the data should provide a good representation of the Terrestrial birds in the region.

Association Between Flight Counts and Environmental Factors

Flight height has been categorised with values “Low”, “Medium” and “High”. For soaring birds only those records where *Medium* flight heights have been recorded were extracted from the database for analysis. All observation periods (VP watch periods) have been divided into ten minute intervals (780 in all) and all flights occurring in each ten minute interval are listed in the database. The environmental factor measurements (*Temperature, Wind Direction* and *Wind Strength*) were made available within each of the ten minute intervals. The associations between counts for birds at *Medium* flight height and the factors *Temperature, Wind Direction* and *Wind Strength* are considered in this section.

Temperature, Wind Direction and Wind Strength are all measured quantitatively: °C, degrees clockwise off North and m/s respectively. These data were categorised since categorisation allows a better opportunity to visualise the associations with the environmental factors that may exist. The categorisations were done as follows:

- Temperature into classes *Cold* (<= 10°C), *Mild* (> 10°C and <= 20°C), *Warm* (> 20°C and <= 30°C) and *Hot* (> 30°C). This dataset did not contain any data for Temperature = *Hot.*
- Wind Direction has the categories of the wind rose: N, NE, E, SE, S, SW, W and NW.
- Wind Strength was categorised according to the Beaufort scale into The Beaufort scale classes (in m/s) are bounded as follows:

    0 ≤ *Calm* ≤ 0.25, 0.25 < *Light Air* ≤ 1.55, 1.15 < *Light Breeze* ≤ 3.35,
    3.35 < *Gentle Breeze* ≤ 5.45, 5.45 < *Moderate Breeze* ≤ 7.95,
    7.95 < *Fresh Breeze* ≤ 10.75, 10.75 < *Strong Breeze* ≤ 13.85,
    13.85 < *Near Gale* ≤ 17.15, 17.15 < *Gale* ≤ 20.75, *Severe Gale* > 20.75.

The Noupoort dataset did not contain any Wind Strengths at *Gale* level or stronger.

When a flight consisted of more than one individual the total count was recorded and hence the total number of birds per 10 minute record was taken into account in the work that follows unless otherwise stated.

Basic Statistics

Table 3 presents the average numerical values of the three environmental factors as well as some basic statistics, in particular the 95% confidence intervals for the average for medium height soaring birds. Only N = 29 flights of medium height soarers were recorded in the 780 10 minute observation periods. These 29 flights consisted of 184 individual birds. Of these, 182 were *Falco naumanni* (Lesser Kestrel) and two were *Anthropoides paradiseus* (Blue Crane). All of these were recorded in the Summer season with no sightings during Spring, Autumn and Winter.
As far as the terrestrial birds are concerned only N = 3 flights consisting of a total of 5 birds were recorded. These sightings occurred, just as for the soaring birds, only in Summer. In the light of the small number of relevant terrestrial birds it is advisable not to list basic statistics for this group as those may be misleading.

Table 3 lists the basic statistics for soaring birds. Temperatures, Wind Directions and Wind Strength statistics are listed for the 29 flights only. These are not weighted with the individual counts.

Table 3. Descriptive statistics for Soaring birds. The quantitative measurements on the three environmental factors, including 95% upper (UCL) and lower (LCL) confidence limits for the mean. Only for the periods in which at least one bird was recorded.

Environmental factor	Soaring birds				
	N	Mean	95% LCL	95% UCL	Std. Dev.
Temp °C	29	22.8	21.3	24.3	3.9
Wind Direction	29	104	87	122	41.8
Wind Strength	29	6.7	6.1	7.2	1.5

Wind direction measurements belong to a type known as *circular data* and ordinary averages for circular data are not valid. The reason for this is that the zero point is arbitrary. There is no physical justification for the direction of North to be designated 0° (or 360°). A direction of 270° can't be said to be "larger" than 90°. For example the two angles: 359° and 1° have a "correct" average of 0° (or 360°) but the customary average value presents the misleading result of (359 + 1)/2 = 180°. The average values and other wind direction statistics are therefore computed as in Zar, 2010, Chapters 26 & 27.

From Table 3, as a rough guide, it can be said that the soaring birds were observed, on average, at *Warm* temperatures, when the Wind Direction was East and when the wind strength was at a *Moderate Breeze*. On closer examination, see Figure 8, actually between NE and SE and when the Wind Strength was at least at a Moderate Breeze.

Statistical Methodology

In what follows the association between the occurrence of Flights and/or *Individual* bird counts and the three environmental factors, Temperature, Wind Direction and Wind Strength are studied. Explanation of the methods is done by using the Temperature data as set out in Table 4 as an example. Table 4 lists the number of *individual* Soaring birds recorded per 10-minute interval for each of the Temperature categories and is used to establish their association with Temperature.

Soaring Birds: Temperature

An explanation of the columns and the interpretation of the caption in Table 4 (also applicable to all the other tables) are provided directly following this table.

Table 4. Soaring birds: basic statistics by Temperature category. Chi-square = 175.7, degrees of freedom (d.f.) = 2, Exact p = 0.0000							
Temp	10 min. Intervals	Observed	Expected	Average / 10 min.	Std.Dev.	Avge/8h	χ^2
Cold	136	0	32.1	0.00	0.00	0.00	32.1
Mild	378	37	89.2	0.10	1.08	4.70	30.5
Warm	266	147	62.7	0.55	2.41	26.53	113.1
All Grps	780	184	184.0	0.249	1.61	11.32	175.7

10 min. Intervals. There were 780 10-minute intervals that occurred during all of the watch periods. In 136 of those the temperature was *Cold*, in 378 *Mild* and in 266 *Warm*.

Observed. These are the number of Soaring birds (individual counts) actually recorded in the each of the temperature categories.

Expected. If the bird count shows *No Association* with one or more categories of Temperature (the null-hypothesis, H_0), the 184 observed sightings would be distributed proportionally over the categories according to the number of 10-minute intervals occurring in each. Thus the expected number in category "Warm", for example, would be proportional to the number of 10-minute intervals, in this case (266/780)*184 = 62.7. The same applies to the other categories. If the observed counts follow the expected counts closely then the hypothesis of *No Association* (or non-preference) will be confirmed, otherwise rejected. Since 147 birds were observed at Warm temperatures whereas only about 63 were expected if there were no association the indication is that there is a Temperature preference. Its statistical significance is tested by the use of a chi-square goodness of fit test (see later).

Average. The 378 10-minute intervals of category Mild, for example, consist of many zero counts and a total of 37 individuals counted. Thus the average number (per 10-minute interval) of Soaring birds when Temperature was Mild is 37/378 = 0.10. The same applies to the other categories.

Std.Dev. This is the standard deviation of the counts in each of the categories (including the zero counts). It is a measure of the variability of the observations.

Avge/8h. The category averages are decimal numbers due to the short duration of a 10-minute interval. By expressing these averages not per 10 minute interval but per 8 hour interval, the numbers are hopefully more easily interpretable. Avge/8h is just a scaled up version of the Average/10-min., viz. Avge/8h = 48*Average.

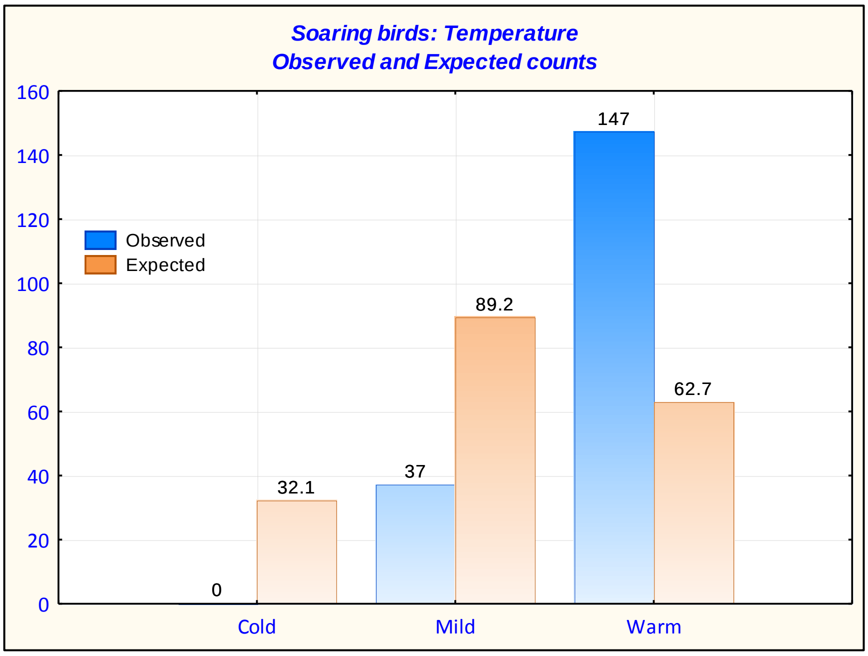
Chi-square. The hypothesis of *No Association* over the categories of Temperature (in this case) is tested by comparing the observed and expected counts by means of Pearson's Chi-square (χ^2) goodness-of-fit test (cf. Zar, 2010, pp. 466 - 474). Values of its p-value less than 5% implies rejection of the *No Association* hypothesis at the 5% level of significance (which will be accepted as the norm throughout this report). In those cases where the p-values are less than 5% it may be concluded that the flight counts are associated with some Temperatures, Wind Directions or Wind Strengths. If there is a reasonable agreement between the observed and expected counts, it is as if the observed flights were randomly distributed into the categories. If they disagree to a significant extent (the difference being quantified by the Chi-square statistic) it may be concluded that specific preferences do exist. In Table 4 the p-value of p = 0.0000 indicates that the *No Association* hypothesis is rejected and thus there is a preference for Warm temperatures.

If the chi-square test is significant, the contribution of each category of the factor (in this case Temperature) to the value of the test statistic is considered. In cases where the observed frequencies are higher than those expected under the hypothesis of no association, those with the largest contribution to chi-square provide an indication of the preference(s) (or aversions, if the observed counts are less than those expected) for a specific category of the factor.

Under certain circumstances, usually when the *expected values* in some categories are too small, the assumptions under which the distribution of the chi-square statistic is derived are violated and the customary p-value becomes invalid. In such cases numerical methods are applied to compute the exact p-value for the statistic. The exact p-values for the chi-square statistic have been computed for all of the following tables using the software *StatXact* 9 (cf. Mehta & Patel, 2010). The p-value is the exact probability (for a specific table) of finding a value as extreme or more extreme than the value of the chi-square statistic found for that table under the null-hypothesis of *No Association*.

The data for observed and expected counts in Table 4 are graphically presented in Figure 4.

Figure 4. Soaring birds: observed and expected counts of individual birds for Temperature.



The conclusion, using the chi-square test, is that Soaring birds have a significant (p = 0.0000) preference when Temperature is Warm. Many more soarers were observed than expected (under H_0) in that situation. Also, far fewer than expected under H_0 were observed when temperature was Mild. These differences both contribute to the value of chi-square to enforce the rejection of H_0 but of course the preference is seen where there are more than expec-ted (see the cell with red background in Table 4 which – on its own – contributes 64% of the value of the test).

Soaring Birds: Wind Direction

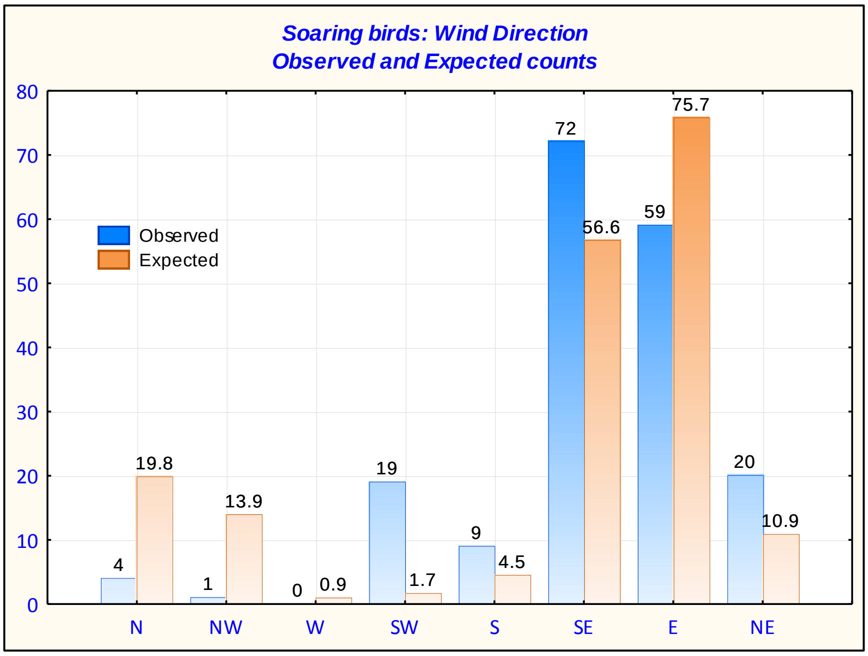
As in the previous section, the number of medium height flights that were counted at each of the wind directions are presented in Table 5, for Soaring birds. The visual presentations of the Wind Direction data are given in Figures 5 and 6.

Table5. Soaring birds: basic statistics by Wind Direction category. Chi-square = 228.0, Exact p = 0.0000.

Wind Direction	10 min. Intervals	Observed	Expected	Average / 10 min.	Std.Dev.	Average/8h	χ^2
N	84	4	19.8	0.05	0.44	2.29	12.6
NW	59	1	13.9	0.02	0.13	0.81	12.0
W	4	0	0.9	0.00	0.00	0.00	0.9
SW	7	19	1.7	2.71	6.75	130.29	182.3
S	19	9	4.5	0.47	1.50	22.74	4.6
SE	240	72	56.6	0.30	2.02	14.40	4.2
E	321	59	75.7	0.18	1.12	8.82	3.7
NE	46	20	10.9	0.43	2.42	20.87	7.7
All Grps	780	184	184.0	0.24	1.61	11.32	228.0

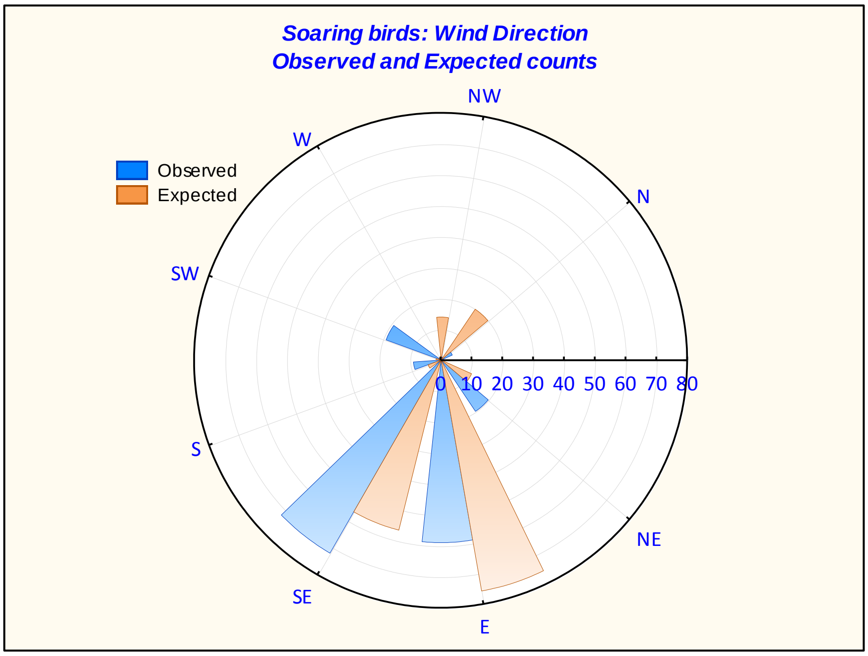
The small p-value shows that the hypothesis of *No Association* may be rejected and hence there is association between flights of Soaring Birds and Wind Direction. The preference is for South-West winds. Compare the large contribution of the SW count to the chi-square statistic.

Figure 5. **Soaring birds: observed and expected counts of individual birds for Wind Direction.**



A useful device for presenting circular data is the polar coordinates diagram. It has the same information as the bar chart but it helps to visualise the associations that may exist somewhat better. The circle is divided into equal sectors, depending on the number of categories. The observed and expected counts are linearly scaled from the centre out to the perimeter and the equispaced circles enable reading the value in any sector. Each of the outgoing “fans” are plotted at the same angle but the larger the number represented is, the larger is the area covered by the fan, thus strengthening the image for larger numbers. Figure 6 is a polar coordinates chart for the Wind Direction for Soaring birds.

Figure 6. Soaring birds: observed and expected counts of individual birds for Wind Direction. Polar coordinates diagram.



Soaring Birds: Wind Strength

Table 6. Soaring birds: basic statistics by Wind Strength category.
Chi-square = 176.8, d.f. = 6, Exact p = 0.0000

Wind Strength	Intervals	Observed	Expected	Average	Std.Dev.	Average /8h	χ^2
Light Air	14	0	3.3	0.00	0.00	0.00	3.3
Light Breeze	51	18	12.0	0.35	2.52	16.94	3.0
Gentle Breeze	137	22	32.3	0.16	0.93	7.71	3.3
Moderate Breeze	182	114	42.9	0.63	2.62	30.07	117.6
Fresh Breeze	236	30	55.7	0.13	1.15	6.10	11.8
Strong Breeze	124	0	29.3	0.00	0.00	0.00	29.3
Near gale	36	0	8.5	0.00	0.00	0.00	8.5
All Grps	780	184	184.0	0.24	1.61	11.32	176.8

The *No Association* hypothesis is rejected with a high level of certainty. The preference is clearly for wind strength at a Moderate Breeze where 42.9 were expected to be seen but 114 were actually observed.

Figure 7. Soaring birds: observed and expected counts of individual birds for Wind Strength.

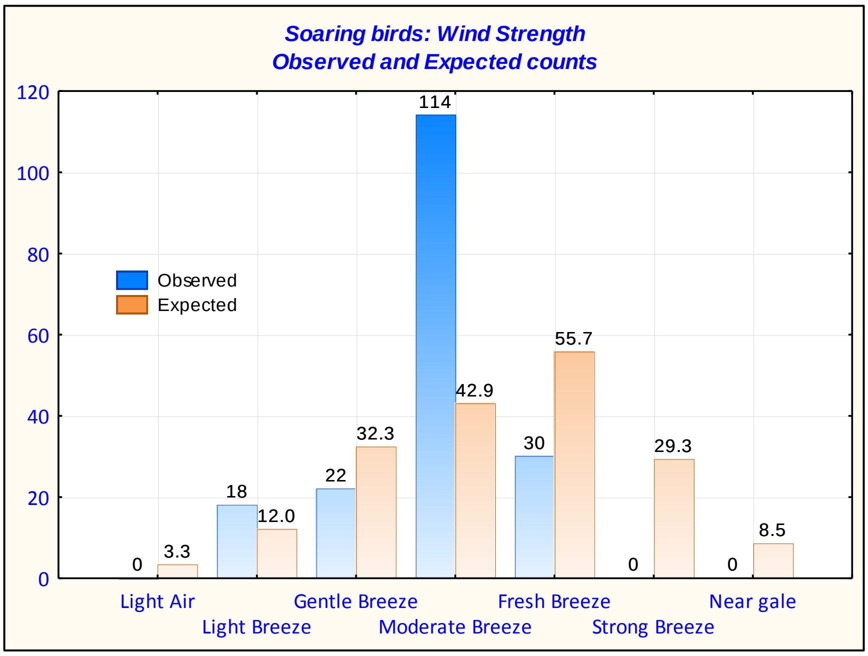
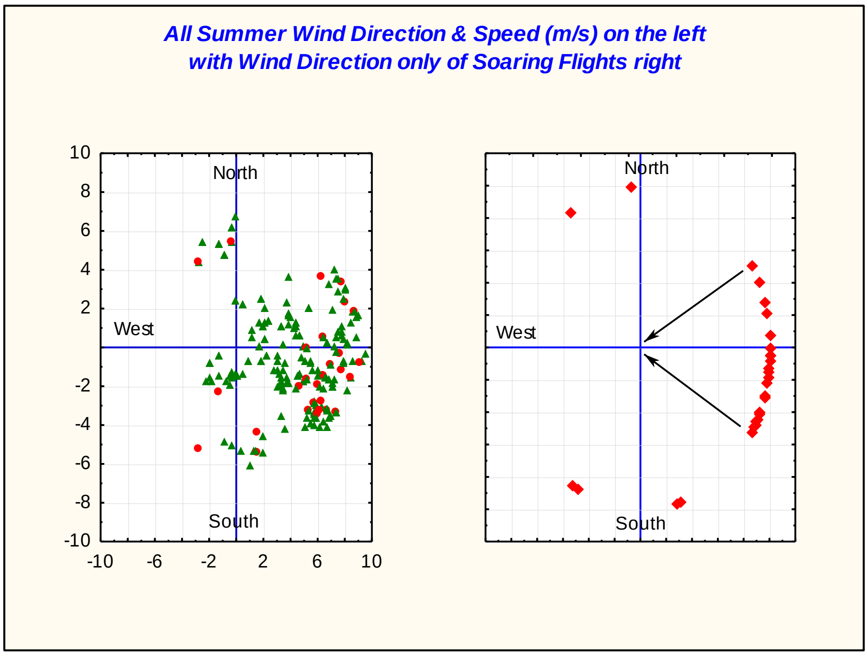


Figure 8 shows the wind directions combined with wind strength during the summer (the time when all soarers were observed). This graph has been created for Soaring Flights only (not for individual counts). It would look no different from the graph for individuals in two dimensions since multiple points would stack on one another.

Figure 8. **Each point in the left graph represents a Wind Direction/Speed at one of the 10-minute intervals during Summer. The angle, clockwise from North is the wind direction and its distance to the origin, the wind speed (m/s). Red dots represent the Wind Direction/Speed for the 29 soaring bird flights.**



The data show that there were only 11 instances of South-Westerly to North-Westerly winds (4.7% of all Summer records), and only in one of these was a strength of more than a Light Breeze achieved. It is therefore not surprising that only two Soaring Flights were observed from those directions.

On the other hand 187 of the 234 (i.e. 79.9%) of all Summer records were between North-East and South-East. Of these, 103 instances (55.1%) were at strength exceeding Moderate Breeze (15.0% at Fresh Breeze or stronger). There were 29 Soaring Flights in all. Of these 23 (79.3%) occurred when the Wind Direction was in the sectors NE to SE. Of these 23, there were 20 (87.0%) that took place when the wind was at least at a strength of Moderate Breeze.

All this shows how the soaring birds actually flew. It does not show that since most of them flew North-East to South-East that they have a preference for those wind directions. Those simply are the existing wind directions and those were expected to be used as observed (if *No Association* held). However, according to the individual data, the large contribution to reject a good fit of the observed to the expected values came from the South-West wind direction where only 1.7 was expected but 19 were recorded (i.e. more than 11 times than expected).

TERRESTRIAL BIRDS

As stated in the section *Basic Statistics* no detailed association analyses will be presented for Terrestrial birds due to the small number of sightings. That in itself is valuable information: since so few Terrestrials are expected to be present from a reasonable sample, it may be concluded that the risk of fatal collisions will be minute.

INDIVIDUAL SPECIES

Frequency tables and charts similar to those presented for Soaring birds have also been prepared for the only individual species for which sufficient information is available to warrant analysis, namely the Lesser Kestrel (*Falco naumanni*). The total number of Lesser Kestrel sighted is 182 and they form the overwhelming majority of the Soaring birds. The analyses for Soaring Birds and for Lesser Kestrel should be (and is) practically identical. These results are, however, presented for the sake of completeness.

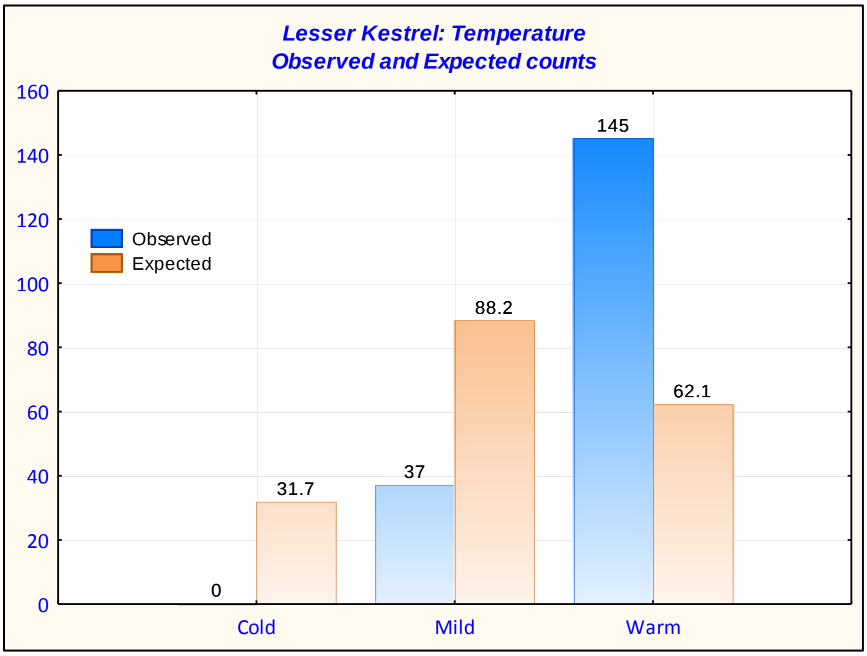
Lesser Kestrel: Temperature

Table 7. Lesser Kestrel: basic statistics by Temperature category. Chi-square = 172.3, d.f. = 2, Exact p = 0.0000

Temp	10 min. Intervals	Observed	Expected	Average / 10 min.	Std.Dev.	Avge/8h	χ^2
Cold	136	0	31.7	0.00	0.00	0.00	31.7
Mild	378	37	88.2	0.10	1.08	4.70	29.7
Warm	266	145	62.1	0.55	2.41	26.17	110.8
All Grps	780	182	182.0	0.23	1.61	11.20	172.3

The chi-square test with p = 0.0000 shows that H_0 is rejected with high confidence. The contribution of Temperature = Warm to chi-square of 110.8 is the overwhelming part thereof and this identifies the preference of these birds.

Figure 9. Lesser Kestrel: observed and expected counts of individual birds for Temperature.



Lesser Kestrel:Wind Direction

Table 8. Lesser Kestrel: basic statistics by Wind Direction category. Chi-square = 231.4, Exact p = 0.0063.

Wind Direction	10 min. Intervals	Observed	Expected	Average / 10 min.	Std.Dev.	Average/8h	χ^2
N	84	4	19.6	0.05	0.44	2.29	12.4
NW	59	1	13.8	0.02	0.13	0.81	11.8
W	4	0	0.9	0.00	0.00	0.00	0.9
SW	7	19	1.6	2.71	6.75	130.29	184.7
S	19	9	4.4	0.47	1.50	22.74	4.7
SE	240	72	56.0	0.30	2.02	14.40	4.6
E	321	57	74.9	0.18	1.12	8.52	4.3
NE	46	20	10.7	0.43	2.42	20.87	8.0
All Grps	780	182	182.0	0.23	1.61	11.20	231.4

The small p-value shows that the hypothesis of *No Association* may be rejected and hence there is association between flights of Soaring Birds and Wind Direction. The preference is for South-West winds. Compare the large contribution of the SW count to the chi-square statistic.

Figure 10. **Lesser Kestrel: observed and expected counts of individual birds for Wind Direction.**

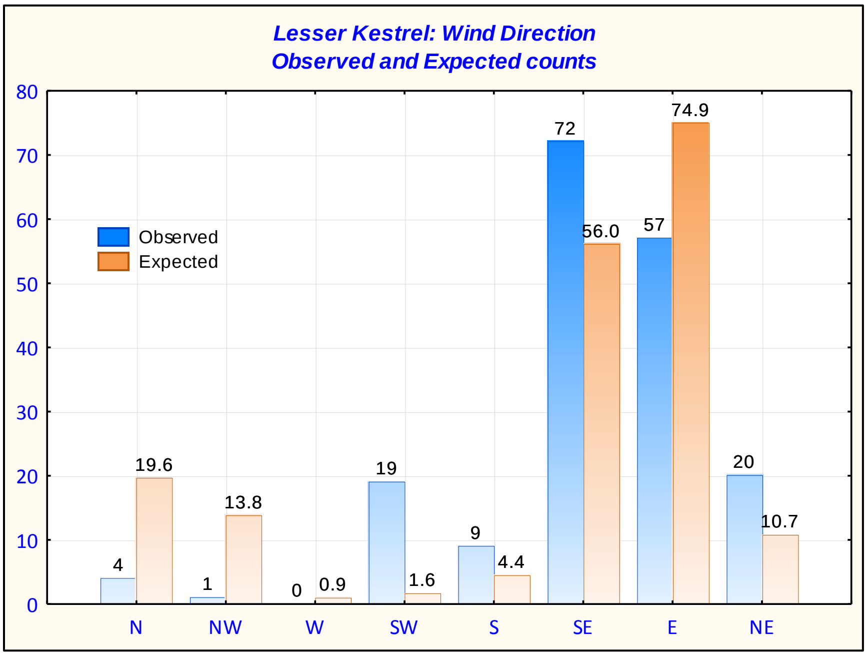
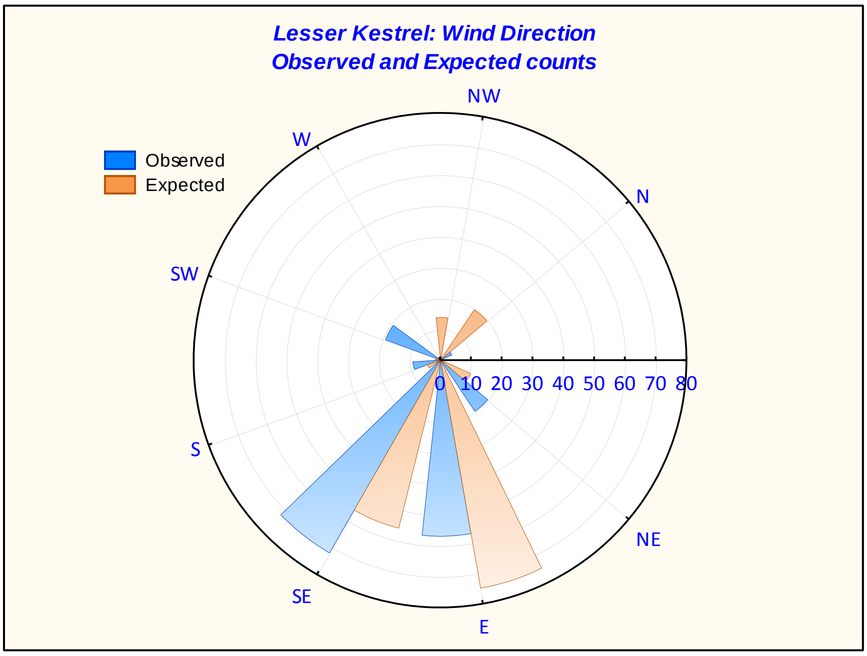


Figure 11. **Lesser Kestrel: observed and expected counts of individual birds for Wind Direction. Polar coordinates diagram.**

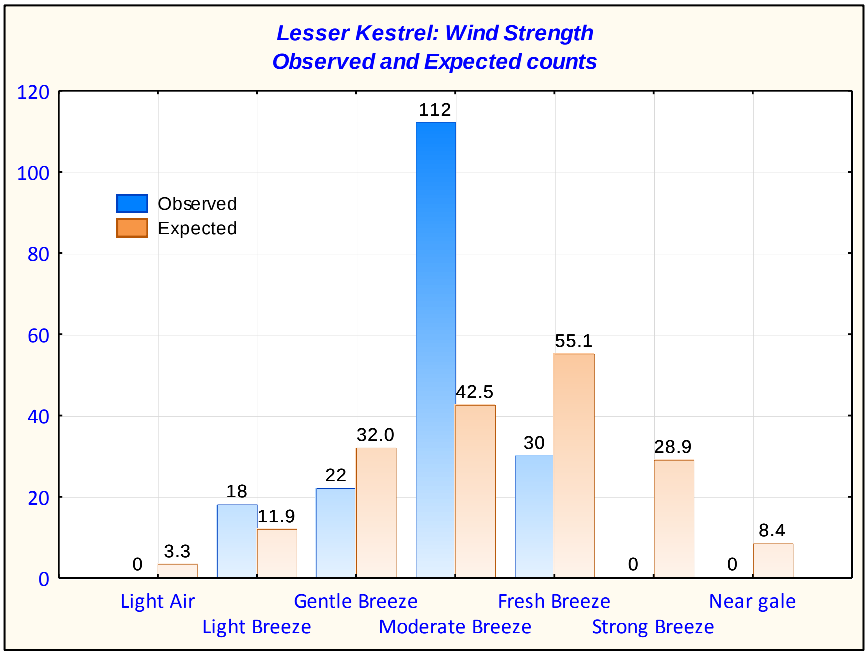


Lesser Kestrel:Wind Strength

Table 9. Lesser Kestrel: basic statistics by Wind Strength category. Chi-square = 14.77, Exact p = 0.0873							
Wind Strength	**Intervals**	**Observed**	**Expected**	**Average**	**Std.Dev.**	**Average /8h**	χ^2
Light Air	14	0	3.3	0.00	0.00	0.00	3.3
Light Breeze	51	18	11.9	0.35	2.52	16.94	3.1
Gentle Breeze	137	22	32.0	0.16	0.93	7.71	3.1
Moderate Breeze	182	112	42.5	0.62	2.62	29.54	113.9
Fresh Breeze	236	30	55.1	0.13	1.15	6.10	11.4
Strong Breeze	124	0	28.9	0.00	0.00	0.00	28.9
Near gale	36	0	8.4	0.00	0.00	0.00	8.4
All Grps	780	182	182.0	0.23	1.61	11.20	172.1

The *No Association* hypothesis is rejected with a high level of certainty. The preference is for Wind Strength at a Moderate Breeze.

Figure 12. Lesser Kestrel: observed and expected counts of individual birds for Wind Strength.



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APPENDIX

Table A: ***Soaring Birds*: counts (Flights and Individuals per 2h watch period and by vantage point) over time with updated (running) averages.**

Date	Season	VP	Flights count	Flights Updated Avge	Individ-uals count	Individuals Updated Avge
19-Oct-11	Spring	VP1	0	0.00	0	0.00
19-Oct-11	Spring	VP2	0	0.00	0	0.00
19-Oct-11	Spring	VP1	0	0.00	0	0.00
19-Oct-11	Spring	VP2	0	0.00	0	0.00
20-Oct-11	Spring	VP3	0	0.00	0	0.00
20-Oct-11	Spring	VP3	0	0.00	0	0.00
20-Oct-11	Spring	VP3	0	0.00	0	0.00
21-Oct-11	Spring	VP1	0	0.00	0	0.00
21-Oct-11	Spring	VP2	0	0.00	0	0.00
21-Oct-11	Spring	VP1	0	0.00	0	0.00
21-Oct-11	Spring	VP2	0	0.00	0	0.00
21-Oct-11	Spring	VP2	0	0.00	0	0.00
21-Oct-11	Spring	VP2	0	0.00	0	0.00
22-Oct-11	Spring	VP3	0	0.00	0	0.00
22-Oct-11	Spring	VP3	0	0.00	0	0.00
22-Oct-11	Spring	VP3	0	0.00	0	0.00
23-Oct-11	Spring	VP1	0	0.00	0	0.00
23-Oct-11	Spring	VP2	0	0.00	0	0.00
06-Feb-12	Summer	VP1	1	1.00	2	2.00
06-Feb-12	Summer	VP2	3	2.00	5	3.50
06-Feb-12	Summer	VP1	0	1.33	0	2.33
06-Feb-12	Summer	VP2	0	1.00	0	1.75
07-Feb-12	Summer	VP3	4	1.60	10	3.40
07-Feb-12	Summer	VP1	14	3.67	54	11.83
07-Feb-12	Summer	VP2	2	3.43	6	11.00
07-Feb-12	Summer	VP1	3	3.38	20	12.13

07-Feb-12	Summer	VP2	0	3.00	0	10.78
08-Feb-12	Summer	VP3	3	3.00	16	11.30
08-Feb-12	Summer	VP3	2	2.91	6	10.82
09-Feb-12	Summer	VP2	3	2.92	27	12.17
10-Feb-12	Summer	VP2	2	2.85	3	11.46
12-Feb-12	Summer	VP1	7	3.14	11	11.43
12-Feb-12	Summer	VP3	3	3.13	8	11.20
12-Feb-12	Summer	VP3	3	3.13	7	10.94
12-Feb-12	Summer	VP3	2	3.06	20	11.47
13-Feb-12	Summer	VP1	6	3.22	39	13.00
08-May-12	Autumn	VP1	0	0.00	0	0.00
08-May-12	Autumn	VP1	0	0.00	0	0.00
09-May-12	Autumn	VP1	0	0.00	0	0.00
09-May-12	Autumn	VP1	0	0.00	0	0.00
09-May-12	Autumn	VP1	0	0.00	0	0.00
09-May-12	Autumn	VP4	0	0.00	0	0.00
10-May-12	Autumn	VP4	0	0.00	0	0.00
10-May-12	Autumn	VP4	0	0.00	0	0.00
11-May-12	Autumn	VP4	0	0.00	0	0.00
11-May-12	Autumn	VP4	0	0.00	0	0.00
11-May-12	Autumn	VP1	0	0.00	0	0.00
11-May-12	Autumn	VP4	0	0.00	0	0.00
07-Aug-12	Winter	VP1	0	0.00	0	0.00
07-Aug-12	Winter	VP4	0	0.00	0	0.00
07-Aug-12	Winter	VP1	0	0.00	0	0.00
07-Aug-12	Winter	VP4	0	0.00	0	0.00
08-Aug-12	Winter	VP1	0	0.00	0	0.00
08-Aug-12	Winter	VP4	0	0.00	0	0.00
08-Aug-12	Winter	VP1	0	0.00	0	0.00
08-Aug-12	Winter	VP4	0	0.00	0	0.00
09-Aug-12	Winter	VP1	0	0.00	0	0.00
09-Aug-12	Winter	VP4	0	0.00	0	0.00
10-Aug-12	Winter	VP1	0	0.00	0	0.00
10-Aug-12	Winter	VP4	1	0.08	1	0.08

Table B: ***Terrestrial Birds*****: counts (Flights and Individuals per 2h watch period and by vantage point) over time with updated (running) averages.**

Date	Season	VP	Flights count	Flights Updated Avge	Individ-uals count	Individuals Updated Avge
19-Oct-11	Spring	VP1	2.0	2.00	2.0	2.00
19-Oct-11	Spring	VP2	0.0	1.00	0.0	1.00
19-Oct-11	Spring	VP1	0.0	0.67	0.0	0.67
19-Oct-11	Spring	VP2	0.0	0.50	0.0	0.50
20-Oct-11	Spring	VP3	0.0	0.40	0.0	0.40
20-Oct-11	Spring	VP3	1.0	0.50	10.0	2.00
20-Oct-11	Spring	VP3	0.0	0.43	0.0	1.71
21-Oct-11	Spring	VP1	0.0	0.38	0.0	1.50
21-Oct-11	Spring	VP2	0.0	0.33	0.0	1.33
21-Oct-11	Spring	VP1	0.0	0.30	0.0	1.20
21-Oct-11	Spring	VP2	0.0	0.27	0.0	1.09
21-Oct-11	Spring	VP1	0.0	0.25	0.0	1.00
21-Oct-11	Spring	VP2	0.0	0.23	0.0	0.92
22-Oct-11	Spring	VP3	0.0	0.21	0.0	0.86
22-Oct-11	Spring	VP3	1.0	0.27	2.0	0.93
22-Oct-11	Spring	VP3	1.0	0.31	2.0	1.00
23-Oct-11	Spring	VP1	0.0	0.29	0.0	0.94
23-Oct-11	Spring	VP2	0.0	0.28	0.0	0.89
06-Feb-12	Summer	VP1	0	0.00	0	0.00
06-Feb-12	Summer	VP2	1	0.50	2	1.00
06-Feb-12	Summer	VP1	0	0.33	0	0.67
06-Feb-12	Summer	VP2	0	0.25	0	0.50
07-Feb-12	Summer	VP3	1	0.40	1	0.60
07-Feb-12	Summer	VP1	0	0.33	0	0.50
07-Feb-12	Summer	VP2	0	0.29	0	0.43
07-Feb-12	Summer	VP1	0	0.25	0	0.38
07-Feb-12	Summer	VP2	0	0.22	0	0.33
08-Feb-12	Summer	VP3	0	0.20	0	0.30
08-Feb-12	Summer	VP3	0	0.18	0	0.27
09-Feb-12	Summer	VP2	0	0.17	0	0.25
10-Feb-12	Summer	VP2	1	0.23	2	0.38
12-Feb-12	Summer	VP1	0	0.21	0	0.36
12-Feb-12	Summer	VP3	1	0.27	2	0.47
12-Feb-12	Summer	VP3	0	0.25	0	0.44
12-Feb-12	Summer	VP3	0	0.24	0	0.41
13-Feb-12	Summer	VP1	3	0.39	4	0.61

08-May-12	Autumn	VP1	0	0.00	0	0.00
08-May-12	Autumn	VP1	0	0.00	0	0.00
09-May-12	Autumn	VP1	0	0.00	0	0.00
09-May-12	Autumn	VP1	0	0.00	0	0.00
09-May-12	Autumn	VP1	0	0.00	0	0.00
09-May-12	Autumn	VP4	1	0.17	1	0.17
10-May-12	Autumn	VP4	0	0.14	0	0.14
10-May-12	Autumn	VP4	0	0.13	0	0.13
11-May-12	Autumn	VP4	1	0.22	2	0.33
11-May-12	Autumn	VP4	0	0.20	0	0.30
11-May-12	Autumn	VP1	0	0.18	0	0.27
11-May-12	Autumn	VP4	1	0.25	2	0.42
07-Aug-12	Winter	VP1	0	0.00	0	0.00
07-Aug-12	Winter	VP4	0	0.00	0	0.00
07-Aug-12	Winter	VP1	0	0.00	0	0.00
07-Aug-12	Winter	VP4	0	0.00	0	0.00
08-Aug-12	Winter	VP1	0	0.00	0	0.00
08-Aug-12	Winter	VP4	0	0.00	0	0.00
08-Aug-12	Winter	VP1	0	0.00	0	0.00
08-Aug-12	Winter	VP4	0	0.00	0	0.00
09-Aug-12	Winter	VP1	0	0.00	0	0.00
09-Aug-12	Winter	VP4	1	0.10	2	0.20
10-Aug-12	Winter	VP1	0	0.09	0	0.18
10-Aug-12	Winter	VP4	1	0.17	1	0.25