DEVELOPMENT OF THE HARMONY MOAB KHOTSONG SOLAR PV FACILITY, VIERFONTEIN, FREE STATE PROVINCE

Avifauna Baseline and Impact Assessment Report

July 2022

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EXECUTIVE SUMMARY

Pachnoda Consulting cc was requested by Savannah Environmental (Pty) Ltd on behalf of Harmony Moab Khotsong Operations Pty (Ltd) to compile an avifauna impact assessment report for three separate solar facilities (referred to as the "Moab Khotsong PV facility") with a combined contracted capacity of up to 100MW located on a site approximately 10km north of the town of Vierfontein in the Free State Province.

The objectives of the avifaunal study were to: (a) describe the avifauna associations in the study area according to species composition and richness prior to construction activities; (b) provide an inventory of bird species occurring in the project area including species prone towards collisions with the proposed infrastructure; (c) provide an impact assessment; and (d) provide an indication of the occurrence of species of concern (e.g. threatened and near threatened species).

Baseline avian data was obtained from point count sampling techniques during two independent sampling sessions (May 2022 and July 2022).

Eight avifaunal habitat types were identified on the study site and surroundings, consisting of four untransformed types (ranging from open grassland with bush clump mosaics, depressions, Imperata cylindrica seep zones to a valley-bottom see/stream) and four transformed units (ranging from agricultural land, *Eucalyptus* plantations, rehabilitated grassland and pastures to pollution control dams). The study site was also surrounded by slimes dams and an impoundment to the east (c. 700m from the site), which provided additional habitat for waterbird and shorebird taxa (especially the latter). Approximately 222 bird species are expected to occur in the wider study area, of which 109 species were observed in the study area (during two independent surveys). The expected richness included five threatened or near threatened species, 18 southern African endemics and 17 near-endemic species. However, the occurrence of threatened and near threatened bird species was predicted to be low, although the natural broad-scale habitat units provided foraging habitat for the occasional occurrence of the vulnerable Lanner Falcon (*Falco biarmicus*) and the regionally near threatened Abdim's Stork (*Ciconia abdimii*). In addition, the valley-bottom seep/stream on the eastern part of the study site provides suitable foraging habitat for the regionally endangered African Marsh Harrier (*Circus ranivorus*), although this species was not observed during the respective surveys. Although the African Marsh Harrier was recorded on the study site during the survey period, it was recommended that all potential habitat be conserved (as a precautionary principle) which included the seep zone/stream on the eastern part of the study site. Sixteen southern African endemics and 11 near-endemic species were confirmed on the study site.

The main impacts associated with the proposed PV solar facility included the following:

- The loss of habitat and subsequent displacement of bird species due to the ecological footprint required during construction.
- Direct interaction (collision trauma) by birds with the surface infrastructure (photovoltaic panels) caused by polarised light pollution and/or colliding with the panels (as they are mistaken for waterbodies).
- Collision with associated infrastructure (mainly overhead power lines).

An evaluation of potential and likely impacts on the avifauna revealed that the impact significance was moderate to low after mitigation (depending on the type of impact). However, the risk for certain waterbirds (mainly large-bodied waterfowl such as the South African Shelduck *Tadorna cana* and Egyptian Goose *Alopochen aegyptiacus*) colliding with the PV infrastructure remained eminent due to the presence of wetland-associated features and pollution control dams in the study area. Post-construction monitoring was recommended along with the installation of appropriate bird diverters to minimise the potential risk of collision trauma in birds.

No fatal-flaws were identified during the assessment, although it was strongly recommended that the proposed mitigation measures and monitoring protocols (e.g. post construction monitoring) be implemented during the construction and operational phase of the project.

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DECLARATION OF INDEPENDENCE

I, Lukas Niemand (Pachnoda Consulting CC) declare that:

- I act as the independent specialist in this application to Savannah Environmental (Pty) Ltd and Harmony Moab Khotsong Operations Pty (Ltd);
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have no vested financial, personal or any other interest in the application;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority; and
- All the particulars furnished by me in this form are true and correct.

Lukas Niemand (Pr.Sci.Nat)
25 July 2022

Lukas Niemand is registered with The South African Council for Natural Scientific Professionals (400095/06) with more than 20 years of experience in ecological-related assessments and more than 15 years in the field of bird interactions with electrical and renewable energy infrastructure. He has conducted numerous ecological and avifaunal impact assessments including Eskom Transmission projects, hydro-electric schemes, solar farms and other activities in South Africa and other African countries.

1. INTRODUCTION

1.1 Project Description

Harmony Gold is looking to supplement its energy supply by implementing PV generation, aiding their transition to a more sustainable and environmentally friendly energy mix. In this regard, Harmony Gold is proposing the construction and operation of 5 solar PV facilities located on 5 different Harmony Gold Mine sites within the Free State Province. The project entails the development of five (5) separate solar PV facilities, each including grid connection and other associated infrastructure. The projects will all tie-in to the electricity grid behind the Eskom meter at the respective Harmony mine customer substations. Each project will be developed through a different Special Purpose Vehicle (SPV).

The successful development of the renewable energy projects will enable Harmony Gold to make a valuable and meaningful contribution towards growing the green economy within the province and South Africa. This will assist the Free State in creating green jobs and reducing Green House Gas emissions, whilst reducing the energy demand on the National Grid.

Pachnoda Consulting cc was requested by Savannah Environmental (Pty) Ltd on behalf of Harmony Moab Khotsong Operations Pty (Ltd) to compile an avifauna impact assessment report for three separate solar facilities (all three herewith referred to as the "Moab Khotsong PV facility") with a combined contracted capacity of up to 100MW located on a site approximately 10km north of the town of Vierfontein in the Free State Province (Figure 1). The study site is situated within the Moqhaka Local Municipality respectively, and within the Fezile Dabi District Municipality. The Solar PV facilities are based near Harmony Moab mining operations and fall within the Klerksdorp Renewable Energy Development Zone (REDZ).

The solar facilities will be located on a 280ha development area, which will include the PV facilities and grid connection infrastructure (Figure 2). The infrastructure associated PV facilities includes:

- Solar PV arrays comprising of bifacial PV modules and mounting structures, using single axis tracking technology. Once installed, it will stand up to 5m above ground level.
- Inverters and transformers, a SCADA room, and maintenance room.
- Cabling between the project components.
- Balance of Plant:
    - Existing spare switchgear panels, upgraded switchgear circuit breakers or additional switchgear panels.
    - EK self-build works as defined in the CEL.

- On-site facility substation to facilitate the connection between the solar PV facilities and Eskom electricity grid. The Size and Capacity of the on-site stations will be 40MW.
- An onsite Medium voltage (MV) switching station forming part of the collector substation.
- Temporary laydown areas.
- Access roads, internal roads and fencing around the development area.
- Up to 132kV Overhead Power Lines (OHPL) with a maximum of 30m height with a 30m servitude width.
- Underground LV cabling will be used on the PV sites.

The PV facilities will be located on the following farm portions:

Farm Name	Portion Number
ANGLO 593	593
HOEKPLAATS 598	598
MISPAH 274	274
MOAB 279	279
ZAAIPLAATS 2/190	2/190
ZAAIPLAATS 1/190	1/190
DOORNKOM WES 446	RE/446
CHRYSTALKOP 69	69
ZUIPING 394	4/394
ZUIPING 394	3/394
ZUIPING 394	5/394
ZUIPING 394	RE/394
ZUIPING 394	1/394

The facilities will tie-in to the Vaalreefs 11, Southvaal Plant and Southvaal (6.6/132 kV) substations respectively. Connection line A and C will have a connection capacity of up to 132kV, and Connection line B a connection capacity of up to 132kV. The lines connecting the PV facility to the respective substations will be up to 44kV.

1.2 Objectives and Terms of Reference

The main objectives of the avifaunal study were to: (a) describe the avifauna associations in the study area according to species composition and richness prior to construction activities; (b) provide an inventory of bird species occurring in the study area including species prone towards collisions with the proposed infrastructure; (c) provide an impact assessment; and (d) provide an indication of the occurrence of species of concern (e.g. threatened and near threatened species; sensu IUCN, 2022; Taylor et al., 2015; Marnewick et al., 2015).

A bird assessment is required as part of the Environmental Impact Assessment process to investigate the impacts of the proposed solar facility on the avian attributes at the study site and its immediate surroundings. The avifaunal attributes at the proposed PV facility will be determined by means of a desktop analysis of GIS based information, third-party datasets and a number of site surveys. It also provides the results from two independent pre-construction surveys as per the best practice guidelines of Jenkins *et al.* (2017).

The terms of reference are to:

- conduct a baseline bird assessment based on available information pertinent to the ecological and avifaunal attributes on the project area and habitat units;
- conduct an assessment of all information on an EIA level in order to present the following results:
    - typify the regional and site-specific avifaunal macro-habitat parameters that will be affected by the proposed project;
    - provide a shortlist of bird species present as well as highlighting dominant species and compositions;
    - provide an indication on the occurrence of threatened, near threatened, endemic and conservation important bird species likely to be affected by the proposed project;
    - provide an indication of sensitive areas or bird habitat types corresponding to the study area;
    - highlight areas of concern or "hotspot" areas;
    - identify and describe impacts that are considered pertinent to the proposed development;
    - highlight gaps of information in terms of the avifaunal environment; and
    - recommend additional surveys and monitoring protocols (*sensu* Jenkins et al., 2017).

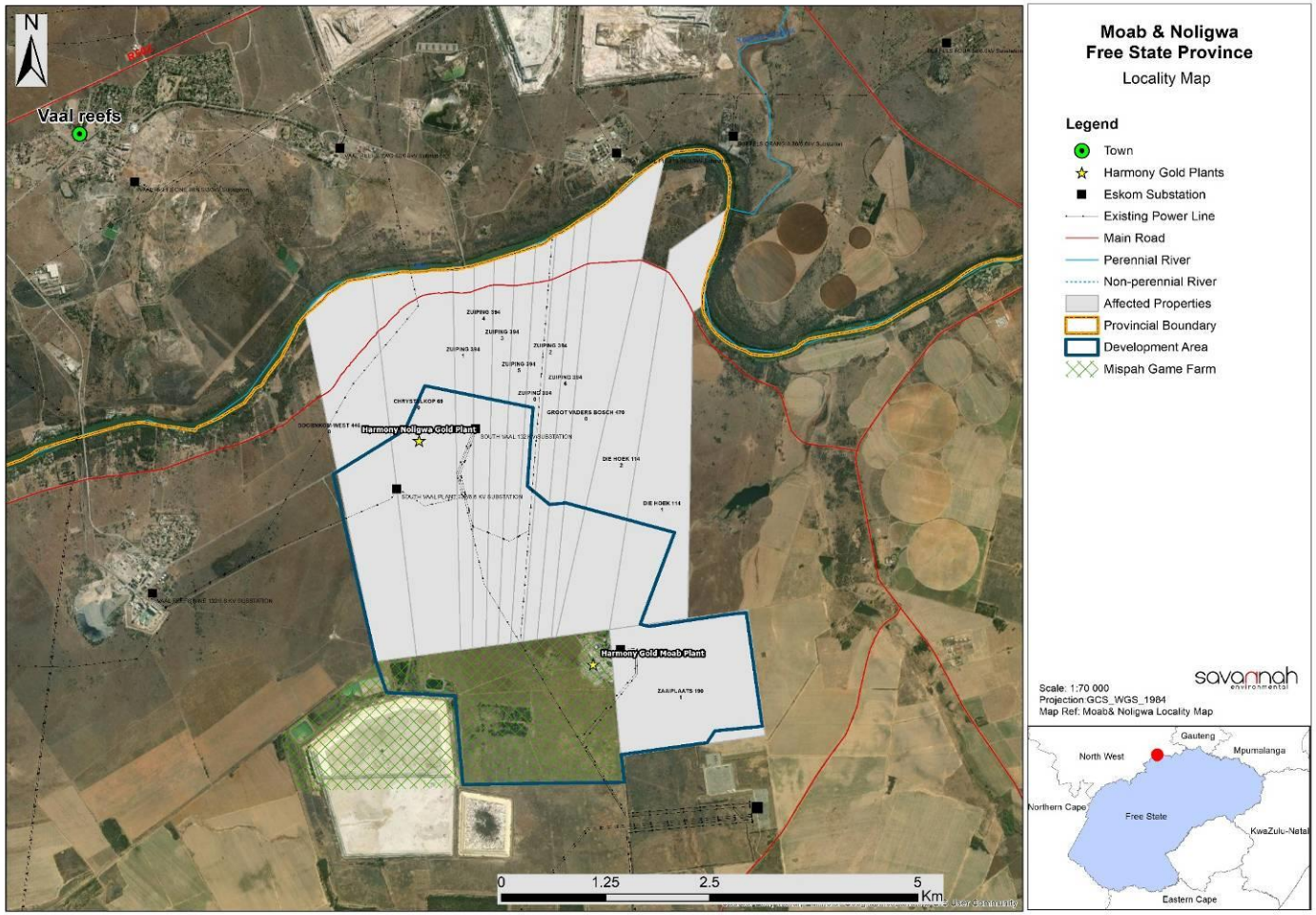


Figure 1: An image illustrating the geographic position of proposed Harmony Moab Khotsong Solar PV facility.

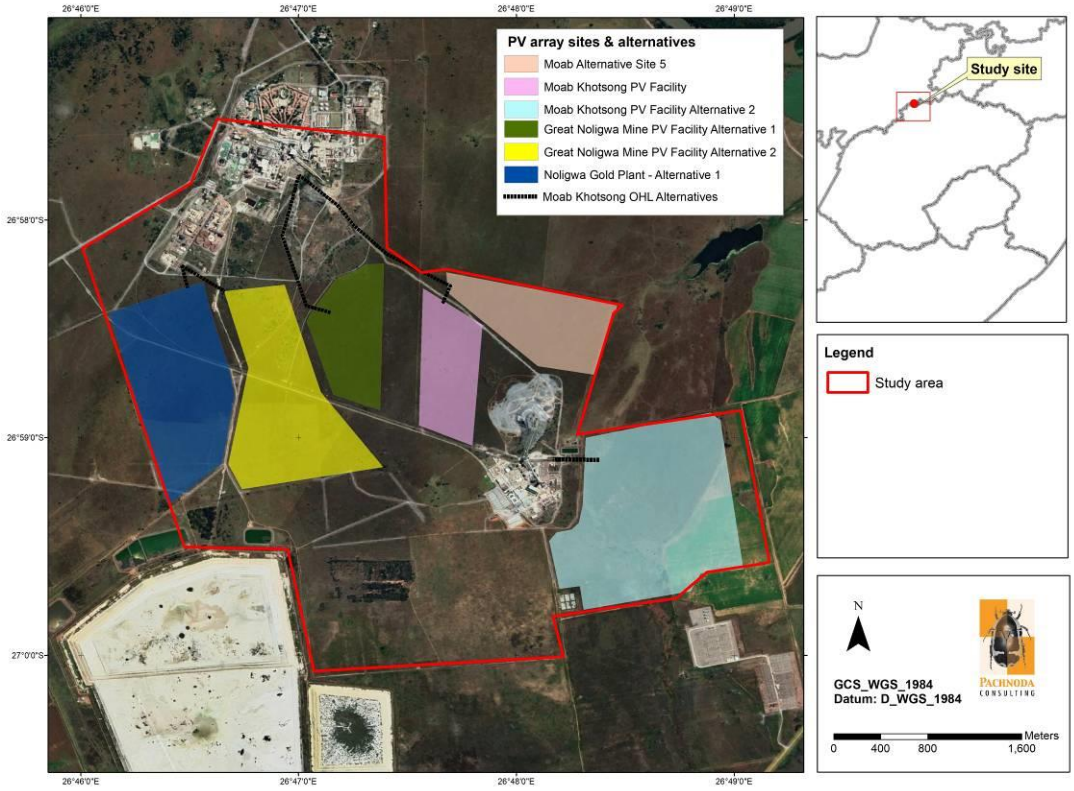


Figure 2: A satellite image illustrating the geographic position of the proposed Harmony Moab Khotsong Solar PV facility and associated infrastructure.

1.3 Scope of Work

The following aspects form part of the Scope of Work:

- A desktop study of bird species expected to occur (e.g. species that could potentially be present), as well as species recorded in the past (e.g. SABAP1);
- A baseline survey of observed bird species according to ad hoc observations and two sampling surveys;
- A list of bird species historically recorded within the relevant quarter degree grid in which the study site occurs (SABAP1);
- Any protected or threatened bird species recorded in the past within the relevant quarter degree grid, their scientific names and colloquial names, and protected status according to IUCN red data lists; and
- The potential of these protected or threatened species to persist within the study area.

The following aspects will be discussed during this avifaunal assessment:

- Collision-prone bird species expected to be present and or observed;

- A list of the dominant bird species;
- A list of observed and expected threatened and near threatened species (according to IUCN red data list);
- Possible migratory or nomadic species;
- Potential important flyways/ congregatory sites and/or foraging sites; and
- Avian impacts associated with the PV solar facility.

2. METHODS & APPROACH

The current report places emphasis on the avifaunal community as a key indicator group on the proposed study area, thereby aiming to describe the conservation significance of the ecosystems in the area. Therefore, the occurrence of certain bird species and their relative abundances may determine the outcome of the ecological sensitivity of the area and the subsequent proposed layouts of the solar facility infrastructure.

The information provided in this report was principally sourced from the following sources/observations:

- relevant literature – see section below;
- observations made during two site visits (23 - 27 May, 2022 and 04 - 08 July 2022); and
- personal observations from similar habitat types in proximity to the study area.

2.1 Literature survey and Database acquisition

A desktop and literature review of the area under investigation was commissioned to collate as much information as possible prior to the detailed baseline survey. Literature consulted primarily makes use of small-scale datasets that were collected by citizen scientists and are located at various governmental and academic institutions (e.g. Animal Demography Unit & SANBI). These include (although are not limited to) the following:

- Hockey *et al*. (2005) for general information on bird identification and life history attributes.
- Marnewick *et al.* (2015) was consulted for information regarding the biogeographic affinities of selected bird species that could be present on the study area.
- The conservation status of bird species was categorised according to the global IUCN Red List of threatened species (IUCN, 2022) and the regional conservation assessment of Taylor *et al.* (2015).
- Distributional data was sourced from the South African Bird Atlas Project (SABAP1) and verified against Harrison et al. (1997) for species corresponding to the quarter-degree grid cells (QDCs) 2626DD (Stilfontein) and 2726BB (Viljoenskroon) (Figure 3). The information was then modified according to the prevalent habitat types present on the development area. The SABAP1 data provides a “snapshot” of the abundance and composition

of species recorded within a quarter degree grid cell (QDGC) which was the sampling unit chosen (corresponding to an area of approximately 15 min latitude x 15 min longitude). It should be noted that the atlas data makes use of reporting rates that were calculated from observer cards submitted by the public as well as citizen scientists. It therefore provides an indication of the thoroughness of which the QDGCs were surveyed between 1987 and 1991;

- Additional distributional data was also sourced from the SABAP2 database (http://www.sabap2.birdmap.africa). The information was then modified according to the prevalent habitat types present on the study area. Since bird distributions are dynamic (based on landscape changes such as fragmentation and climate change), SABAP2 was born (and launched in 2007) from SABAP1 with the main difference being that all sampling is done at a finer scale known as pentad grids (5 min latitude x 5 min longitude, equating to 9 pentads within a QDGC). Therefore, the data is more site-specific, recent and more comparable with observations made during the site visit (due to increased standardisation of data collection). The pentad grid relevant to the current project is 2655_2645 (although all eight pentad grids surrounding grid 2730_2255 were also scrutinised) (Figure 4).
- The choice of scientific nomenclature, taxonomy and common names were recommended by the International Ornithological Committee (the IOC World Bird List v. 12.1), unless otherwise specified (see www.worldbirdnames.org as specified by Gill et al, 2022). Colloquial (common) names were used according to Hockey *et. al.* (2005) to avoid confusion;
- The best practice guidelines for assessing and monitoring the impact of solar power generating facilities on birds in southern Africa were also consulted (Jenkins *et al.,* 2017).

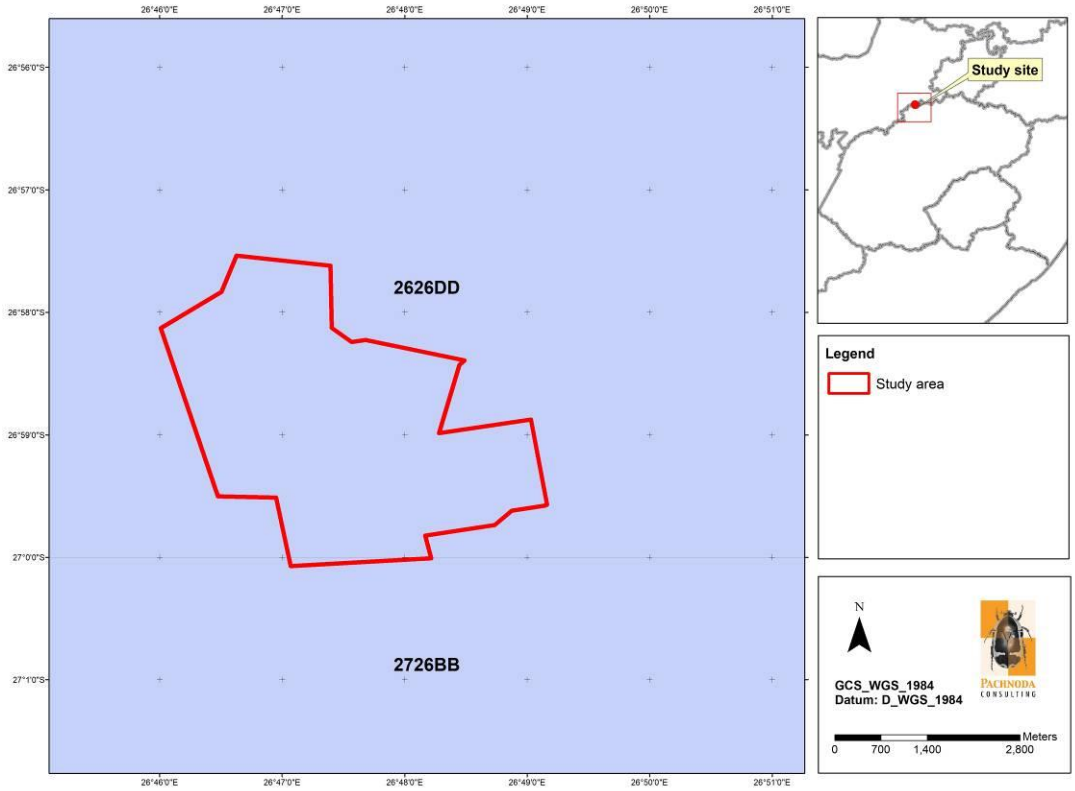


Figure 3: A map illustrating the quarter-degree grid cells that were investigated for this project.

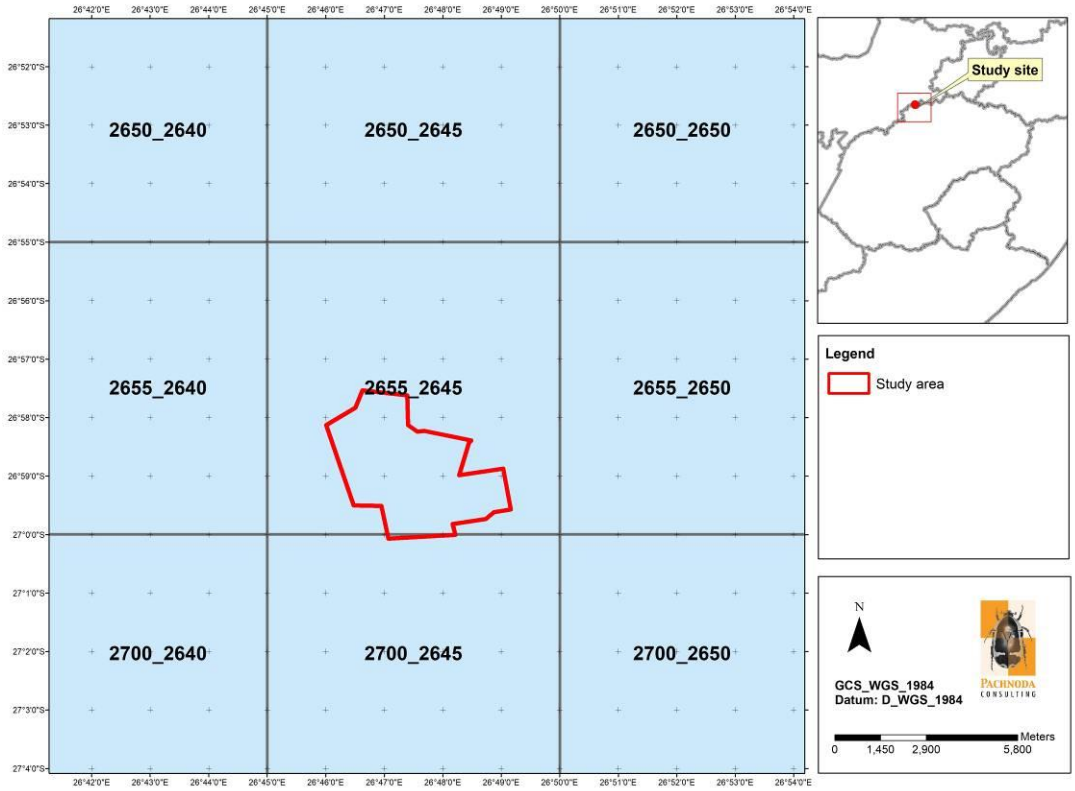


Figure 4: A map illustrating the pentad grids that were investigated for this project.

2.2 Field Methods

The avifauna of the study site was surveyed during two independent site visits (May 2022 and July 2022).

The baseline avifaunal survey was conducted by means of the following survey techniques:

2.2.1 Point Counts

Bird data was collected by means of 30 point counts (as per Buckland et al. 1993) from the study area. Data from the point counts has been analysed to determine dominant and indicator bird species (so-called discriminant species), relative densities and to delineate the different bird associations present.

The use of point counts is advantageous since it is the preferred method to use for skulking or elusive species. In addition, it is the preferred method to line transect counts where access is problematic, or when the terrain appears to be complex (e.g. mountainous). It is considered to be a good method to use, and very efficient for gathering a large amount of data in a short period of time (Sutherland, 2006). The spatial position of each point count is illustrated in Figure 5. The spatial placement of the point counts was determined through a stratified random design which ensures

coverage of each habitat type and/or macro-habitat (Sutherland et al., 2004).

Therefore, the sampling approach was adapted so that all the bird species seen within approximately 50m from the centre of the point were recorded (resulting in an area of 0.78 ha) along with their respective abundance values (a laser rangefinder was used to delineate the area to be surveyed at each point). Each point count lasted approximately 20 -30 minutes, while the area within the 50m radius of homogenous habitat was slowly traversed to ensure that all bird species were detected and or flushed (as proposed by Watson, 2003). To ensure the independence of observations, points were positioned at least 200 m apart. Observations were not truncated, and in order to standardise data collection, the following assumptions were conformed to (according to Buckland *et al.*, 1994):

- All birds on the point must be seen and correctly identified. This assumption is in practice very difficult to meet in the field as some birds in the nearby vicinity may be overlooked due to low visibility or were obscured by vegetation (e.g. graminoid cover). Therefore, it is assumed that the portion of birds seen on the point count represents the total assemblage on the point.
- All birds must be recorded at their initial location. All movements of the birds are random and therefore natural in relation to the movements of the observer. None of the birds moved in response to the presence of the observer, and birds flying past without landing were omitted from the analysis.
- In other words, no bird is recorded more than once.

2.2.2 Random (ad hoc) surveys

To obtain an inventory of bird species present (apart from those observed during the point counts), all bird species observed/detected while moving between point counts were identified and noted. Particular attention was devoted to suitable roosting, foraging and nesting habitat for species of conservation concern (e.g. threatened or near threatened species). In addition, the fly patterns of large non-passerine and birds of prey were recorded, as well as the locality of collision-prone birds.

2.2.3 Analyses

Data generated from the point counts was analysed according to Clarke & Warwick (1994) based on the computed percentage contribution (%) of each species, including the consistency (calculated as the similarity coefficient/standard deviation) of its contribution. Hierarchical Agglomerative Clustering (a cluster analysis-based group-average linkages; Clarke & Warwick 1994) was performed on calculated Bray-Curtis coefficients derived from the data. A cluster analysis is used to assign "species associations" between samples with the aim to objectively delineate groups or assemblages. Therefore, sampling entities that group together (being more similar) are believed to have similar compositions.

The species richness and diversity of each bird association was analysed by means of richness measures (such as the total number of species recorded (S) and Shannon Wiener Index) were calculated to compare the associations with each other.

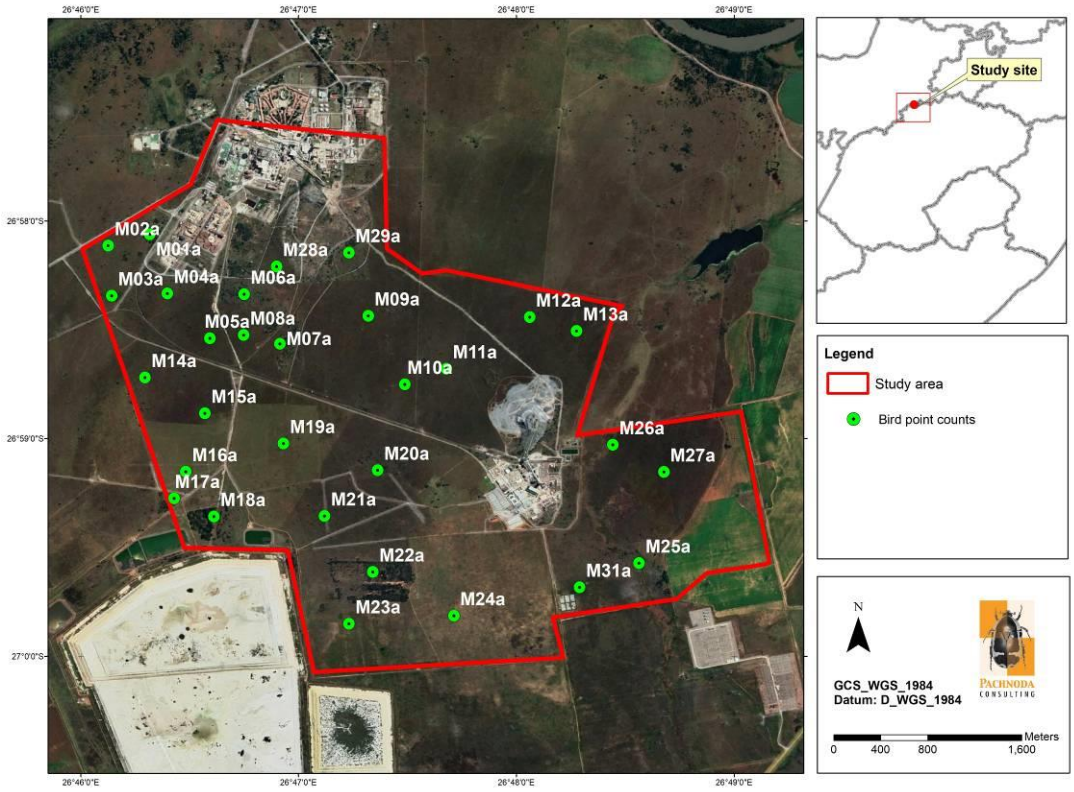


Figure 5: A map illustrating the spatial position of 30 bird point counts located within the study area.

2.3 Sensitivity Analysis

A sensitivity map was compiled based on the outcome of the baseline results.

The ecological sensitivity of any piece of land is based on its inherent ecosystem service (e.g. wetlands) and overall preservation of biodiversity.

2.3.1 Ecological Function

Ecological function relates to the degree of ecological connectivity between systems within a landscape matrix. Therefore, systems with a high degree of landscape connectivity amongst one another are perceived to be more sensitive and will be those contributing to ecosystem services (e.g. wetlands) or the overall preservation of biodiversity.

2.3.2 Avifaunal Importance

Avifaunal importance relates to species diversity, endemism (unique species or unique processes) and the high occurrence of threatened and protected species or ecosystems protected by legislation.

2.3.3 Sensitivity Scale

- *High* – Sensitive ecosystems with either low inherent resistance or low resilience towards disturbance factors or highly dynamic systems considered important for the maintenance of ecosystem integrity. Most of these systems represent ecosystems with high connectivity with other important ecological systems OR with high species diversity and usually contain high numbers of threatened, endemic or rare bird species. These areas should preferably be protected;
- *Moderately high* - Untransformed or productive habitat units (which can also be artificial) which contain high bird numbers and/or bird richness values. These areas are often fragmented OR azonal, and hence of small surface area that are often surrounded by habitat of moderate or low sensitivity. These habitat units also include potential habitat for threatened species. Development is often considered permissible on these areas if there is enough reason to believe that these areas are widespread in the region and future planned developments are unlikely to result in the widespread loss (>50 %) of similar habitat at a regional scale.
- *Medium* – These are slightly modified systems which occur along gradients of disturbances of low-medium intensity with some degree of connectivity with other ecological systems OR ecosystems with intermediate levels of species diversity but may include potential ephemeral habitat for threatened species; and
- *Low* – Degraded and highly disturbed/transformed systems with little ecological function and are generally very poor in bird species diversity (most species are usually exotic or weeds).

2.4 Limitations

- It is assumed that third party information (obtained from government, academic/research institution, non-governmental organisations) is accurate and true.
- Some of the datasets are out of date and therefore extant distribution ranges may have shifted although these datasets provide insight into historical distribution ranges of relevant species.
- The datasets are mainly small-scale and could not always consider azonal habitat types that may be present on the study area (e.g. artificial livestock watering points). In addition, these datasets encompass surface areas larger

than the study area, which could include habitat types and species that are not present on the study site. Therefore the potential to overestimate species richness is highly likely while it is also possible that certain cryptic or specialist species could have been be overlooked in the past.

- Some of the datasets (e.g. SABAP2) managed by the Animal Demography Unit of the University of Cape Town were recently initiated and therefore incomplete.
- A replicative sampling protocol (two sampling surveys) was followed representing the end of the austral wet season and during the peak austral dry season. The austral dry season is not the optimal time of the year to conduct bird surveys since many of the migratory species (Palearctic and Intra-African migratory species) will be absent. However, these species represent a small percentage of the expected species that could occur on the study site. In addition, many resident species also become less vocal (e.g. cisticolas) during the dry season with the risk that these species may be overlooked. However, replicative surveys detected the majority of these species and the observed species list for the study site is considered to be a true representation of the expected richness.
- This company, the consultants and/or specialist investigators do not accept any responsibility for conclusions, suggestions, limitations and recommendations made in good faith, based on the information presented to them, obtained from the surveys or requests made to them at the time of this report.

3. DESCRIPTION OF THE AFFECTED ENVIRONMENT

3.1 Locality

The proposed PV facility will be located near the Harmony Moab mining operations located and approximately 10km North of the town of Vierfontein, Free State Province (Figure 1).

3.2 Regional Vegetation Description

The study site corresponds to the Grassland Biome and more particularly to the Dry Highveld Grassland Bioregion as defined by Mucina & Rutherford (2006). It comprehends two ecological types known as (1) Vaal Reefs Dolomite Sinkhole Woodland and (2) Vaal-Vet Sandy Grassland (Mucina & Rutherford, 2006) (Figure 6).

From an avifaunal perspective it is evident that bird diversity is positively correlated with vegetation structure, and floristic richness is not often regarded to be a significant contributor of patterns in bird abundance and their spatial distributions. Although grasslands are generally poor in woody plant species, and subsequently support lower bird richness values, it is often considered as an important habitat for

many terrestrial bird species such as larks, pipits, korhaans, cisticolas, widowbirds including large terrestrial birds such as Secretarybirds, cranes and storks. Many of these species are also endemic to South Africa and display particular narrow distribution ranges. Due to the restricted spatial occurrence of the Grassland Biome and severe habitat transformation, many of the bird species that are restricted to the grasslands are also threatened or experiencing declining population sizes.

1. Vaal Reefs Dolomite Sinkhole Woodland

Vaal Reefs Dolomite Sinkhole Woodland is confined to a small area associated with dolomite sinkholes in the Stilfontein and Orkney areas corresponding to the North West and Free State Provinces. It is located on the northern and central parts of the study site, where it occurs on slightly undulating landscapes dissected by prominent chert ridges, thereby supporting a grassland-woodland floristic mosaic. A prominent floristic structure of this vegetation type is woodland formations in the form of bush clumps around sinkholes and dolomite outcrops.

The Vaal Reefs Dolomite Sinkhole Woodland is a threatened (**Vulnerable**) ecosystem with only a small patch conserved in the statutorily conservation are of the Sterkfontein Caves (part of the Cradle of Humankind World Heritage Site). In addition, the proposed "Highveld National Park" is supposed to conserve a large section of this vegetation type, which is considered to be one of the most aesthetically pleasing and scenic landscapes in the western Grassland Biome. Approximately 25% of this vegetation type has been transformed due to mining activities and cultivation, and it corresponds to an area with the highest concentration of mines when compared to other vegetation types. In addition, the Vaal Reefs Dolomite Sinkhole Woodland is a Threatened Ecosystem (as per Section 52 of National Environmental Management Biodiversity Act, (Act No. 10 of 2004)) and a Critical Biodiversity Area as per the Free State Conservation Plan (DESTEA, 2015).

2. Vaal-Vet Sandy Grassland

The Vaal-Vet Sandy Grassland occurs in the Free State and North-West Provinces, where it extends from Lichtenburg and Ventersdorp southwards to Klerksdorp, Leeudoringstad, Bothaville and the Brandfort area north of Bloemfontein. It occurs at an altitude of 1 220-1 560 m and is mainly confined to aeolian and colluvial sand overlying shales and mudstones. It is confined to the southern part of the study site. The floristic structure of the Vaal-Vet Sandy Grassland is a low tussocky grassland with many karroid elements. In its untransformed condition, *Themeda triandra* is an important dominant graminoid, while intense grazing and erratic rainfall is responsible for an increase of *Elionurus muticus, Cymbopogon pospischilii* and *Aristida congesta*.

The Vaal-Vet Sandy Grassland is a threatened (**Endangered**) ecosystem with only a few remaining patches of untransformed grassland being statutorily conserved (c. 0.3 % at Bloemhof Dam, Schoonspruit, Sandveld, Faan Meintjies, Wolwespruit and Soetdoring Nature Reserves). In addition, the Vaal-Vet Sandy Grassland is a

Critically Endangered Ecosystem (as per Section 52 of National Environmental Management Biodiversity Act, (Act No. 10 of 2004)) and a Critical Biodiversity Area as per the Free State Conservation Plan (DESTEA, 2015). More than 63 % of this grassland type is already transformed by cultivation, and intense livestock grazing.

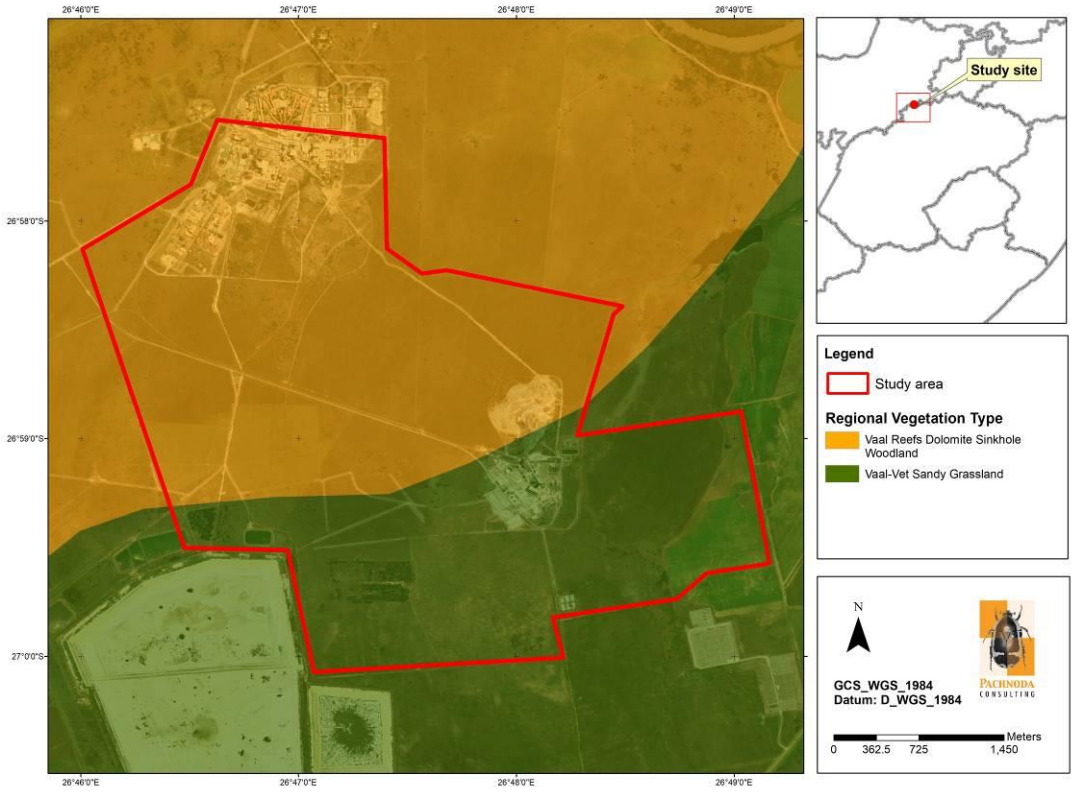


Figure 6: A satellite image illustrating the regional vegetation type corresponding to the study area. Vegetation type categories were defined by Mucina & Rutherford (2006).

3.3 Land cover, land use and existing infrastructure.

According to the South African National dataset of 2013-2014 (Geoterrainimage, 2015) the study area comprehends the following land cover categories (Figure 7):

Natural areas:

- Mainly Grassland;
- Low shrubland; and
- Wetlands.

Transformed areas:

- Mine infrastructure and build-up land;
- Eucalyptus plantations; and
- Cultivation.

From the land cover dataset it is evident that most of the is occupied by natural grassland with scattered bush clumps (especially in the south), wish a natural seep area located on the eastern part of the study site. Existing infrastructure includes the two Harmony Moab (on the central part) and Noligwa (in the north) gold plants. Other transformed land cover classes include commercial agricultural land in the east, a few pollution control dams in the south as well as scattered *Eucalyptus* plantations in the south.

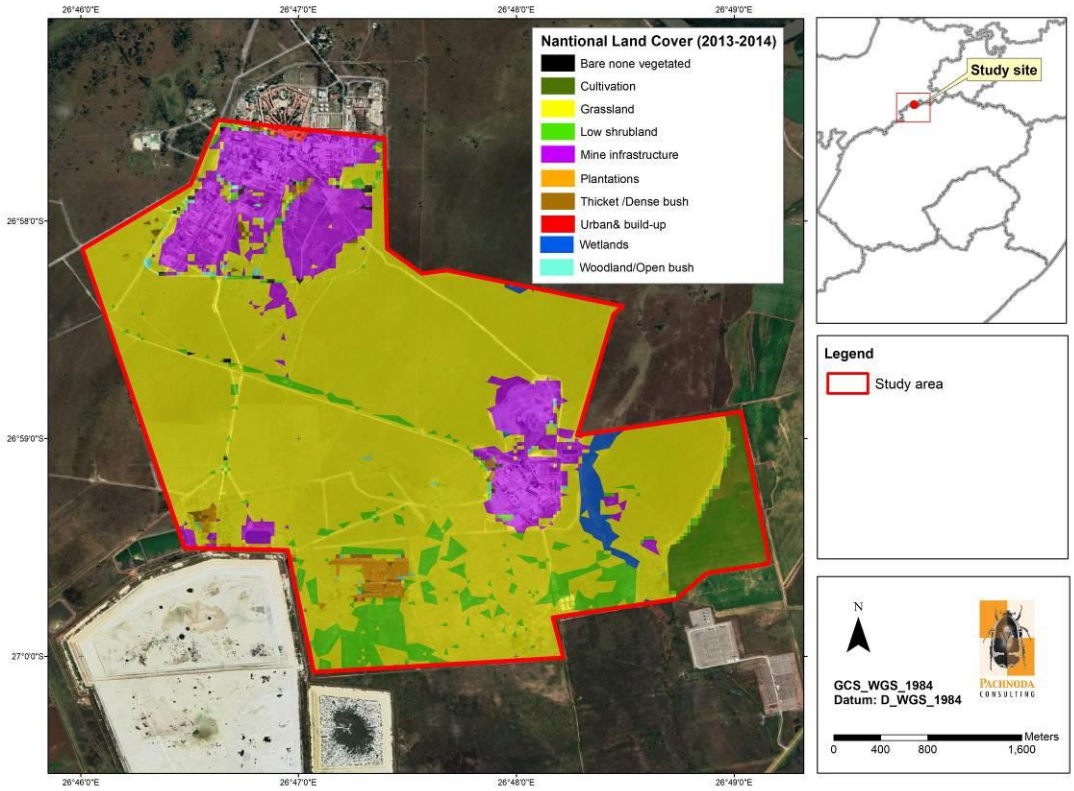


Figure 7: A map illustrating the land cover classes (Geoterrainimage, 2015) corresponding to the proposed study area.

3.4 Conservation Areas, Protected Areas and Important Bird Areas

There are no formal/legal protected or conservation areas or any Important Bird and Biodiversity Areas in close proximity to the study area. However, the southern section of the study area overlaps with the Mispah Game Farm (see figure 1), which is already partly transformed by a slimes dam.

3.5 Annotations on the National Web-Based Environmental Screening Tool

Regulation 16(1)(v) of the Environmental Impact Assessment Regulations, 20145 (EIA Regulations) provides that an applicant for Environmental Authorisation is required to submit a report generated by the Screening Tool as part of its application.

On 5 July 2019, the Minister of Environmental Affairs, Forestry and Fisheries published a notice in the Government Gazette giving notice that the use of the Screening Tool is compulsory for all applicants to submit a report generated by the Screening Tool from 90 days of the date of publication of that notice.

The Screening Tool is intended to allow for pre-screening of sensitivities in the landscape to be assessed within the EA process. This assists with implementing the mitigation hierarchy by allowing developers to adjust their proposed development footprint to avoid sensitive areas. The Screening Tool report will indicate the (preliminary) environmental sensitivities that intersect with the proposed development footprint as defined by the applicant as well as the relevant Protocols.

As the Screening Tool contains datasets that are mapped at a national scale, there may be areas where the Screening Tool erroneously assigns, or misses, environmental sensitivities because of mapping resolution and a high paucity of available and accurate data. Broad-scale site investigations will provide for an augmented and site-specific evaluation of the accuracy and 'infilling' of obvious and large-scale inaccuracies. Information extracted from the National Web-based Environmental Screening Tool (Department of Environmental Affairs, 2020), indicated that the study site holds a **medium** sensitivity with respect to the relative animal species protocol (Figure 8) (report generated 25/04/2022):

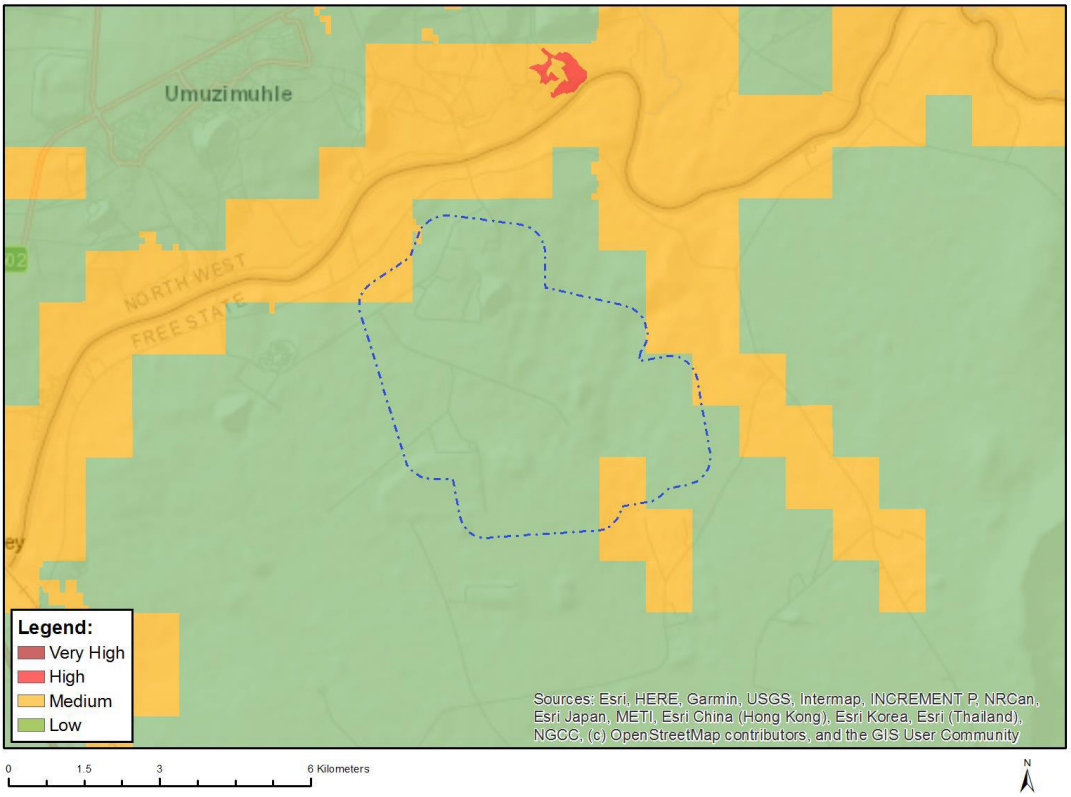


Figure 8: The animal species sensitivity of the study area (including a 500m buffer) according to the Screening Tool.

Sensitive features include the following:

Sensitivity	Feature(s)
Low	Subject to confirmation
Medium	Aves - *Circus ranivorus*
Medium	Mammalia-*Hydrictis maculicollis*

It is evident from the results of the Screening Tool report that the south-eastern and northern parts of the study area contains habitat of medium sensitivity for one threatened bird species, which includes the endangered African Marsh Harrier (*Circus ranivorus*).

The study site holds a **low** sensitivity with respect to the relative avian theme (Figure 9) (report generated 25/04/2022):

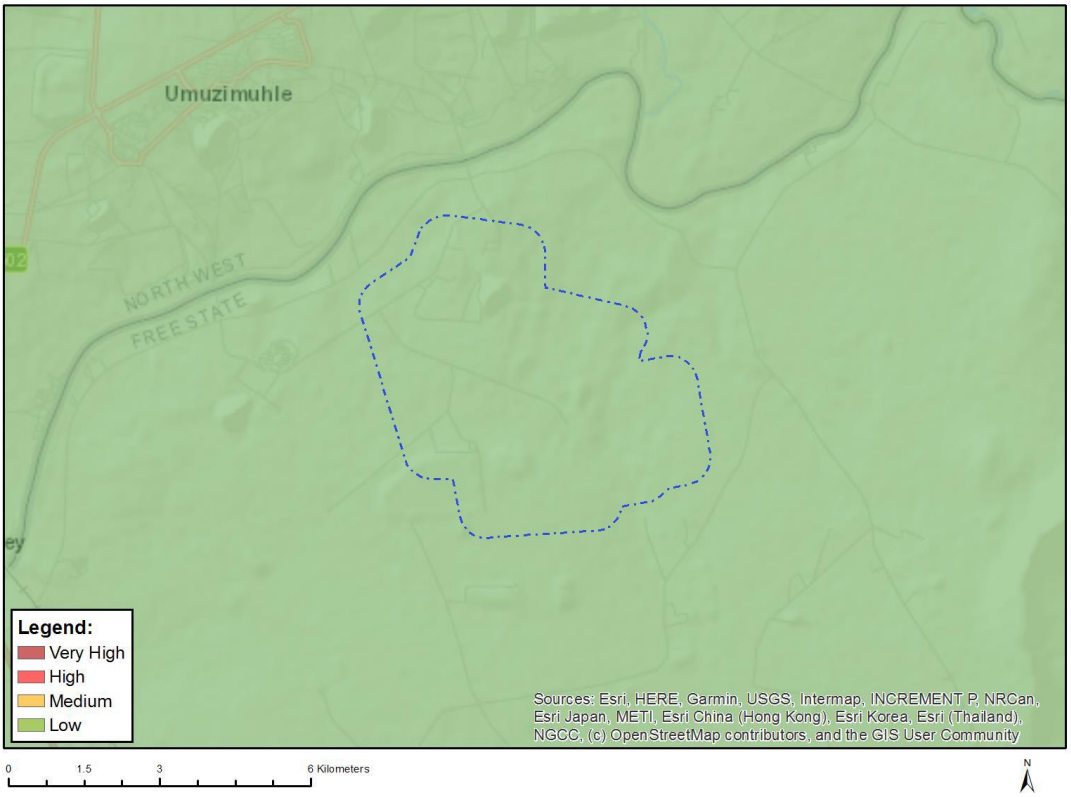


Figure 9: The relative avian sensitivity of the study area (including a 500m buffer) according to the Screening Tool.

It is evident from the results of the Screening Tool report that the study area is potentially not an important area for bird species with a high probability to interact with the solar infrastructure and that the site does not potentially overlap with important avian flyways.

However, the study site holds a **very high** sensitivity with respect to the relative terrestrial biodiversity theme (Figure 10) (report generated 25/04/2022):

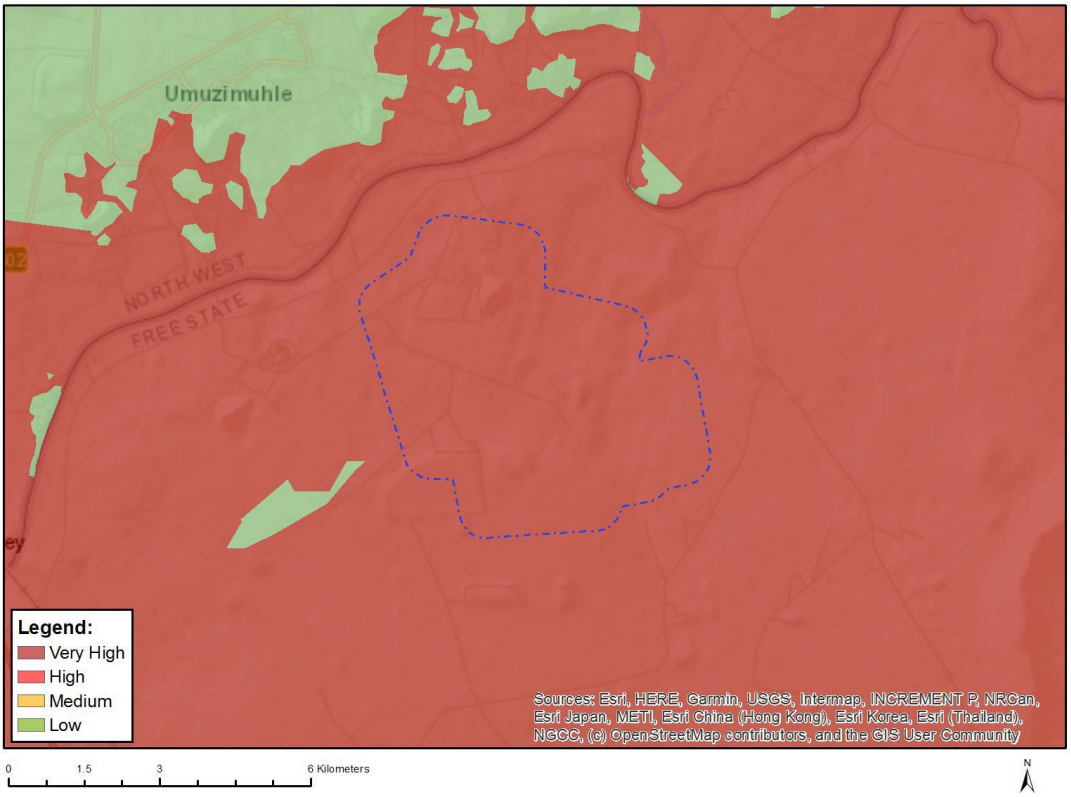


Figure 10: The relative terrestrial biodiversity sensitivity of the study area (including a 500m buffer) according to the Screening Tool.

Sensitive features include the following:

Sensitivity	Feature(s)
Very High	Critical Biodiversity Area 1
Very High	Critical Biodiversity Area 12
Very High	Ecological Support Area 1
Very High	Ecological Support Area 2
Very High	Endangered Ecosystem
Very High	Mispah Game Farm

It is evident from the results of the Screening Tool report that the entire study area coincides with a Critical Biodiversity Area 1 and 2 (CBA 1 & 2) and an Ecological Support Are 1 and 2 (ESA 1 & 2) as per the Free State Biodiversity Plan (DESTEA, 2015). It also corresponds to an endangered ecosystem which relates to the Vaal-Vet Sandy Grassland. In addition, the southern section of study site is located on the Mispah Game Farm.

4. RESULTS AND DISCUSSION

4.1 Avifaunal habitat types

The study area consists of four discrete broad-scale habitat units that are of **untransformed** nature and important to bird species (Figure 11 and Figure 12):

1. *Open dolomite grassland with scattered bush clumps:* This unit is prominent on the study site and covers nearly the entire surface area of the study site. It is represented by two discrete floristic variations which also provide habitat for two discrete avifaunal associations. The first floristic variation consists of open untransformed to slightly grazed dolomite grassland. The grassland variation is represented by untransformed and semi-transformed Vaal Reefs Sinkhole Dolomite Woodland in the north, and depending on grazing intensity, the graminoid layers is dominated "late-successional" graminoids such a *Cymbopogon caesius, C. pospischilii, Trachypogon spicatus, Triraphis andropogonoides* and *Eragrostis chloromelas.* The latter was prominent where grazing by livestock was eminent. On dolomite outcrops the graminoid layer was significantly taller and dominated by *Setaria sphacelata, Schizachyrium sanguineum* and *Tristachya rehmannii.* In the south the grassland composition occurred on predominantly sandy soils with high affinities towards the Vaal-Vet Sandy Grassland, of which the compositions consists of a large part of secondary graminoid taxa such as *Aristida congesta* and *Pogonarthria squarrosa*. The bird composition is composed of typical grassland taxa dominated by insectivorous and granivore passerine bird species such as Desert Cisticola, (*Cisticola aridulus*), Cloud Cisticola (*C. textrix*), Melodious Lark (*Mirafra cheniana*), Rufous-naped Lark (*Mirafra africana*), Eastern Clapper Lark (*Mirafra fasciolata*), African Pipit (*Anthus cinnamomeus*) and during the peak dry season also Plain-backed Pipit (*Anthus leucophrys*) and Capped Wheatear (*Oenanthe pileata*). Prominent non-passerine species include Orange River Francolin (*Scleroptila gutturalis*), Swainson's Spurfowl (*Pternistis swainsonii*), Northern Black Korhaan (*Afrotis afraoides*) and, Crowned Lapwing (*Vanellus coronatus*).

   The bush clumps form a prominent mosaic characterised by the dominance of a woody layer of *Searsia lancea, Vachellia karoo* and *Asparagus laricinus*. In some areas localised disturbances, was responsible for the proliferation of agrestal weeds and secondary graminoids such as *Bidens cf. biternata, Tagetes minuta, Eragrostis curvula* and *Hyparrhenia hirta*. The occurrence of bush clumps were more prominent on the northern parts of the study site and invariably corresponds to dolomite outcrops. The eminent increase in vertical heterogeneity provided by the woody layer is responsible for a "Bushveld" bird association consisting of insectivorous passerines such as Black-chested Prinia (*Prinia flavicans*), Chestnut-vented Warbler (*Sylvia subcoerulea*), Kalahari Scrub Robin (*Cercotrichas paena*), Fiscal Flycatcher (*Melaenornis silens*), African Red-eyed Bulbul (*Pycnonotus nigricans*) as well as granivores such as Yellow Canary (*Crithagra flaviventris*), Southern Masked Weaver (*Ploceus velatus*) and Black-faced Waxbill (*Brunhilda erythronotos*). Passerine bird taxa are represented by Laughing Dove (*Spilopelia senegalensis*), Ring-necked Dove (*Streptopelia capicola*), Acacia Pied Barbet (*Tricholaema leucomelas*) and White-backed Mousebird (*Colius colius*).

2. *Depressions:* This unit is highly localised on the southern section of the study site. It is represented by discrete depressions which become inundated during precipitation events. It is represented by *Cynodon dactylon* and *Verbena bonariense*. This habitat provides habitat for a unique bird composition represented by many smaller wetland-associated passerine species, although larger non-passerines such as waterfowl were uncommon since the presence of open water and lentic conditions were mostly absent, which will discourage waterfowl and shorebirds from utilising this particular habitat. Typical bird species include Zitting Cisticola (*C. juncidis*), Levaillant's Cisticola (*C. tinniens*), Common Waxbill (*Estrilda astrild*) and Lesser Swamp Warbler (*Acrocephalus gracilirostris)*.

3. *Imperata cylindrica seep zones*: This unit is also highly localised on the southern part of the study site and characterised by a seasonal wet conditions which were colonised by tall *Imperata cylindrica* grassland with Seriphium plumosum along the edges. It provides habitat for a unique bird composition represented by many smaller wetland-associated passerine species such as Zitting Cisticola (*Cisticola juncidis*), Levaillant's Cisticola (*C. tinniens*) and African Stonechat (*Saxicola torquata*). It also provides foraging habitat for non-passerine species such as the Blacksmith Lapwing (*Vanellus armatus*) and Hadeda Ibis (*Bostrychia hagedash*), while it holds at least one to two pairs of Marsh Owl (*Asio capensis*).

4. *Valley-bottom seep/stream*: A small perennial valley-bottom seep/stream is located on the south-eastern part of the study site. The upper reaches are permanently inundated and characterised by obligatory wetland-associated vegetation such as *Phragmites australis, Typha capensis, Cyperus* spp., *Nasturtium officinale* which were interspersed by patches of *Imperata cylindrica*. The lower reached are often colonised by dense patches of *Panicum schinzii*. Some parts along the system has formed open ponds which provide foraging and roosting habitat for waterbirds such as Yellow-billed Duck (*Anas undulata*), Egyptian Goose (*Alopochen aegyptiaca*) and South African Shelduck (*Tadorna cana*). The upper reaches also provide ephemeral foraging habitat for the endangered African Marsh Harrier (*Circus ranivorus*).

The study area also consists of four discrete broad-scale habitat units that are of **transformed** nature (Figure 11 and Figure 13):

5. *Agricultural land*: These are represented commercial cultivated land which is used for the production of maize*.* The bird composition is often of low richness and composed of generalist taxa such as Speckled Pigeon (*Columba guinea*), Ring-necked Dove (*Streptopelia capicola*) and Cape Sparrow (*Passer melanurus*).

6. *Eucalyptus plantations*: These areas are represented exotic plantations consisting of *Eucalyptus* spp. In general this habitat provides habitat for a poor richness of bird species, although on the study site the vertical heterogeneity was responsible for a diverse assemblage of bird species which included Swallow-tailed Bee-eater (*Merops hirundineus*), Orange River White-eye (*Zosterops pallidus*), Southern Masked Weaver (*Ploceus velatus*), Red-eyed Dove (*Streptopelia semitorquata*), Neddicky (*Cisticola fulvicapilla*), Cape Robin-chat (*Cossypha capensis*), Red-billed Firefinch (*Lagonosticta senegala*) and Cardinal Woodpecker (*Dendropicos fuscescens*).

7. *Rehabilitated grassland and pastures*: These areas are represented by rehabilitated land consisting of monotonous stands of *Chloris cf. gayana* and *Cynodon dactylon* pastures. These often provide habitat for widespread Highveld bird species with dominants such as Desert Cisticola (*Cisticola aridulus*), Ant-eating Chat (*Myrmecocichla formicivora*) and Quailfinch (*Ortygospiza atricollis*).

8. *Pollution control dams*: These areas are confined to the extreme southern part of the study site and are represented by a series of small ponds. These, although of artificial origin, attract a variety of waterbird species which include amongst others species such as Yellow-billed duck (*Anas undulata*), Red-billed Teal (*A. erythrorhyncha*), Egyptian Goose (*Alopochen aegyptiacus*), Red-knobbed Coot (*Fulica cristata*), Common Moorhen (*Gallinula chloropus*), Little Grebe (*Tachybaptus ruficollis*) and Reed Cormorant (*Microcarbo africanus*).

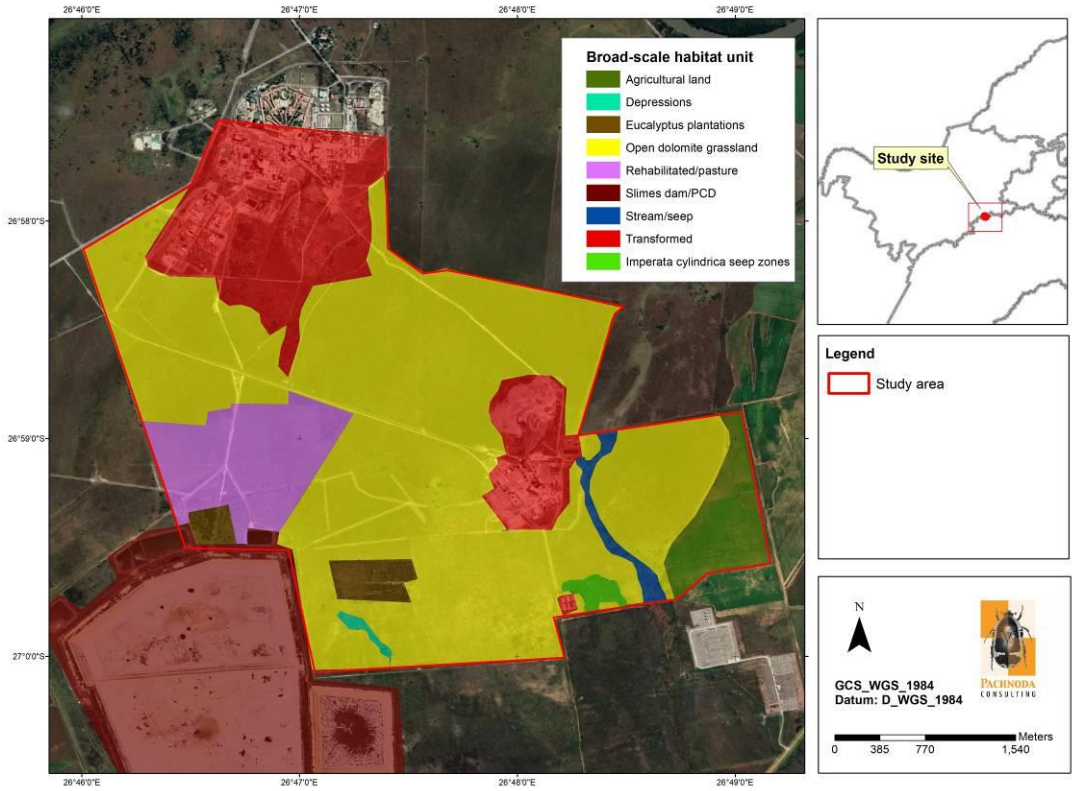
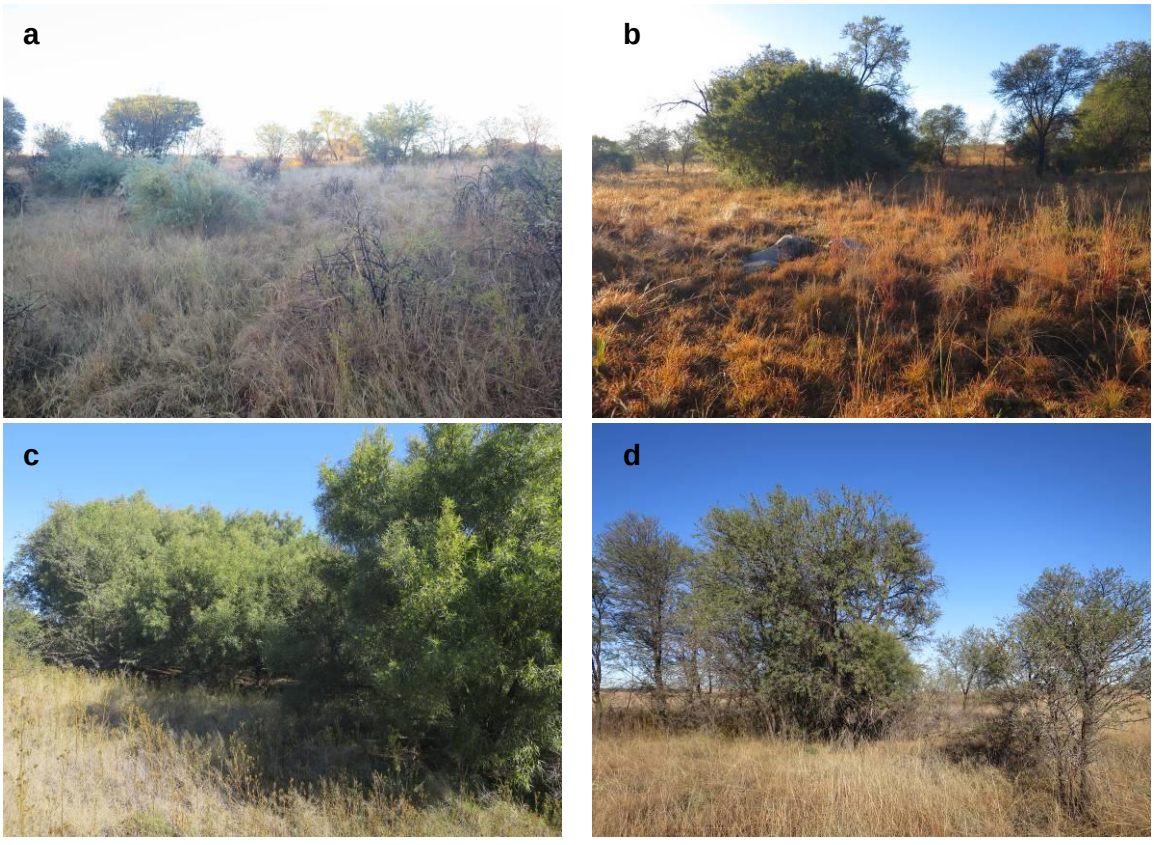


Figure 11: A map illustrating the avifaunal habitat types on the study and development areas.

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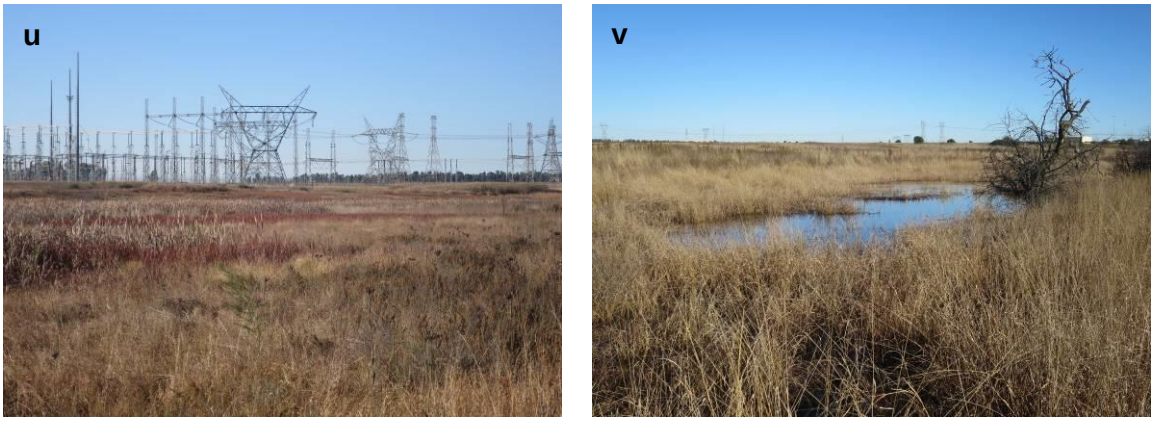

Figure 12: A collage of images illustrating examples of avifaunal habitat types confined to untransformed broad-scale habitat units: (a - j) open dolomite grassland and bush clumps (k - l) depressions, (m - p) *Imperata cylindrica*-dominated seeps and (q - v) valley-bottom seep/stream.

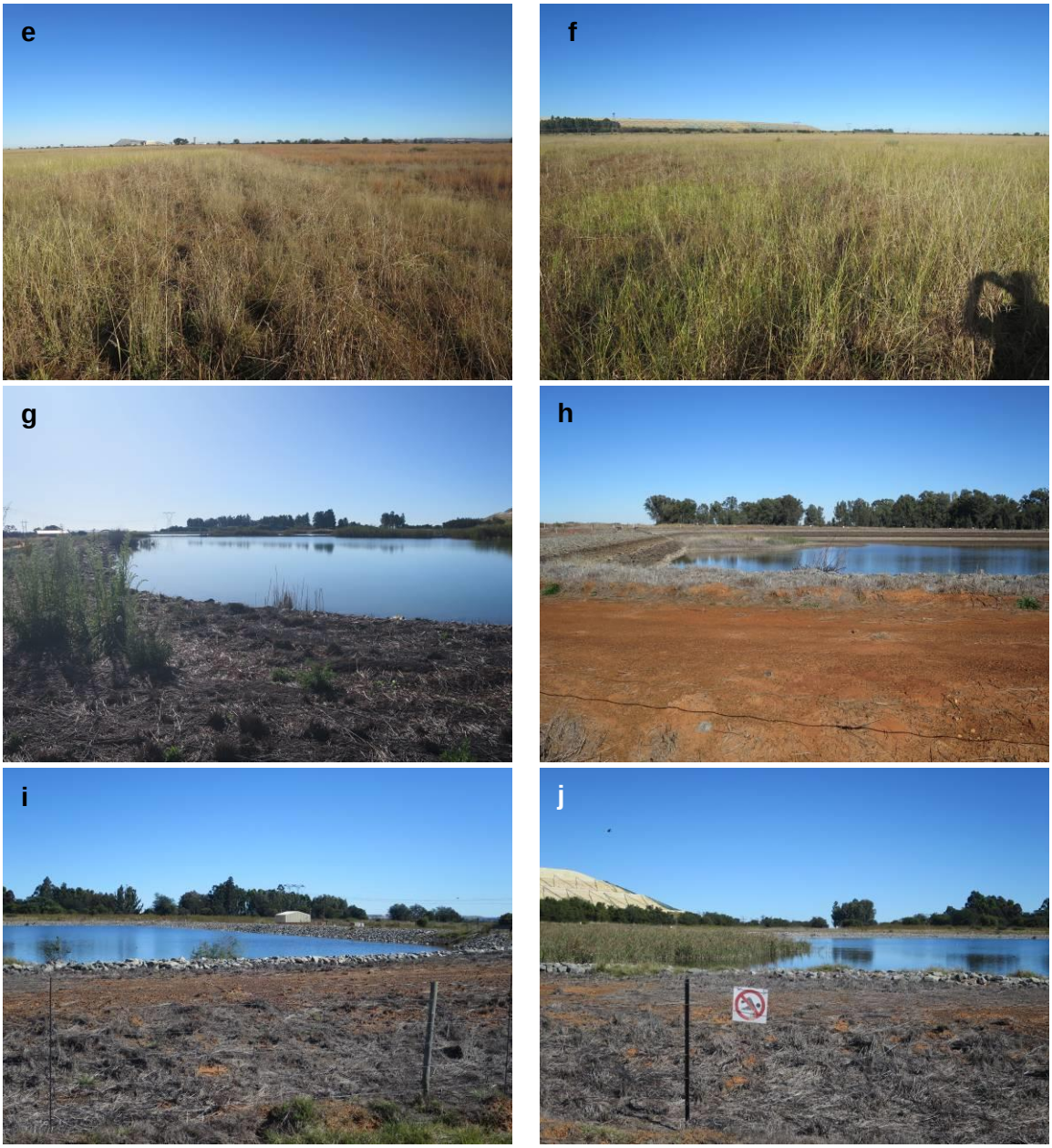

Figure 13: A collage of images illustrating examples of avifaunal habitat types confined to transformed broad-scale habitat units: (a - d) *Eucalyptus* plantations (e - f) rehabilitated grassland and pastures and (g - j) pollution control dams.

4.2 Species Richness and Summary statistics

Approximately 222 bird species are expected to occur in the study area (refer to Appendix 1 and Table 1). The expected richness was inferred from the South African Bird Atlas Project (SABAP1 & SABAP2)[1] (Harrison et al., 1997; www.sabap2.birdmap.africa) and the presence of suitable habitat in the study area. The expected richness is also strongly correlated with favourable environmental conditions (e.g. during good rains) and seasonality (e.g. when migratory species are present). This equates to 22 % of the approximate 987[2] species listed for the southern African subregion[3] (and approximately 25 % of the 871 species recorded within South Africa[4]). However, the species richness obtained from the pentad grid 2655_2645 corresponding to the study area[5] is lower than the expected number of species with an average of 57.3 species recorded for each full protocol card submitted (for observation of two hours or more; range = 33 - 94 species). The lower richness is explained due to the spatial scale of the pentad grid and habitat variability, whereby the study site is much smaller in surface area and will encompass less habitat variability (as opposed to a larger surface area, e.g. the 2655_2645 also incorporate habitat unit which consists of the Vaal River and tributaries, urban gardens and parks, wetlands and extensive *Vachellia* woodland).

According to field observations (May and July 2022), the total number of species observed on the study area is *ca*. 109 species (see Appendix 1). It shows that the surveys on the study area produced a higher tally when compared to the average richness recorded for the corresponding pentad grid and were regarded as sufficient. On a national scale, the species richness per pentad on the study area is considered to be high (refer to Figure 14).

According to Table 1, the study area is poorly represented by biome-restricted[6] (see Table 2) and local endemic bird species. However, the observed ratio of regional endemic species and near-endemic species is high when compared to the expected number of species, which suggests that most of the endemic species that could occur on the study site was observed during the surveys. Approximately 13 threatened or near threatened species is known to be present in the wider study area with only four recorded within the pentad grid corresponding to the study site (threatened or near threatened species were absent during the surveys). Furthermore, 16 southern African endemics and 11 near-endemic species were confirmed on the study site and the immediate surroundings (Table 3). Waterbird

[1] The expected richness statistic was derived from the pentad grid 2655_2645 totalling 226 bird species and modified according to habitat suitability, personal observations and probability of occurrence (based on 64 submitted cards, 54 being full protocol cards and 10 being ad hoc cards).

2 *sensu* www.zestforbirds.co.za (Hardaker, 2020) including four recently confirmed bird species (vagrants).

3 A geographical area south of the Cunene and Zambezi Rivers (includes Namibia, Botswana, Zimbabwe, southern Mozambique, South Africa, eSwatini and Lesotho).

4 With reference to South Africa (including Lesotho and eSwatini (BirdLife South Africa, 2022).

[5] Including observations made during the May 2022 and July 2022 surveys.

[6] A species with a breeding distribution confined to one biome. Many biome-restricted species are also endemic to southern Africa.

species were present on the pollution control dams and along the valley-bottom seep/streams (mainly Yellow-billed duck *Anas undulata*, Red-knobbed Coot *Fulica cristata*, Common Moorhen *Gallinula chloropus* and Little Grebe *Tachybaptus ruficollis*), along with regular fly-overs of South African Shelduck (*Tadorna cana*) and Egyptian Goose (*Alopochen aegyptiacus*).

The 2022 surveys also detected three bird species that are novel (new) species, which were observed for the first time within pentad grid 2655_2645. These species were previously overlooked. These include:

- Southern Boubou (*Laniarius ferruginea*) - observed from (and highly vocal) *Eucalyptus* plantations.
- Cape Grassbird (*Sphenoeacus afer*) - observed from moist rank grassland bordering a slimes dam; and
- Fiery-necked Nightjar (*Caprimulgus pectoralis*) - an adult male flushed observed (flushed) within a *Eucalyptus* plantation.

Table 1: A summary table of the total number of species, Red listed species (according to Taylor *et al*., 2015 and the IUCN, 2022), endemics and biome-restricted species (Marnewick *et al*., 2015) expected (*sensu* SABAP1 and SABAP2) to occur in the study site and immediate surroundings.

Description	Expected Richness Value (study area and surroundings)***	Observed Richness Value (study area)****
Total number of species*	222 (25 %)	109 (49 %)
Number of Red Listed species**	13 (9 %)#	0 (0 %)
Number of biome-restricted species – Zambezian and Kalahari-Highveld Biomes*	3 (21%)	3 (100 %)
Number of local endemics (BirdLife SA, 2022)*	2 (5 %)	2 (100 %)
Number of local near-endemics (BirdLife SA, 2022)*	8 (27 %)	7 (88 %)
Number of regional endemics (Hockey *et al.,* 2005)**	18 (17 %)	16 (89 %)
Number of regional near-endemics (Hockey *et al.,* 2005)**	17 (28 %)	11 (65 %)

* only species in the geographic boundaries of South Africa (including Lesotho and eSwatini) were considered.

** only species in the geographic boundaries of southern Africa (including Namibia, Botswana, Zimbabwe and Mozambique south of the Zambezi River) were considered

*** Percentage values in brackets refer to totals compared against the South African avifauna (*sensu* BirdLife SA, 2022).

**** Percentage values in brackets refer to totals compared against the expected number of species in the project area.

Includes taxa recorded from pentad grids adjacent to 2655_2645.

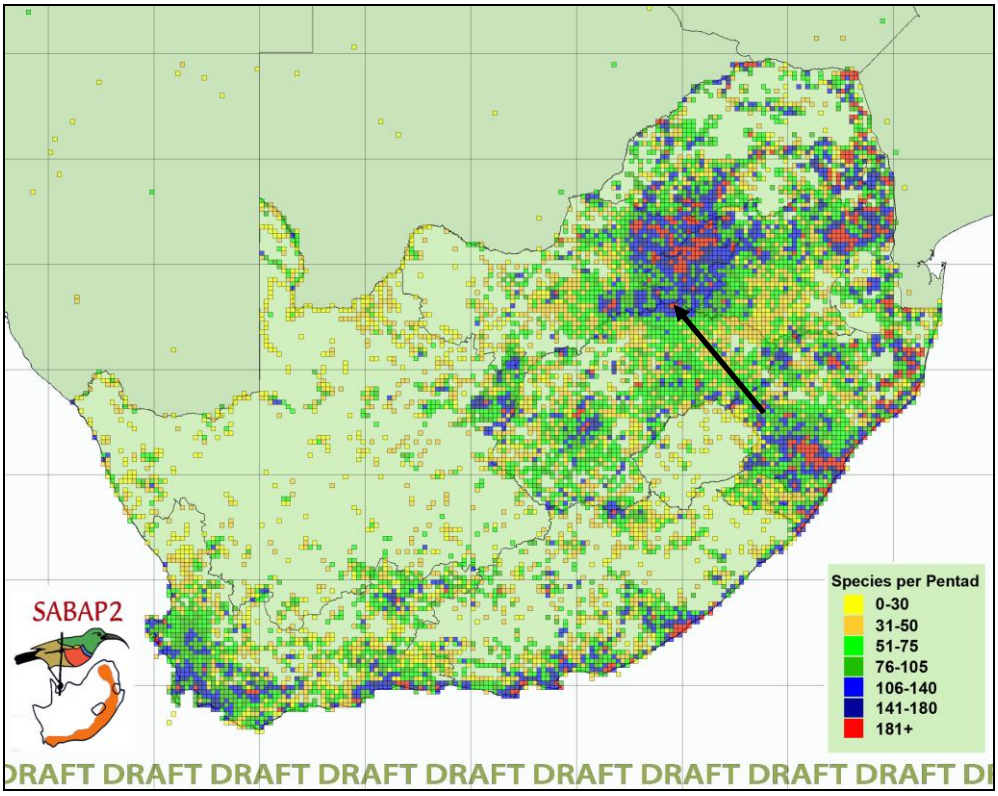

Figure 14: The bird species richness per pentad grid in comparison to the broader study area (see arrow) (map courtesy of SABAP2 and the Animal Demography Unit). According to the SABAP2 database, the study area hosts over 181 bird species.

Table 2: Expected biome-restricted species (Marnewick *et al*, 2015) likely to occur on the study area.

Species	Kalahari-Highveld	Zambezian	Expected Frequency of occurrence
Kalahari Scrub-robin (*Cercotrichas paena)*	X		Common (restricted to bush clumps)
White-throated Robin-chat (*Cossypha humeralis)*)		X	Fairly common (restricted to dense/large bush clumps)
White-bellied Sunbird (*Cinnyris talatala*)		X	Uncommon

Table 3: Important bird species occurring in the broader study area which could collide and/ or become displaced by the proposed PV infrastructure.

Common Name	Scientific name	Regional Status	Global Status	Observed (May & Jul. 2022)	Collision with power lines	Collision with PV panels	Displacement (disturbance & loss of habitat)
Martial Eagle	*Polemaetus*	EN	EN		1		

Common Name	Scientific name	Regional Status	Global Status	Observed (May & Jul. 2022)	Collision with power lines	Collision with PV panels	Displacement (disturbance & loss of habitat)
	bellicosus						
Curlew Sandpiper	*Calidris ferruginea*		NT			1	
South African Shelduck	*Tadorna cana*	End		1	1	1	
Cape Shoveller	*Anas smithii*	End			1	1	
Northern Black Korhaan	*Afrotis afraoides*	End		1	1		1
White-backed Mousebird	*Colius colius*	End		1			1
Melodious Lark	*Mirafra cheniana*	End		1			1
Karoo Thrush	*Turdus smithi*	End					1
Ant-eating Chat	*Myrmecocichla formicivora*	End		1			1
White-throated Robin-chat	*Cossypha humeralis*	End		1			1
Fiscal Flycatcher	*Melaenornis silens*	End		1			1
Fairy Flycatcher	*Stenostira scita*	End		1			1
Cape Grassbird	*Sphenoeacus afer*	End		1			1
Cape Longclaw	*Macronyx capensis*	End		1			1
Southern Boubou	*Laniarius ferrugineus*	End		1			1
Cape White-eye	*Zosterops virens*	End		1			1
Cape Weaver	*Ploceus capnesis*	End		1			1
Orange River White-eye	*Zosterops pallidus*	End		1			1
South African Cliff Swallow	*Petrochelidon spilodera*	End		1			1
Orange River Francolin	*Scleroptila gutturalis*	N-end		1	1		1
Natal Spurfowl	*Pternistis natalensis*	N-end			1		1
Acacia Pied Barbet	*Tricholaema leucomelas*	N-end		1			1
Eastern Clapper Lark	*Mirafra fasciolata*	N-end		1			1
Pink-billed Lark	*Spizocorys conirostris*	N-end					1
Ashy Tit	*Parus cinerascens*	N-end					1
African Red-eyed Bulbul	*Pycnonotus nigricans*	N-end		1			1
Kalahari Scrub Robin	*Cercotrichas paena*	N-end		1			1
Chestnut-vented Warbler	*Curruca subcoerulea*	N-end		1			1
Pririt Batis	*Batis pririt*	N-end					1
Bokmakierie	*Telophorus zeylonus*	N-end					1
Cape Sparrow	*Passer melanurus*	N-end		1			1
Scaly-feathered Weaver	*Sporopipes squamifrons*	N-end		1			1
Shaft-tailed Whydah	*Vidua regia*	N-end					1
Yellow Canary	*Crithagra flaviventris*	N-end		1			1

Common Name	Scientific name	Regional Status	Global Status	Observed (May & Jul. 2022)	Collision with power lines	Collision with PV panels	Displacement (disturbance & loss of habitat)
Cloud Cisticola	*Cisticola textrix*	N-end		1			1
Caspian Tern	*Hydroprogne caspia*	VU				1	
Yellow-billed Stork	*Mycteria ibis*	EN			1		
	Totals:	**36**	**2**	**25**	**7**	**4**	**31**

Threatened and near threatened species are indicated in red
CR - Critically endangered, EN - endangered, VU - vulnerable, NT - near threatened
End - southern African endemic
N-end - southern African near-endemic

Prior to further analyses where species richness values are considered, it is imperative to determine if all bird species present were sufficiently sampled. Species accumulation curves (SAC) provide a means to examine data and sampling efficacy. For this project the species accumulation curves (SAC) for the point count data were generated using the software program Estimates S (version 9) with 100 randomizations (as recommended in Colwell, 2013). Curves were generated for the full data set (all point counts). Sampling sufficiency was determined by establishing whether a point had been reached where a line representing one new sample adding one new species was tangent to the curve (Brewer & McCann, 1982). The Michaelis-Menten equation (Soberôn & Llorente 1993) was fitted to the predicted number of species using Estimates S (Raaijmakers, 1987). A satisfactory level of sampling was achieved if between 80-90 % of the bird species were detected, and hence predicted by the model (Moreno & Halffter, 2000).

The species accumulation curve (SAC) reached an asymptote at approximately 20 point counts (Figure 15). The sampling captured approximately 67.88% of the number of species predicted by the Michaelis-Menten model at 16 point counts. Approximately 84% of the species was captured by 60 counts. Sampling effort was considered sufficient and recorded most of the species present on the study area during the respective survey sessions.

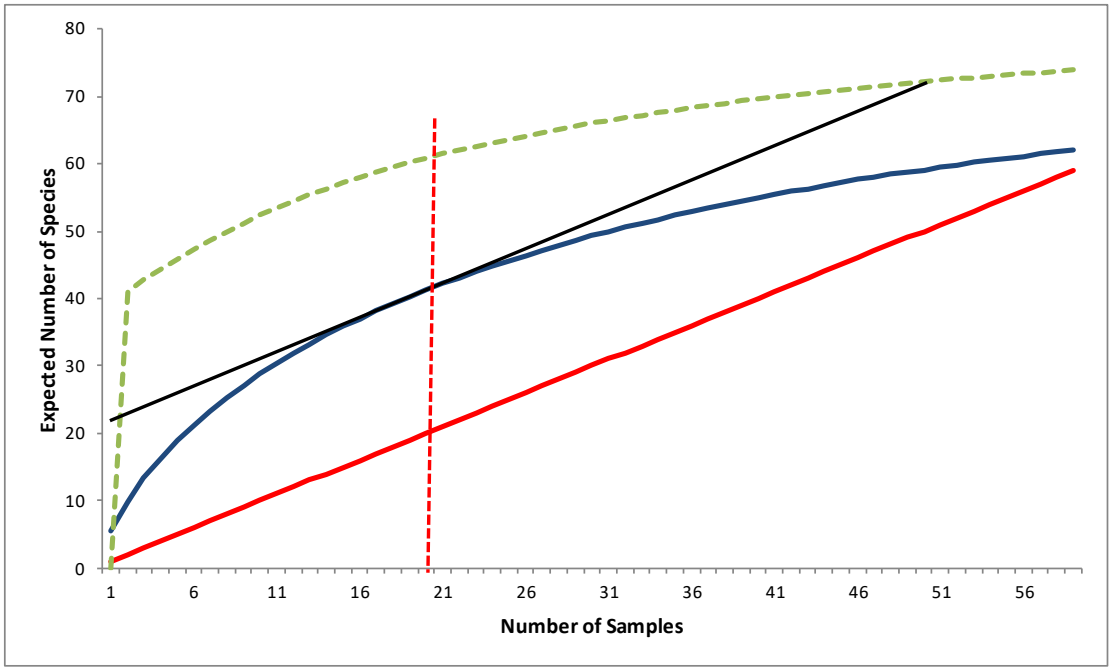

Figure 15: The species accumulation curve (SAC) (red line) for bird points sampled during the May 2022 and July 2022 survey sessions. The blue line represents an accumulation of one species for every additional point count. The black line is parallel to the blue one and is tangent to the SAC approximately after 20 counts (as represented by the vertical red stippled line). The green stippled line represents the Michaelis-Menten curve.

4.3 Bird species of conservation concern

Table 4 provides an overview of bird species of conservation concern that could occur on the development area based on their historical distribution ranges and the presence of suitable habitat. According to Table 4, a total of 13 species have been recorded in the wider study area (sensu SABAP2) which include four globally threatened species, three globally near threatened species, four regionally threatened bird species and two regionally near threatened species. In addition, only four of these species have been recorded within the study site (sensu pentad grid scale) which include the globally endangered Martial Eagle (*Polemaetus bellicosus*), globally near threatened Curlew Sandpiper (*Calidris ferruginea*), the regionally vulnerable Caspian Tern (*Hydroprogne caspia*) and the regionally endangered Yellow-billed Stork (*Mycteria ibis*).

It is evident from Table 4 that these most of the species have reporting rates less than 2 % which suggests that these species are highly irregular visitors to the development area due to the absence of suitable habitat on the study site. However, suitable habitat, depending on water levels and the environmental conditions (e.g. salinity, presence of resources) dictate that most of the waterbird taxa could occur along the impoundment that is located approximately 700m east of the study site (as opposed to occurring on the study site). This is the only habitat feature in the study

region that is likely to have high probability to sustain bird waterbird and wading bird species with a high probability to occur within the study region.

Nevertheless, species with reporting rates over 1-2% could potentially occur on the study area, which include the occasional occurrence of the regionally vulnerable Lanner Falcon (*Falco biarmicus*) and the regionally near threatened Abdim's Stork (*Ciconia abdimii*). From the SABAP2 data it is also evident that high reporting rates occur for the occurrence of the vulnerable Caspian Tern (*Hydroprogne caspia*). However, most of the observations in the study area stem from the nearby Vaal River which comprises of dispersing/foraging individuals which disperse between Bloemhof Dam and the Vaal Dam (this species has previously bred at both sites), although the probability that this species could occur on the study site is low.

In addition, the valley-bottom seep/stream on the eastern part of the study site provides suitable foraging habitat for the regionally endangered African Marsh Harrier (*Circus ranivorus*), although this species was not observed during the respective surveys. Although it was only observed from the northern study region (Figure 16), all potential habitat should be conserved (as a precautionary principle) which include the seep zone as delineated on the eastern part of the study site.

Table 4: Bird species of conservation concern that could utilise the study area based on their historical distribution range and the presence of suitable habitat. Red list categories according to the IUCN (2022)* and Taylor et al. (2015)**.

Species	Global Conservation Status*	National Conservation Status**	Mean Reporting rate: SABAP2: Nine pentad grids	Mean Reporting rate: SABAP2: 2655_2645	Preferred Habitat	Potential Likelihood of Occurrence
Ciconia abdimii (Abdim's Stork)	-	Near threatened	1.11 (eight observations)	-	Open stunted grassland, fallow land and agricultural fields.	An uncommon summer foraging visitor to areas consisting of secondary grassland or arable land.
Falco biarmicus (Lanner Falcon)	-	Vulnerable	2.8 (23 observations)	-	Varied, but prefers to breed in mountainous areas.	An occasional foraging visitor to the study site. Currently only known from habitat adjacent to the study site.
Calidris ferruginea (Curlew	Near-threatened	-	0.41 (three observations)	1.85 (single observation)	Restricted to permanent wetlands with	Highly uncommon to irregular summer foraging

Species	Global Conservation Status*	National Conservation Status**	Mean Reporting rate: SABAP2: Nine pentad grids	Mean Reporting rate: SABAP2: 2655_2645	Preferred Habitat	Potential Likelihood of Occurrence
Sandpiper)					extensive reedbeds.	visitor. Probably absent due to the absence of suitable habitat on the physical study site. It could occur along the shoreline of the dam located to the east of the study site on Farm Doornkom-Oost 447 (approx. 700m east of site boundary).
Circus ranivorus (African Marsh Harrier)	-	Endangered	0.14 (single observation)	-	Restricted to permanent wetlands with extensive reedbeds.	Probably absent from the study site, ephemeral foraging habitat observed along the valley-bottom wetland on the eastern part of the study site. Only known from a single observation during 2017 in the wider study region. (sensu SABAP2).
Glareola nordmanni (Black-winged Pratincole)	Near threatened	Near threatened	0.14 (singe observation)	-	Varied, but forages over open short grassland, pastures and agricultural lands (especially when being tilled)	A highly irregular foraging summer visitor to the to the study site. Only known from a single observation during 2010 in the wider study region. (sensu SABAP2).
Phoenicopterus roseus (Greater Flamingo)	-	Near-threatened	0.56 (five observations)	-	Restricted to large saline pans and other inland water bodies.	A highly irregular foraging visitor to the to the study site. Probably absent on the physical study site due to the absence of

Species	Global Conservation Status*	National Conservation Status**	Mean Reporting rate: SABAP2: Nine pentad grids	Mean Reporting rate: SABAP2: 2655_2645	Preferred Habitat	Potential Likelihood of Occurrence
						suitable habitat. It could occur on the dam (depending water levels and resource conditions) located to the east of the study site on Farm Doornkom-Oost 447 (approx. 700m east of site boundary).
Phoeniconaias minor (Lesser Flamingo)	Near-threatened	Near-threatened	0.14 (two observations)	1.85	Restricted to large saline pans and other inland water bodies containing cyanobacteria.	A highly irregular foraging visitor to the to the study site. Probably absent on the physical study site due to the absence of suitable habitat. It could occur on the dam (depending water levels and resource conditions) located to the east of the study site on Farm Doornkom-Oost 447 (approx. 700m east of site boundary).
Polemaetus bellicosus (Martial Eagle)	Endangered	Endangered	0.14 (single observation)	1.85	Varied, from open karroid shrub to lowland savanna.	A highly irregular foraging visitor to the study area. Only known from a single observation during 2010 (sensu SABAP2).
Mycteria ibis (Yellow-billed Stork)	-	Endangered	0.30 (two observations)	1.85 (single observation)	Wetlands, pans and flooded grassland.	An irregular foraging visitor to the to the study site. Suitable habitat is present along the shoreline of the dam (depending water levels and

Species	Global Conservation Status*	National Conservation Status**	Mean Reporting rate: SABAP2: Nine pentad grids	Mean Reporting rate: SABAP2: 2655_2645	Preferred Habitat	Potential Likelihood of Occurrence
						resource conditions) located to the east of the study site on Farm Doornkom-Oost 447 (approx. 700m east of site boundary).
Hydroprogne caspia (Caspian Tern)	-	Vulnerable	2.81 (21 observations)	22.22 (12 observations)	Large impoundments and large pans, also estuaries.	An irregular foraging visitor to the to the study site, probably due to the absence of suitable habitat. Suitable habitat is present along the shoreline of the dam (depending water levels and resource conditions) located to the east of the study site on Farm Doornkom-Oost 447 (approx. 700m east of site boundary). **This species has a high reporting rate for the study area, which is owing to birds observed dispersing along the nearby Vaal River (a major flyway for this species between Bloemhof Dam and the Vaal Dam; it regularly breeds at these sites).**
Gyps africanus (White-backed Vulture)	Critically Endangered	Critically Endangered	0.14 (two observations)	-	Breed on tall, flat-topped trees. Mainly restricted to large rural or game farming areas.	An irregular foraging/scavenging visitor to the study area pending the presence of food/carcasses. Mainly observed overhead.

Species	Global Conservation Status*	National Conservation Status**	Mean Reporting rate: SABAP2: Nine pentad grids	Mean Reporting rate: SABAP2: 2655_2645	Preferred Habitat	Potential Likelihood of Occurrence
Oxyura maccoa (Maccoa Duck)	Endangered	Vulnerable	0.28 (two observations)	-	Large saline pans and shallow impoundments.	Regarded as highly irregular foraging visitor to the study site. It could occur on the dam (depending water levels and resource conditions) located to the east of the study site on Farm Doornkom-Oost 447 (approx. 700m east of site boundary).
Sagittarius serpentarius (Secretarybird)	Endangered	Endangered	0.13 (single observation)	-	Prefers open grassland or lightly wooded habitat.	A highly irregular foraging visitor and probably historically displaced due to anthropogenic activities. It has not been recently observed on the study area (it was last recorded during 2016; *sensu* SABAP2).

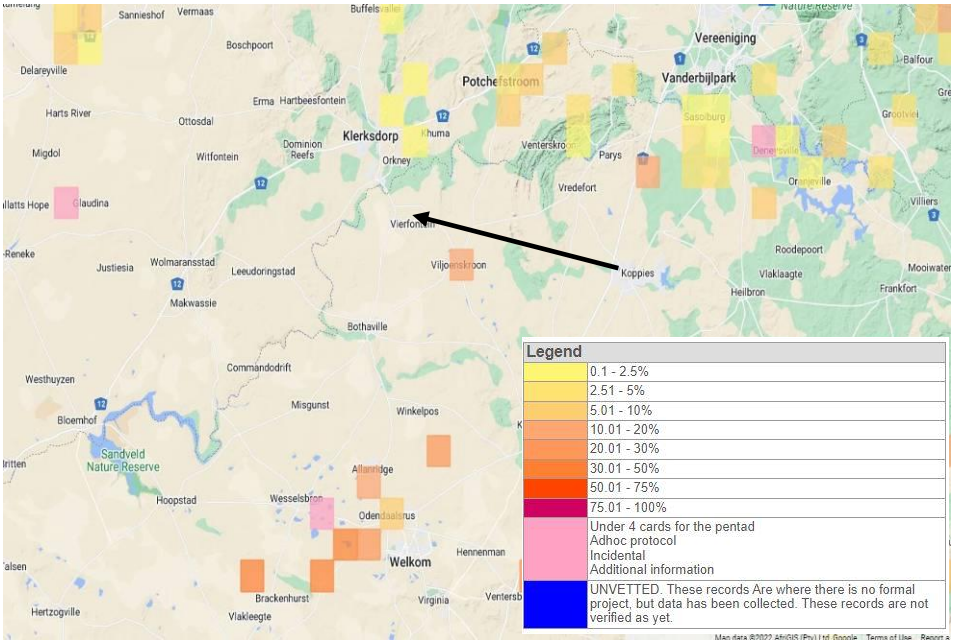

Figure 16: The extant (current) occurrence of African Marsh Harrier (*Circus ranivorus*) on the study area according to SABAP2 reporting rates (the arrow indicates the position of the study site). Note the presence of observations (c. low reporting rates) to the north (Klerksdorp area) and south of the study area (map courtesy and copyright of SABAP2 and Animal Demography Unit).

4.4 Bird Assemblage Structure and Composition

4.4.1 Summary of point counts

A total of 62 bird species and an average abundance of 362 individuals were recorded from 30 bird points (representing two replicative counts) located on the study area. The data provides an estimate of the bird richness and their numbers on the study site and immediate surroundings obtained during two independent survey sessions. A mean of 7.63 species and 12.06 individuals were recorded per point count. The average mean number of bird species and the average number of individuals was relatively low when compared to areas with similar habitat units (e.g. dolomite grassland with bush clump habitat) where the mean bird richness and mean number of individuals are receptively >10 and >15. The highest number of species and individuals recorded from a point count was 20 species (manly from tall grassland on undulating topography and from *Eucalyptus* plantations) and between 41 and 47 individuals (manly from tall grassland on undulating topography and from *Eucalyptus* plantations). The lowest number of species and individuals was respectively one species and one individual (highly moribund dolomite grassland). One of the point counts (M28a, on transformed grassland) produced zero birds (for at least 20-30 minutes).

The mean frequency of occurrence of a bird species in the study area was 12.31 % and the median was 6.67%, while the most common value (mode) was 3.33%. The

latter represents those species that were encountered in only one point count. Only three species occurred 50% or more of the point counts (c. Desert Cisticola *Cisticola aridulus*, Black-chested Prinia *Prinia flavicans* and Ring-necked Dove *Streptopelia capicola*), while another two species occurred in 30% or more of the counts (Table 5),

Table 5: Bird species with a frequency of occurrence greater than 30% observed on the study area (according to 30 counts).

Species	Frequency (%)	Species	Frequency (%)
Desert Cisticola (*Cisticola aridulus*)	63.33	African Red-eyed Dove (*Pycnonotus nigricans*)	43.33
Black-chested Prinia (*Prinia flavicans*)	60.00	Chestnut-vented Warbler (*Curruca subcaerulea*)	36.67
Ring-necked Dove (*Streptopelia capicola*)	50.00		

4.4.2 Summary of richness and average abundance (per point count)

Displacement of birds by the proposed infrastructure is one of the impacts that is anticipated to occur. By mapping the spatial distribution of the number of species and average abundance values obtained from each point count, it is possible to predict where displacement of birds will be more intensive. According to Figure 17 and Figure 18 it is evident that the highest bird numbers were observed from transformed habitat units which comprises of *Eucalyptus* plantations and bush clumps. In addition, the presence of tall canopy tree cover and wetland habitat were also responsible for moderate to high numbers of bird species (Figure 17). Nevertheless, it appeared that bird richness and abundance values on open dolomite and sandy grasslands were relatively low. Therefore, the potential displacement of birds due to the loss of habitat during construction is likely to occur at natural habitat which features the presence of wetland habitat (c. depressions, valley-bottom seeps and *Imperata cylindrica* seep zones) and large natural bush clumps.

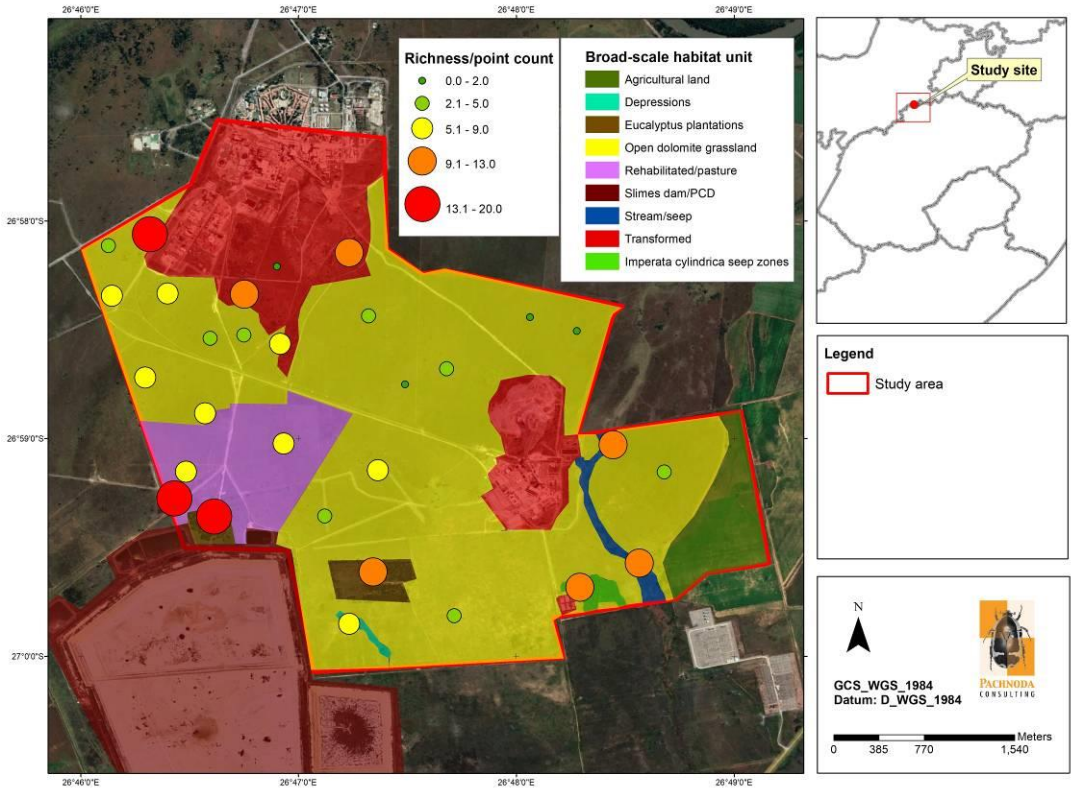

Figure 17: A map of the study area illustrating the spatial distribution of bird richness values (number of species) obtained for each point count.

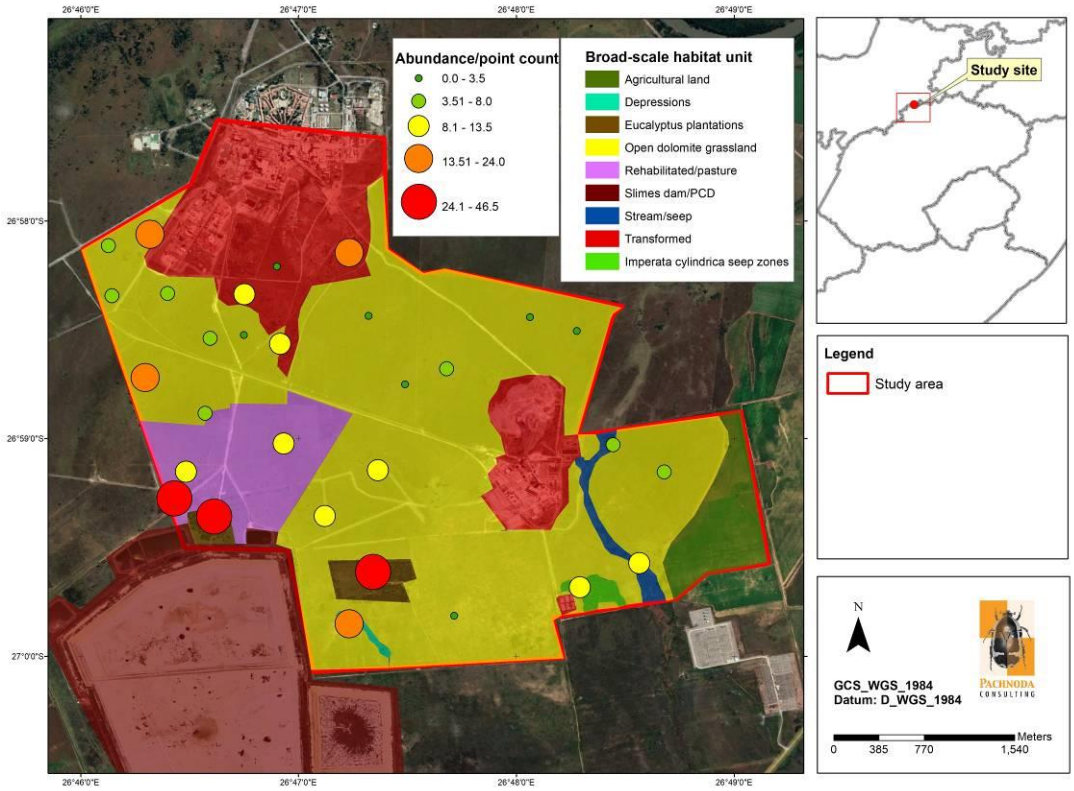

Figure 18: A map of the study area illustrating the distribution of bird abundance values (average number of individuals) obtained for each point count.

4.4.3 Dominance and typical bird species

The dominant (typical) species on the study area are presented in Table 6. Only those species that cumulatively contributed to more than 90% to the overall similarity between the point counts are presented.

The three most typical bird species on the study area include the Desert Cisticola (*Cisticola aridulus*), Black-chested Prinia (*Prinia flavicans*) and Ring-necked Dove (*Streptopelia capicola)*). These species are considered widespread species in the broader study area and occur in most of the habitat types that area present. It is also evident from Table 6 that the typical bird assemblage is predominantly represented by insectivores (insect-eating) and by granivores (seed-eating taxa). The Black-chested Prinia (*Prinia flavicans*) and Southern Masked Weaver (Ploceus velatus) are also the two most dominant species (numerically abundant) on the study site.

Table 6: Typical (high frequency of occurrence) bird species on the study area.

Species	Av.Abundance	Consistency (Sim/SD)	Contribution (%)	Primary Trophic Guild
Desert Cisticola (*Cisticola aridulus*)	0.76	0.73	33.14	Insectivore: upper canopy foliage gleaner

Black-chested Prinia (*Prinia flavicans*)	1.17	0.69	19.55	Insectivore: upper canopy foliage gleaner
Ring-necked Dove (*Streptopelia capicola*)	0.72	0.54	11.40	Granivore: ground gleaner
African Red-eyed Bulbul (*Pycnonotus nigricans*)	0.59	0.46	7.69	Frugivore/Insectivore: upper canopy gleaner
Chestnut-vented Warbler (*Curruca subcoerulea*)	0.57	0.37	5.22	Insectivore: upper canopy foliage gleaner
Eastern Clapper Lark (*Mirafra fasciolata*)	0.17	0.26	4.43	Granivore/Insectivore: ground gleaner
Levaillant's Cisticola (*Cisticola tinniens*)	0.36	0.24	2.68	Insectivore: upper canopy foliage gleaner
Southern Masked Weaver (*Ploceus velatus*)	0.91	0.23	1.68	Granivore: lower to ground gleaner

4.4.4 Composition and diversity

Multidimensional scaling and hierarchical agglomerative clustering ordination of bird abundance values obtained from 30 point counts on the study area differentiate between three discrete bird associations (Global R= 0.56, p=0.001; Figure 21), with statistically significant differences between open grassland, *Eucalyptus* plantations/ bush clump mosaics and the wetland-associated habitat (depression/Imperata grassland and valley bottom seeps). The bird composition on the rehabilitated grassland was statistically similar to the natural open grassland units, while the composition on the *Eucalyptus* plantations was similar to that of the bush clump mosaics.

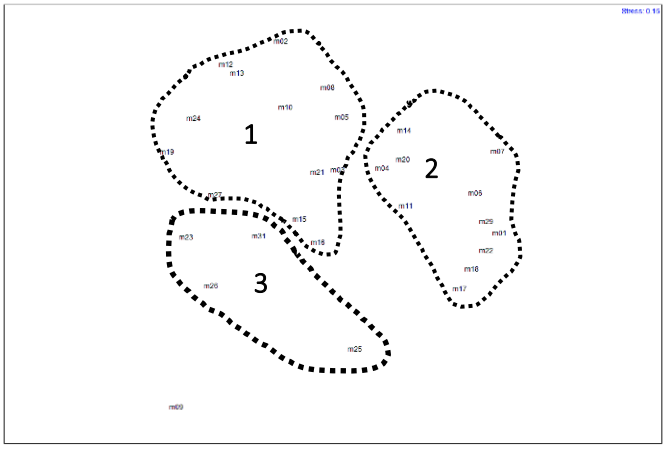

Figure 19: A two-dimensional non-metric multidimensional scaling ordination (stress=0.16) of the relative abundances of bird species based on Bray-Curtis similarities obtained from 30 point counts on the project area. It differentiates between three major bird associations: (1) an association on open grassland habitat,

(2) an association on bush clump mosaics and *Eucalyptus* plantations and (3) an association confined to wetland-associated habitat.

The following bird associations are relevant to the study site and immediate surroundings:

1. Association on open grassland (in the absence of any woody cover)

Dominant species: Desert Cisticola (*Cisticola aridulus*), Eastern clapper Lark (*Mirafra fasciolata*), Black-chested Prinia (*Prinia flavicans*), Ring-necked Dove (*Streptopelia capicola*) and Quailfinch (*Ortygospiza atricollis*).

Indicator species[7]: Ant-eating Chat (*Myrmecocichla formicivora*), Crowned Lapwing (*Vanellus coronatus*) and Quailfinch (*Ortygospiza atricollis*).

2. Association on bush clump mosaics and Eucalyptus plantations

Dominant species: Black-chested Prinia (*Prinia flavicans*), Chestnut-vented Warbler (*Curruca subcoerulea*), Ring-necked Dove (*Streptopelia capicola*), African Red-eyed Dove (*Pycnonotus nigricans*), Southern Masked Weaver (*Ploceus velatus*), Orange river White-eye (*Zosterops pallidus*), Neddicky (*Cisticola fulvicapilla*) and Laughing Dove (*Spilopelia senegalensis*).

Indicator species: Chestnut-vented Warbler (*Curruca subcoerulea*), Neddicky (*Cisticola fulvicapilla*), Orange river White-eye (*Zosterops pallidus*), White-throated Robin-chat (*Cossypha humeralis*), Brown-crowned Tchagra (*Tchagra australis*), Jameson's Firefinch (*Lagonosticta rhodopareia*) and Red-billed Firefinch (*Lagonosticta senegala*).

3. Association on wetland-associated habitat (Valley-bottom seeps, Imperata cylindrica grassland and depressions)

Dominant species: Levaillant's Cisticola (*Cisticola tinniens*), Zitting Cisticola (*C. juncidis*) and African Stonechat (*Saxicola torquatus*).

Indicator species: Marsh Owl (*Asio capensis*), Blacksmith Lapwing (*Vanellus armatus*) and Lesser Swamp Warbler (*Acrocephalus gracilirostris*).

The highest number of bird species on the study area was observed from pans and areas with surface water, followed by the bird association on tall Kathu Bushveld (Table 7). The lowest number of bird species was recorded from dense short Kathus Bushveld.

[7] Indicator species refers to a species with high numbers that is restricted to a particular habitat.

Table 7: A summary of the observed species richness and number of bird individuals confined to the bird associations on the study area.

Bird Association	Number of species	Number of Individuals	Shannon Wiener Index H'(log_e)
Bush Clump Mosaics (incl. *Eucalyptus* plantations)	44	21.5	3.11
Wetland-associated habitat	25	13.25	2.87
Open grassland	24	5.17	2.76

4.5 Passerine bird densities

Forty-six passerine bird species were recorded from 30 point counts on the study area. The study area accommodates approximately 7.69 species.ha^{-1} (Appendix 2). The average density per hectare is 12.26 birds.ha^{-1} and ranges between 1.28 birds.ha^{-1} to 47.44 birds.ha^{-1}.

4.6 Movements/dispersal of Collision-prone birds

The only **regular** movements observed for waterbird species were the South African Shelduck (*Tadorna cana*) and Egyptian Goose (*Alopochen aegyptiacus*) which could potentially collide with the PV infrastructure when visiting nearby water features in the area (Figure 22). Both species were regularly observed (especially in the early mornings) flying across the study site with many individuals also observed perching on the existing pylon structures. Most of these individuals tend to take advantage of the wet conditions created by the foot slopes of the tailing facilities and the control dams. In addition, other waterbird species such as the White-breasted Cormorant (*Phalacrocorax lucidus*) and the Yellow-billed Duck (*Anas undulata*) were also observed flying over the study site, while the latter species was observed roosting on open water pertaining to the valley-bottom seep. A roosting/breeding pair of Marsh Owls (*Asio capensis*) and Gabar Goshawk (*Micronisus capensis*) was also observed on the study site.

The home ranges of approximately three pairs of Northern Black Korhaan (*Afrotis afraoides*) correspond to the study area (Figure 21). These individuals have a high probability to become displaced from the study area due to the loss of habitat to accommodate the PV arrays.

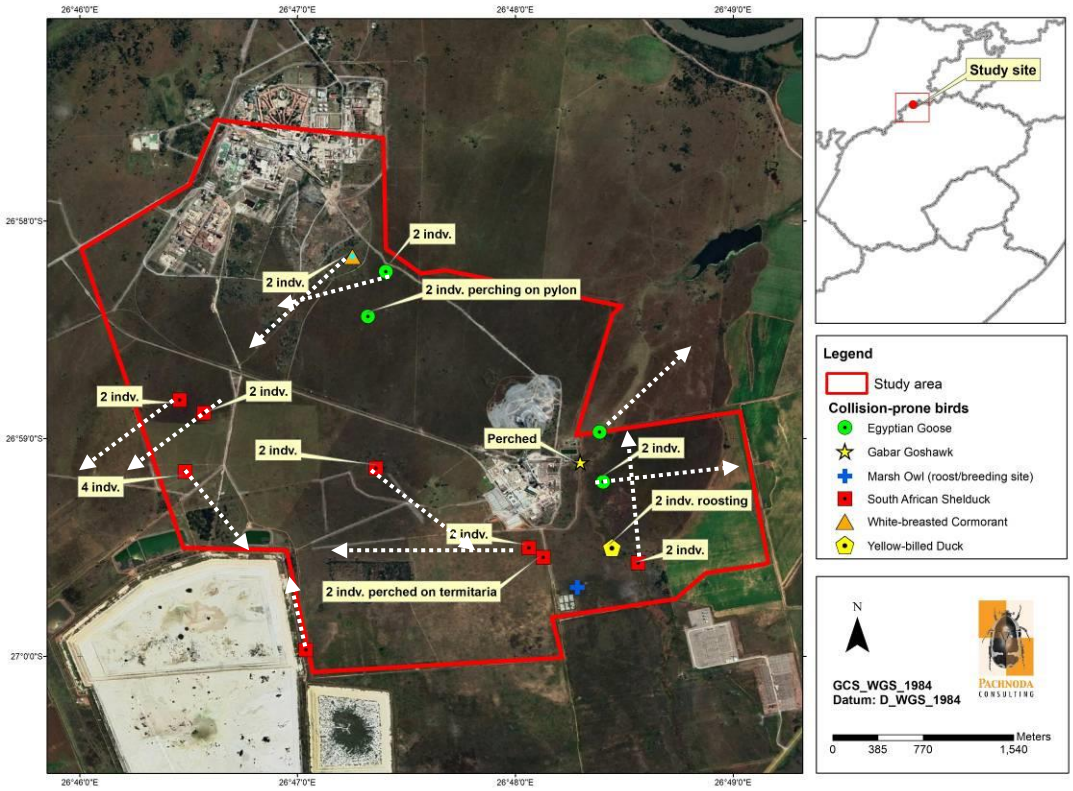

Figure 20: A map of the study site illustrating the occurrence and movements of collision-prone birds.

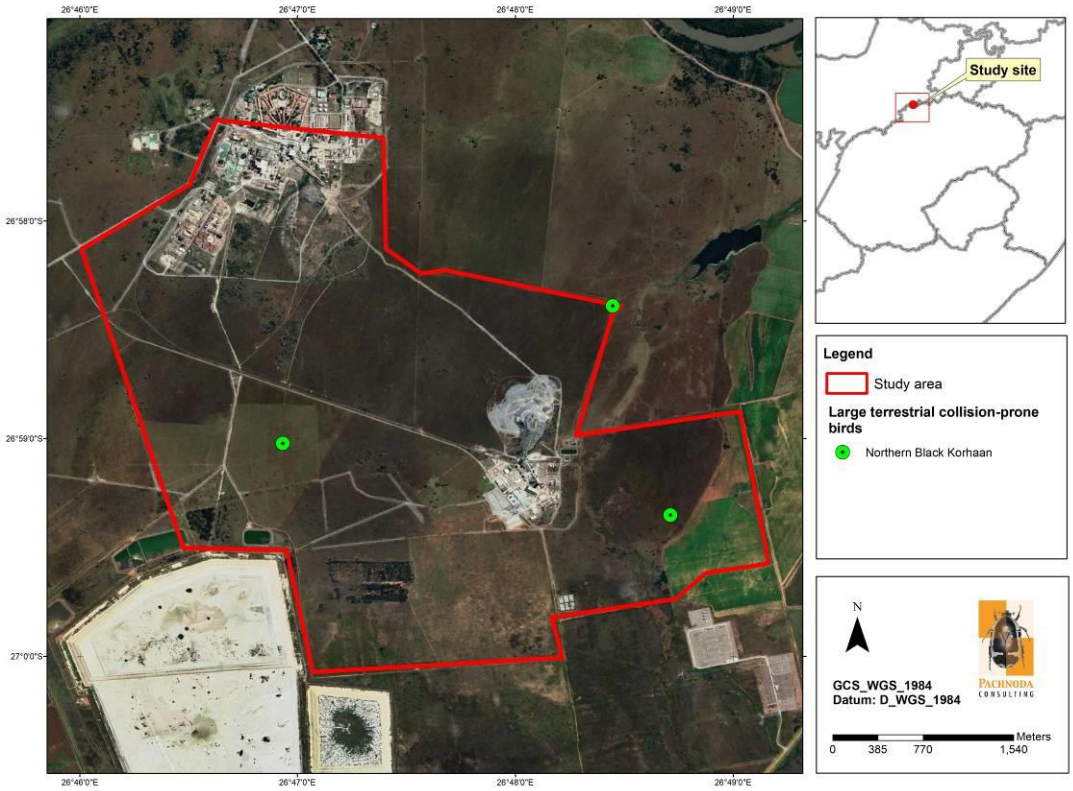

Figure 21: A map of the study area illustrating the occurrence of collision prone terrestrial bird species.

4.7 Avifaunal sensitivity

A sensitivity map was compiled, illustrating habitat units comprising of potential sensitive elements based on the following arguments (Figure 22):

Areas of high sensitivity

The wetland-associated habitat units (c. depressions, pollution control dams, Imperata cylindrica seeps and the valley-bottom seeps) and their respective buffers are of high sensitivity. These features provide habitat for a variety of collision-prone bird species which include waterbird and shorebird taxa. The placement of electrical infrastructure and PV panels in close proximity to these pans/dams as well as on areas where the frequency of fly-overs by waterbirds are high could increase potential avian collisions with the infrastructure.

Areas of medium sensitivity

It includes the open grassland and bush clump mosaics which are prominent in the wider study region and provides potential suitable foraging habitat for some collision-prone bird species, including the Northern Black Korhaan (*Afrotis afraoides*) with the potential to interact (e.g. collide) with the proposed electrical infrastructure. In

addition, reporting rates for threatened and near threatened bird species are anticipated to be relatively low for these units, thereby suggesting a medium sensitivity rating instead of a high sensitivity even though the majority of the habitat is natural.

Areas of low sensitivity

These habitat units are represented by transformed habitat, mine infrastructure, agricultural and rehabilitated land and the *Eucalyptus* plantations. These habitat types are of artificial origin and although the bird richness was often high on certain parts of these units (e.g. areas with tree cover) most of the bird species are either generalists or have widespread distribution ranges.

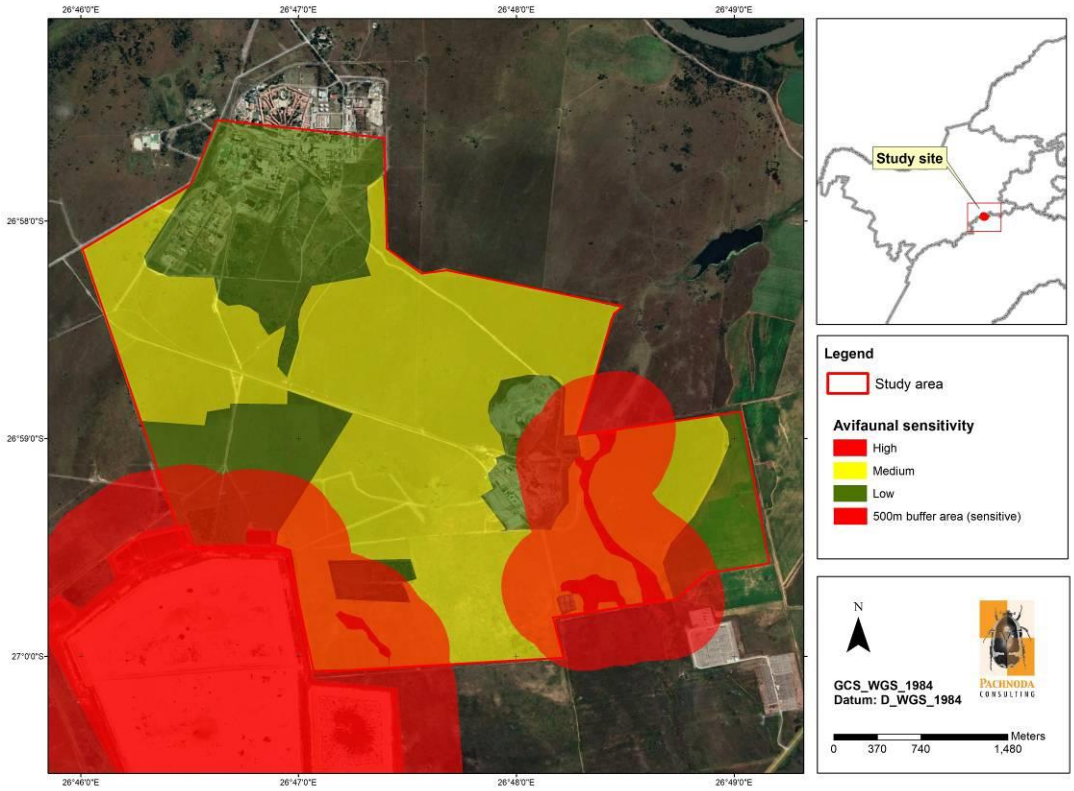

Figure 22: A map illustrating the avifaunal sensitivity of the study area based on habitat types supporting bird taxa of conservation concern and important ecological function.

4.8 Overview of Avian Impacts at Solar Facilities

4.8.1 Background to solar facilities and their impact on birds

Birds are mobile, and are therefore also more readily affected by solar facilities than other taxonomic groups (e.g. mammals). In fact, birds are also vulnerable to impacts caused by other types of energy facilities such as overhead power lines and wind

farms. Little information is available on the impacts of solar energy facilities on birds although Gunerhan *et al.* (2009), McCrary *et al.* (1986), Tsoutsos *et al.* (2005) and the recent investigation reports on bird fatalities in the USA by Kagen *et al*. (2014) and Walston *et al*. (2016) provide discussions thereof. These studies have shown that avian fatalities vary greatly between the geographic positions of the solar facilities and also depend on the type of solar facility. In addition, very few of the large solar facilities in operation undertake systematic monitoring of avian fatalities, which explains the lack of detailed information of avian impacts. According to these studies conducted at both Concentrated Solar Power (CSP) and PV facilities, avian incidental fatalities range from 14 to over 180 birds which were summarised over a survey period conducted during one to three years. According to the Walston *et al.* (2016) assessment, the average annual mortality rate for known utility-scale solar facilities (the annual number of estimated bird deaths per megawatt of electrical capacity) is 2.7, and 9.9 for known and unknown fatalities (which include carcasses found on the project site of which the death is not known). McCrary *et al.* (1986) found an average rate of mortality of 1.9-2.2 birds per week affecting 0.6-0.7% of the local bird population. However, most of the avian fatalities at these solar facilities are also probably underestimated since 10-30% of dead birds are removed by scavengers before being noted. From these analyses and assessments it was evident that:

- Medium levels of bird fatalities occur at PV sites when compared to CSP sites (due to solar flux-based mortalities associated with CSP sites).
- Approximately 81 % of all avian mortalities were caused by collisions, including collisions with electrical distribution lines.
- Most of the mortalities were small passerines (especially swallows).
- Fatalities at these solar facilities also include waterbirds (e.g. grebes, herons and gulls) which were probably attracted by the apparent "lake effect" caused by the reflective surface of the PV panels.
- Approximately 10-11 % of the fatalities consists of waterbirds, but could be as high as 49 % at certain facilities.
- It is unclear if the "lake effect" caused by the panels (at PV facilities) or mirrors (at CSP facilities) are the main cause of birds colliding or interacting with the infrastructure (since both waterbirds and other passerines are colliding with the infrastructure).
- Most of the fatalities are of resident birds as opposed to migratory species.

In a review report by Harrison *et al.* (2016), an attempt was made to provide evidence of the impacts caused by solar PV facilities alone (not combined with CSP facilities) on birds in the UK. These authors reviewed approximately 420 scientific documents, including 37 so-called "grey" literature from non-government and government organisations for any evidence relating to the ecological impacts of solar PV facilities. Their main findings were as follows:

- The majority of the documents were not relevant and peer-reviewed documents of experimental scientific evidence on avian fatalities were non-existent.
- Results based on carcass searches suggest that the bird collision risk at PV developments are low, although these studies did not take collision by overhead power lines into account.
- Many of the documents recommended that PV developments in close proximity to protected areas should be avoided.
- The PV panels reflect polarised light, which can attract polarotactic insects with potential impact to their reproductive biology. In addition, the polarising effect of the PV panels may also induce drinking behaviour in some birds, which may mistake the panels for water.
- They conclude that impact assessment reports should consider taxon-specific requirements of birds and their guilds.

4.8.2 Impacts of PV solar facilities on birds

The magnitude and significance of impacts to birds caused by solar facilities will depend on the following factors:

- The geographic locality of the planned solar facility;
- The size or surface extent of the solar facility;
- The type of solar facility (according to the technologies applied, e.g. PV or CSP); and
- The occurrence of collision-prone bird species (which are often closely related to the locality of the solar facility).

Any planned solar facility corresponding to an area with many threatened, range-restricted or collision-prone species will have a higher impact on these birds. In addition, any planned solar facility located in close proximity to important flyways, wetland systems or roosting/nesting sites used by the aforementioned species will have a higher impact.

The main impacts associated with PV solar facilities include (Jenkins *et al*., 2017):

- The loss of habitat and subsequent displacement of bird species due to the ecological footprint required during construction;
- Disturbances caused to birds during construction and operation;
- Direct interaction (collision trauma) by birds with the surface infrastructure (photovoltaic panels) caused by polarised light pollution and/or waterbirds colliding with the panels (as they are mistaken for waterbodies);
- Collision with associated infrastructure (mainly overhead power lines and reticulation); and
- Attracting novel species to the area (owing to the artificial provision of new habitat such as perches and shade) which could compete with the residing bird population.

4.9 Impacts associated with the Harmony Moab Khotsong Solar Energy Facilities

Table 8 provides a summary of the impacts anticipated and quantification thereof.

4.9.1 Loss of habitat and displacement of birds

Approximately 280 ha will be cleared of vegetation and habitat to accommodate the panel arrays and associated infrastructure. Clearing of vegetation will inevitably result in the loss of habitat and displacement of bird species. From the results, approximately 7.69 species.ha^{-1} and 12.26 birds.ha^{-1} will become displaced should the activity occur (as per Jenkins et al., 2017). Displacement will mainly affect regional endemic passerine and smaller non-passerine species inhabiting the open dolomite grassland and bush clump mosaics of medium avifaunal sensitivity, although at least three pairs of Northern Black Korhaan could become displaced.

The following bird species are most likely to be impacted by the loss of habitat due to their habitat requirements, endemism and conservation status (although not limited to) due to the proposed development:

- Northern Black Korhaan (*Afrotis afraoides*);
- Kalahari Scrub Robin (*Cercotrichas paena*);
- Orange River Francolin (*Scleroptila gutturalis*);
- Melodious Lark (*Mirafra cheniana*);
- White-throated Robin-chat (*Cossypha humeralis*); and potentially also
- Cape Grassbird (*Sphenoeacus afer* - only recently "discovered" on the study site.

4.9.2 Creation of "new" avian habitat and bird pollution

It is possible that the PV infrastructure (during operation) could attract bird species which may occupy the site or interact with the local bird assemblages in the wider region. These include alien and cosmopolitan species, as well as aggressive omnivorous passerines which could displace other bird species from the area:

- House Sparrow (*Passer domesticus*);
- Common Myna (*Acridotheres tristis*);
- Pied Crow (*Corvus albus*);
- Speckled Pigeon (*Columba guinea*); and potentially also
- Egyptian Goose (*Alopochen aegyptiacus*).

The infrastructure may attract large numbers of roosting columbid taxa, especially Speckled Pigeons (*Columba guinea*), which may result in avian "pollution" through excreta, thereby fouling the panel surfaces. The same applies to the locally abundant

Egyptian Goose (*Alopochen aegyptiacus*) which may roost on the infrastructure. The impact is manageable and will result in a low significance.

4.9.3 Collision trauma caused by photovoltaic panels (the "lake-effect")

The presence of wetland-associated habitat units and nearby bodies of surface water (e.g pollution control dams) could increase the risk of waterbirds and shorebird taxa interacting with the proposed PV panels. Placement of the proposed PV panels will be critical and should preferably avoid areas of high sensitivity as illustrated by Figure 22. Appropriate bird deterrent devices should be installed at strategic localities, and these should include a combination of rotating flashers/reflectors to increase the visibility of the infrastructure. In addition, post construction monitoring to quantify mortalities will be important during to early operational phase in order to determine "hotspot" areas (areas where high mortalities are prevalent) which may require additional mitigation measures. Waterbirds with a high frequency of occurrence which could interact with the PV panels are the Egyptian Goose (*Alopochen aegyptiaca*), South African Shelduck (*Tadorna cana*), Yellow-billed Duck (*Anas undulata*) and potentially also White-breasted Cormorant (*Phalacrocorax lucidus*) and Reed Cormorant (*Microcarbo africanus)*).

Desktop results and site observations show that the following species could interact with the panel infrastructure:

- South African Shelduck (*Tadorna cana*);
- Egyptian Goose (*Alopochen aegyptiaca*);
- Yellow-billed Duck (*Anas undulata*);
- Red-billed Teal (*Anas erythrorhynchus*);
- Reed Cormorant (*Microcarbo capensis*);
- White-breasted Cormorant (*Phalacrocorax lucidus*);
- African Sacred Ibis (*Threskiornis aethiopicus*) and potentially also
- Little Grebe (*Tachybaptus ruficollis*);
- Red-knobbed Coot (*Fulica cristata*);
- Common Moorhen (*Gallinago chloropus*);
- Black-headed Heron (*Ardea melanocephala*);
- Cape Shoveller (*Anas smithii*);
- African Spoonbill (*Platalea alba*); and
- Black-winged Stilt (*Himantopus himantopus*).

4.9.4 Interaction with overhead powerlines and reticulation

The three proposed solar PV facilities will tie-in to the Vaalreefs 11, Southvaal Plant, and Southvaal (6.6/132 kV) substations via three separate overhead connection lines with a capacity of up to 132kV. However, a number of existing overhead powerlines occur on the study site (see Figure 1) and it is recommended that the proposed overhead corridors be placed alongside these existing powerlines which will greatly increase the visibility of the lines, and thereby reduce the potential for collision-prone

bird species to interact with the powerlines. Impacts with powerlines include the following:

- *Electrocution*

Electrocution happens when a bird bridges the gap between the live components or a combination of a live and earth component of a power line, thereby creating a short circuit. This happens when a bird, mainly a species with a fairly large wingspan attempts to perch on a tower or attempts to fly-off a tower. Many of these species include vultures (of the genera *Gyps* and *Torgos*) as well as other large birds of prey such as the Martial Eagle (*Polemaetus bellicosus*) (Ledger & Annegarn, 1981; Kruger, 1999; Van Rooyen, 2000). These species will attempt to roost and even breed on the tower structures if available nesting platforms are a scarce commodity in the area. Other types of electrocutions happen by means of so-called “bird-streamers”. This happens when a bird, especially when taking off, excretes and thereby causes a short-circuit through the fluidity excreta (Van Rooyen & Taylor, 1999).

Large transmission lines (from 220 kV to 765 kV) are seldom a risk of electrocution, although smaller distribution lines (88 – 132kV) pose a higher risk. However, for this project, the design of the pylon is an important consideration in preventing bird electrocutions.

Collision

Collisions with earth wires have probably accounted for most bird-powerline interactions in South Africa. In general, the earth wires are much thinner in diameter when compared to the live components, and therefore less visible to approaching birds. Many of the species likely to be affected include heavy, large-bodied terrestrial species such as bustards, korhaans and a variety of waterbirds that are not very agile or manoeuvrable once airborne. These species, especially those with the habit of flying with outstretched necks (e.g. most species of storks) find it difficult to make a sudden change in direction while flying – resulting in the bird flying into the earth wires.

Areas where bird collisions are likely to be high could be ameliorated by marking the lines with appropriate bird deterrent devices such as “bird diverters” and “flappers” to increase the visibility of the lines.

- *Physical disturbances and habitat destruction caused during construction and maintenance*

It is anticipated that part of the overhead servitude will be cleared of vegetation. In addition, construction activities go hand in hand with high ambient noise levels.

Although construction is considered temporary, many species will vacate the area during the construction phase and will become temporarily displaced.

Table 8: The quantification of impacts associated with the proposed PV facility and its infrastructure.

1. Nature: Losses of natural habitat and displacement of birds through physical transformation, modifications, removals and land clearance. This impact is mainly restricted to the construction phase and is permanent.		
PV Layout (and associated infrastructure)	**Without mitigation**	**With mitigation**
Extent	Local (2)	Local (2)
Duration	Long-term (4)	Long-term (4)
Magnitude	High (8)	Moderate (6)
Probability	Definite (5)	Highly Probable (4)
Significance	**High (70)**	**Medium (48)**
Status (positive or negative)	Negative	Negative
Reversibility	Low	Low
Irreplaceable loss of resources?	Yes	Yes
Can impacts be mitigated?	Yes, to some extent	Yes, to some extent
Mitigation: It is difficult to mitigate against the loss of habitat since clearing of vegetation (or habitat) will be required for the infrastructure associated with the project. Both the PV facility and associated infrastructure occur predominantly on habitat types of medium and low sensitivity. The best practicable mitigation will be to consolidate infrastructure (e.g. proposed powerlines) to areas where existing impacts occur (e.g. placing the proposed powerline alongside existing powerlines) and to avoid areas of high sensitivity.		
Residual: Decreased bird species richness, low evenness values and subsequent loss of avian diversity on a local scale. The impact will also result in sterilisation of local landscapes and increased fragmentation of habitat.		

2. Nature: The creation of novel or new avian habitat for commensal bird species or superior competitive species. This is expected to occur during the operation phase of the facility.		
PV Layout (and associated infrastructure)	**Without mitigation**	**With mitigation**
Extent	Footprint (1)	Footprint (1)
Duration	Medium-term (3)	Medium-term (3)
Magnitude	Minor (2)	Minor (2)
Probability	Probable (3)	Improbable (2)
Significance	**Low (18)**	**Low (12)**
Status (positive or negative)	Negative	Negative
Reversibility	Moderate	Moderate
Irreplaceable loss of resources?	No	No
Can impacts be mitigated?	Yes, with experimentation	Yes
Mitigation: Apply bird deterrent devices and remove nest structures constructed on infrastructure associated with the PV facility under the guidance of the ECO.		
Residual:		

Secondary displacement by completive bird species such as crows and increased fecundity rate for commensal bird species that are adapted to anthropogenic activities. The impact is regarded as low.

3. Nature: Avian collision impacts related to the PV facility during the operation phase (collision with the PV panels).		
PV Layout (and associated infrastructure)	**Without mitigation**	**With mitigation**
Extent	Site and immediate surroundings (4)	Site and immediate surroundings (3)
Duration	Long-term (4)	Long-term (4)
Magnitude	High (8)	Moderate (6)
Probability	Highly Probable (4)	Probable (3)
Significance	**High (64)**	**Medium (39)**
Status (positive or negative)	Negative	Negative
Reversibility	Low	Low
Irreplaceable loss of resources?	Yes, potential loss of waterfowl and certain shorebird taxa species.	Yes, potential loss of waterfowl and certain shorebird taxa species.
Can impacts be mitigated?	Yes, with experimentation	Yes, with experimentation
Mitigation: Apply bird deterrent devices such as rotating flashers/reflectors to the panels for birds that may mistake the panels for open water and to prevent them from landing on the panels - these should especially be placed at panels nearest to wetland features, pollution control dams and slimes dams. Security/CCTV cameras may be installed to quantify mortalities (cameras are also installed along the perimeter fence for security measures and may also proved effective to quantify mortalities). Buffer wetland features, slimes dams and pollution control dams by at least 500m. If post-construction monitoring predicts and/or confirms bird mortalities, an option is to employ video cameras at selected areas to document bird mortalities and to conduct direct observations and carcass searches on a regular and systematic basis.		
Residual: Direct mortality is possible and may still occur irrespective of applied mitigation measures. Regular and systematic monitoring is proposed to assess the efficacy of applied mitigation and further research and testing is suggested to improve mitigation measures (e.g. bird deterrent devices). The residual impact is regarded as moderate.		

4. Nature: Avian collision impacts related to overhead power lines during operation.		
Overhead powerline corridors	**Without mitigation**	**With mitigation**
Extent	Local (2)	Local (2)
Duration	Long-term (4)	Long-term (4)
Magnitude	Moderate (6)	Minor (2)
Probability	Highly Probable (4)	Probable (3)
Significance	**Medium (48)**	**Low (24)**
Status (positive or negative)	Negative	Negative
Reversibility	Low	Low
Irreplaceable loss of resources?	Yes (to some extent), owing to the potential loss of terrestrial bird and waterbird species.	Yes (to some extent), owing to the potential loss of terrestrial bird and waterbird species.
Can impacts be mitigated?	Yes	Yes
Mitigation: Apply bird deterrent devices to the power lines and make use of "bird-friendly" pylon structures. It is highly to		

retrofit existing powerlines with bird deterrent devices. To aid post-construction monitoring and/or monitoring of bird mortality rates, it is advised to conduct direct observations and carcass searches on a regular and systematic basis. Collisions will be reduced if the proposed corridors are placed alongside existing powerlines.
Residual: Direct mortality is possible and may still happen irrespective of applied mitigation measures. The residual impact will be low.

5. Nature: Avian electrocution related to the new distribution lines during operation.		
Overhead powerline corridors	**Without mitigation**	**With mitigation**
Extent	Local (2)	Local (2)
Duration	Long-term (4)	Long-term (4)
Magnitude	Moderate (6)	Minor (2)
Probability	Probable (3)	Probable (3)
Significance	**Medium (36)**	**Low (24)**
Status (positive or negative)	Negative	Negative
Reversibility	Low	Low
Irreplaceable loss of resources?	Yes (to some extent), owing to the potential loss of terrestrial bird and waterbird species.	Yes (to some extent), owing to the potential loss of terrestrial bird and waterbird species.
Can impacts be mitigated?	Yes, to some extent	Yes, to some extent
Mitigation: Avoid the placement of overhead electrical infrastructure in close proximity to wetland features and pollution control dams. Make use of bird-friendly pylons and bird guards as recommended by EWT.		
Residual: Direct mortality is possible and may still happen irrespective of applied mitigation measures. The residual impact will be low.		

4.9.5 Collision-prone bird species

A total of 76 collision-prone bird species have been recorded in the wider study area, of which 13 species are birds of prey and 54 are waterbirds/shorebird taxa (Table 9). Collision-prone species with the highest probability to occur along the power-line servitude includes the Helmeted Guineafowl (*Numida meleagris*), Speckled Pigeon (*Columba guinea*), Pied Crow (*Corvus albus*), Northern Black Korhaan (*Afrotis afraoides*), South African Shelduck (*Tadorna cana*), Egyptian Goose (*Alopochen aegyptiacus*), Yellow-billed Duck (*Anas undulata*) and White-breasted Cormorant (*Phalacrocorax lucidus*). According to Table 9, it is evident that the number of potential collision-prone waterbird and shorebird taxa in the wider study area is high (c. 71% of the total number of collision-prone bird species recorded in the area).

Table 9: Collision-prone bird species expected to be present on the study area and inferred from the South African Atlas Project (SABAP2). Species highlighted in red refers to threatened of near threatened species (sensu Taylor et al, 2015; IUCN, 2022).

Common Name	Scientific Name	SABAP2 Reporting Rate	
		Full Protocol (%)	Ad hoc Protocol (%)
African Black Duck	*Anas sparsa*	3.70	0.00
African Crake	*Crecopsis egregia*	1.85	0.00
African Darter	*Anhinga rufa*	51.85	10.00
African Fish Eagle	*Haliaeetus vocifer*	31.48	0.00
African Rail	*Rallus caerulescens*	1.85	0.00
African Sacred Ibis	*Threskiornis aethiopicus*	5.56	0.00
African Snipe	*Gallinago nigripennis*	3.70	0.00
African Spoonbill	*Platalea alba*	5.56	0.00
African Swamphen	*Porphyrio madagascariensis*	14.81	0.00
Amur Falcon	*Falco amurensis*	9.26	0.00
Black Crake	*Zapornia flavirostra*	20.37	0.00
Black Heron	*Egretta ardesiaca*	9.26	0.00
Black-headed Heron	*Ardea melanocephala*	20.37	10.00
Black-necked Grebe	*Podiceps nigricollis*	1.85	0.00
Black-winged Kite	*Elanus caeruleus*	38.89	20.00
Black-winged Stilt	*Himantopus himantopus*	11.11	0.00
Blue-billed Teal	*Spatula hottentota*	5.56	0.00
Cape Shoveler	*Spatula smithii*	9.26	10.00
Caspian Tern	*Hydroprogne caspia*	22.22	0.00
Common (Steppe) Buzzard	*Buteo buteo vulpinus*	12.96	0.00
Common Greenshank	*Tringa nebularia*	1.85	0.00
Common Moorhen	*Gallinula chloropus*	44.44	0.00
Common Myna	*Acridotheres tristis*	72.22	0.00
Common Sandpiper	*Actitis hypoleucos*	9.26	0.00
Curlew Sandpiper	*Calidris ferruginea*	1.85	0.00
Egyptian Goose	*Alopochen aegyptiaca*	68.52	20.00
Gabar Goshawk	*Micronisus gabar*	5.56	0.00
Giant Kingfisher	*Megaceryle maxima*	7.41	0.00
Glossy Ibis	*Plegadis falcinellus*	7.41	10.00
Goliath Heron	*Ardea goliath*	1.85	0.00
Great Crested Grebe	*Podiceps cristatus*	1.85	0.00
Great Egret	*Ardea alba*	3.70	0.00
Greater Kestrel	*Falco rupicoloides*	3.70	20.00
Grey Heron	*Ardea cinerea*	40.74	10.00
Grey-headed Gull	*Chroicocephalus cirrocephalus*	5.56	0.00
Hadada Ibis	*Bostrychia hagedash*	72.22	10.00
Hamerkop	*Scopus umbretta*	7.41	0.00

Helmeted Guineafowl	*Numida meleagris*	68.52	10.00
Intermediate Egret	*Ardea intermedia*	0.00	10.00
Lesser Kestrel	*Falco naumanni*	1.85	0.00
Little Bittern	*Ixobrychus minutus*	3.70	0.00
Little Egret	*Egretta garzetta*	9.26	0.00
Little Grebe	*Tachybaptus ruficollis*	38.89	0.00
Little Stint	*Calidris minuta*	9.26	0.00
Long-crested Eagle	*Lophaetus occipitalis*	1.85	0.00
Marsh Owl	*Asio capensis*	3.70	10.00
Marsh Sandpiper	*Tringa stagnatilis*	3.70	0.00
Martial Eagle	*Polemaetus bellicosus*	1.85	0.00
Natal Spurfowl	*Pternistis natalensis*	29.63	0.00
Northern Black Korhaan	*Afrotis afraoides*	42.59	0.00
Orange River Francolin	*Scleroptila gutturalis*	3.70	0.00
Peregrine Falcon	*Falco peregrinus*	1.85	0.00
Pied Avocet	*Recurvirostra avosetta*	1.85	0.00
Pied Crow	*Corvus albus*	66.67	10.00
Pied Kingfisher	*Ceryle rudis*	20.37	0.00
Purple Heron	*Ardea purpurea*	12.96	0.00
Red-billed Teal	*Anas erythrorhyncha*	22.22	0.00
Red-knobbed Coot	*Fulica cristata*	40.74	20.00
Reed Cormorant	*Microcarbo africanus*	61.11	10.00
Ruff	*Calidris pugnax*	5.56	0.00
South African Shelduck	*Tadorna cana*	24.07	0.00
Southern Pochard	*Netta erythrophthalma*	1.85	0.00
Spotted Eagle-Owl	*Bubo africanus*	3.70	10.00
Spur-winged Goose	*Plectropterus gambensis*	38.89	30.00
Squacco Heron	*Ardeola ralloides*	7.41	0.00
Swainson's Spurfowl	*Pternistis swainsonii*	48.15	10.00
Western Barn Owl	*Tyto alba*	1.85	0.00
Western Cattle Egret	*Bubulcus ibis*	50.00	10.00
Whiskered Tern	*Chlidonias hybrida*	7.41	0.00
White-breasted Cormorant	*Phalacrocorax lucidus*	31.48	0.00
White-browed Sparrow-Weaver	*Plocepasser mahali*	64.81	20.00
White-faced Whistling Duck	*Dendrocygna viduata*	11.11	10.00
White-winged Tern	*Chlidonias leucopterus*	1.85	0.00
Wood Sandpiper	*Tringa glareola*	11.11	0.00
Yellow-billed Duck	*Anas undulata*	79.63	20.00
Yellow-billed Stork	*Mycteria ibis*	1.85	0.00

4.10 Cumulative Impacts

Cumulative impacts are defined as impacts that result from additional or incremental activities caused by past or present actions together with the current project. Therefore, cumulative impacts are those that will affect the general avifaunal community on the study area due to other planned solar farm projects and electrical infrastructure in the region.

According to the National Screening Report (generated 25/04/2022), there is currently eight solar PV facilities with an approved environmental authorisation under consideration within 30km of the proposed Harmony Moab Khotsong PV facility (Table 10). Four of these are within 2.3 km of the study site.

Table 10: Solar developments with an approved Environmental Authorisation or applications under consideration within 30 km of the proposed area (sensu the results of the National Screening Tool).

No	EIA Reference No	Classification	Status of application	Distance from proposed area (km)
1	12/12/20/2513/3	Solar PV	Approved	2.3
2	14/12/16/3/3/2/777	Solar PV	Approved	6.5
3	12/12/20/2513/1	Solar PV	Approved	2.3
4	12/12/20/2513/2	Solar PV	Approved	5.2
5	14/12/16/3/3/2/954	Solar PV	Approved	20.7
6	12/12/20/2513/1/AM3	Solar PV	Approved	2.3
7	12/12/20/2513/4	Solar PV	Approved	2.3
8	14/12/16/3/3/2/778	Solar PV	Approved	8.4

The cumulative impacts are likely to increase the displacement and loss of habitat. In addition while the grid connection (via overhead powerlines) of these facilities could potentially contribute towards bird strikes with powerlines and avian mortalities due to collision in the region.

A summary of the cumulative impacts is provided in Table 11.

Table 11: A summary of the cumulative impacts.

1. Nature: Regional losses of natural habitat and subsequent displacement of birds.		
	Overall impact of the proposed project considered in isolation	**Cumulative impact of the project and other projects in the area**
Extent	Local (2)	Local and immediate surroundings (3)
Duration	Long-term (4)	Long-term (4)
Magnitude	Moderate (6)	Moderate (6)
Probability	Highly Probable (4)	Highly Probable (4)
Significance	**Medium (48)**	**Medium (52)**

Status (positive or negative)	Negative	Negative
Reversibility	Low	Low
Loss of resources?	Yes	Yes
Can impacts be mitigated?	To some extent	To some extent
Confidence in findings: High.		
Mitigation: It is difficult to mitigate against the loss of habitat without considering alternative sites. The best practicable mitigation will be to consolidate infrastructure (e.g. proposed powerline) to areas where existing impacts occur (e.g. placing the proposed powerline alongside existing powerlines) and to concentrate infrastructure on land with a low biodiversity conservation value.		
2. Nature: Avian collision impacts related to the PV facility during the operational phase (collision with the PV panels).		
	Overall impact of the proposed project considered in isolation	**Cumulative impact of the project and other projects in the area**
Extent	Site and immediate surroundings (3)	Local and immediate surroundings (3)
Duration	Long-term (4)	Long-term (4)
Magnitude	Moderate (6)	High (8)
Probability	Probable (3)	Highly Probable (4)
Significance	**Medium (39)**	**Medium (60)**
Status (positive or negative)	Negative	Negative
Reversibility	Low	Low
Irreplaceable loss of resources?	Yes, potential loss of waterfowl and certain shorebird taxa species.	Yes, potential loss of waterfowl and certain shorebird taxa species.
Can impacts be mitigated?	Yes, to some extent	Yes, to some extent
Confidence in findings: Low.		
Mitigation: Apply bird deterrent devices to the panels for birds that may mistake the panels for open water and to prevent them from landing on the panels. To aid post-construction monitoring and/or monitoring of bird mortality rates, it is advised to employ video cameras to document any bird mortalities and to conduct direct observations and carcass searches on a regular and systematic basis. Apply appropriate buffer zones to water features and wetlands.		
3. Nature: Avian collision impacts related to the powerline reticulation and new distribution lines during operation.		
	Overall impact of the proposed project considered in isolation	**Cumulative impact of the project and other projects in the area**
Extent	Local (2)	Local (2)
Duration	Long-term (4)	Long-term (4)
Magnitude	Minor (2)	Moderate (6)
Probability	Probable (3)	Probable (3)
Significance	**Low (24)**	**Medium (36)**
Status (positive or negative)	Negative	Negative
Reversibility	Low	Low
Irreplaceable loss of resources?	Yes, potential loss of waterfowl and certain shorebird taxa species.	Yes, potential loss of waterfowl and certain shorebird taxa species.
Can impacts be mitigated?	Yes, to some extent	Yes, to some extent
Confidence in findings:		

High.		
Mitigation: Apply bird deterrent devices to the power line and make use of "bird-friendly" pylon structures. **Allow for construction of new powerlines parallel to existing lines**. To aid post-construction monitoring and/or monitoring of bird mortality rates, it is advised to conduct direct observations and carcass searches on a regular and systematic basis. As a priority, all new power lines should be marked with bird diverters.		
4. Nature: Avian electrocution related to the powerline reticulation and new distribution lines during operation**.**		
	Without mitigation	**With mitigation**
Extent	Local (2)	Local (2)
Duration	Long-term (4)	Long-term (4)
Magnitude	Minor (2)	Low (4)
Probability	Probable (3)	Probable (3)
Significance	**Low (24)**	**Medium (36)**
Status (positive or negative)	Negative	Negative
Reversibility	Low	Low
Irreplaceable loss of resources?	Yes, potential loss of waterfowl and certain shorebird taxa species.	Yes, potential loss of waterfowl and certain shorebird taxa species.
Can impacts be mitigated?	Yes, to some extent	Yes, to some extent
Confidence in findings: Moderate.		
Mitigation: Apply bird deterrent devices to the power line and make use of "bird-friendly" pylon structures. As a priority, all new power lines should be marked with bird diverters. Make use of bird-friendly pylons and bird guards. **Position electrical infrastructure in close proximity to existing infrastructure**.		

4.11 Recommended avifaunal mitigation

4.11.1 Loss of habitat and displacement bird taxa

It is difficult to mitigate against the loss of habitat when fixed infrastructure is applied. However, proper site selection of the facility is key to reducing the predicted impacts.

The following mitigation measures are proposed:

- Concentrate all surface infrastructure on habitat of medium to low avifaunal sensitivity. The development footprint of the various individual facilities must be kept as small as possible and sensitive habitats must be avoided.
- Where possible, existing access roads should be used and the construction of new roads should be kept to a minimum.
- Prevent an overspill of construction activities into areas that are not part of the proposed construction site.
- Use indigenous plant species native to the study area during landscaping and rehabilitation.
- All internal electrical reticulation should be placed underground, while the alignment of the overhead power lines should be placed parallel to existing powerlines lines.

4.11.2 Creation of "new" avian habitat and bird pollution

The following mitigation measures are proposed:

- Apply bird deterrent devices at selective areas (for example at the corners and middle part of the facility) to the PV panels to discourage birds from colonising the infrastructure or to discourage birds from constructing nests. These could include visual or bio-acoustic deterrents such as highly reflective rotating devices, anti-perching devices such as bird guards, scaring or chasing activities involving the use of trained dogs or raptors and/or netting. Nests should be removed when nest-building attempts are noticed under the guidance of the ECO.
- Reduce or minimise the use of outdoor lighting to avoid attracting birds to the lights or to reduce potential disorientation to migrating birds.
- Use indigenous plant species native to the study area during landscaping and rehabilitation.

4.11.3 Collision trauma caused by photovoltaic panels (the "lake-effect")

The following mitigation measures are proposed:

- Apply bird deterrent devices to the panels at selective areas (for example at the corners and middle part of the facility) to discourage birds from colonising/colliding with the infrastructure. Bird deterrent devices should especially be placed at panels nearest to ("facing") wetland features, bodies of water and slimes dams These could include visual or bio-acoustic deterrents such as highly reflective rotating devices, flashers, anti-perching devices such as bird guards, scaring or chasing activities involving the use of trained dogs or raptors and/or netting. An option is to employ video cameras at selected areas to document bird mortalities.
- Buffer all wetland-associated habitat, pollution control dams as well as slimes dams by at least 500m.
- Apply systematic reflective/dynamic markers to the boundary fence to increase the visibility of the fence for approaching birds (e.g. korhaan taxa) and to avoid potential bird collisions with the fence structure.
- Reduce or minimise the use of outdoor lighting to avoid attracting birds to the lights or to reduce potential disorientation to migrating birds.

4.11.4 Power line interaction: collision and electrocution with power lines

The following mitigation measures are proposed:

- All internal electrical infrastructure and cabling should be placed underground.

- Position the proposed grid connection alongside existing powerline servitudes.
- EWT should be consulted on an appropriate pylon design to be used for the project (if pylons are to be used). In general, the proposed pylon design must incorporate the following design parameters:
  - The clearances between the live components should be as wide as possible within the design limitations/capabilities of the power line.
  - The height of the tower should allow for unrestricted movement of terrestrial birds between successive pylons.
  - The live components should be "bundled" to increase the visibility for approaching birds.
  - "Bird streamers" should be eliminated by discouraging birds from perching above the conductors. In addition, conductors should be strung below the pole to avoid bridging the air gap by perching birds of prey.

It is therefore recommended that the pylon design incorporates "features as illustrated in Figure 23[8].

From Figure 23 it is clear that perching by birds is discouraged by the addition of diagonal crossbars or by doing away with the crossbars that holds the conductors in place. Bird "streamers" are also eliminated by fitting the poles with bird guards/spikes above the conductors. However, safe perching is facilitated by the fitment of a horizontal bar on top of the pole structure without the risk of electrocution (due to the perpendicular orientation of the bar relative to the conductors).

Figure 23: Two bird-friendly tower designs to be considered for the current project.

- All new and planned power lines should be fitted with bird flight diverters (see Figure 24). The maximum distance between the diverters should not exceed 5 m. For dynamic devices (e.g. Viper live bird flapper), flappers should be

[8] Please note that these are examples of recommended pylon designs. These are taken from steel monopole pylons.

applied to earth wires while alternating between different colours (e.g. between black and yellow or black and red) and should be fitted to the middle 60 % of the span (corresponding to the lower part of the span). All flappers should be spaced at 5 m intervals from each other.

- It is recommended that existing powerlines be retrofitted with bird flight diverters, especially when a wetland/seep/stream/dam/pollution control dam is crossed. The actual crossover span as well as one span on either side of the wetland/seep/stream/dam/pollution control dam should be marked.

Figure 24: Examples of bird flight diverters to be used on the power lines: Double loop bird flight diverter (left) and Viper live bird flapper (right).

4.11.5 General mitigation measures

- All construction sites/areas must be demarcated on site layout plans (preferably), and no construction personnel or vehicles may leave the demarcated area except those authorised to do so. Those areas surrounding the construction sites that are not part of the demarcated development area should be considered as “no-go” areas for employees, machinery or even visitors.
- All road networks must be planned with care to minimise dissection or fragmentation of important avifaunal habitat type. Where possible, the use of existing roads is encouraged.
- Open fires is strictly prohibited and only allowed at designated areas.
- Killing or poaching of any bird species should be avoided by means of awareness programs presented to the labour force. The labour force should be made aware of the conservation issues pertaining to the bird taxa occurring on the study site. Any person found deliberately harassing any bird species in any way should face disciplinary measures, following the possible dismissal from the site.
- Checks must be carried out at regular intervals to identify areas where erosion is occurring. Appropriate remedial action, including the rehabilitation of eroded areas should be undertaken.

4.12 Suggested monitoring and Environmental Management Plan

Information on collision trauma (bird mortalities) and the displacement of birds caused by PV solar facilities is insufficient. Therefore, as per the guidelines of Jenkins *et al.* (2017) it is highly recommended that additional monitoring be implemented to augment existing data:

- At least one additional pre-construction survey is recommended, consisting of a minimum of four days which is necessary to inform the final EMPr during operation. The survey should coincide with the peak wet season when most of the nearby wetland features in the wider study region are inundated.
- A post-construction survey during operation with a minimum of 3 x 3-5 day surveys over a six month period (including the peak wet season). The surveys aim to obtain mortality data from birds colliding with the panels to advise on appropriate mitigation measures to be implemented to reduce potential bird mortalities. The surveys should be conducted in a regular and systematic manner by means of direct observations (and the use of installed video cameras) and carcass searches. A management programme must be compiled to assess the efficacy of applied mitigation measures and consult or change measures to reduce on-going mortalities when detected. Additional mitigation measures should be tested or applied, especially if mortalities include species of conservation concern.
- It is possible that mortalities due to collision will occur at the powerlines even after mitigation. The post-construction monitoring (during operation) should also quantify mortalities caused by the powerline network. Monitoring should be implemented once a month for at least one year. All searches should be done on foot. A management programme must be compiled to assess the efficacy of applied mitigation measures and consult or change measures to reduce on-going mortalities when detected. Additional mitigation measures should be tested or applied, especially if mortalities include species of conservation concern.

OBJECTIVE 1: Minimize potential collision trauma with infrastructure and augmenting existing information on bird interactions with solar infrastructure

Project Component/s	» PV panel arrays
Potential Impact	» Collision trauma caused by photovoltaic panels (the "lake-effect")
Activity/Risk Source	» Construction and operation of PV infrastructure
Mitigation: Target/Objective	» Zero bird mortalities due to collision trauma caused by PV panels

Mitigation: Action/Control	Responsibility	Timeframe
• Apply bird deterrent devices to the PV panels to discourage birds from colonising the infrastructure or to discourage birds from constructing nests. These could include visual or bio-acoustic deterrents such as highly reflective rotating devices, flashers, anti-perching devices such as bird guards, scaring or chasing activities involving the use of trained dogs or raptors and/or netting. Nests should be removed when nest-building attempts are noticed.	ECO & OM	Operation (on-going)
• Reduce or minimise the use of outdoor lighting to avoid attracting birds to the lights or to reduce potential disorientation to migrating birds.	ECO & OM	Operation (on-going)
• Use indigenous plant species native to the study area during landscaping and rehabilitation.	CER & ECO	Construction phase
• Implement post-construction monitoring and carcass surveys	OM & CER	Directly after construction and during operation - At least 3 surveys, each 3-5 days for a 6 month period
• Implement pre-construction monitoring protocols (as per Jenkins et al., 2017)	OM & CER	Prior to construction - At least 1 survey of 4 days (during wet season)
• Compile management programme to assess efficacy of mitigation and on-going research/trials	EM & OM	Operation (on-going)

Performance Indicator	Reduced statistical detection/observation of bird mortalities
Monitoring	• Implement at least one pre-construction survey consisting of a minimum of 4 days.

	• Implement post-construction surveys during operation with a minimum of 3 x 3-5 day surveys over a six month period (including the peak wet season). • Surveys should coincide with the peak wet season when most of the wetland features in the wider study region are inundated. • Obtain quantified data on waterbird richness and potential flyways, which will contribute towards our understanding of impacts related to collision trauma with the panels. • Obtain mortality data from birds colliding with the panels and advise on appropriate mitigation measures to be implemented to reduce potential bird mortalities. • Conduct post-construction monitoring in a systematic manner by means of direct observations and the use of installed video cameras and carcass searches. • Implement management programme to assess the efficacy of applied mitigation measures and consult or change measures to reduce on-going mortalities when detected. Additional mitigation measures should be tested or applied, especially if mortalities include birds of prey and species of conservation concern.

OBJECTIVE 2: Minimize collisions and electrocution associated with powerlines

Project Component/s	» Overhead powerlines
Potential Impact	» Collision and electrocution caused by powerlines
Activity/Risk Source	» Overhead powerlines
Mitigation: Target/Objective	» Reduced bird mortalities due to collision/electrocution

Mitigation: Action/Control	Responsibility	Timeframe
• Apply bird deterrent devices to all new powerlines	ECO & CER	Construction
• Implement post-construction monitoring and carcass surveys	OM & CER	Operation - once a month for at least one year
• Compile management programme to assess efficacy of mitigation and on-going research/trials	OM	Operation (on-going)
• Report mortalities (number, locality and species) to Electrical Energy Mortality Register at EWT	OM	Operation (on-going)

Performance Indicator	Reduced statistical detection/observation of bird mortalities
Monitoring	• Implement post-construction monitoring to quantify bird mortalities caused by the powerline network. All searches should be done on foot. • Compile a management programme to assess the efficacy of applied

	mitigation measures and consult or change measures to reduce on-going mortalities when detected. Additional mitigation measures should be tested or applied, especially if mortalities include birds of prey and species of conservation concern.

4.13 Opinion regarding the feasibility of the project

Pachnoda Consulting cc was requested by Savannah Environmental (Pty) Ltd on behalf of Harmony Moab Khotsong Operations Pty (Ltd) to compile an avifauna impact assessment report for three separate solar facilities (referred to as the "Moab Khotsong PV facility") with a combined contracted capacity of up to 100MW located on a site approximately 10km north of the town of Vierfontein in the Free State Province.

Eight avifaunal habitat types were identified on the study site and surroundings, consisting of four untransformed types (ranging from open grassland with bush clump mosaics, depressions, Imperata cylindrica seep zones to a valley-bottom see/stream) and four transformed units (ranging from agricultural land, *Eucalyptus* plantations, rehabilitated grassland and pastures to pollution control dams). The study site was also surrounded by slimes dams and an impoundment to the east (c. 700m from the site), which provided additional habitat for waterbird and shorebird taxa (especially the latter). Approximately 222 bird species are expected to occur in the wider study area, of which 109 species were observed in the study area (during two independent surveys). The expected richness included five threatened or near threatened species, 18 southern African endemics and 17 near-endemic species. However, the occurrence of threatened and near threatened bird species was predicted to be low, although the natural broad-scale habitat units provided foraging habitat for the occasional occurrence of the vulnerable Lanner Falcon (*Falco biarmicus*) and the regionally near threatened Abdim's Stork (*Ciconia abdimii*). In addition, the valley-bottom seep/stream on the eastern part of the study site provides suitable foraging habitat for the regionally endangered African Marsh Harrier (*Circus ranivorus*), although this species was not observed during the respective surveys. Although the African Marsh Harrier was recorded on the study site during the survey period, it was recommended that all potential habitat be conserved (as a precautionary principle) which included the seep zone/stream on the eastern part of the study site. Sixteen southern African endemics and 11 near-endemic species were confirmed on the study site.

An evaluation of potential and likely impacts on the avifauna revealed that the impact significance was moderate to low after mitigation (depending on the type of impact). However, the risk for certain waterbirds (mainly large-bodied waterfowl such as the South African Shelduck *Tadorna cana* and Egyptian Goose *Alopochen aegyptiacus*) colliding with the PV infrastructure remained eminent due to the presence of wetland-associated features and pollution control dams in the study area. Post-construction monitoring was recommended along with the installation of appropriate bird diverters to minimise the potential risk of collision trauma in birds.

No fatal-flaws were identified during the assessment, although it was strongly recommended that the proposed mitigation measures and monitoring protocols (e.g. post construction monitoring) be implemented during the construction and operational phase of the project.

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Appendix 1: A shortlist of bird species expected to be present on the study area. The list provides an indication of the species occurrence according to SABAP2 reporting rates. The list was derived (and modified) from species observed in pentad grid 2655_2645 (the eight surrounding grids were also consulted) and from personal observations. The reporting rates include submissions made during the May and July 2022 surveys.

#	Common Name	Scientific Name	Observed (May & July 2022	SABAP2 Reporting Rate			
				Full Protocol (%)	Number of cards	Ad hoc Protocol (%)	Number of cards
432	Acacia Pied Barbet	*Tricholaema leucomelas*	1	74.07	40	0.00	0
95	African Black Duck	*Anas sparsa*		3.70	2	0.00	0
380	African Black Swift	*Apus barbatus*		3.70	2	0.00	0
199	African Crake	*Crecopsis egregia*		1.85	1	0.00	0
52	African Darter	*Anhinga rufa*		51.85	28	10.00	1
833	African Firefinch	*Lagonosticta rubricata*		7.41	4	0.00	0
149	African Fish Eagle	*Haliaeetus vocifer*	1	31.48	17	0.00	0
418	African Hoopoe	*Upupa africana*	1	31.48	17	0.00	0
228	African Jacana	*Actophilornis africanus*		1.85	1	0.00	0
387	African Palm Swift	*Cypsiurus parvus*	1	33.33	18	0.00	0
682	African Paradise Flycatcher	*Terpsiphone viridis*		7.41	4	0.00	0
685	African Pied Wagtail	*Motacilla aguimp*		12.96	7	0.00	0
692	African Pipit	*Anthus cinnamomeus*	1	31.48	17	0.00	0
197	African Rail	*Rallus caerulescens*		1.85	1	0.00	0
544	African Red-eyed Bulbul	*Pycnonotus nigricans*	1	92.59	50	0.00	0
606	African Reed Warbler	*Acrocephalus baeticatus*		46.30	25	0.00	0
81	African Sacred Ibis	*Threskiornis aethiopicus*	1	5.56	3	0.00	0
250	African Snipe	*Gallinago nigripennis*		3.70	2	0.00	0

#	Common Name	Scientific Name	Observed (May & July 2022	SABAP2 Reporting Rate			
				Full Protocol (%)	Number of cards	Ad hoc Protocol (%)	Number of cards
85	African Spoonbill	*Platalea alba*		5.56	3	0.00	0
576	African Stonechat	*Saxicola torquatus*	1	79.63	43	20.00	2
208	African Swamphen	*Porphyrio madagascariensis*		14.81	8	0.00	0
247	African Wattled Lapwing	*Vanellus senegallus*		42.59	23	0.00	0
772	Amethyst Sunbird	*Chalcomitra amethystina*		1.85	1	0.00	0
119	Amur Falcon	*Falco amurensis*		9.26	5	0.00	0
575	Ant-eating Chat	*Myrmecocichla formicivora*	1	12.96	7	0.00	0
514	Ashy Tit	*Melaniparus cinerascens*		7.41	4	0.00	0
510	Banded Martin	*Riparia cincta*		1.85	1	0.00	0
493	Barn Swallow	*Hirundo rustica*	1	29.63	16	20.00	2
622	Bar-throated Apalis	*Apalis thoracica*		11.11	6	0.00	0
203	Black Crake	*Zapornia flavirostra*		20.37	11	0.00	0
64	Black Heron	*Egretta ardesiaca*		9.26	5	0.00	0
650	Black-chested Prinia	*Prinia flavicans*	1	98.15	53	20.00	2
431	Black-collared Barbet	*Lybius torquatus*	1	40.74	22	0.00	0
841	Black-faced Waxbill	*Brunhilda erythronotos*	1	9.26	5	0.00	0
55	Black-headed Heron	*Ardea melanocephala*	1	20.37	11	10.00	1
5	Black-necked Grebe	*Podiceps nigricollis*		1.85	1	0.00	0
245	Blacksmith Lapwing	*Vanellus armatus*	1	98.15	53	10.00	1
860	Black-throated Canary	*Crithagra atrogularis*	1	72.22	39	0.00	0
130	Black-winged Kite	*Elanus caeruleus*	1	38.89	21	20.00	2
270	Black-winged Stilt	*Himantopus himantopus*		11.11	6	0.00	0
839	Blue Waxbill	*Uraeginthus angolensis*	1	51.85	28	0.00	0
99	Blue-billed Teal	*Spatula hottentota*		5.56	3	0.00	0

#	Common Name	Scientific Name	Observed (May & July 2022	SABAP2 Reporting Rate			
				Full Protocol (%)	Number of cards	Ad hoc Protocol (%)	Number of cards
722	Bokmakierie	*Telophorus zeylonus*		11.11	6	0.00	0
823	Bronze Mannikin	*Spermestes cucullata*		1.85	1	0.00	0
443	Brown-backed Honeybird	*Prodotiscus regulus*		9.26	5	0.00	0
714	Brown-crowned Tchagra	*Tchagra australis*	1	53.70	29	0.00	0
402	Brown-hooded Kingfisher	*Halcyon albiventris*		24.07	13	0.00	0
509	Brown-throated Martin	*Riparia paludicola*	1	68.52	37	20.00	2
731	Brubru	*Nilaus afer*		7.41	4	0.00	0
695	Buffy Pipit	*Anthus vaalensis*	1	7.41	4	0.00	0
4131	Burchell's Coucal	*Centropus burchellii*		14.81	8	0.00	0
	Cape Grassbird	*Sphenoeacus afer*	1	n/a			
703	Cape Longclaw	*Macronyx capensis*	1	35.19	19	0.00	0
581	Cape Robin-Chat	*Cossypha caffra*	1	77.78	42	0.00	0
94	Cape Shoveler	*Spatula smithii*		9.26	5	10.00	1
786	Cape Sparrow	*Passer melanurus*	1	50.00	27	0.00	0
737	Cape Starling	*Lamprotornis nitens*	1	57.41	31	0.00	0
316	Ring-necked Dove	*Streptopelia capicola*	1	96.30	52	0.00	0
686	Cape Wagtail	*Motacilla capensis*	1	51.85	28	0.00	0
799	Cape Weaver	*Ploceus capensis*	1	1.85	1	0.00	0
1172	Cape White-eye	*Zosterops virens*	1	16.67	9	0.00	0
568	Capped Wheatear	*Oenanthe pileata*	1	3.70	2	0.00	0
450	Cardinal Woodpecker	*Dendropicos fuscescens*	1	24.07	13	0.00	0
290	Caspian Tern	*Hydroprogne caspia*		22.22	12	0.00	0
658	Chestnut-vented Warbler	*Curruca subcoerulea*	1	96.30	52	0.00	0
673	Chinspot Batis	*Batis molitor*	1	12.96	7	0.00	0

#	Common Name	Scientific Name	Observed (May & July 2022	SABAP2 Reporting Rate			
				Full Protocol (%)	Number of cards	Ad hoc Protocol (%)	Number of cards
872	Cinnamon-breasted Bunting	*Emberiza tahapisi*	1	12.96	7	0.00	0
631	Cloud Cisticola	*Cisticola textrix*	1	5.56	3	0.00	0
154	Common (Steppe) Buzzard	*Buteo buteo vulpinus*		12.96	7	0.00	0
263	Common Greenshank	*Tringa nebularia*		1.85	1	0.00	0
210	Common Moorhen	*Gallinula chloropus*	1	44.44	24	0.00	0
734	Common Myna	*Acridotheres tristis*	1	72.22	39	0.00	0
258	Common Sandpiper	*Actitis hypoleucos*		9.26	5	0.00	0
421	Common Scimitarbill	*Rhinopomastus cyanomelas*		9.26	5	0.00	0
843	Common Waxbill	*Estrilda astrild*	1	16.67	9	0.00	0
594	Common Whitethroat	*Curruca communis*		12.96	7	0.00	0
439	Crested Barbet	*Trachyphonus vaillantii*	1	75.93	41	0.00	0
711	Crimson-breasted Shrike	*Laniarius atrococcineus*		3.70	2	0.00	0
242	Crowned Lapwing	*Vanellus coronatus*	1	68.52	37	0.00	0
251	Curlew Sandpiper	*Calidris ferruginea*		1.85	1	0.00	0
630	Desert Cisticola	*Cisticola aridulus*	1	27.78	15	30.00	3
352	Diederik Cuckoo	*Chrysococcyx caprius*		46.30	25	0.00	0
849	Dusky Indigobird	*Vidua funerea*		1.85	1	0.00	0
1183	Eastern Clapper Lark	*Mirafra fasciolata*	1	9.26	5	0.00	0
89	Egyptian Goose	*Alopochen aegyptiaca*	1	68.52	37	20.00	2
404	European Bee-eater	*Merops apiaster*		29.63	16	20.00	2
678	Fairy Flycatcher	*Stenostira scita*	1	1.85	1	0.00	0
570	Familiar Chat	*Oenanthe familiaris*	1	5.56	3	0.00	0
665	Fiscal Flycatcher	*Melaenornis silens*	1	70.37	38	0.00	0
	Fiery-necked Nightjar	*Caprimulgus pectoralis*	1	n/a			

#	Common Name	Scientific Name	Observed (May & July 2022	SABAP2 Reporting Rate			
				Full Protocol (%)	Number of cards	Ad hoc Protocol (%)	Number of cards
162	Gabar Goshawk	*Micronisus gabar*	1	5.56	3	0.00	0
595	Garden Warbler	*Sylvia borin*		3.70	2	0.00	0
395	Giant Kingfisher	*Megaceryle maxima*		7.41	4	0.00	0
83	Glossy Ibis	*Plegadis falcinellus*		7.41	4	10.00	1
447	Golden-tailed Woodpecker	*Campethera abingoni*		14.81	8	0.00	0
56	Goliath Heron	*Ardea goliath*		1.85	1	0.00	0
4	Great Crested Grebe	*Podiceps cristatus*		1.85	1	0.00	0
58	Great Egret	*Ardea alba*		3.70	2	0.00	0
603	Great Reed Warbler	*Acrocephalus arundinaceus*		11.11	6	0.00	0
122	Greater Kestrel	*Falco rupicoloides*		3.70	2	20.00	2
502	Greater Striped Swallow	*Cecropis cucullata*	1	37.04	20	0.00	0
419	Green Wood Hoopoe	*Phoeniculus purpureus*	1	9.26	5	0.00	0
830	Green-winged Pytilia	*Pytilia melba*	1	20.37	11	0.00	0
54	Grey Heron	*Ardea cinerea*		40.74	22	10.00	1
288	Grey-headed Gull	*Chroicocephalus cirrocephalus*		5.56	3	0.00	0
84	Hadada Ibis	*Bostrychia hagedash*	1	72.22	39	10.00	1
72	Hamerkop	*Scopus umbretta*		7.41	4	0.00	0
192	Helmeted Guineafowl	*Numida meleagris*	1	68.52	37	10.00	1
784	House Sparrow	*Passer domesticus*	1	7.41	4	0.00	0
596	Icterine Warbler	*Hippolais icterina*		7.41	4	0.00	0
60	Intermediate Egret	*Ardea intermedia*		0.00	0	10.00	1
835	Jameson's Firefinch	*Lagonosticta rhodopareia*	1	22.22	12	0.00	0
586	Kalahari Scrub Robin	*Cercotrichas paena*	1	62.96	34	0.00	0
1104	Karoo Thrush	*Turdus smithi*		40.74	22	0.00	0

#	Common Name	Scientific Name	Observed (May & July 2022	SABAP2 Reporting Rate			
				Full Protocol (%)	Number of cards	Ad hoc Protocol (%)	Number of cards
317	Laughing Dove	*Spilopelia senegalensis*	1	90.74	49	20.00	2
706	Lesser Grey Shrike	*Lanius minor*		3.70	2	0.00	0
442	Lesser Honeyguide	*Indicator minor*		9.26	5	0.00	0
125	Lesser Kestrel	*Falco naumanni*		1.85	1	0.00	0
604	Lesser Swamp Warbler	*Acrocephalus gracilirostris*	1	81.48	44	0.00	0
646	Levaillant's Cisticola	*Cisticola tinniens*	1	87.04	47	30.00	3
410	Little Bee-eater	*Merops pusillus*		5.56	3	0.00	0
67	Little Bittern	*Ixobrychus minutus*		3.70	2	0.00	0
59	Little Egret	*Egretta garzetta*		9.26	5	0.00	0
6	Little Grebe	*Tachybaptus ruficollis*	1	38.89	21	0.00	0
609	Little Rush Warbler	*Bradypterus baboecala*	1	18.52	10	0.00	0
253	Little Stint	*Calidris minuta*		9.26	5	0.00	0
385	Little Swift	*Apus affinis*	1	50.00	27	0.00	0
621	Long-billed Crombec	*Sylvietta rufescens*		7.41	4	0.00	0
138	Long-crested Eagle	*Lophaetus occipitalis*		1.85	1	0.00	0
852	Long-tailed Paradise Whydah	*Vidua paradisaea*		3.70	2	0.00	0
818	Long-tailed Widowbird	*Euplectes progne*		16.67	9	0.00	0
397	Malachite Kingfisher	*Corythornis cristatus*		12.96	7	0.00	0
361	Marsh Owl	*Asio capensis*	1	3.70	2	10.00	1
262	Marsh Sandpiper	*Tringa stagnatilis*		3.70	2	0.00	0
607	Marsh Warbler	*Acrocephalus palustris*		14.81	8	0.00	0
142	Martial Eagle	*Polemaetus bellicosus*		1.85	1	0.00	0
456	Melodious Lark	*Mirafra cheniana*	1	3.70	2	0.00	0
564	Mountain Wheatear	*Myrmecocichla monticola*	1	7.41	4	0.00	0

#	Common Name	Scientific Name	Observed (May & July 2022	SABAP2 Reporting Rate			
				Full Protocol (%)	Number of cards	Ad hoc Protocol (%)	Number of cards
318	Namaqua Dove	*Oena capensis*		11.11	6	0.00	0
183	Natal Spurfowl	*Pternistis natalensis*		29.63	16	0.00	0
637	Neddicky	*Cisticola fulvicapilla*	1	77.78	42	0.00	0
1035	Northern Black Korhaan	*Afrotis afraoides*	1	42.59	23	0.00	0
179	Orange River Francolin	*Scleroptila gutturalis*	1	3.70	2	0.00	0
1171	Orange River White-eye	*Zosterops pallidus*	1	83.33	45	0.00	0
498	Pearl-breasted Swallow	*Hirundo dimidiata*		1.85	1	0.00	0
113	Peregrine Falcon	*Falco peregrinus*		1.85	1	0.00	0
269	Pied Avocet	*Recurvirostra avosetta*		1.85	1	0.00	0
522	Pied Crow	*Corvus albus*	1	66.67	36	10.00	1
394	Pied Kingfisher	*Ceryle rudis*		20.37	11	0.00	0
746	Pied Starling	*Lamprotornis bicolor*	1	25.93	14	0.00	0
490	Pink-billed Lark	*Spizocorys conirostris*		1.85	1	0.00	0
846	Pin-tailed Whydah	*Vidua macroura*		12.96	7	30.00	3
694	Plain-backed Pipit	*Anthus leucophrys*	1	1.85	1	0.00	0
674	Pririt Batis	*Batis pririt*		27.78	15	0.00	0
57	Purple Heron	*Ardea purpurea*		12.96	7	0.00	0
850	Purple Indigobird	*Vidua purpurascens*		3.70	2	0.00	0
844	Quailfinch	*Ortygospiza atricollis*	1	27.78	15	20.00	2
642	Rattling Cisticola	*Cisticola chiniana*	1	55.56	30	0.00	0
708	Red-backed Shrike	*Lanius collurio*		29.63	16	30.00	3
837	Red-billed Firefinch	*Lagonosticta senegala*	1	22.22	12	0.00	0
805	Red-billed Quelea	*Quelea quelea*	1	40.74	22	30.00	3
97	Red-billed Teal	*Anas erythrorhyncha*	1	22.22	12	0.00	0

#	Common Name	Scientific Name	Observed (May & July 2022	SABAP2 Reporting Rate			
				Full Protocol (%)	Number of cards	Ad hoc Protocol (%)	Number of cards
488	Red-capped Lark	*Calandrella cinerea*	1	1.85	1	0.00	0
343	Red-chested Cuckoo	*Cuculus solitarius*		18.52	10	0.00	0
813	Red-collared Widowbird	*Euplectes ardens*		27.78	15	0.00	0
314	Red-eyed Dove	*Streptopelia semitorquata*	1	96.30	52	30.00	3
392	Red-faced Mousebird	*Urocolius indicus*	1	77.78	42	10.00	1
212	Red-knobbed Coot	*Fulica cristata*	1	40.74	22	20.00	2
453	Red-throated Wryneck	*Jynx ruficollis*		1.85	1	0.00	0
50	Reed Cormorant	*Microcarbo africanus*	1	61.11	33	10.00	1
940	Rock Dove	*Columba livia*		3.70	2	0.00	0
506	Rock Martin	*Ptyonoprogne fuligula*	1	3.70	2	0.00	0
256	Ruff	*Calidris pugnax*		5.56	3	0.00	0
458	Rufous-naped Lark	*Mirafra africana*	1	37.04	20	0.00	0
460	Sabota Lark	*Calendulauda sabota*		3.70	2	0.00	0
789	Scaly-feathered Weaver	*Sporopipes squamifrons*	1	40.74	22	0.00	0
847	Shaft-tailed Whydah	*Vidua regia*		1.85	1	0.00	0
504	South African Cliff Swallow	*Petrochelidon spilodera*	1	11.11	6	0.00	0
90	South African Shelduck	*Tadorna cana*	1	24.07	13	0.00	0
707	Southern Fiscal	*Lanius collaris*	1	51.85	28	10.00	1
4142	Southern Grey-headed Sparrow	*Passer diffusus*	1	55.56	30	0.00	0
803	Southern Masked Weaver	*Ploceus velatus*	1	98.15	53	0.00	0
102	Southern Pochard	*Netta erythrophthalma*		1.85	1	0.00	0
808	Southern Red Bishop	*Euplectes orix*	1	66.67	36	50.00	5
390	Speckled Mousebird	*Colius striatus*		35.19	19	0.00	0
311	Speckled Pigeon	*Columba guinea*	1	74.07	40	0.00	0

#	Common Name	Scientific Name	Observed (May & July 2022	SABAP2 Reporting Rate			
				Full Protocol (%)	Number of cards	Ad hoc Protocol (%)	Number of cards
474	Spike-heeled Lark	*Chersomanes albofasciata*	1	1.85	1	0.00	0
368	Spotted Eagle-Owl	*Bubo africanus*	1	3.70	2	10.00	1
654	Spotted Flycatcher	*Muscicapa striata*		22.22	12	0.00	0
275	Spotted Thick-knee	*Burhinus capensis*	1	3.70	2	0.00	0
88	Spur-winged Goose	*Plectropterus gambensis*		38.89	21	30.00	3
62	Squacco Heron	*Ardeola ralloides*		7.41	4	0.00	0
185	Swainson's Spurfowl	*Pternistis swainsonii*	1	48.15	26	10.00	1
411	Swallow-tailed Bee-eater	*Merops hirundineus*	1	3.70	2	0.00	0
649	Tawny-flanked Prinia	*Prinia subflava*		3.70	2	0.00	0
804	Thick-billed Weaver	*Amblyospiza albifrons*		20.37	11	0.00	0
238	Three-banded Plover	*Charadrius tricollaris*	1	35.19	19	0.00	0
851	Village Indigobird	*Vidua chalybeata*		7.41	4	0.00	0
735	Wattled Starling	*Creatophora cinerea*	1	42.59	23	0.00	0
359	Western Barn Owl	*Tyto alba*		1.85	1	0.00	0
61	Western Cattle Egret	*Bubulcus ibis*	1	50.00	27	10.00	1
305	Whiskered Tern	*Chlidonias hybrida*		7.41	4	0.00	0
391	White-backed Mousebird	*Colius colius*	1	59.26	32	0.00	0
763	White-bellied Sunbird	*Cinnyris talatala*	1	16.67	9	0.00	0
47	White-breasted Cormorant	*Phalacrocorax lucidus*	1	31.48	17	0.00	0
780	White-browed Sparrow-Weaver	*Plocepasser mahali*	1	64.81	35	20.00	2
100	White-faced Whistling Duck	*Dendrocygna viduata*		11.11	6	10.00	1
409	White-fronted Bee-eater	*Merops bullockoides*		22.22	12	30.00	3
383	White-rumped Swift	*Apus caffer*		14.81	8	0.00	0
582	White-throated Robin-Chat	*Cossypha humeralis*	1	7.41	4	0.00	0

#	Common Name	Scientific Name	Observed (May & July 2022	SABAP2 Reporting Rate			
				Full Protocol (%)	Number of cards	Ad hoc Protocol (%)	Number of cards
495	White-throated Swallow	*Hirundo albigularis*		42.59	23	0.00	0
304	White-winged Tern	*Chlidonias leucopterus*		1.85	1	0.00	0
814	White-winged Widowbird	*Euplectes albonotatus*		22.22	12	0.00	0
599	Willow Warbler	*Phylloscopus trochilus*		14.81	8	0.00	0
264	Wood Sandpiper	*Tringa glareola*		11.11	6	0.00	0
866	Yellow Canary	*Crithagra flaviventris*	1	40.74	22	0.00	0
96	Yellow-billed Duck	*Anas undulata*	1	79.63	43	20.00	2
76	Yellow-billed Stork	*Mycteria ibis*		1.85	1	0.00	0
812	Yellow-crowned Bishop	*Euplectes afer*		14.81	8	0.00	0
859	Yellow-fronted Canary	*Crithagra mozambica*		1.85	1	0.00	0
788	Yellow-throated Bush Sparrow	*Gymnoris superciliaris*		7.41	4	0.00	0
629	Zitting Cisticola	*Cisticola juncidis*	1	12.96	7	20.00	2

Appendix 2: Preliminary density estimates of birds recorded from the study area during two independent surveys conducted during May 2022 and July 2022.

Species	m01	m02	m03	m04	m05	m06	m07	m08	m09	m10	m11	m12	m13	m14	m15
Ant-eating Chat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
African Pipit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
African Red-eyed Bulbul	1.5	0	0.5	1	1	2	1.5	0	0	0	0	0	0	1	0
Black-chested Prinia	2	0	1	2	2	2	2	2	0	0	2	0	0	2	1
Black-faced Waxbill	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brown-crowned Tchagra	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0
Blue Waxbill	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capped Wheatear	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Cloud Cisticola	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Cape Grassbird	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cape Longclaw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cape Robin-chat	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Chinspot Batis	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Cape Sparrow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cape Starling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chestnut-vented Warbler	2	0	0	1	0	2	2	0	0	0	0.5	0	0	1	0
Cape Wagtail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Common Waxbill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cape White-eye	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desert Cisticola	0	1.5	1.5	0.5	1	0	0	1	0	1	0	1	1	1.5	1
Eastern Clapper Lark	0	1.5	0.5	0.5	0.5	0	0	0	0	0	0	0	0.5	0	0
Fairy Flycatcher	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0

Species	m01	m02	m03	m04	m05	m06	m07	m08	m09	m10	m11	m12	m13	m14	m15
Jameson's Firefinch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kalahari Scrub-robin	1	0	0	0	0	1	0.5	0	0	0	0	0	0	0	0
Levaillant's Cisticola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Lesser Swamp Warbler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mountain Wheatear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neddicky	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Orange River White-eye	1	0	0	0	0	2	3.5	0	0	0	0	0	0	0	0
Plain-backed Pipit	0	0	0.5	0	0	0	0	0	0.5	0	1	0	0	0	0
Pied Starling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Quailfinch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rattling Cisticola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red-billed Firefinch	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red-capped Lark	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Rufous-naped Lark	0	0.5	0	0	0	0	0	0.5	0	0	0	0	0	1	0
Southern Fiscal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Southern Grey-headed Sparrow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spike-heeled Lark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Southern Masked Weaver	2.5	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0	0
African Stonechat	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0
Wattled Starling	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0
White-bellied Sunbird	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
White-browed Sparrow-weaver	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
White-throated Robin-chat	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zitting Cisticola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of individuals	16.5	4.5	4.5	5.5	4.5	12	11	3.5	1.5	1	3.5	1	1.5	22.5	6.5

Species	m01	m02	m03	m04	m05	m06	m07	m08	m09	m10	m11	m12	m13	m14	m15
Number of species	12	5	6	6	4	9	7	3	2	1	3	1	2	8	6
Number of birds/ha	**21.15**	**5.77**	**5.77**	**7.05**	**5.77**	**15.38**	**14.10**	**4.49**	**1.92**	**1.28**	**4.49**	**1.28**	**1.92**	**28.85**	**8.33**
Number of species/ha	**15.38**	**6.41**	**7.69**	**7.69**	**5.13**	**11.54**	**8.97**	**3.85**	**2.56**	**1.28**	**3.85**	**1.28**	**2.56**	**10.26**	**7.69**
Average number of birds/ha	**12.26**														
Average number of species/ha	**7.69**														

Species	m16	m17	m18	m19	m20	m21	m22	m23	m24	m25	m26	m27	m29	m28	m31	Mean birds/ha
Ant-eating Chat	1	0	0	2	0	3.5	0	0	0	0	1	0	0	0	0	**0.011**
African Pipit	0	0	0	0.5	0	0	0	0	0	0	1	0	0	0	0.5	**0.003**
African Red-eyed Bulbul	0	1.5	2	0	0	1	2	0	0	1	0	0	1	0	0	**0.024**
Black-chested Prinia	1	1	4	0	2	2	2	0	0	0	0	0	2	0	2	**0.048**
Black-faced Waxbill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.003**
Brown-crowned Tchagra	0	0	0.5	0	1	0	0.5	0	0	0	0	0	0	0	0	**0.004**
Blue Waxbill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.001**
Capped Wheatear	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.001**
Cloud Cisticola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.001**
Cape Grassbird	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**0.001**
Cape Longclaw	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	**0.004**
Cape Robin-chat	0	1	2	0	0	0	0	0	0	0	0	0	0.5	0	0	**0.006**
Chinspot Batis	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	**0.004**
Cape Sparrow	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**0.001**
Cape Starling	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.001**
Chestnut-vented Warbler	0	2	2	0	1	0	1	0	0	0	0	0	2	0	0	**0.024**
Cape Wagtail	0	0	0.5	0	0	0	0	0	0	0	0.5	0	0	0	0	**0.001**
Common Waxbill	0	2	0	0	0	0	0	9.5	0	0	0	0	0	0	0	**0.016**

Species	m16	m17	m18	m19	m20	m21	m22	m23	m24	m25	m26	m27	m29	m28	m31	Mean birds/ha
Cape White-eye	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	**0.004**
Desert Cisticola	1	0	0	1.5	1	1	0	2	0.5	0	1	1.5	0	0	1.5	**0.031**
Eastern Clapper Lark	0	0	0	0.5	0	0	0	0	0.5	0	0	0	0	0	0.5	**0.007**
Fairy Flycatcher	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**0.002**
Jameson's Firefinch	0	0	0	0	1.5	0	0	0	0	0	0	0	0	0	0	**0.002**
Kalahari Scrub-robin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.004**
Levaillant's Cisticola	0	0.5	0.5	0	0	0	0	1.5	0	2	1	1	0	0	2	**0.015**
Lesser Swamp Warbler	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	**0.001**
Mountain Wheatear	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	**0.001**
Neddicky	0	1	3	0	0.5	0	2.5	0	0	0	0	0	1	0	0	**0.013**
Orange River White-eye	0	1	5	0	0	0	3	0	0	0	0	0	0	0	0	**0.022**
Plain-backed Pipit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.003**
Pied Starling	4.5	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.011**
Quailfinch	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	**0.006**
Rattling Cisticola	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.001**
Red-billed Firefinch	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	**0.006**
Red-capped Lark	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	**0.001**
Rufous-naped Lark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.003**
Southern Fiscal	1	0.5	0	0	0	0	0	0	0	1.5	0.5	0	0	0	0.5	**0.006**
Southern Grey-headed Sparrow	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**0.001**
Spike-heeled Lark	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	**0.004**
Southern Masked Weaver	0	3	4	0	0	0	14	0	0	0	0	0	2	0	0	**0.038**
African Stonechat	0	0	0	0	0	2	0	1.5	0	0	0	1	0	0	2	**0.010**
Wattled Starling	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.046**
White-bellied Sunbird	0	0	0	0	0	0	0	0	0	0	0	0	1.5	0	0	**0.004**
White-browed Sparrow-weaver	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.001**

Species	m16	m17	m18	m19	m20	m21	m22	m23	m24	m25	m26	m27	m29	m28	m31	Mean birds/ha
White-throated Robin-chat	0	0.5	0	0	0	0	0	0	0	0	0	0	1	0	0	**0.004**
Zitting Cisticola	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1	**0.004**
Number of individuals	10.5	37	27.5	8.5	7	9.5	28	18.5	1	5.5	7	4.5	13	0	10	**0.409**
Number of species	7	16	13	6	6	5	8	7	2	4	9	4	10	0	8	**0.256**
Number of birds/ha	**13.46**	**47.44**	**35.26**	**10.90**	**8.97**	**12.18**	**35.90**	**23.72**	**1.28**	**7.05**	**8.97**	**5.77**	**16.67**	**0.00**	**12.82**	
Number of species/ha	**8.97**	**20.51**	**16.67**	**7.69**	**7.69**	**6.41**	**10.26**	**8.97**	**2.56**	**5.13**	**11.54**	**5.13**	**12.82**	**0.00**	**10.26**	
Average number of birds/ha	**12.26**															
Average number of species/ha	**7.69**															